Een lach

Een traan

Een herinnering

...

Mama,

deze is voor jou!

Promotor Prof. dr. Wim De Clercq
Department of Archaeology

Copromotor Prof. dr. Koenraad Verboven
Department of History

Dean Prof. dr. Gita Deneckere

Rector Prof. dr. Rik Van de Walle

Nederlandse vertaling:
Zout van het Noorden
Een interdisciplinaire studie van de technische en sociale organisatie van Romeinse zoutproductie in de civitas Menapiorum (Gallia-Belgica)

Cover: Reconstruction painting of the late second - early third century CE salt production activities in the Menapian coastal plain © Yannick De Smet, www.de-smet.me and Michiel Dekoninck/UGent

FACULTEIT LETTEREN
EN WIJSBEGEERTE

Salt of the North

An Interdisciplinary Study into the Technical and Social Organisation of Roman Salt Production in the Civitas Menapiorum (Gallia-Belgica)

Michiel Dekoninck

Dissertation submitted to obtain the degree of Doctor in Archaeology
2023

UNIVERSITEIT
GENT

Acknowledgements

Allow me to start this acknowledgement section with a cliché: it is the journey, not the destination that matters. And, this dissertation has been an incredible journey that has shaped me into the person I am today. However, I did not travel this journey alone. Therefore, at the beginning of this dissertation, I would like to take this opportunity to thank those who have crossed my path, offered guidance or helped make this dissertation possible.

First and foremost, I would like to thank my promotor prof. dr. Wim De Clercq, who first enthused me for historical archaeology and guided me through my bachelor's and master's dissertation. I'm grateful you've entrusted me to work on one of the burning questions you've identified in your PhD project: the importance of salt production in the *Menapian civitas*. Throughout this four-year scholarship awarded by the Special Research Fund (BOF) at Ghent University, your advice, enthusiasm, encouragement and insight helped shape this research into the dissertation that is now in front of you. Furthermore, I'm grateful for the support, guidance and feedback from my co-promotor Prof. dr. Koenraad Verboven. Though the research took a somewhat different turn than anticipated, your insights into Roman economic history helped to contextualise the results in a broader socio-economic framework.

Secondly, I would like to take the opportunity to give thanks to several institutions and organisations that provided access to the unpublished excavation data of numerous sites and loaned a large number of boxes with archaeological material for study: Regionaal Archeologisch Museum aan de Schelde (RAMS), V.O.B.o.W., Raakvlak, Agentschap Onroerend Erfgoed, Erfgoed Zeeland and Archeologisch depot Zuid-Holland.

I also want to thank the members of my examination committee, Prof. dr. Anthony Harding, Prof. dr. Christine Hoët-Van Cauwenberghe, Prof. dr. Roland Dreesen, Prof. dr. Frank Vermeulen, Prof. dr. Maud Devolder, and Prof. dr. Philippe Crombé, for their questions, remarks, and suggestions, which have improved the final version of this dissertation.

During the project, we also received news of two new salt production sites being excavated in the province of Zeeland. A big thanks to Artefact! and Bodac for contacting me and allowing me to tag along during these excavations. They provided me with plenty of time in the sun or the rain that would otherwise be spent indoors in the lab or the office. If you plan to excavate a salt production site, please call again! In line with the excavations, I would like to thank Em. Prof. dr. Hugo Thoen for taking the time to talk with me about the salt production site he excavated at Leffinge in the 1970s. Furthermore, my profound gratitude goes to dr. Eric Goemaere for teaching me about clays, vitrification and newly formed high-temperature minerals. Without your help, I would still lie awake at night contemplating what these acicular minerals could be! Also, many thanks to dr. Vince Van Thienen for teaching me the basics of ceramic petrography, answering my endless (archaeometry) questions and encouraging words during the final months. In addition, I want to extend my gratitude to Paulina Biernacka for teaching me how to process XRD results. Further, thank you prof. dr. Koen Deforce for your help in determining a research strategy to analyse the ash and identify the fuel used on these salt production sites. And thanks to Joris Angenon for making the technical drawings of the pottery.

Other important collaborations were carried out with prof. dr. Stijn Dewaele, prof. dr. Johan De Grave, dr. Thierry Leduc, dr. Dimitri Vandenberghe, dr. Welmoet Out, dr. Joeri Kaal, dr. Pieter Tack and Sylvia Lycke. These fruitful collaborations have or will result in some interesting publications and shape the interpretation of this dissertation.

Over the last four years, I have had the pleasure of crossing paths and working together with other researchers and archaeologists. Many of you might not remember what you did exactly, but know that it helped shape this dissertation. In a way, this is an ungrateful task because, inadvertently, you always end up forgetting people. A heartfelt apology for those I may have forgotten and know that it was not on purpose. In no particular order, thanks to Robert van Dierendonck, Joost van den Berg, Nathalie de Visser, Jan Wattenberghe, Els Coppens, Frederik D'hondt, Senne Diependaele, Juanita Kiburg, Domenique Winterswijk, Aagje Feldbrugge, David Kneuvels, Dieter Demey, Marcel De Koning, Dicky De Koning (†), Aletta Sanders, Leo den Heijer, Dieter Verwerft, Jan Huyghe, Jari Hinsch Mikkelsen, Leo Declercq, Ine Demerre, prof. dr. Anthony Harding, Guus Besuijen, Karel-Jan Kerckhaert, Jeroen van Vaerenbergh, Yannick De Smet, Philippe Hannois, Hendrik Hameeuw, Edward Biddulph, Annelies Claus, Luc Vermeiren, Sophie Oudry, Britt Claes, Geert Verbrugge, Alain Proumen, Philippe Ducrocq, Geraldine Teysseire, Geraldine Faupin.

Many (former) colleagues/friends from the Archaeology department contributed to this dissertation, be it intellectually or emotionally. There are too many of you to name individually, and I want to save myself the embarrassment of accidentally forgetting someone. I enjoyed our chats and laughs in the hallways or during lunch in the year before and after Covid. Thank you all for creating a welcoming and enjoyable atmosphere. Especially the members of Racing Senseo, turned Locomotiv Nespresso, helped me feel at home and offered a teambuilding activity. My special thanks go out to Dimitri; your relentless encouragement during the entire project and the long months of writing helped tremendously. Also, the fact that you volunteered to proofread several chapters, including the one on *chapelure* pottery meant a lot!

A special shout-out is reserved for my (ex)colleagues, who, over the years, turned friends at the HARG research group: Ewoud, Dante, Jan, Sibrecht, Tim, Sadi, Toon, Paulina, Jeroen, Sofie, Bieke, Dirk, Celeste, Gerben, Maxime, Lennert, Vince and Jessica. A special thanks to Sadi, Gerben, Tim and Maxime for reviewing parts of the thesis. Tim, thank you for the numerous discussions on salt, artisanal activity, the Roman economy and several off-topic conversations. Gerben, thank you for the warm welcome and our numerous conversations about delicious food, wines etc. during the first year of my PhD. And Ewoud, thank you for being my office mate during the last four years and allowing me to bug you with an endless stream of (sometimes stupid) questions. Dante, my go-to friend for all questions relating the archaeology of Zeeland. Our talks, whether professional or personal, always put a smile on my face.

To all my friends (especially the ARCHEOYOLO gang), thank you for your encouragement, (sometimes feigned) interest, silly jokes about salt, making me laugh, offering distraction, playing squash, and so much more. Ward, Klaartje, Stijn, Sophie, Julie, Maxim, Amke, Cedric, Sander, Dante, Sophie, Elliot, Niels, Paulien, Femke, Nathan, Margo, Jasper, Jens, Kelsey, Lowie, Emmy, Ruben, Sander, thank you for being there!

Switching to Dutch, een bijzonder woord van oprechte dank voor mijn familie in West-Vlaanderen en Leuven. Hoe vaak Margit en ik ondertussen een Tour de Flanders hebben afgelegd voor etentjes, feestjes of gewoon om samen te zijn valt niet meer te tellen. Dikke merci voor de steun, interesse, aanmoediging en zo veel meer. Margit, dank je voor je onvoorwaardelijke steun gedurende de afgelopen jaren. Uitschrijven wat je voor mij betekent en hoe jouw steun dit werk mee heeft vormgeven is niet in woorden te beschrijven. Merci voor alles, want zonder jou was dit alles niet mogelijk geweest. Een laatste oprechte dankbetuiging wil ik richten aan mijn ouders. Mama en papa, dank jullie om mij te vormen in de persoon die ik vandaag ben. Papa, jouw steun en aanmoediging de laatste jaren betekende enorm veel. Ik weet dat ik deze dankbaarheid niet altijd onder woorden breng, dus bij deze een welgemeende dank je wel. Aan Mama die ons veel te vroeg ontnomen is. Je had gehoopt dat ik dit project kon aanvatten, maar je hebt me spijtig genoeg nooit weten starten. Toch weet ik dat je bij me bent bij elke stap. Graag wil ik dit werk dan ook als een blijvende herinnering aan jou opdragen.

Ghent, March 2023

Preface

For this doctoral research, I was granted a four-year scholarship by the Ghent University Special Research Fund (BOF) under grant number BOF18/DOC/330. The research was conducted within the Historical Archaeology Research Group (HARG) at the Department of Archaeology under supervision of promotor Prof. dr. Wim De Clercq and copromotor Prof. dr. Koenraad Verboven.

Structure of this dissertation

This dissertation comprises both published and unpublished material in accordance with Art. 8 of the doctoral regulations of the Faculty of Arts and Philosophy at Ghent University. Over the course of this research, incorporated papers were supplemented with new or adjusted data and/or insights. These publications are presented as separate chapters wherever possible. Yet, since this thesis is not purely a collection of papers, publications have been divided into several parts and allocated under different chapters when required. The following publications have been incorporated in their original or altered form:

Dekoninck, M., Goemaere, E., Dewaele, S., De Grave, J., Leduc, T., Vandenberghe, D., De Clercq, W. (2022). Geochemical and mineralogical characterisation of vitrified waste material discovered in large quantities on Roman salt production sites along the southern North Sea coast, *Journal of Archaeological Science* 146, 105665.

Dekoninck, M., De Clercq, W. (2022). Settling the Salinaria? Evaluating Site Location Patterns of Iron Age and Roman Salt Production in Northern Gaul. In: Van Limbergen, D., Hoffelinck, A., Taelman, D. (eds.), *Reframing the Roman Economy*: *New Perspectives on Habitual Economic Practices*, Palgrave Studies in Ancient Economies, Cham: Palgrave Macmillan, 267-303.

Dekoninck, M., de Ruijsscher, D., De Clercq, W. (2022). Heated Crafts on the Roman Shore. Revisiting the Debate on the Exploitation of Coastal Wetlands. The Case of Roman Aardenburg (Zeeland, the Netherlands), *Latomus* 81/4, 788-818.

This dissertation takes up ten chapters that are divided into three parts. The first part introduces the subject to the reader and outlines the aims and research questions within the theoretical framework. Furthermore, the archaeological *status quaestionis* of the research area (the Menapian coastal plain) and the research topic (salt production) is discussed. The second part forms the main body of this dissertation and discusses the salt production activities in the Menapian *civitas*. In the third part, the results described into part two are integrated and related to the theoretical and conceptual frameworks. This third part also includes the conclusion and formulates future research opportunities. A summarised overview of the individual chapters is given below.

Part 1 – An introduction to salt production and the Menapian coastal plain

Chapter 1 – General introduction introduces the subject of the dissertation, defines the geographical and chronological boundaries, outlines the research questions and considers the theoretical discourses and methodologies that directed the interpretation of the data.

Chapter 2 – The coastal plain of the civitas Menapiorum in Roman times provides a state of the art of the Roman occupation in the study area.

Chapter 3 – Aspects of salt production in Western Europe: an introduction offers an overview of what salt is and how it was produced in Western Europe in Roman times. Furthermore, it describes the socio-economic background of salt in the Roman world.

Part 2 – Salt production in the Menapian *civitas*: facts and figures

Chapter 4 – Settling the Salinaria? Evaluating site location patterns of Iron Age and Roman salt production in northern Gaul analyses the distribution of Iron Age and Roman salt production sites in northern Gaul from a chronological and geographical point of view

Chapter 5 – Heated crafts on the Roman shore. Revisiting the debate on the exploitation of coastal wetlands: the case of Roman Aardenburg (Zeeland, the Netherlands) discusses the nature of the heated artisanal activities in the study area by using Aardenburg as a case study.

Chapter 6 - late first early second century salt production sites in the northern Menapian territory examines the late first – early second century salt production sites and analyses the briquetage material discovered on these sites.

Chapter 7 – late second – early third century salt production sites in the northern Menapian territory examines the potential of the unpublished late second – early third century salt production sites in the study area.

Chapter 8 – Geochemical and mineralogical characterisation of vitrified waste material discovered in large quantities on Roman salt production sites along the southern North Sea coast describes the cross-disciplinary study of the vitrified 'salt slags'. Through a multi-proxy approach, these materials are systematically studied to determine their composition, formation and relation to the salt production process.

Part 3 – Towards a new understanding of salt production in the Menapian *civitas*

Chapter 9 – Towards a new understanding of salt production in the civitas Menapiorum integrates and discusses the results of the different chapters presented in Part 2.

Chapter 10 – Conclusions and prospects for future research summarises the results and findings of this dissertation, and offers prospects for future research.

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Part 1 An introduction to salt production and the Menapian coastal plain

Chapter 1 General introduction

Therefore, Heaven knows, a civilized life is impossible without salt, and so necessary is this basic substance that its name is applied metaphorically even to intense mental pleasures.

Pliny, *Naturalis Historia,* XXXI, 88 (trans. by Jones 1963)

Of this art of yours every wave is a bondservant. In the quest for gold a man may be lukewarm: but salt every one desires to find; and deservedly so, since to it every kind of meat owes its savour.

Cassiodorus, *Variae Epistolae* XXII, 24.6 (trans. by Hodgkin 1886)

These extracts by Pliny the Elder and Cassiodorus are amongst the most quoted passages on ancient salt. Though they lived almost 400 years apart, both authors reflect on the perceived value of salt in Roman society and its importance in everyday life. In the absence of refrigeration techniques, salt was the preferred preservative of premodern societies enabling them to stock up on winter supplies and to transport perishable products over long distances. This ubiquitous and vital character paradoxically opposes the limited accessibility of the resource. Therefore, the discovery of the Hallstatt salt mine and its rich early Iron Age cemetery led archaeologists to believe that those who controlled the production and distribution of salt acquired wealth resulting in social differentiation (Harding, 2013, 99). Furthermore, historians agree that the control of the salt trade was a critical factor that made Venice a commercial heavyweight in medieval Europe (Hocquet, 1978). The potential to generate wealth by controlling the salt exploitation and - trade, and its multifaceted use is one of the reasons salt has been termed the 'white gold.' This term captures both the fascination of scholars studying ancient salt production, use and trade and highlights the esteem salt held in past societies. Accordingly, the word 'white gold' often found its way into book titles, for instance, *Salt: White Gold in Early Europe* (Harding, 2021); *Salt: White Gold of the Maya* (McKillop, 2002); *Salt and Gold: The Role of Salt in Prehistoric Europe* (Nikolov and Bacvarov, 2012), and so on.

Salt archaeology has become increasingly popular in the last decades, and researchers worldwide strive towards a common goal: understanding how past communities extracted, distributed, and consumed salt. Furthermore, the growing interdisciplinary character of the field challenges and encourages us, researchers, to look at the data holistically to try and answer more complex questions on salt extraction technology. Moreover, a holistic approach enables a more far-reaching discussion on the socio-economic and socio-political aspects of salt production and -trade. This dissertation is embedded into this still-expanding field of research. It contributes to our knowledge of salt production and - economy in an ill-known, remote part of the Roman Empire: the *civitas Menapiorum*. From a Roman perspective, the *civitas Menapiorum* situated on the northern fringe of *Gallia Belgica*, was a rather 'marginal' territory on the outskirts of the Empire. This is reflected in Vergil's (Aeneid, 8.727) statements on the *Morini*, the western neighbours of the *Menapii*, who he called *extremi hominum,* the furthest of mankind. Yet, as stated by De Clercq (2009c, 2011), marginality is a relative concept as these wetland areas had a high potential for specific, landscape-based resource exploitation strategies such as salt production.

In the nineteenth century, epigraphic inscriptions mentioning so-called *salinatores* in the *civitas Menapiorum* and *Morinorum* (northern Gaul) were found near the Porta Sant' Andrea in Rimini (IT). In 1970, further epigraphic evidence emerged when a large collection of Nehalennia-altars were recovered from the Eastern Scheldt. Several of the dedicants who erected the altars had professions related to the trade in salt and derivative productions (Hondius-Crone, 1955; Stuart and Bogaers, 2001; Stuart, 2013). The *salinatores* inscriptions, combined with the Nehalennia-inscriptions, led historians and archaeologists to assume a thriving salt trade in the study area (Will, 1962; Stuart and Bogaers, 2001). Yet, estimating how salt was integrated into the wider economic network and who was involved in the salt trade remained unanswered.

Furthermore, at the end of the nineteenth century, archaeological data (e.g. briquetage elements, hearth infrastructure and water management structures) was discovered in the coastal area indicating the presence of salt production centres. In 1961, Nenquin (1961) published an overview of all known sites and created an ethnographic-technological framework for future research. His seminal overview, ranging from Neolithic to Roman times, still counts as the first synthesis of salt production in western Europe. Pioneering work along the French Atlantic coast was conducted by Coppens (1953), resulting in a synthesis by Gouletquer (1970). The work of Daire (1994, 2003) could be seen as an update on salt production in this area. The discovery of multiple well-preserved salt production sites in northern France in the 1990s led to new insights into the Iron Age salt production mechanisms (Prilaux, 2000a). Recently, the project *Sel et Société* tried to bundle and facilitate the publication of new studies and Malta-driven archaeological discoveries in France (Hoët-van Cauwenberghe et al., 2017, 2020). In Belgium, important work was done by Thoen (1973, 1978a, 1986, 1987), who discovered the well-preserved Roman salt production site at Leffinge. Crucial work in the coastal areas of the Netherlands has been conducted by van den Broeke (1986, 1995b, 1996). He examined the Iron Age salt production process in the Low Countries and devised a regional typo-chronological evolution of the briquetage pottery found in the area.

Each of the abovementioned studies contributed to the regional knowledge of salt production. However, most researchers focused on the Iron Age and had no thought for the Roman salt-making in the area. Several important Roman salt production sites have been excavated since the 1970s, but these sites received little attention and were never published in their entirety (Ovaa, 1975; Thoen, 1978a, 1986, 1987). Nor was the *chaîne opératoire* applied to produce salt in these northern provinces fully understood. Furthermore, a recent, overarching overview combining French, Belgian and Dutch data has been lacking. As a result, Roman salt production along the southern North Sea coasts has received only fragmented attention, notwithstanding the available potential as well as the archaeologically and historically attested economic significance. This lack of a synthesis causes the area to form a 'blind spot' within recent international literature (Harding, 2013; Hoët-van Cauwenberghe et al., 2017, 2020; Harding, 2021). This dissertation aims to (partially) close these knowledge gaps by studying how salt was extracted in the Menapian *civitas,* assessing the wider economic processes at work, and discussing the social actors involved in the production. We hope that this study provides a solid basis for future research and discussion, and will allow the integration of the Menapian region into an international framework.

1.1 Geographical and chronological framework

Historical sources, primarily Caesar's treaty on the Gallic Wars (*Commentarii de Bello Gallico*), are often used to gain insights into the political geography of Gaul in the late Iron Age and the early Roman period. The socio-political cohesion of the pre-Roman communities, as perceived by Caesar, formed the basis for Augustus' territorial and institutional reform between 16-12 BCE. Part of this reform was the creation of semi-autonomous *civitates* of a different status (federate, free or tributary) with varying privileges like the exemption from paying tax or from external interference (Wightman, 1985; Raepsaet-Charlier, 2009; Raepsaet and Raepsaet-Charlier, 2013).

The coastal area of the Roman provinces *Gallia Belgica* and *Germania Inferior* consisted of several tribal entities which transferred into *civitates* in the early Roman period (Figure 1). At the northernmost part of the Atlantic coast, the *civitas Ambianiorum* was situated between the estuaries of the Scie and the Canche. The *civitas* territory of the *Morini* and the one of the *Menapii* both stretched along the southern North Sea coast. The former from the mouth of the river Canche in the south to the mouth of the river Aa in the north and the latter from the Aa in the south to the river Scheldt in the north, nowadays the Eastern Scheldt (De Laet, 1961; Delmaire, 1976; De Clercq, 2011; Raepsaet and Raepsaet-Charlier, 2013). The northernmost coastal zone, between the Eastern Scheldt –in Roman times the only mouth of the river Scheldt– and the Rhine, was part of *Germania*, which became the independent province of *Germania Inferior* in 85 CE under Emperor Domitian (Carroll, 2001). Initially, this area was occupied by the Batavians, who settled in the Rhine delta in the second half of the first century BCE as part of the Roman frontier policy (Roymans, 2004). According to Raepsaet and Raepsaet-Charlier (2013), two new *civitates* (*civitas Frisiavones* and *Cannanefates*) were created in the coastal area in the first half of the first century CE at the expense of the Batavians. The aforementioned situation remained unchanged until the administrative reforms of Diocletian around 293 CE (Wightman, 1985, p. 202-218).

This overview of the coastal *civitates* is necessary to understand how distinct salt production landscapes emerged that shifted in location through time due to landscape changes and the socio-economic and political context. Yet, this dissertation mainly concerns the coastal area of the *civitas Menapiorum* and specifically focuses on the northern part of the *civitas* between the Yser and the Eastern Scheldt. In modern administrative terms, the *civitas Menapiorum* contains (part of) the Belgian provinces of East-, West-Flanders and Hainaut, a large part of the Dutch province of Zeeland, and the northernmost part of the North French departments Nord and Pas-de-Calais. Chronologically this thesis stretches the early Iron Age[1] (ca. 800 BCE) until the end of the Roman period in 410/476CE.[2] The study primarily focuses on the Roman period which is subdivided into the early-Roman period (ca.50BCE-70CE), middle-Roman period (70CE-275CE) and late-Roman period (ca. 275-410/476CE).

[1] The Iron Age situation is only discussed in Chapter 3 when covering the evolution of the salt production sites. In Chapter 3, the Iron Age was subdivided into the early Iron Age (800–475/450 BCE), middle Iron Age (475/450–250 BCE) and late Iron Age (250–57 BCE).

[2] The withdrawal of the Roman army from *Britannia* and Alaric's looting of Rome in 410 CE is a generally accepted date for the end of the Roman era in northwestern Europe. However, the deposition of the last Roman emperor in 476 CE is sometimes taken as the end date.

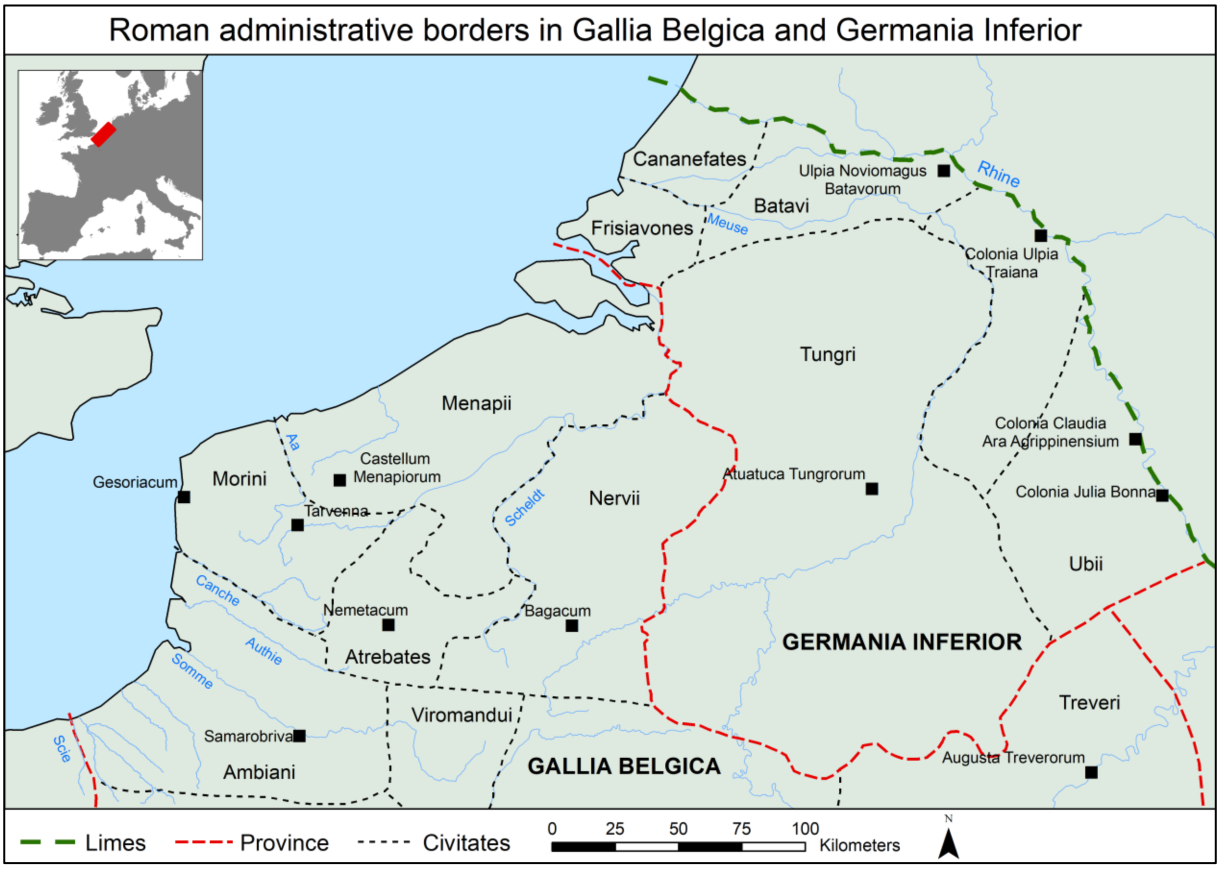


Figure 1 Situating the study area (*civitas Menapiorum*) in the wider political and administrative geography of northern Gaul (*Gallia Belgica* and *Germania Inferior*) during the Principate.

1.2 Research aim and objectives

Now that we framed the project within its geographical and chronological borders, we can introduce its research questions and objectives. This dissertation aims to contribute to our understanding of habitual economic practices, specifically salt production, in a remote part of the Roman Empire. First and foremost, this will be achieved by providing a descriptive framework of the salt production activities in the *civitas Menapiorum*. From this overarching objective, a **first research question** can be defined:

(1) How was salt as a basic resource extracted from the sea in the study area throughout the Roman period, and how are the salt production activities reflected in the archaeological record?

This general question can be broken down into three topics for which a series of specific questions and objectives were formulated.

a. Assessment of the chronological and geographical distribution of the pre-Roman and Roman salt production sites in northern Gaul (Chapter 3)
   i. How does salt production in northern Gaul develop from a chronological and geographical point of view?

ii. How does this relate to the political and economic development of northern Gaul?

b. Assessment of the archaeological evidence of Menapian salt production (chapters 5, 6 and 7)
    i. Were different types of heated crafts pursued in the Menapian coastal plain?
    ii. What are the primary characteristics of late first-early second century CE salt production in the Menapian coastal plain?
    iii. Did the salt production process develop through time, and if so, what are the characteristics of late second-early third century CE salt production sites?

c. Assessment and evaluation of the archaeometric evidence of salt production related artefacts (Chapter 8 and Dekoninck et al. (In prep))
    i. What is the composition of the vitrified 'salt slags', how are they formed, and how do they relate to the salt production process?
    ii. What combustible was used to fuel the salt production hearths?

Furthermore, this dissertation aims to go beyond a purely descriptive study of the archaeological evidence of the production activities. Based on the collected archaeological and scientific data, this study aims to reconstruct the choices of the salt producers and how this affected the overall *chaîne opératoire*. Moreover, this study aspires to contextualise the Menapian salt production into a wider socio-economic and socio-cultural framework. The **second research question** is hence defined as follows:

(2) Who were the social actors involved in salt production, how was the production organised, and what was the socio-economic and socio-cultural impact of the production activities in the study area and the wider region?

Two additional questions can concretise this general question:

a. Which social actors were involved in salt production, and how does this relate to other salt production regions in northwestern Europe?
b. What role does salt production play in the socio-economic development of the study area?

These research questions and objectives are explored in the individual chapters. Chapter 9 will integrate and contextualise the results presented in the individual chapters in order to provide a comprehensive answer to the overarching research questions.

1.3 Materials and methods

This dissertation uses wide range of source materials and techniques to answer the research questions described above. Given the variety of (analytic) methods used in this thesis, only the overarching methodology of the dissertation is discussed in this section. A more detailed methodology containing the technical information of the employed techniques is embedded within the respective chapters.

1.3.1 Data collection and inventory

The first step of this study was to construct a Microsoft Excel database of known Iron Age and Roman salt production sites between the Somme (Fr) and the Rhine (De). In order to be as complete as possible, all archaeological salt production sites known through trial-trenching or excavation and all briquetage findspots dated between 800 BCE and 476 CE were inventoried (APPENDIX 1). In addition, a second Microsoft Excel database was constructed containing all sites and finds within the territory of the *civitas Menapiorum* with a date that (partially) falls within the parameters of the early and mid-Roman period (57 BCE – 276 CE). This overarching database was then filtered to only contain *in situ* finds or sites. In order to adequately use the data, each site, context or find was assigned to a specific site category: rural habitation, central places (*vici*, military and religious), maritime, salt production and peat extraction. The first database forms the basis for the chronological and geographical development discussed in Chapter 4. The separate site categories of the second dataset are discussed in Chapter 2.

The following resources were used to construct the abovementioned databases:

1) State- or regional-level online archaeological databases (CAI and ARCHIS database)
2) Published literature
3) Unpublished literature ('grey' literature)

The latter category consists of unpublished technical reports of archaeological operations. For Flanders and the Netherlands, these were consulted at the libraries of agentschap Onroerend Erfgoed or Erfgoed Zeeland. For northern France, several reports were obtained through personal contact with the responsible archaeologists.

In addition, several excavations of salt production sites in Flanders (Leffinge) and Zeeland (Koudekerke, Ritthem, 's-Heer Abtskerke and Middelburg Oude Vlissingseweg) were never processed. The archive of Leffinge was made available by the V.O.B.o.W, Regionaal Archeologisch Museum aan de Schelde (RAMS) and agentschap Onroerend Erfgoed. The archives of the Dutch sites were made available by Erfgoed Zeeland.

1.3.2 Site analysis and material culture studies

The unprocessed and published sites harboured an untapped potential to examine the salt production activities in the study area. The study of these sites can be divided into two parts: site analysis and material cultural analysis.

1.3.2.1 Site analysis

Before the sites could be analysed, compared and contextualised, the raw excavation data had to be processed into comprehensible site plans, profiles, sections and feature lists. The excavation plans were georeferenced and digitised in ArcGIS. The profiles and sections were digitised using Adobe Illustrator and Adobe InDesign. The processed data, included in APPENDIX 4A, was then used to describe the salt production related features of the sites in the different chapters.

1.3.2.2 Material culture and archaeometric studies

A large collection of (salt production related) artefacts was discovered at the excavated sites. Studying these artefacts could contribute immensely to our understanding of the salt production process. Therefore, all recovered artefacts, except the regular pottery of Zeebrugge Achterhaven, Koudekerke Meinersweg and Middelburg-Oude Vlissingseweg, were (re)-examined in the framework of this dissertation. As the regular pottery of these sites was studied in De Clercq's PhD (2009c, 2009a, 2009b), this study could rely on and build upon this dataset. The pottery of Koudekerke Meinersweg is the topic of a separate study by Erfgoed Zeeland.

Typological analysis and quantification of regular pottery

Only pottery fragments > 1 cm² are registered as sherds. These sherds were first grouped into fabrics by analysing fresh fractures using an Olympus SZX7 stereo microscope at magnifications x10 – x40. When possible, references to known fabric groups were made, for example, the work of Brulet et al. (2010) or Vanhoutte et al. (2009b). Yet, detailed fabric descriptions will not be provided except for the handmade pottery. The fabrics of the handmade ware will be studied in more detail because these recipes might correlate with the briquetage pottery. Even though the same terminology is used, the handmade fabrics do not correspond to the handmade fabrics defined by Vanhoutte et al. (2009b). The handmade fabrics were described following the methodology devised by De Clercq (2009c). After that, the pottery was categorised by form and type. For this, a wide variety of known typologies was consulted, for instance, Dragendorff (1895), Ludovici (1927), Holwerda (1923), Brunsting (1937), Oelmann (1914), Stuart (1963), Vanvinckenroye (1991), and so on.

After attributing the sherds to fabric and typological groups, they were quantified by sherd count and minimum number of individuals (MNI). In the former technique, all sherds were counted, considering the number of joining sherds (matching sherds were counted as one). In the latter approach, each fabric group's diagnostic sherds (rim, base, handle and distinctive body sherds were counted to estimate the minimum of individuals present.

Technological and typological analysis of the briquetage material

A detailed description of the methodology is given in Chapter 6. Therefore, this section only briefly covers more general aspects of the briquetage methodology.

Following Anglo-Saxon tradition, each piece of briquetage was first assigned to one of four major categories: (salt) containers or briquetage vessels; support[3] material; structural or hearth material and miscellaneous material (see, amongst others, Fawn et al., 1990; Lane and Morris, 2001; Hathaway, 2013). Fragments < 1cm² are undiagnostic and are registered as a miscellaneous subcategory.

This study considers both technological and typological aspects of briquetage material. The main objective of a technological analysis is to understand and reconstruct the successive stages and actions of transforming raw material into finished objects (i.e. the *chaîne opératoire*). Fresh fractures were analysed using an Olympus SZX7 stereo microscope at magnifications x10 – x40 to study the clay and the preparation techniques. The methodology used to characterise and describe these fabrics is based on Peacock (1977), Orton et al. (1993), Whitbread (2001) and Quinn (2013). In addition to the ceramic composition, several other aspects of pottery technology, such as fashioning and finishing

[3] The term 'support' denotes all types of objects, such as stabilisers, pedestals, firebars, etc., that have been created to support the containers (Lane and Morris, 2001, 42).

methods, can be studied macroscopically. Fashioning techniques of both briquetage vessels and support elements (e.g. pedestals) have been documented by, amongst others, Prilaux (2000a), Lane and Morris (2001), and Hathaway (2013).

After dividing the briquetage into fabric groups, the material was categorised by form and type. This typological classification was based on previous studies of Iron Age and Roman briquetage from the Low Countries (van den Broeke, 1986, 1995b, 1995a, 1996, 2007, 2012), northern France (Prilaux, 2000a; Donnadieu and Willems, 2015) and the UK (Fawn et al., 1990; Lane and Morris, 2001; Pool, 2012; Hathaway, 2013). The briquetage was quantified using sherd count and weight. All results of all observations were registered and summarised in an Excel database (APPENDIX 3). A more detailed overview of all registered parameters is presented in Chapter 6.

Petrography

Often macroscopic fabric descriptions are complemented by ceramic thin-section analysis (Whitbread, 2001; Quinn, 2013). Thin-section petrography is an established technique to study the composition of ceramics, providing insights into pottery provenance and technology. Although initially planned, ceramic petrography was not used to study the briquetage pottery as this was no longer feasible due to covid-related delays of the PhD project. Thin-section petrography should therefore be included in future research as this method enables more detailed fabric descriptions including the identification of mineralogical inclusions, and allows us to study pottery technology in more detail.

Petrography was used to study the composition and formation of the vitrified 'salt slags'. For this purpose, 30 thin sections (0.03 mm or 30 μm thick) of vitrified 'salt slags' and fired clays are analysed using a polarising microscope with a rotating stage and two types of light: plane-polarised (PPL) and cross-polarised light (XP). The petrographic analysis is performed in collaboration with dr. Eric Goemaere of the Geological Survey of Belgium (Royal Belgian Institute of Natural Sciences, Brussels). A detailed overview of the samples and methodology of the petrographic analysis is given in Chapter 8.

Scanning Electron Microscopy/Energy Dispersive X-Ray Spectroscopy (SEM/EDS)

The SEM/EDS analyses are used to study the composition of the objects at higher magnification and to identify the newly formed minerals. Furthermore, the EDS system was used to determine the objects' and minerals' elementary oxide composition. The SEM/EDS analyses were conducted in collaboration with dr. Eric Goemaere of the Geological Survey of Belgium and dr. Thierry Leduc of the Royal Institute of Natural Sciences (Brussels). A more detailed overview of these analyses is provided in Chapter 8.

X-Ray diffraction (XRD)

XRD was used to analyse the bulk mineralogy of the vitrified and fired clay objects and to identify the high-temperature crystalline phases occurring in the samples. A more detailed overview of these analyses is provided in Chapter 8.

PY-GC-MS, phytoliths and XRF

Several ash samples were preserved at the late second-early third century salt production sites. A multi-proxy approach combining microscopy, PY-GC-MS, phytoliths and XRF analyses was devised to identify the type of combustible used to fuel the hearths. Unfortunately, due to the COVID-19 pandemic, this aspect of the research was seriously delayed. This paper, currently in prep. contains a detailed methodology and the technical information of the employed techniques (Dekoninck et al., In prep). This study was conducted in close collaboration with prof. dr. Koen Deforce, dr. Joeri Kaal, dr. Welmoed Out, dr. Vince Van Thienen, dr. Pieter Tack and Sylvia Lycke.

1.3.3 Overarching interpretation and contextualisation

Interpretation and contextualisation of the results from the different analyses will occur on two levels. In the first level, the specific research questions and objectives are answered and contextualised based on previous ethnographic and archaeological research in other regions. The second level integrates the results of the different chapters and applies the theoretical framework set out below (section 1.4) to answer the overarching research questions. Moreover, in Chapter 9, the results will also be further contextualised in a historical and economic setting.

1.4 Theoretical framework

This section discusses the conceptual framework for this dissertation and provides a theoretical background to answer the central research questions. This theoretical framework will enable us to interpret the salt production activities in the northern Menapian *civitas* on a deeper social, economic and cultural level. This framework comprises several theoretical concepts and will be put into practice throughout the dissertation,. First, Bourdieu's 'practice theory' will be briefly outlined as a way to interpret and make sense of the archaeological record. And second, the ideas of object biography, *chaîne opératoire*, and production organisation will be considered.

1.4.1 Material culture and practice theory

Material culture is at the heart of the archaeological discipline, and from the beginning, archaeologists tried to interpret or make sense of the meaning embedded in artefacts. Initially, archaeological practice focused on collecting and constructing artefact typologies which were linked to unilineal evolutionary models of successive, increasingly complex cultures (Dietler and Herbich, 1998; Lucas, 2012). During the 1960s, the New Archaeology movement criticised these overly simplistic views and introduced new ways of archaeological thinking. In the 1980s and 1990s, postmodernist currents of thought drawn from wider social, linguistic and philosophical fields encouraged numerous new approaches to study the past. In this study, especially the social theory, also known as 'practice theory', of Pierre Bourdieu (1977, 1990) and intellectually related authors, such as Anthony Giddens (1984), will be used to gain insight into the archaeological record. Their work emphasised the role of individual actors in the material world, and the production and developments in material culture are understood as the results of social practice (Tilley, 1989; De Clercq, 2009c, 27; Deschepper, 2022, 81). This notion of social practices and the role of individuals also found its way into more technological, artefact-driven studies (Lemonnier, 1993; Martinon-Torres, 2002).

In *Outline of a Theory of Practice*, Bourdieu (1977) sets out to reconcile the apparent opposition between social structures and individual agency by introducing the concept of *habitus*. In plain terms, *habitus* can be seen as the existing socio-cultural structure that has been shaped by past and present circumstances (e.g. upbringing, education) and, at the same time, structures current and future practices (i.e. actions) (Bourdieu, 1977, 78; 1990, 53; Maton, 2008, 51). Practices or actions have an important place in Bourdieu's theory and, in addition to *habitus*, are determined by the concepts of *field* and *capital*. Simply put, practice results from the relation between *habitus* and one's position in a field (*capital*) within the current state of play of that social arena (*field*) (Bourdieu, 1994; Maton, 2008, 51). The concept of *field* relates to the social space in which social agents interact and transactions and events occur. These *fields* are competitive by nature as the various social agents try to maintain or improve their position. The competition within fields revolves around the accumulation of different types of *capital*. In total, four types of capital are distinguished: economic (property, money), cultural (knowledge, education), social (family, network) and symbolic capital (prestige, reputation) (Thomson, 2008, 68-69). These patterned and predictable 'rules of the game' are known intuitively by the social agents who operate within the *field*. Although the social order within *fields* is hierarchised (i.e. dominant social agents with more decision-making power exist), there is agency and change (Thomson, 2008, 70-74). As such, *habitus*, *field* and *capital* are mutually constituting and evolving, meaning that they shape each other, and change in one involves change in the other (Deschepper, 2022, 81).

However, it should be emphasised that *habitus* is not a static concept. Through a set of learned dispositions and a process of reasoning, individuals can respond to practical demands or a changing field within the limits of what is considered possible. In doing so, individuals (as social agents) will gradually alter practices which, in turn, affects the *habitus* (Dietler and Herbich, 1998, 247). Nevertheless, in this view, agency or the free will of people to act beyond the imposed social structures is still somewhat limited by the range of possibilities present in the *habitus* (Bourdieu, 1977, 1990; Maton, 2008, 51-52).

The concepts of *habitus*, *field* and *capital* are interdependent, and practices result from the interchange between these concepts. In short, this implies that each individual or collective practice (or action) has a social meaning. Therefore, the production and manipulation of material culture, as a product of (physical) practice, can be considered socially significant actions. Studying artefacts can thus provide information about the individuals and the society that produced and used them (Caple, 2006, 1). Nevertheless, it must be stressed that the relationship between artefacts and society is complex as objects are not simply a mirror of social practice but also actively shape practice (Tilley, 1989, 188). The following sections will discuss in more detail how objects can be used to interpret aspects of society.

1.4.2 Chaîne opératoire and cultural biography of things

Although all artefacts have meaning, it must be stressed that not every object has the same degree of meaning, and often objects contain a range of meanings (Hodder, 1987; Caple, 2006). In addition, objects do not occur in isolation but exist in a context, and should therefore be seen in relation to the context from which they derive (Appadurai, 1986; Caple, 2006). Simply put, an artefact consists of multiple layers of information depending on its use and context, and all of these layers need to be combined to understand and interpret the object's significance.

One way to approach this multi-layered nature of objects is through the concept of biography. This principle revolves around the fact that throughout their life, people and objects are constantly transformed, and these transformations of persons and objects are interlinked (Gosden and Marshall, 1999, 169). Caple's (2006) object production and use sequence (OPUS) approach also reflects this holistic appreciation of objects. In this theory, raw materials are transformed into objects by the expertise of artisans using the tools and resources available to them. Before these objects were discarded, they could have had multiple use cycles including reuse and recycling (Caple, 2006, 13). This life cycle approach, in which objects are ascribed a more active role and can accumulate different meanings over time through social interactions, is a reaction to the processual archaeologist's static concept of use-life (or lifespan), in which objects are considered passive things to which things happen (Gosden and Marshall, 1999, 169-170).

The notion of the biography of things goes back to Kopytoff (1986). He argued that to fully understand objects, one must consider their different life stages, including birth, life and death, as well as the people who made them. What makes an object biography cultural is the perspective that objects are entities to which meaning is ascribed by the people who made it.. That being said, Kopytoff's view is very object-centred and pays little attention to the wide range of contexts in which objects are used (Dannehl, 2009). Dannehl (2009, 180-181) therefore suggests an approach in which object life stories (i.e. the transformations of an object through varying contexts) and life-cycle mapping are combined to create a more generalised narrative covering the object's entire lifespan. Cultural biographies thus offer a way to study the wide variety of symbolic and social values attributed to objects. Yet, this approach places a strong emphasis on objects, and human action takes a backseat. This is where the concept of *chaîne opératoire* comes in as an alternative approach to cultural biography.

Chaîne opératoire focuses on the sequence of actions that shape object life cycles and places human agency at the forefront. The term *chaîne opératoire* (operational sequence) was first introduced by Leroi-Gourhan (1964), who used it as a way to describe the productive sequence(s) and decision-making strategies that transform raw material into usable objects. The main innovation of Leroi-Gourhan's concept is that the production of objects is seen as an ordered sequence of technical acts executed by individuals. As such, technical acts can be considered social acts which have meaning beyond the meaning conveyed by the produced object (Dobres, 1999; Martinon-Torres, 2002, 31). Moreover, many researchers, i.e. Sellet (1993) and Martinon-Torres (2002) agree that the concept of *chaîne opératoire* should encompass not only the artefact's origin but also its entire life history. Martinón-Torres (2002, 33) considers this the 'length of the *chaîne opératoire*,' in which the concept is used to emphasise every transformation from raw material until deposition including all the actions, gestures, agents, tools and knowledge that were involved.

Over the years, a new dimension was gradually added to the concept of *chaîne opératoire*. For instance, Sellet (1993, 106) considered *chaîne opératoire* a 'technological approach that seeks to reconstruct the organisation of a technological system at a given archaeological site.' Dobres (1999, 124) goes even further and defined *chaîne opératoire* as an 'interpretative methodology and analytical method capable of forging robust inferential links between the material pattering of technical acts and the sociopolitical relations of the production accounting for them.' In other words, Dobres (1999) believes that the production of objects cannot be disentangled from the political, economic and/or social context in which it was produced. This consideration of the operational sequence as a socially embedded reality with the potential to go beyond a technological description of objects and to address agency and society is what Martinón-Torres (2002, 33) calls the width of the *chaîne opératoire*.

An important aspect of the *chaîne opératoire* approach is that the technical actions are performed by human actors who make choices at all stages of the production process. In other words, during every (technical) action, people can choose from several technological options known to them. As a result, there is never only one possible way of doing things (Lemonnier, 1993). These so-called 'technological choices' can take place within five main fields: raw material, tools, energy, techniques and sequence of gestures. At the same time, these fields present a series of constraints as the range of choices is not limitless but determined by the possibilities present in the artisan's *habitus* (Gosselain, 1992; Lemonnier, 1993; Dietler and Herbich, 1998; Martinon-Torres, 2002). In other words, production techniques are the result of *habitus* but also have the ability to reproduce and transform it (Dietler and Herbich, 1998, 246; 260). As these technological choices are also a reflection of the socio-cultural sphere, producers can decide not to use the most efficient or natural way of doing things from a technological perspective (Lemonnier, 1993; Martinon-Torres, 2002).

1.4.3 Technological change and innovation

The ability of social actors to make technical choices within the *chaîne opératoire* is the premise of change and innovation. Contrary to earlier beliefs (i.e. the social evolutionary theory), innovation is not a unique event but a continuous, complex process from the conception of a new idea or behaviour until its acceptance and implementation in society (Torrence and van der Leeuw, 1989; Dobres and Hoffman, 1994). The process of accepting and implementing new inventions into society is often described as 'the adoption' of the idea (Torrence and van der Leeuw, 1989). However, there is a clear distinction between the invention of a technique and its acceptance by the community. In other words, it may take a while for inventions to be widely accepted by society after the initial introduction (Dobres and Hoffman, 1994). Moreover, it is often overly simplistic to always consider individuals as the introducing agents or drivers behind change. While it is undoubtedly true that individuals or small groups can act on their own accord, innovation and change can equally result from sharing information and collective decision-making. The latter reduces the (social) risks that are inevitably connected to change but, in turn, also greatly diminishes the gain of the instigators relative to other members of the group (Torrence and van der Leeuw, 1989, 10-11).

Furthermore, there is the question of who introduced the innovations into the community: the society leaders (top-down perspective) or the common people (bottom-up approach) (Costin et al., 1989; Torrence and van der Leeuw, 1989; Dobres and Hoffman, 1994). According to Costin et al. (1989, 107), **'top-down'** technological change mainly occurs when political centralisation allows the elite to take control over production. This form of control enables the elite to mobilise the resources to support themselves and fend off challengers to their position. On the other hand, '**bottom-up**' change occurs when people adopt and/or invent new techniques that are more productive and/or more efficient. Naturally, one does not exclude the other, and both processes can be involved in the introduction and/or adoption of technological change. However, it is important to emphasise that the intrinsic motivation of the different social actors might be fundamentally different (i.e. control vs. efficiency) (Costin et al., 1989; Dobres and Hoffman, 1994). While a thorough understanding of the forces that drive change is crucial, it should be noted that adopting these changes can be met with resistance in any society. For instance, in a bottom-up change, the lack of capital or labour severely hinders the widespread integration of new techniques. In addition, there is always an element of uncertainty and risk as the results of a new process are unknown (Costin et al., 1989, 108).

The overview above illustrates how technological changes are introduced but does not explain how these changes spread through society. Indeed, before individuals can adopt certain technological changes, these changes have to diffuse through the community. The concept of diffusion can be defined as the process by which an innovation (idea, knowledge, practice, object etc.) is communicated through certain channels over time among the members of a social system (Rogers, 2003). These members (individuals or larger units within a society) then have to decide whether they adopt or reject the innovation. This innovation-decision process consists of five stages or steps (Rogers, 2003, 169-192):

(1) The knowledge stage, i.e. an individual is exposed to an innovation's existence
(2) The persuasion stage, i.e. an individual forms an attitude toward the innovation
(3) The decision stage, i.e. an individual engages in activities that lead to a choice to adopt or reject the innovation
(4) The implementation stage, i.e. an individual puts innovation into use
(5) The confirmation stage, i.e. an individual evaluates the decision to adopt or reject the innovation.

As the first three stages are non-material, overt behavioural change only occurs at the implementation stage, when the innovation is put into practice. At that stage, the adopters can run into potential problems on how to use the innovation and may decide to modify or apply changes to the innovation to better fit their own needs; this process is called re-invention (Rogers, 2003, 180-184). A crucial element of the diffusion process is that the innovations are adopted gradually over time, and the speed at which this happens is called the 'rate of adoption.' The adoption rate is generally measured as the number of individuals who adopt the innovation in a certain period (Rogers, 2003, 221). The fact that not all individuals embrace the innovation at the same time allowed Rogers (2003, 280-281) to classify the individuals into five ideal adopter categories: innovators (first 2.5%), early adopters (13.5%), early majority (34%), late majority (34%) and laggards (16%). When these categories are plotted non-cumulatively, the distribution will approach a Gaussian distribution. An important point in the diffusion's trajectory is what has been described as the 'take-off point.' This is the point where the innovation is adopted by enough individuals who can influence their peer's decisions by providing them with a positive evaluation of the innovation. Once this take-off point is reached, the diffusion becomes self-sustaining by the innovation's social momentum and needs no additional promotion. Gradually, the innovation then loses its 'newness' and becomes part of daily practice (Rogers, 2003, 180, 360; Deschepper, 2022, 87-88).

Applying Roger's diffusion theory to archaeological practice is not always that easy as, for instance, his adopter categories represent an ideal (theoretical) classification. When applied to archaeological examples, these categories might not approach a perfect Gaussian distribution. In addition, the archaeological visibility has a significant impact on the diffusion of innovations as it is not always easy to identify the innovators and the early adaptors (Fokkens, 2008).

1.4.4 Organising production

In addition to the theoretical concepts that frame how objects are produced, it is equally important to consider how the production of these objects was organised. Production can be organised in different ways depending on the availability of raw materials and labour, the nature of the technology, the economic needs and the consumption patterns. The concept of craft specialisation is often recurring in the organisation of production systems. Multiple definitions of specialisation have been proposed, but central is the idea that production varies through time, space and personnel and exceeds the producer's consumption requirements (Costin, 1991, 2001, 2005). In other words, there are more consumers than producers.

Since production is shaped by, amongst other, social, economic, political and technological factors, researchers agree that the production context can take many forms. This variation in production systems is often approached typologically by categorising them into *modes of production*. Often cited typologies are those of van der Leeuw (1977) and Peacock (1982). In this study, only Peacock's model is discussed. The reasons for this are twofold. First, Peacock's model was specifically developed to explain the variability in production in the Roman world. And secondly, compared to van der Leeuw's model, Peacock's typology considers the geographic organisation of production and the possibility of elite or government production (Van der Leeuw, 1977; Peacock, 1982; Costin, 1991, 2005). Peacock's typology (1982) consists of eight levels or modes of production and is presented in Table 1

Table 1 Peacock's (1982, 8-11) modes of production (estate and military production are combined here).

Production mode	Description
Household production	Production for domestic use. Sporadic, little organisation or specialised equipment
Household industry	Production for domestic use and sale/gift/exchange. Production is on a part-time basis at home. Limited use of specialised equipment
Estate and military production	Individuals with crafts skills are employed full-time to produce objects for an organisation (elite or military). Production to meet own demand and for the market. Use of specialised equipment.
Individual workshop	Specialised production intended for exchange or sale. Production is carried out by craftsmen and is the primary source of income. Individual scale of production
Nucleated workshop	Specialised production exclusively for exchange/sale by full-time craftsmen. Substantial investment in specialist equipment and facilities. Larger scale which promotes shared use and multiple users on site. Nucleation is favoured by access to raw materials, labour and markets.
Manufactory	Large-scale (mass) production by several full-time craftsmen working together to produce objects. Workers specialise in certain tasks. Extensive use of specialised equipment and buildings
Factory	Identical to the manufactory, but on a much larger scale. Use of post-industrial equipment like water-/steam-/electric powered machinery. Highly organised mass production with a large number of workers carrying out specialised tasks (modern periods)

Although this typological approach can be incredibly useful to study the organisation of specific craft industries, it remains a conceptual, generic framework imposed upon an inherent variable situation (Costin, 1991, 2005). As such, there will always be examples that do not fit into the typology, a situation that Peacock (1982, 8) himself recognised and acknowledged. An alternative to the typological approaches is Costin's concept of a *production system* which allows greater flexibility and precision in describing and explaining the production organisation (Costin, 1991, 2001, 2005). A *production system* describes the production by a set of six constituent components[4] (Costin, 2001, 2005):

[4] The elements that make up each component can be found in Costin's 'Craft Production Systems' (2001).

(1) **Artisans**: the people who make the objects, the identity of the artisans
(2) **Means of production**: the raw materials, tools, knowledge and skill necessary to produce the objects
(3) **Organization and social relations of production**: principles through which members of a production unit are organised and interact
(4) **The objects**: the things that are made in craft production systems
(5) **Relations of distribution**: the mechanisms through which objects are transferred from producers to consumers
(6) **Consumers**: the people who use the objects.

By approaching production as a system affected by various socio-economic and political factors, this method offers a more nuanced (socio-economic) view of the organisation of production. Particularly interesting is the notion that the organisation of production partly depends on the consumer, by matching the desired output and consumer demand. The demand refers to the amount of a particular good consumers desire at a given price and depends on the object's function, distribution and nature of the consumers (Costin, 2005). In other words, consumption is inextricably linked to production since the way something is made influences and is influenced by how the object is used.

Attached and independent production are two specific types of producer-consumer relations. In a system of attached production, elites or political institutions control (some of) the components of the production systems like access to raw materials, technical choice, labour organisation, distribution etc. As such, these forms of craft organisation serve to enhance or uphold the group's privileged access to certain resources and objects. Conversely, independent production systems are not controlled by elite networks, so the produced objects often tend to be utilitarian (Costin, 2001, 2005). However, in complex societies, the division between attached and independent production is less straightforward as degrees and indirect forms of elite control can exist (Costin, 2005).

While it is important to realise the effects of consumer behaviour on the production of objects, theoretical concepts behind consumption will not be explored here as consumption is not an integral part of this study. However, as this study touches upon aspects of trade and/or exchange, the principles of distribution will be briefly discussed. The term distribution refers to the processes and mechanisms for transporting objects between individuals. Exchange or the transfer of goods is an integral part of specialised production because the producer and consumer are not the same. Consequently, objects need to be transferred from producer to consumer, a process which is embedded in social and political actions (Costin, 2001, 304-305).

In non-industrialised economies, the transfer of goods is often described in terms of three processes: reciprocity, redistribution, and exchange (Polanyi, 1957; Earle, 1977; Rice, 2015, 187). Reciprocity refers to the movement of objects, typically considered 'gifts', between individuals based on symmetrical relationships. The material aspect of the transaction is less significant compared to the social and symbolic act that the transaction represents (Polanyi, 1957; Rice, 2015, 187). In the concept of redistribution, all goods are accumulated or appropriated, moved to a central place, and then reallocated or dispersed (Hirth, 1996; Rice, 2015). Earle (1977) distinguished four types of redistribution of which the mobilisation of goods by and for a separate entity, usually an elite, was the most important. This type of redistribution in which political entities initiate a hierarchical transfer of goods can only exist in stratified societies (Hirth, 1996, 188; Rice, 2015).

Finally, exchange refers to any transactional process in which goods change hands in return for other goods or services. From a more narrow point of view, the term exchange is equated with commercial exchange which implies the presence of an impersonal market. Nevertheless, a small connotational difference remains between the terms trade and exchange as the former involves a market economy in which goods are transported over longer distances, and the relationship between partners is relatively formal and institutionalised (Rice, 2015, 188-189). However, none of these processes describes how the different actors and the goods physically came together. These logistical mechanisms were developed by Rice (2015, 189-190), who distinguished five different, generic options: consumer travels to producer (a); producer travels to consumer (b); producer and consumer travel to a third location (c); middleman (third party) transports the goods from the producer to the consumer (d); producers transports the goods to a central redistributive agency (e) (Figure 2).

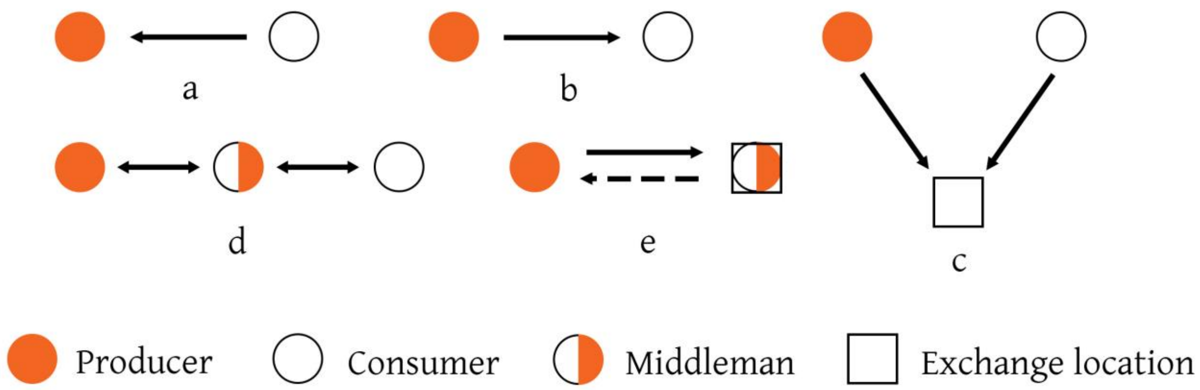


Figure 2 Model of distribution relationships (redrawn after Rice, 2015, 189, figure 11.1)

Chapter 2 The coastal plain of the *civitas Menapiorum* in Roman times

Before discussing the salt production activities, it is important to have a thorough understanding of the physical landscape and the occupational context in which the activities take place. Hence, this chapter outlines the research tradition, the landscape, the Roman occupation and exploitation of the Menapian coastal plain.

2.1 A long standing research tradition

On the fifth of January 1647, a storm on the coast of Zeeland revealed the remains of a Roman sanctuary with several altars dedicated to the native goddess Nehalennia. These finds, now displayed at the *Rijksmuseum van Oudheden* (Leiden), are the oldest preserved Roman discoveries in the Menapian coastal plain (Hondius-Crone, 1955; Stuart and Bogaers, 2001). In the eighteenth and nineteenth centuries, multiple find assemblages were discovered during peat extraction activities, but the nature of the structures from which they emerged was vague and obscure.[5] Back then, no research tradition existed, and only the museum worthy finds were collected and sold at auction to private collectors or museums (Thoen, 1973, 1978a).

At the beginning of the twentieth century, large infrastructural works at Bruges and Zeebrugge led to the discovery of a Roman boat and a wooden framework on top of the peat (section 2.3.3). Both times, baron A. de Loë, curator of the Royal Museum of Art and History (KMKG) in Brussels, was called to the scene and, in the case of Bruges, he considered archaeological investigation unnecessary. At Zeebrugge, he was able to document a large enigmatic structure whose interpretation has changed multiple times over the years (Rutot, 1902-1903; de Loë, 1904; de Pélichy, 1905). At the same time, de Loë (1901-02, 1906, 1908) conducted the first excavations in the dunes of the Panne, which Rahir (1927) continued in the 1920s (Lehouck and Thoen, 2012). Some years later, the amateur-archaeologist Loppens (1932) published a summary of the current geological and archaeological knowledge between Calais and Knokke. In 1951, Lambrechts (1951) wrote a new synthesis focusing on the Roman occupation between the North Sea and river Scheldt. However, his publication focused on the larger

[5] For an overview of these eighteenth-century discoveries: see De Bast (1808)

political-historical aspects of the Menapian coastal plain, and only sporadically mentioned archaeological finds or sites.

In the 1970s, Thoen (1973, 1978a) bundled and studied all the ancient discoveries in the Belgian coastal plain, which he presented as an overview of 147 sites. After critically reviewing the evidence, Thoen reduced this overview to 77 sites, of which only 37 sites contained Roman material *in situ* (Thoen, 1978a, 63). Most of these *in situ* finds were accidentally discovered during peat digging (21), found in clay quarries (4) or encountered during other large-scale earthworks (6) (Thoen, 1978a, 65). However, practically none of these sites were excavated, and information regarding the nature of these sites was extremely limited. In his published doctoral dissertation, Thoen (1978a, 204-205) concluded that the Roman coastal plain was characterised by very loose, scattered habitation, which was focused on fishing, salt production and sheep husbandry. Nevertheless, questions on how the Roman communities in the Belgian coastal plain lived, worked and died largely remained unanswered. At the same time, Trimpe Burger (1973) published an overview titled: '*the Islands of Zeeland and South Holland in Roman Times*'. While more excavations and important chance finds (Domburg and Colijnsplaat) occurred in Zeeland, information regarding the nature of the Roman occupation was equally limited. In 1987, a more popular account of the Belgian coastal plain in Roman times appeared containing an updated overview of the *in situ* finds (Thoen, 1987). Compared to the earlier studies, no significant new sites had been discovered that could significantly alter the perception of the Roman occupation. Hence, Thoen (1987) rightly summarized the state of knowledge as follows:

> "… as strange as this may sound, the knowledge is still extremely limited. A number of crucial aspects is still totally unknown such as the nature and appearance of the habitation" (Thoen, 1987, 47).

During the monitoring of large-scale infrastructural works at the Zeebrugge harbour, new sites with *in situ* finds were discovered from the late 1980s onwards (Hillewaert and Hollevoet, 1986c, 1987; Hollevoet, 1989; Hollevoet and Hillewaert, 1989). In Zeeland, interesting artisanal and habitation sites were found and excavated by members of the *Archeologische Werkgemeenschap voor Nederland* (AWN) in the 1980s. Yet, these sites were only marginally published and did not find their way to international literature. In 1999, Ervynck et al. (1999) published a critical overview of the coastal plain rejecting the transgression model (section 2.2.2) and reviewing the human occupation during the first millennium. For the Roman period, they adequately summarised the current state of knowledge in the following paragraph:

> "From the published data, therefore, it is possible to conclude that the evidence for human occupation in the coastal plain is somewhat enigmatic during the Roman period. There is no doubt that people were active in the area but whether there was continuous occupation remains obscure. The scarcity of building remains suggests that settlements were rare and the impression given is that permanent habitation only developed along the dune belt and on the coast. It is not impossible that agriculture was practised near these habitation sites, but more archaeological proof is needed. Activities in the present polder area must have been oriented towards salt (and fish sauce?) production (where salt water was entering the coastal plain) and, possibly, towards the herding of sheep and goats. Both types of activities, however, will have been of seasonal nature." (Ervynck et al., 1999, 109)

From this passage, it is clear that the understanding of the Roman coastal plain was still extremely limited at the beginning of the 21st century. From the late 1990s onwards, Malta-driven rescue archaeology gradually altered this view. Large projects at Zeebrugge (Patrouille, 2013), Dudzele (In 't

Ven and De Clercq, 2005), Ellewoutsdijk (Sier, 2003; Van der Heijden and Sier, 2006) and Serooskerke (Dijkstra and Zuidhoff, 2011) provided new insights into the habitation structures (section 2.3.1). De Clercq's doctoral dissertation (2009c) on the characterisation and transformation of the Roman period settlement landscape in the *civitas Menapiorum*, bundled these new insights, and presented an overview which significantly altered the understanding of the Roman coastal plain abolishing idea of seasonal habitation. This overview revealed a differentiated spectrum of permanent occupation types established either on dried-out peat, Pleistocene sandy outcrops (*donken*) or artificially raised platforms (*terp*) (De Clercq, 2009c, 2011). Since then, new discoveries, primarily in Zeeland, have been made confirming De Clercq's assumptions of a permanent Roman occupation in the coastal plain. In addition, Dhaeze (2011; 2021) reviewed the evidence of the Roman military coastal defence system, and syntheses of specific military forts like Aardenburg (van Dierendonck and Vos, 2013) and Oudenburg (Vanhoutte, *in press*) have since been published. Nevertheless, while the knowledge of habitation structures grew over time, information regarding the funerary practices and the exploitation of natural resources remained rather limited.

2.2 Understanding the coastal landscape of the northern Menapian *civitas*

In order to understand the Roman occupation and activities, it is imperative to have a thorough understanding of the landscape. The local landscape not only determined the availability of natural resources but also regulated the overall accessibility as erosion and sedimentation processes constantly modified the outlook of the coastal plain. Exactly this dynamic character makes coastal landscapes unique, yet it also complicates the interpretation of past human activity. This section presents an overview of the landscape-historical theories and models applied to the coastal area. Over the years, the early twentieth-century transgression model has been thoroughly refuted. Yet, understanding and explaining this theory is crucial since it was used to interpret the landscape surrounding several earlier discovered sites. In the last decades, new research into the coastal development of the Belgian coast and its adjoining coastal areas brought many new insights. Without going into too much detail, first the transgression model will be briefly explained. After that, the current theory on the Holocene coastal landscape evolution will be summarized.[6] Finally, the outlook of the northern Menapian coastal plain during Roman times and the human impact on the landscape is discussed.

[6] Two recent doctoral dissertations (Deckers, 2014; Trachet, 2016) and several articles (Vos and Van Heeringen, 1997; Baeteman, 2007a, 2008, 2013; Trachet et al., 2015; 2016, 2018) provide excellent summaries of the landscape evolution in the Belgian coastal plain. This brief overview of the landscape-historical theories presented here is largely based on the abovementioned sources and follows a similar structure.

2.2.1 The Roman coastal landscape in historical sources

Caesar's conquest of Gaul provided, albeit from a Roman perspective, a first comprehensive account of northern Gaul. While the *Commentarii de bello Gallico* focused on the military campaigns and were propaganda to defend his (political) actions, Caesar did refer on multiple occasions to the landscape of the Menapian *civitas.* During these campaigns, the *Menapii* used the local landscape to their advantage in what can only be described as guerrilla warfare techniques (Wightman, 1985, 26-39). In 56 BCE, Caesar depicted the landscape of the *Menapii* and the neighbouring *Morini* as follows:

> '(...) and possessing continuous forests and marshes, they conveyed themselves and all their stuff thither (...)'
>
> (Caesar, BG III 28, trans. by Edwards 1917)

A year later (55 BCE), *Labienus* defeated the *Morini* but the *Menapii* retreated in their forests and did not surrender:

> "(...) the enemy had no place of retreat, by reason of the dryness of the marshes, their refuge in the previous year; almost all of them, therefore, came and surrendered to Labienus. As for Quintus Titurius and Lucius Cotta, the lieutenant-generals who had led legions into the territory of the Menapii, they did not return to Caesar until they had laid waste all the fields of the natives, cut down the corn-crops, and burnt the buildings, because the Menapii had all hidden in their densest forests."
>
> (Caesar, BG IV 38, trans. by Edwards 1917)

In the campaigns of 54 BCE, Caesar mentioned the landscape and the withdrawal of the *Menapii* into their forest and marshes for the last time :

> "(...) there were the Menapii, near the borders of the Eburones, defended by continuous marshes and forests (...)."
> "(...) they had raised no force, but, relying only on the protection of the country, fled all into the forests and marshes, and gathered their stuff there also (...)."
>
> (Caesar, BG VI 5, trans. by Edwards 1917)

These passages suggest that the landscape was dominated by large forests and extensive marshlands. Even if Caesar might have slightly exaggerated, it is generally assumed that large forests were present on the sandy Pleistocene subsoils and that the marshlands refer to the coastal wetlands (De Clercq, 2009c, 148-149).

At the end of the third century CE, a panegyric was delivered at Trier honouring *Constantius Chlorus*' restoration of Britain to the Roman Empire after defeating the Menapian usurper *Carausius* (Nixon and Rodgerds, 1994, 104-108). In this panegyric, the estuaries of the rivers Scheldt and Rhine are described as extremely wet, treacherous marshland. While this passage mainly referred to the neighbouring Batavian territory, similar conditions might have prevailed at the end of the third century CE in the neighbouring coastal wetlands of the *civitas Menapiorum*:

> "During the whole of this period, however, you never ceased to destroy those enemies whom terra firma permitted you to approach, although that region which was liberated and purged of the enemy by your divine campaigns, Caesar, through which the Scaldis flows with its meandering channels and which the Rhine embraces with its two arms, is hardly land at all, if I may hazard the expression. It is so thoroughly soaked and drenched with waters that not only where it is obviously marshy does it yield to pressure and engulf the foot which treads it, but

> even where it seems a little firmer it shakes when subjected to the tramp of feet and attests by its movement that it feels the weight from afar. Thus the fact is that this land swims on what underlies it and, suspended there, trembles so extensively that one might claim with justification that such terrain existed to give soldiers practice in naval warfare"
>
> (Pan. Lat. VIII.8.1-3 – Panegyric of Constantius, trans. by Nixon and Rodgers 1994, 120-121)

During the first century CE, Pliny the Elder wrote a remarkable passage on the coastal landscape of the *Chauci*, situated north of the Rhine. In this account, he described in detail the tidal landscape and the *Chauci* way of life:

> "(...) what is the nature and what are the characteristics of the life of people living without any trees or any shrubs. We have indeed stated that in the east, on the shores of the ocean, a number of races are in this necessitous condition; but so also are the races of people called the Greater and the Lesser Chauci, whom we have seen in the north. There twice in each period of a day and a night the ocean with its vast tide sweeps in a flood over a measureless expanse, covering up Nature's age-long controversy and the region disputed as belonging whether to the land or to the sea. There this miserable race occupy elevated patches of ground or platforms built up by hand above the level of the highest tide experienced, living in huts erected on the sites so chosen, and resembling sailors in ships when the water covers the surrounding land, but shipwrecked people when the tide has retired, and round their huts they catch the fish escaping with the receding tide. It does not fall to them to keep herds and live on milk like the neighbouring tribes, nor even to have to fight with wild animals, as all woodland growth is banished far away. They twine ropes of sedge and rushes from the marshes for the purpose of setting nets to catch the fish, and they scoop up mud in their hands and dry it by the wind more than by sunshine, and with earth as fuel warm their food and so their own bodies, frozen by the north wind. Their only drink is supplied by storing rain-water in tanks in the forecourts of their homes. And these are the races that if they are nowadays vanquished by the Roman nation say that they are reduced to slavery! That is indeed the case: Fortune oft spares men as a punishment"
>
> (Pliny the Elder NH. XVI. 2-4, trans. by Rackham 1945)

This passage is particularly important since the conditions must have been very similar in the coastal wetlands of Northern Gaul. For example, the platforms to which Pliny referred, resembles the excavated artificial platforms of Ramskapelle (Verwerft et al., 2019b) (section 2.3.1.1), and 'earth as fuel' pertains to peat of which several extraction pits have been found in the Menapian *civitas* as well (section 2.4.1.3) (Baeteman, 2007b). Nevertheless, all the above mentioned passages are very simplified depictions that do not capture the complexity and diversity of the coastal landscape. However, they do offer a Roman perspective on what they perceived as a difficult and rather marginal landscape on the fringe of the Roman Empire.

2.2.2 First theories on coastal landscape evolution: the Dunkerque transgression model

The northern Menapian coastal plain is part of the North Sea lowlands that stretches from the Cap Blanc-Nez (Fr.) to northern Denmark. Although the North Sea lowlands underwent a similar development, the overview presented here specifically focuses on the local Holocene development of the northern Menapian coastal plain. In general, the coastal plain in the study area is characterised by a complex stratigraphy of late Holocene deposits.

Already at the start of the twentieth century, geologists tried to explain how these deposits formed. Dubois (1924) was the first to recognise two main clay sediment layers ('*Assise de Calais*' and '*Assise de Dunkerque*') separated by a peat bed (so-called surface or Holland peat) in the coastal stratigraphy of northern France. Briquet (1930) adopted these terms and associated them with large-scale marine inundations (so-called transgressions) caused by a rise in sea-level followed by a period of sedimentation. Tavernier (1938, 1948), who studied the quaternary deposits in particular, supported Briquet's interpretation and subdivided the Dunkerque transgression, dated to the post-Roman period, into a series of individual transgressions (DI to DIII). By connecting these inundations to chronological gaps in the archaeological and historical record, Tavernier (1938, 1948) considered the coastal area inaccessible for human occupation during each of these transgression phases.

From the 1950s onwards, Moormann (1951) and Ameryckx (1954) carried out systematic soil mapping in the Belgian coastal plain. During these soil mapping activities, it soon became apparent that they had problems applying this tripartite division to the complex stratigraphy at hand. To explain the observed stratigraphy, Moormann (1951) and Ameryckx (1954) introduced new transgression phases and subphases (so-called Oudland, Middelland and Nieuwland) to Tavernier's model. In addition, Ameryckx (1959) detected vegetative horizons between the clay deposits for which he introduced the concept of regression phases. During these regression phases, he considered the coastal plain to be more accessible which in turn facilitated human occupation. At the same time, a collaboration with historians was established to provide a chronological framework to date the transgression and regression phases. The 1958 colloquium aimed to combine the geological data with the historical sources, resulting in the construction of the Dunkerque Transgression Model (Ameryckx and Verhulst, 1958). In subsequent years, both Verhulst (1959, 1964) and Ameryckx (1959, 1960) integrated their new findings in several papers, synthesising and promoting the results.

This comprehensible Dunkerque Transgression Model[7] (Table 2) was established quickly in international literature, and was uncritically adopted by geologists, archaeologists and historians over the next two decades. During this time, no geological research occurred but important historical, such as Gottschalk (1971) and Dekker (1971), and archaeological research took place, for instance, Verhaeghe (1977) and Thoen (1978a). While Gottschalk (1971) focused on the frequency of medieval storm surges, Verhaeghe (1977) carried out a survey of medieval settlements on clays deposited during the Oudland and Middelland transgression phases in part of the Veurne Ambacht. Both concluded that the current medieval transgression phases could not adequately explain the archaeological and historical data. Similarly, Thoen (1978a) reviewed the archaeological evidence for the Roman period and established that the chronology of the Dunquerke II-phase did not fit the evidence at hand. Another colloquium was organised in 1978 by Verhulst and Gottschalk to address the growing critique (Verhulst and Gottschalk, 1980). Despite the critique, the concept of catastrophic flooding (transgressions), followed by retreating water levels (regressions) was maintained. Consequently, the transgression model continued to be applied in archaeological and historical research (Baeteman, 2013; Trachet et al., 2015).

[7] In short, the Dunkerque Transgression Model consist of three marine transgression phases with subphases (DI, DII (Oudland), DIIIA (Middelland) and DIIIB (Nieuwland) separated by regression phases (Roman regression and the Carolingian regression). During transgression phases the coastal plain is considered uninhabitable while during regression phases the coastal area was occupied (Ervynck et al., 1999; Tys, 2001) .

Table 2 Basic chronological framework of the transgression model (after Ervynck et al., 1999; Deckers, 2014)

Geological phase	Dating elements	Date
Dunkerque I transgression		200 BCE - 100 CE
Roman regression	Archaeological elements	100 - 400 CE
Dunkerque II transgression (Oudland deposits)		400 - 800 CE
Carolingian regression	Historical sources	800 - 1000 CE
Dunkerque III transgression (Middelland and Nieuwland deposits)	Historically attested storm surges	1000-1200 CE

2.2.3 Recent insights into the Holocene development of the northern Menapian coastal plain

Notwithstanding the slight changes in chronology, a growing scepticism towards the simplistic patterns of transgression and regressions phases remained (Thoen et al., 2013). However, it was not until the 1980s that new geological research into the Holocene evolution of the coastal plain took place. While Baeteman (1981) studied the western coastal plain, Mostaert (1985) focused a few years later on the eastern coastal plain. Both geologists refuted the simplistic transgression-regression model and constructed a new geomorphological framework to explain the Holocene evolution of the coastal plain. That being said, it took almost 20 years for these insights to find its way into popular and historical literature. In the 1990s, interdisciplinary research combining archaeological, environmental and historical data successfully deconstructed the transgression model (Ervynck et al., 1999; Tys, 2001). Gradually, a new geomorphological model for Holocene development of the coastal plain in the Low Countries (infra) was proposed by Vos and Van Heeringen (1997), Vos (2015) and Baeteman (1981, 2007a, 2008, 2013, 2016, 2018). For the French part of the coastal plain a similar chronological development has been proposed by Mrani-Alaoui and Anthony (2011).

In this new geomorphological framework, the current outlook of the coastal plain is the result of a complex sequence of clay, peat and sand deposited on top of the underlying Pleistocene substrate. The pre-Holocene topography was formed during the final stages of the Weichselian ice age when predominant northwest winds created an undulating landscape consisting of SW-NE coversand ridges, small elevations and depressions (Deckers, 2014, 15-16; Trachet, 2016, 37-38). Some of these small cover sand ridges remained visible as outcrops (*donken*) until at least the Roman period (Baeteman, 2008). While the palaeovalleys of the Scheldt and the Yser formed large depressions in the Pleistocene surface of Zeeland and the western Belgian coastal plain respectively, the more elevated eastern Belgian coastal plain sloped gently towards a major east-west ridge running over Gistel-Bruges-Maldegem-Stekene (see yellow ridge in Figure 4) (Vos and Van Heeringen, 1997; Baeteman, 2013, 18; Bogemans et al., 2016; Trachet, 2016, 37-38). The onset of the Holocene (11.7 ka) was characterised by a rapid rise in relative sea level (RSL) (> 7m/ka) and the sea gradually entered the area through the large palaeovalleys transforming them into tidal landscapes. In addition, the rising sea level caused higher groundwater levels which allowed freshwater marshes with (Basal) peat to grow on the edge of the tidal area. These peaty freshwater marshes constantly shifted landwards following the rising sea level (Figure 3) (Baeteman, 2013, 18; 2016, 19-21; 2018, 316-317). The coastal area of Eastern Belgium and West-Zealandic Flanders was hardly affected by this early Holocene sea level rise due to their slightly elevated position (de Boer, 2005, 51; Baeteman, 2013).

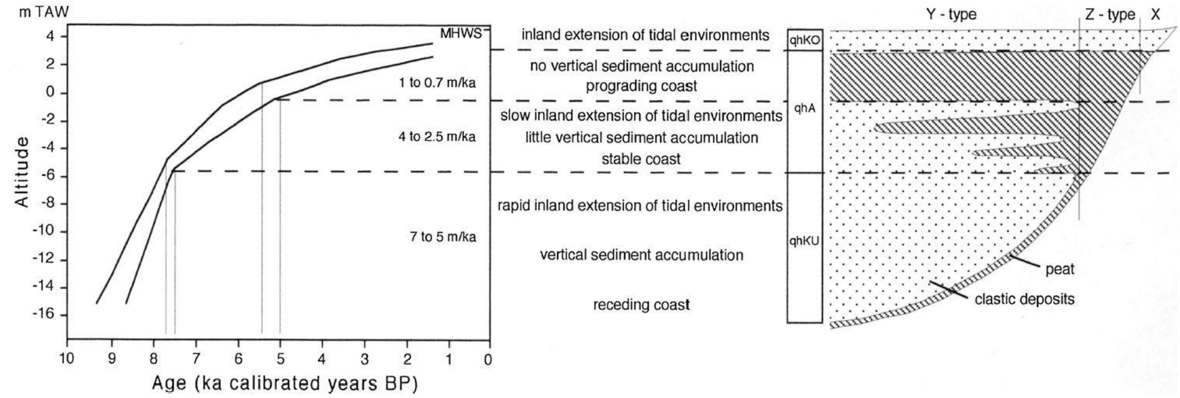


Figure 3 Schematic representation of the depositional history of the Holocene coastal plain in relation to the relative sea level rise (after Baeteman, 2018, 317)

Around 7500/7000 calBP, the RSL slowed significantly (2.5m/ka), stabilising the receding coastline and the position of the coastal barrier. In this period, parts of the tidal flats silted up and locally freshwater marshes with peat developed. This peat formation was often short lived and stratigraphically a number of peat beds with varying thickness alternate with marine deposits (Baeteman, 2013, 18; 2016, 21-22; 2018, 316-318). Gradually, the RSL decelerated and averaged 0.7m/ka from ca. 5500/5000 cal BP onwards. As more sediment became available, the tidal basin silted-up further and the coastline extended seawards. Behind this new coastal barrier, a tidal landscape with tidal channels, mudflats and salt marshes developed. However, further inland the freshwater marshes expanded substantially allowing extensive peat growth (up to 3 m thick) (Figure 3, middle section Figure 4). Throughout this period, the large tidal channels remained open and mostly served as drainage for the peatbogs and the Pleistocene hinterland. Additionally, the elevated position of some coversand outcrops (*donken*) might have prevented peat formation in some localised spots (Baeteman, 2013, 18; Deckers, 2014, 18; 2016, 21-22; 2018, 316-318).

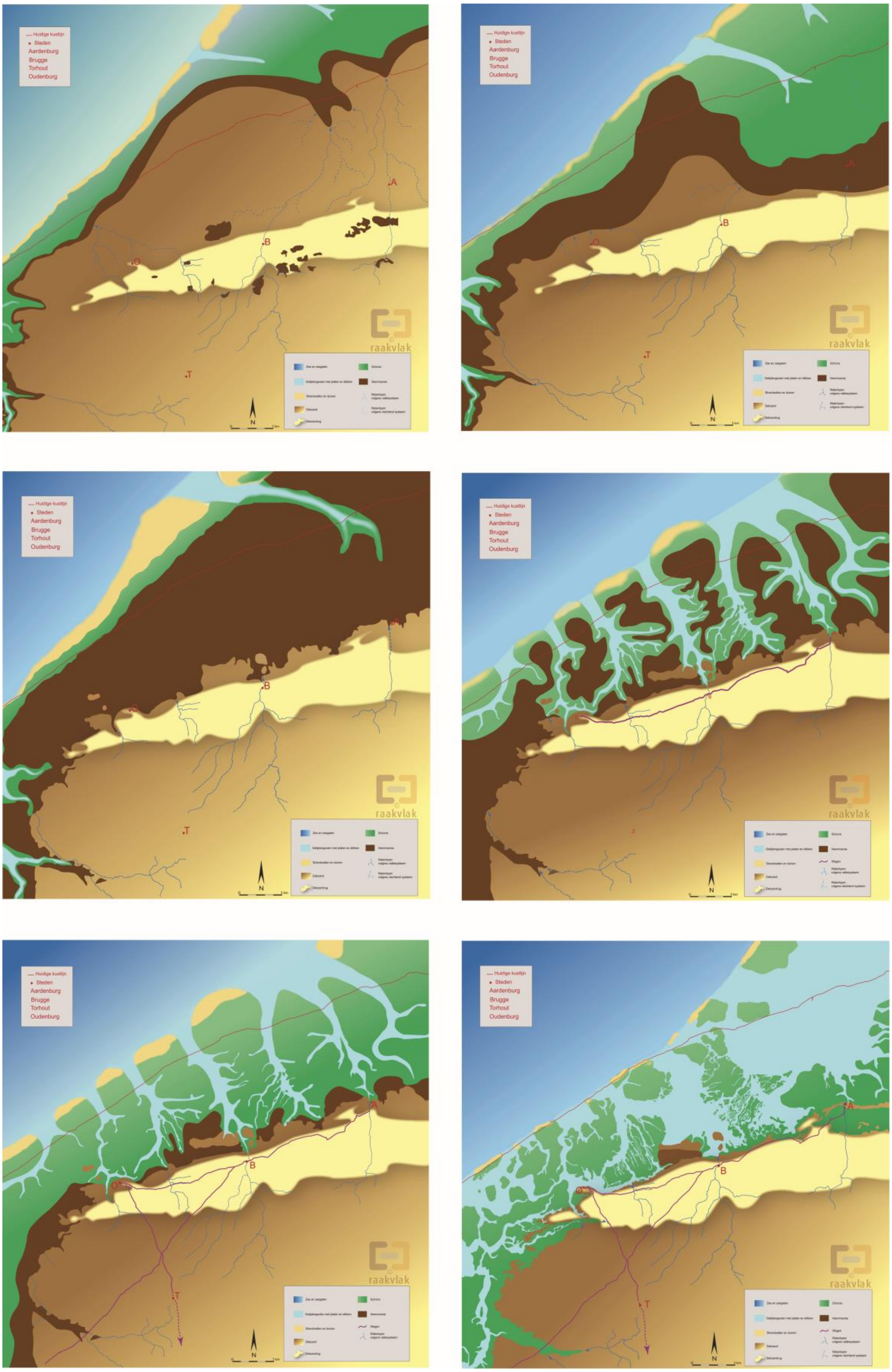


Figure 4 Landscape reconstructions of the Bruges area from the Mesolithic (upper left) to the late Roman period (below right). Yellowish brown = (cover) sand, darkbrown = peat, green = tidal areas (© Raakvlak).

After a long period of uninterrupted peat growth (ca. 2000-3000 years), a renewed expansion of the tidal influence reactivated the mid-Holocene tidal channels and deposited marine sediments on top of the surface peat. Presumably, the increased tidal influence came about 2500-2000 BP but this date differs across the coastal plain as the end of the peat growth was not synchronous (Figure 4, bottom left) (Baeteman, 2005, 2007a, 2013, 2018).[8] Several mutually reinforcing factors have been suggested causing this gradual shift towards a tidal environment. A first, obvious factor is the continuous rise in relative sea level (RSL) over a long period time. Secondly, a depletion of offshore sediment might have resulted in erosion and landward migration of the coastal barrier. Although Baeteman (2005, 2147) assumed the erosion of the coastal barrier of minor importance for the Belgian coastal plain, Vos and Van Heeringen (1997) considered this to be of greater importance in Zeeland. Additionally, Baeteman (2013, 2018) suggested that the onset of the cooler Subatlantic climate period around 2800 cal BP also involved an increase in precipitation. Moreover, human activities, such as peat extraction, drainage and dyke building, during the Iron Age and Roman period played a crucial role as they resulted in compaction of the peat bed. Furthermore, deforestation of the Pleistocene hinterland combined with the increased precipitation from the Subatlantic period onwards led to excessive run-off from the hinterland (Baeteman, 2013, 21; Trachet, 2016, 40; Baeteman, 2018, 318-319).

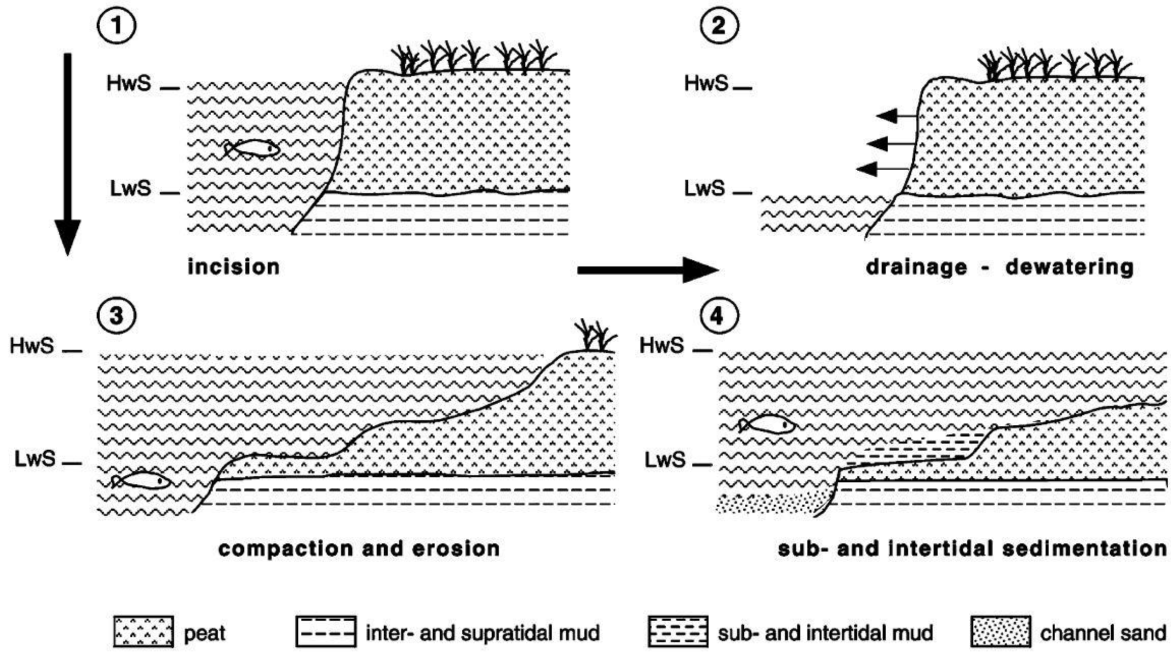


Figure 5 Schematic representation of channel incision (1) resulting in peat drainage (2) with consequently compaction (3) and sedimentation in sub- and intertidal position (3) (after Baeteman, 2005, 2160, fig. 2113)

The increased run-off scoured the existing mid-Holocene channels allowing the tidal waters to penetrate deep into the peat bog. As a consequence peat growth stopped adjacent to the channels as

[8] The start of the renewed tidal activity is largely based on C14-dating of the top of the surface peat. Unfortunately, erosion, oxidation and surface reworking make it difficult to accurately date the end of the peat formation. According to Baeteman (2013, 21; 2018, 318), the end of the peat growth in the western coastal plain ranged from 3370 to 1525 calBP, with a cluster occurring between 2250 and 2000 cal BP. In Zealandic-Flanders, De Boer (2005, 52) and Vos and Van Heeringen (1997, 61), date the increased tidal influence around 2500 BP.

the peat losses its potential to store water. As illustrated in Figure 5, this will lead to compaction and subsidence of the peat. Peat extraction and man-made drainage ditches had a similar effect and reinforced the abovementioned process (Baeteman, 2005, 2007b; 2013, 21). Although the effects were modest at first, the continuous compaction of the peat bog in the vicinity of the channels constantly enlarged the accommodation space in which marine sediments could be deposited. This self-enforcing process started in the main inlets and as the channel network gradually enlarged, the whole coastal area became susceptible for tidal activity (Vos and Van Heeringen, 1997, 61-66; Baeteman, 2013, 21-22). Nevertheless, Ervynck et al. (1999, 118) stated that the human impact cannot be minimalised and might have significantly influenced the natural processes. By 1600-1500 cal BP (350-400 CE), major parts of the coastal plain must have been in intertidal or subtidal position (Figure 4, bottom right) (Baeteman, 2005, 2013, 2018).

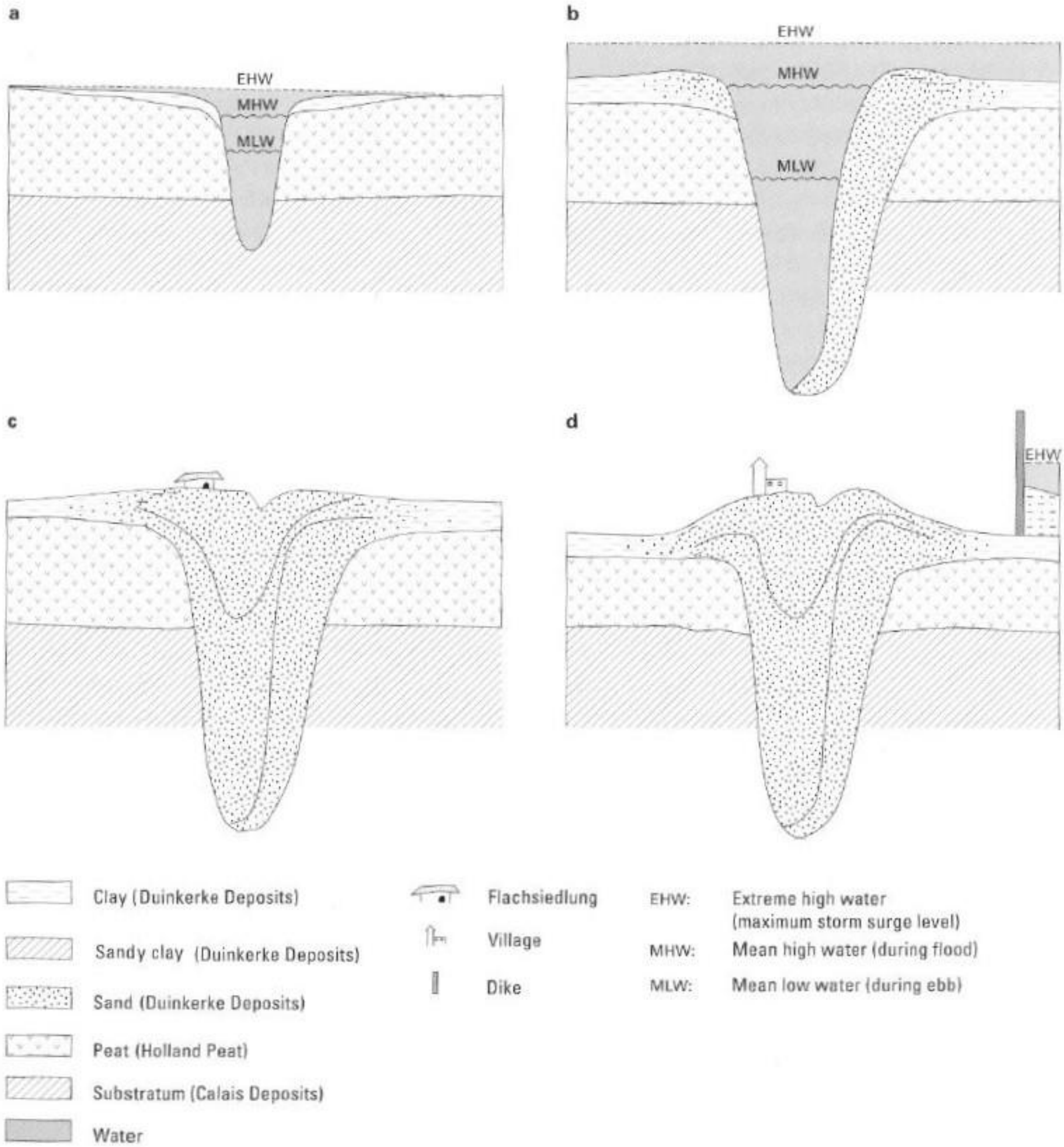


Figure 6 Schematic cross-section of the origin of tidal channel inversion ridges in Zeeland (after Vos and Van Heeringen, 1997, 16, fig. 18)

A chronological gap between the top of the peat and the overlapping sediments suggested that initially sediments were deposited in the tidal channels followed by sedimentation in the accommodation space (Baeteman, 2005, 2160; 2013, 23). Around 1400/1200 cal BP (550/750 AD), an equilibrium between relative sea level rise, sediment availability and accommodation space was reached. As a result, the tidal channels, now in intertidal position, silted up with layers of sand and clay, and the tidal area gradually developed into supratidal mudflats, salt marshes and eventually salt meadows (Baeteman, 2005, 2007a, 2008, 2018). However, the position of the channels was not fixed and due to lateral migration, so called 'meandering', part of the tidal channels could revert from intra- to subtidal position and the other way around (Deckers, 2014, 20). As these channels were primarily filled with coarser sediments, they reacted differently to drainage than the clay-covered peat. While the clay was highly compacted, the sand in the channels subsided less, and eventually formed slightly elevated features in the landscape (i.e. relief inversion) (Figure 6) (Vos and Van Heeringen, 1997, 17; de Boer, 2005, 54; Baeteman, 2008, 13; Deckers, 2014, 23; Trachet, 2016, 42). Together with the Pleistocene outcrops and the higher salt meadows, these infilled channels formed an attractive location for early medieval occupation. Recently, Deckers (2014) suggested that the earliest traces of medieval occupation can be found on the banks of infilled tidal channels. Soens et al. (2014) described this early medieval coastal society as a 'terp society' focused on the exploitation of maritime resources such as fishing and sheep husbandry.

From the tenth and eleventh century onwards, the salt marshes were gradually embanked which drastically changed the outlook of the coastal plain as only the larger tidal channels preserved their natural state. The transformation from salt marsh to polder, which was largely funded by the Count of Flanders and monastic institutions, required a tremendous set of technological skills as dikes, ditches, dams and sluices had to be created (Tys, 2013; Baeteman, 2018, 321). However, these manmade polder landscapes were vulnerable as the land behind the dikes subsided and the accommodation space of the tidal channels was reduced. In consequence, high-energetic (storm) surges and high tides were forced in small funnels significantly enhancing the chances of dike breaches and potentially disastrous floods. Nevertheless, this process of repeated embankment and inundations continued throughout the medieval and post-medieval period shaping the current outlook of the coastal plain (Trachet, 2016, 45).

2.2.4 Reconstructing the natural environment of the northern Menapian coastal plain in Roman times

2.2.4.1 Climate

By using several paleo-ecological proxies like tree rings, glacier retreat, ice cores, speleothems, solar activity and so on, researchers try to understand and reconstruct past climates and their impact on societies (McCormick et al., 2012; Harper and McCormick, 2018). It is generally assumed that the northwestern provinces of the Roman Empire (*Britannia*, *Gallia Belgica*, *Germania Inferior*) were characterised by exceptional climate stability between ca. 200 BCE and 150 CE[9] (Harper and

[9] It should be noted that studies on climate reconstruction largely depend on the evaluation of proxy data. The use of different proxy records, but also the geographical scale of the study might impact the proposed chronological frameworks. Over the years

McCormick, 2018, 34). In this period, referred to as the Roman Climate Optimum (RCO) or Roman Warm Period, warmer and wetter conditions prevailed. From about 150 CE, Harper and McCormick (2018) consider the climate to be less stable and multiple proxies signal low temperatures in northwest Europe in the third century CE. In the fourth century CE, some proxies agree that the temperature was again somewhat higher with more precipitation (Harper and McCormick, 2018).

Contrary to Harper and McCormick (2018) who used global proxies to reconstruct the Roman climate, Reichelmann and Gouw-Bouman (2019) specifically used proxies from the area north of the Alps. In this study, the temperature proxies show relatively warmer summer conditions until ca. 340 CE (+130/-90), followed by colder summer conditions until ca. 720 CE (+80/-70). In terms of precipitation, relatively wet conditions occurred until ca. 500 CE (+80/-150), followed by drier conditions until ca. 800 CE (+210/-90) (Reichelmann and Gouw-Bouman, 2019, 126-127).

Although the chronological framework somewhat differs, both studies agree that during the first centuries CE northwestern Europe experienced a warmer period with higher precipitation (so-called Roman Warm Period), and that from the fourth century CE onwards, a gradual shift towards a colder climate with drier conditions occurred (Harper and McCormick, 2018; Reichelmann and Gouw-Bouman, 2019, 126-127). The exact impact of these climatic shifts is difficult to assess due to the poor dating resolution of the proxies, but also because local paleoclimatic archives are lacking from the study area. Moreover, connecting these larger climatic changes to socio-political and economic developments is practically impossible as these changes impacted each region differently and regional climatic variability might have occurred (Haldon et al., 2018).

2.2.4.2 Building stones of the coastal landscape

Coastal wetlands (Figure 7) are a tide-dominated, dynamic landform composed of a series of landscape elements (coastal dunes, tidal channels, sand and mudflats, creeks, salt marshes and – meadows) or as Baeteman called them 'sedimentary environments' (Figure 8) (Rippon, 2000; Baeteman, 2018, 316). Contrary to earlier beliefs, all of these elements could be present simultaneously at relative close proximity as the shifting play of ebb and flow could rapidly change the outlook of the coastal plain (Baeteman, 2007a, 2008, 2013; Trachet et al., 2015; Baeteman, 2018). The most seaward element, the **coastal barrier**, consisted of a 1-2 km wide stretch of sandy beach, dunes, the subsurface foreshore and the tidal deltas. As the coastal barrier formed a dynamic equilibrium with the sea level and the accommodation space, its position was not fixed and could recede or prograde depending on the situation. Compared to the modern coastline, the Roman shorefront was situated approximately 2 kilometres further seaward (Baeteman, 2008). Behind the coastal barrier, an intertidal area of **mudflats**, situated between mean high and low tide, was flooded twice a day depositing small layers (a few mm) of sediment at a time. Gradually the mudflats and the tidal network silted up and fell out of the mean tidal range forming a **salt marsh** (Figure 8). The supratidal salt marshes were only submerged during spring tide and extreme high tides, allowing pioneering halophytic (salt tolerant) vegetation to grow. When flooded, the vegetation catched additional sediment particles accelerating

different frameworks have been suggested in other studies (Esper et al., 2012; McCormick et al., 2012; Clauzel et al., 2020; Margaritelli et al., 2020; Bernigaud et al., 2021) confirming the general trends. However, in these studies, the Roman Climate Optimum (RCO) is often regarded as a longer climatic event (300 BCE – 300 CE (Clauzel et al., 2020); 1 -500 CE (Margaritelli et al., 2020)). It should also be emphasized that these are not fixed chronological frameworks as the discovery of new proxies might alter the frameworks in the future. In addition, it is important to keep in mind that these studies reconstruct a supra-regional or global events and cannot take local variations into account (primarily due to the lack of local high-resolution data).

salt marsh formation (Rippon, 2000, 14-17; Baeteman, 2008, 19-20; 2013, 17; Deckers, 2014, 22-24). If enough sediment built up on the landwards side, the salt marshes fell out of tidal range and a freshwater layer could form beneath the surface. In turn, this freshwater layer enabled peat formation in **freshwater mashes**. In dryer conditions, a **salt meadow** formed instead of a freshwater marsh (Figure 8) (Baeteman, 2008). However, the transformation of mudflat to salt marsh to salt meadow was not a synchronous one-directional process. The lateral migration of subtidal **channels** and intertidal **creeks** resulted in erosion and sedimentation processes which constantly changed the outlook of the coastal landscape (Baeteman, 2013; Deckers, 2014; Baeteman, 2018). Finally, on the landward side, the coastal plain is demarcated by the Pleistocene cover sand ridge.

Figure 7 Aerial photograph of the Drowned Land of Saeftinghe, situated in the western Scheldt estuary. During the 16th century Eighty Years' War, a large area of reclaimed land was deliberately flooded in an attempt to defend the city of Antwerp. To this day, an intertidal area of mudflats and salt marshes pierced by a meandering network of larger tidal channels and creeks remains providing insight in how the intertidal roman coastal landscape would have once looked like (https://beeldbank.rws.nl, Rijkswaterstaat, Jood van Houdt).

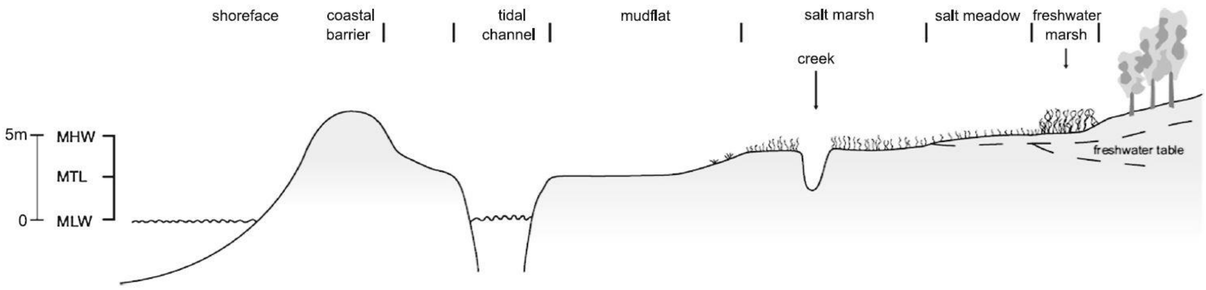


Figure 8 Schematic representation of the coastal landscape in relation to the water levels. MHW = high water springtide; MTL = mean low water spring (after Baeteman 2018, 316, fig. 19.3)

Table 3 Overview of the palaeo-ecological studies in the northern Menapian coastal plain

Site	Date	Palynology	Macro botany	Wood determination	Dendrochronology	Archaeozoology	Diatom	C14-dating	Soil micromorphology	Ostracods and forams	References
Borsele-Ellewoutsdijk	ca. 60/70 - 150 CE	x	x	x	x	x					Sier (2003)
Bredene-Sluisvlietlaan	ca. 70-100 CE	x	x			x		x			Peters (1987)
Colijnsplaat-Noordhoeksenol	ca. 20-50 CE					x		x			Lauwerier and van Mensch (1993)
Kats-Oud Hamerstee	ca. 1-100 CE					x					Lauwerier and van Mensch (1993)
Leffinge Zwarte Weg	ca. 175-250 CE	x						x			Baeteman et al. (1981)
Serooskerke Gapingse Watergang	ca. 50 BCE	x	x			x	x	x	x	x	Dijkstra and Zuidhoff (2011)
Serooskerke Wattelseweg	175-250 CE	x	x			x	x	x	x	x	Dijkstra and Zuidhoff (2011)
Serooskerke Molenweg	1-50 CE	x	x								Dijkstra and Zuidhoff (2011)
Domburg Roosjesweg	ca. 175-250 CE	x	x			x					Dijkstra (2021)
Dudzele Zonnebloemweg	phase 1: ca. 69-125 CE; phase 2: 175-250 CE		x								Verwerft et al. (2014) Verwerft et al. (2022)
Ramskapelle Heistlaan	ca. 175-250 CE	x			x	x		x	x		Verwerft et al. (2019b) Verwerft et al. (2019a)
Stene-Prins Roselaan	ca. 70-150 CE	x	x	x		x	x	x			Demey et al. (2013)
Wenduine Kleiputten	2nd half 2nd cent.	x				x					Gheysen et al. (2014)
Bredene Landweg	ca. 200-225 CE	x	x				x	x			Deconynck et al. (2021)
Walraversijde	2nd half 2nd cent.		x								Pieters et al. (2013)
's Gravenpolder	ca. 175-250 CE										This volume
Kapelle Smokkelhoek	ca. 200-250 CE	x	x	x			x	x			Bouma and Dijkstra (2021)

2.2.4.3 Dominant vegetation types in the coastal landscape

Over the last decade, the increase in archaeological research and discoveries has led to an increase in paleo-ecological studies. Compared to the study of De Clercq (2009c, 142, tabel 7.1) whose overview contained 5 paleo-ecological studies, no fewer than 17 studies are now listed in Table 3. These studies significantly enhanced our understanding of the vegetation and landscape surrounding the Roman sites. Unfortunately, as little research was done on the landscape around the artisanal sites, the dataset is somewhat biased towards the vegetation surrounding Roman habitation sites.

Overall, the paleo-ecological studies present a rather uniform picture of the vegetation surrounding the sites[10]. Of course, local variation occurs but, in general, all sites are located in an open mudflat-saltmarsh-salt meadow landscape dominated by grassland and herbaceous plants. Depending on the vicinity of tidal channels and creeks and the presence of dikes, slight changes in the environment (salt, brackish or freshwater) might have influenced the vegetation present. Most of the times, a mixture between brackish, salt-tolerant plants and freshwater species was observed. Specifically, multiple grass families (e.g. *Poaceae* and *Cyperaceae*) occurred together with a lot of plants from the goosefoot family (*Chenopodiaceae*). Several species of this family are salt tolerant like seepweeds (*Suaeda Maritima*), samphire (*Salicornia*), sea lavender (*Limonium Vulgare*) and saltbush (*Atriplex*) etc.). In addition, a whole range of different species was observed like saltmarsh rush (*Juncus gerardii*), silverweed (*Potentilla anserina*), etc. On a more regional scale, tree pollen of pine (*Pinus sylvestris*), birch (*Betula*), oak (*Quercus*), hazel (*Corylus*) etc. were present indicating a combined presence of small coniferous forest/groves and deciduous forest/groves on the coastal barrier and higher Pleistocene hinterland (Dijkstra and Zuidhoff, 2011; Demey et al., 2013; Verwerft et al., 2019a; Bouma and Dijkstra, 2021; Dijkstra, 2021).

[10] For a detailed reconstruction of the landscape surrounding the individual sites see references in Table 3

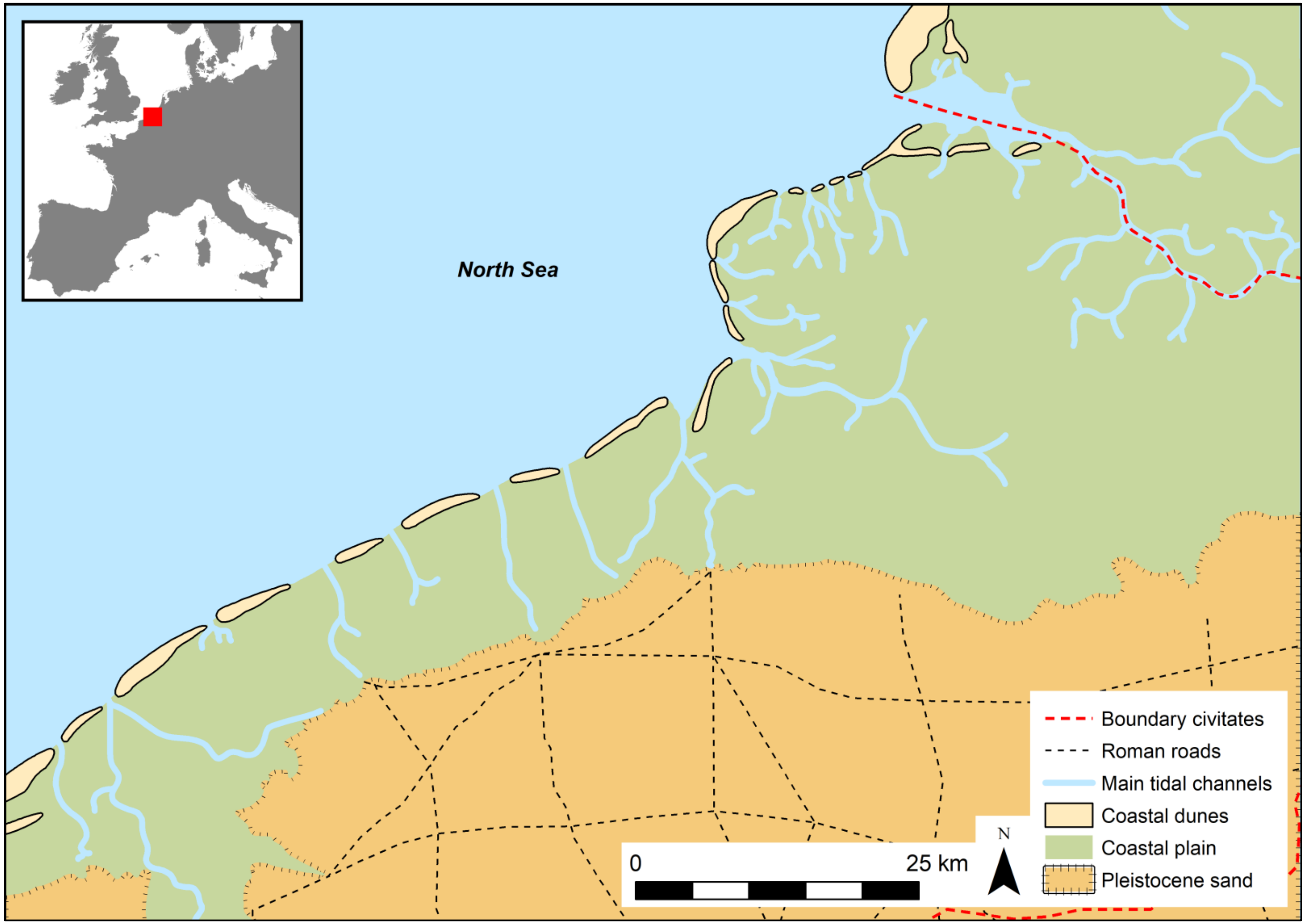


Figure 9 Simplified paleogeoraphic map reconstructing the northern Menapian coastal plain in Roman times with the main tidal channels (overview of the data used to create this map is presented in section 2.2.4.4).

2.2.4.4 The simplified palaeogeographical reconstruction map explained

The shifting play of ebb and flow created a dynamic landform of meandering tidal channels, mudflats, salt marshes and salt meadows which makes it difficult to present a detailed reconstruction of the coastal landscape at a fixed moment in time. Figure 9 shows the coastal plain of Belgium and Zeeland in Roman times based on the available paleo-geographical and geological data. This map is not intended for geographic, social and/or landscape analysis in GIS. It mainly provides a map-based background to better understand the landscape position of the Roman sites relative to the main tidal channels. These larger tidal channels had a more fixed position than side branches and creeks which meandered abundantly and could silt up rapidly. Besides, the available data lacked the detailed spatial and chronological resolution to distinguish which side branches were active at a certain moment in time.

In Zeeland, a first important study on the landscape combining geological, palaeoecological and archaeological data was published by Ovaa (1971). While he still used the transgression model to explain the landscape evolution, he also drew attention to the fact that the peat area was inhabited in Roman times, and that the rectilinear creek ridge patterns on Walcheren and Zuid-Beveland might represent a Roman attempt to drain said peat (Ovaa, 1971). In 1997, Vos and Van Heeringen (1997) created a series of maps reconstructing the Holocene landscape development in Zeeland based on geological and archaeological data. This paleogeographic map, in part based on the soil mapping survey in the late 1940s and 1950s by the *Stichting voor Bodemkartering*, has become an indispensable tool for archaeologists and historians to understand the landscape evolution (Vos and Van Heeringen, 1997). Since then, the map has been updated a few times, and the 2020-version was integrated into Figure 9 to depict the coastal plain of Zeeland, with the exception of the Zwin area (Vos, 2015; Vos et al., 2020).

A coastal barrier with natural tidal inlets separated the mudflats and salt marshes from the sea. The large estuary of the *Scaldis* (now Eastern Scheldt) acted as the *civitas* border and cut through the coastal plain connecting the hinterland to the sea. One of the most notable differences in the 2020 update was the extent of the Western Scheldt predecessor (Figure 9) (Vos et al., 2020). Compared to earlier versions, a large Roman tidal channel, situated in the current Western Scheldt, now penetrated much further into the coastal plain. This option was first proposed by archaeologists and paleo-ecologists[11] (van Dinter, 2003; De Clercq and van Dierendonck, 2006; De Clercq, 2009c). Furthermore, the transition between the coastal plain and Pleistocene hinterland (the edge of the coastal peat bog) in Zeeland was based on Van Rummelen (1965) and Verhoeve and Verbruggen (2006).

In the Zwin-area, two large tidal channels were drawn using preliminary, unpublished results of the multidisciplinary project ‘High Tide, Low Tide. The late-medieval harbour of Bruges as a maritime-cultural landscape’. For the remainder of the Belgian coastal plain, the reconstruction map of Baeteman, De Ceunynck, Mostaert and Thoen was used (Thoen, 1987). In this reconstruction, the main

[11] The extent of the Western Scheldt predecessor has been a matter of debate since the discovery of the Roman settlement of Borsele-Ellewoutsdijk (Sier, 2001, 2003; Van der Heijden and Sier, 2006). The archaeobotanical research indicated the presence of salt marsh vegetation (salt marsh grass, sea lavender, saltmarsh rush etc.), which suggested the presence of nearby salt marshes. In turn, the presence of these salt marshes pointed to an increased marine influence further inland than suggested by the 1997 paleogeographic map (Sier, 2003; De Clercq, 2009c, 153-155). In addition, the fossil pines used as construction material at Ellewoutsdijk most likely originated from the ‘so-called’ drowned forest of Terneuzen (ca. 6 km from Ellewoutsdijk) (Munaut, 1967; Sier, 2003, 135-136). As the forest was later covered with peat, these trees would have been inaccessible in the first century CE unless they were uncovered by erosion which could happen near an active marine tidal channel (De Clercq, 2009c, 153-155).

tidal channels are presented without any side branches as well as different 'coastal landscapes'. On the map, a distinction was made between peat (situated in the more landward parts of the paleo valley of the Yser), drowned peat (covering a large area of the paleo valley of the Yser, the area northwest and northeast of Oudenburg) and mudflats and salt marshes. Baeteman (1987) characterised both the peat and the drowned peat areas as unattractive for habitation, but the latter could be inhabited during the dryer seasons. However, it is quite unclear how Baeteman, and by extension, the other authors in the same volume, perceived this drowned peat area (Thoen, 1987). Often, they described it as silted-up peat or peat covered with clay sediment, which seems very similar to mudflats. In any case, as Baeteman (2007a, 2008, 2013, 2016, 2018) stated in later publications, the coastal plain is a dynamic landform of sedimentary environments (mudflats, salt marshes, salt meadows etc.) which could be present simultaneously at relatively close proximity. For that reason, Figure 9 contains no references to landscape units (sedimentary environments), with the exception of the coastal dune barrier and the tidal channels. In the past, these main tidal channels were named from west to east: the 'Bulskampsgeul', the 'Avekapellegeul', the Spermaliegeul', the Bredena (connecting Oudenburg to the North Sea) and the 'Blankenbergegeul' (connecting Bruges to the North Sea) (Thoen, 1987).

A new series of maps reconstructing the landscape between Aardenburg and Oudenburg (eastern Belgian coastal plain) from the mid-palaeolithic until the 9th century CE were published in the book: 'Op het raakvlak van twee landschappen. De vroegste geschiedenis van Brugge' (Figure 4) (Hillewaert and Ryckaert, 2019). A deliberate decision was made not to incorporate the reconstruction map of the Roman period for various reasons. First and foremost, the displayed tidal channels are large and might represent the maximum extent of the tidal basin in which the channels meandered instead of the hypothetical course of the tidal channels during Roman times. In addition, quite a lot of side branches are depicted, but it is difficult to know which of these branches were active at any given time. That being said, the reconstruction does have its merits because it gives an indication of where smaller side branches were present throughout the Roman period. However, it is difficult to integrate the map in Figure 9 as the resolution of the other data is different and only visualises the main tidal channels without side branches. A different resolution of one specific area might cause confusion as it gives the impression of a large tidal network between Oudenburg and Aardenburg, even though this was not necessarily the case.

Finally, as the study focused on the coastal plain, the Pleistocene hinterland was not subdivided into soil units as was the case in the studies by De Clercq (2009c) and Van Thienen (2016). Furthermore, it must be stressed that Figure 9 only represents the main tidal channels in the northern Menapian coastal plain during Roman times. Undoubtedly, the tidal network was much larger, which could rapidly transform the outlook and accessibility of the coastal plain.

2.3 Roman occupation of the northern Menapian coastal plain

In the last decades, multiple new Roman sites have been discovered in the northern Menapian coastal plain, significantly enhancing our knowledge of how rural communities exploited this dynamic landscape. In this section, we present an updated overview of these sites representing the Roman occupation.[12] This overview is a collection of all sites and finds within the territory of the *civitas Menapiorum* that are considered to have a date that (partially) fall within the parameters of the early and mid-Roman period (57 BCE – 276 CE)[13]. The data has been collected by an extensive literature study (published data and 'grey literature'), and the consultation of the *Centrale Archeologische Inventaris* (CAI) and the *Archeologisch Informatiesysteem* (Archis). The latter databases contained information on excavations, prospections and finds for Flanders and the Netherlands (Figure 10). Nevertheless, these databases need to be used with caution due to double entries and inconsistent labelling. In addition, they often mention Roman finds with no or (post-) medieval context. Similarly, single or multiple Roman sherds found during prospection campaigns are entered as individual sites, but these sherds do not necessarily indicate the presence of an *in situ* Roman site. After careful revision of all available data (CAI, Archis and literature), 187 (potentially) *in situ* finds or sites remained[14]. In order to adequately use the data, each site, context or find was assigned to a certain site category referring to the function of the main archaeological features. In this study, the following categories were used: habitation (25), salt production (13), peat extraction (6), religious (2), *castellum* (4), maritime (3), dike (2) and stray finds (132) (Figure 11). The latter category contained two minor subcategories (salt production? (5) and briquetage findspot (19)). In addition, the stray finds incorporate what Thoen (1978a, 1987) defined as burial sites. The presence of these burial sites was deduced based on multiple complete pottery vessels discovered during eighteenth and nineteenth-century peat extraction. Yet, as no context is known, they provide little information about the nature of possible Roman burial sites. Therefore, these finds are not categorised as burial sites, but as stray finds.

This overview of the different site categories largely builds on the work of De Clercq (2009c). His insights and classification of settlement types were adopted and complemented with new discoveries. Therefore, some form of overlap is unavoidable. Besides, it is not our intention to present an exhaustive description of the individual sites within each site category.[15] The goal is to give a decent synopsis of the habitation forms, the military presence, the impact on the landscape, and so on. Understanding the Roman activity in the landscape is pivotal to interpret the salt production activities. These activities did not occur in an 'empty' landscape but were an integral part of the native coastal community.

[12] The French part of the *civitas* has been deliberately excluded. As no central database containing all Roman sites in northern France existed, creating an exhaustive overview of all Roman findspots *in situ* fell out of the scope of this study. When required, references will be made and parallels will be drawn to major sites in northern France. This does not include the findings related to salt production. In Chapter 5 all finds and sites related to salt production have been incorporated.

[13] In this study, the decision was made not to incorporate the late Roman period (276-410/76 CE). As the study of van Thienen (2016) showed, very few late Roman sites have been discovered in the Belgian coastal plain to this day. It is generally assumed that by 350 CE major parts of the coastal plain were in intertidal or subtidal position, limiting the overall accessibility (Baeteman, 2013, 2018). Late Roman occupation did continue on the coastal dunes (e.g. Domburg and De Panne) (Lehouck and Thoen, 2012; Van Thienen, 2016). Furthermore, military camps (e.g. Oudenburg and Aardenburg) at the edge of the coastal plain were still active (Van Thienen, 2016; Vanhoutte, *in press*)

[14] It should be noted that extensive Roman find complexes such as Oudenburg and Aardenburg have been reduced to a single entry.

[15] Tables presenting all sites with the site date; main elements and the most important bibliographic references will be provided throughout the text.

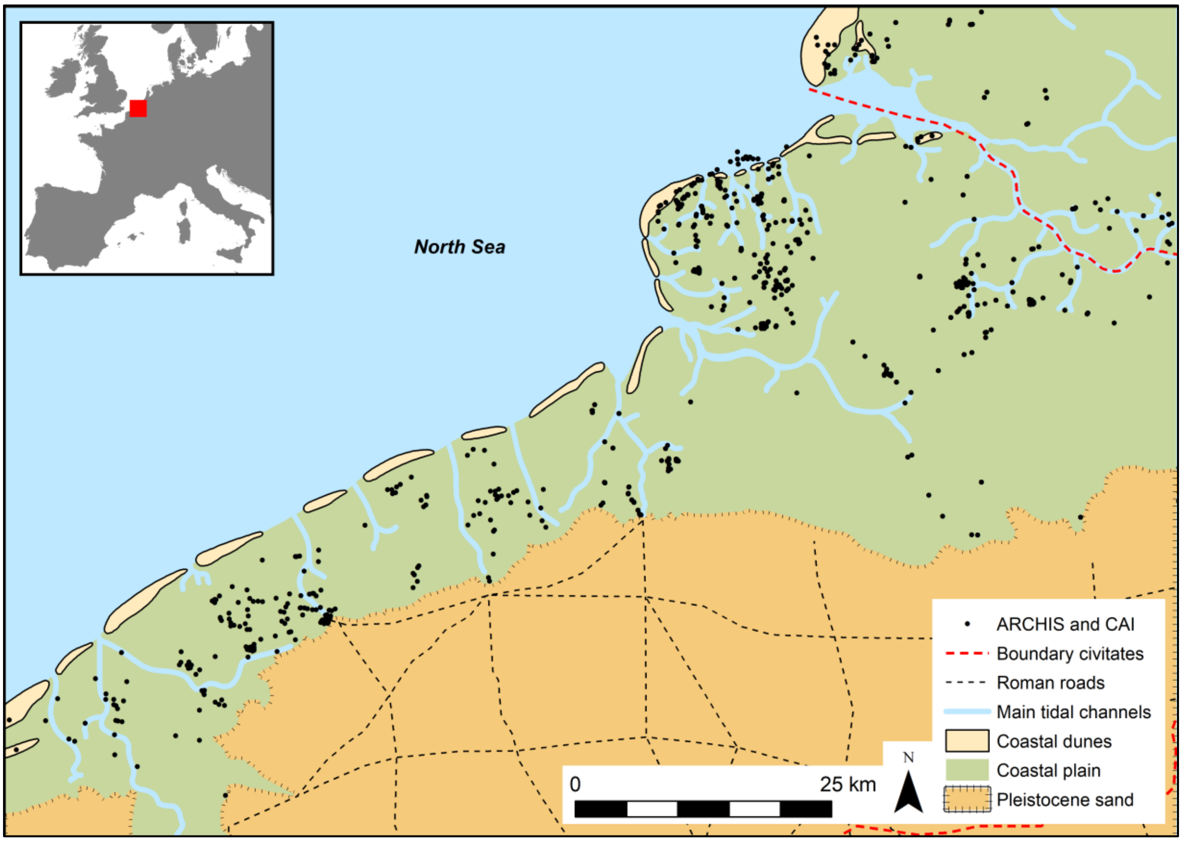


Figure 10 Locations of all Roman sites in the Menapian coastal plain present in the CAI and Archis database (last consulted on 1/12/2021).

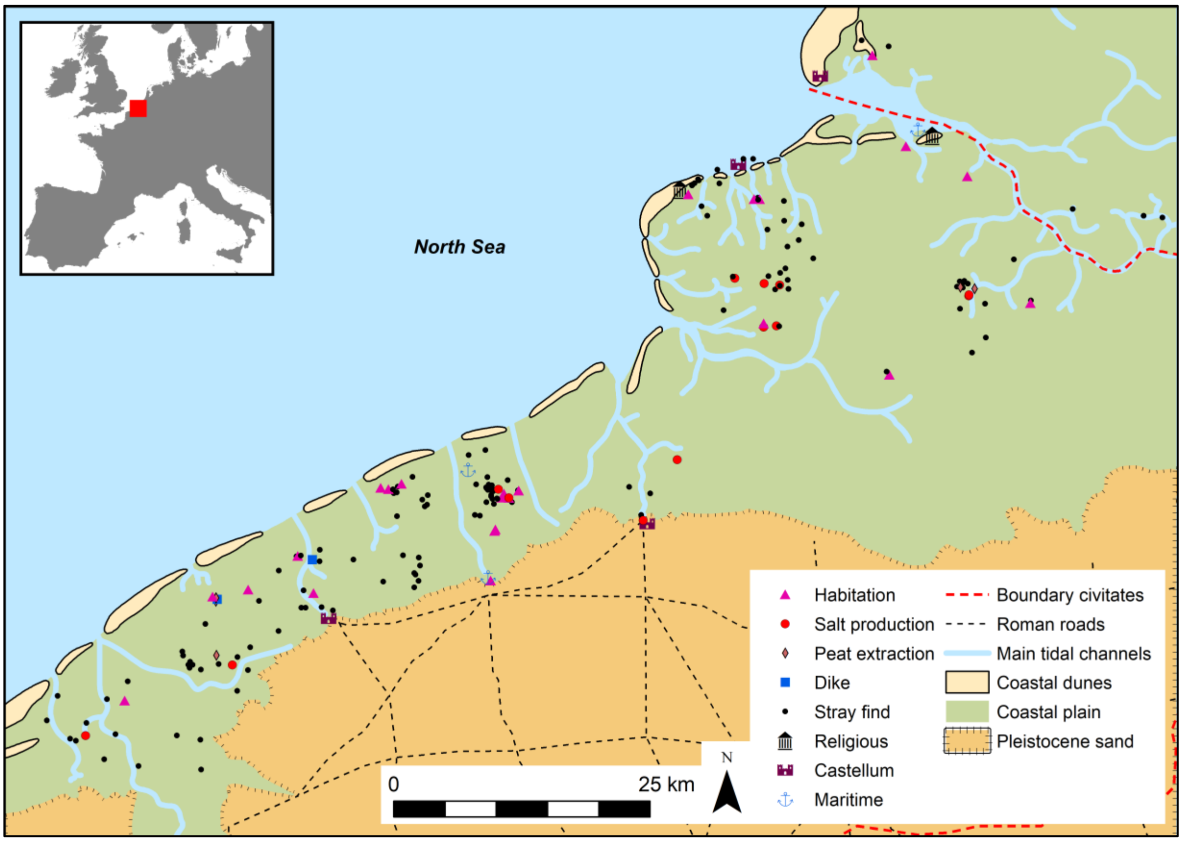


Figure 11 Locations of all Roman sites *in situ* in the Menapian coastal plain assigned to different sites categories.

2.3.1 Rural habitation structures

In the last two decades, Malta-driven rescue excavations significantly enhanced the knowledge of the habitation forms. While Ervynck et al. (1999) painted a poor picture of a scarcely populated landscape, ten years later, De Clercq (2009c) depicted a much more nuanced view of a permanently occupied landscape. In this landscape, settlements occurred on dried-out peat, Pleistocene sandy outcrops (*donken*) or artificially raised platforms (*terps*). De Clercq's (2009c, 202-217; 2011) framework has been adopted in this study as the more recent discoveries perfectly fit within the different habitation types.

2.3.1.1 Artificially raised platforms

Over the last fifteen years, several artificially raised habitation platforms (*terp*) have been discovered in the Menapian coastal plain. The concept of artificial dwelling mounds in dynamic coastal wetland areas has been known since the beginning of the 20th century (Nieuwhof et al., 2019). In the salt marsh regions of northern Netherlands and north-western Germany, large *terp* regions dating from the Iron Age until the late medieval period developed to cope with the regular tidal inundations (Kossack et al., 1984; van Londen, 2006; Nieuwhof, 2011; Nieuwhof et al., 2019). In addition to archaeological sources, Plinius described similar living arrangements in the first century CE to characterise the habitation structures of the *Chauci*, living between the rivers Eems and Weser (section 2.2.1). In the northern Menapian territory, De Clercq (2009c, 202) defined these dwelling mounds as: "an artificial or semi-artificial elevation with a flat top protruding above the tidal level which was used for (non)-permanent habitation". Currently, six of these platforms have been found in Belgium and Zeeland (Table 4; Figure 14). The sites of Stene (Demey et al., 2013) and Serooskerke Wattelsweg (Dijkstra and Zuidhoff, 2011) were almost simultaneously excavated in 2008, while Ramskapelle Heistlaan (Verwerft et al., 2019a), Ritthem Mariniers (de Groot, 2016) and Domburg Roosjesweg (Dijkstra, 2021) were discovered more recently. The site of Plassendale-Industrie was actually the first to be excavated in 1999-2001, but only after the discoveries of Stene and Serooskerke it became clear that the enigmatic inclined layers might be part of an artificially raised platform (Vanhoutte and Pieters, 2003; Vanhoutte and De Clercq, 2007; De Clercq, 2009c, 208).

At Stene, the oldest excavated feature consisted of a slightly curved dyke (at least 25 m long, 8 m wide at the base and 0.8 m high), which followed and embanked an active tidal channel. After a short period of time, an artificially raised platform (17 m long, 8 m wide and 1 m high) from clay and peat sods was constructed against the eastern side of this dyke. On top of the platform, remains of two successive habitation structures were observed: an older 10 m construction with two alder wood uprights and a younger sod house or a wall-ditched structure. On the flanks of the platform and the dyke, debris layers containing late first-early second-century pottery, many shells and animal bones were deposited (Demey et al., 2013).

A similar construction with a multiphase dyke system was found at Serooskerke. After a period of disuse and inundation, a second dyke (at least 82 m and 0.8 m high) was constructed largely following the trajectory of an earlier first dyke (at least 70 m long and 0.16 m, presumably 0.7 m, high). The youngest dyke connected to the southwestern corner of an artificially raised platform (at least 7.5 m long, 7.5 m wide and 0.8 m high), which was partly erected on top of the oldest dyke phase. Both dykes and the platform were built with local peat and clay sods which were probably collected from a salt marsh environment (Dijkstra and Zuidhoff, 2011). In addition, several waste layers consisting of large quantities of shells and late second-early third-century pottery could be observed on the platform slopes. Based on the stratigraphy of the platform, Dijkstra and Zuidhoff (2011, 68-69) suspected a multiphased, possibly a continuous, occupation. With the exception of a hearth, no habitation structures were found on top of the platform. According to Dijkstra and Zuidhoff (2011, 69), the relatively small surface area might suggest seasonal rather than permanent occupation. Furthermore, the site could have functioned as a special purpose site focused on the processing of shells for inland consumption. While shell processing might have been an important (seasonal) activity, a permanent occupation in sod houses cannot be excluded (De Clercq, 2009c, 204; 2011).

Although all platforms had similar functions, some differences could be noted in the more recently discovered sites of Ramskapelle and Domburg. The latter platform (9.35 m long, 3.75/4.1 m wide and 0.2 m high) was constructed on top of a creek ridge with sandy sods on the inside and more clayey sods on the outside. Initially, a smaller structure was built dating to the end of the second-early third century. However, after a small inundation, the platform was rebuilt and extended in the first half of the third century (Dijkstra, 2021). On the edge of the platform and the creek ridge, large shell layers were found, prompting Dijkstra (2021, 199) to interpret the site as a shell processing site. With the exception of two possible hearths, no habitation traces were found.

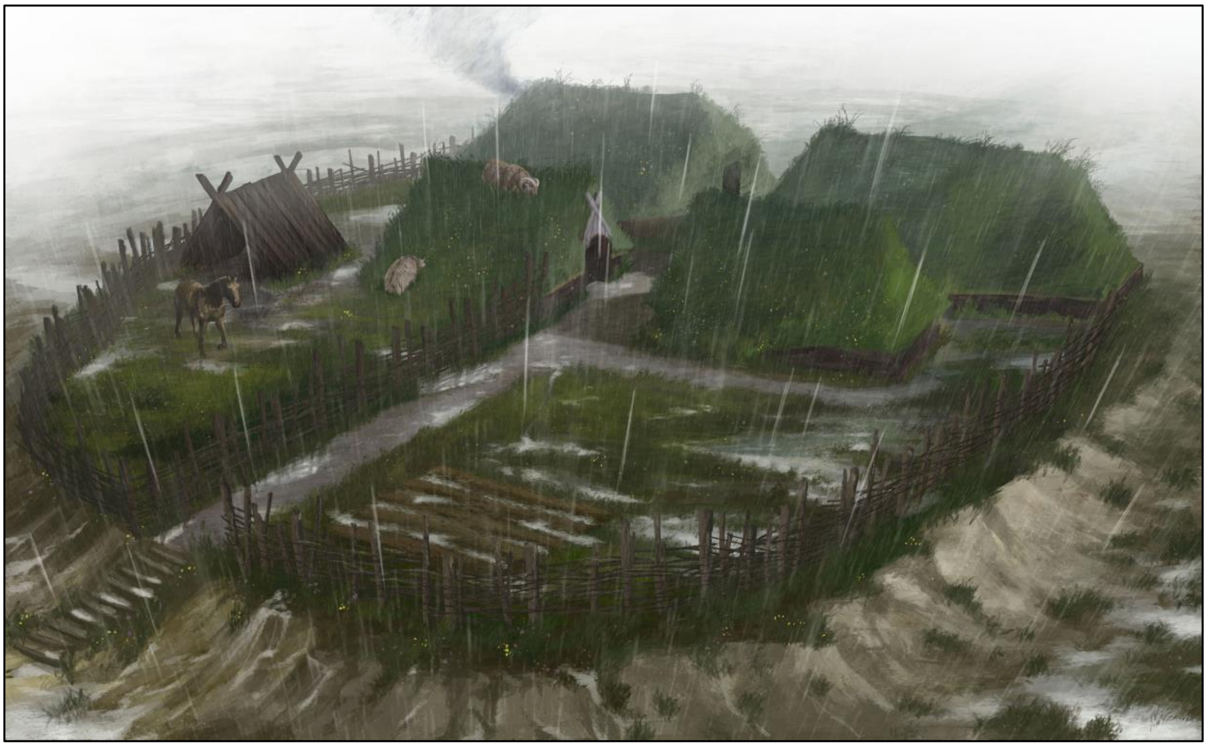


Figure 12 Reconstruction of the terp of Ramskapelle illustrating the sod-houses constructed on top of a slightly elevated platform (courtesy of Yannick De Smet and Raakvlak ©)

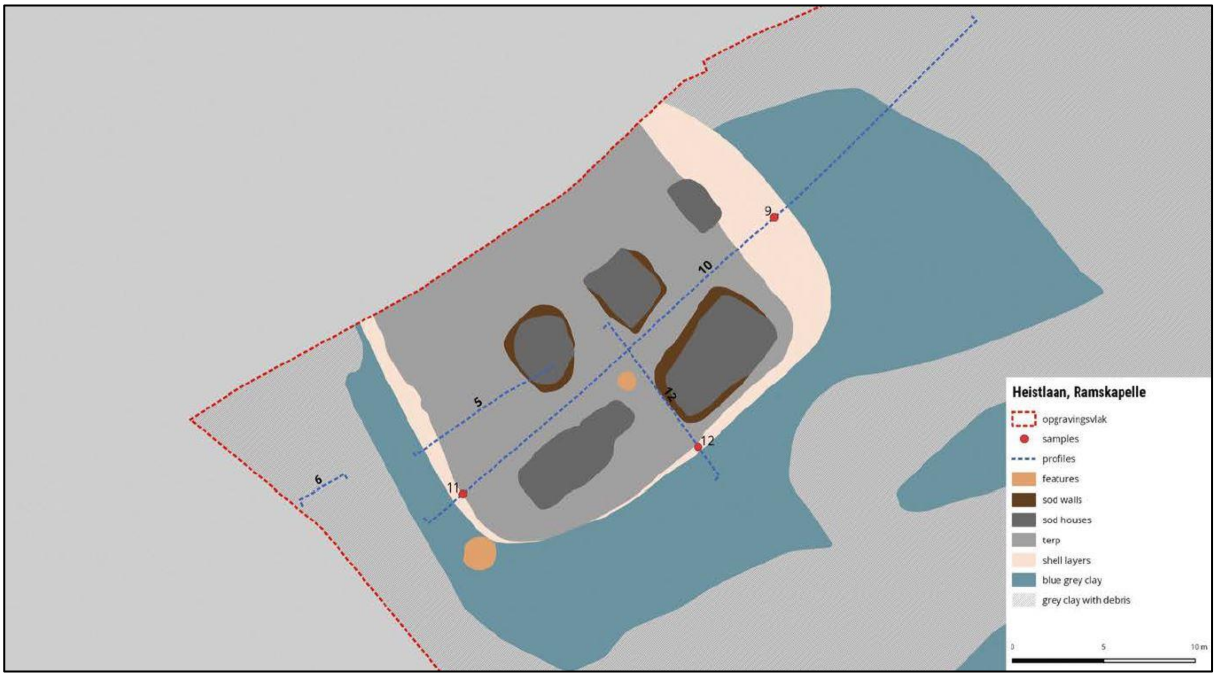


Figure 13 Simplified excavation plan of Ramskapelle depicting the *terp* construction with the sod houses (after Verwerft et al. (2019b, fig. 4))

Similarly, the artificially raised platform (16 m long, 24 m wide and 0.9 m high) of Ramskapelle was constructed on top of estuarine sediments, and not on peat or on clay-covered peat. In addition, no dyke system was present in the immediate vicinity of the platform. The platform itself was thoroughly built with sandy sods on the inside and more clayey sods on the outer edge (Verwerft et al., 2019a; Verwerft et al., 2019b). According to Verwerft et al. (2019a), the use of different sods was deliberate since the sandy sods on the inside increased the soil permeability. On the edge and flanks of the platform, layers containing large quantities of shells were detected. However, these shells were not interpreted as the remains of a shell processing activity, but rather as a way to reinforce the platform and increase its visibility (Verwerft et al., 2019a). On top of the platform, five sod houses were excavated (Figure 13). The material culture dates to the end of the second-early third century, and suggests that the site had an elevated status in society (Verwerft et al., 2019a).

During a trial trenching campaign at Ritthem, De Groot (2016) observed an anthropogenic elevation (at least 85 m long, 60 m wide and 0.5-0.7 m high) which he interpreted as a possible artificially raised habitation platform. However, this interpretation should be approached with caution. Not only were no clay or peat sods observed, but also the dimensions of this structure deviate from all known examples in the area. Instead of clay or peat sods, De Groot (2016) noticed that the structure primarily consisted of layers of ash, burned clay and settlement waste (pottery, animal bones etc.). According to de Groot (2016), there are no indications of artisanal activity, yet, based on the description, the described debris layers strongly resembled the debris layers found in 's Gravenpolder near the salt production site of 's Heer Abtskerke (cfr. 7.3). Therefore, the interpretation as artificially raised habitation platform is doubtful as the layers could just as well represent a debris zone connected to a salt production site.

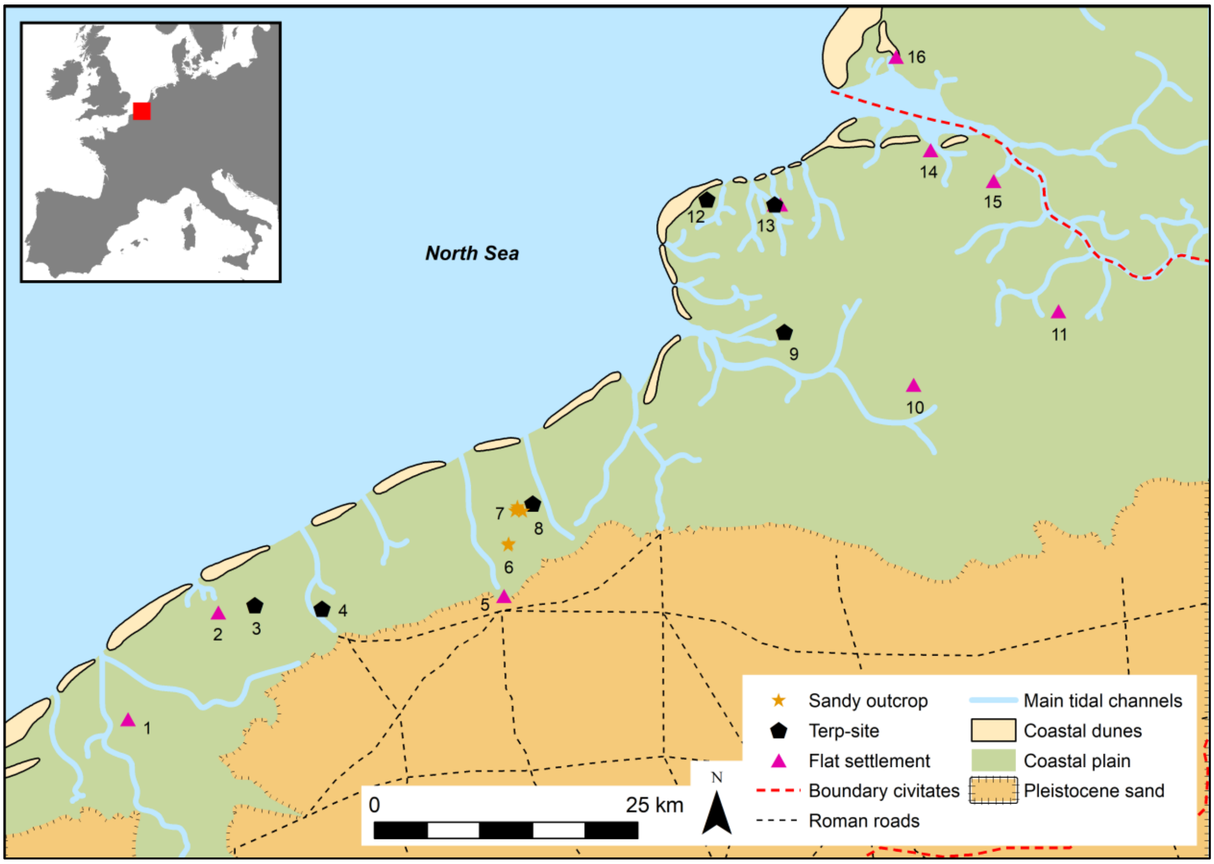


Figure 14 Locations of the rural habitation sites in the northern Menapian coastal plain across the different habitation types with 1) Wulpen Steendam 2) Raversijde-Mariakerke 3) Stene Prins Roselaan 4) Plassendale-Industrie 5) Brugge Wulpenstraat 6) Dudzele Landslag Oost 1 & 2 7) Zeebrugge Achterhaven 1-3 8) Ramskapelle Heistlaan 9) Ritthem Plangebied Mariniers 10) Borsele-Ellewoutsdijk 11) Kapelle-Handelsweg 12) Domburg Roosjesweg 13) Serooskerke Wattelsweg, Molenweg & Gapingse Watergang 14) Colijnsplaat Noordhoeksenol 15) Kats Oud Hamerstee 16) Haamstede Brabers

2.3.1.2 Pleistocene sandy outcrops (*donken*)

In the area of Bruges, Pleistocene sandy outcrops provided, just as the artificially raised platforms, a slightly elevated (and drier) position in the coastal landscape. Several of these outcrops contained Roman *in situ* material, indicating some form of occupation (De Clercq, 2009c) (Table 4; Figure 14). Except Dudzele Zonnebloemweg, the sites of Dudzele Landslag Oost 1-2 and Zeebrugge Achterhaven donk 1-3 contained few features. Instead, the sites mainly consisted of debris layers at the edge (and partially on top) the sandy outcrops. Unfortunately, little is known about the nature of the habitation structures (De Clercq, 2009c). Pottery dated the sites of Zeebrugge Achterhaven donk 1 and 2 at the end of the first century and Landslag Oost 2 at end of the first-early second century (In 't Ven et al., 2005b; De Clercq, 2009b; Patrouille, 2013). The occupation of Dudzele Landslag Oost 1 and Zeebrugge Achterhaven donk 3 was dated somewhat younger at the end of the second-first half of the third century (In 't Ven et al., 2005a; De Clercq, 2009b; Patrouille, 2013).

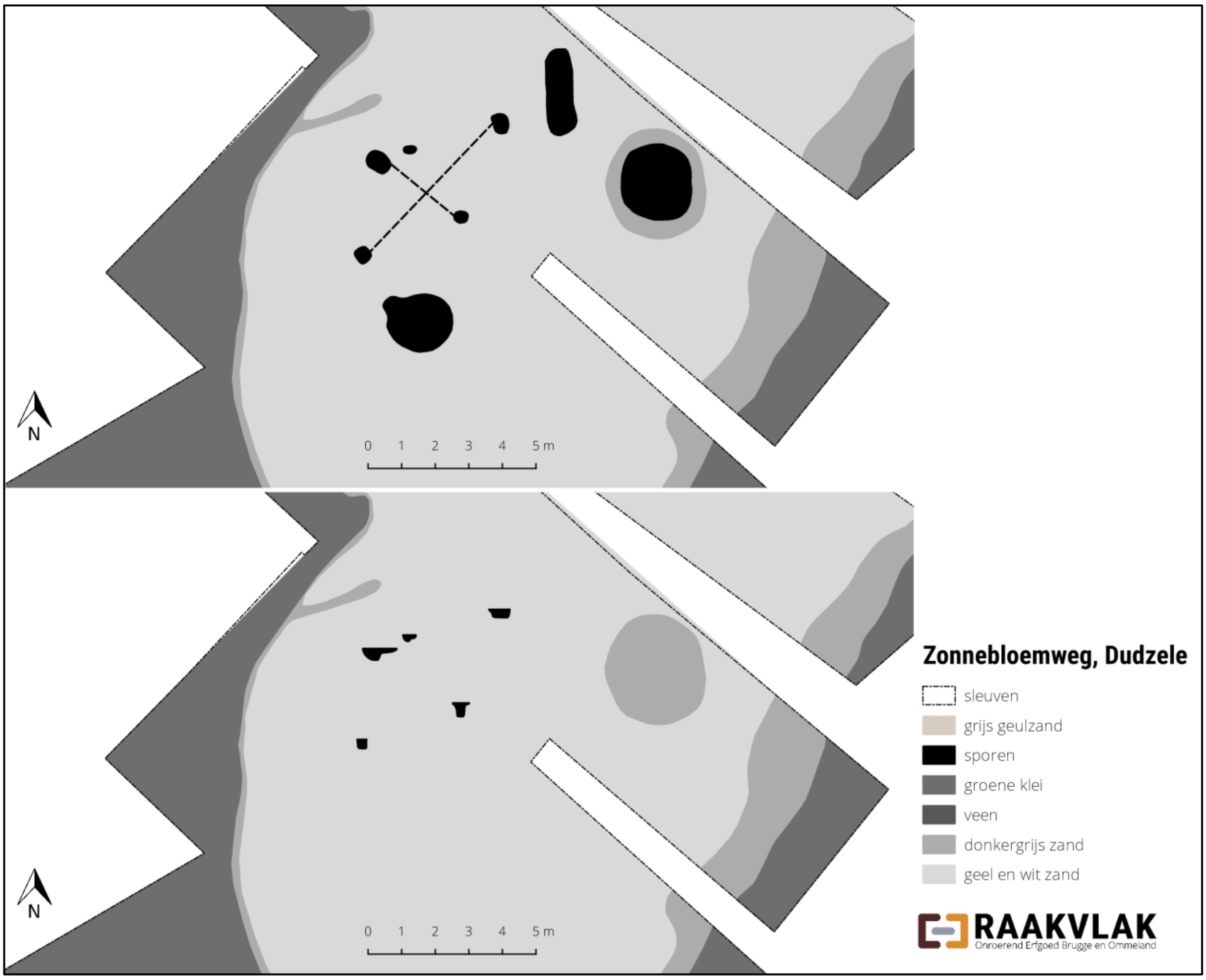


Figure 15 Detail of the excavation plan of Dudzele Zonnebloemweg depicting the phase II small farmstead building and a water well on top of a Pleistocene sandy outcrop (Verwerft et al., 2022, fig. 11)

Although multiple sites are known, the knowledge regarding the occupation of these *donken* remains limited. Recently, Dudzele Zonnebloemweg provided some crucial insights into the nature of the Roman habitation. In the first phase (69-125 CE), several postholes and other features pointed towards a more permanently occupied habitation structure. Unfortunately, no building could be recognised in the posthole configuration. Yet, some other excavated features might indicate the presence of sod house constructions (Verwerft et al., 2022). In a second phase (175-250 CE), a small farmstead building (type De Clercq IIB) with a well were discovered (Figure 15). These features strongly resembled the Roman building traditions of the nearby Pleistocene sandy hinterland, indicating that these known traditions were adopted and adapted to the specific conditions on site (De Clercq, 2009c; Verwerft et al., 2022). Keeping the sod house constructions of Dudzele Zonnebloemweg and Ramskapelle Heistlaan in mind, Verwerft et al. (2022) sees similarities with features found on top of some other sandy outcrops in the area (e.g. Zeebrugge Achterhaven donk 1-3). Even though this might be a real possibility, further research and new sites are needed to confirm this hypothesis.

2.3.1.3 Flat settlements on top of the peat

A third and final occupation type is flat settlements built on top of the dried-out peat. At the moment, this settlement type is primarily found in Zeeland (7 sites), and only two possible sites are known from

Belgium (Table 4; Figure 14). Since De Clercq's overview in 2009, only a limited number of new sites have been discovered, making a detailed overview somewhat redundant. Remarkable is the fact that most of these flat settlements, except the recently discovered site of Kapelle Handelsweg, date from the early Roman and Flavian periods (Table 4). In addition, Borsele-Ellewoutsdijk stood out as three building phases could be discerned. The first phase dates from the Flavian period, followed by a rebuilding phase around 100 CE and a final occupation around 130 CE. The site was definitely abandoned by 150 CE and quickly covered by marine sediments (Sier, 2003; Van der Heijden and Sier, 2006; De Clercq, 2009c).

In the peat soil, the perishable building materials were preserved quite well, and two main building traditions were observed: two-aisled and (partially) three-aisled constructions. Definitely, some form of evolution in building tradition can be noted in the area, but, at the moment, the dataset is too small to thoroughly grasp these evolutions. The oldest buildings found at Arnemuiden, Serooskerke Gapingse Watergang and Colijnplaats Noordhoeksenol are three-aisled farmsteads for which parallels are present in the northern and western coastal plain of the Netherlands (De Clercq, 2009c, 2011; Dijkstra and Zuidhoff, 2011). At Serooskerke Molenweg, a transition type (so-called Oss-Ussen type 5a) between a two-aisled and three-aisled construction was discovered (Dijkstra and Zuidhoff, 2011). Lastly, the settlement of Ellewoutsdijk contained farmsteads with two different house-building traditions: two-aisled Alphen-Ekeren type farmsteads (Figure 16) and partially three-aisled buildings with an A-frame roof construction (Sier, 2003; De Clercq, 2009c, 2011). The latter method was absent in the adjacent Pleistocene hinterland but is well known in the coastal regions further north, suggesting a northern influence. At Colijnsplaat, the material culture definitely pointed towards a distinct Germanic influence at the site (De Clercq, 2009c, 2011).

The settlement of Ellewoutsdijk (Sier, 2003; Van der Heijden and Sier, 2006) is still the only site to provide insight into the spatial organisation and larger settlement structure of these flat settlements. At Ellewoutsdijk, each phase consisted of several compounds composed of a single farmstead, wells, some outbuildings (granaries) and corrals. In these compounds several families lived together forming a larger community. These compounds were not enclosed with a series of ditches but instead used natural gullies and small creeks. After a generation, new houses were built in slightly different locations within the same settlement area (De Clercq, 2009c). As some form of corral was present at several sites (Table 4), sheep and goat husbandry appears fairly important in the immediate vicinity of the settlements.

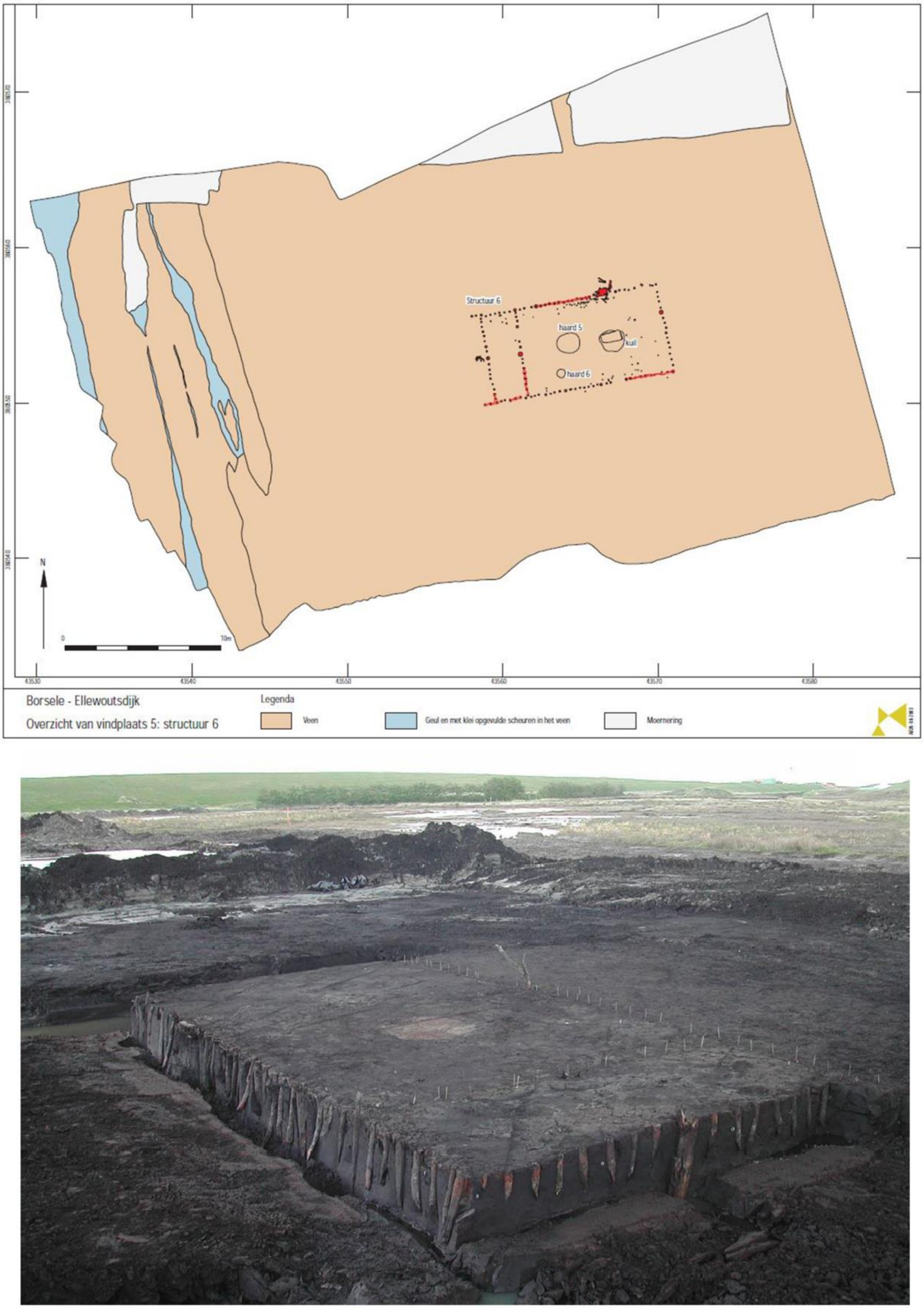


Figure 16 Excavation plan and cross-section of Ellewoutsdijk ‘house 6’ constructed following the Alphen-Ekeren building tradition, after Sier (2003, afb. 3.22-23).

Table 4 Overview of the *in situ* sites in the coastal plain (salt production sites not included)

Site	Site category	Features	Date	references
Aardenburg	Castellum	Multiple castellum phases + industrial debris layers	late 2nd, early 5th cent.	van Dierendonck and Vos (2013)
Arnemuiden-Oud Brakenburg	Flat settlement	Farmstead	ca. 200-50 BCE	Van de Berg and Hendrikse (1978)
Borsele-Ellewoutsdijk	Flat settlement	Farmsteads, outbuildings, corrals	ca. 60/70-150 CE	Sier (2001) Sier (2003) Van der Heijden and Sier (2006)
Bredene	Vicus?	Small cemetery? Debris layers	'mid Roman'	Thoen (1973, 1978a, 1987, 1988) Peters (1987)
Bredene-Landweg	Dyke	Elongated dyke	ca. 200-225 CE	Deconynck et al. (2021)
Brugge Fort Lapin	Harbour	Boat fragments + jetty	late 2nd, 3rd cent.	Marsden (1976) Vlierman (2023)
Brugge-Wulpenstraat	Flat settlement	Debris layers adjacent tidal channel	late 2nd, early 3rd cent.	Hillewaert and Ryckaert (2019)
Colijnsplaat	Religious + harbour	Nehalennia altars + harbour site *Ganuenta*	late 2nd, early 3rd cent.	Bogaers and Gysseling (1971) Stuart and Bogaers (2001)
Colijnsplaat-Noordhoeksenol	Flat settlement	Farmsteads + corral	ca. 20-50 CE	van Heeringen (1988, 1993) Trimpe Burger (1993) Lauwerier and van Mensch (1993)
Domburg	Religious	Nehalennia altars	late 2nd, early 3rd cent.	Hondius-Crone (1955) Stuart and Bogaers (2001) Stuart (2013)
Domburg Roosjesweg	Terp-site	Platform, shell and debris layers	ca. 175-250 CE	Dijkstra (2021)
Dudzele Landslag Oost 1	Pleistocene sandy outcrop	debris layers	ca. 175-250 CE	In 't Ven et al. (2005a)
Dudzele Landslag Oost 2	Pleistocene sandy outcrop	debris layers	ca. 69-150 CE	In 't Ven et al. (2005b)
Dudzele-Zonnebloemweg	Pleistocene sandy outcrop	Sod houses, farmstead with well	phase 1: ca. 69-125;phase 2: 175-250	Verwerft et al. (2022)
Kapelle-Handelsweg	Flat settlement	Farmstead, lararium?	ca. 200-250 CE	Bouma and Dijkstra (2021)
Kats-Oud Hamerstee	Flat settlement	Outbuilding	ca. 1-100 CE	Trimpe Burger (1966)
Oudenburg	Castellum + vicus	Multiple castellum phases + civil settlement	late 2nd, early 5th cent.	Vanhoutte (*in press*)
Plassendaele-Industrie	Terp-site	shell and debris layers	ca. 175-250 CE	Vanhoutte and De Clercq (2007)

Ramskapelle-Heistlaan	Terp-site	Platform, sod houses	ca. 175-250 CE	Verwerft et al. (2019a) Verwerft et al. (2019b)
Raversijde - Mariakerke	Flat settlement	Wooden posts, wooden beams	late 2nd, early 3rd cent.	Thoen (1987)
Ritthem Plangebied Mariniers	Terp-site	Layers of ash, burned clay and settlement waste	ca. 100-200 CE	de Groot (2016)
Serooskerke Gapingse Watergang	Flat settlements	Farmstead, outbuilding (granary?)	ca. 50 BCE	Dijkstra and Zuidhoff (2011)
Serooskerke Molenweg	Flat settlements	Farmstead + corral?	ca. 1-50 CE	Dijkstra and Zuidhoff (2011)
Serooskerke Wattelsweg	Terp-site	Dike, platform, shell and debris layers	ca. 175-250 CE	Dijkstra and Zuidhoff (2011)
Stene-Prins Roselaan	Terp-site	Dyke, platform, shell and debris layers	ca. 70-150 CE	Demey et al. (2013)
Walraversijde	Dyke	Elongated dyke	2nd half 2nd cent.	Pieters et al. (2013)
Wenduine	Vicus?	debris layers, wooden building?, small cemetery?	'mid-Roman'	Thoen (1973, 1978a, 1987)
Wulpen-Steendam	Flat settlements	Farmstead?	'mid-Roman'	Thoen (1973)
Zeebrugge Achterhaven 1	Pleistocene sandy outcrop	debris layers	ca. 69-96 CE	Patrouille (2013)
Zeebrugge Achterhaven 2	Pleistocene sandy outcrop	debris layers	ca. 69-96 CE	Patrouille (2013)
Zeebrugge-Achterhaven 3	Pleistocene sandy outcrop	debris layers	ca. 175-250 CE	Patrouille (2013)
Zeebrugge-Oud Ferrydok	Harbour?	Wooden framework	late 2nd, early 3rd cent.	This volume

2.3.2 Central places in the coastal plain

2.3.2.1 Vici-type settlements?

In analogy with larger centres (*vici*) of the Pleistocene hinterland, for example, Waasmunster-Pontrave and Merendree, larger sites must have been present in the coastal plain that fulfilled central functions for the surrounding area. At the moment, little is known about these sites, and their existence is often inferred by the expanse of stray find zones (De Clercq, 2009c). In addition to the attested *vici*-type settlement near the military site of Oudenburg (Vanhoutte, 2007; Vanhoutte, *in press*), two possibly larger settlements were discovered at Wenduine and Bredene (Thoen, 1973, 1978a, 1987, 1988) (Table 4; Figure 17). At Wenduine, Roman material was found on the beach from the eighteenth century onwards, and multiple small-scale excavations were conducted in the first half of the 20th century. During these excavations, debris layers and the possible remains of wooden buildings and - road construction were discovered.[16] Based on these finds, Thoen (1978a, 1987) presumed that a Flavian settlement was partially situated at the present-day beach of Wenduine. This settlement extended eastwards in the course of the second century, forming a large *vicus*-type settlement. According to Thoen (1987, 1988), a first to third-century settlement was situated at Bredene. In the late 70s, a rescue excavation took place near the Sluisvlietlaan providing some insight into what Thoen called "the artisanal quartier of the settlement". An augering campaign indicated that the Roman settlement might have covered an area of ca. 20 hectares (Thoen, 1988). Nonetheless, little actual fieldwork was conducted, making interpretations regarding the nature of the settlement hypothetical at best.

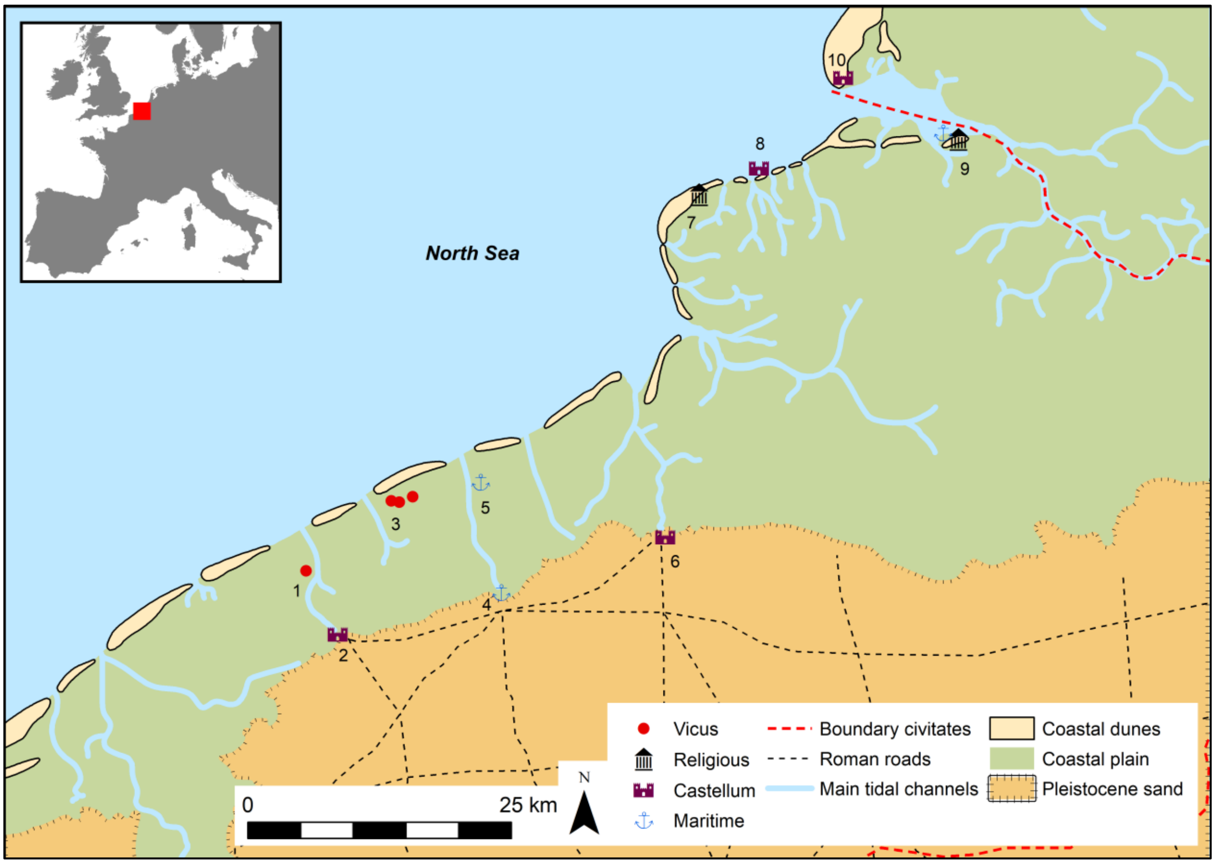


Figure 17 Locations of the central places in the northern Menapian coastal plain with 1) Bredene 2) Oudenburg 3) Wenduine 4) Brugge- Fort Lapin 5) Zeebrugge- Wooden framework 6) Aardenburg 7) Domburg 8) Oostkapelle-Oranjezon 9) Colijnsplaat 10) Walcheren Roompot

2.3.2.2 Roman military occupation

After Gaul's integration into the Roman Empire, military troops were a common sight in northern Gaul. Given the proximity to the Rhine Limes, several units were probably stationed in *castella* scattered across the Menapian territory. Unfortunately, very little is known about the early, first-century Roman military occupation. An exception is Aalter-Loveld where the oldest features date back to the first century. A second phase might correspond with a temporary occupation following the Batavian revolt (De Clercq, 2009c, 382-386; 393-394). At the end of the second century, there are

[16] For a short summary of the different excavations with corresponding discoveries, see Gheysen et al. (2014)

clear indications of a (renewed) Roman military occupation at Aalter and a new *castellum* at Maldegem-Vake (Thoen, 1991; De Clercq, 2009c).

Moreover, towards the end of the second century, the military occupation shifted from the hinterland towards the edge of the coastal plain as several new military camps (*castella*) were constructed. Since their discovery in the mid-twentieth century, these camps have attracted much scholarly interest. In 2011, Dhaeze (2011) obtained his PhD on a synthesis of the Roman Channel coastal defence system in which he included the Menapian coastal forts.[17] A detailed overview of all excavations and research on the military camp of Aardenburg[18] appeared in 2013 (van Dierendonck and Vos, 2013). Recently, Vanhoutte (*in press*) published the results of her PhD-dissertation focusing on the military camp of Oudenburg and its place in the wider coastal defence system. These three important works form the basis of this overview.

Both the military forts of Oudenburg and Aardenburg were strategically positioned at the edge of a coversand ridge overlooking the coastal plain on a junction of land- and waterways (Figure 17) (van Dierendonck and Vos, 2013; Vanhoutte, *in press*). At Aardenburg, a first (temporary) military occupation with an earth-and-timber fort has been suspected between 170-185/190 CE. Under emperor Commodus, the Aardenburg fort was renovated or rebuilt, and the first earth-and-timber fort was constructed in Oudenburg. The construction of both castella might have been part of a more extensive military building program initiated by Commodus in which the coastal region of *Gallia Belgica* became militarised, and forts along the Rhine and Danube limes were renovated (van Dierendonck and Vos, 2013; Vanhoutte, *in press*). The late second century has been characterised as a period of local (*Bellum Desertorum*, *Chauci* raids etc.) and global political-economic turmoil (Antonine plague, *Marcomanni* wars, the succession war between *Clodius Albinus* and *Septimus Severus* etc.) (De Clercq, 2009c). While the need for security and protection is evident in such a period, the military presence might also have met more strategic goals, such as controlling economic activities in the coastal plain (De Clercq, 2009c, 2011).

In the first two decades of the third century, Vanhoutte (*in press*) noted at Oudenburg an interruption in the fort's occupation after which a new earth-and-timber fort was built (220-245/50 CE). Van Dierendonck and Vos (2013) presumed a continued occupation of the Aardenburg castellum from ca. 185/190 CE until 240/245 CE with a renovation around 222CE. Vanhoutte (*in press*), on the other hand, suggested a hiatus at the beginning of the third century and the construction of a new fort around 220 CE following the chronology of Oudenburg.[19] Furthermore, she linked the observed hiatus to Septimus Severus' campaigns in Scotland in which continental troops stationed, amongst others, at Oudenburg and Aardenburg could have been employed. At Aardenburg, the destruction of several buildings and the silting up of the defence ditch marked a (temporary) end of the military occupation around 240/245 CE (van Dierendonck and Vos, 2013). A similar destruction was not noted at Oudenburg. Presumably, the occupation continued with a new earth-and-timber fort (phase 3) which underwent several renovations as the garrisons alternated quickly (Vanhoutte, *in press*).

Under the usurper Postumus, the *castella* of both Aardenburg and Oudenburg were rebuilt in stone. The construction of these forts was probably again part of a larger building campaign to protect the

[17] An updated, slightly adapted version of his PhD-dissertation was published in 2021 (Dhaeze, 2021)

[18] The synthesis of van Dierendonck and Vos (2013) has been crucial to understanding the fort chronology and the associated features. However, there are some issues with the chronology of the early fort phases and especially the existence of a pre-military phase (Chapter 5)

[19] For a detailed argumentation, see: Vanhoutte (*in press*)

Gallic and Britannic coasts from increased Germanic seaborne attacks, but also as a defence against the central Roman authorities (Vanhoutte, *in press*). After the Gallic Empire, both forts remained occupied for some time after which they got destroyed. Unfortunately, the precise end of both castella is difficult to define. Based on coin evidence, Chameroy (2013) dated the definite end of Aardenburg's military occupation in the 280s, which he related to the campaigns of emperor Maximianus.[20] Vanhoutte (*in press*) placed the violent end of the Oudenburg fort after 280/290 CE indicating that the fort might have remained in use during Carausius' *Imperium Britanniarum* (286-296 CE). After a short period of abandonment, the stone castellum of Oudenburg was renovated and reoccupied between 325/330 – 360 CE (phase 5A) and between ca. 380-430 CE (phase 5B)[21] (Vanhoutte, *in press*)

Next to the attested castella of Oudenburg and Aardenburg, potential forts are suspected at Oostkapelle-Oranjezon, Walcheren-Roompot and Bruges (Figure 17). At Oostkapelle, multiple finds on the beach, including stamped tegulae, suggested the presence of a military fort protecting the estuary of the river Scheldt. Most likely, the fort, dating from the late first century until the third century, was a fleet station of the *Classis Germanica* since all recovered stamps bore the letters CGPF (*Classis Germanica Pia Fidelis*). On the other side of the Scheldt estuary, northeast of Oostkapelle-Oranjezon, another fort (Walcheren-Roompot) might have been present. No archaeological indications exist at this time, but an old seventeenth-century map mentioned its presence (De Clercq and van Dierendonck, 2006; De Clercq, 2009c; Dhaeze, 2011). In addition, at Bruges, some of the finds, primarily dated in the third century, may point to a military occupation nearby. From a strategical point of view, a military fort at Bruges would have been a logical choice, but at the moment, no *in situ* traces have been found confirming this hypothesis (De Clercq and van Dierendonck, 2006; De Clercq, 2009c; Dhaeze, 2011).

2.3.2.3 Religious sites

In 1647, the remains of a Roman sanctuary with multiple altars dedicated to the native goddess Nehalennia were discovered on the beach of Domburg. These altars were displayed in the local church, but most were destroyed in 1848 when the church burned down. The surviving pieces were donated to the *Zeeuws Genootschap* and are in the collection of the *museum of the Zeeuws Genootschap der Wetenschappen* (Middelburg). Luckily, all pieces were drawn by multiple artists and scholars in the seventeenth and eighteenth centuries, preserving some of the epigraphic and iconographic information (Hondius-Crone, 1955; Stuart, 2013). These altars have long been considered a curiosity until 1970 when a fisherman discovered two Nehalennia altars in the Eastern Scheldt estuary near Colijnsplaat. In the following years, multiple fishing campaigns recovered more than 320 (pieces of) altars[22], fragments of statues, pottery and building material which indicated the presence of a second temple near Colijnsplaat[23] (Figure 17) (Stuart and Bogaers, 2001; De Clercq and van Dierendonck, 2006; Derks, 2014). Based on the recovered building material, the temple of Colijnsplaat was most likely built as a Gallo-Roman temple with an ambulatory (De Clercq and van Dierendonck, 2006; De Clercq, 2009c, 375). While Domburg seems to be active from the first century onwards, Colijnsplaat is dated

[20] As part of the "High tide, low tide project", de Ruijsscher explores the evolution of Aardenburg from the late Roman until the late medieval period. Preliminary results suggest some form of late Roman occupation at Aardenburg, but at the moment, the nature of the occupation is this unclear.

[21] For more information on the late Roman occupation of Oudenburg, see Vanhoutte (*in press*) and Van Thienen (2016)

[22] In total, 110 almost complete altars were recovered which are displayed in the Rijksmuseum voor Oudheidkunde (Leiden)

[23] A multi-disciplinary research project on the sanctuary of Colijnsplaat is currently ongoing. In this project, the geological provenance of the altar stones will be assessed, which will shed new light on the trade mechanisms at play.

somewhat later, from the middle of the second century until the first half of the third century. The names of consuls on the altars of Colijnsplaat indicate that dedicants made pledges and offerings between 188 and 227 CE (Stuart and Bogaers, 2001; De Clercq and van Dierendonck, 2006, 40-41). In addition to the Nehalennia temple, a large harbour and civil trade centre were situated near Colijnsplaat. According to Bogaers and Gysseling (1971), this harbour and trade centre might have been called *Ganuenta*, a name mentioned on the votive stone of *Gimio.*

Even though the temple is no longer preserved, the recovered votive stones contained a wealth of iconographic and epigraphic information on the cult of Nehalennia.[24] Contrary to Domburg, where some altars were dedicated to the traditional pantheon, for example, Jupiter and Neptunus, the votive stones of Colijnsplaat exclusively mentioned the native Germanic goddess Nehalennia (Stuart and Bogaers, 2001). Like other cults, the dedicants pledged to offer something (for example an altar) if the goddess granted their wishes. In this case, the dedicants most likely asked for divine protection for themselves, their cargo and their ships during seaborne voyages and trade. The fact that the altars often depicted Nehalennia on the prow of a ship or with shipping elements confirms these ideas (Stuart and Bogaers, 2001; Stuart, 2013; Derks, 2014). According to Raepsaet-Charlier (Raepsaet-Charlier, 2015, 211), Nehalennia might also be the local goddess of salt and salted products.

Fascinating is the vast collection of dedicant names, of which the majority were Roman citizens (81 names) compared to a smaller amount of *peregrini* (18 names). According to Derks (2014), the dominance of Roman citizens is not surprising and testifies to the advanced naturalisation of native communities in the second and third centuries CE. In total, 26 dedicants explicitly stated their active involvement in trade and water transport, either as free contractors or as auxiliary staff. Of these 26 inscriptions, nine *negotiatores* mention the goods in which they traded, whereby the four *negotiatores salarii* (salt merchants) and the three *negotiator allecarii* (trader in fish sauce) are of importance in this study[25] (see Chapter 9) (Figure 18) (Derks, 2014). In the past, researchers[26] assumed these inscriptions reflected the use of Domburg and Colijnsplaat solely as transit and transhipment ports for Rhenish merchants importing (salt and fish sauce) and exporting goods (pottery and wine) to and from *Britannia.* However, the presence of large salt production centres in the vicinity of the temples indicates that next to a transition zone, local and regional commodities might have been a substantial part of the exported goods.

[24] For more information on the iconography and epigraphy of the altars see (Stuart and Bogaers, 2001; Stuart, 2013); For more information on the dedicants and the wider social context of the altars, see Derks (2014)

[25] The *negotiatores salarii* will be discussed in detail in section 9.4.2

[26] See Hassall (1978)

Figure 18 Nehalennia altars erected by *negotiatores salarii* M. Exgingius Agricola (A) from Cologne and Q. Cornelius Superstis (B) (© Rijksmuseum voor Oudheidkunde, Leiden (the Netherlands)).

2.3.3 Maritime activity and harbour sites

Besides the harbour in *Ganuenta*, another harbour site was found in Bruges[27] (Table 4; Figure 17). In 1899, the remains of a shipwreck were discovered in Fort Lapin while digging a canal connecting Bruges to the North sea. Unfortunately, the discovery was not made at once, and as the work progressed, parts of the boat were dug out and the timbers were thrown on a pile (Vlierman, 2023). Luckily, a selection of pieces, such as the side rudder, side frames, parts of a mast, a mast-step frame and planking, was preserved, which Jonckheere (1903) published for the first time in 1903. In 1973, Marsden (1976) redrew and restudied the pieces to compare them with the Blackfriars I shipwreck. Recently, all evidence, including the boat timbers and the old drawings, were re-examined by Vlierman (2023). Despite the small number of pieces, he concluded that the fragments do not represent a single carvel-built shipwreck and that at least one part of a second vessel was present. The exact length of the Bruges boat could not be deduced, but the maximum width might have been ca. 4.2 m and the height amidship ca. 1.55m. The Bruges boat might be a larger version of the Barland's Farm boat, of which the slightly higher sides made the vessel more seaworthy, enabling coastal shipping and Channel-crossing in calm weather conditions. Whether the ship had a military function as a patrol vessel rather than a commercial use cannot be said for certain as both options are plausible (Vlierman, 2023). At a certain point, the vessels were secondarily used to make a revetted jetty or abutment on the bank of an active tidal channel called the Blankenberge geul. Radiocarbon dating

[27] I would like to thank dr. Karel Vlierman for sharing his published and unpublished version of the article on the boat of Bruges.

placed the ship's construction in the third century. Near the boat fragments, pottery found during the same infrastructural works points towards a settlement on the bank of the tidal channel, dated between the end of the second–the third quarter of the third century (Thoen, 1978a, 101-105).

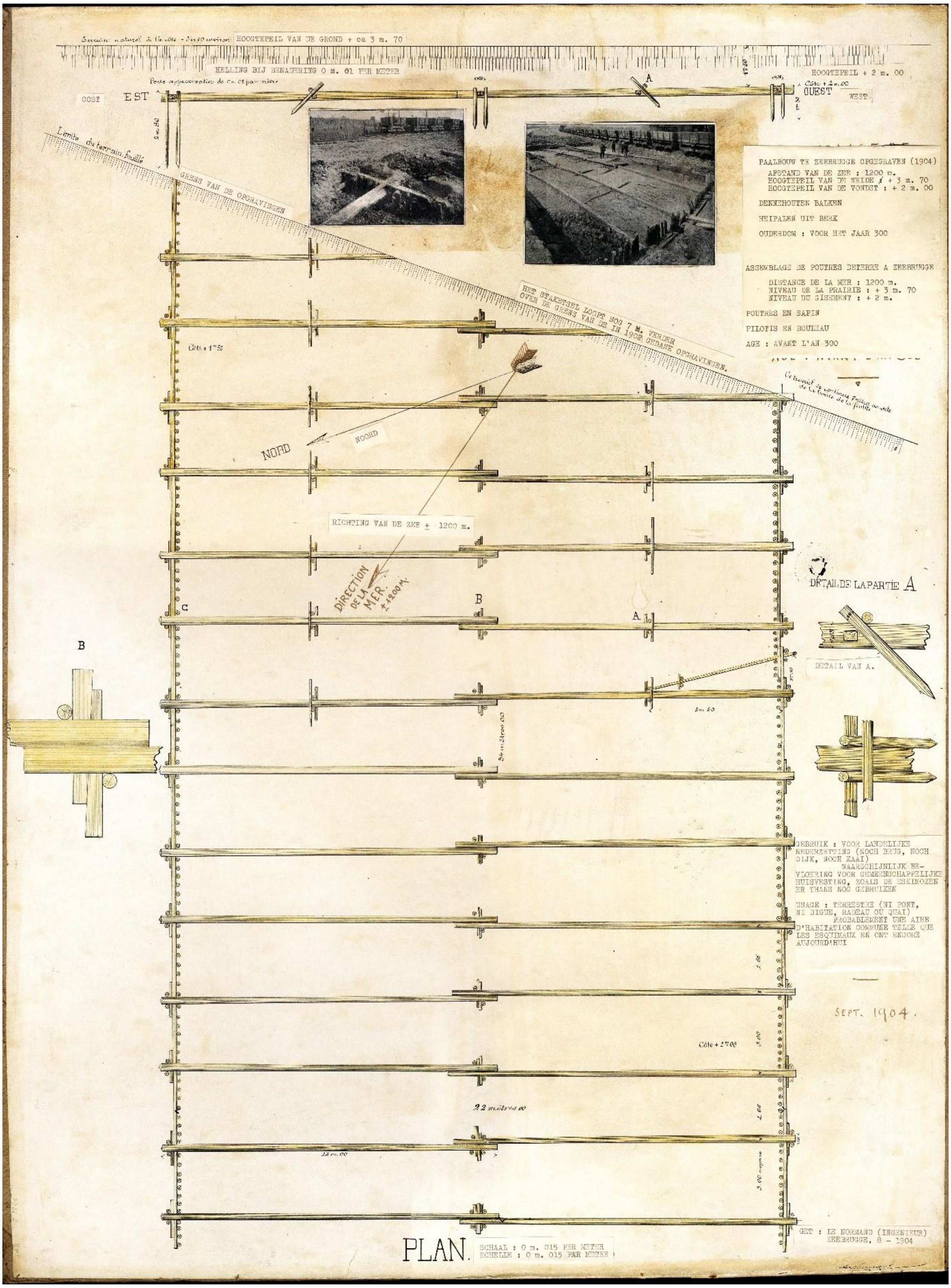


Figure 19 Drawing of the wooden framework found at the Oud Ferrydok (Zeebrugge) in 1904 (courtesy of Raakvlak)

In addition to these two harbour sites, a third possible maritime site was discovered during the construction of the Zeebrugge harbour in 1904 (Figure 17). On top of the peat, workers found the remains of a northwest-southeast, slightly eastward sloping rectangular wooden framework (22 m wide and at least 39.5 m long) (Figure 19; Figure 20). A total of 748 m² was excavated, but an augering campaign immediately following the discovery indicated that the structure continued eastwards forming a much larger structure of approximately 1500 m². The structure consisted of twelve 'compartments', alternately 3 and 2.66 m wide, constructed with 12 m long pinewood beams/poles. Two of these beams were fastened in the middle with pinhole connections and driven posts. The outer edges of the structure were formed by pinewood beams/poles secured on the inside with contiguous birchwood poles measuring between 1.3 and 2.8 m (de Pélichy, 1905; Thoen, 1973, 1978a). Over the years, various hypotheses have been put forward regarding the function of the structure. De Loë (1904, 85-86) and de Pélichy (1905) thought it resembled the sub-structure of an 'artificial island' (crannoge) in the marshland. According to Cumont (1919, 100), such crannogs could also function as a jetty providing access to the coastal wetlands. Lambrechts (1951, 38) and Verhulst (1964, 12) supported this idea and interpreted the wooden framework as the remains of a Roman harbour. Unfortunately, neither of them provided some form of argument supporting their views.

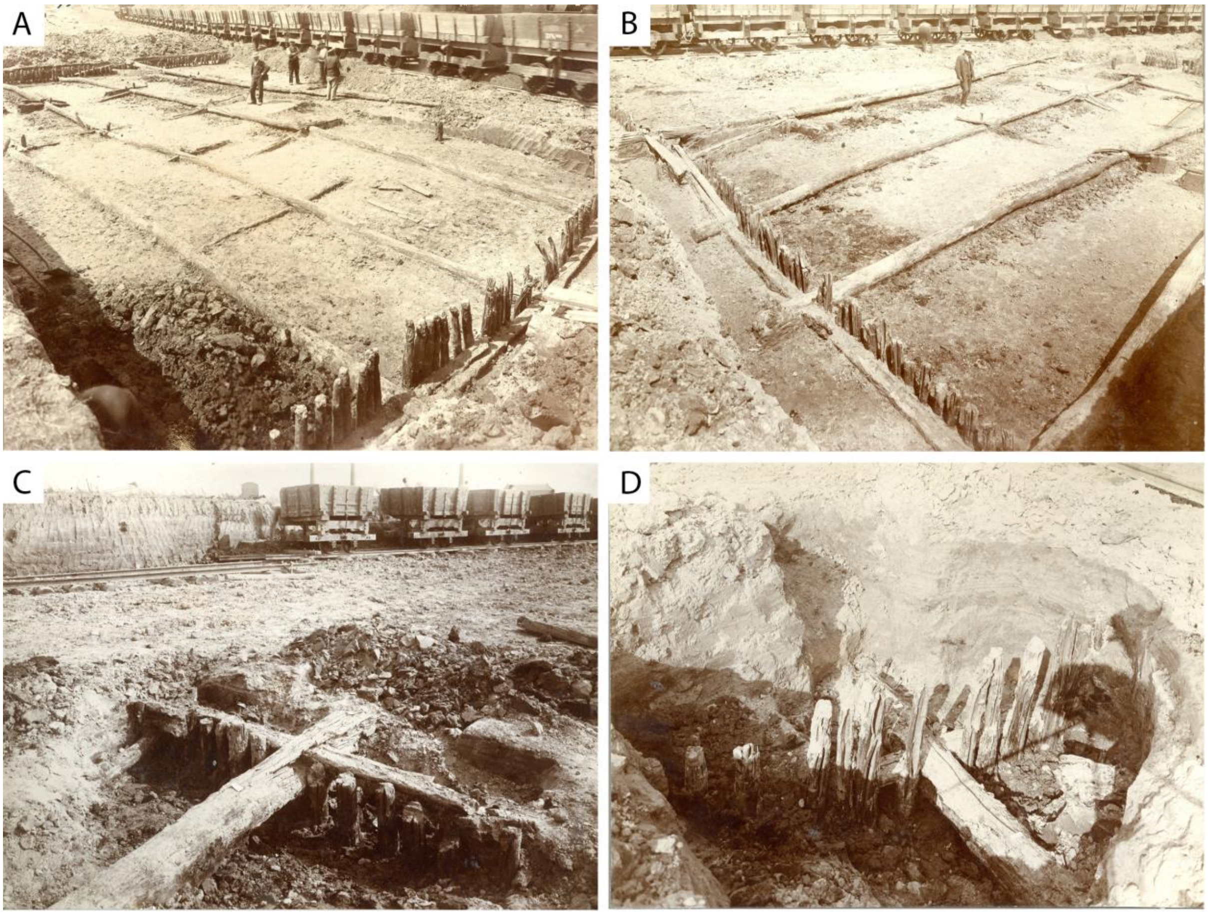


Figure 20 Old excavations photographs of the in 1904 discovered enigmatic structure depicting the larger structure (A-B) and the inner fastening of the structure with birchwood poles (C-D) (photo's courtesy of the KMKG)

Alternatively, Breuer (1946, 89) interpreted the structure as a saltern (*zoutkeet*) in which salt was produced using briquetage pottery. The lack of briquetage on site meant that this hypothesis was only marginally accepted. Favorel (1961) adopted Breuer's idea and considered the wooden framework part of a more industrialised Roman salt production technique compared to the Iron Age briquetage technique. Thoen (1973, 1975a, 1978a, 1987, 2000) further developed this hypothesis and provided two main arguments in favour of a salt-related function. Firstly, an active tidal channel was located near the wooden framework which could provide salt water. And secondly, several small moulds were found which could function as briquetage salt moulds. The structure would then have worked similarly to a present-day salt pan (for example, the salt pans Guérande) in which seawater flowed through a series of shallow basins. In these consecutive basins, the water evaporated through natural solar activity forming a concentrated brine and eventually crystallised salt (Alonso Villalobos and Ménanteau, 2006; Carusi, 2008a).

Since then, the hypothesis of a Roman salt pan has been uncritically adopted. However, several arguments can be put forward questioning the validity of this interpretation. Firstly, these so-called salt moulds' exact context and location are unknown. They were not found during the excavation of the wooden framework and, thus, must have come from elsewhere, a fact that Thoen also acknowledged (Thoen, 1973). Secondly, climatological conditions, primarily the lack of sunshine and abundant rain, impeded the natural crystallisation of salt in this area (Daire, 2003, 26). Thoen (1978a, 92; 2000) also mentioned this but remained quite vague and noted that the end product might also be a concentrated brine. Even if they used the structure only to create a concentrated brine, it still had to be boiled above a fire to crystallise the salt. This would defeat the purpose of the structure. A third, less significant, argument might be the lack of Roman parallels along France's climatically much more favourable Atlantic coast. The oldest known examples of salt pans only appeared in the area of Saintonge from the seventh century onwards (Daire, 2003, 27). Nevertheless, as the absence of evidence is not the evidence of absence, the lack of Roman salt pans along the Atlantic coast might be due to the current state of knowledge and not represent the historic reality.

A fourth and final argument concerned the overall construction of the wooden framework. The ample use of long birchwood poles (up to 2.8 m) to anchor the construction and the different methods of securing the beams[28] (pinhole connections, oblique birchwood poles etc..) indicate a structure that transcends a mere salt pan. The known Roman or modern-day examples from the Mediterranean (Garcia Vargas and Martinez Maganto, 2017) are simple constructions built with local materials (earth, slib etc.). In addition, the abundant use of birch and pinewood beams and poles in a primarily treeless landscape indicates a considerable investment of scarce resources. While birchwood could be sourced locally, pinewood had to be transported from the Pleistocene hinterland or collected from prehistoric submerged forests like the construction material from Ellewoutsdijk. The import of large quantities of wood and the overall size of the structure implied the direct involvement of a central authority figure, the Roman army or private entrepreneurs. The wooden framework clearly could not have functioned as a 'perfectioned' salt pan, and a reinterpretation is necessary. The feature's overall location in the coastal plain in the vicinity of a tidal channel and the solid construction capable of supporting quite a lot of weight does suggest some sort of maritime function. Yet, the exact function (slipway, jetty, harbour) is still unclear.

[28] From the pictures, it is clear that these were not small beams but practically untrimmed trees

2.3.4 Roman interventions in the coastal landscape

Over the last decade, it became increasingly clear that the coastal plain was permanently inhabited in Roman times, and that the population actively bent the dynamic coastal landscape to their will by building dikes and digging drainage ditches. These dikes were either connected to habitation sites, for example, at Stene (Demey et al., 2013) and Serooskerke-Wattelsweg (Dijkstra and Zuidhoff, 2011), or occurred isolated in the landscape, e.g. Raversijde (Pieters et al., 2013) and Bredene (Deconynck et al., 2021). At Raversijde, the embankment, dated to the second half of the second century, measured at least 107 m in length[29], 12.16 m in width and 1.12 m in height. This structure was mainly constructed from clay sods with three parallel peat sods walls in the western half of the dike (Figure 21). As peat was more resistant to water erosion, this might indicate that the tidal channel was located west of the embankment (Pieters et al., 2013). Pieters et al. (2013, 85-86) calculated that at least 800 m^3 of soil and 875 workdays were needed for the dike's construction. These infrastructural works also affected a larger area which suggested that the Roman military or a central authority figure might have been involved in the dike's construction.

Figure 21 Cross-section of the Roman dike encountered Raversijde displaying the three parallel peat sods walls in the western half of the dike (Demey et al., 2013, 60, fig. 37)

Recently, a second (isolated?) NE-SW oriented dike (at least 60 m long, base 15-25 m wide; top 7-10 m wide and 1.2-1.5 m high) was discovered at Bredene-Landweg. This dike, constructed with local clay sods, protected the polders in the southeast from an active tidal channel northwest of the dike. This tidal channel partly eroded the dike in a first phase, after which the dike was reinforced and raised.

[29] On the beach of Raversijde, Etienne Cools observed rows of peat sods similar to the ones found during the excavation. According to Pieters et al. (Pieters et al., 2013), the observations on the beach might be part of the same dike structure which would quadruple the dike's length.

Pottery dated the embankment in the first quarter of the third century, which was confirmed by radiocarbon dating (Deconynck et al., 2021, 103-109). Both at Bredene Landweg and Raversijde, a stabilization horizon denoted the inner dike area, and *de facto* provided evidence for its use as a local defensive dike against tidal inundations (Pieters et al., 2013; Deconynck et al., 2021). Evidence for this was also found at Serooskerke Wattelweg where the inner dyke area was sometimes flooded. Nevertheless, a clear distinction in the environment was observed with a more brackish environment outside the dike compared to a more freshwater habitat in the inner dike area (Dijkstra and Zuidhoff, 2011). Similar observations were made at Stene with a more freshwater environment developing in the inner dike area (Demey et al., 2013). Next to dike-building, there are some indications that the Romans actively tried to drain and reclaim some areas of the coastal plain systematically. Unusual rectilinear creek systems found on Walcheren, Zuid-Beveland, and between Stalhille and Houtave are often seen as evidence of Roman attempts to drain the peat (Ovaa, 1971; Thoen, 1978a, 68-70; 1987, 66; Thoen and Hollevoet, 2001).

2.4 Roman exploitation of coastal resources

Although the coastal wetlands were often considered 'marginal' landscapes with limited economic potential, multiple scholars (see, amongst others, Rippon, 2000; De Clercq, 2009c, 2011) have argued that precisely the opposite was true. Dynamic wetland areas are incredibly rich ecosystems with a high potential for specific resource exploitation strategies such as sheep/goat husbandry, fishing and shell processing, salt production[30] and peat extraction.

2.4.1.1 Animal husbandry and agricultural production

At the habitation sites of Colijnsplaat and Ellewoutsdijk, the combined presence of houses with a stable area, a corral, and a large concentration of sheep/goat bones indicated some form of sheep farming on the salt marshes (Lauwerier and van Mensch, 1993; Sier, 2003). No stable area or corral was found on the terps of Stene and Ramskapelle, but the dominance of sheep bones pointed towards specialised sheep husbandry practices (Demey et al., 2013; Verwerft et al., 2019a). The same might be true for the *vicus* of Bredene where an extensive collection of sheep bones was discovered (Peters, 1987). Even though the number of habitation sites is still relatively small, the fact that most sites contain a large collection of sheep bones suggests that sheep/goat husbandry, and by extension wool production, played an essential part in the economy of these coastal communities (De Clercq, 2009c, 2011). The same is true for the early and high-medieval period in which large, well-organised, specialised sheep farming estates developed on the initiative of the Counts of Flanders and major monasteries (Tys, 2004; Soens et al., 2014; Buchan et al., 2015).

The archaeozoological evidence indicates that sheep husbandry on salt marshes near the habitation sites was important. Still, all sites contained a mixed livestock (sheep/goat, cattle and) in which different animals were kept to serve multiple purposes (wool, milk, meat, draft animals etc.).

[30] This section primarily focuses on the exploitation of coastal resources besides salt production. Salt production is the main topic of the dissertation and will be exhaustively studied in the following chapters.

In addition to sheep/goat bones, cattle were present in various amounts on each of these sites. However, as the bone assemblages are sometimes relatively small, the ratio between the different species might not entirely represent the site as a whole. Furthermore, horse bones were found at Bredene (Peters, 1987), Serooskerke Wattelsweg (Dijkstra and Zuidhoff, 2011) and Ramskapelle Heistlaan (Verwerft et al., 2019a), indicating that horses were used as draft animals or as mounts. It should be noted that evidence for the presence and use of horses was more pronounced at Ramskapelle. This can be deduced by the number of bone fragments and the associated finds, such as fragments of horse gear and a horseshoe (Verwerft et al., 2019a). Except for Ramskapelle Heistlaan (Verwerft et al., 2019a), pig bones were rare, suggesting that pigs were only rarely kept and consumed on the coastal sites.

Around the habitations sites, archaeobotanical evidence (macrobotanical and pollen studies) indicated an open landscape dominated by freshwater, brackish and salty grass and herbaceous vegetation which was well suited for animal husbandry (Sier, 2003; Dijkstra and Zuidhoff, 2011; Demey et al., 2013; Verwerft et al., 2019a; Bouma and Dijkstra, 2021; Dijkstra, 2021). On most of the sites, pollen of common field weeds might suggest the presence of fields, or at least man-made activity, near the sites. However, field weeds might also result from processing imported cereals on-site (Dijkstra and Zuidhoff, 2011; Dijkstra, 2021). There are some minor indications for local cultivation of the more salt-tolerant barley at Ellewoutsdijk (Sier, 2003) and Kapelle Handelsweg (Bouma and Dijkstra, 2021). Still, evidence is limited at the moment, and more sites are needed to confirm the local cultivation of barley in the coastal plain. At Ellewoutsdijk, the remains of *Camelina sative* and flax seed indicated the local cultivation of flax. Furthermore, at Ellewoutsdijk (Sier, 2003), Steene (Demey et al., 2013), Serooskerke Wattelsweg (Dijkstra and Zuidhoff, 2011), Ramskapelle Heistlaan (Verwerft et al., 2019a) and Domburg Roosjeweg? (Dijkstra, 2021) there is evidence for the local cultivation of faba beans (sometimes horsebean) and sporadically white turnip. Although white turnip and faba beans can be cultivated for human consumption, Demey et al. (2013) suggested that these crops were primarily grown as fodder and that agricultural production, if present, was in function of animal husbandry activities.

2.4.1.2 Fishing, shell processing and fish sauce production

On multiple habitation, artisanal and military sites, layers containing large quantities of shells were discovered. The exact amount of shell fragments was difficult to quantify objectively, and only samples of shell layers were analysed at species level. These analyses pointed towards a selective exploitation of mussels (ca. 80-90%) and cockles (10-20%) complemented with different bycatch species (common periwinkle, whelk etc.). Oysters, considered a delicacy in the Roman world (Marzano, 2013), were only sporadically present in very low quantities on all coastal sites (De Clercq and van Dierendonck, 2006; De Clercq, 2009c; Dijkstra and Zuidhoff, 2011).

The selected exploitation of mussels and cockles indicated that these crustaceans were harvested for consumption. Based on the assemblage at Stene-Prins Roselaan, Demey et al. (2013, 54) stated that the crustaceans were directly consumed on-site and that there are no indications that these shells were traded as surplus. However, Dijkstra and Zuidhoff (2011, 69) roughly estimated that the shell layers at Serooskerke Wattelsweg contained ca. 5500 portions (assuming one portion to be one kilograms of shells). The layers might have formed during only two seasons, so they considered exclusive local consumption improbable. Instead, Dijkstra and Zuidhoff (2011, 69) interpret the site as a special purpose site focused on processing crustaceans for inland consumption. Similarly, the large shell layers found on the edge of the *terp* and at the creek ridge at Domburg Roosjesweg prompted Dijkstra (2021) to interpreted the terp of Domburg as a special purpose site as well.

Although the *terp* of Ramskapelle contained many shells, these shells were not interpreted as consumption waste. Alternatively, the layers were interpreted as a reinforcement of the clay layers deposited after the terp was constructed and perhaps even as a way to enhance the visibility of the *terp* in the coastal area (Verwerft et al., 2019a; Verwerft et al., 2019b). Saltwater molluscs, including oysters, mussels etc., were definitely consumed in the hinterland. Shell fragments have been found, amongst others, at the vicus of Merendree, the villa of Nevele and the town of Tongeren indicating a well-established, well-organised trade of shellfish to the adjacent hinterland (Vanderhoeven et al., 1992; Ervynck et al., 1997; Van Neer and Ervynck, 2007, 2016; Ervynck et al., 2017). The trade and inland consumption of shellfish has also been well documented archaeologically in Roman Britain (Cool, 2006) and on inland Roman military sites[31] (Davies, 1971). However, the presence of large-scale shell depositions on coastal sites indicates that processed shellfish were transported to the hinterland in addition to raw shellfish. At the moment, it is unclear whether these mussels and cockles were preserved (e.g. dry salting, pickling etc.) and transported in storage vessels or if the shellfish was an integral part of a local fish sauce recipe.[32]

Despite their convenient position, fishbones only occur sporadically on these coastal sites, indicating that fishing and, by extension, fish consumption were rather limited. Only a few fragments of codfish, herring, small whiting, three-spined stickleback, and different species of flatfish such as stingray, plaice and flounder have been discovered (Peters, 1987; Demey et al., 2013; Verwerft et al., 2019a; Dijkstra, 2021). Surprisingly, most of these species, like cod, herring and the different species of flatfish, occur in coastal waters or open sea, suggesting that these fish might not have been caught locally in the tidal channels (Demey et al., 2013). In contrast, consumption refuse from a well at Oudenburg, dated to the second half of the third-first half of the fourth century, contained a larger collection of primarily small fishbones, such as flatfish, smooth-hound, thinlip mullet, seabass etc. (Vanhoutte et al., 2009a). According to Vanhoutte et al. (2009a), the identified species indicated that fishing primarily took place in creeks and tidal inlets and, possibly in shallow coastal waters. Although there is some discussion as to where fishing took place, all studies agree that the scarcity of fishbones is remarkable. Consequently, they concluded that on these coastal sites fishing was not an important activity (Vanhoutte et al., 2009a; Dijkstra and Zuidhoff, 2011; Demey et al., 2013).

Remains of large marine fish were also rare at (large) inland settlements. At the moment, only a handful of sites (Nevele, Tournai, Liberchies and Tongeren) in Belgium contain some fish remains (mostly flatfish) originating from a coastal or estuarine environment (Van Neer and Ervynck, 2016; Ervynck et al., 2017). Interestingly, fragments of Spanish mackerel have been discovered on several sites in northern Gaul.[33] Spanish mackerel were imported as salted fish, also called *salsamenta,* in the northern part of the Empire between the first and the third century CE (Van Neer and Ervynck, 2004, 2007; Van Neer et al., 2010; Van Neer and Ervynck, 2016). The consumption of fish and salted fish was

[31] Interestingly, the transport and consumption of oysters were mentioned in a letter addressed to *decurion Lucius*, who was stationed at Vindolanda (Tab. Vindol. II 299) (Bowman, 1994, 76-77; Bowman and Thomas, 1994, 272-273)

[32] Since the yield of mussels and cockles is relatively low, shellfish must have been a complementary ingredient since a local fish sauce recipe solely based on shellfish seems improbable.

[33] Next to Spanish mackerel, other salted fish species were imported from the Mediterranean. However, at the moment, primarily Spanish mackerel have been found on Belgian sites. For an overview of sites (e.g. Tongeren, Velzeke, Tournai etc.) and references regarding the inland consumption of *salsamenta* on Belgian sites and, by extension, sites in northwestern Europe, see: Van Neer and Ervynck (2004), Van Neer et al. (2010) and Ervynck et al. (2017).

largely absent from the local Iron Age diet.[34] Consequently, the import of Mediterranean salted fish might initially have been directed towards the Roman citizens or local elites who wanted to flaunt a 'Romanised' way of living (Van Neer and Ervynck, 2004). However, based on the limited evidence, it is unclear how popular (salted) fish became with the local population and whether it was considered a high-status luxury item or a basic imported staple food. According to Van Neer and Ervynck (2004), a local variant of North Sea *salsamenta* never developed to compete with imported Mediterranean products. Yet, the presence of typical North Sea species in the hinterland suggested that at least some form of preservation (salting or drying) took place before transport.

More than *salsamenta,* fish sauces were regarded as an absolute necessity to the Roman way of life and, as attested by fish sauce amphorae on multiple sites, the product was initially imported from the Mediterranean to supply the Roman elite and troops stationed in northern Gaul (Martin-Kilcher, 1990; Curtis, 1991; Van Neer et al., 2010; Tsigarida, 2014a; Curtis, 2016). Over the last decades, careful sieving of archaeological contexts of Tienen (Lentacker et al., 2004; van Neer et al., 2005), Tongeren (Van Neer and Ervynck, 2004; Van Neer et al., 2010; Ervynck et al., 2017), Braives (Van Neer and Lentacker, 1994) and Arlon (Van Neer et al., 2010; Deforce et al., 2021) revealed evidence of a local production of fish sauce (*garum, allec*). This fish sauce was made using young, small marine fishes (e.g. herring, whiting, flounder, three-spined stickleback etc.) living on soft-bottomed, sheltered zones of North Sea or North Atlantic estuaries. These finds of a locally produced fish sauce were dated roughly from the mid-second century CE onwards (Van Neer and Lentacker, 1994; van Neer et al., 2005; Van Neer et al., 2010).

As noted by Martin-Kilcher (1990) and Van Neer et al. (2010), the number of amphorae documenting the import of Mediterranean salted fish products started to decrease from the end of the first - beginning of the second century CE onwards, which coincided with the emergence of local alternatives. Exactly what prompted the local production of fish sauce in northern Gaul still needs to be clarified. On the one hand, the local production might have been a reaction to a failing or insufficient supply of Mediterranean products. On the other hand, the production might also have started as a competitive enterprise against the southern products as the local alternative would have significantly decreased transport costs and, perhaps, production cost. In addition, changes at the consumer level (military installations, local inhabitants etc.) might also have resulted in a declined demand for the 'original' Mediterranean product (Van Neer et al., 2010; Van Neer and Ervynck, 2016).

It is generally assumed that local fish sauce production activities in northern Gaul occurred near the salt production sites, following the Mediterranean example (Van Neer and Ervynck, 2004; van Neer et al., 2005; Van Neer et al., 2010; Marzano, 2013). However, unlike in the Mediterranean, where the fish sauce was produced in large masonry vats, artificial heating was necessary to produce fish sauce in northern Gaul (Van Neer and Lentacker, 1994; van Neer et al., 2005). Heating infrastructure occurred on salt production sites in the *civitas Menapiorum*. Yet, at the moment, there are no solid archaeological indications of a multifunctional use combining salt and fish sauce production. However, as most of the salt production sites were excavated some time ago and detailed sieving of

[34] Dobney and Ervynck (2007) noted a meagre presence of fish bones on Iron Age sites in southern and central Britain and Belgium. Consequently, they suggested that the exploitation and consumption of fish in these areas might have been restricted for ideological reasons. In contrast, several Iron Age coastal sites in the Netherlands contained ample evidence for fishing and fish consumption as part of a subsidence strategy (Dobney and Ervynck, 2007). As Dobney and Erynck (2007) and Rainsford and Roberts (2013), indicated, this might, in part, represent a state of research as the recovery of fish remains required intensive sieving on archaeological sites.

archaeological context did not take place, a multifunctional use cannot be excluded. Indeed, a recently excavated salt production site in Essex contained a context with abundant remains of tiny bones and scales from small and juvenile fish, suggesting a local fish sauce production in the late Roman period (Biddulph et al., 2012; Nicholson, 2012). In addition, Alessandri et al. (2019) indicated that besides salt production, the briquetage vessels at the Tyrrhenian coast could also have been used to produce fish sauce. These studies prove that only thoroughly excavated new sites combined with archaeozoological and geochemical studies might shed much needed light on the multifaceted use of the Menapian salt production sites.

Figure 22 Nehalennia altars erected by *negotiatores L. Secundius Similis* and *T. Carinius Cratus* (left) and *C. Catullinius Secco* (right) (© Rijksmuseum voor Oudheidkunde, Leiden (the Netherlands)).

In the meantime, there is ample indirect evidence of fish sauce related activities in the Menapian coastal plain. Firstly, at Aardenburg, the large-scale consumption of (locally produced?) fish sauce has been attested by a dolium rim fragment bearing the scratch mark ALIIC XI S (De Clercq and van Dierendonck, 2006; De Clercq, 2009c; van Dierendonck and Vos, 2013). And secondly, three votive altars (no. A34, A39 and B44) at Colijnsplaat were erected by four *negotiatores allecarii* (trader in fish sauce) in the late second - early third century CE keeping their promise to the native goddess Nehalennia (Stuart and Bogaers, 2001). Altar A34 was heavily fragmented and only five matching fragments were recovered containing the following inscription:

Deae N[e]hale[ ] / [.] A[...]us G[r]atus / nego[tiat(or) all]ecar(ius) / pro se [et suis] v(otum) s(olvit) l(ibens) m(erito) (Stuart and Bogaers, 2001, 76).

Altar A39 was completely preserved and depicted Nehalennia sitting on a throne with a cornucopia in her left hand. On her right, a basket full of apples with detailed wickerwork and the front paws of a dog is shown (Figure 22). In the upper left register stands a servant holding a bowl and jug; in the right register, a fully robed woman carrying a bowl with poultry was displayed (Stuart and Bogaers, 2001, 78). The altar contained the following inscription:

De(ae) / Nehalenniae L(ucius) Secundius / Similis et T(itus) Carinius / Gratus negotiatores /allecari v(otum) s(olverunt) l(ibentes) m(erito) / [[- - -]] (Stuart and Bogaers, 2001, 78)

Contrary to altars A34 and A39, altar B44 was pilar shaped with no figurative decorations (Figure 22) (except a large pediment and a few rosettes) and contained an inscription:

In h(onorem) d(omus) d(ivinae) / deae / Nehalenniae / C(aius) Catullinius / Secco / negotiator / allecarius / cives Trever / pro se / et suis / v(otum) l(ibens) p(osuit) (Stuart and Bogaers, 2001, 130).

Remarkably, *L. Secundius Similis* and *T. Carinius Cratus* erected an altar together. According to Curtis (1984), they formed a small *societas* to trade salt-fish products in the area. Unfortunately, they did not refer to their hometown or their destination. In contrast, the merchant *C. Catullinius Secco* clearly stated that he was a citizen of Trier, and the name *Catullinius Secco* itself refers to a Celtic origin (Curtis, 1984; Stuart and Bogaers, 2001, 131). Although the inscriptions point towards an active trade in fish sauce at Colijnsplaat, they do not necessarily prove that fish sauce was locally produced in the *civitas Menapriorum*.

Archaeological evidence in the form of multiple large salting installations consisting of a 'battery' of a varying number of masonry tanks have been discovered on the coasts of Brittany[35] (Fr.) (Immerzeel, 1990; Driard, 2011, 2014; Driard et al., 2017). Recently, these sites have been the topic of intensive archaeological, chemical, archaeozoological and experimental research enabling a detailed reconstruction of the fish sauce production process (Driard, 2011, 2014). The archaeozoological analyses of residues recovered from the masonry salting vats of multiple sites (e.g. Étel-La Falaise, Kerlaz-Lanévry) indicated that primarily clupeiform species (e.g. sardines) were used with an anecdotal presence of herring, mackerel and whiting (Driard, 2011, 412-421; Driard et al., 2017). However, archaeozoological analyses of fish sauce residue discovered on consumption sites in the Belgian hinterland suggested that different taxa were used. As a result, the fish sauce on the Belgian consumption sites was not imported from Armorica (contra Immerzeel (1990)).

Hassall (1978) assumed that the *negotiatores* of Colijnsplaat imported fish sauce and salt from Britain to the Rhineland. While it is true that salt (Fawn et al., 1990; Lane and Morris, 2001) and fish sauce (Bateman and Locker, 1982; Jones, 1988) were locally produced in Britain, De Clercq (2009c, 473) considered a large scale import from *Britannia* unlikely. Instead, it is more logical to assume that at least part of the merchandise was locally produced in the vicinity of the temples and was shipped through Colijnsplaat in different directions. Therefore, although salting installations are yet to be discovered in the northern Menapian territory, local fish sauce production might have taken place near large estuaries, for instance, the Eastern Scheldt.

[35] For an overview of all fish sauce production sites on the coasts of Brittany, see: Driard (2011, 2014)

2.4.1.3 Peat extraction

During Roman times, peat was a valued resource of coastal wetlands and was exploited to provide fuel for domestic and industrial purposes[36] (Thoen, 1978a, 1987; De Clercq and van Dierendonck, 2006). Interestingly, Pliny the Elder (NH. XVI. 2) described that the *Chauci*, north of the river Rhine, used the 'earth as fuel' to warm their food and bodies. The 'earth' to which Pliny referred most likely pertains to peat, making it the oldest historical record on the use of peat. Contrary to the Roman period, the use of peat as an energy source has been well documented by historical and archaeological sources in medieval times. Especially from the mid-twelfth century onwards, large-scale, systematic peat extraction took place in the Belgian coastal plain and in Dutch Zeeland to supply larger cities with fuel (Verhulst, 1995; Jongepier et al., 2011). In addition to fuel, the salt-impregnated peat was intensively used to produce salt in the Dutch Delta region during the Middle Ages (see 3.6) (Leenders, 2004, 2007).

Based on these well-documented medieval parallels, the use of peat as a fuel source and as a salt production resource has also been assumed for the Roman period. However, this assumption cannot be taken at face value. Salt could be produced in various manners, and (prehistoric) wood, herbaceous vegetation and even coal might have been employed to fuel artisanal and domestic hearths. For example, in *Britannia*, scientific analyses indicated that peat had been used on several Romano-British salt production sites. Yet, these analyses also demonstrated that many other production sites preferred timber and brushwood over the locally available peat (Rippon, 2000, 102-104). This shows that besides local availability, the choice of fuel depended on several factors and that scientific analyses of char and ash are needed to confirm the fuel use on site. Even though no such studies have been performed yet, there is ample (in)direct evidence in the form of extraction pits that peat was cut and used locally as a fuel source in the Menapian territory.

Before describing the local Roman peat exploitation activities in detail, it is important to understand what peat is and how it formed. Several definitions of peat exist, of which most are highly similar to the definition of Reydin and Jeglum (2013, 4):

> Peat is the remains of plant and animal constituents accumulating under more or less water-saturated conditions owing to incomplete decomposition. It is the result of anoxic conditions, low decomposability of the plant material, and other complex causes. Peat is organic material that has formed in place, i.e. as sedentary material.

In short, peat consists of partially decomposed plant matter that accumulated in waterlogged conditions (Waller and Kirby, 2021). The world of peat is incredibly complex and peatlands have been classified in a number of ways (Charman, 2002; Rydin and Jeglum, 2013). Peat classification is mainly based on the type of vegetation influenced by the water chemistry and nutrient status. Peatlands (mainly peat bogs) that formed due to high groundwater levels are termed minerotrophic and tend to be more nutrient-rich, also called meso- or eutrophic. Rain-fed peatlands are termed ombrotrophic and are inevitably nutrient-poor (oligotrophic) (Rydin and Jeglum, 2013; Waller and Kirby, 2021).

Like any other ecosystem, peatlands are not static and subjected to change. These short-term directional changes, also called succession, in vegetation, habitat, substrates and soils are driven by eternal (allogenic) and internal (autogenic) factors. In the case of peatlands, successions typically progress towards ombrotrophic conditions with an increased acidity (final stage of peat

[36] The fuel used in the salt production process will be discussed in detail in APPENDIX 6

development). However, succession in peatland is not one-directional and allogenic factors (e.g. climate, flooding or grazing) might set the vegetation back to earlier stages of peat development. These successive vegetational communities are preserved as a sequence in the accumulated peat (Rydin and Jeglum, 2013, 127-130). Peat deposits can be roughly divided into a sequence of five major peat types (Rydin and Jeglum, 2013; Waller and Kirby, 2021):

(1) Reed peat dominated by *Phragmites australis,* which grew in species-poor swamps in seasonally or permanently submerged sedimentary environments

(2) Sedge peat formed in seasonally or periodically flooded areas and is a heterogenous group dominated by *Carex* species, but other types of rushes and grasses frequently occur as well.

(3) Woody peat developed from woodland and shrub communities in freshwater wetlands which are relatively dry compared to previous environments. Local conditions can severely affect the vegetation composition, but typically pioneering species, like black alder (*Alnus*), birch (*Betula*), and willow (*salix*), dominate.

(4) Ericaceae peat refers to a range of vegetation that occurs in an environment with a low pH but can still be influenced by groundwater and rainwater. Typically, the environment is rather nutrient-poor (mesotrophic-oligotrophic) in which primarily *Ericaceae* species developed.

(5) Sphagnum peat is the final stage of peat development, and sphagnum species dominated the ombrotrophic, nutrient-poor environment

In the coastal wetlands of the southern North Sea, peat beds are an integral part of the Holocene sedimentary history and started to form under specific conditions, with the water table being an important contributing factor. During the early and mid-Holocene (ca. 5500 cal. BP), the rising RSL and the onshore movement of sediment created suitable conditions for continued peat formation (Waller and Kirby, 2021). In the beginning, peat formation was short-lived, and peat beds with varying thicknesses were buried within marine deposits (Baeteman, 2013, 18; 2016, 21-22; 2018, 316-318). As the RSL rise decelerated, the freshwater marshes expanded into which peat accumulated (Baeteman, 2018; Waller and Kirby, 2021). In the late Holocene, a combination of natural and anthropogenic processes ended this long period of peat growth (section 2.2). Throughout the Belgian coastal plain, the end of the peat growth was not synchronous as local conditions might have enabled peat accumulation for a longer period of time. Additionally, erosion of the peat surface makes it difficult to date these changes accurately. However, it is generally assumed that by the late Iron Age (specifically around ca. 2250-2000 cal. BP) peat accumulation had ended in large parts of the Belgium coastal plain and Dutch Zeeland (Vos and Van Heeringen, 1997; Baeteman, 2018).

From the late Iron Age and early Roman period onwards, the coastal wetlands were permanently occupied, and several farmsteads on top of the dried-out peat have been discovered in Dutch Zeeland (sections 2.3.1 and 2.5). During that time, the peat outcropped and was not yet covered by marine sediments. Gradually, throughout the Roman period, tidal influence increased and the peat further compacted, after which marine sediments covered it. Nevertheless, compared to the Medieval period, the peat was well-accessible in Roman times and definitely exploited by coastal communities. Roman peat extraction pits have been found at multiple sites in the study area (Figure 23), for example, at Goes (NL) (Van Heeringen, 1994), Borsele (NL) (Sier, 2003, 33), Serooskerke Wattelsweg (Dijkstra and Zuidhoff, 2011), Kapelle Smokkelhoek (NL) (De Clercq and van Dierendonck, 2006) (NL) and Raversijde (BE) (Pieters, 2013; Baeteman and Pieters, 2015).

At Goes, several rectangular extraction pits of varying dimensions have been discovered. Remarkably, in one of the pits, the next peat bricks had already been prepared with spade cuts before they decided to abandon this spot and move to a new area (Figure 24). Radiocarbon dating on molluscs determined that the clay infill of the extraction pit was deposited in the third quarter of the third century or the fourth century CE (Van Heeringen, 1994). Multiple rectangular peat-cutting pits have also been attested at Raversijde (Pieters, 2013; Baeteman and Pieters, 2015). Although radiocarbon dating suggested a date in the late Iron Age, Pieters (2013) considered it a real possibility that the pits were made in the Roman period. Given their proximity to the second-century dike of Raversijde, which was partially constructed with peat bricks, a possible relation between the dike and the peat-cutting pits cannot be excluded (Pieters, 2013).

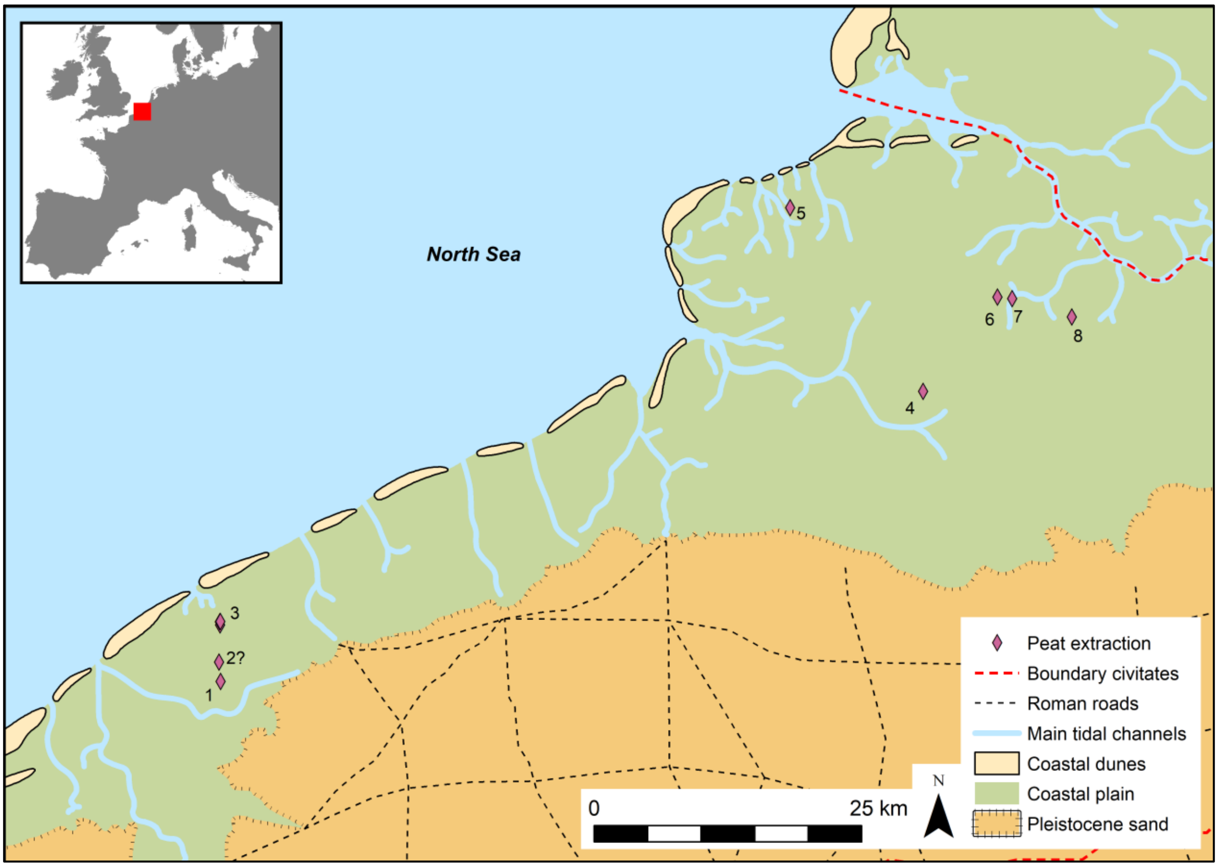


Figure 23 Locations of attested peat extraction pits in the northern Menapian coastal plain with 1) Middelkerke Ringweg 2) Survey Middelke-Slijpe? 3) Raversijde 4) Borsele 5) Serooskerke Wattelsweg 6) Goes De Poel 7) Goes A58 8) Kapelle Smokkelhoek

Furthermore, a geological survey in the area of Middelkerke-Slijpe divulged a large concentration of (possible) peat extraction pits of which multiple locations coincide with a high concentration of Roman sherds. The stratigraphy of the infilled pits and the undisturbed overlying tidal deposits indicate that the peat extraction occurred before the tidal environment was re-installed and marine sediments were deposited. In this area, the number of boreholes containing evidence of peat extraction is rather high, demonstrating that in Roman times peat was extracted on a larger scale than previously and generally assumed (Baeteman, 2007b). Recently, large-scale Roman peat extraction was discovered in northern France at Teteghem and Marck-en-Clasaisis (Lançon and Boulen, 2019), and on the other side of the Western Scheldt at Tholen (Van Benthem and Van Dinter, 2021). In addition, evidence for peat cutting occurred throughout Fenland where some larger Roman turbaries (e.g. March, Stonea and Upwell) have been discovered (Rippon, 2000, 102-103). Furthermore, prehistoric large-scale peat extraction, dated roughly between 600 BCE – 300 CE has been well documented at Assendelver Polder in North Holland (Therkorn et al., 2006).

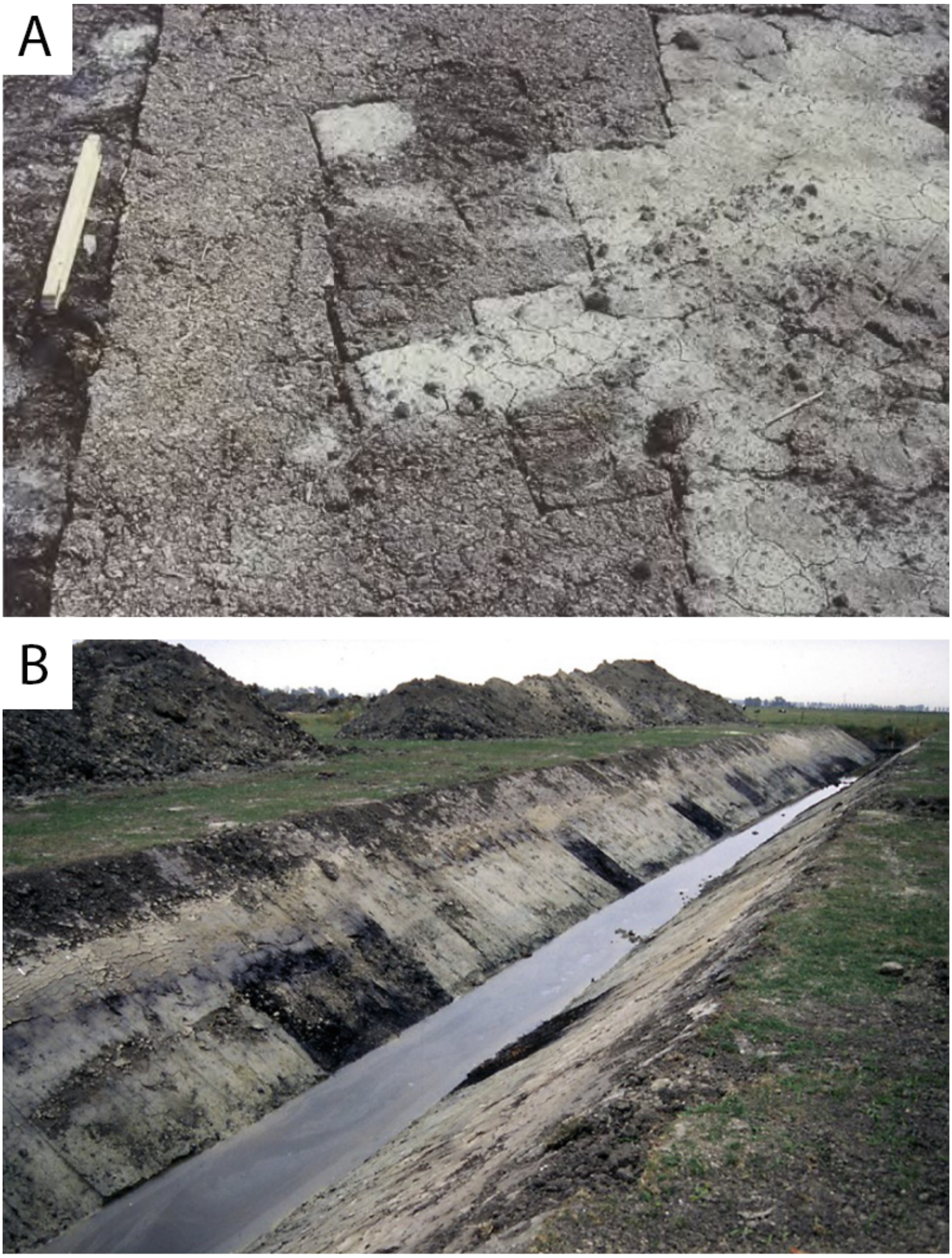


Figure 24 (A) Surface view of a Roman peat extraction pit at Goes illustrating that peat bricks were prepared with spade cuts before extraction (Vos, 2015, 90, fig. 93.91.92a). (B) An example of large-scale Roman peat extraction in the area of Middelkerke-Slijpe. Especially note the undisturbed marine sediments overlying the peat indicated that they were deposited after the peat extraction took place (Baeteman, 2018, 319, fig. 319.317)

2.5 Chronological evolution of the Roman occupation in the northern Menapian territory

Coastal wetlands are a tide-dominated, dynamic landform in which sediments are deposited in different sedimentary environments. The rate of relative sea level rise, sediment supply and accommodation space mainly drove this sedimentological process. Together with several positive-feedback loops (increased precipitation, deforestation in the hinterland, peat extraction etc.), these factors caused an end to a long period of uninterrupted peat growth between 2250-2000 cal. BP (Baeteman, 2018). At that time, roughly corresponding with the late Iron Age, the renewed tidal activity penetrated further inland using the existing mid-Holocene tidal network. This increased tidal activity stopped the peat growth and resulted in the compaction of the peat bog and subsidence of the land adjacent to the channels. This process continued in Roman times, and gradually the tidal network enlarged until most of the coastal plain was in an intertidal or subtidal position (Baeteman, 2013, 2018).

At the beginning of the 20th century, Ervynck et al. (1999) painted a poor picture of a scarcely inhabited, seasonally exploited coastal Roman landscape. De Clercq's (2009c) study on the characterisation and transformation of the Roman settlement landscape of the *civitas Menapiorum* disproved this idea of seasonal habitation. Instead, he introduced the concept of a permanent Roman occupation established on dried-out peat, Pleistocene sandy outcrops (*donken*) or artificially raised platforms (*terp*-sites). Over the years, multiple discoveries confirmed this concept of a permanently occupied coastal landscape in which coastal communities (gradually) adapted to an ever-changing landscape in search of higher (dry) places unaffected by tidal inundations.

As the tidal network steadily expanded, the native communities gradually transitioned from flat settlements on dried-out peat to artificially raised platforms (*terp*-sites). This hypothesis was already proposed by De Clercq (2009c), but at the time, the limited number of well-excavated and well-dated sites restricted interpretations. Over the years, new research has extended the dataset enabling a chronological evolution (Figure 25-Figure 26-Figure 27) of the Roman occupation in the northern Menapian coastal plain. Nevertheless, it should be noted that the chronological resolution of 98 of the 187 (potentially) *in situ* finds was insufficient to fit them within the proposed timeframes. However, as these finds were categorised either as stray finds or as peat extraction pits, their impact on the chronological overview is limited. Even though these finds indicate Roman activity, the precise nature and significance of the activity can never be ascertained with certainty.

In the early Roman period, occupation of the coastal plain was limited, and settlements developed on top of the drained peat (Figure 25). At the moment, only four of these early Roman farmsteads have been discovered at Walcheren. Three-aisled farmsteads were observed at three of these sites (Arnemuiden, Serooskerke Gapingse Watergang and Colijnsplaat Noordhoeksenol). As indicated by De Clercq (2009c, 2011), three-aisled farmsteads were absent in the Pleistocene hinterland in Roman times, but are well known from the coastal areas of the northern Netherlands. In addition, the pottery at Colijnsplaat Noordhoeksenol had distinct characteristics of which parallels can be found in the northern Netherlands. Both the building traditions as well as the material culture suggested a strong cultural connection with the more northerly situated coastal communities (De Clercq, 2009c, 2011).

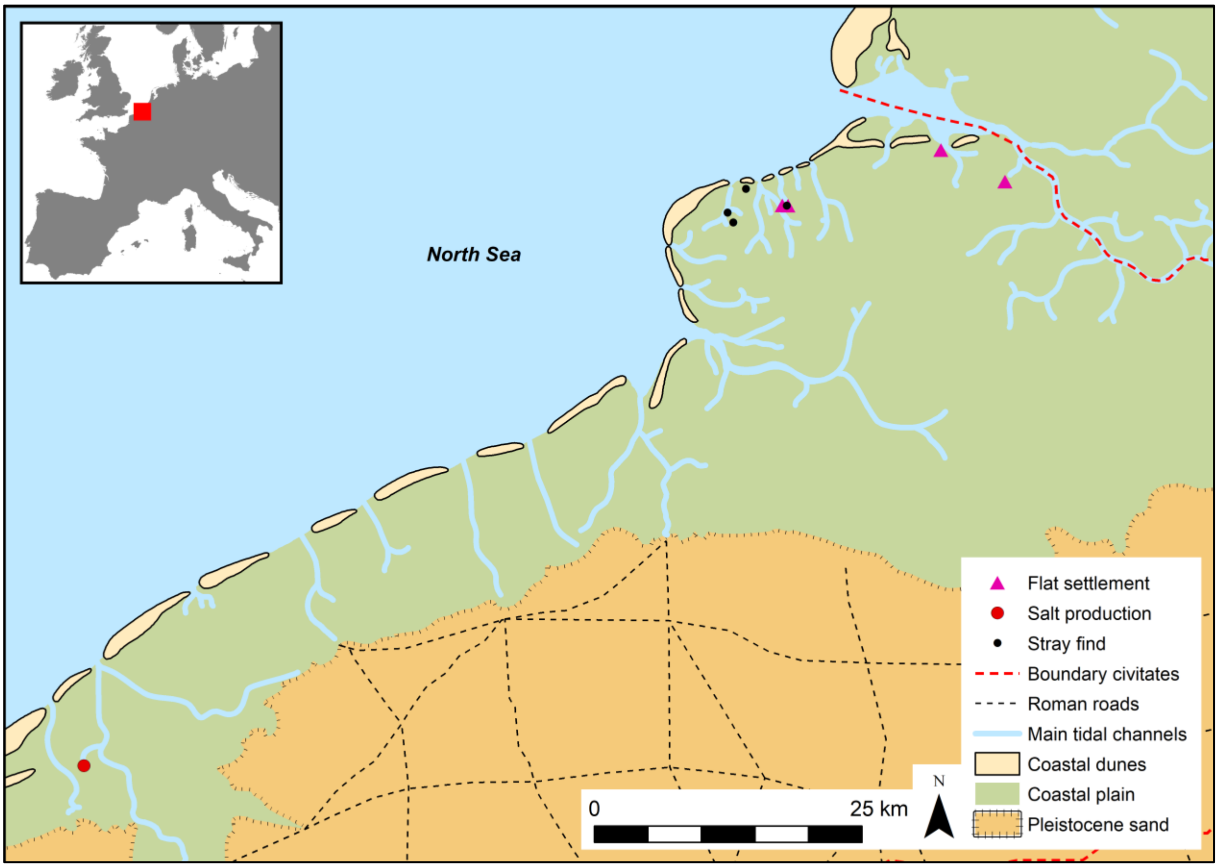


Figure 25 Roman occupation of the northern Menapian coastal plain firmly dated in the early Roman period.

From the Flavian period onwards (Figure 26), the Roman occupation steadily increased and large find ensembles discovered at Wenduine and Bredene suggested the presence of larger *vici*-type? settlements (Thoen, 1978a, 1987). In addition, a first civil settlement developed on the border of the coastal plain at Oudenburg (Vanhoutte, *in press*). Furthermore, a first military presence has been suspected at Oostkapelle based on the presence of first-century Samian ware and building material bearing the stamp of the *classis Germanica* (C.G.P.F) (Dhaeze, 2011). The rural occupation in the late first-early second century was well documented at Ellewoutsdijk. At Ellewoutsdijk, a multi-phased settlement was discovered consisting of several farmsteads. These farms were either a two-aisled Alphen-Ekeren construction or a partially thee-aisled construction in which an A-frame construction supported the roof. Similar to the early Roman three-aisled farmsteads, parallels of the latter building tradition can primarily be found in coastal areas further north (Sier, 2003; De Clercq, 2009c, 2011). Around 150 CE, the occupation at Ellewoutsdijk was abandoned and quickly covered by marine sediments indicating an increased tidal influence in the vicinity of the site and a landscape transition towards an intertidal or subtidal position.

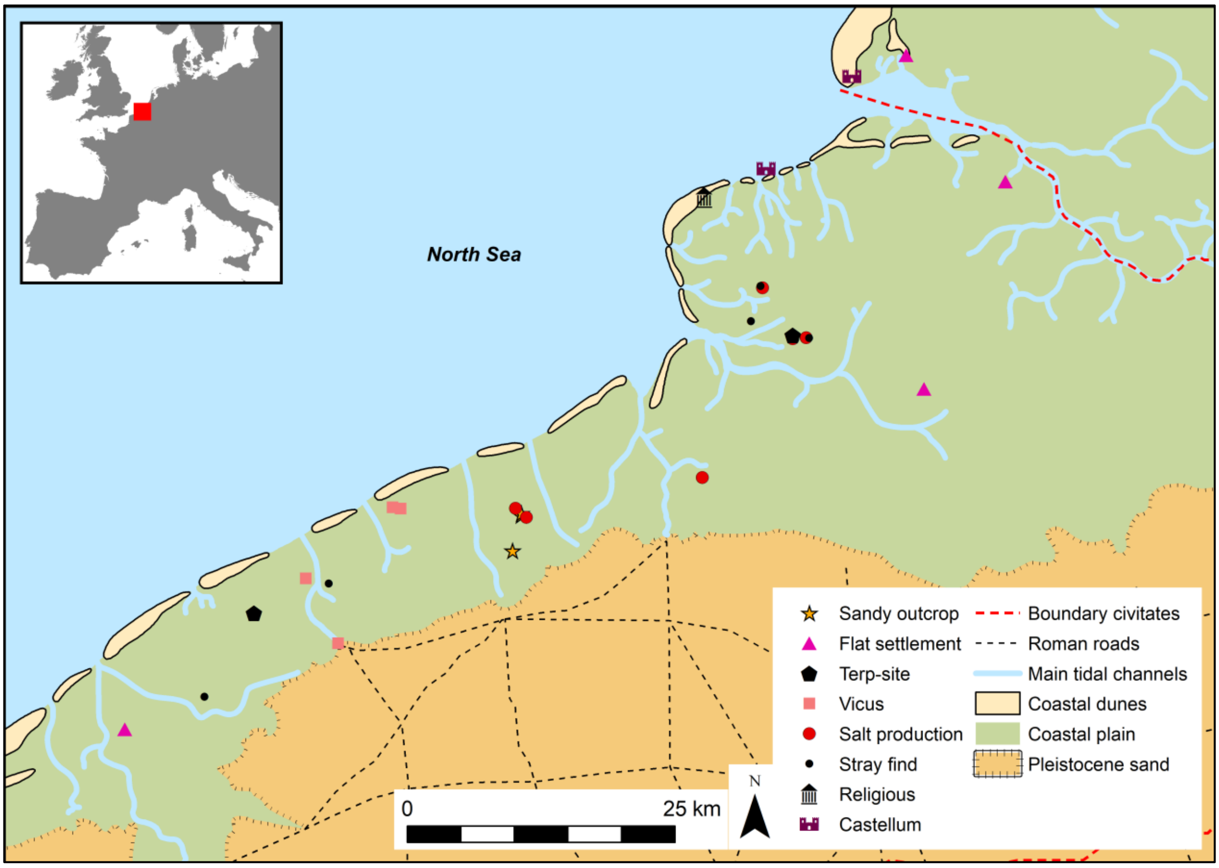


Figure 26 Roman occupation of the northern Menapian coastal plain firmly dated between 69-150 CE

Next to these settlements on dried-out peat, habitation occurred on Pleistocene sandy outcrops and artificially raised platforms (*terps*). At this time, the first terp-like structure in the northern Menapian territory was constructed at Stene between 69-150 CE. Equivalent to the contemporaneous three-aisled farmsteads, artificially dwelling mounds are well-known from salt marsh regions of the northern Netherlands and north-western Germany (van Londen, 2006; Nieuwhof et al., 2019). Pliny even described similar constructions in the first century CE to characterise the habitation structures of the *Chauci* (section 2.2.1). These terps provided a slightly elevated, drier position in a regularly inundated landscape and might have been constructed in the Menapian *civitas* as a reaction against an increased tidal influence. Baeteman (2013, 2018) indicated that the transition from mudflat to salt marsh to salt meadow was not a synchronous one-directional process. Lateral migration of channels and creeks constantly changed the outlook of the coastal plain and gradually extended the subtidal and intertidal area. However, local and regional landscape variation definitely occurred, enabling both flat settlements as well as *terp*-structures depending on the local conditions. Compared to the early Roman period, the native coastal communities might have adapted to changing circumstances and, just as coastal areas further north, started to build terp-sites to cope with regular tidal inundations. Similar to the terp-sites, the sandy Pleistocene outcrops in the Bruges areas provided natural elevations well suited for habitation.

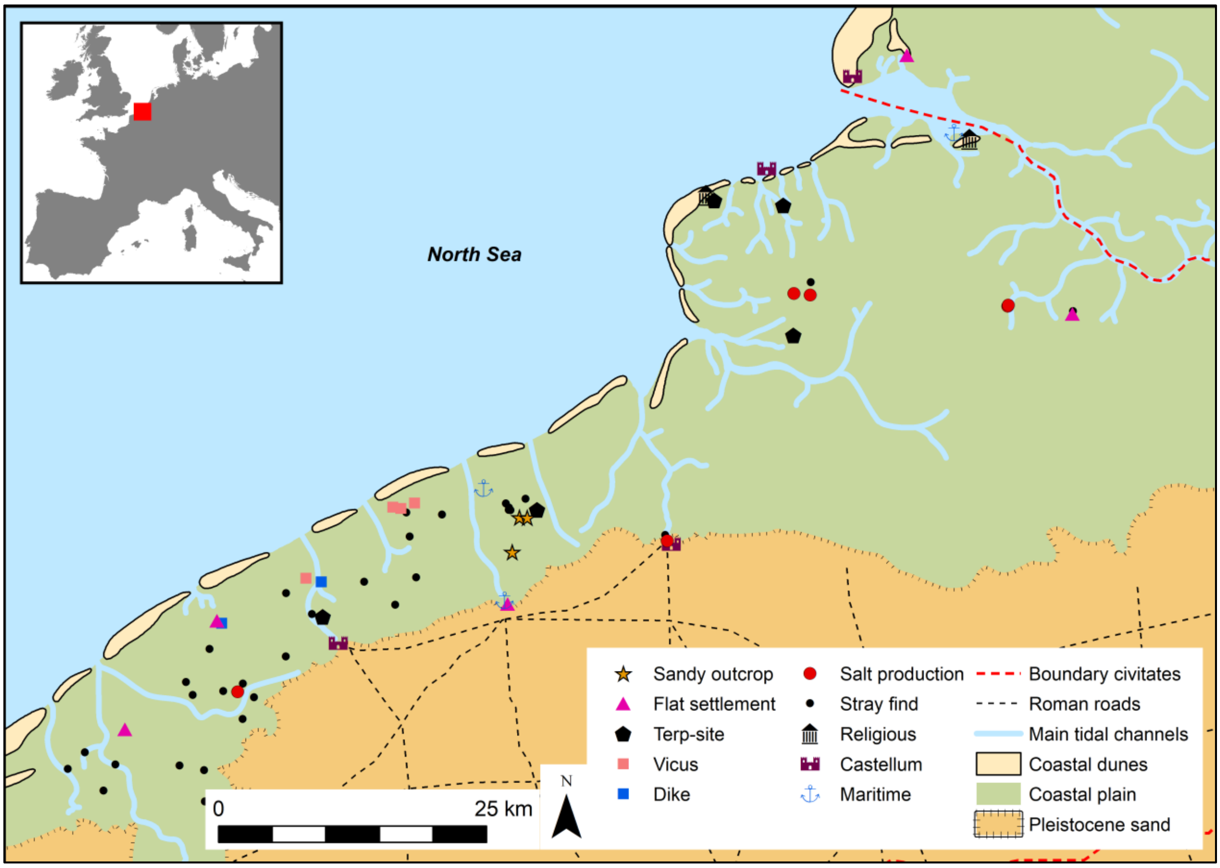


Figure 27 Roman occupation of the northern Menapian coastal plain firmly dated between 150-276 CE

In the late second - first half of the third century CE (ca. 175-250), the number of sites increased exponentially (65 of 195 potentially *in situ* finds) (Figure 27). This increase was already observed in the 1970s by Thoen (1978a, 1987), who characterised the increase as the coastal plain apogee after a short period of unrest caused by *Chauci*-raids. These *Chauci* attacked and looted the coasts of *Gallia Belgica* between 171/172 and 174 CE under governor *Marcus Didius Iulianus.*[37] As described in the historical sources, he fought against the raiders with hastily recruited local troops:

> '(...) and following that he ruled Belgium[38] long and well. Here, with auxiliaries hastily levied from the provinces, he held out against the Chauci (a people of Germany who dwelt on the river Elbe) as they attempted to burst through the border; and for these services, on the recommendation of the emperor, he was deemed worthy of the consulship (...)'
>
> (Hist. Aug. Didius Julianus I.7-9, transl. by Magie 1921)

According to Thoen (1978a, 1987, 1991), Dhaeze (2011), Vanhoutte (*in press*) and van Dierendonck and Vos (2013), the *Chauci* raids demonstrated the need for a coastal defensive system. These scholars regarded Commodus' military building program, including the construction of the Oudenburg and Aardenburg fort, as a Roman military response in the aftermath of these sea-borne invasions. However, as indicated by De Clercq (2009c, 488-495), the impact of these raids should be nuanced. They are a symptom/consequence of a more significant socio-political and economic crisis in late second-century Gaul rather than the main driver of change. De Clercq (2009c, 488-495) provides a

[37] For an overview of all source material and (supposedly) archaeological evidence for the *Chauci* raids, see Thoen (1991)
[38] *Gallia Belgica*

detailed overview of the late second-century political-economic turmoil, including the Antonine plague, the *Marcomanni*-wars, the succession war between *Clodius Albinus* and *Septimus Severus*, the revolt of *Maternus* (*Bellum Desertorum*), the *bagaudae*, and so on. Although the impact of each separate event can be discussed, the accumulation of (possible) events occurring directly in northern Gaul or the wider Empire indicates some form of political-economic turmoil that affected the Gallo-Roman communities. The historically attested late second-century turmoil was also, in part, reflected in the archaeological record. In the Pleistocene hinterland of the Menapian *civitas,*[39] the majority of farms were already abandoned before 200 CE, and the number of (coin) hoards increased. The surviving farms were downsized, restructured and/or defended, and sporadically new sites were created nearby. It is striking that the number of findspots, and consequently the population, increased in the coastal plain when the hinterland population clearly dwindled.

Determining why the number of findspots in the coastal plain increased is complex and is most likely the result of multiple factors. De Clercq (2011, 240) rightly stated that the increase, in part, should be seen as a '*peak in the occurrence of a few well datable find categories such as Samian ware*.' However, as confirmed by recent discoveries, the boost in activity definitely represents a historical reality. Thoen (1978a, 1987) advocated that the military presence at Oudenburg and Aardenburg provided security and protection, which directly stimulated the surge in activity. While the need for security and protection is evident in such a period, the military presence might also have met more strategic goals, such as controlling economic activities in the coastal wetlands (De Clercq, 2009c, 2011). That being said, it is unclear whether the camps were built to protect the already present economic activity or if they were constructed first and thus provided a safe haven enabling habitation and (in)directly stimulating economic activity.

The increased economic activity is not only manifested by the number of salt production sites but is also displayed by the harbour sites and the central places. At *Ganuenta* (near Colijnsplaat), Bruges and perhaps Zeebrugge, goods directly produced in the coastal plain were traded and shipped to *Britannia* and the Rhineland. In addition, the larger *vici*-type settlement at Wenduine and Bredene remained active, as well as the religious temple of Domburg. The names of consuls found on the Nehalennia altars of Colijnsplaat indicate that the temple was primarily used at the end of the second - early third century CE (Stuart and Bogaers, 2001).

Compared to the late first - early second century CE, the rural occupation in the northern Menapian coastal plain was now characterised by *terp*-sites. As indicated above, these *terp*sites provided a slightly elevated, drier position in a regularly inundated landscape. At the moment, the knowledge regarding the habitation structures on these *terps* is limited. Only Ramskapelle Heistlaan provided evidence of permanent habitations structures in the form of sod houses (Verwerft et al., 2019a; Verwerft et al., 2019b).[40] Next to *terp*-sites, Pleistocene sandy outcrops in the Bruges area were still an attractive, drier location well-suited for habitation. At Dudzele Zonnebloemweg, the construction of the farmstead resembled the building traditions of the adjacent Pleistocene hinterland. As indicated by Verwerft et al. (2022), sod houses could just as easily have been used in an earlier phase. Unfortunately, at this time, it remains an open question whether house-building traditions from the sandy hinterland were commonly used and adapted to the conditions on these outcrops sites or if the houses resembled the sod house constructions found on the terp-sites.

[39] Similar observations were made for different parts of *Gallia Belgica* and *Germania Inferior*. For examples and references, see De Clercq (2009c, 490)

[40] A sod house construction has also been suspected at Serooskerke Wattelsweg.

However, it should be noted that some flat settlements were still present, but these sites are badly documented. In fact, only the site of Kapelle Handelsweg was well excavated and contained the remains of a (partial) building and late second - early third-century pottery (Bouma and Dijkstra, 2021). This site attests that local conditions still permitted the construction of flat settlements on top of dried-out peat in the late second - early third century CE. Nevertheless, the increase in terp-sites and the occurrence of large dykes clearly suggested a continued increase in tidal activity.

Both the large (isolated?) dikes discovered at Raversijde, Bredene-Landweg, and the dike linked to the *terp* of Serooskerke Wattelsweg clearly demonstrated that the coastal communities actively tried to intervene and shape the coastal landscape. It is unclear whether these were attempts to reclaim land or to minimise the tidal influence in specific areas, for instance, close to habitation sites or near fields and meadows. The construction of the large dikes (Raversijde at least 107 m long, Bredene-Landweg at least 60 m long, Serooskerke Wattelsweg at least 82 m long) required a considerable investment of both manpower and time. In addition, their construction affected not only the immediate vicinity of a site but also a larger area suggesting that they were coordinated and organised by a regional or local authority (De Clercq, 2011; Pieters et al., 2013). In addition, the construction of terp-sites also required a large investment. Similar to the dikes, the construction might be communal or organised by an authority figure. In the case of Ramskapelle Heistlaan, this idea is supported by the fact that the site might have a higher status due to the relative wealth in material culture (Verwerft et al., 2019a). A military connection (perhaps in the form of a veteran?) can be suspected based on the presence of specific horse gear fragments and the iconography on these fragments. As the military presence increased from the late second century onwards, it is tempting to link the organisation and execution of these large infrastructural works to the Roman military. However, at the moment, this is an open hypothesis as hard evidence for the social organisation in the coastal plain is lacking. The dikes might just as well be an initiative by the local elite. Moreover, it does not necessarily have to be one or the other as they might have been the result of a combined effort.

Chapter 3 Aspects of salt production in Western Europe: an introduction

3.1 Introduction

3.1.1 Biological need for salt

From a biological point of view, a daily salt intake is required for human and animal health as sodium enables the transition of nerve impulses, supports muscle function and maintains fluid levels in the body. Consequently, a deficit or an excess of salt can cause various health problems. Too much sodium has several short-term and long-term effects, including high blood pressure. In turn, high blood pressure increases the risk of heart disease and strokes. It is generally assumed that in sedentary societies, the increased consumption of cereals and boiled food led to a decreased intake of sodium chloride, which had to be compensated by adding salt. There is little agreement on how much salt the human body requires (Kurlansky, 2002). The World Health Organisation (WHO) recommends a salt intake of less than 5 g per day to reduce health risks, but some say that only 1 g is necessary (Kinory, 2012, 10; Harding, 2013, 14). For mammals, the required intake is significantly higher, and the craving of animals for salt has been abundantly demonstrated by Denton (1984).

3.1.2 What is salt, and where does it occur?

When people use the term salt, 99% of the time they refer to regular table salt (sodium chloride) used on a daily basis to season food. However, chemically speaking, salt is an ionic compound consisting of a positively charged cation and a negatively charged anion. This means that a large variety of chemical compounds can be called salts (Lide, 2003).

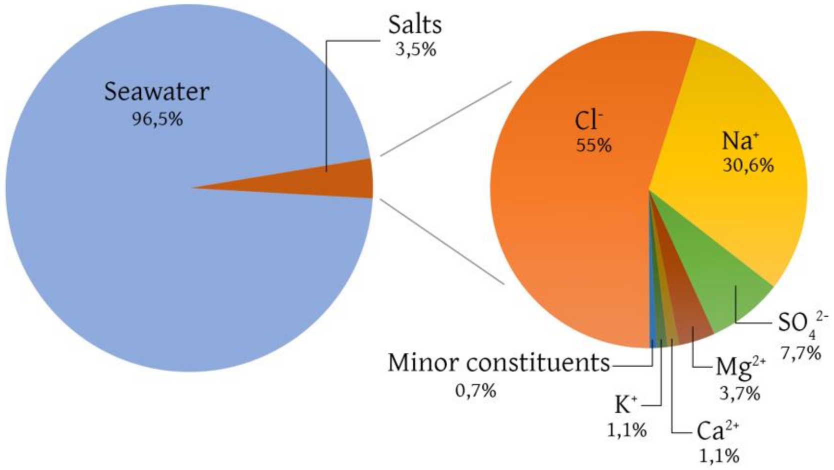
On Earth, salts can naturally be found dissolved in seawater and/or crystallised in sedimentary deposits. The amount of salts dissolved in water can be measured using the salinity parameter[1], and the following categories are distinguished (Babel and Schreiber, 2014, 487; Hussein et al., 2017):

Freshwater (< 0.5‰) -> brackish (0.5 – 30‰) -> saline (30-50‰) -> brine (> 50‰)

[1] The absolute salinity (S) is the mass of dissolved salts per mass of that solution (S = mass (dissolved salts)/mass (saline solution)) and is typically given in g per kg (‰) or ppt (parts per thousand) (Babel and Schreiber, 2014, 487).

As the scheme above clearly demonstrates, brine technically denotes a solution with a high concentration of dissolved salts. Upon evaporation, the salt concentration of seawater will increase forming a brine. However, brines also occur naturally in brine springs and the salinity and composition of these springs might vary considerably depending on the rainfall, the depth of the salt deposition, etc. (Harding, 2013, 24).

Seawater is a prime example of a saline solution and the salinity typically lies between 31-35‰. Consequently, one litre of seawater consists of approximately 96.5% (965 g) of water and 3.5% (35 g) of dissolved salts (Figure 28). These salts are composed of chloride, sodium, sulfate, magnesium, calcium, potassium and minor constituents like bromide, strontium, boron, and fluor. The concentration of these specific salts in seawater varies depending on the local environmental conditions[2] (Hussein et al., 2017). For an overview of the composition of seawater, see Figure 28.



Chloride (Cl^-)	18,25g
Sodium (Na^+)	10,48g
Sulfate (SO_4^{2-})	2,6g
Magnesium (Mg^{2+})	1,26g
Calcium (Ca^{2+})	0,41g
Potassium (K^+)	0,38g
Minor constituents (HCO_3^-, Br^-, Sr^{2a})	0,25g

Figure 28 General composition of seawater (adapted from Hussein et al. (2017))

The most effective way to separate the dissolved salts from the solution is through evaporation which either occurs naturally through insolation or by artificially heating the water. According to Babel and Schreiber (2014, 486), evaporation acts in two ways. Firstly, evaporation gradually brings the undersaturated solution into a (super)saturated state (transition from seawater to brine). Secondly, it promotes the precipitation of salts from the (super)saturated solution or brine. These salts do not precipitate haphazardly but follow successive crystallisation paths or a crystallisation sequence based on their solubility[3] (Babel and Schreiber, 2014). In plain terms, the solubility of salt minerals differs which means that, at certain intervals, the brine will be saturated with specific salt minerals which will then precipitate (Table 5). This sequence of salt mineral crystallisation is relatively well-known from observations in modern-day solar saltworks, experimental research and theoretical models[4] (McCaffrey et al., 1987; Babel and Schreiber, 2014). The crystallisation sequence is summarised in Table 5 and Figure 29.

[2] Slightly different composition of seawater from several studies is presented in Babel and Schreiber (2014)

[3] Lide (2003, section 2, 56) defined solubility as ‘a quantity expressing the maximum concentration of some material (the solute) that can exist in another liquid (solvent) at specified temperature and pressure.

[4] Babel and Schreiber (2014) provide an excellent overview of evaporite geochemistry and how they crystallise from seawater. The overview presented here is mainly based on their work. For additional information, we refer to their work and references therein.

Table 5 Crystallization sequence of the major salt minerals formed upon the complete natural solar evaporation of seawater with their solubility in water and their precipitation range (after data presented by Babel and Schreiber (2014))

Mineral	Chemical formula	Solubility (g/l)	Temperature (°C)	Precipitation range (‰)	Evaporation stage
Calcite	$CaCO_3$	0.012	25	~35‰ - ~140/200‰	1
Aragonite	$CaCO_3$	0.014	25	~35‰ - ~140/200‰	1
Dolomite	$CaMg(CO_3)_2$	0.05	25	~35‰ - ~140/200‰	1
Gypsum	$CaSO_4 \cdot 2H_2O$	2.4	25	~140/200‰ - ~290/320‰	2
Halite	NaCl	360	25	~290/320‰ - ~375‰	3
Epsomite	$MgSO_4 \cdot 7H_2O$	385	25	> 375‰	4
Kainite	$4KCl \cdot 4MgSO_4 \cdot 11H_2O$			> 375‰	5
Sylvite	KCl	355	25	> 375‰	5
Carnallite	$KCl \cdot MgCl_2 \cdot 6H_2O$			> 375‰	5
Bischofite	$MgCl_2 \cdot 6H_2O$	2635	20	> 375‰	5

At the start of evaporation, carbonate minerals will crystallise quickly due to their low solubility, and different polymorphs of calcium carbonate (calcite or aragonite) or dolomite will form. The precipitation begins in seawater with a slightly elevated salinity (> 35 ‰) and continues until the salinity in the brines reaches ~140-200 ‰ (Table 5; Figure 29). Due to the low concentration of Ca^{2+} and HCO_3^- ions, the amount of crystallised $CaCO_3$ is negligible (less than 1% of all salts) compared to the ensuing salts. That being said, a large amount of carbonates can accumulate upon a continued supply of seawater or brine (Babel and Schreiber, 2014, 499-501). After the carbonates, gypsum ($CaSO_4 \cdot 2H_2O$) (ca. 3.5% of all salts) starts to precipitate at ~ 150 ‰ and continues up to the beginning of halite (NaCl) crystallisation at a salinity of ~290-320 ‰ (Table 5; Figure 29). As these crystallisation fields slightly overlap, some form of gypsum and halite mixing will inevitably occur (Babel and Schreiber, 2014, 501). Halite crystallisation takes place at salinity levels between ~290-320 ‰ and ~375 ‰. At the start of halite precipitation, approximately 90% of the seawater has evaporated. Contrary to other minerals, halite (ca. 77% of all crystallised salts) begins to precipitate relatively quickly. In addition, it only requires a low degree of supersaturation meaning that, compared to other minerals, the period of halite crystallisation is quite long (Table 5; Figure 29) (Babel and Schreiber, 2014, 501-502).

The residual, most concentrated brine (> ~375 ‰) is often referred to as bittern. Synonyms for bittern are ‘mother liquor’ or exhausted brine (Babel and Schreiber, 2014; Hussein et al., 2017). However, determining the exact crystallisation sequence of the K-Mg salts from the bittern is tricky as, in nature, the succession strongly depends on multiple environmental factors (e.g. temperature, humidity, evaporation rate, precipitation rate). From observations in modern-day saltwork pans, it appears that after (and partly concurrent with) halite invariably epsomite ($MgSO_4 \cdot 7H_2O$) (ca. 4.7% of the crystallised salts) precipitates. During further evaporation, the remaining K-Mg salt minerals (ca. 13.5 % of the salts) - kainite ($4KCl \cdot 4MgSO_4 \cdot 11H_2O$), sylvite (KCl), carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$) and bischofite ($MgCl_2 \cdot 6H_2O$) - will consecutively and partly simultaneously crystallise (Table 5; Figure 29) (Babel and Schreiber, 2014, 503-504).

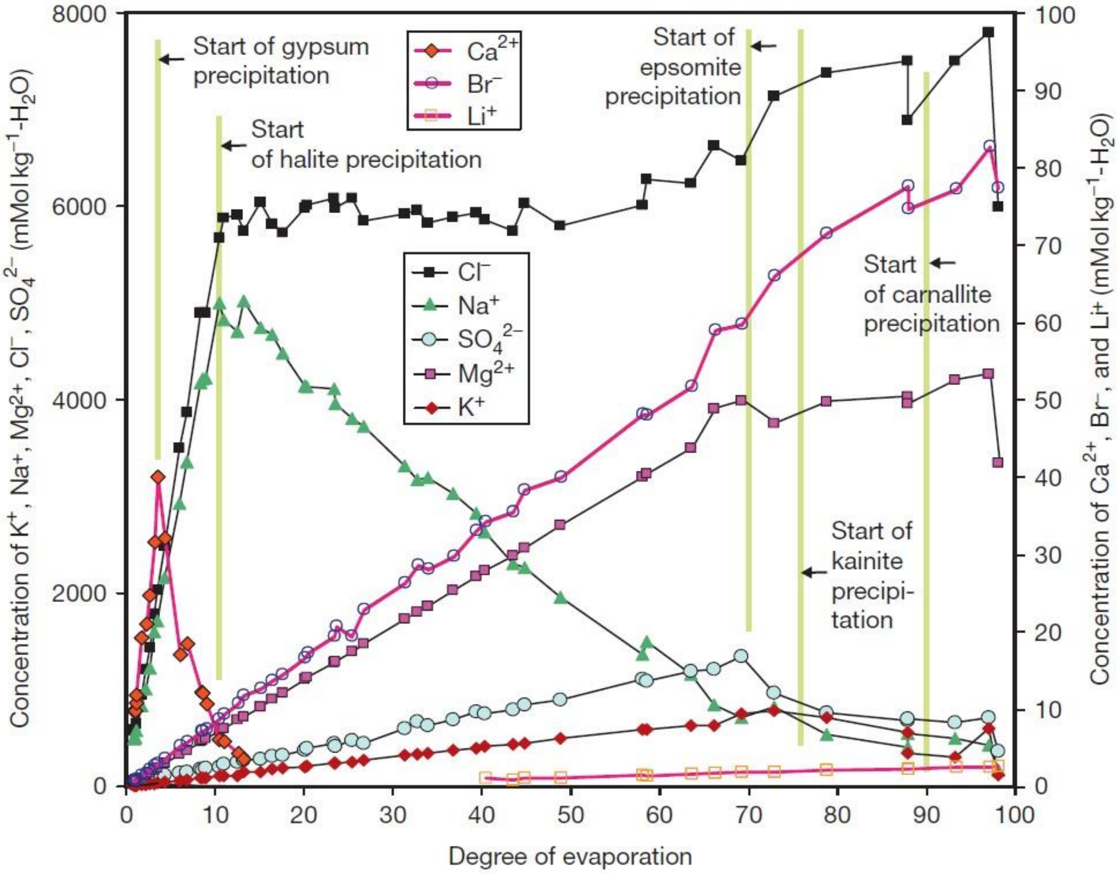


Figure 29 Crystallisation sequence of major salt minerals in evaporating Caribbean seawater. In addition, the graph shows how the concentration of the major and minor ions increase upon the evaporation of water after which the ion concentration decreases upon precipitation. The degree of evaporation is calculated after Li^+ and Ca^{2+} concentration and thus not simply depict the amount of evaporated seawater (for the method of calculating the degree of evaporation see McCaffrey et al. (1987)) (Figure from Babel and Schreiber, 2014, 502, figure 508)

The presented crystallisation sequence mainly applies to the natural evaporation of seawater through insolation. Although the order in which the salt minerals precipitate will remain unchanged in the artificial evaporation processes, some minor details must be considered. Firstly, the solubility of chemical compounds increases with temperature (Lide, 2003). This means that generally speaking, it will take longer to bring an undersaturated solution into a (super)saturated state enabling the precipitation of salt minerals. And secondly, different ways to create artificial brines (see section 3.4.2.3) might impact the brine's ionic composition, which in turn might affect the mineralogy of the crystallised salts.

From this crystallisation sequence, it is clear that, next to the desired halite/sodium chloride, unwanted salt minerals with a different solubility crystallised when evaporating seawater or brine. It is generally assumed that in (pre-)Roman times, similar to modern-day marine salt production, these impurities that impair taste (particularly the bitter tasting K-Mg salts) were removed from the finalised product (Fawn et al., 1990; Kinory, 2012; Hathaway, 2013; Harding, 2021). Different 'purification' techniques could have been used to remove the undesired salts to obtain 'pure' sodium chloride. However, as discussed later, these refinement strategies remain mostly hypothetical since no crystallised salt preserved in the archaeological record and historical sources, excluding early modern sources such as Agricola (1556) or Brownrigg (1748), remain quite vague on the topic.

Next to seawater, salts occur crystallised in sedimentary deposits. In geology, saline or salt deposits are often described as evaporites. Twenhofel (1950, 486) defines the evaporites as a ‘group of sedimentary deposits whose origin is largely due to evaporation.’ These sedimentary or salt deposits thus formed when ancient seas evaporated and the crystallised salt accumulated. These deposits were then subjected to tectonic processes over a geological timescale. When buried, the density of the overlying sediments will eventually surpass the density of the salt strata, deforming the salt deposits (compression, folding etc.). Sometimes these salt deposits are then pushed to the Earth’s surface, forming so-called salt diapirs or salt domes. In mountainous areas, various tectonic processes uplifted these salt diapirs making the rock salt more easily accessible at or near the Earth’s surface for quarrying or mining purposes (Harding, 2013, 22; Babel and Schreiber, 2014; Harding, 2021, 3). In rare cases, these salt domes might outcrop and form salt mounts and ‘salt glaciers’ (Talbot et al., 2009; Babel and Schreiber, 2014). Moreover, percolating rainwater and groundwater might (partially) dissolve underground diapirs creating a brine. When this brine is forced upwards, it emerges as a saltwater spring (Harding, 2013, 22; 2021, 3).

Many evaporite deposits were formed in different geological eras throughout the Earth's history. Rough estimates indicate that evaporite deposits occur underneath ca. 25% of the continental area (Babel and Schreiber, 2014, 546). In Europe, several salt deposits from different geological eras are known (Figure 30). For instance, the Zechstein formation stretches from eastern England to northern Poland, and Triassic salt deposits are known in Spain and France. In Britain, both Zechstein and Triassic deposits are present, but the Triassic deposits within the Cheshire Basin are more important (Harding, 2013). Throughout history, these salt deposits have been intensely exploited, and today Germany is still the largest producer of salt in Europe.

In conclusion, salt occurs naturally in seawater and underground salt deposits. These inland deposits were accessible directly through mining or indirectly in the form of saltwater springs. The method used to exploit the salt largely depended on the nature of the deposit. Salt was obtained either through mining and quarrying techniques (solid rock salt) or through the evaporation of saline liquids (seawater or brine springs). No underground salt deposits occur in the study area, stretching from northern France to Dutch Zeeland. In consequence, mining and the exploitation of brine springs are out of the question. In this area, seawater is the only available salt source. Therefore, this study primarily focuses on the marine exploitation of salt. For the sake of completeness, other exploitation techniques like salt mining and the so-called through technique will be briefly outlined but not covered in detail.

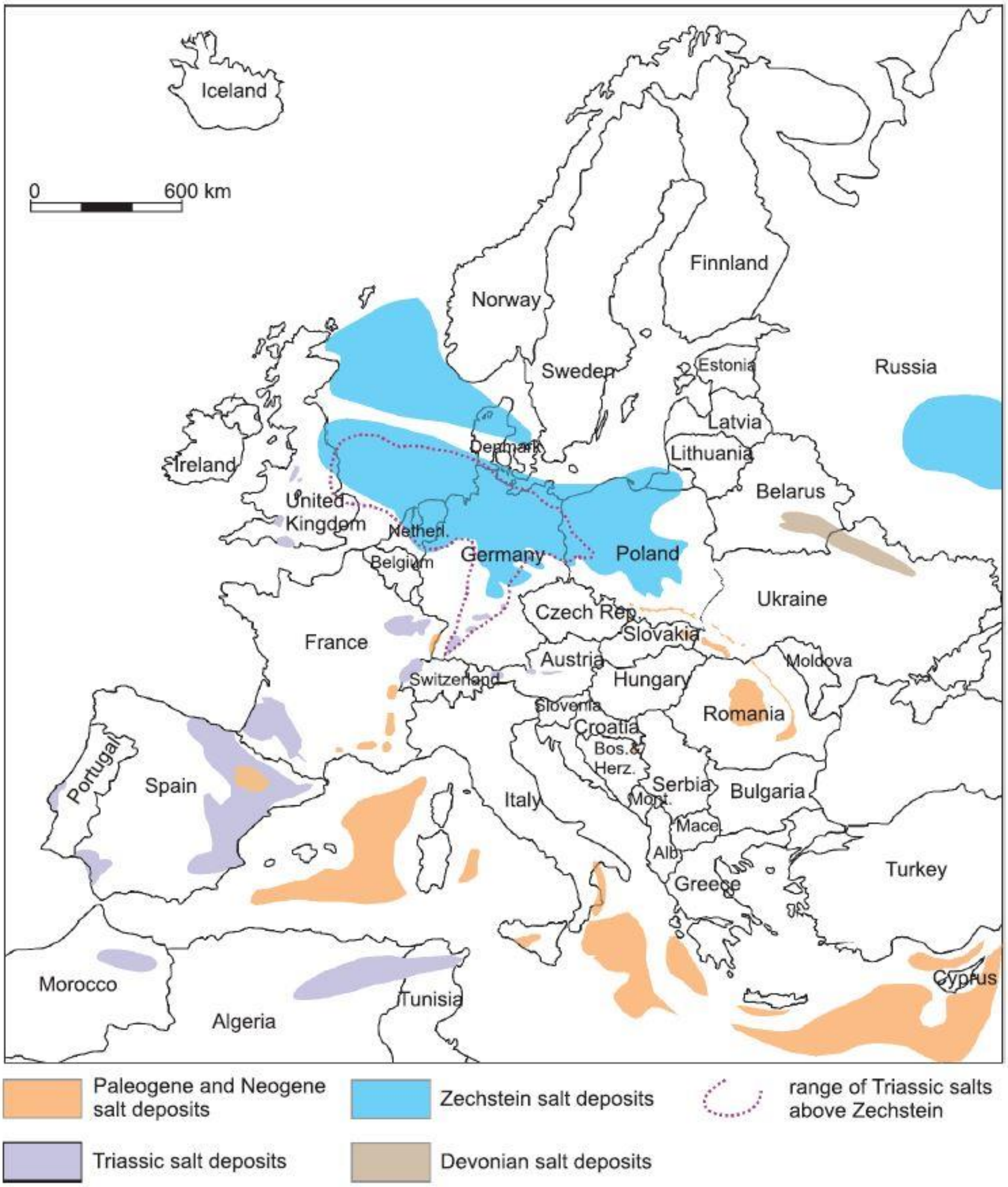


Figure 30 Map of Europe depicting the major salt deposits present in the subsoil and their geological age (Harding, 2014, fig. 1).

3.2 Proto- and early historical salt mining and quarrying

The extraction of rock salt is known above all from the mining sites of Hallstatt and Dürrnberg, situated in the Austrian Alps. At Hallstatt, the mining areas are divided into groups of shafts with the northern group dendrochronologically dated to the Middle and Late Bronze Age and the eastern and western areas belonging to the early Iron Age (Grabner et al., 2007; Kern et al., 2009; Harding, 2013; Reschreiter and Kowarik, 2019; Harding, 2021). Why mining at Hallstatt ceased around the middle of the thirteenth century BC is still unclear. Researchers suggest that a combination of environmental factors, such as increased rainfall, sediment deposition and landslips, caused the shafts to collapse.

After approximately 300 years, mining activities at Hallstatt resumed in the Iron Age around ca. 900 BCE. These activities continued until rock falls and sediment filled the galleries and shafts in the middle of the fourth century BCE. After that, in the La Tène period (second century BCE), mining moved further uphill in the Dammweise, but unfortunately, little is known about this phase due to historic and modern-day salt mining (Stöllner, 2007; Kern et al., 2009; Reschreiter and Kowarik, 2019; Grabner et al., 2021). At Dürrnberg near Hallein, the rock salt deposits were exploited from the sixth/fifth century BCE onwards and ended around the middle of the first century BCE. Some radiocarbon dates indicate minor activities in the early Roman period, but at the moment, this phase cannot be linked to specific features (Stöllner, 1999, 2002; Stöllner et al., 2003; Stöllner, 2007; Kern et al., 2009, 166-169).

Remarkably, salt appears to have been mined only on a local, small-scale basis in the East Alpine region during Roman times (Stöllner, 2007, 169; Kern et al., 2009). Primarily from historical sources, it is clear that Roman salt mining took place in North Africa, Spain and Romania. Unfortunately, locating these mines is extremely difficult. Consequently, little to no archaeological research has been conducted yet (Carusi, 2008a; Harding, 2013; Moinier and Weller, 2015). In Roman Dacia (present-day Romania), salt mining was an integral part of the Roman economy. Salt extraction is suspected at multiple locations, for instance, Ocna Mures, *Potaissa*-Turda and Ocna Sibiului (Wollmann, 1996, 240-249; Oltean, 2007; Moinier and Weller, 2015; Mihailescu-Bîrliba and Asăndulesei, 2019). Particularly interesting are the multiple epigraphs providing evidence of the Roman administration of the Dacian saltworks (see section 3.5.3) (Tsigarida, 2012a; Mihailescu-Bîrliba, 2016).

As salt inhibits the action of microorganisms that normally lead to decay, the organic material in the mines has been preserved in good condition enabling researchers to reconstruct the mining techniques and everyday life (Kern et al., 2009; Reschreiter and Kowarik, 2019). At Hallstatt, the mining technology differed between the Bronze Age and the Iron age. In the Bronze Age, the mines consisted of large, vertical central shafts connecting multiple superimposed mining galleries with each other and the outer surface. These shafts served multiple purposes as they were used for ventilation, entering and exiting the mine and transporting the produce (Reschreiter and Kowarik, 2019, 102-105). In the mining galleries, salt extraction was focused on producing small chips of rock salts. Although the interpretation of the extraction technique deduced from pick marks is still up for discussion, bronze picks may have been used to hack deep parallel grooves in the rock salt surface, after which the salt between the grooves was hammered out. Subsequently, the broken pieces were sorted, and the pure salt chips were transported to the shafts in carrying sacks with a capacity of 28kg. These salt sacks were then hoisted to the surface using an elaborate system of ropes[5] (Figure 31) (Kern et al., 2009; Reschreiter and Kowarik, 2019; Harding, 2021).

[5] For a more detailed overview of Bronze Age salt mining and working conditions in Hallstatt, see: Reschreiter and Kowarik (2019)

Figure 31 Reconstruction of Bronze Age salt mining at Hallstatt (Reschreiter and Kowarik, 2019, NHM Vienna).

In the Early Iron Age, salt mining at Hallstatt reached its apogee and compared to the Bronze Age, completely new strategies and techniques were used. Instead of large vertical shafts, narrow slanted tunnels inclined at 45° with logs braced between the tunnel walls as stepping stones connected the mining galleries to the surface. In these galleries, the miners cut horizontal adits with lengths up to 200 m and heights of over 20 m to follow the rock salt veins (Kern et al., 2009, 85; Reschreiter and Kowarik, 2019, 102-103; Harding, 2021, 37). In contrast to Bronze Age mining which produced small salt chips, Iron Age mining specialised in extracting large salt tablets. This technique used picks (bronze at Hallstatt, iron at Dürrnberg) to create heart-shaped blocks. These blocks were then prised off the wall with as little waste as possible. Recovered fragments indicate that these blocks could weigh up to 42 kg, and negatives on the rock surface suggest that salt tablets up to 150 cm wide weighing as much as 100 kg were extracted. These salt tablets could not be transported in the specialised Bronze Age carrying sacks and/or hoisted upwards with elaborate rope systems. Instead, these salt blocks were presumably carried upwards to the surface and various ways of carrying loads have been established. Interestingly, the smaller rock salt fragments broken off during the picking process were not collected and were left on the ground to accumulate in waste deposits[6] (Kern et al., 2009; Reschreiter and Kowarik, 2019). Nevertheless, small local variations between mines should be taken into account as there is evidence that rock salt chips were collected at Dürrnberg (Kern et al.,

[6] For a more detailed overview of Iron Age salt mining and working conditions, see: Stöllner et al. (2003), Kern et al. (2009), Reschreiter and Kowarik (2019).

2009, 166-169). Furthermore, during the Iron Age, salt mining and quarrying were not confined to the Alpine region as recently salt quarrying activities have been attested at Bãile Figa (Romania) and might have occurred on other sites in the Carpathian Basin as well (Harding, 2013, 71; 2021, 38).

Recently, a peculiar method to exploit rock salt has been discovered in Transylvania, called the 'trough technique'. This Bronze Age technique uses perforated wooden troughs (hollowed out tree-trunks) to slowly drip water onto the rock salt surface, causing the rock salt to dissolve locally in small depressions. Wedges can then be used to enlarge these small depressions and to break up the rock surface. Although the first evidence already dates from the early nineteenth century, the excavations at the site of Bãile Figa and experimental research have been crucial in understanding how this technique functioned (Harding and Kavruk, 2010; Harding, 2013, 63-66; 2018; 2021, 10-11). In addition, deposits of rock salt outcropping on the surface would have attracted people wishing to exploit them. Unfortunately, this form of exploitation leaves little archaeological traces. Only the presence of tools, such as hammers, picks, grinding tools etc., in the vicinity of these outcrops might indicate the existence of such work (Harding, 2013, 2021).

3.3 Producing salt through natural solar evaporation

The easiest way to obtain salt from seawater consists of evaporating the water naturally through insolation. As the Roman author Pliny (N.H. XXXI, 73-74) describes, salt crystallises without human intervention on beaches and rock surfaces and can easily be collected for individual use. However, to ensure larger populations of a steady salt supply, natural evaporation through insolation occurred on a large scale in artificial structures, often termed salinas or *salinae*.[7] These salinas occur primarily in climates with a dual seasonal pattern characterised by a warm, dry summer (with abundant hours of sunshine, a sufficiently high mean temperature and a strong, dry wind regime) and a winter season receiving up to 80% of the annual rainfall[8] (Davis, 2000; Alonso Villalobos and Ménanteau, 2006; Rodrigues et al., 2011; Gauci et al., 2017). However, these are only general parameters and regional climatological variability will influence the production output. For instance, on the Atlantic coasts, weather conditions (e.g. higher rainfall and lower solar irradiance) are less favourable than Mediterranean climates, which will inevitably lead to a lower salt output per hectare (Rodrigues et al., 2011). According to Daire (2003, 25), these climatological factors prohibit solar salt production in salinas above 48° latitude. In Europe, this roughly corresponds with the south of Brittany (Fr).

To this day, industrial and artisanal salinas are still intensively exploited in different parts of the world. At the end of the 20th century, Walmsley (1999) recorded 165 salinas in the Mediterranean, of which 90 salinas were actively exploited and 64 lay abandoned. From the 1950s onwards, traditional Mediterranean saltworks have continuously declined (Gauci et al., 2017). This is unfortunate from an

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[7] In literature, different terms (e.g. salterns, saltpans, saltworks, salt-gardens, salinas or salines) are used to describe artificial structures related to modern-day and historical solar salt production (Gauci et al., 2017).

[8] These parameters mainly apply to seasonal saltworks (shores of the Atlantic, the Mediterranean, the Black Sea, San Francisco Bay etc.) producing salt from spring to autumn. Continuously (year-round) operated salinas are only found in dry climates with low annual rainfall (e.g. Brazil, Mexico, Caribbean) (Davis, 2000).

archaeological and ethnographical point of view since these artisanal salinas are very informative on how *salinae* might have functioned in Antiquity.

Modern-day salt pans consist of a connected series of shallow basins and canals through which seawater flows and evaporates until salt crystals form. These basins or compartments can be roughly divided into three categories (Figure 32) (Alonso Villalobos and Ménanteau, 2006; Rodrigues et al., 2011; Currás, 2017):

(1) large accumulation ponds (supply ponds) collect the seawater at high tide or through inlets. In these ponds insoluble sediments (sand, silt and clay) are deposited

(2) concentration or evaporation basins. In these ponds, the seawater evaporates and the brine salinity gradually increases in each successive evaporation pond. Due to differences in solubility, calcium carbonate and gypsum will precipitate in different compartments.

(3) shallow crystallisation ponds. In these basins, sodium chloride crystallises from the oversaturated brine. These salt crystals were harvested directly from the bottom of the pans with shovels or flat rakes. The harvested salt was then left to dry on small salt heaps on the edge of the ponds. In these crystallisation ponds, the salinity was kept in check to prevent the co-precipitation of the undesired K-Mg salts.

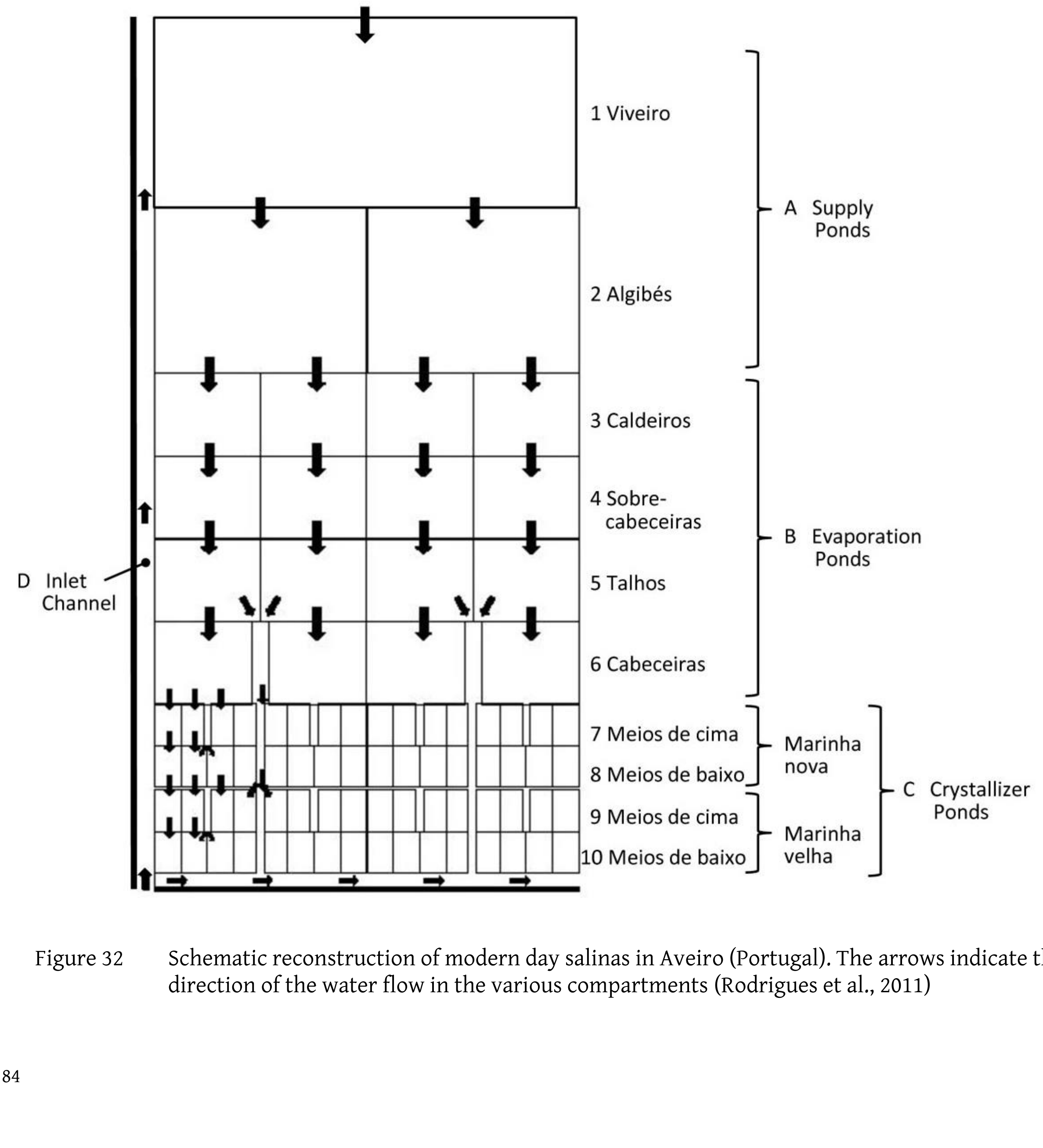


Figure 32 Schematic reconstruction of modern day salinas in Aveiro (Portugal). The arrows indicate the direction of the water flow in the various compartments (Rodrigues et al., 2011)

3.3.1 Archaeological evidence of Roman *salinae*

Despite numerous references to *salinae* in literary texts, the available archaeological evidence is underwhelming, and the first Roman saltworks were only discovered fairly recently.[9] Next to several possible salt pans, for example, at Antibes (Daveau and Sivan, 2010) and Cadiz (Alonso Villalobos et al., 2003; Alonso Villalobos and Ménanteau, 2006), only the sites of Rome 'Vignole-Interporto,' Caunus and Vigo 'O Areal' have been more thoroughly excavated.

The first well-documented salt pan is situated in the marshy area north of Portus (near Rome) and has been considered the ancient *Campus Salinarum Romanorum*. The discovered hydraulic structure, dating back to the first half of the first century CE, consisted of a dam built with 1439 amphorae and channels controlled by sluices. These channels were used to distribute the water across the *salinae* and acted as accumulator ponds collecting and storing seawater from the lagoon. According to Grossi et al. (2015), the flat areas between the channels served as crystallisation ponds where the salt was collected (Grossi et al., 2015; Garcia Vargas and Martinez Maganto, 2017).

At Caunus (Turkey), 48 circular salt pans with a diameter of 4.28 m and 14-18 cm deep were discovered during excavations in 2005. These ponds, arranged in eight lines of six pans, had an *opus caementicium* floor and can be divided into five sections separated by rectangular canals (Figure 33). These canals were probably used as seawater accumulation ponds in which the first stage of evaporation occurred. After that, the brine was transferred to the circular crystallisation ponds situated on both sides of the channels. As no connection exists between the circular ponds and the channels, the workers would have to fill the salt pans by hand (Atik, 2008; Currás, 2017; Garcia Vargas and Martinez Maganto, 2017). Interestingly, epigraphic and historical evidence complemented the archaeological data at Caunus. For instance, Pliny (NH XXI, 99) described that the salt from Caunus was particularly good for curing eye ailments and the 'Customs Regulations' inscription from Caunus stated that the tax on salt should be paid following the existing regulations (Carusi, 2008a; Marzano, 2013, 126-127; Tsigarida, 2015).

Over the last two decades, archaeological research has revealed an extensive salt production site at Vigo (Spain). This site was established in the mid-first century CE and abandoned during the third/fourth century CE (Castro Carrera, 2006; Currás, 2017). The excavated features can be divided into an east and west sector, but multiple surveys suggest that both sectors were part of one large complex installed along the coast of O Areal (Vigo, Spain). If these assumptions are correct, the Roman *salinae* at O Areal would have extended over 8.5 ha. The excavated features consisted of a series of rectangular E-W oriented evaporation pans. Both the morphology and dimensions of these compartments can vary, but overall three major types could be distinguished: (1) small ca. 5 x 2.5 m compartments with stone and clay pavement delineated by ca. 10 cm high stone slabs (Figure 34), (2) medium ca. 10 x 5 m ponds with 15-25 cm high border stones and (3) large ca. 15 x 8 m stone bordered ponds (Currás, 2017; Garcia Vargas and Martinez Maganto, 2017).

In addition to the *salinae* at O Areal, Curras (2017) documented multiple (possible) saltworks (e.g. Angeiras, Gelfa, O Seixal, Lontreiras) along the northwest coast of the Iberian peninsula. Unfortunately, a clear dating is often lacking, but based on similarities with the saltworks of O Areal, a Roman date can be suspected. Interestingly, several saltworks, such as A Igrexiña, Angerias and O

[9] Excellent summaries of the available archaeological evidence has been provided by Currás (2017) and Garcia Vargas and Martinez Maganto (2017). The work of Currás (2017) is particularly interesting as he provides detailed evidence for the *salinae* of O Areal (Vigo) and several previously unknown possible *salinae* in Northwest Iberia.

Areal, can be directly linked to Roman fish-salting factories. The production of salted fish and fish sauce required large volumes of salt and these examples clearly prove that both activities were carried out at large compounds in the same immediate area (Currás, 2017).

Figure 33 Salina of Caunus (Turkey) depicting all 48 circular salt pans arranged in eight lines of six pans separated by four large rectangular canals (Atik, 2008)

Figure 34 Well-preserved crystallization ponds in the west sector of the O Areal *salina* (Vigo, Spain). In total 8 complete 5 x 2.5m compartments with a carefully constructed stone and clay pavement delineated by ca. 10cm high stone slabs can be observed (Castro Carrera, 2006, fig. 11)

3.4 Producing salt through artificial evaporation

In large parts of the world, climatological conditions prevent natural evaporation through insolation.[10] In these areas, salt was extracted by artificially heating a brine in evaporation vessels above hearth-like structures. This technique was predominantly used to produce salt in northwest Europe from the Neolithic onwards (Harding, 2013; Weller, 2015; Harding, 2021), but is also known from Asia (Chen, 2008; Flad, 2011; Kawashima, 2015), America (McKillop, 2002; Watson and McKillop, 2019) and Africa (Antonites, 2013, 2016). Since this type of salt production is the main topic of this dissertation, we will briefly outline the major trends in research, followed by a discussion of the wide variety of choices that the salt producers faced during the production process.

3.4.1 Artificial salt production in Europe: a historiography

Given the importance of salt in daily life, the production and use of this resource attracted quite a lot of scholarly interest. Already in the middle of the nineteenth century, the first more or less systematic studies[11] appeared, for instance, the works of Hehn (1873) and Schleiden (1875). These works focused on the etymology of salt place names, the historical references to salt and (pre)historic production areas (Nenquin, 1961, 15; Harding, 2013, 16). Of greater importance were the discovery and excavation of the Hallstatt cemetery between 1846 and 1863 (Von Sacken, 1868). In Hallstatt, the richness of graves might be linked to the control and exploitation of the nearby major salt source. The earliest traces of the ancient exploitation and the significance of the protohistoric salt mine were first described by Hochstetter (1881), followed by the work of Szombathy (1900), Much (1902) and numerous others. Since then, the excavations of the Hallstatt-Museum have continuously added new, and often surprising, information on the life and work in the Hallstatt salt mines (see section 3.2) (Kern et al., 2009).

More important for this study was the increased scholarly attention to the sites in the Saale (Germany) and Seille (France) river valleys at the end of the nineteenth century. Already in 1740, the French engineer Félix-François le Royer d'Artézé de la Sauvagère noted in the area of Marsal and Moyenvic the presence of significant accumulations of burnt earth and ceramic material, which he called 'briquetage'. These deposits were repeatedly noticed throughout the nineteenth century. Yet, their their function remained enigmatic until, at the beginning of the 20th century, amongst others, Keune (1901) and Grosse (1903, 1904) were able to connect the briquetage elements in the Seille valley to the production of salt (Nenquin, 1961, 17-18; Olivier and Kovacik, 2006). In the Saale valley, Schmidt (1894) described similar fragments of unusual pottery of unknown use on multiple sites around Halle. However, Voss (1901) noted the similarities in the briquetage material used in salt production from Lorraine and the pottery from the Saale-valley. From this time onwards, the term briquetage was undeniably linked to salt production and was gradually adopted throughout Europe to describe the ceramic equipment used in the salt production process (Gouletquer, 1970). Over the years, the term briquetage has been used more 'holistic' to describe the technique of salt making using clay elements.

[10] As demonstrated by i.a. Alessandri et al. (2019), along the Tyrrhenian coast, artificial evaporation techniques could have been preferred or have been used in addition to natural insolation.
[11] For a complete overview of nineteenth-century studies, see Nenquin (1961, 15-21)

As a result, the term briquetage not only includes the ceramic equipment (briquetage vessels and support elements) but also the debris from the heating infrastructure (Gouletquer, 1974; Lane and Morris, 2001, 8). Simultaneously with the inland salt sites, research commenced on numerous mounds of so-called Red Hills along the southeast coast of England. By 1906 the Red Hill Exploration Committee had been set up to systematically study the origin of these hills (Fawn et al., 1990). Based on similarities with the briquetage material from France, Smith (1918) was able to thoroughly connect these sites and the ceramics found on them to salt production.

The work of Nenquin (1961) marks a turning point in the study of salt archaeology. His seminal overview can be considered the first systematic study on salt encompassing Europe from the Neolithic to Roman times. Nenquin's study put the archaeological study of salt on the map, and future researchers have continued to build upon his work. In the 1960s and 70s, new regional syntheses, including new discoveries in salt production areas that were by then well-known, significantly enhanced the knowledge of the briquetage technique. These studies are numerous, but worth mentioning is the work of Riehm (1954, 1961, 1962) and Matthias (1961, 1976) in the Saale valley, the publications of Bertaux (1976, 1977) in the Seille valley, the study by Gouletquer (1970) in Brittany and the work of De Brisay (1975, 1978, 1981) in Essex. In 1974, several of these leading salt scholars attended one of the first conferences specifically devoted to the archaeology of salt. The often-cited proceedings of this conference synthesised and discussed salt production across the globe in different time periods (De Brisay and Evans, 1975).

In the following decades, salt archaeology boomed in northwestern Europe with the discovery of new sites and the integration of new research methodologies. As such, the number of studies drastically increased and presenting all major publications is not feasible in this short overview. An excellent chronological overview summarising the current understanding of salt production on both inland as well as coastal sites in prehistoric Europe has been published by Harding (Harding, 2013, 2021). In this overview, he highlights the major sites and developments making a detailed overview of the main publications here redundant. Nonetheless, some works of leading salt scholars on coastal salt production will be presented as they significantly impact this study. For instance, Daire (1994, 2003) synthesised and discussed the Iron Age salt production along the French Atlantic coast, while Prilaux (2000a) and Masse (Masse and Prilaux, 2016, 2017) provided a synthesis of the Iron Age salt ateliers recently discovered along the English Channel. Across the Channel, important regional syntheses of Iron Age and Roman salt production exist for the Fenlands (Lane and Morris, 2001; Lane, 2018b), Essex (Fawn et al., 1990), Somerset and southern Britain (Hathaway, 2013).

In the last decades, archaeometric techniques have been used more intensively to answer specific salt-related research questions.[12] For instance, at the Iron Age and Roman salt production site of Stanford Wharf Nature Reserve, soil micromorphology, geochemistry and archaeobotanical analyses were used to identify the type of fuel, to determine how the brine was produced and to confirm the use of lead evaporation vessels (Biddulph et al., 2012; Hunter, 2012; Macphail et al., 2012). Additionally, soil morphology and geochemistry were used to analyse the composition of sedimentary deposits to determine their relationship to the salt production activities (Sills et al., 2016; Graham et al., 2017; Sordoillet et al., 2018). Recently, Sevink et al. (2021) used chemical data to detect the enrichment of magnesium, potassium, sulphur and boron in the dump zone, which they relate to the removal of the bitterns at the end of the salt production process.

[12] This overview aims to give an idea of how archaeometric techniques can be used to answer questions related to the salt production process. It is not our intention to provide an exhaustive overview of archaeometry studies on salt production sites.

Beside these site-based studies, more in-depth artefact-related studies on the characterisation of briquetage material exist. For instance, Van den Broeke (2012), Sandu et al. (2012), Ichikawa et al. (2021) and Larreina-García et al. (2021) used a combination of thin-section petrography, XRF, SEM/EDS and XRD to study the fabric composition and firing conditions. And Weller (2002, 2004b), Ard and Weller (2012), Flad et al. (2005) and Horiuchi et al. (2011) tried to develop a methodology to detect whether pottery, and briquetage vessels in particular, were actually used in the salt production process. Weller's methodology (2002, 2004b; 2012) uses XRF to measure the chlorine concentration in pottery. These analyses revealed a significantly higher concentration of Cl-ions in the supposed container vessels compared to regular pottery. Flad et al. (2005) focused on the differences in both chlorine (Cl) and/or sodium (Na) concentration between the inner and outer surface of the briquetage vessels through SEM-EDS analyses. Horiuchi et al. (2011) developed a method to extract and measure the concentration of chloride ions (Cl^-) in pottery vessels of which high chlorine concentrations might indicate their role in salt making. However, Raad et al. (2014) tested Horiuchi et al.'s methodology and concluded that it is unreliable to identify salt- making vessels. Recently, Alessandri et al. (2019) built on Flad et al.'s methodology (2005) and analysed the 1D and 2D elemental distribution of Na and Cl by SEM-EDS and EMPA. Finally, Proske (2009) developed a methodology based on archaeomagnetic reorientation of magnetite and hematite minerals to detect the correct orientation in which supports, specifically pedestals, were employed during the salt production process in late Bronze -early Iron Age Vietnam (2900-2200 cal. BP).

Furthermore, in several parts of the world, people have continued to produce salt in a non-industrialised way. As several aspects of the salt-making process leave little archaeological traces, research into these processes has benefitted greatly from these ethnographical observations. When called for, these ethnographic observations will be integrated in the following chapters.[13]

3.4.2 Artificial salt production: a production model

The overarching principle behind artificial evaporation techniques is relatively simple: a brine is heated in evaporation vessels above hearth-like structures until salt crystals form. Yet, in practice, salt production is a complex affair in which various technical choices shape the production. These (un)conscious decisions on how to produce salt and the sequence of actions resulting from it can be considered the *chaîne opératoire* of salt production. Over the years, several attempts have been made to reconstruct the *chaîne opératoire* of the salt production activities based on the locally available evidence. Prime examples are the study of Sevink et al. (2021) of the Bronze Age salt production site at Puntone (Tuscany, IT), the reconstruction of Weller (2000) of the salt production activities at Sorrus and Prilaux's (2000a, 66-70) *chaîne opératoire* of Iron Age salt manufacturing in northern France. However, before applying the *chaîne opératoire* concept to the Roman salt production sites in the Menapian *civitas* (Chapter 9), it is important to thoroughly grasp the variability in how salt was produced.

In general, salt production consists of six stages in which the salt producers are presented with a series of choices that shape the overall *chaîne opératoire*. This section briefly outlines these stages and

[13] More information on the ethnography of salt can be found in Delbos (2008); Reina and Monaghan (1981); Davison (1993); Godelier (1969); Lemonnier (1984); Weller et al. (1996); Pétrequin et al. (2000); (2001); (1975); Antonites (2016); Yankowski and Puangthip (2013); Yankowski et al. (2015); Connah (1991); Connah et al. (1990)

key choices to provide a background for further interpretations. The following six (non-consecutive) stages make up the salt production process:

(1) Raw material procurement
(2) Preparing the site
(3) Preparing the production activities
(4) Salt crystallisation and drying
(5) Transport and consumption
(6) Debris deposition

3.4.2.1 Stage 1: raw material procurement

The decision to engage in salt production activities required (un)conscious consideration of many different factors. This included an assessment of the knowledge and skills needed to produce salt as well as more practical matters such as detecting and selecting suitable locations to perform the activities. Choosing such a location will have been affected by social (e.g. tradition), logistical (access to the economic network, resources etc.), and environmental factors (Hathaway, 2013, 163; Masse and Prilaux, 2017). Especially the access to suitable, locally available raw materials will have been a deciding factor since several types of resources were required.

Firstly, a source of **clay** was needed to create evaporation vessels and support elements, but also to build heating structures and other types of infrastructure (Hathaway, 2013, 165; Masse and Prilaux, 2017). Secondly, a **fuel supply** was essential to heat the hearths during the evaporation process and to pre-fire briquetage elements and the heating structures (Prilaux, 2000a; Lane and Morris, 2001; Akridge, 2008). The choice of fuel depended on the local ecological conditions, and a variety of fuel types, such as peat, wood, cereal waste etc., have been attested archaeologically (Prilaux, 2000a; Rippon, 2000; Lane and Morris, 2001; Biddulph et al., 2012; Masse and Prilaux, 2017). However, tradition and technological choice might trump ecological conditions and, in some instances, specific fuel types were preferred over the abundant, locally available fuel source. This phenomenon was established, for example, at Romano-British salt production sites where wood, brushwood and cereal processing waste were preferred to the locally available peat (Rippon, 2000; Lane and Morris, 2001). A third and final group of raw materials consisted of the **saline resource** used to produce the brine. Most important, of course, is the access to saltwater either directly on the coastline or indirectly through tidal inlets. Furthermore, additional types of saline resources such as salt-impregnated sand or silt from the tidal zone, salt-impregnated peat or halophytic plants could be gathered and used in the brine manufacturing process.

3.4.2.2 Stage 2: preparing the site

After a suitable location was found, decisions had to be made on how space would be used within the site. This involved defining and creating a **working area(s)** where the salt production activities would take place. The working area comprises both the water management system and the heating structures necessary to produce salt. It was not uncommon for producers to define such a working area with a series of ditches which could be part of the water management system like at Stanford Wharf (Figure 35) (Biddulph et al., 2012).

The **water management system** involves the supply of saltwater and the subsequent processing and storage of the brine. A wide variety of features could have been used in such a water management system. Again, primarily the local environmental conditions, regional traditions and technological choices will determine which features were adopted in a certain region in a specific period of time.

Especially how the brine was produced on site (section 3.4.2.3) will affect the construction of the water management features. The main feature types include feeders and settling tanks or brine tanks. Feeders, feeder ditches or feeder channels are artificial ditches that carry the salt water from the tidal zone, - inlet or creeks to the site (Figure 35). Since a well-functioning site depends on a controllable supply of saltwater, these ditches must have been designed with a way to control the water intake and flow (Lane and Morris, 2001; Lane, 2005; Hathaway, 2013). While several options are possible, the easiest way might have been a wooden sluice system as found, for example, at Lydd Quarry (Kent, GB) (Hathaway, 2013). Such a system would have been essential, especially if these ditches were connected to saltwater reservoirs, settling tanks etc.

Brine or settling tanks is the umbrella term to describe the features involved in brine production and/or - storage. These features were multi-purpose, and their primary function was allowing the sediments and impurities to 'settle' at the bottom of the tanks. Moreover, an amount of water will evaporate naturally in hot weather, increasing the brine strength. In addition, they serve as storage for the brine used in subsequent stages of the salt production process (Fawn et al., 1990; Prilaux, 2000a; Daire, 2003; Biddulph et al., 2012; Hathaway, 2013).

Settling tanks are a well-known phenomenon in various salt production regions in Britain and different types occurred. The multi-celled examples often consisted of three adjacent tanks that worked together to provide a hearth with a constant supply of brine. Numerous examples of this type of brine tanks can be found at salt production sites in Essex (Fawn et al., 1990; Biddulph et al., 2012; Biddulph, 2016) and southern Britain (Hathaway, 2013). Next to these multi-celled settling tanks, single 'isolated' brine tanks have been found in various regions in Britain and the continent. These structures can be quite large, as shown by examples at Conchil-le Temple (FR) (Lemaire, 2012), Sorrus (FR) (Defossés, 2000), Middleton (EN) (Lane and Morris, 2001), Nantwich (EN) (Arrowsmith and Power, 2012) etc. Sometimes these larger settling tanks are called brine reservoirs emphasising the structure's size (see Hathaway, 2013, 178), but most often, the terms reservoir and tank are used interchangeably.

In close proximity to the brine tanks, a **heating structure** was then constructed to evaporate the brine (Figure 35). These heating structures are pivotal in the salt production process and use one of two heating systems: direct or indirect heat. In a direct heating system, the evaporation vessels are exposed to the heat source, while in an indirect system, the heat source itself is removed from the containers. A characterising element of the latter technique is separating the evaporation vessels and the actual fire so that only the heat reaches the containers (Lane and Morris, 2001, 373-374). Following Lane and Morris (2001, 373), structures that use a direct heating system are termed saltern hearths, while the structures that employ an indirect system are termed saltern ovens. It should be noted that the term oven is preferred to kiln since the top of the structure needs to be open to replenish the evaporation vessels. Hathaway (2013, 193-195) makes a similar division between direct and indirect heat, but also distinguishes between open and enclosed structures. This additional parameter allows for a more nuanced description of the heating structures. For instance, Hathaway (2013) differentiates between open or enclosed hearths with direct or indirect heat, and retains the term oven for more complex heating structures consisting of multiple chambers with a flue.

These two parameters enable a general description of the heating structures discovered on site. Naturally, more elaborate chronological and regional typologies of heating structures exist based on the hearths' shape, size and construction technique. Furthermore, there is a constant interaction between the type of heating structure and the type of evaporation vessels and support elements used in the salt production process (section 3.4.2.3). As these heating structures and briquetage elements shape each other, change in one often involves change in the other.

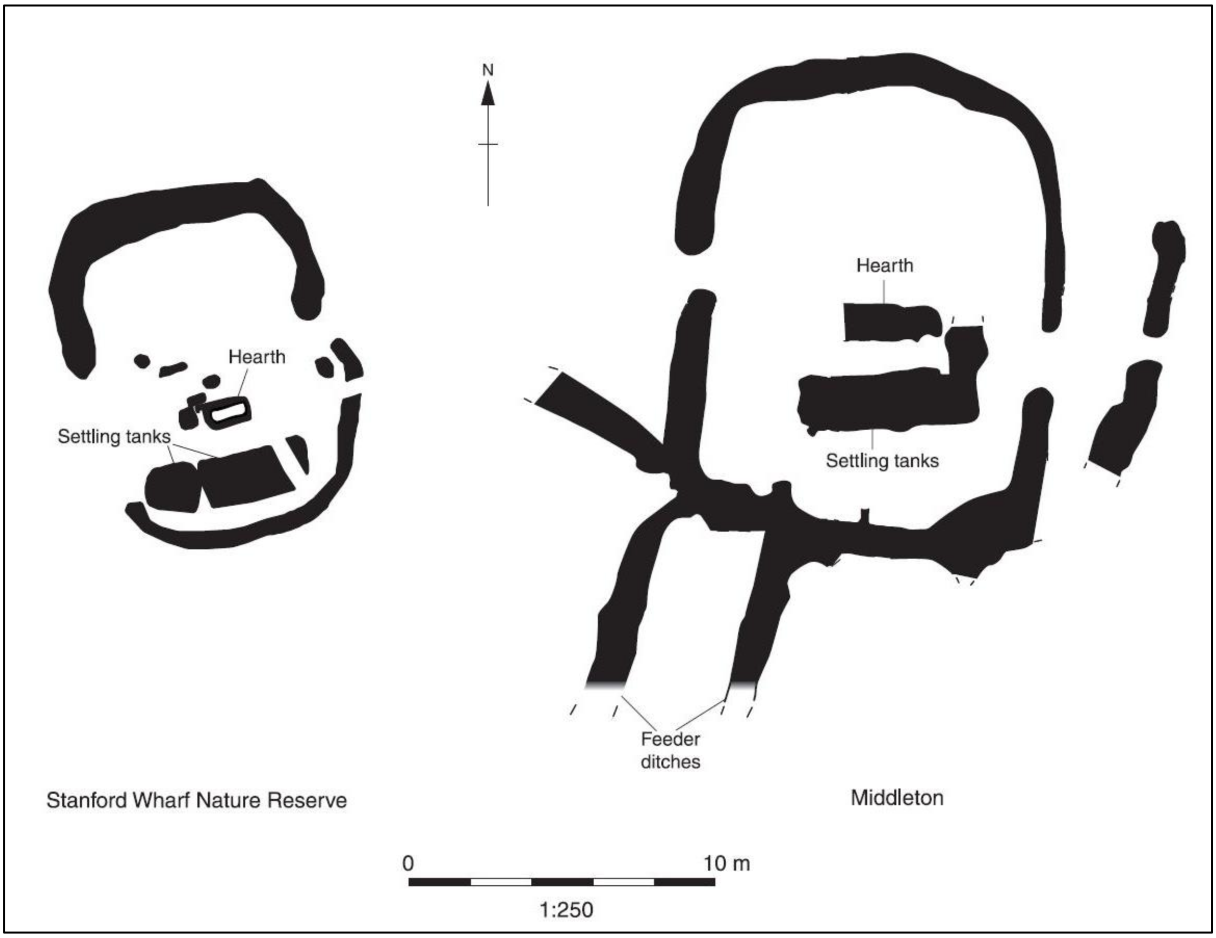


Figure 35 Working areas of the late Roman salt production sites at Stanford Wharf Nature Reserve (GB) and at Middleton (GB) showing the feeder ditches supply the salt water, the ditches defining the working area, the settling tanks and the hearth infastructure (Biddulph et al., 2012, 160, figure 166.157).

3.4.2.3 Stage 3: preparing the production activities

In addition to and perhaps simultaneous with the construction of the working area, the raw materials were processed in preparation of the salt production activities. This stage consists of producing or procuring the evaporation vessels, briquetage support elements, and the concoction of the brine.

The evaporation vessels are a crucial element of the salt production process as they are used to evaporate the brine. These containers were usually crudely fashioned from the locally available clay, but from mid-Roman times onwards, metal containers started to appear (Lane and Morris, 2001; Arrowsmith and Power, 2012; Hathaway, 2013). It is generally assumed that the salt producers made the clay vessels while the metal vessels were procured from other artisans. In addition to the evaporation vessels, a wide variety of support elements (pedestals, firebars, wedges, stabilisers, platforms etc.) was created to support the containers above the fire (Fawn et al., 1990; Hathaway, 2013; Masse and Prilaux, 2017). As indicated above, the shape and dimensions of these support elements were closely linked to the hearth types. The different types of ceramic equipment (salt containers, support elements, but also the fragments of the heating structures) related to the salt production process are often termed briquetage.

Besides the production of these briquetage elements, a brine was produced from the collected saline resources. As described in section 3.1.2, the term brine denotes a solution with a high concentration of dissolved salts. Since the salinity of seawater typically lies between 31-35‰, it is logical to assume that the salt producers wished to increase the salt concentration in the brine before transferring it to the evaporation vessels. That way, the brine reaches a (super) saturated more quickly, saving the producers energy and labour. Different ways of creating a brine exist. The simplest method was to collect the seawater in the brine tanks and, if given a sufficient amount of time, the brine concentration will gradually increase through natural evaporation (Biddulph et al., 2012; Harding, 2013; Hathaway, 2013).

In a second method known as sleeching (*lixiviation* in French), salt-rich sand or silts were collected in inter-tidal zones or shores. These sediments were then washed with (salt) water and filtered above brine tanks. Alternatively, the salt-rich sediments were added to the brine tanks and allowed to settle on the bottom (Prilaux, 2000a; Daire, 2003; Biddulph et al., 2012; Masse and Prilaux, 2017). This technique in which salts are leached from salt-rich materials is well-known from ethnographic observations in different parts of the world, such as Uganda (Connah et al., 1990), Niger (Gouletquer, 1975) and South Afrika (Antonites, 2013). Archaeologically, this method was suspected at Iron Age sites in Brittany and northern France (Daire, 1994; Prilaux, 2000a; Daire, 2003; Masse and Prilaux, 2017). In Britain, leaching salt-impregnated soil is attested in the medieval period in Dorset, Lincolnshire and other coastal areas (Keen, 1988; McAvoy, 1994).

The third method to create a brine is based on the same leaching principles as the method described above. the salts are leached from plant ash instead of salt-rich soil. Not all types of plants are eligible as a high salt content is required. Highly suitable are so-called halophytic plants growing in marine or brackish environments that absorb and store salt through osmosis. These plants were then collected and burned, and the ash was mixed or filtered with (salt) water (Biddulph et al., 2012). Again, this method is relatively well-known from ethnographic observations (Gouletquer, 1975; Davison, 1993; Antonites, 2013). Recently, the use of this technique in Iron Age and Roman Britain has been conclusively proven for the first time at Stanford Wharf Nature Reserve (Biddulph et al., 2012). This method was commonly used in medieval times to produce salt in the Netherlands, particularly in Zeeland.[14] However, when describing medieval salt production in the Netherlands, this method is called *selnering* as salt-impregnated peat was used to produce salt instead of halophytic plants (van Geel and Borger, 2005; Leenders, 2007, 2010).

3.4.2.4 Stage 4: salt crystallisation and drying

After all the necessary preparations were concluded, and the evaporation vessels and support elements were fitted inside the heating structure, production could commence. Logical first steps include filling the vessels with the produced brine and firing the heating structure. Gradually, the brine heats up, and through evaporation the undersaturated solution is brought into a (super)saturated state. As explained in detail in section 3.1.2, the brine consists of different types of salt with a different solubility. As such, these salts will not crystallize haphazardly but follow successive intervals based on their solubilities. First, the carbonate minerals crystallise, followed by gypsum. Subsequently, the desired halite (NaCl) forms, after which the precipitation of the K-Mg salts, also referred to as bitterns, signal the end of the evaporation process (Babel and Schreiber, 2014).

[14] More a more elaborate discussion of medieval salt production in the Low Countries, see section 3.6

The vessels were constantly monitored and replenished with brine during evaporation to prevent production downtime. Again, producers were presented with a choice to let the salt crystallise and accumulate in the briquetage containers or to harvest the salt crystals from the brine. The use of both methods has been demonstrated archaeologically. For example, the former method was attested on salt production sites in northern France (Prilaux, 2000a; Masse and Prilaux, 2017), while the latter method was demonstrated in certain areas of Britain (Lane and Morris, 2001; Biddulph et al., 2012).

One aspect of salt production still to consider is the (potential) removal of impurities or undesired salts during or after crystallisation. It is generally assumed that the crystallisation of the K-Mg salts, which are bitter and unpleasant to the taste, was prevented or that these bitterns were removed afterwards from the finalised product. According to Fawn et al. (1990, 19-20), the produced salt was largely unaffected by bitterns when the salt crystals were removed from the evaporation vessels as they appeared. Another ethnographically observed refinement technique consisted of washing and filtering the wet salt with fresh water (Gouletquer, 1975; Hathaway, 2013, 247-250). However, it remains difficult to assess how much refinement actually took place on the pre-modern salt production sites as these processes left few archaeological traces. Recently, Sevink et al. (2021) chemically analysed the dump zone to demonstrate that K-Mg salts were probably not allowed to precipitate and instead were disposed of at the end of the evaporation process.

3.4.2.5 Stage 5: transport and consumption

Most of the produced salt was not consumed on-site but distributed to consumption sites in the hinterland. One way to transport salt involved using the briquetage vessels in which the salt crystallised. This method is well known in certain areas in Britain (Morris, 1985; Kinory, 2012) and the Low Countries (van den Broeke, 1986, 1995b, 1995a). Next to briquetage containers, the use of other ceramic vessels for transporting salt is sometimes suspected, for instance, the southeast Dorset Black Burnished Ware (Gerrard, 2008). That being said, salt could just as easily be transported in organic containers like leather bags or baskets, which would not be expected to survive in the excavated archaeological record except in very special circumstances (Lane and Morris, 2001). At the consumption sites, the salt could then be used for various purposes discussed in section 3.5.2.

3.4.2.6 Stage 6: debris deposition

The final step of the production process consisted of dumping the waste materials. Salt production produces significant amounts of waste, including fuel ash, sediments, broken and discarded briquetage elements, dismantled hearth infrastructure, domestic debris etc. Hence, it would make sense to consider how debris was managed before the start of the production activities to prevent the obstruction of movement on the site. In consequence, the debris zones are situated at the edge of the site at some distance from the working area. In these areas, debris accumulates as layers or heaped mounds at the ground surface (Hathaway, 2013). The latter method could have significantly altered the surrounding landscape over time, and prime examples are the Red Hills in Essex which can still be seen in the landscape (Fawn et al., 1990).

3.5 Salt in the Roman world

3.5.1 Classical sources on salt production

3.5.1.1 The occurrence and classification of salt

Although salt is considered of high importance to ancient communities, historical sources about the occurrence, production and use of salt in Antiquity are relatively scarce. The most informative and extensive passages about salt and salt production can be found in Pliny's Natural History (XXXI, 73-105). It is generally accepted that Pliny based this section on Theoprastus' lost treatise "*On salts, niter, and alum*" quoted by Diogenes Laertius (*Vit. Phil.* 5.42). As such, the work should be seen as a synthesis of the knowledge on salt in the first century CE rather than a reliable account of salt production sites and techniques (Carusi, 2008a, 16-18; 2008b, 354; 2018). Overall, Pliny's chapter on salt can be divided into three sections: (1) occurrence and exploitation of salt (XXXI, 73-83), (2) characterisation and description of salts (XXXI, 84-89) and (3) the use of salt and derivative products (XXXI, 90-105) (Morère Molinero, 2008, 366).

In his first section, Pliny (N.H. XXXI, 73) distinguished two main categories of salt: *sal nativus* and *sal facticius*. Natural salt (*sal nativus*) formed spontaneously in nature, for example, through the natural evaporation and crystallisation of salt on rocks or beaches (XXXI, 73-74) (Carusi, 2008b; Morère Molinero, 2008, 354-355). On the other hand, Pliny used the term artificial salt (*sal facticius*) to describe salt that was deliberately produced, for instance, the production of salt in *salinae* where seawater was artificially led into basins to evaporate naturally (N.H. XXXI, 81-82) or salt obtained using artificial heating (fire) (XXXI, 81-83) (Carusi, 2008b, 354-355; Morère Molinero, 2008, 366-369).

Pliny's bipartite division in *sal nativus* and *sal facticius* clearly differs from earlier sources, notably Varro (*De re rus.* I.7.8), Dioscorides (IV. 109) and Galenus (*Simpl. Med*. XXII. 372), who make a distinction between *sal fossicius* (rock salt) and *sal maritimus* (sea salt). Both Varro and Dioscorides based their distinction primarily on the origin of salt, while Pliny transcends this distinction as he considers the method of how salt was created more important (Carusi, 2008a; 2008b, 354-355; Morère Molinero, 2008, 366-369).

3.5.1.2 The production of salt in *salinae*

According to Pliny (NH. XXXI. 81), marine *salinae* were commonly used to produce salt in Antiquity. Multiple references to *salinae* can be found in Pliny's work. Yet, it should be emphasised that the term *salinae* can also be used generically to denote places where salt was produced and thus not necessarily refers to marine solar evaporation pans (Ørsted, 1998, 18-22; Harding, 2021). However, Carusi (2008a, 33) concluded that most historical attestations should be attributed to the evaporation of salt water. For an overview and discussion of the historical references to possible *salinae* in the Mediterranean, see Carusi (2008a) and Moinier and Weller (2015).

Besides the location of *salinae*, the ancient writers Manilius (first century CE) and Rutilius Namatianus (fifth century CE) provide a more detailed, though poetic, account of how these *salinae* functioned. In book V, he narrates the chaos of the seas and explains the production of fish sauce as well as the exploitation of *salinae* (Carusi, 2008a, 2008b; Lowe, 2018):

> Moreover, such men will be able to fill great salt-pans, to evaporate the sea, and to extract the sea's venom: they prepare a wide expanse of hardened ground and surround it with firm walls, next conduct therein waters channelled from the nearby sea and then deny them exit by closing sluice-gates: so the floor holds in the waves and begins to glisten as the water is drained off by the sun. When the sea's dry element has collected, Ocean's white locks are shorn for use at table, and huge mounds are made of the solid foam; and the poison of the deep, which prevents the use of sea-water, vitiating it with a bitter taste, they commute to life-giving salt and render a source of health
>
> (Manilius, *Astronomica* V 682-92, transl. by Goold 1977)

Rutilius Namatianus wrote a similar, more detailed and more famous account of the salt pans in the fifth century CE. In his poem *De Reditu suo*, he describes his journey from Rome to Gaul along the Tyrrhenian coastline and mentions the salt pans at Vada (Tuscany, Italy), which belonged to the villa of his friend Albinus (Carusi, 2008a, 2008b; Currás, 2017):

> We find time to inspect the salt-pans lying near the mansion: it is on this score that value is set upon the salt marsh, where the sea-water, running down through channels in the land, makes entry, and a little trench floods the many-parted ponds. But after the Dog-star has advanced his blazing fires, when grass turns pale, when all the land is athirst, then the sea is shut out by the barrier-sluices, so that the parched ground may solidify the imprisoned waters. The natural incrustations catch the penetrating sun, and in the summer heat the heavy crust of salt cakes, just as when the wild Danube stiffens with ice and carries huge wains upon its frost-bound stream. Let him who is given to weigh natural causes examine and investigate the different effect worked in the same material: frost-bound streams melt on catching the sun, and on the other hand liquid waters can be hardened in the sun
>
> (Rutilius Namatianus *De reditu suo*, 475-90, transl. by Duff and Duff 1934)

Ignoring the poetic elements and language, it is clear that the general idea of salt production does not deviate much from modern-day saltworks. Both authors described a controlled flow of seawater through a series of channels regulated by a system of sluices. Ditches then distributed the seawater into multiple ponds/reservoirs. According to Manilius, these ponds, whose bottom and dykes had been carefully constructed, required a 'large plain'. Similarly, Rutilius mentions 'many-parted' ponds indicating that the saltworks may have extended over a large area. After the sluices were closed, the water evaporated and the salt 'hardened' on the surface. Manilius then described how the salt was harvested and piled in large heaps (Carusi, 2008a, 2008b; Currás, 2017, 338-342). It remains an open question whether there was a real knowledge about the progressive precipitation of salts and certain refinement processes. For instance, using different ponds might stem from a real desire to control the salinity increase and to regulate the formation of different salts. In any case, Pliny (NH 31.81; 85) indirectly refers to salt refinement when he mentions the use of fresh water to make the salt more 'agreeable' (Currás, 2017).

3.5.1.3 Artificial evaporation of salt

While some historical evidence on the presence and functioning of marine *salinae* exists, literary sources on artificial salt evaporation techniques are very scarce, if not non-existent. The few surviving extracts prove that ancient scholars knew that other salt-producing techniques existed besides salt mining and natural insolation. Unfortunately, these passages only refer to the marvellous or foreign character of the salt and provide no actual information about the production itself (Carusi, 2008a, 2008b).

For instance, both Aristotle (fourth century BCE) and Strabo (first century BCE - first century CE) mention a border dispute for the control of an inland brine spring in the Illyrian hinterland. In these passages, they describe a rather unorthodox way to produce salt from a brine spring which deviates from the known process of solar evaporation of seawater (Alexianu, 2007; Carusi, 2008b):

> Among the Illyrians who are called Ardiaeans along the boundary between them and the Autariatae, they say there is a high mountain, and near to it a glen from which the water rises, not at all seasons but in the spring, in considerable quantity, which they take and keep under cover by day, but put in the open at night. After they have done this for five or six days, the water hardens and becomes very fine salt, which they keep especially for the cattle
>
> (Aristotle, de Mirabilibus Auscultationibus 138, transl. by Hett 1936)

> Now the Autariatae were once the largest and best tribe of the Illyrians. In earlier times they were continually at war with the Ardiaei over the salt-works on the common frontiers. The salt was made to crystallise out of water which in the springtime flowed at the foot of a certain mountain-glen; for if they drew off the water and stowed it away for five days the salt would become thoroughly crystallised.
>
> (Strabo, Geographica VII, 5, 11, transl. by Jones 1924)

A similar border dispute was mentioned by Tacitus (first century CE) between the *Hermunduri* and the *Chatti* in Germania:

> In the same summer [58 CE], a great battle was waged between the Hermunduri and Chatti, both attempting to appropriate by force a river which was at once a rich source for salt and the frontier line between the tribes. Apart from their passion for deciding all questions by the sword, they held an ingrained religious belief that this district was peculiarly close to heaven and that nowhere did the gods give more immediate audience to human prayer. Hence, by the divine favour, salt in that river and in these forests was not produced, as in other countries, by allowing water to evaporate in a pool left by the sea, but by pouring it on a blazing pile of trees, crystallization taking place through the union of two opposed elements, water and fire.
>
> (Tacitus, Annals XIII, 57, transl. by Jackson 1937)

Interesting is the way Tacitus describes how salt was produced by pouring brine on top of a burning pyre of wood as Pliny described the same technique:

> In Cappadocia too they bring water into salt pools from wells and a spring. In Chaonia there is a spring, from which they boil water, and on cooling obtain a salt that is insipid and not white. In the provinces of Gaul and Germany they pour salt water on burning logs.
>
> (In one part of the provinces of Spain they draw the brine from wells and call it muria.) The former indeed think that the wood used also makes a difference. The best is oak, for its pure ash by itself has the properties of salt; in some places hazel finds favour. So when brine is poured on it even wood turns into salt. Whenever wood is used in its making salt is dark. I find in Theophrastus that the Umbrians were wont to boil down in water the ash of reeds and rushes, until only a very little liquid remained. Moreover, from the liquor of salted foods salt is recovered by reboiling, and when evaporation is complete its saline character is regained
>
> (Pliny, *Naturalis Historia*, XXXI, 82-83, transl. by Jones 1963)

This technique of pouring salt water on burning logs may seem surprising at first. However, experimental research showed this was a valid method to produce salt (Hees, 2022). After the salt water was poured on top of the logs, the brine concentrated on its way down until it crystallised upon contact with the embers. At the end of the process, these salt crystals with a relatively high potassium content could then be collected from the ashes. Furthermore, there are clear indications that (a variant of) this technique was used to produce salt in the area of Franche-Comté (eastern France, near the Alps) from the Middle Neolithic onwards (Dufraisse et al., 2004; Weller, 2004a). For the sake of completeness, it should be mentioned that Varro (De re rus. I.7. 8) mentioned this technique, though quite inaccurate and incomplete, already a century earlier (Carusi, 2008b, 360).

In the same passage, Pliny mentions that the Umbrians in central Italy produced salt by boiling water with the ash of reeds and rushes. The same passage, though slightly more detailed, was narrated by Aristotle in the fourth century BC in a more extensive discussion on the reasons for the sea's saltness (Carusi, 2008b):

> In Chaonia there is a spring of brackish water which flows into a neighbouring river that is sweet but contains no fish. For the inhabitants have a story that when Heracles, on his way through with the oxen from Erytheia, gave them the choice, they chose to get salt instead of fish from the spring. For they boil off some water from it and let the rest stand; and when it has cooled and the moisture has evaporated with the heat salt is left, not in lumps but in a loose powder like snow. It is also rather weaker than other salt and more of it must be used for seasoning, nor is it quite so white. Something of a similar sort happens also in Umbria. There is a place there where reeds and rushes grow: these they burn and throw their ashes into water and boil it till there is only a little left, and this when allowed to cool produces quite a quantity of salt.
>
> (Aristotle, *Meteorologika* II, 3, 359a-b, transl. by Lee 1952)

Carusi (2008b, 361) doubts that the process described by Aristotle actually resulted in sodium chloride as reeds and rushes might not have been halophytic plants with a high salt content. Indeed, it is difficult to determine whether Aristotle described a way to produce salt or if he tried to make a certain point in his argumentation. Nevertheless, at the beginning of the same section, Aristotle does mention the production of salt by boiling water from a brine spring, which differs from natural evaporation through insolation.

From the passages above, it is clear that among ancient authors, there was some notion that different methods to produce salt existed in peripheral regions besides natural evaporation through insolation. Although the curious nature of the techniques (e.g. pouring brine on burning logs or mixing plant ashes with water) is mentioned, these sources lack the understanding of how these techniques could actually be used to produce large quantities of salt. Consequently, combining archaeological and ethnographical data is essential to grasp the ins and outs of the different artificial evaporation techniques.

3.5.2 Use of salt in the Roman world

In premodern societies, salt was omnipresent in all aspects of everyday life. However, as salt is invisible in the archaeological record, scholars heavily rely on ancient texts and ethnographical observations to study the role and function of salt in society. In Antiquity, various practical uses like food processing, animal husbandry, and deeper social and ritual aspects of salt have found their way into the works of several classical authors. In recent years, several excellent studies have been published discussing the use and role of salt in the ancient world (see Moinier and Weller (2015) and Tsigarida (2012b)). Therefore, only a summary of the most important aspects of salt has been included here.

3.5.2.1 Salt and food preservation

The use of salt is most commonly mentioned in the context of food preservation. In the absence of refrigeration, salt was the main preservative technique in ancient societies besides drying and smoking. Salt is a good preservative because it generates a high osmotic (i.e. hypertonic) reaction. In other words, salt dehydrates the product and creates a hostile environment for bacterial growth that would cause spoiling (Thurmond, 2006; Kinory, 2012). In general, there are two approaches to salt preservation: placing the product in a deep coating of salt (dry curing) or immersing the product in a salt solution (brining) (Kinory, 2012).

In Roman times, the most frequently preserved meat product was pork, but other types of meat could also be dry-cured, brined or pickled (Thurmond, 2006). Wet brining would have been the preferred technique when salt was in short supply, but this method is only marginally mentioned in Roman sources. In these sources, most attention is paid to the dry-curing process of hams (Cato, Agr. 162; Columella DRR, 12.55). These cured hams were a coveted product, and several Gallic tribes (Insubrians, Comacine and Cuvarine) were known for their production (Thurmond, 2006; Kinory, 2012; Moinier and Weller, 2015). Particularly interesting are the Menapian hams which are mentioned by Martial (ep. 13.54) and appear in Diocletian Edict on Maximum Prices.

In the Mediterranean, the preservation of fish was more important than meat. Due to the cost and slowness of cartage, the vast majority of seafood would have been consumed as salted fish or fish sauce (Thurmond, 2006). Both salted fish (*salsamentum*) and fish sauces (*garum, liguamen, allec,* and *muria*) were manufactured in installations called *cetariae* or salteries. The production of salted fish and fish sauces are intimately linked as they can be seen as subsequent steps in the same 'industrial' process. Byproducts (small fish and innards of large fish) of the production of *salsamenta* were used to make *garum,* and *allec* was the residue consisting of the byproducts of *garum* production (Curtis, 1991, 2005; Thurmond, 2006; Curtis, 2016). Archaeologically, several well-preserved *cetariae* are known from North Africa and the Iberian Peninsula. As discussed in section 2.4.1.2, fish sauce in northern Gaul was initially imported from these Mediterranean production centres, but from the second century CE onwards, more local alternatives also emerged.[15] Besides the large quantities of salted meat and - fish, several ancient texts describe methods to cure and pickle vegetables and dairy products (Thurmond, 2006; Moinier and Weller, 2015)

3.5.2.2 Various other uses of salt

The use of salt in medicinal recipes to cure small ailments is exclusively known from historical sources. In these sources, salt is listed as an ingredient in various remedies to alleviate dermatological, gastroenterological and rheumatological complaints. In addition, salt could have been used for wound cleansing as the same antibacterial action responsible for food preservation could have prevented infection (Kinory, 2012; Moinier and Weller, 2015). Furthermore, salt served an important role in daily ritual practices as it was an indispensable ingredient of the *mola salsa*, a mixture of coarse flour and salt, which was commonplace during domestic and public sacrifices (Tsigarida, 2012b; Moinier and Weller, 2015). Last but not least, salt could have been used in various artisanal processes like leatherworking and metallurgy (Kinory, 2012; Moinier and Weller, 2015).

[15] For more information on *cetariae* and the production of fish sauce, see Curtis (1991, 2005, 2016)

3.5.3 Salt and the Roman economy

Pre-industrialised economies depended heavily on the exploitation of natural resources, and the access and control of these resources was therefore of crucial importance. In the case of salt, it is generally assumed that salt production and trade fell entirely under the control of the Roman state. This idea of a Roman salt monopoly, i.e. the exclusive right reserved by the Roman state to deal in salt, found its way into scholarly research (Cagnat, 1882; Rostovtzeff, 1902; Blümner, 1920; Pikulska, 2008). The existence of such a state monopoly, however, raises quite a few questions on the ownership and administration of salt production as well as on the role of taxation. These questions have been the topic of several studies. Unfortunately, the available evidence regarding the legal status of the salt pans and the role of the Roman state in the management of the resource is rather scarce to draw definitive conclusions on the matter (Ørsted, 1998; Carusi, 2008a; Pikulska, 2008; Tsigarida, 2012a, 2015). This section deals with the most important points of discussion and summarises the answers to questions such as who owned the salt pans, how the production was organised, etc. As will become clear later on, this is an incredibly complex, albeit very interesting, discussion. Nevertheless, a complete review of the evidence incorporating all sources falls out of the scope of this study.[16]

3.5.3.1 Ownership and exploitation of the salt works

In the case of Rome and the Roman empire, it appears evident from the historical sources that in the Republic, the state regulated the sale of salt (section 3.5.3.2). However, these sources provide very little information on the ownership and management of salt pans. A common-held idea is that all saltworks across the empire were considered the property of the Roman people, with the state entrusting their exploitation to *societates* through a lease system (Bekker-Nielsen, 2012; Marzano, 2013, 138-139). Indeed, multiple passages in the *Digest*, for instance, 39.4.13; 50.16.17.1; 3.4.1, refer to publicly owned *salinae* exploited by a *societates publicanorum*. However, as Ørsted (1998) pointed out, the public *salinae* mentioned in the *Digest* most likely refers to salt mines, and not marine salt pans. In addition, Ørsted (1998) assumes that salt extraction from the sea was free to everyone from a legal point of view, and therefore no state-owned salt pans could have existed. Carusi (2008a) contests this interpretation, believing that the Roman people, cities and private individuals could own salt works. As exemplified by the legal dispute between the citizens of Priene and the *publicani* at the beginning of the first century BCE, the status and ownership of the salt pans in the Roman provinces is complicated by the absence of a homogenous legal framework (Carusi, 2008a; Marzano, 2013, 138-140; Tsigarida, 2015). Furthermore, the available sources are often insufficient to address issues of ownership with certainty, and as a consequence, the question of ownership is either hypothesised or not addressed. Based on the arguments above, it is clear that the salt pans were clearly not always the property of the Roman people (Carusi, 2008a).

Regarding the exploitation of the salt pans, epigraphic data confirms the existence of a *societas salariorum* at Caralis (CIL I 2226) and at Minturnae (CIL I, 2691; 2693; 2698 and 2703) in the Republic period (first century BCE). These inscriptions indicate that until the end of the Republic, at least in Minturnae and Caralis, the right to exploit publicly owned salt pans was sold at auction to a *societas* (Carusi, 2008a; Cébeillac-Gervasoni and Morelli, 2014). According to Cébeillac-Gervasoni and Morelli (2014), *conductores* gradually took the place of the *societas* during the second century CE, as was the

[16] For the most extensive discussion on the role of salt in the Greek and Roman states see Carusi (2008a)

case for the *portoria* (customs duties). This is demonstrated by an inscription by two *conductores salinarum Romanarum* dated to 135CE. This inscription proves that the Roman state leased the salt pans' exploitation on the Tiber banks to private individuals. However, at the moment, the information is too sparse to draw definitive conclusions on how the leasing contracts for public salt works evolved. It appears that collective management by *societates* was gradually replaced by individual management by *conductores* (Cébeillac-Gervasoni and Morelli, 2014).

Besides the inscription from Rome, six *conductores* inscriptions (CIL III, 1209 and 1363, ILD 804; IDR 3.4.248; AE 2005, 1296) are known from Roman Dacia. These inscriptions are dated at the end of the second – early third century CE and have been discussed by Tsigarida (2012a) and Mihailescu-Bîrliba (2016). Mihailescu-Bîrliba's paper focuses more on the freedmen and slaves who erected the inscriptions, while Tsigarida's paper discusses the role of the *conductores* in the salt production system of Roman Dacia. From these inscriptions, it is evident that the Roman state owned the salt mines in Dacia and auctioned the exploitation rights to the highest bidder for a fixed period of time. These individuals or *conductores salinarum* had to be members of the local elite or at least of certain social standing as they could pay the levies on the lease (Tsigarida, 2012a; Mihailescu-Bîrliba, 2016). However, though there is no direct evidence, Tsigarida (2012a) considers it likely that the *conductores*, in turn, leased the exploitation to (several) smaller subcontractors tasked with the salt extraction. Yet, it is equally possible that the *actores* (freedmen and slaves), who dedicated the inscriptions and were in charge of the day-to-day business, oversaw the production (Tsigarida, 2012a).

The abovementioned inscriptions suggest that the Roman state quite often chose to exploit the resources indirectly through a lease system under the supervision of the provincial *procurators*. This leasing system guaranteed the state a fixed revenue while reducing the risks and saving the costs of organising the exploitation. As the share for the state was fixed, the leaseholders could turn a substantial profit by increasing the productivity or collecting more 'rent' (Tsigarida, 2012a). Similar to the tax-farming contracts, Augustus' administrative reorganisation might have changed the nature of the lease from a fixed sum to a percentage of the acquired revenue (Günther, 2016; Gutiérrez and Martínez-Esteller, 2022). Naturally, the direct or indirect system described above only applies to salt pans owned by the Roman people/imperial government or cities. The privately owned salt pans would have to organise the production themselves, and could have paid some form of tax similar to the tax rates on privately owned agricultural land (Kehoe, 2013).

Following Carusi (2008a), some caution is required about seeing the ownership and the exploitation of the salt pans in a uniform way throughout the empire and under the control of the Roman imperial government. Local traditions, production mechanisms, and jurisprudence might have impacted how production was organised, and significant differences could have existed between provinces. As addressed in the beginning of this section, the available sources are often insufficient to address issues of ownership with certainty. Especially in the western provinces evidence is practically non-existent.

3.5.3.2 Salt trade in the Roman Empire

According to Livy (I.33.9), king Ancus Marcius constructed and exploited the first salinae on the banks of the Tiber. Subsequently, he (II.9.6) describes how at the start of the Republic, the salt trade was taken out of the hands of private individuals and put under state supervision. Pikulska (2008, 368) believes this passage should be interpreted as the introduction of a state monopoly on the salt trade. However, both Carusi (2008a, 200) and Bekker-Nielsen (2012) agree that this passage may be a backward projection of later events and that it is rather unlikely that the city of Rome already introduced a monopoly on the sale of salt in the sixth century BCE. In another passage, Livy (IXXX.37.3) describes how in 204/203 BCE the censors *M. Livius Salinator* and *C. Claudius* introduced a vectigal on the salt trade by contracting out the right to sell salt to private individuals. Through this leasing system, the state controlled the salt price and stipulated that the salt had to be sold at a low, fixed price in Rome but at a different, higher price in the surrounding territories (Cagnat, 1882; Ørsted, 1998; Carusi, 2008a, 199-202; Pikulska, 2008).

According to Carusi (2008a, 201), the censors did not introduce this leasing system but only a new vectigal, which suggests that the state already controlled the wholesale trade of salt before the end of the third century BCE. This vectigal (so-called indirect tax)[17] on the sale of salt was also recorded by Cassius Dio (Fragm., 57.70), who added that prior to the censors' decision salt used to be exempt from tax (Carusi, 2008a, 201; Pikulska, 2008). In relation to this vectigal, the reference of Servius Auctus (ad Verg., Aen. 4.244), quoting Cato the Elder, on the *salinatores aerarii* is worth mentioning (Will, 1962; Chevallier, 1991; Ørsted, 1998). Ørsted (1998) believes that these *salinatores aerarii* enforced the state monopoly by purchasing salt from the producers on behalf of the state and organising its sale. In the process, they could then collect the taxes (vectigal) on that sale. Blümner (1920) suggested that the decision to sell salt at a variable price outside the city of Rome was made purely for economic reasons as from the third century BCE onwards, the gradual expansion of Roman territory made a fixed salt price impossible to maintain. The legally diverse nature of the provinces and the vastness of the Empire are also the main reasons for Cagnat (1882) to assume that, at a certain point, the monopoly on the salt trade gradually loosened. Carusi (2008a, 201-202) supports this view and believes it improbable that the salt trade monopoly was maintained during the Principate, if such a monopoly existed in the first place.

While it is true that there is little or no evidence for a state monopoly on the salt trade in imperial times, the salt merchants' association of Tebtunis (P. Mich V, 245) is often put forward to suggest a continued state monopoly in Roman Egypt[18] (Boak, 1937). However, as Broekaert (2019) rightly pointed out, the text does not explicitly state that the association had obtained the sole right to sell salt in *Tebtunis* from the imperial government. The text only reads that the association's president collected from its members the levies to be paid that year for exercising their trade (Carusi, 2008a; Broekaert, 2019). Broekaert (2019) believes that the government only granted the merchants' association a concession or license to sell salt in *Tebtunis* and the surrounding villages, not monopolistic rights. Interestingly, the merchants' association collectively tried to manage the distribution of the resource by setting minimum prices (Table 6) and by granting members the sole right to sell salt in a certain area to avoid competition among its members (Boak, 1937; Carusi, 2008a; Broekaert, 2019). The amount the salt merchants of *Tebtunis* paid for their concession in 45/46 and 46/47 CE was registered in the list of deeds kept in the village registry office (P. Mich. II 123; P. Mich. II 128). In addition to the association of *Tebtunis*, the list also mentions several other associations of salt merchants active in neighbouring towns (Boak, 1937; Carusi, 2008a; Adams, 2013). As indicated by several other papyri, for instance, P. Oxy. LIV 3734 and P. Oxy. LIV 3750, associations of salt merchants

[17] On taxation during the Roman Principate, see (Günther, 2016; Gutiérrez and Martínez-Esteller, 2022)

[18] Several papyri, for instance, P. Tebt. III 732, indicate that in pre-Roman, Ptolemaic Egypt, the royal administration not only auctioned the right the sell salt to individuals but also had some form of control over the production (McGing, 2002; Adams, 2013, 272). Yet, recently, Dogaer (2021) suggested that caution should be exercised considering the existence of monopolies in Ptolemaic Egypt.

remained actively involved in the salt trade in Roman Egypt throughout the imperial period (Carusi, 2008a).

These documents show that in Roman Egypt, the right to sell salt was granted in concession to associations of salt merchants for which they paid a *phoros* or tax. Therefore, Broekaert (2019) believes that the concessions granted to the merchants should be seen as nothing more than a means to facilitate tax collection on the sale of salt. A tax on salt is also mentioned in a decree of the city of *Caunus,* which stipulated that the 'taxes received from salt shall remain at their current rate'. As *Caunus* was a free *civitas* at that time, the tax on salt was clearly a municipal tax that the city collected for its own benefit (Carusi, 2008a; Marzano, 2013). Similarly, an inscription (CIS II 3913; IGR III 1056) from *Palmyra* containing a list of tax provisions indicates that the city collected a tax on both the production and trade of salt (Carusi, 2008a).

As already stated, none of these sources confirms an empire-wide monopoly on the salt trade during imperial times. Such monopoly would be almost impossible to maintain. Yet, the abovementioned sources may point to the existence of some form of tax on salt that was either collected by the state (in the case of Egypt) or by the cities (in the case of *Caunus* and *Palmyra*). Although Carusi (2008a) does not believe that tax measures affected the salt trade at the provincial or inter-provincial level, it seems unlikely that the Roman state did not try to obtain some form of revenue. In the late Roman period, traces of active state involvement can be found in the imperial constitution issued by emperors Arcadius and Honorius in the late fourth century CE (Pikulska, 2008). This passage (Cod. Iust, IV, 6, 11) stated that the salt produced in privately owned salt pans could only be sold in the commercial circuit through the mediation of the contractors who managed the state-owned salt pans (Carusi, 2008a; Pikulska, 2008; Saile, 2015).

Table 6 Known prices of salt in the Roman imperial period (after Stockinger (2015))

Date	Source	Place	Commodity	Amount	Litres	Price	Asses	Asses/L	Annonation
47 CE	P. Mich. V 245	Tebtunis	άλς καλός	1 metron	ca. 3.9	2 obols 4 chalci	1 2/3	ca. 0.43	min. price
47 CE	P. Mich. V 245	Tebtunis	άλς λξπτός	1 metron	ca. 3.9	2 obols	1 1/3	ca. 0.34	min. price
47 CE	P. Mich. V 245	Tebtunis	άλς λξπτότξρος	1 metron	ca. 3.9	1 obol 4 chalci	1	ca. 0.26	min. price
111 CE	Tab. Vind. 186	Vindolanda	sal	≥ 85 pondera	ca. 23.2	≥ 2 asses	≥ 2	ca. 0.52	purchase by soldier through Audax
150-199 CE	SB XIV 11960 col. 1	Oxyrhynchites	άλς	2 metra	ca. 7.8	2 drachmas 2 chalci	4 1/6	ca. 0.53	estate's account
258-259 CE	P. Lond. III 1170 verso col. 3	Theadelphia	άλς	1 metron	ca. 3.9	1 drachmas	2	ca. 0.51	estate's account
301 CE	Edict. Diocl. 3.8	Roman Empire	sal	1 castrensis modius	ca. 11.6	100 denarii communes	-	-	max. price
301 CE	Edict. Diocl. 3.9	Roman Empire	sal conditum	1 sextarius	ca. 0.5	8 denarii communes	-	-	max. price

Although information about the economic value of salt is limited, several sources state the price at which salt was sold in parts of the Roman Empire (Table 6). However, these sources should be treated with caution as they only provide a snapshot of the salt price in a particular time and area. As such, these salt prices are just numbers unless they can be compared to the price of other resources in the same area. Luckily, a contemporaneous, first-century papyrus (P. Mich. II 127) allows the price of salt to be compared to other goods such as grain (2.4 times the price of salt) (Stockinger, 2015). Similarly, in addition to the price of salt, Diocletian's price edict mentions the maximum price of other resources such as grain as well as skilled labour. Interestingly, at the start of the fourth century, the maximum price of salt and grain was the same (Stockinger, 2015). These sources suggest that salt prices were modest throughout the imperial period. This is not surprising since salt was integrated in several aspects of everyday life and therefore had to be accessible to all regardless of their standing in society. In Roman Egypt, the salt trade was organised by several *collegia* of salt merchants who were granted a concession by the state to sell salt in certain areas (Boak, 1937; Carusi, 2008a). Whether this system was also used in the rest of the empire is difficult to ascertain based on the current data.

3.6 Medieval salt production in the Low Countries

After a short interlude in the late Roman period, three historical mentions, dating to 776, 877, and 897, indicate that salt production resumed in the Low Countries in the early Middle Ages. The oldest one concerns the donation by a certain Godebert of a dependent farm (*mansus*) with its attached lands, a church, a dependent family, and seventeen *culinas ad sal faciendum* to the abbey of Lorsch. This estate was located on the island of Schouwen (Zeeland) between the river Scheldt and the 'Zonnemare'. The exact meaning of the term '*culinas*' is unclear, but it most likely refers to installations that were used to produce salt from peat. The number of installations seems to suggest that, already in the early Middle Ages, salt production took place on a considerable, almost industrial, scale on Godebert's estate. Similar to the abbey of Lorsch, the abbey of Saint Getrud in Nivelles (central Belgium) owned in 877 *in Frisa terram et mancipia ad salem*, which was confirmed in 897 as *in Fresia terra ad sal acquirendum*. Again, the exact meaning of these passages is unclear, but they seem to suggest that the abbey of Nivelles owned in Dutch Zeeland several holdings which produced salt (Verhulst, 2002, 80-81; Leenders, 2004).

Despite the fact that historical sources confirm its existence, little or nothing is known about the early medieval salt production process. Based on later historical sources, it is generally assumed that salt-impregnated peat was used to produce salt (van Geel and Borger, 2005; Leenders, 2007, 2010). In Dutch literature and historical sources, these high-salinity peat deposits used in salt production are often called *darink,* and the extraction is described as *darinkdelven*. When referring to the process of producing salt from peat, the term *selnering* is often used. The most extensive description of this *selnering* process is provided by Leenders (2001, 2004, 2007, 2010), for which he combined early modern sources, for instance, Agricola (1556), van Boxhorn (1644) and Brownrigg (1748), as well as iconographic sources like the painting 'Darinkdelven' from Zierikzee (Figure 36).

The first step of the salt production process consists of collecting the salt-impregnated peat. Leenders (2010, 9-13) describes several ways of how *darink* was extracted in both the embanked area and the area outside the dikes. Next, the *darink* was dried and burned to ash (zel). A brine was produced by mixing the ash/*zel* with (salt) water in a barrel, which was then boiled indoors in large lead or iron pans until the salt crystallised (Leenders, 2007, 2010). Lead evaporation pans are known from Britain (McNeil, 1983) and France (Carpentier et al., 2012, 168-175), but in the Low Countries, most likely iron pans were used. Unfortunately, the dimensions of these iron pans are not specifically mentioned in the medieval sources. Yet, early modern sources indicate that the size of the pans might have steadily increased over time (Leenders, 2007, 2010).

Van Dam (2006, 94) suggested that in the area of Tholen initially, prior to the 14th century, the *zel*- and salt production were spatially and economically linked, i.e. smaller salt farms carried out both the *zel* and salt production at the same site. They extracted the necessary darink from their own property within an embanked area to produce salt. Various 13th century prohibitions by, amongst others, the counts of Flanders on *darink* extraction within embanked areas confirm that *darink* extraction definitely took place at such locations (Leenders, 2010, 43-45). From the mid-14th century onwards, Van Dam (2006, 94) observed a spatial separation of *zel* and salt production activities, with the *zel* manufactured in the area outside the dikes and the salt produced in the cities. Van Dam's interesting hypothesis is not entirely supported by Leenders (2007, 2010), who assumes that the *zel* and salt production were already separated prior to the mid-14th century. This hypothesis requires further investigation, but one does not exclude the other, and both systems may have coexisted for some time.

Figure 36 Eighteenth or nineteenth century copy of the sixteenth century painting darinkdelven depicting the first stages of the medieval salt production process: collection and production of zel by burning of salt-impregnated peat. In the background the salt houses are visible in which the brine was evaporated (© Zeeuws Museum).

Undeniable is that from the 14th century onwards, salt production using *zel* took place in several cities in the county of Flanders, the county of Holland and Zeeland and the duchy of Brabant. The transport of *zel* to the cities and the taxes on this product are well documented in company and toll bills, for instance, the moerneringsrekening of Puttermoer (van Dam, 2006; Leenders, 2010). Based on the historical sources, it seems that salt production from *zel* flourished in the 13th and 14th centuries. From the middle of the 15th century, all salt producers in the cities gradually switched from salt production using *zel* to the refinement of French and Portuguese bay salt, i.e. solar-evaporated sea salt (De Kraker, 2007; Leenders, 2007, 2010). The exact reason is still debated, but most likely, this transition was caused by a combination of several factors, like the impact of large-scale peat extraction on the landscape and the cheap import of coarse sea salt from the south of France. The refinement of solar-evaporated sea salt is not unique and occurred in northern France from the 13th century onwards (Louis and Bernez, 2017). During this refining process, the impure coarse, grey Atlantic salt that nobody wished to consume was transformed into fine, white salt, which was more favourable for both consumption and the herring industry (De Kraker, 2007; Louis and Bernez, 2017). Most of the area's historical sources concern the refinement of salt in the 15th and 16th centuries. The number of cities involved in the production and the number of salt houses that are mentioned indicates that this was a massive industry of which very little is known. An excellent overview of the rise and fall of the salt cities in the Low Countries in the 15th and 16th centuries was published by De Kraker (2007).

As the abovementioned text indicates, the medieval salt production industry is primarily known from historical sources. Only recently, Malta-driven rescue excavations provided the first archaeological data of medieval salt production activities in several of the salt cities, for instance, Biervliet (D'hondt, 2011; van den Bosch and Ras, 2017), Vlissingen (de Boer et al., 2010), Tholen (Mientjes, 2015) and Hulst (Depuydt, 2009). It is not our intention to discuss the results of these excavations in detail here, but it is striking that the archaeological knowledge remains fairly limited. Quite often, the only archaeological features are thick layers of *zelas*, interpreted as refuse layers containing the insoluble ash, sediment and impurities removed from the salt pans (Leenders, 2010). Only at Hulst and Tholen, traces of heating structures and brine storage pits have been discovered (Depuydt, 2009; Mientjes, 2015). Building plans of so-called salt houses are yet to be found. Nevertheless, more archaeological data gradually emerges which will enable more detailed reconstructions of the salt production process in the future.

3.7 Summary

On Earth, salt occurs naturally in seawater and underground salt deposits. These inland deposits were accessible directly through mining or indirectly in the form of saltwater springs. Salt can be extracted from these saline liquids (seawater and brine springs) through evaporation which either occurs naturally through insolation or artificially through fire. However, technically speaking, a wide array of chemical ionic compounds can be called salts. As such, seawater contains a variety of dissolved salts which do not precipitate haphazardly from a (super)saturated state but follow successive crystallisation paths based on their solubility (Babel and Schreiber, 2014). This sequence of salt mineral crystallisation is well known and first carbonate minerals like calcite or dolomite will precipitate, followed by gypsum and finally halite (NaCl). After halite, the dissolved K-Mg salts (epsomite, kainite, sylvite etc.) will successively crystallize, but their exact sequence may vary depending on the environmental conditions (Babel and Schreiber, 2014).

The easiest way to obtain salt from saline solutions is by natural solar evaporation in man-made structures, often termed salinas or *salinae*. To this day, salinas mainly occur in areas with a dual seasonal pattern characterised by warm, dry summers with abundant hours of sunshine, sufficiently high temperatures and a strong, dry wind regime (Gauci et al., 2017). In the Roman Mediterranean, salt was produced in such *salinae,* whose occurrence is mainly known from historical sources (Carusi, 2008b). Unfortunately, these structures leave little archaeological traces and the first Roman saltworks were only discovered fairly recently (Currás, 2017). In large parts of Europe, climatological conditions prevented natural evaporation through insolation and salt was extracted by artificially heating the brine in evaporation vessels above hearth-like structures. Yet, in practice, the production of salt is a complex affair and generally speaking, salt production consists of six stages in which the salt producers are presented with a series of choices that shape the overall *chaîne opératoire*: 1) raw material procurement; 2) preparing the site; 3) preparing the production activities; 4) salt crystallisation and drying; 5) transport and consumption and 6) debris deposition. The variety of choices reflected in the archaeological record also explains how regional salt production traditions developed over time.

In the Roman world, salt was integrated into all aspects of life. It was not only used to preserve food but was an integral part of artisanal processes, medicinal recipes and ritual practices. In the past, it was generally assumed that all saltworks across the empire were the property of the Roman people and that their exploitation was entrusted to *societates*. However, based on the available evidence, Carusi (2008a) believes that the Roman people, cities, and private individuals could own the saltworks. Epigraphic data confirms that, until the end of the Republic, the right to exploit the publicly owned salt pans was leased to *societates*. How long these *societates* remained active is unclear, but from the second century CE onwards, *conductores* or private individuals took their place. In other words, collective management by *societates* was apparently replaced by individual management by *conductores* (Cébeillac-Gervasoni and Morelli, 2014).

The historical sources also suggest that in Republican times the state took measures to control the salt price by leasing the right to sell salt to private individuals. This *de facto* monopoly on the sale of salt was introduced prior to the end of the third century BCE. Most scholars agree that the gradual expansion of the Roman territory made fixed salt prices impossible to maintain and that such a strict monopoly was not long-lived (Carusi, 2008a). As evidenced from Roman Egypt, it is possible that the Roman state auctioned off concessions with the right to sell salt in certain areas to merchants associations. However, this might have been a way to rationalize tax collection rather than granting monopolistic rights (Broekaert, 2019). Besides the *vectigal* on the sale of salt introduced by censors *M. Livius Salinator* and *C. Claudius* at the end of the third century BCE, there is very little information on potential taxes on the production and sale of salt. Some form of tax may have existed in certain parts of the empire, but it is unclear whether an empire-wide tax existed during the Principate. In other words, collective management by *societates* was apparently replaced by individual management by *conductores.*

Part 2 Salt production in the Menapian *civitas*: facts and figures

Chapter 4 Settling the Salinaria? Evaluating site location patterns of Iron Age and Roman salt production in northern Gaul.

The content of this chapter has been published as:

Dekoninck, M., De Clercq, W. (2022). Settling the Salinaria? Evaluating site location patterns of Iron Age and Roman salt production in northern Gaul. In D. Van Limbergen, D. Taelman and A. Hoffelinck (eds.), *Reframing the Roman Economy – New Perspectives on Habitual Economic Practices*. Cham: Palgrave McMillan, 267-303.

4.1 Introduction

Even though the importance of salt has diminished in our present-day society, researchers still contemplate its role and function in ancient societies and their economies. This should not come as a surprise given the vital character salt represents for human life and its multifaceted use in cooking and crafts (e.g. metallurgical processes, tannery). Moreover, several classical sources mention the symbolic and ritual aspects of salt as well as its medicinal effect.[1] However, more importantly, salt was the preferred preservative of pre-modern societies, enabling them to stock up on winter supplies, prepare provisions for military campaigns and transport perishable products over long distances. For example, the salting of the Menapian hams allowed their transport from northern Gaul to Rome, as indicated by Martial (Epig. 13.54) and Diocletian's Price Edict (*Edictum de pretiis rerum venalium* 4.8) (Carusi, 2008a, 15-44; De Clercq, 2009c; Kinory, 2012; Tsigarida, 2012b; Moinier and Weller, 2015). This ubiquitous and vital character paradoxically opposes the limited accessibility of the resource as it only occurs in seawater, inland brine springs or geological layers (Chapter 3) (Harding, 2013, 21-26). This limited access made salt a highly sought-after commodity of which the exploitation and trade were often controlled by the state, elites or specific groups within society. They ensured a local supply for its inhabitants and the military apparatus, but also used salt to acquire and maintain wealth and status as illustrated by many societies throughout the world and time. For instance, the importance

[1] For a detailed overview and references regarding the use of salt in Antiquity, see Carusi (2008a, 2008b), Kinory (2012), Tsigarida (2012b), and Moinier and Weller (2015, 153-248).

of salt for Roman society has been widely demonstrated by archaeological and historical research (Carusi, 2008a, 2008b; Tsigarida, 2012b, 2014b).

This chapter aims to assess the various aspects of pre-Roman and Roman salt-making at the most northern fringes of the Roman Empire. Indeed, with the contrasting context of unfavourable climatic conditions for natural evaporation on the one hand and a huge demand for salt from the nearby Rhine-legions on the other hand, this region offers an interesting potential to assess the transformations in *chaîne opératoire* and exchange and consumption mechanisms from the Iron Age into the Roman period, and the integration of the craft in the Roman economic and social networks. Furthermore, this chapter discusses how the location of the salt production sites evolved from the early Iron Age until the late Roman period[2] in the coastal area of northwestern Europe between rivers Rhine (NL) and Somme (FR).[3] Finally, these site location patterns will be explained in a broader socio-economic context.

4.2 Salt production landscapes in northern Gaul (ca. 800 BCE – 400 CE)

Before providing a more detailed discussion on the economic aspects of salt making along the most northern continental shores of the Roman Empire, the spatial distribution of the production sites (excavated as well as prospection sites) in the coastal landscape is assessed through time. Even though large-scale infrastructural developments (the harbour extension of Zeebrugge, the construction of the A16 highway etc.) might positively affect the number of sites in a specific area, a picture of distinct productive landscapes appears despite the environmental challenges of working in a dynamic, often hostile, environment influenced by the tides. Within the coastal zone, several clusters of production sites can be found which seem to have shifted in location through time.

In the early Iron Age, the first salt production sites started to appear along the coast of northwestern Europe (Figure 37a). With the exception of Vignacourt (FR) (Prilaux, 2000a), the sites seem to cluster around the estuary of the Rhine. Van den Broeke (1986, 1995a, 1995b, 1996) was the first to study these sites and concluded that, based on the presence of solid briquetage elements, salt was produced by artificially heating brine in pottery vessels (the so-called briquetage technique) which was then dried in semi-cylindrical vessels and transported to the hinterland. Since then, new sites (e.g. Den Haag-Wijndaelerplantsoen (NL) (Stokkel, 2012)and Den Haag-Wateringseweld (NL) (Siemons and Bulten, 2014)) have been discovered, confirming van den Broeke's assumptions. However, it should be noted that the cluster primarily represents older excavations which are not always securely dated. Therefore, some sites may or may not have continued into the middle Iron Age. That being said, the wide distribution of coastally produced semi-cylinders, used to transport sea salt, in the hinterland (western Netherlands and the Rhineland) confirms the presence of salt production sites near the Rhine estuary in the early Iron Age (Van den Broeke, 1995a).

In the middle Iron Age, salt production near the Rhine continues, but new types of salt containers start to emerge, indicating a slight shift in production technique. The semi-cylinders are replaced by a variety of forms characterised by their thickness and larger volume (van den Broeke, 1986).

[2] Iron Age: early (800-475/450 BCE), middle (475/450-250 BCE) and late (250-57 BCE). Roman period: early (57 BCE – 69 CE), middle (69 – 276 CE) and late (276-410/476 CE).

[3] The dataset of this chapter has been included in APPENDIX 1.

Gradually, a second group of production sites appears along the coasts of Belgium and northern France, specifically near the rivers Canche and the Somme (Figure 37b).

At the end of the middle Iron Age, a new type of heating structure emerged in northern France. This heating structure, characteristic of late Iron Age salt production, can be described as a rectangular hearth with a griddle (*fourneau à grille*) on top of which containers for boiling brine into salt were placed. The dimensions of these hearths suggest a huge increase in production capacity (Masse and Prilaux, 2016, 2017). So, while salt production dwindles and disappears near the Rhine, production will boom in northern France in the late Iron Age (Figure 37c). Specifically, the sites are found in the territory of the *Ambiani* near the estuaries of the Somme, l'Authie and La Canche. Most of these salt workshops are incorporated within an enclosure-type habitat and are closely related to habitation structures (Daire, 2003; Masse and Prilaux, 2016). Surprisingly, some salt-manufacturing sites with *in situ* heating structures (e.g. Arras Antiparc (FR) (Jacques and Prilaux, 2003) and Champagne Le Muid (FR) (Sarrazin and Louesdon, 2017)) can be found in the hinterland in other tribal areas. These sites are located far from the salt source and can perhaps be interpreted as sites where salt was refined and redistributed (Sarrazin and Louesdon, 2017, 101-102).

After reaching its heyday in the late Iron Age, production sharply declined at the beginning of the Roman period (Figure 37d). One can assume that the arrival of the Roman army severely impacted the production mechanisms, the elite networks and the existing trade relations and, thus, might have caused the production in northern France to collapse. In this area, only two new sites (Conchil-le-Temple (FR) (Lemaire, 2012) and Croixrault La Dériole (FR) (Duvette, 2017)) were founded in the early Roman (Augustan) period, after which salt production disappeared completely in the *civitas Ambianorum*. These sites, producing according to late Iron Age traditions supplemented with small innovations (e.g. the construction of the salt containers and the increased size of the heating structure), can be seen as the final stage of development within a large and old production area. Currently, no sites have been dated in the Claudian-Neronian or the middle Roman period in this area, suggesting that salt production came to an end.

In the middle Roman period, the number of salt production sites increased considerably (Figure 38a). These new sites are situated in and are largely confined to, the coastal area of the *civitates* of the *Morini* and *Menapii*. More than half of these sites are documented as prospection finds with little added context value except for their landscape position. However, the fact that multiple finds are made within a specific area does suggest the existence of well-developed salt production areas in Roman times (e.g. Bruges and Looberghe area). Unfortunately, these prospection finds often lack chronological markers making it difficult to incorporate them in more detailed chronological overviews. However, when considering only the excavated sites, a first surge of securely dated sites can be distinguished during the Flavian period (Figure 38b). These complexes are mainly found in the Bruges area (BE) and the nearby Zeeland Province (NL) to the north. Between 100-175 CE, salt production continued in the area, but the identified sites almost always have some form of chronological overlap with the previous and/or the later period, making it difficult to assess the production in this timeframe (Figure 38c). A second spike of well-dated production sites can be found in the late second - early third century CE (Figure 38d). Contrary to the Flavian period, these sites are less geographically clustered and more equally spread out across the Flemish coastal plain. This peak also represents the final stage of salt production in the area as no late Roman sites have been found to this day. This spatial-chronological pattern in Roman times corresponds well with the chronological evolution of general settlement density in the region, both in the coastal area as well as in the hinterland (De Clercq, 2011).

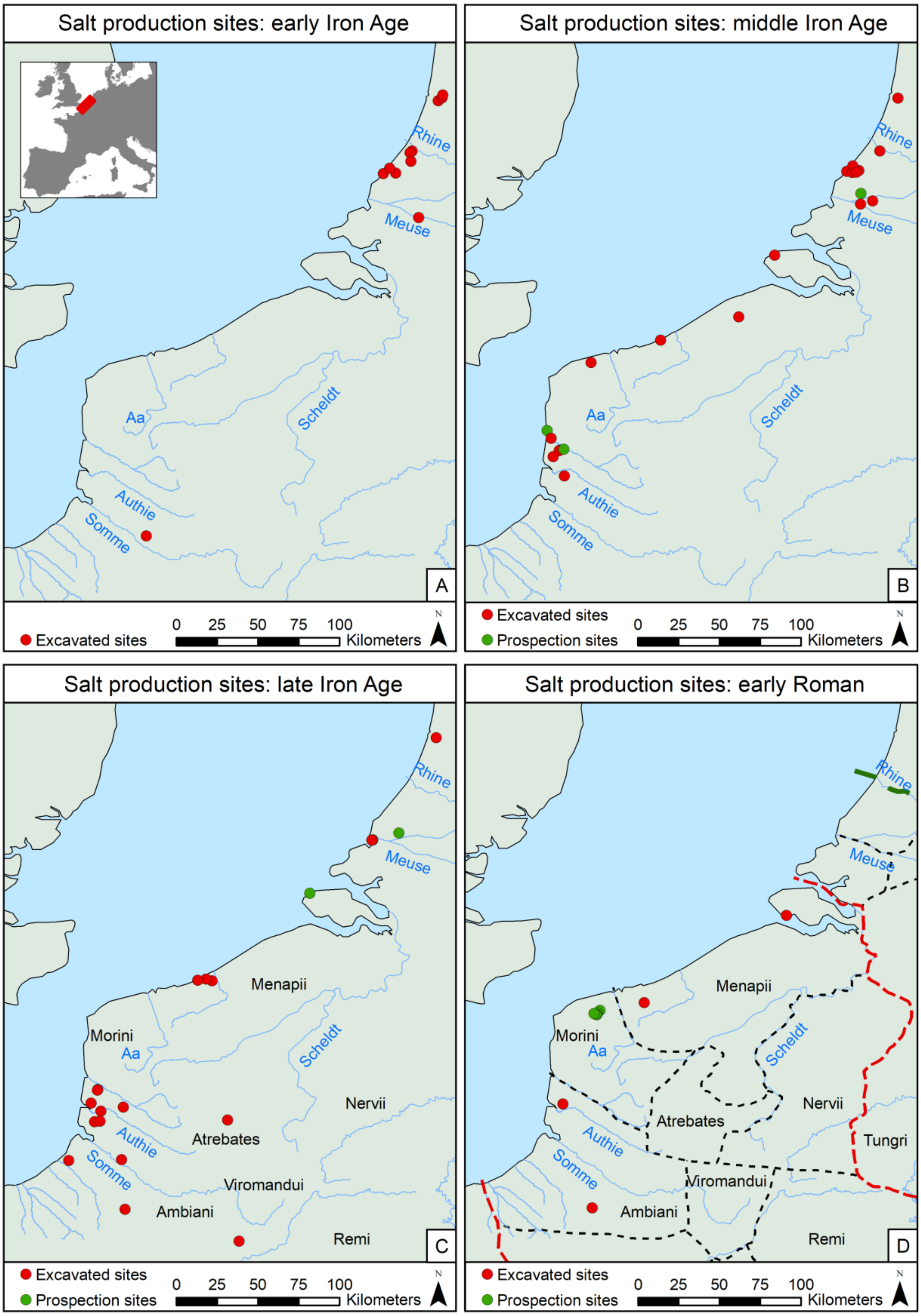


Figure 37 Chronological evolution of the salt production sites in northern Gaul with: A) early Iron Age B) middle Iron Age C) late Iron Age D) early Roman period

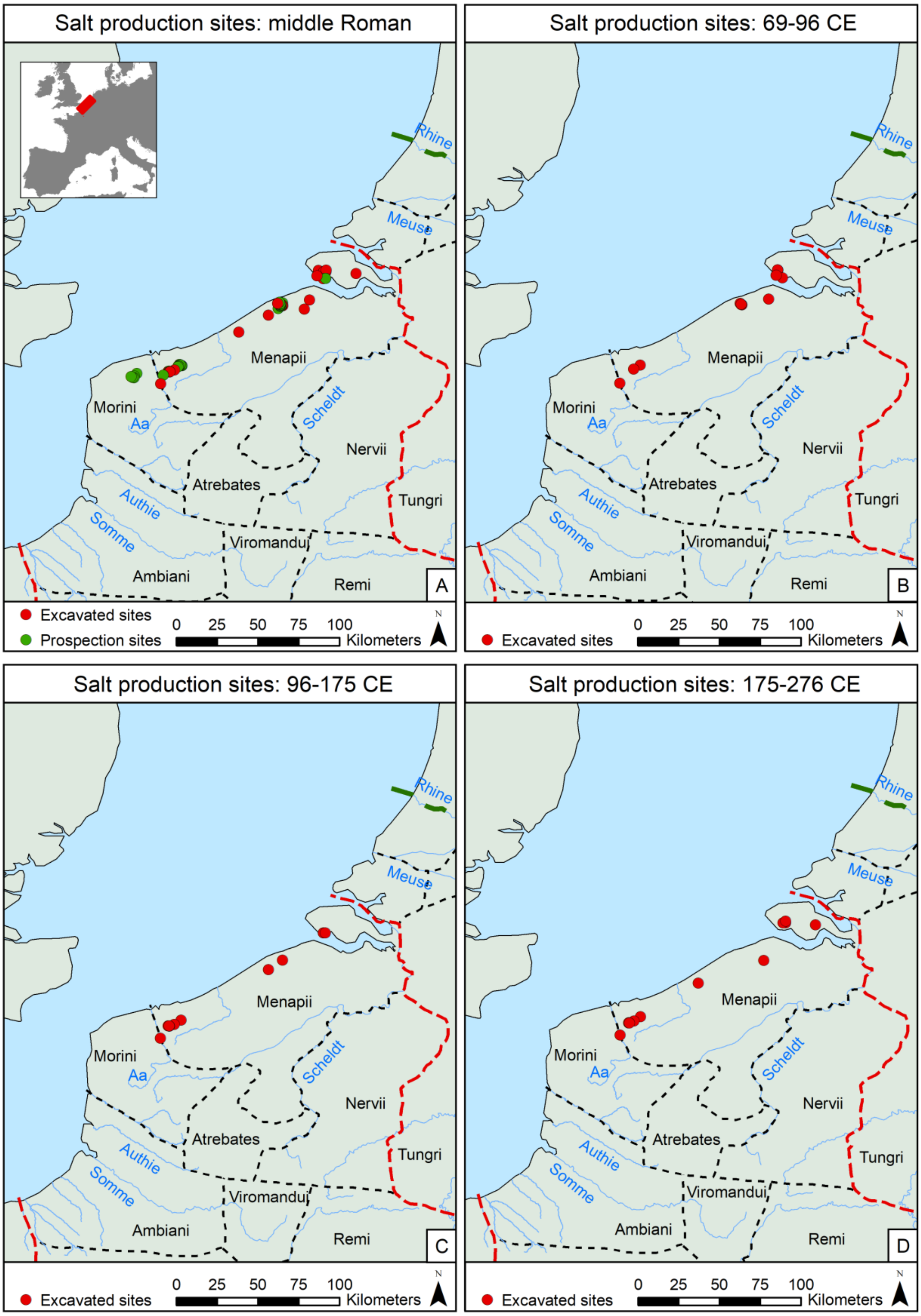


Figure 38 Chronological evolution of the salt production sites in northern Gaul with: A) middle Roman period B) 69-96 CE C) 96-175 CE D) 175-276 CE

4.3 The development of Iron Age and Roman coastal salt production

4.3.1 Early Iron Age salt production and gift exchange in the Netherlands

The discovery of the Hallstatt salt mine and the associated rich early Iron Age cemetery led archaeologists to believe that those who controlled the production and distribution of salt might have been able to acquire wealth which led to social differentiation observable in funerary practices (Harding, 2013, 99). Similarly, Roymans (1991, 49-54) suggested that the development of prestige burials such as the ones in Weert or Oss in the Lower Rhine Basin are connected to the production and trade of locally produced sea salt. He assumed that local elites in the Lower Rhine area might have controlled and centralised part of the salt surplus created in the coastal areas and distributed it as 'middlemen' to trade partners in the Upper Rhine area. Through these southern contacts, they became part of a larger exchange network which enabled them to acquire exotic prestige goods and consolidate their status in society (Roymans, 1991).

Even though van den Broeke (1986, 1995a) believes, as Roymans (1991, 49-54) suggested, that the elite controlled sea salt trade on a local or regional level, he is hesitant whether or not it gave these powerful groups the means to acquire prestige goods from Central Europe. The salt production waste in the Lower Rhine estuary (Figure 37a) was rather modest compared to contemporaneous inland European salt-producing communities, like the early Iron Age workshops in the Seille valley (FR) (Olivier, 2003; Olivier and Kovacik, 2006; Olivier, 2010, 2015; Riddiford et al., 2016). It is far more likely that the upper Rhine communities obtained the bulk of their salt from these inland production centres. In comparison, only small quantities of sea salt from the Lower Rhine were distributed to the hinterland as indicated by the distribution pattern of coastally produced semi-cylinders used to transport sea salt (Van den Broeke, 1995a, 2012). Whether or not the salt was traded or exchanged in the form of gift- or down-the-line exchange can be debated. Gift exchange relies on the reciprocal altruism principle in which resources, 'the initial gift', are shared with recipients with the expectation that on a non-fixed moment in time, a 'return gift' will follow. On the other hand, trade is based on the principles of supply and demand in which goods are exchanged immediately. Determining the exact nature of the exchange mechanisms at play here is extremely difficult as the ritualistic nature of gift exchange might have easily facilitated some form of trade between communities (Silk and Boyd, 2010; Carlà and Gori, 2014; Verboven, 2014). In any case, the lack of luxury goods in the coastal area suggests that the occupants did not acquire wealth through the exchange and might have used salt primarily to obtain basic resources such as querns or grain (Van den Broeke, 1995a, 151-153).

4.3.2 The emerging of a late Iron Age salt "industry" in northern France

In the early Iron Age, a productive landscape focused on salt production developed in the coastal Lower Rhine area. However, from the fifth century BCE onwards, the presence of coastal salt containers[4] in the hinterland dwindles, indicating a disruption in distribution mechanisms. Salt production in the western Netherlands did continue on a more domestic scale, but the salt was not

[4] The presence of coastally produced salt containers in the hinterland is used as a proxy to interpret salt trade and inland salt consumption.

distributed regionally and might have been used for local consumption only. Approximately at the same time (ca. 450 BCE), salt mining shifted from Hallstatt to the Dürrnberg (Hallein) region and more coastal as well as inland areas in western Europe started to engage in salt production using the briquetage technique (Kern et al., 2009; Harding, 2013). In doing so, the population, and by extension the La Tène elite, ensured themselves of a more local salt supply. The continuation of small production sites in the western Netherlands and the emergence of new sites along the coasts of Belgium and northern France (fig. 2b), dating to the early La Tène period, should be seen in this regard.

At the beginning of the third century BCE, new production mechanisms (e.g. rectangular heating structures with a griddle and large brine tanks) developed in northern France giving way to a more efficient and large-scale production process. In northern France, the oldest example of such a hearth with a well-defined water management strategy, has been found in Sorrus and dates to the first half of the third century BCE (Weller, 2000; Daire, 2003; Masse and Prilaux, 2016). This development partly coincides with the arrival of new exogenous populations (which are later called *Belgae*) originating from the other side of the Rhine. According to Fichtl (2003), these groups were installed in northern France at the end of the fourth, beginning of the third century BCE after a series of negotiations. However, this migration is primarily known through historical sources[5] and the archaeological impact has not yet been clearly established.[6] So even though a technological influx cannot be excluded, an autochthonous development from smaller pillar hearths is equally (perhaps even more) possible as similar narrow rectangular hearths started to appear along the Atlantic coast in the late Iron Age as well (Daire, 2003). In any case, this technological innovation had a huge impact on the *chaîne opératoire* of salt making, as from the third century BCE onwards, all salt production sites in northern France are characterised by a rectangular hearth with a griddle. Often, these hearths were situated within an enclosure-type habitat, but far from the dwellings on one of the extremities of the enclosure, indicating a spatial separation of craft and domestic areas within the same settlement (Masse and Prilaux, 2016).

Steadily the number of production sites further increased, reaching a heyday in the final stages of the late Iron Age (fig. 2c). The dimensions of the hearths and the brine tanks continued to increase as well, favouring the production output per site (Prilaux, 2000a; Masse and Prilaux, 2016). Remarkably, the production sites and the production technique using this specific type of rectangular hearths with griddle cluster in the tribal territory of the *Ambiani*. The development of such a productive landscape with a distinct type of heating structure suggests that the powerful *Ambiani* elite centralised and controlled the production in the coastal area.

A first argument in favour of this type of elite control might be the fact that the salt producers themselves did not seem to have had a privileged status and might not have benefitted much from the salt trade, despite the fact that salt was an important economic activity and was produced in technologically highly specialised sites. Practically none of the inhabitants on the production sites (Pont-Rémy, Sorrus, Rue, etc.) displayed their status through material and infrastructural wealth which deviated from other groups in society (Prilaux, 2000a, 94-95). Secondly, the production technique with this new type of heating structure was kept within the tribal area and did not spread to neighbouring production areas, for example, to the coastal area of the *Menapii* or the *Morini*. Some

[5] Caesar BG II.4.1-2

[6] Archaeological data (e.g. the distribution of a distinctive form of enclosed sanctuary from 250 BCE onwards) does however suggests a strong relationship between the *Belgae* communities differentiating themselves from neighbouring Gallic tribes, see Lamb (2018, 336-337)

indications for salt production along the North Sea coast do exists, but these are small-scale domestic sites producing salt with small pillar hearths. In other words, in the late Iron Age the production output in the tribal area of the *Menapii* and the *Morini* was rather modest compared to these large *Ambian* production centres. Thus, the local elite, who most likely regulated the salt trade from their oppida, probably benefited the most and part of their wealth can most likely be found in their characteristic sanctuaries, for example, at Ribemont-sur-Ancre. Unlike other coastal tribes, such as the *Menapii* or the *Morini*, the *Ambiani* also had their own coinage which could be seen as an expression of status and wealth (Delestrée, 1996; Fichtl, 2004).

4.3.3 An unexpected early Roman decline in salt production

In the second half of the first century BCE, the number of salt production sites in northern France drastically declined (Figure 37d). In the course of a few decades, the once so prosperous salt production area ceased to exist. Roughly at the same time, Saile (2015) noted a similar decrease in salt production in Central Europe (salt mining as well as salt evaporation) which comes as a surprise since the demand for salt would not have decreased.

An important factor might have been Caesar’s campaigns (58-52 BCE) in northern Gaul. The *Belgae*, *Ambiani* included, were quickly subdued in 57 BCE, but it took Caesar (BG II.4; III.28-29; IV.38; VI.5-6) several campaigns to defeat the *Morini* and *Menapii* as they used guerrilla warfare techniques and retreated constantly in their forests and marshes (Wightman, 1985, 26-39). Even though the archaeological record suggests a high degree of continuity in settlement and material culture, Caesar’s campaigns would have disrupted existing elite-exchange networks and the flow of commodities between communities. Also, some form of taxes (*tribute*) had to be paid to the Roman military apparatus (Wightman, 1985). While the impact of the Roman conquest on salt production in the tribal area of the *Ambiani* should not be underestimated, it was most likely not the only reason, and several other socio-economic factors could have contributed to its decline.

Under Augustus, two new sites were established in Ambian territory: Conchil-le-Temple(Lemaire, 2012) and Croixrault “La Dériole” (Duvette, 2017). These sites should be seen as native initiatives established according to late Iron Age production traditions. The design and layout of the hearth and water management structures are similar to the oldest examples of Sorrus and several other younger sites, such as Pont-Rémy and Rue. The only difference was probably the production output since the dimensions of the hearth and the brine tank in Conchil-le-Temple are much bigger (Prilaux, 2000a; Lemaire, 2012; Masse and Prilaux, 2016, 2017). So, despite a possible hiatus around the middle of the first century BCE, the sites continued to evolve towards larger production centres with a larger production output. It is unclear how long these sites remained operational. Yet, they are the last production sites in Ambian territory as no (other) new Roman sites were established south of the river Canche (Figure 38a). These sites can be interpreted as the last remnants of an ancient production during a time when the Roman authorities gradually increased their presence and control in the area.

Why the production paradoxically declined at a time when the Roman troops stationed at the Rhine caused an increased demand is unclear. In addition to the local residents, approximately 40.000 legionaries and 40.000 auxiliary troops needed a constant supply of salt to prepare provisions and to ensure successful military campaigns (Tsigarida, 2014a; 2014b, 70-71). According to Tsigarida (2014b, 2014a), local production centres could not meet this increased demand. Instead, long-distance trade in salt from the Mediterranean was probably established during the first half of the first century CE to ensure a continued salt supply to the Rhine legions. In the Mediterranean, salt was produced naturally by solar evaporation, which was cheaper and less labour-intensive than artificially heating brine using the briquetage technique (Carusi, 2008a; Marzano, 2013). While import from the Mediterranean cannot be disputed, some form of local production did still exist indicated by the production sites of Conchil-le-Temple and Croixault "La Dériole". Also, salt containers found in the Augustan military settlement of Kops Plateau in Nijmegen (Van den Broeke, 2013, 205; 2014) and large quantities in the Tiberian-Claudian ditched ceremonial enclosure of Tienen (Martens et al., 2002; Martens, 2012), point to some form of long-distance exchange networks and local production along the North Sea coast. The exact provenance of these salt containers has not yet been established. Both van den Broeke (2013) and Martens et al. (2002) suggested they were produced in the *civitas Morinorum* or *Menapiorum*. Some new production sites, such as Ardres (Florent and Cabal, 2004) and Steene (Faupin, 2017b), were probably established in this area in the early Roman period (Figure 37d), but unfortunately no heating structures have been found *in situ*.

Currently, few early Roman production sites have been discovered along the North Sea coast. Based on the number and distribution of sites attributed to the late Iron Age (Figure 37c) and the middle Roman period (Figure 38a), the observed decline in production sites might reflect a historic reality. That being said, the fact that the Roman coastline laid further seawards and that part of the production sites may have been eroded must be taken into account. However, it should be noted that in the early Roman period, the data suggest a shift in salt production from the territory of the *Ambiani* towards the *civitates* of the *Menapii* and the *Morini*. This shift coincides with major administrative reforms such as the introduction of self-governing civitates with fixed boundaries and an administrative apparatus (16-12 BCE), the introduction of a new taxation system, etc. (Aarts, 2000, 11-18; Carroll, 2001, 41-43; Raepsaet and Raepsaet-Charlier, 2013). Also, the consolidation of the Rhine limes after the disastrous campaign of Varus could have affected supply routes. A centralised production in the *civitas Menapiorum* and *Morinorum* might have been more cost-effective in the long run than long-distance transport.

4.3.4 A Flavian cluster of production sites in the northern Menapian coastal area

From the middle of the first century CE, salt production is situated in an entirely new area using different production techniques. The innovative late Iron Age large-scale hearths with a griddle from the *Ambiani* were abandoned, and production moved northwards where smaller pillar hearths were used. In the northern part of the *civitas Menapiorum* and, more particularly, in the Bruges area (BE) and Zeeland (NL), a distinct concentration of Flavian production sites can be found (see, Chapter 6) (Figure 38b). The similarities in briquetage pottery suggested that the multitude of prospection sites in the Bruges area had a Flavian date (Dekoninck, 2017), indicating intensive large-scale salt production over a wide area. Tsigarida (2014b, 2014a) connected this boost in local production with an increased military demand for salt from the troops stationed at the Rhine and a change toward cost-efficient local supply instead of long-distance trade. A close salt-based relationship between the Rhine army and the production sites seems well established, as exemplified by the Rimini inscriptions. This trade relationship is confirmed by unusually large numbers of Cologne colour-coated pottery found in Koudekerke and other salt-making sites (De Clercq, 2011).

As native groups were integrated into the Roman Empire, they were confronted with a *tributum* imposed by the Roman authorities. Initially, these newly formed *civitates* had different statutes (federate, free or tributary) with varying privileges, exempt from paying tax, external interference, etc. By the time of Tiberius, these titles were primarily honorific as tax privileges were abolished

(Roymans, 1996; Raepsaet-Charlier, 1998; Aarts, 2000). From the beginning, the *civitas Menaporium* and *Morinorum* were a *civitas stipendaria* and had to pay taxes. As multiple scholars have pointed out (Duncan-Jones, 1990; Roymans, 1996; Aarts, 2000; De Clercq, 2011), the contribution of the *civitates* was a combination of taxation in kind, money and/or levies for the army. Compared to the Batavian or the Nervian *civitates*, which were heavily taxed in manpower, the *civitas Menapiorum* paid their tribute largely in kind (Roymans, 1996; De Clercq, 2011). The *procurator Augusti provinciae* of *Gallia Belgica* collected this *tributum* and paid the army in *Germania Inferior* and *Superior*. In this regard, it is likely that the taxes from *Gallia Belgica* were primarily used to support the troops. Commodities such as wool, salted meat and dairy products from the sandy hinterland or salt produced in the coastal plain might have played a primary role in this transaction (Aarts, 2000; De Clercq, 2009c, 466-468; 2011, 238).

A close relationship existed between the Menapian and Morini *civitates* and the Roman army during the Flavian period. In a territory where a local epigraphical tradition does not seem to have been developed, the scarce written evidence sheds an important light on the salt-based relationship between the Roman army and the two *civitates*. In the well-known Rimini inscriptions (CIL XI.390; XI.391), the *salinatores* of the *civitates Menapiorum* and *Morinorum* honoured *Lucius Lepidius Proculus* of the Anienis tribe. *Proculus* enlisted as a soldier in *legio V Macedonia,* where he was promoted to a centurion and received the *dona militaria* in Vespasian's Jewish war (69/70 CE). After that, he transferred to *legio VI Victrix,* which was stationed in *Novaesium* (Neuss) on the Rhine under Vespasian. This legion was part of Cerealis's strike force that defeated *Iulius Civilis* in 70 CE. Subsequently, he was stationed with *legio XV Appolinae* and ended his career as *primus pilus* in the *legio XII Gemina* (Will, 1962; Thoen, 1986; Napoli, 2007; De Clercq, 2009c, 475-478). Thoen (1986, 24-26) rightly pointed out that the inscription must have been erected before 79 CE as Vespasian was not yet deified. The contacts between the *salinatores* and the centurion thus date somewhere between 70-75 CE.

As each legion could organise its own supply and supply routes, most scholars (Will, 1962; Thoen, 1986; Napoli, 2007; De Clercq, 2009c)[7] agree that *Proculus* was a provisions officer responsible for the legions', and by extension perhaps the Rhine army's salt supply. That is why *Proculus* might have been honoured by the *salinatores* who also benefited from their relationship. However, who exactly these *salinatores* were and what their precise role was has been endlessly discussed.[8] Thoen (1978a, 1986, 1987, 2000) always assumed the *salinatores* were salt producers. Napoli (2007) and, by extension, Marzano (2013) and Lowe (2018) follow this hypothesis and connect the *salinatores* to ownership of the salt works. They believe the *salinatores* were local operators who leased the exploitation of the stately or *civitas*-owned salt production centres.

This hypothesis has been disputed by Hocquet (1994) because, according to him, the nomenclature does not support the identification of *salinatores* as salt producers. He believes in a clear distinction between salt producers (*conductores* or *salarii*), merchants (*negotiatores*) and some sort of supervising officials (*salinatores*). The only other historical mention of *salinatores*, next to Livy's *vectigal* on salt (IXXX.37.3), is in a comment on the Aeneid by *Servius Auctus* (ad Verg., Aen. IV.244). He quoted Cato the Elder about *salinatores aerarii* as state tax officials collecting the recently imposed *vectigal* on salt (Will, 1962; Chevallier, 1991; Ørsted, 1998). Even though the meaning and function of the *salinatores* might have changed between the Republic and the Imperial period, Blümner (1920) and Ørsted (1998) agree that the *salinatores* were not mere salt producers but rather purchasers of salt or some sort of officials. Following Hocquet, De Clercq (2009c, 2011) interprets the first-century *salinatores* as a group

[7] Contra Hassall (1978) who supposes that Proculus was an official supervising the production

[8] For a summary of the discussion, see De Clercq (2009c, 475-478)

of officials operating on a *civitas* level who controlled the salt production and trade and collected part of the profits as a form of tax for the state treasury. The discovery of an altar in *Atuatuca Tungrorum* (Tongres) erected by *Catius Drousus*, a Menapian *sal(inator*?), might suggest that they were also involved in the salt transport and/or supply of the city's storehouse in the late second - early third century (Vanvinckenroye, 1994).

As taxes could partly be paid in kind, it is logical to assume that salt was used to fulfil some of the taxation burden. The salt, collected as tax, would have been transported to and used by the Roman army (Roymans, 1996; Aarts, 2000; De Clercq, 2009c, 2011). Each local government (*civitates*) was responsible for its own tax collection and might have leased the collection to private individuals. Perhaps these *salinatores* were private individuals (local entrepreneurs, local elite) who operated as tax leaseholders. They might not only have collected the salt that was due as part of the larger *civitas* tax, but they also might have organised the transport to the Rhine. It could explain the use of the older nomenclature and the close relationship with the army officials (e.g. *Proculus*).

Notwithstanding the fact that leaseholders could exploit the salt works, like in Asia minor (Tsigarida, 2015), it is unclear if this was the case in northern Gaul in the first century CE, as suggested by Napoli (2007), Marzano (2013) and Lowe (2018). The peripheral nature of the region, illustrated by a high degree of handmade pottery and few imports, indicates a slow and different adoption of (new) Roman ways of living in an agro-pastoral society (De Clercq, 2009c). On the other hand, veterans, having served as auxiliaries in the Roman army, would be more familiar with exploitation contracts. These veterans are sometimes seen as Romanisation actors and might have introduced and adopted a more classical Mediterranean way of thinking and living. They could therefore be involved in appropriating a leasing system (Derks and Roymans, 2006; Roymans, 2011). A leasing system, however, does imply that a form of collective ownership of the production centres existed at the state or *civitas* level which could be leased. Another option is that the government sold the right to produce salt in a certain area for a fixed period of time. Little evidence can be found in the area to confirm or refute ownership claims, but the nature of the production sites in the area (infra) might suggest the latter. Evidence remains scarce to draw definitive conclusions on the exact role of the *salinatores*. Either the *salinatores* were private individuals who leased the right to produce salt in a certain area and thus acted as *conductores* or they were tax leaseholders who collected salt as part of the larger *civitas* tax.

Irrefutable, however, is a Flavian boost in production sites in the northern part of the *civitas Menapiorum* (Figure 38b). Contact with the Roman army as established in the Rimini inscriptions, returning local veterans and/or a population created a larger market for salt. Internal (local population growth) and external demands (taxation, commodities for non-producers like the Roman army) perhaps forced the local inhabitants toward the opportunities - and thus the exploitation - of these so-called "marginal" regions such as the coastal wetlands. As the production sites cluster in a specific area, state involvement cannot be excluded. Yet, this does not necessarily equal state ownership of the individual sites. As few sites were thoroughly excavated and no *in situ* traces of heating or water management structures have been found, the exact nature of the production sites remains unclear. However, the archaeological study of the prospection finds and the study of some excavated refuse dumps does suggest the presence of multiple small production sites using smaller pillar hearths which might correlate with a more individual "domestic" production level (Dekoninck, 2017). If this was the case, individual ownership of the sites is more likely than state ownership. The state would not own multiple small sites but create larger sites on a more communal "industrial" production level. The central authorities might have sold/leased the right to produce salt in a certain area for a fixed amount of time to private individuals who could then organise the production themselves or sublet the exploitation to several persons. The latter might explain the number of individual small-scale production sites in the area. This type of lease system combined with salt being part of the *civitas* tax would also explain why salt production did not lead to an accumulation of capital in the area, or it must have been expressed in an archaeologically less visible manner.

In this regard, interesting parallels of state involvement in coastal wetlands areas can be drawn with Britain, such as the Fenlands and the Somerset Levels, where similar habitation, reclamation and exploitation patterns were revealed. Just as in the Menapian area, this did not appear to have led to an accumulation of local wealth. While Rippon (2000) suggested that the salt production of Somerset took place in an imperial estate, Fincham (1999; 2002, 84-89) interpreted the systematic exploitation in the Fenlands as the development of a taskscape for the production of salted meat for the Roman army. Similarly, Gerrard (2008) suggested that the Dorset BB1 industry might have been an army-controlled supply line in salted products. The intense exploitation of the marginal northern Menapian coastal wetlands in the Flavian period, exemplified by the number of salt production sites (Figure 38b), illustrates how the coastal area became a taskscape or productive landscape, focused on salt production and derivative products, aimed at the supply of salt for the Roman Rhine army and the adjacent civil hinterland (De Clercq, 2009c, 2011).

4.3.5 A thriving late second – early third century Roman salt "industry"

After the Flavian period, salt production continued in the area (Figure 38c), but the lack of securely dated sites makes it difficult to grasp the scale and nature of this production. From the late second - early third century CE onwards, multiple new sites occurred in a wide area (Figure 38d), suggesting a second revival of salt production. These sites used a hitherto unknown variant of the briquetage technique in which a linear succession of heating structures, a so-called hearth battery, was installed to evaporate the brine. The number of hearths could vary as the site of Leffinge counted two successive rows of fifteen hearths (Thoen, 1976, 1977b, 1986, 1987), while the site of 's Heerabtskerke only had six adjacent hearths (Ovaa, 1975). This technological development seems to be characteristic of the northern Menapian region since this phenomenon has not yet been established in any other region. The use of these hearth batteries must have pushed the production capacity of the sites to unprecedented levels (see, Chapter 7).

This production boost in the late second - early third century CE coincides with increased evidence for a thriving salt trade. The famous Nehalennia altars mention different types of merchants. Of all professions attested on the more than 300 altars, *negotiator salarius* (salt merchant) and *negotiator allecarius* (trader in salted fish sauce) are the most common. Moreover, the provenance of these merchants and the stones themselves suggest strong trading connections between the Rhineland, the coastal area of the *civitas Menapiorum* and *Britannia* for salt and derivative products (Stuart and Bogaers, 2001; De Clercq and van Dierendonck, 2006; De Clercq, 2009c). In the past, researchers, primarily Hassall (1978), assumed that these inscriptions reflected merchants passing through the area and crossing the Channel to import merchandise (salt, fish sauce, pottery, etc.) from *Britannia*. However, the presence of large salt production centres in the vicinity of the temples indicates that next to a transition zone, local and regional commodities might have been a substantial part of the exported goods (De Clercq, 2009c).

In addition to an economic boost, the population in the peripheral coastal wetlands most likely increased as more habitation sites can be found dating to the late second - early third century CE (Thoen, 1978a, 1981, 1987; De Clercq and van Dierendonck, 2006; De Clercq, 2009c). It is striking that the habitation and production sites increased in the coastal plain at a time when the number of sites in the hinterland drastically dwindled and several large complexes showed signs of decline (De Clercq, 2009c, 488-495). In the late second century CE, several events occur throughout the Roman Empire which might have had ramifications on the political-economic situation in Gaul. Events worth mentioning are the *Chauci* raids (170-174 CE) on the Gallic coast, the revolt of *Maternus* (*Bellum Desertorum*), the Antonine plague, the disastrous *Marcomanni* wars and the succession war between *Clodius Albinus* and *Septimus Severus* (De Clercq, 2009c, 488-495). Even though the impact of each individual event can be discussed, their accumulation in such a short period of time indicates some form of political-economic turmoil in the late second century CE.

Also, on the edge of the coastal plain, several new military camps were erected in the late second century CE, like the camps of Oudenburg (Vanhoutte, *in press*) and Aardenburg (van Dierendonck and Vos, 2013). Thoen (1991) directly related the construction of these camps with the *Chauci* raids, but the overall political-economic turmoil outlined above may provide a more solid argumentation. While the need for security and protection is evident in such a period, the military presence might also have met more strategic goals, such as controlling economic activities (De Clercq, 2009c, 2011). However, it is unclear whether the camps were built in order to protect the already present economic activity or if they provided a safe haven for the development and a new boost in salt exploitation. Initially, the army might have wanted to protect the existing salt production sites, but as an indirect result it might have contributed to a population increase and a renewed boost in salt production activity.

From the second half of the third century CE, in correspondence with the sandy hinterland, the population of the coastal area started to decline (Thoen, 1978a, 1987; De Clercq, 2009c). Again, political instability (e.g. *Postumus*' Imperium Galliarum) might have played a role, but the coastal area also became less accessible. Continued human activities (e.g. drainage, peat-extraction, deforestation etc.) caused the peat to compact and subside, making the area more susceptible to tidal activity, which extended the network of creeks and tidal channels (Baeteman, 2013, 2018). This process gradually transformed the coastal area from a salt marsh into an uninhabitable tidal zone. At the moment, no salt production or habitation sites dating to the end of the third century have been found in the coastal area. However, it does not mean that salt production could not have continued in archaeologically less visible manners. More plausibly, salt, just as grain, was imported from Britannia or the Mediterranean in the late Roman period (Morris, 2010).

4.4 Conclusion

By combining recent discoveries with older regional studies, this chapter discussed the evolution and development of salt production sites from the early Iron Age until the late Roman period in the coastal wetlands of northern Gaul. In these marginal landscapes, distinct productive landscapes focused on the exploitation of salt, developed to meet local and (supra) regional salt demand. Within the coastal zone, these production clusters seem to have shifted in location through time due to the changing socio-economic and political context and the development of new production mechanisms.

In northern Gaul, salt production clustered in the estuary of the Rhine during the early Iron Age. However, around 450 BCE, more and more regions started to produce salt and steadily, a new salt production region with a distinct type of heating structure developed in northern France. This productive landscape in the territory of the *Ambiani* reached its heyday in the late Iron Age with multiple sites producing salt on an "industrial" scale. Even though there was a small revival during Augustan times, Caesar's campaigns in northern Gaul, probably combined with other unknown socio-economic factors, might have caused a significant decline in salt production. Consequently, during the early Roman period, salt production shifted from the territory of the *Ambiani* towards the *civitates* of the *Menapii* and the *Morini*. A combination of internal (population growth) and external (taxation, military supply) stimuli might have caused a Flavian boost in production sites in the northern part of the Menapian *civitas*. A second boost in production sites combined with a technological advancement (so-called hearth batteries) could be identified in the late second - early third century CE. Remarkably, this surge in salt production coincided with a period of political-economic distress in which occupation in the hinterland dwindled. After that, salt was probably imported as no late Roman salt production sites have been found in northern Gaul.

This succession and shifting of salt production regions in dynamic coastal environments were closely linked to the success of the local Iron Age elite or higher institutional powers in Roman times. The fact that distinct productive landscapes could develop suggests that both the Iron Age elite as well as the Roman state were directly or indirectly involved in controlling the production and/or the salt trade. Also, the elite seems to have benefitted the most from the production as no accumulation of wealth or display of status can ever be found on the production sites. The increased demand for salt and its economic potential might have stimulated the exploitation of these "marginal" coastal wetlands, which led to the development of different pre-Roman and Roman salt-making landscapes.

Chapter 5 Heated crafts on the Roman shore. Revisiting the debate on the exploitation of coastal wetlands: the case of Roman Aardenburg (Zeeland, the Netherlands)

Parts of this chapter has been accepted for publication in *Latomus*

Dekoninck, M., De Ruijsscher, D. and De Clercq, W. (2022). *Heated crafts on the Roman shore. Revisiting the debate on the exploitation of coastal wetlands: the case of Roman Aardenburg (Zeeland, the Netherlands)*

5.1 Introduction

From a Roman political and geographical point of view, the *civitas Menapiorum* situated on the northern fringe of *Gallia Belgica,* was a rather 'marginal' territory on the outskirts of the Empire (Figure 39) (De Clercq, 2011). According to Groenewoudt (2009),[1] a marginal landscape should be defined as an area of low agricultural productivity and low population density during a certain period of time.[2] From an agricultural point of view, coastal wetlands are considered to be of 'marginal' importance. These areas are prone to environmental changes, which limits their overall accessibility and thus impacts productivity and population density. However, as argued by Rippon (2000) and De Clercq (2009c, 2011), exactly the dynamic character transforms these wetland areas into rich ecosystems with a high potential for specific, landscape-based resource exploitation strategies such as sheep husbandry, fishing and salt production. For these purposes, the coastal wetlands of northwest Europe have been more intensively exploited from Roman times onwards as indicated by recent studies on the Roman exploitation of the Somerset Levels (GB) (Rippon, 2000) and the Fenlands (GB) (Lane and Morris, 2001; Fincham, 2002; Lane, 2018a).

In the 1970s, Thoen (1978a, 1987) published his seminal overview of the Roman Belgian coast arguing that the coastal wetlands of the Menapian territory were inhabited and exploited in Roman times. However, Ervynck et al. (1999) interpreted and attributed these finds to seasonal off-site phenomena instead of permanent occupation. Recent discoveries of habitation structures altered the

[1] On the concept of marginality, see Turner and Young (2007).

[2] Nevertheless, marginality is rather relative concept influenced by varying economic, geographical, social and cognitive parameters, see Groenewoudt (2009).

perception of the Menapian coastal wetlands from a marginal, seasonally exploited landscape into an intensely exploited, permanently occupied landscape (De Clercq, 2009c, 2011; Verwerft et al., 2019b). Nevertheless, high-resolution data regarding the diverse nature and the exploitation of the natural resources remain limited (De Clercq, 2009c, 2011). Indeed, multiple sites containing large debris layers, with or without heating structures, have been discovered at Koudekerke (van den Berg and Hendrikse, 1980), Leffinge (Thoen, 1974, 1975b, 1976, 1977b, 1978a, 1978b, 1986, 1987), ‘s-Heer Abtskerke (Ovaa, 1972, 1975), Middelburg (van den Berg, 1988) and Aardenburg (van Dierendonck and Vos, 2013) (Figure 39). However, the interpretation of these sites has been a matter of debate for decades. Over time, a wide variety of heated crafts were suggested, yet each hypothesis lacked solid argumentation (van den Berg and Hendrikse, 1980; Van Heeringen, 1996; De Clercq and van Dierendonck, 2006; De Clercq, 2011; van Dierendonck and Vos, 2013).

In this chapter, we address this long-lasting discussion by using Aardenburg as a case study. Aardenburg is exemplary for the wider region as the site contained multiple workshops, debris and ash layers. The nature of the workshops and the composition of the debris layers will be examined in detail to understand how they might relate to the specific craft activities. Deconstructing the old hypotheses is a necessary first step to wipe the slate clean and to provide a meaningful contribution to the debate based on new evidence. Furthermore, this will provide a solid basis for future research and will enable discussion on the economic integration and role of the Menapian *civitas* in provisioning the Rhine army or the civil hinterland with salt and derivative products.

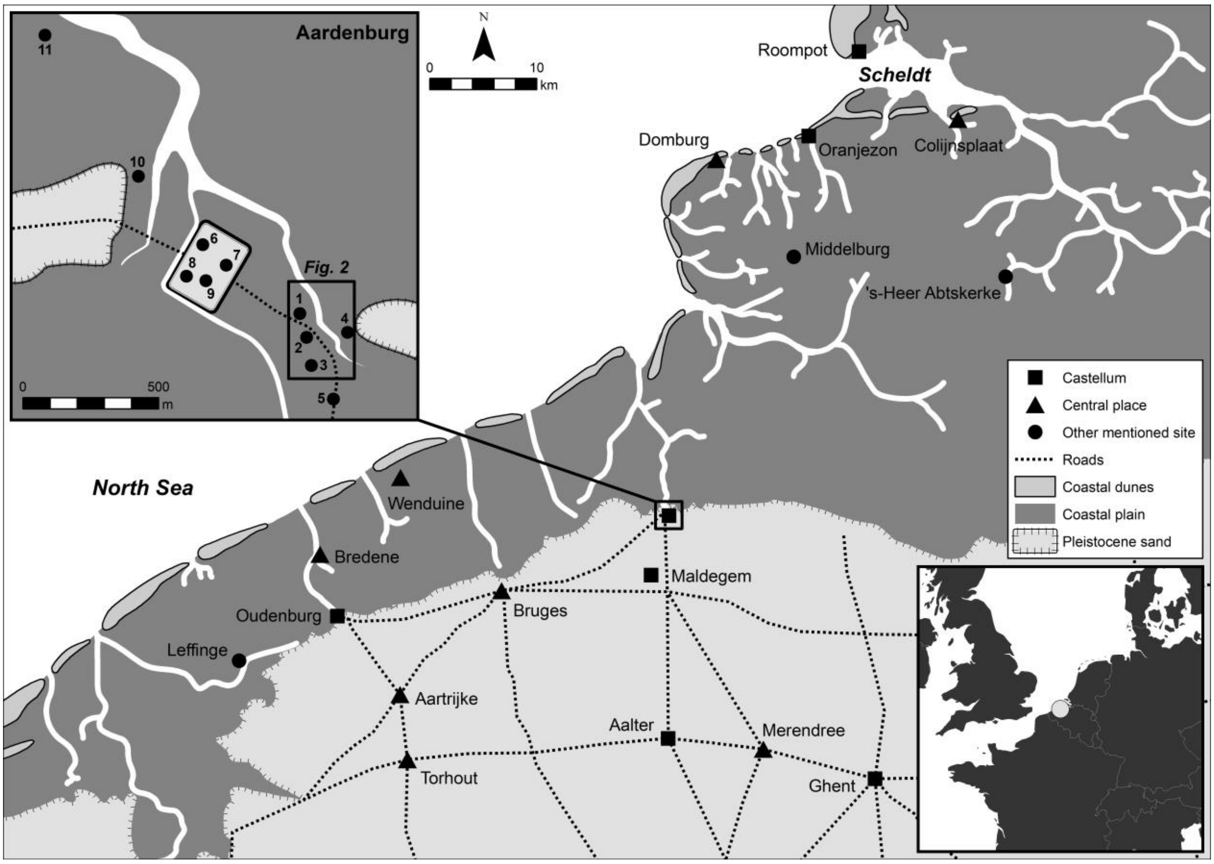


Figure 39 Simplified map of the most important sites in the northern Menapian territory in the late second - early third century CE, including a detailed map of the Aardenburg area with the location of the sites Oude Stad (1), Hof Buize I (2), Hof Buize II (3), Kamp Rodanborg (4), Vestinggrachten (5), Tuin Ds. Vis (6), Tuimelsteenstraat (7), Weide De Smet (8), Weide Quataert (9), Peurssensstraat (10) and Draaibrugseweg (11).

5.2 Situating the Roman settlement of Aardenburg

From the mid-twentieth century onwards, archaeological research revealed a considerable number of structures and debris related to heated crafts near the Roman military *castellum* at Aardenburg (Zeeland, the Netherlands). The fort was positioned at the edge of the coastal plain, on the most seaward outcropping edges of a Pleistocene sand ridge (Ovaa, 1958; Van Rummelen, 1965). This sandy elevation was cut by the Ee-river basin, which flows into the North Sea (Figure 39). he channel infills found outside the settlement indicate a river basin running from south to north, which widened towards the coastal plain in the north (Ovaa, 1957). Channel infills found directly north (Hoevenberg and Van Suijlekom, 2003; Diependaele, 2013), west (JROB, 1975, 1976; Trimpe Burger, 1985; Diependaele, 2009), and south-east (R. Van Heeringen, 1989; van Heeringen, 1992) of the *castellum* demonstrate that the river basin consisted of a dendritic system of waterways when crossing the sand ridge near the *castellum*. All of this suggests that the site was located at the most inland navigable section of the Ee, giving direct access to the North Sea. The Aardenburg *castellum* had a unique position at the end point of at least two main roads leading into the hinterland. One of the roads ran in western direction towards the Oudenburg *castellum* and the *civitas* capital (*Castellum Menapiorum*), and the other road ran in southern direction towards Bavay (*Bagacum Nerviorum*), connecting Aardenburg with the urbanized regions of central Gaul (Verbrugghe et al., 2017). The combination of multiple land-, and waterways on the edge of the Pleistocene sand ridge overlooking the coastal wetlands, gave Aardenburg a unique military and strategic economic position.

According to Van Dierendonck & Vos (2013), a civil settlement focused on the exploitation of marine resources was active at Aardenburg from the middle of the second century CE (phase I), followed by a first military occupation between 170-185/190 CE (phase II). However, after closely examining the evidence of the pre-*castellum* phase (phase I), it became apparent that all features attributed to phase I could just as well be part of phase II, casting doubt on the existence of a pre-military phase.[3] In any case, the fort was renovated or rebuilt (ca. 185/190 CE.) under emperor Commodus (phase III) (van Dierendonck and Vos, 2013). The construction of the Aardenburg and Oudenburg fort might have been part of Commodus' larger military building program in which the coastal region of Gallia Belgica became militarised during the late second-century political-economic turmoil (De Clercq, 2009c; Vanhoutte, *in press*). At Aardenburg, the destruction of several buildings and the silting up of the defence ditch marked a (temporary) end of the military occupation around 240/245 CE (van Dierendonck and Vos, 2013). Under the usurper Postumus (260-269 CE), both the *castella* of Aardenburg (phase IV) and Oudenburg were rebuilt in stone, probably again part of a larger

[3] van Dierendonck and Vos (2013) suspected a pre-castellum phase (150-170 CE) based on the presence of two Samian ware fragments attributed to the potter Avitus from Blickweiler/Eschweilerhof (105-160 CE) in heating structure O-26, a drag. 33 with stamp MALLV[RO] in well W-10, the pottery in the cart tracks, the pottery in pit K-9 and an early date of building G13. However, regarding the stamp of Avitus, it should be noted that van Dierendonck and Vos do not mention the stamp type or the vessel type and do not refer to their source. As multiple potters by the name of Avitus are known, this information is crucial to correctly date the context (Hartley et al., 2008). Additionally, Samian ware might be used for a longer period of time before it was broken and deposited. Next, the pottery of well W-10 was dated between 130-180 CE which partially overlaps with phase II. Furthermore, Dhaeze (2013) clearly stated that the pottery of the cart tracks and of pit K-9 should be dated after 160 CE and before 200 CE and thus can belong to phase II. Finally, there are no solid arguments to date building G13 to phase I as it belongs to a military instead of the local native and civilian house-building tradition (De Clercq, 2009c). As presented here, there are little arguments to exclusively date the aforementioned contexts to phase I (150-170 CE) as suggested by van Dierendonck and Vos (2013). On the contrary, there are several arguments to attribute the contexts to phase II (170-180/190 CE) instead or at least to let them overlap with phase II.

building campaign.[4] After the Gallic Empire, both forts remained occupied for some time after which they were destroyed. Unfortunately, the precise end of both *castella* is difficult to define. Based on coin evidence, Chameroy (2013) dated the definite end of Aardenburg's occupation in the 280s, which he related to the campaigns of emperor Maximianus. Nevertheless, some pottery and coins point towards a small (Germanic?) reoccupation of the site during the fourth century (van Dierendonck and Vos, 2013, 331).

5.3 Archaeological traces of artisanal activity at Aardenburg discovered during earlier excavations

5.3.1 Potential workshops in the artisan quarter

The area approximately 400 m southeast of the *castellum*'s eastern wall, along the main road leading south,[5] is characterised by an extensive 'industrial' or artisanal zone (Figure 39 no. 1-4; Figure 40). This area consists archaeologically of a complex sequence of multiple layers of brownish-red clay, with char inclusions, interspersed with large dumps of fired clay, indicative of numerous heating activities, next to multiple discrete features such as hearths and refuse pits (van Dierendonck and Vos, 2013, 168). No less than 27 hearth structures were uncovered during excavation campaigns between 1973 and 1991 (Oude Stad, Hof Buize I, Hof Buize II, Kamp Rodanborg I and Kamp Rodanborg II) (Figure 40). These digs covered an area of ca. 6500 m^2 in which several clusters of heating structures were discovered. These clusters indicate that the hearths were not part of one large workshop but instead might represent smaller workshops consisting of one or multiple working units that operate simultaneously or consecutively. Most likely, these features only represent a fraction of the hearths once present since the debris layers also contained numerous fragments of dismantled heating structures. Unfortunately, during the initial excavations, these structures did not receive the necessary attention to fully comprehend the nature and construction of the hearths. The features consisting of (burned) clay were only recorded in plan as an orange-red patch, and no cross-sections were made to study the stratigraphical relation or the relative chronology of the hearths. Sometimes a clear distinction was made between the hearth filling, representing the combustion chamber, and the supposed hearth lining (Figure 41). Yet, often these features were recorded as one structure. In addition, only a few photographs of the 'artisanal' zone were taken, and no detailed photographs of the individual features exist (Figure 41). Furthermore, little is known about the find collection strategy during the different excavations, and none of the publications nor the excavation archives

[4] On the Channel coast of Britain, several Shore forts were active or rebuilt during the Gallic Empire as well, see Drinkwater (1983); Dhaeze (2011); (2021); Vanhoutte (*in press*).

[5] van Dierendonck and Vos (2013) assume an eastern direction of the road for which there is no evidence. A southern direction for the roman road, as presented here, is more logical as the road follows the course of the main medieval road leading south (Zuidstraat-Hogeweg).

mentions any recovered hearth infrastructure.[6] Despite these difficulties, van Dierendonck and Vos (2013, 325) attempted to date each feature based on the finds in and near the structures and to connect them to the different Roman occupation phases of Aardenburg (Figure 40).

One of the earliest workshops (phase II?) consisted of two consecutive hearths (or hearth phases) with an external diameter of 1.5 m and 1 m (Figure 40). Both hearths were constructed on a small artificially raised work zone using sods (van Dierendonck and Vos, 2013, 179-180). Another workshop/unit with one hearth (external diameter 1-1.3 m), south of the eastern road in the heart of the industrial zone, was assigned to phase II or phase III (Figure 40). Most of the securely dated hearths (eight in total) can be ascribed to phase III (Figure 40). As these hearths were spread out across the artisan quarter, they must represent different workshops active at different moments in time. However, defining the number of workshops or the amount of heating structures per workshop is impossible. Two of these hearths were used simultaneously since they were internally connected with a flue. North of these hearths, another cluster of eight heating structures was situated closer to the road (Figure 40; Figure 41) (R. Van Heeringen, 1989; de Visser, 2001; van Dierendonck and Vos, 2013, 171-176; 325-329). Only three hearths could be firmly attributed to phase III based on pottery fragments, but a contemporaneous or consecutive use of all eight hearths cannot be excluded. The dimensions of the supposed hearth lining/burned clay vary significantly, but the combustion chamber of six of the hearths is approximately 0.5-0.8 m in diameter (Figure 41). In the southern part of the industrial zone, a cluster of three hearths might represent a single workshop with multiple working units active during the final occupation phase (phase IV) (R. Van Heeringen, 1989; de Visser, 2001; van Dierendonck and Vos, 2013, 171-176; 330). The remaining thirteen hearths are spread out across the debris zone. However, these hearths lacked diagnostic material to attribute them with certainty to a specific occupation phase (Figure 40). Nevertheless, together with the remaining debris, they indicate more intense artisanal activities in some, if not all, occupation phases.

In all phases, the heating structures were remarkably similar. They were constructed from clay sods on a prepared, slightly raised surface regularly reinforced with shells. Although the delineation was often not clear in plan, the external diameter of the features seems to have varied significantly. This resulted in a broad ‘hearth lining’ compared to the actual size of the combustion chamber. Only taking the external dimensions into account would give false impressions regarding the usable workspace of each hearth. When recorded, the internal diameter of the hearths rarely exceeded 1 m and was sometimes as small as 0.5 m, indicating rather small heating structures (van Dierendonck and Vos, 2013, 170-180). Finally, during a more recent excavation at Aardenburg Draaibrugseweg (Figure 39; no. 11), a potential workshop was discovered north of the *castellum* at the west bank of the main waterway leading into the coastal plain. The feature itself was badly preserved, making interpretations hypothetical at best. Yet, the presence of vitrified clay elements and hammer scale might be an additional argument to assume artisanal activities in that area as well (Wattenberghe and van Jole-de Visser, 2012).

[6] de Visser (2001) exhaustively studied all recovered material from the 1988 Hof Buize II excavation for her master dissertation. From this study, it is clear that no hearth furniture was recovered (or perhaps discovered) in the 1988 excavation. van Dierendonck and Vos (2013) performed a quick scan of the material from the other excavations to search for diagnostic elements to date the remaining hearths for their publication of Roman Aardenburg. Taking these studies into account, the decision was made not to (re)examine the finds from the old excavations.

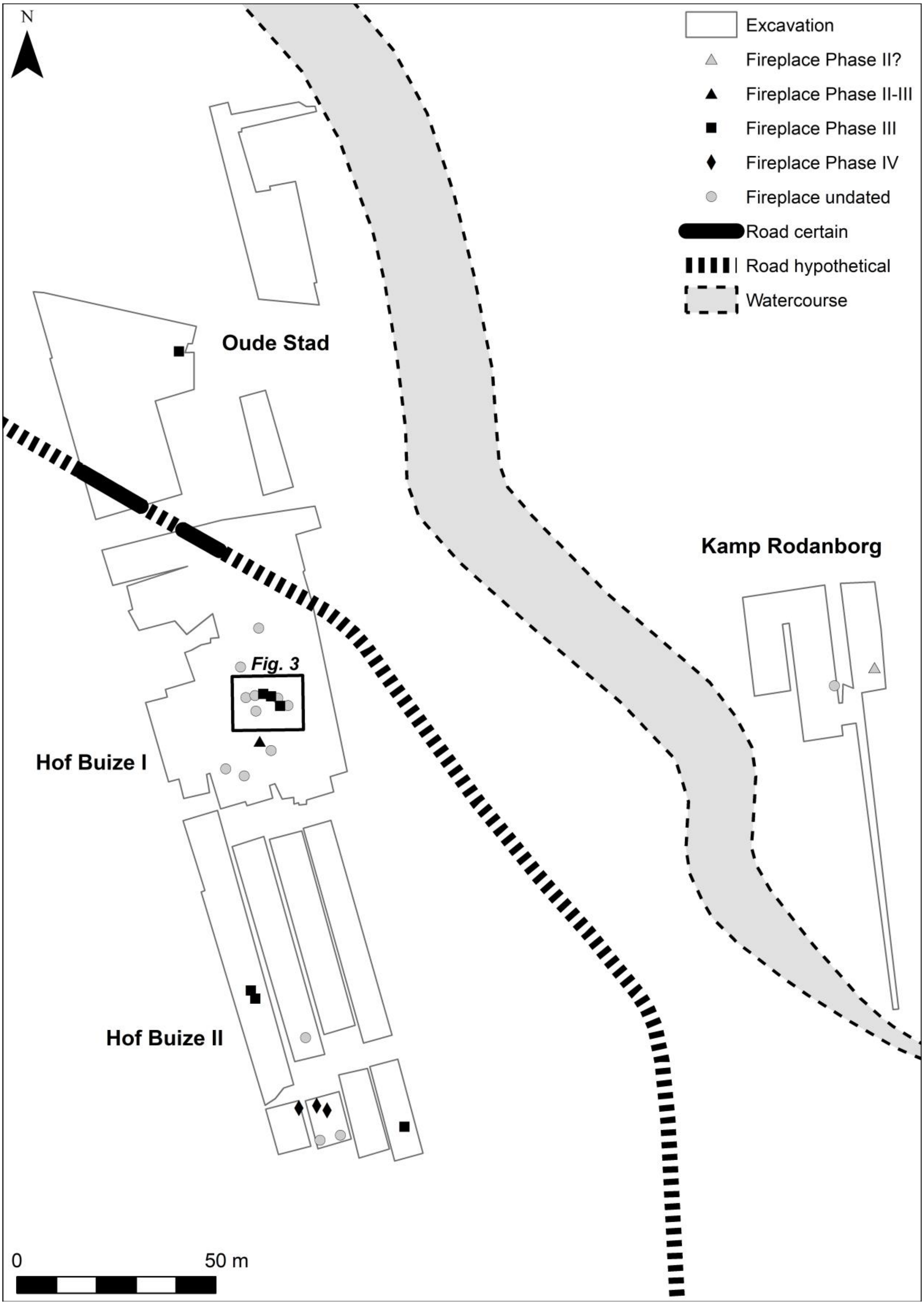


Figure 40 Simplified map of the artisan quarter east of the castellum of Aardenburg (supplemented and modified after van Dierendonck and Vos (2013, fig. 8.21)).

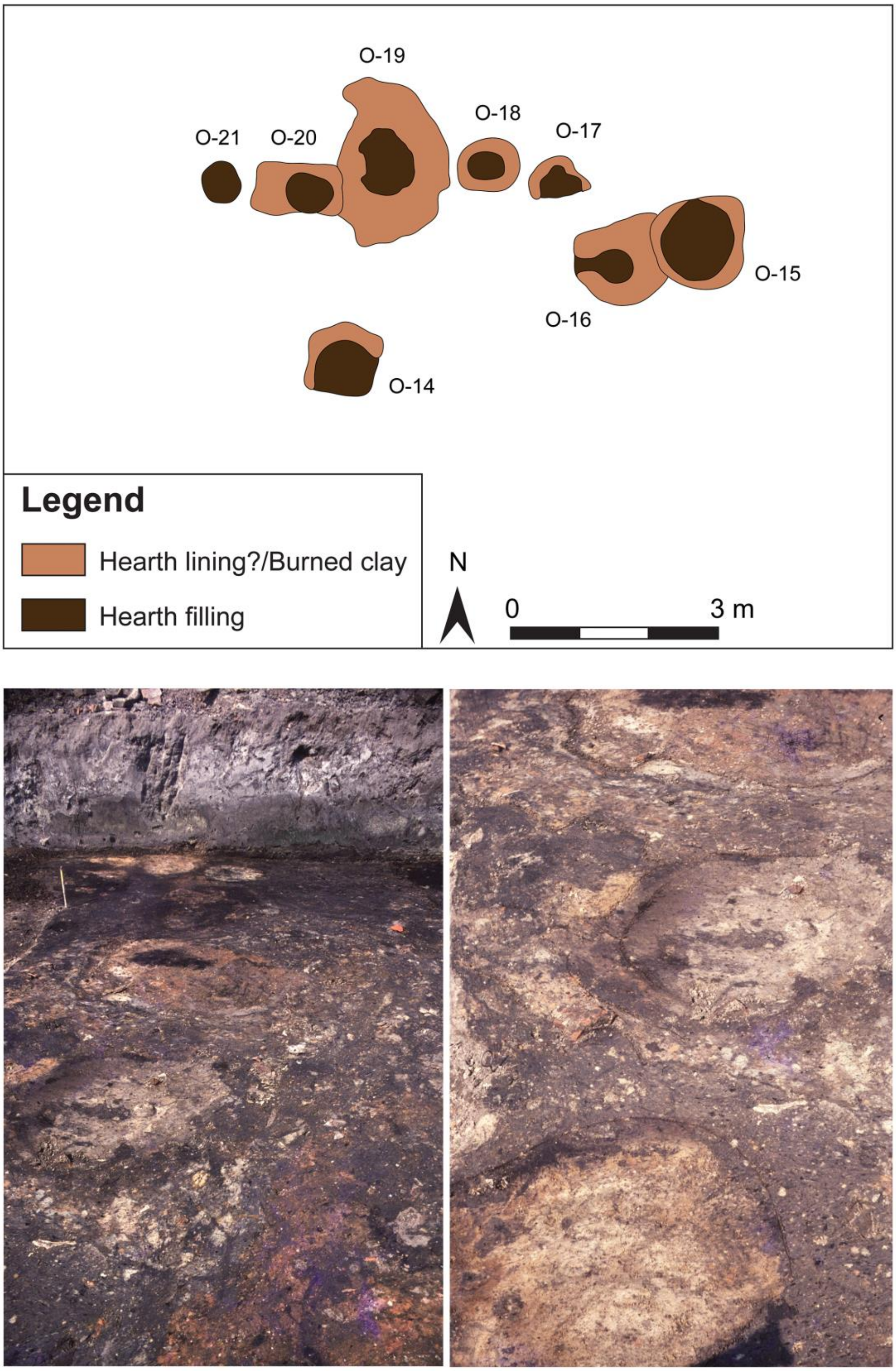


Figure 41 Excavation plan and photographs of the heating structures O14-O21 discovered during the excavation of Hof Buize I in 1976/78. Heating structure O16, O18 and O19 could be attributed to phase III, but the remaining hearths lacked diagnostic material to date them to a specific occupation phase (excavation plan modified after the unpublished excavation archive and van Dierendonck and Vos (2013, fig. 6.59); the unpublished photographs were made available by Erfgoed Zeeland).

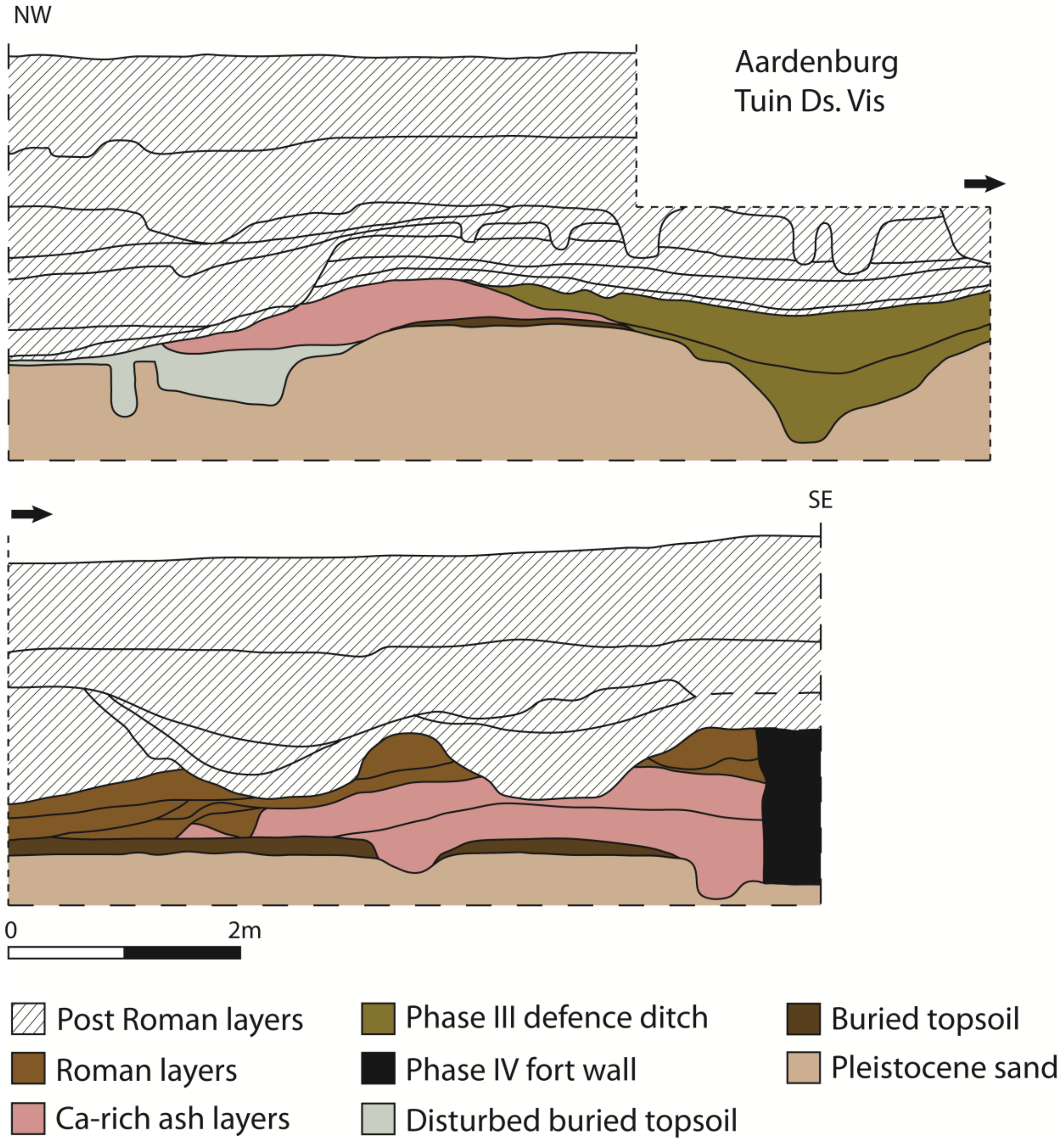


Figure 42 North-west -– south-east profile of excavation 'Tuin ds. Vis' with calcium rich ash layers on top of the Pleistocene subsoil (drawn after the unpublished excavation archive made available by Erfgoed Zeeland).

5.3.2 Debris depositions related to artisanal activities discovered during previous excavations

In addition to the extensive industrial zone with multiple heating structures *in situ*, several locations in and around the fort provide indirect evidence for large-scale artisanal activities. These locations contain ash-rich deposits and are found underneath the later castellum features. These ash-rich deposits were disregarded during the initial excavation and dismissed by van Dierendonck and Vos (2013). In 1961 and 1979, a 0.5 m thick deposit of whitish, calcium-rich ash was excavated at Tuin Ds. Vis in the northwestern part of the *castellum* (Figure 39; no. 6). The layers were found just outside, underneath and on the inside of the western *castellum* wall. In section (Figure 42), it became apparent that the V-shaped defensive ditch (phase III) and the foundation ditch of the stone *castellum* wall (phase IV) cut through the ash deposition providing a *terminus ante quem* for the layer's accumulation/deposition (JROB, 1979).

A similar ash-rich layer was found in the Tuimelsteenstraat (Figure 39; no. 7) underneath a stone building. Samian ware from the workshop of MAIIAAVS (Trier) and an *as* of emperor Trajanus date this ash deposition before 190 CE (van Dierendonck and Vos, 2013, 112). In addition, ash layers on top of the (reworked) Pleistocene sand were observed in large areas of 'Weide Quataert' and 'Weide De Smet' (Figure 39; no. 8 and 9). One of these ash layers was situated stratigraphically underneath the *principia* building, of which the construction is dated at the end of the second century CE (phase III). According to van Dierendonck and Vos (2013, 115), two early phase II buildings next to and underneath the later *principia* building were covered by an ash layer. They interpreted this layer as a destruction layer which suggests a violent end of the phase II occupation. If such a destruction event is accepted, the large quantities of ash underneath a substantial part of the later *castellum* would imply that quite a large phase II occupation, much larger than the currently accepted *castellum* area for which there are no indications, was destroyed. Additionally, the destruction of the wooden buildings cannot adequately explain the large calcium concentrations noted in the ash found at the site 'Tuin ds. Vis'. More likely, the ash originated from artisanal activities and was dumped next to the early cart tracks running east-west through the later phase III fort area.

Next to ash layers, more general refuse dumps were also discovered. One of these refuse dumps was situated approximately 200 m south of the 'industrial' zone (Figure 39; no. 5). Even though this dump could only be partially excavated, the presence of multiple vitrified clay elements suggests that debris from nearby artisanal activities was used to (partially) fill a depression in the landscape. The finds are dated between the end of the second and the third quarter of the third century CE, which corresponds with the activity at the nearby artisan quarter (D'hondt, 2010).

5.4 Recent discovery of an artisanal refuse zone at Aardenburg Peurssensstraat

5.4.1 Excavating the Peurssensstraat site

In June 2020, Bodac[7] conducted a preventive excavation (ca. 1150 m²) west of the *castellum* called 'Aardenburg Peurssensstraat,' (Figure 39; no. 10). This excavation, unexpectedly, provided opportunities to assess the western extent of the potential *vicus* surrounding the fort. In the western part of the excavation, the remains of a NE-SW-oriented wooden building measuring 8.5 m in length and 6.5 m in width were discovered. This type of one-aisled farmstead with a cruciform layout (type De Clercq IIB) is commonly found in the northern Menapian sandy hinterland and is dated between the Flavian period and the end of the second century CE (De Clercq, 2009c, 283-290; 2011). Recently,

[7] We would like to thank the Bodac team (Marcel, Niels and Aletta) for giving us the opportunity to assess and study the debris depositions in the field.

this building type was also attested for the first time in the coastal plain as well. On a sandy Pleistocene outcrop, a similar small farmstead dated to the end of the second century CE was discovered at Dudzele Zonnebloemweg (Verwerft et al., 2022).

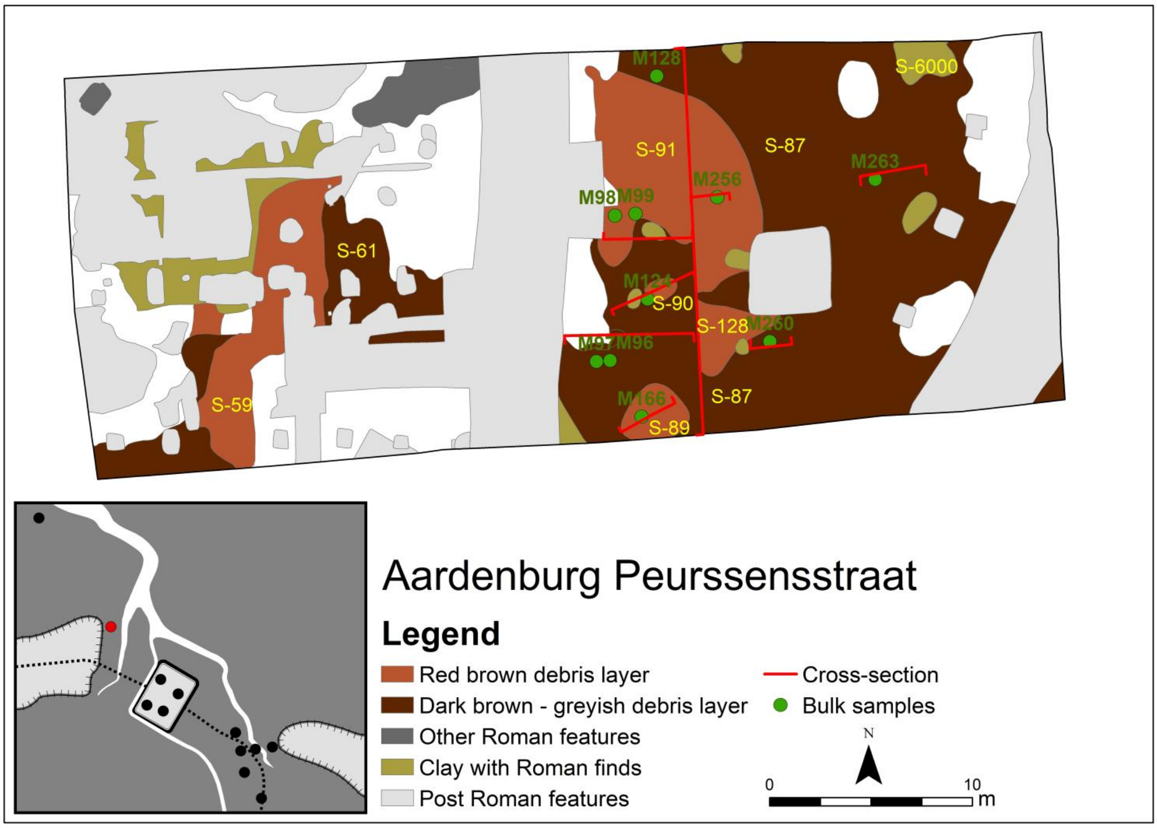


Figure 43 Excavation plan of Aardenburg Peurssensstraat depicting the red-brown and dark brown–greyish debris layers as well as the location of the cross-section and bulk samples.

More important for the current research was the 500 m² refuse zone consisting of red-brown and dark brown-greyish debris layers in the excavation's central and eastern parts [8] (Figure 43). The thickness of the debris deposition varied considerably across the site, which might relate to the fickle nature of the underlying Pleistocene coversand. The underlying sand gently slopes from east to west towards a Roman period tidal channel, and the thickness of the archaeological layers increased on this slope. The thickness of the deposit evolved from a few centimetres on the outer edges (east and west) towards approximately 25 cm in the central part of the debris zone (Figure 44). Towards the south, the thickness of the layer remains significant, indicating that the debris zone extended beyond the limits of excavation. In order to determine the site's extent, a geophysical (electromagnetic induction) survey was conducted in a pasture north of the excavation. The results of this survey confirmed the presence of a tidal channel (depicted in Figure 39) but disproved the existence of heating structures preserved *in situ*. [9]

[8] The Roman debris layer in the central part of the excavation was heavily disturbed by later medieval activity. In this zone, a large 14th century building measuring at least 20m in length and 15m in width was discovered. At the moment, the exact function is still unclear but given the buildings dimensions, a tithe barn is suspected.

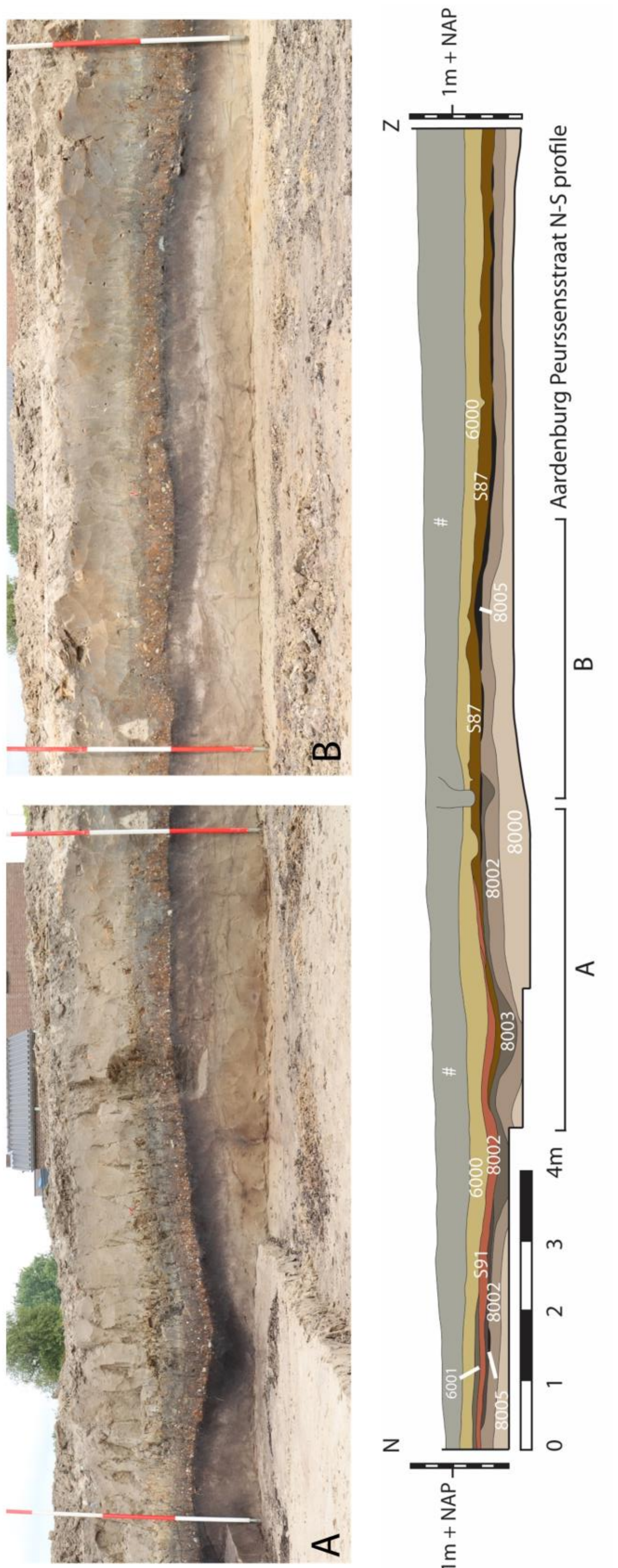
[9] Previous studies, e.g. Lane and Morris (2001); Olivier (2010); Riddiford et al. (2016), Hathaway (2013), have shown the potential of geophysical surveys to detect salt-related heating structures.

The 500 m² debris zone comprised red-brown and dark brown-greyish debris layers (Figure 44). These layers were very heterogenous and contained quite a lot of amorphous, very fragmented material. Delineating these red-brown and dark brown-greyish layers proved to be no easy task due to the diffuse transition between these layers both horizontally as well as vertically. Overall, the red-brown layers were mainly found in the northwestern and central part of the debris zone, while the dark brown-greyish layers occurred in the eastern and southwestern parts (Figure 43). Unfortunately, no direct traces nor structures related to craft activities were found in the debris layers, suggesting that the activity took place elsewhere and that the production waste was dumped here.

As the look and feel of the red-brown and dark brown-greyish debris layers were considerably different, a low-cost methodology was devised to verify whether the composition of these debris layers differed and, if so, how these differences could be explained. In order to answer these questions, strategically targeted bulk samples were taken of the different debris layers in the eastern part of the debris zone to study the layer's composition. In total, eight cross-sections were made and the material was collected in ten bulk samples (Figure 43). Two cross-sections were made mechanically, resulting in four larger samples of 1000 l. In order to compare and measure the impact of the sample size, two smaller sections with a sample size of 100 l were made by hand near the large bulk samples. The remaining four sections with a sample size of 100 l were spread out across the debris zone to detect possible variations in layer composition (Figure 43). Altogether, four bulk samples (2 x 1000 l and 2 x 100 l) were collected from the red-brown layers, and six bulk samples (2 x 1000 l and 4 x 100 l) were taken from the dark brown-greyish debris layers.[10]

These bulk samples were then wet-sieved using a 2 mm mesh to determine the fragmentation degree and collect all finds.. Similar to the collection strategy, two different sieving strategies were used. The large 1000 l samples were sieved with an automatic, mechanical sieving installation, while the smaller 100 l samples were sieved by hand. Subsequently, the sieve residues were air-dried for approximately one month, after which the residues were dry sieved and separated in different sieve fractions: 2-5 mm, 5-10 mm and > 10 mm. Only the latter sieve category (> 10 mm) contained diagnostic material, and this material was divided into several object categories (pottery, fired clay, vitrified clay etc.) and studied separately. Although the main goal concerned the layer's composition, the devised methodology had the additional purpose of testing whether the sample size, collection – and sieving strategy impacted the results. However, as large and small samples needed to be taken closely to compare the results, the spatial distribution of the samples in the debris zone was far from ideal. Consequently, statistical spatial analysis of the bulk samples in ArcGIS was impossible.

[10] Additional data of the excavation has been presented in APPENDIX 2



Layer	Description
8000	Parent material C, Pleistocene sand, 'flamed' browned to yellow-brown
8002	Eluviated subsoil B/E, sand, brown
8003	Buried topsoil with accumulation of organic matter (Ah), sand, dark grey- greyish black
8005	Buried topsoil with accumulation of organic matter (Ah), sand, greyish black
6000	Parent material C, marine clay, greenish yellow
6001	Parent material C, marine clay, greenish yellow with common baked clay and charcoal inclusions (cm-wide).
S87	Dark brown/dark grey heterogeneous sandy clay with frequent char, baked clay and vitrified clay inclusions (cm-wide)
S91	Red-brown/Brown/dark-brown heterogeneous sandy clay dominated by multicoloured baked clay and vitrified clay inclusions (cm-wide)
#	plough soil

Figure 44 North-south profile across the entire debris zone showing and describing the stratigraphy of the Aardenburg Peurssensstraat site.

Table 7 Classification and quantification of the archaeological material recovered from sieve fraction > 10mm.

Sample	Sample size (l)	Pottery		Baked clay		Vitrified clay		CBM		Stone		Metal		Glass		Animal bone		Shell		Char		TOTAL	TOTAL
		no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt (g.)
M. 96	1000	602	2964	510	1377	533	2820			7	58	4	14			9	27			5	5	**1670**	**7265**
M. 97	1000	197	1086	300	732	396	2672			34	273					18	34	4	6	1	1	**950**	**4804**
M. 98	1000	315	1332	1014	2627	41	338			41	338	4	7			8	20			5	6	**1428**	**4668**
M. 99	1000	315	1545	850	2386	299	1109			14	68	4	15			7	36	2	1			**1491**	**5160**
M. 116	100	32	285	212	587	95	325	4	97	4	25	2	6									**349**	**1325**
M. 124	100	47	314	260	621	230	1450	3	1184	4	29			1	1	3	7					**548**	**3606**
M. 128	100	204	1425	191	362	52	152			5	49	2	8	3	3	4	40					**461**	**2039**
M. 256	100	26	118	196	544	79	305	2	50	2	2											**305**	**1019**
M. 260	100	71	370	138	448	90	369	5	315	10	64	1	3									**315**	**1569**
M. 263	100	15	79	9	17	10	31			22	78	1	3									**57**	**208**
TOTAL	**4600**	**1824**	**9518**	**3680**	**9701**	**1825**	**9571**	**14**	**1646**	**143**	**984**	**18**	**56**	**4**	**4**	**49**	**164**	**6**	**7**	**11**	**12**	**7574**	**31663**

Table 8 Classification and quantification of the pottery fragments discovered in sieve fraction > 10mm.

Category		TS.	C.C.			TN	Flag.		Amp.	Dol.	Mort.		Ox.		Red.	Hand.	Salt	Ind.	TOTAL
Subcategory			KOL	TRI	Ind.		RME	Ind.	BAT	Ind.	Ind.	BAV	RME	Ind.	Ind.	NOM			
M. 96	Sherds	4	119				52	25	1		1		10	89	22	79	78	122	602
	MNI	2	8				2	3	1		1		3	7	1	9	6		43
M. 97	Sherds	3	17		1		14	10	1	5			2	49	38	33	24		197
	MNI	3	3		1		1	1	1	1			1	2	3	5	1		23
M. 98	Sherds	3	46				3	30		2		2	2	41	87	74	11	14	315
	MNI	1	5				1	2		1		1	1	2	8	7	1		30
M. 99	Sherds	1	34				8	27		5				50	51	122	9	8	315
	MNI	1	3				1	1		1				3	7	17	1		35
M. 116	Sherds		3										4	7	5	13			32
	MNI		1										1	1	2	3			8
M. 124	Sherds		1					1	5				2	8	16	14			47
	MNI		1					1	2				2	1	2	1			10
M. 128	Sherds	2	10					8		1			1	39	20	53	62	8	204
	MNI	1	2					1		1			1	2	2	6	2		18
M. 256	Sherds		4					5					1	3	4	8	1		26
	MNI		2					1					1	1	3	1	1		10
M. 260	Sherds		7			2		6		3			5	18	13	16	1		71
	MNI		3			1		1		2			1	2	1	1	1		13
M. 263	Sherds	1	1	2				4						1	3	2	1		15
	MNI	1	1	1				1						1	1	1	1		8
TOTAL	Sherds	**14**	**242**	**2**	**1**	**2**	**77**	**116**	**7**	**16**	**1**	**2**	**27**	**305**	**259**	**414**	**187**	**152**	**1824**
	MNI	**9**	**29**	**1**	**1**	**1**	**5**	**12**	**4**	**6**	**1**	**1**	**11**	**22**	**30**	**51**	**14**		**198**

5.4.2 Composition of the debris layers

In order to study the composition of the debris layers, ten bulk samples (4x 1000 l and 6x 100 l) were wet sieved, after which the residues were dry sieved and separated in different sieve fractions. In total, the ten bulk samples contained 71.1 kg of archaeological material across three sieve categories: 2-5 mm (19.8 kg), 5-10 mm (18.3 kg) and > 10 mm (32.9 kg). Only the latter sieve category (> 10 mm) contained diagnostic material, and this material was divided into several object categories: pottery (9.5 kg); baked clay (9.7 kg); sintered clay (9.5 kg); ceramic building material (1.6 kg); stone (0.9 kg); metal (56 g); glass (4 g); animal bone (164 g); shell (7 g) and coal (12 g) (Table 7).

In total, 1824 fragmentary potsherds, representing 198 MNI, could be identified (Table 8). Only a small amount of samian ware (14 sherds, 9 MNI) was present: two fragments of thin-walled relief decorated cups (probably Déch. 68), dating to the second half of the second century CE, the base of a Drag. 33 cup and a rim of a Lud Ti' dish (Figure 45; no. 1). The latter type occurs from the middle of the second century CE onwards (Brulet et al., 2010)

Compared to the samian ware, the ensemble contains quite a large amount of highly fragmented colour-coated ware (245 sherds, 29 MNI). Except for of two sherds (1 MNI) in the characteristic second-century CE Trier fabric, all sherds had a white fabric with a greyish-black coating which can be attributed to Cologne colour-coated ware. In this assemblage, two forms of cups were present: cup Hees 2 (14 MNI) (Figure 45, no 2-4) and cup Niederbieber 32 (1 MNI). Most fragments show signs of roughcasting decoration and some are indented or folded. These colour-coated Hees 2 cups with a cornice rim produced in the area of Cologne are dated in the second century CE (Brunsting, 1937; Brulet et al., 2010, 312-314). Typical third-century characteristics of colour-coated ware, such as a metallic finish or barbotine decoration, are lacking in this assemblage (Brulet et al., 2010).

Next to luxurious tableware, several categories of storage vessels were present: flagons (193 sherds, 17 MNI), amphorae (7 sherds, 5 MNI) and dolia (16 sherds, 6 MNI) (Table 8). Roughly two types of flagons occurred: white flagons from the Rhine-Meuse valley (77 sherds; 5 MNI) and regionally produced flagons from the Scheldt valley or in Low Lands ware fabric (116 sherds, 12 MNI). The high fragmentation rate and lack of diagnostic features made it difficult to assess this category typologically. Only one ring-shaped flagon rim could be identified (Figure 45; no. 6). Also, several amphora sherds and handle fragments were present. Typologically a few sherds could be recognized as Dressel 20 olive oil amphorae from *Baetica*. In the vicinity of sample 116, another Dressel 20 handle was recovered, which was stamped with P.CICELI. This stamp could be attributed to *P. Clodius Icelus,* who produced amphorae between ca. 149-161 CE in one of the workshops of *Municipium Flavium Arvense* (Arva), a Roman town in the province *Baetica* near current-day Sevilla (Millet, 2008). As amphorae and dolia are typically larger vessels, the low amount of sherds compared to the high number of individuals seems strange. This can be explained, however, by the fact that each sample from the debris layer was counted as an individual context which could lead to a slight overestimation of the number of individuals present.

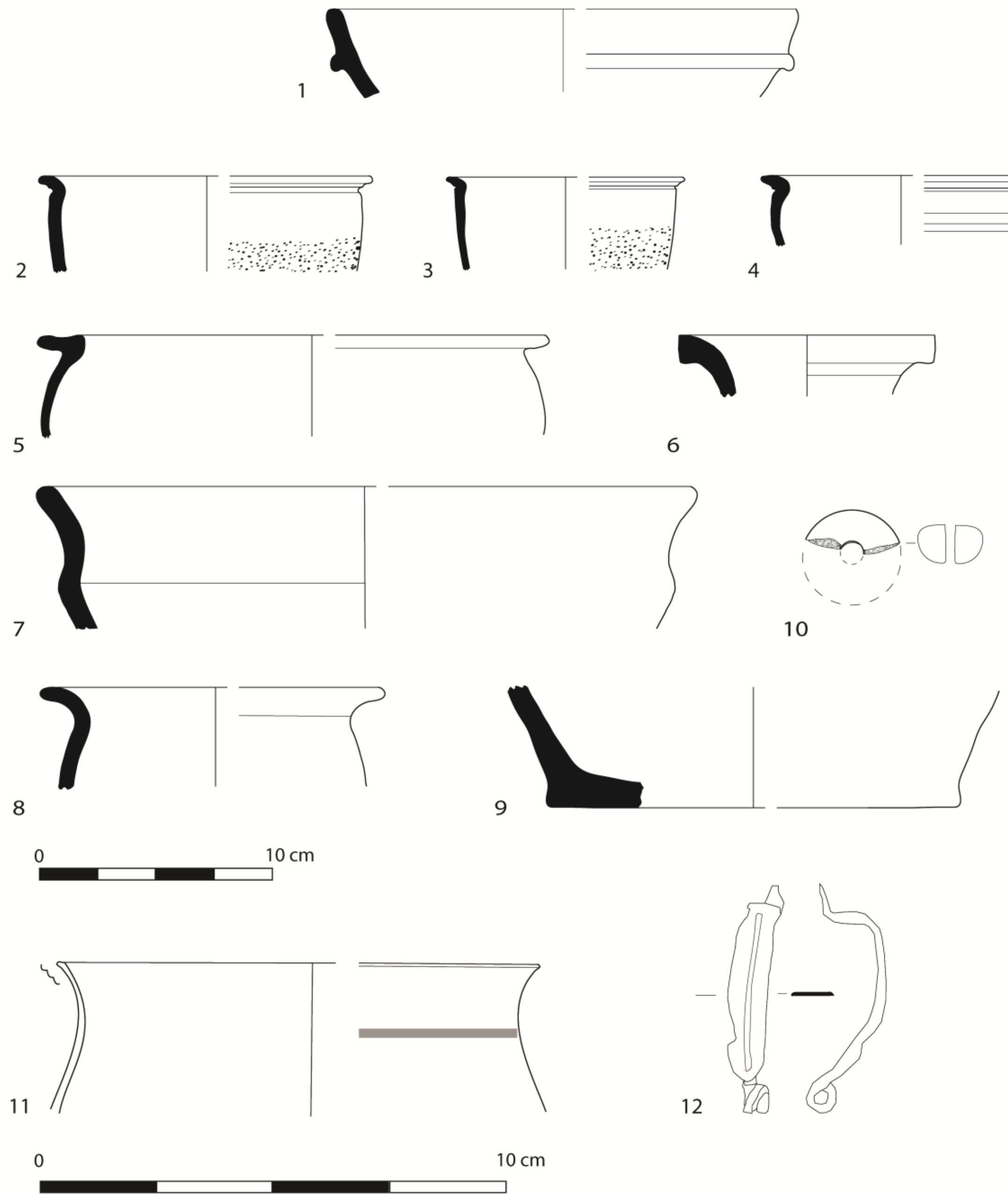


Figure 45 Selection of finds from sieve fraction > 10mm with samian Lud. Ti’ dish (1) Cologne colour coated Hees 2 cups (2-4) oxidised ware Stuart 210 bowl (5) ring shaped flagon rim (6) handmade bowl type De Clercq K2 (7) handemade cooking pot type De Clercq P2 (8-9) reduced spindle whorl fragment (10) glass cup type Augusta Raurica 38 (11) fibula type van Heeren and Van der Feijst type 47 (12).

The assemblage contained a large amount of highly fragmented reduced (259 sherds, 30 MNI) and oxidised ware (332 sherds, 33 MNI). Except for a small contingent of Rhine-Meuse-Eifel ware (27 sherds, 11 MNI), the sherds seem to have an unknown local or regional provenance. Typologically, rim sherds could be attributed to bowl types Stuart 210 (2 MNI) (Figure 45; no. 5) and Niederbieber 104/Stuart 211, a lid-seated pot type Niederbieber 89/Stuart 203 and a lid fragment. Except for Stuart 210, all types occur from the second century onwards (Oelmann, 1914; Stuart, 1963). In addition, a large amount of northern Menapian handmade pottery (414 sherds; 51 MNI) is observed.

Typologically fragments with an everted rim and S-shaped rim-shoulder evolution could be attributed to a type P2 cooking pot (7 MNI) (Figure 45, no.8-9), a very common type in the Menapian area during Roman times (De Clercq, 2009c). One larger rim fragment (1 MNI) (Figure 45; no. 7) was clearly a bowl type K2, while two lip-seated rims (2 MNI) and lid fragments (2 MNI) were also present. Several rims were decorated with fingertip impressions, and many burnishing traces could be noted on the sherds. Remarkably, many fragments were secondary burned, indicating that they were used in a heat-intensive activity. While the amount of handmade ware at this site seems rather large, this is a typical phenomenon for sites located on/near the coastal plain of the *civitas Menapiorum* as attested by pottery studies of Oudenburg (Vanhoutte et al., 2009b), Stene (Demey et al., 2013), Plassendaele (Vanhoutte and De Clercq, 2007), Middelburg (De Clercq, 2009a), etc. Finally, 187 fragments (14 MNI) of soft-baked organic tempered salt containers were found.

Besides pottery, the debris layer contained two spindle whorl fragments in a reduced fabric (Figure 45, no. 10), as well as a few metal objects and glass sherds. Most metal objects are fragments of wrought iron nails with a round head and rectangular section. Yet, a fibula in an unknown copper allow was also recovered (Figure 45, no. 12). This curved band fibula with an underwire spring construction is similar to a van Heeren and Van der Feijst type 47/Riha type 7 fibula, which is firmly dated in the second century CE (Riha, 1979; Heeren and Van der Feijst, 2017). In addition, four discoloured, transparent fragments of thin-walled glass with thinly engraved linear decoration and two turquoise circular beads, probably part of a bead necklace, were discovered. One steep, slightly everted fluted rim (Figure 45, no. 11) can be attributed to a *Steilwandiger Becher mit nach aussen gewölbtem Rand* type Augusta Raurica 38 (type Trier 39/Aventicum 47). Fünfschilling (2015) dates this type between 100/120-180 CE. This beaker type primarily occurs in the northern provinces (*Gallia Belgica, Germania, Britannia*). However, it is a relatively uncommon beaker type and might be imported from a specialised production centre (Fünfschilling, 2015).

In addition, two other large object categories were present: baked clay fragments (3680 pieces; 9.7 kg) and sintered clay 'slags'(1825; 9.5 kg). The soft-fired, porous, purplish-white to orange-red clay fragments were found abundantly in the red-brown debris layers and, to a lesser extent, in the dark grey layers. These fragments are extremely weathered due to depositional (dumping, transport etc.) and post-depositional processes and pulverise easily. Unfortunately, no diagnostic features were recognised in this fired clay category. At salt production sites, large amounts of miscellaneous, undiagnostic fired clay fragments are quite common due to the destruction and disintegration of clay-built heating structures and other briquetage elements (pedestals, slabs etc.) (Lane and Morris, 2001; Pool, 2012; Hathaway, 2013).

In the vitrified clay category, several types could be distinguished:

(1) smaller lightweight vesicular, highly porous, pale greenish-grey fragments that resemble fuel ash slag.

(2) larger, heavier and solid vitrified clay fragments.

(3) small amorphous fragments that could not be assigned with certainty to either category.

Fuel ash slag results from a high-temperature reaction between alkali-rich fuel ash from the fire and silica-rich material such as sand or clay (Biek and Bayley, 1979; Bayley, 1985). As they can be formed in any sufficiently hot fire, they are not indicative of any specific craft activity, and their presence has been attested at salt production sites (Hathaway, 2013; Biddulph, 2016) as well as at glass ateliers (Biek and Bayley, 1979) and metallurgical workshops (Bachmann, 1982; Hauptmann, 2020). Together with fragmented baked clay pieces, fragments of these brittle fuel ash slags mainly form the content of sieve fractions 2-5 mm and 5-10 mm.

The larger amorphous greenish-grey, solid vitrified clay fragments are highly similar to one another but vary considerably in form and size. In total, 231 fragments weighing 4.6 kg were retrieved from the bulk samples, and 198 additional fragments (4.8 kg) were collected by hand across the debris zone during excavation. However, it should be noted that the collected fragments are only a fraction of the material present in the debris layers. The composition was studied through targeted bulk samples, and the debris layers were not completely excavated to retrieve all finds. Quite often, a thermal transition from a highly vitrified inner surface to a slightly vitrified flat/slightly plano-convex clay bottom can be observed (Figure 46). Similar objects have been found in large quantities on other artisanal sites in the Menapian coastal plain, for example, at Leffinge (cfr. 7.2) and the complex 's-Heer Abtskerke-'s Gravenpolder (cfr. 7.3). Chapter 8 discusses these amorphous vitrified clay fragments found at different salt production sites in the northern Menapian territory in detail.

Figure 46 Examples of vitrified clay fragments discovered at Aardenburg Peurssensstraat, with the slightly vitrified flat/slightly plano-convex clay bottom on the left, the highly vitrified/glassy inner surface in the middle, and the cross section showing the gradual thermal transition on the right (© C. Verhelst and UGent)

5.4.3 Comparing the debris layers

In the field, two types of debris layers with a distinct hue (dark grey or red-brown) were observed, which might have slightly different compositions. Even though the lateral and vertical transition between these layers was rather diffuse, clear core areas could be defined (Figure 43). In order to compare the composition of the different debris depositions, bulk samples were taken at strategic locations and sieved on different mesh widths to objectively quantify the fragmentation rate. By comparing the percentage ratio of the different sieve fractions in a ternary plot (Figure 47), differences in sample size and the absolute amount of material are evened out. On the graph, two clusters stand out: a red and black cluster. The red cluster contains the samples from the red-brown debris layers, while the black cluster contains all six samples from the dark grey layers (Figure 47). The fact that the bulk samples from the red-brown and dark grey debris layers cluster nicely indicates that the fragmentation rate of the different layers is similar regardless of where the samples were taken. In contrast to the red cluster in which the archaeological material is evenly distributed across the different sieve fractions, the black samples cluster towards sieve fraction >10mm. The dark grey debris layers thus contain proportionally larger material than the red-brown layers, indicating that the material from the red-brown layers is more fragmented.

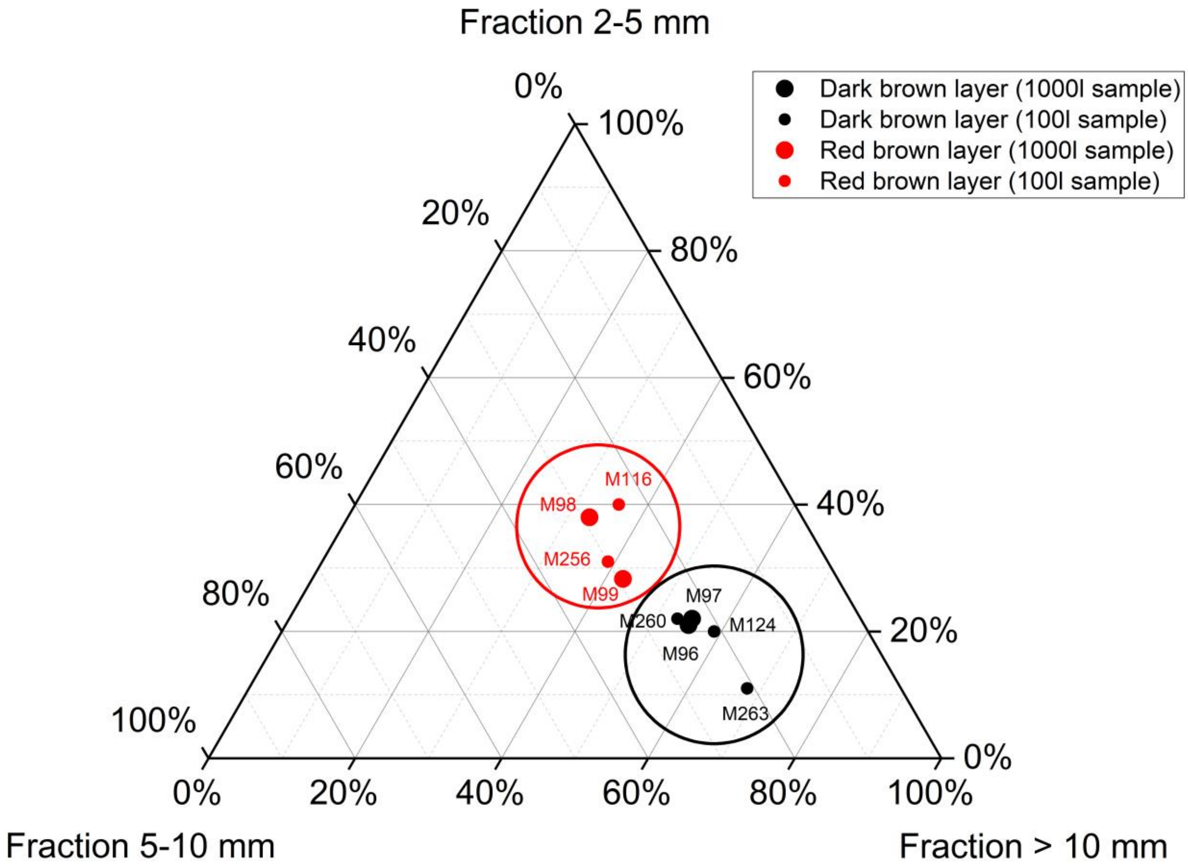


Figure 47 Ternary plot of the percentage ratio of the different sieve fractions from each bulk sample.

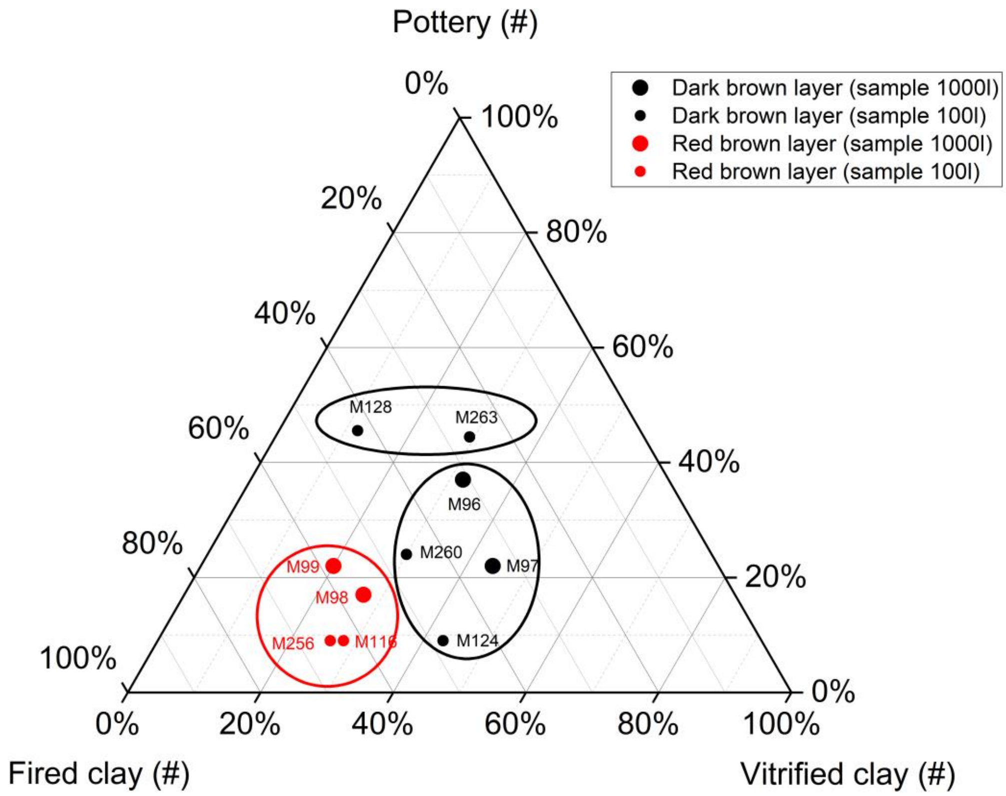
Similarly, the number of fragments and the weight of the three largest object categories[11] (pottery, baked clay and sintered clay) recovered from sieve fraction > 10 mm are compared in two ternary plots (Figure 48). The first ternary plot (Figure 48, top) compares the number of fragments in each object category from the different samples. In this graph, not two, but three clusters could be recognised. The first cluster comprised samples 128 and 263. These samples primarily consist of pottery complemented with either baked clay (sample 128) or vitrified clay (sample 263). A second cluster contained the remainder of the black samples (samples 96, 97, 124 and 260). These bulk

[11] The three main find categories are responsible for the overall composition of the debris layers, as the other find categories only marginally occur and do not really influence the overall composition.

samples have at least 30% vitrified clay but show a larger variation in pottery and fired clay content. A third and final cluster bundles the samples from the red-brown layers and is characterised by a large proportion of fired clay fragments (> 55%) and a few pottery and sintered clay fragments (Figure 48).

As the fragmentation rate of the material is an important proxy, a second plot (Figure 48 bottom) was made based on the weight of the several object categories that occurred in each sample. The three clusters observed in the previous ternary plot are confirmed and even magnified in this graph. From this second plot, it is clear that samples 128 and 263 form a distinct cluster primarily composed of pottery sherds. The remaining samples of the dark brown-greyish debris layers contained more vitrified material than the samples from the red-brown layers primarily composed of fired clay. Remarkably, all clusters in the weight graph seem to shift slightly away from the fired clay category towards to sintered clay category. This shift can be explained by the higher fragmentation rate of baked clay fragments compared to sintered clay fragments. On average, the absolute number of sintered clay fragments is lower, but these are slightly heavier. This also explains why the dark grey layers cluster towards sieve fraction >10 mm in Figure 47. As the vitrified material is slightly heavier and less prone to disintegrate, proportionally larger fragments of vitrified clay preserved in the archaeological record.

Despite the clusters shifting slightly between the graphs, the pattern remains unchanged and clearly indicates that the composition of the red-brown and dark brown-greyish debris layers are slightly different. The red-brown layers contain proportionately more fired clay fragments (in numbers as well as in weight) than the dark grey layers, while the latter primarily contained vitrified clay fragments. These soft-fired clay fragments are more susceptible to fragmentation which would explain the more evenly balanced distribution across the sieve fractions (higher portion of fine material in sieve fractions 2-5mm and 5-10mm). The high concentrations of low-fired orange/red clay fragments may also be responsible for the reddish hue of the debris layers. Samples 128 and 263 form a separate cluster which was dominated by pottery fragments and a few baked clay or sintered material. The peripheral position of the samples can perhaps explain their unusual composition near the outer edge of the dump zone (Figure 43).



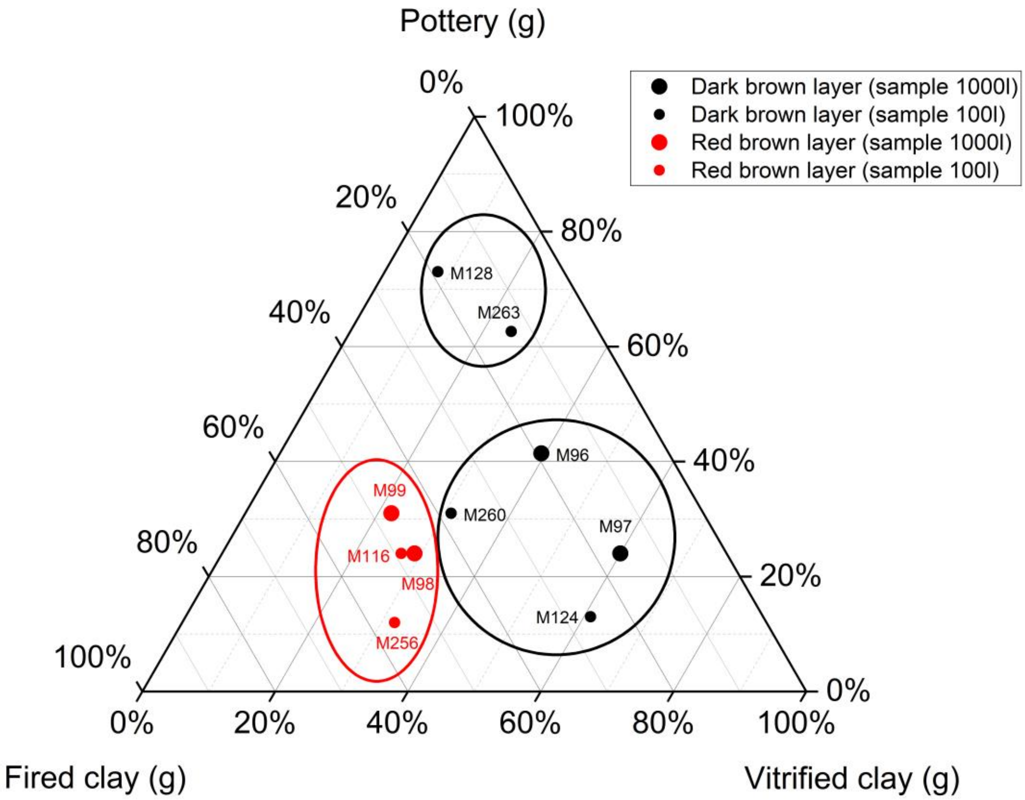


Figure 48 Ternary plots comparing the three largest object categories (pottery, fired – and vitrified clay) found in sieve fraction >10mm. The top ternary plot compares the number of fragments from each category while the bottom ternary plot compares the weight of each category.

5.4.4 The debris zone at Aardenburg Peurssensstraat interpreted

Several diagnostic finds, such as the Déch. 68 cups, the Lud Ti' dish, the Hees 2 cups, the amphorae stamp of P.CICELI and the glass beaker type Augusta Raurica 38, date the debris layers in the second half of the second century CE. Based on the dating of these finds, the debris zone can be assigned to Aardenburg's occupation phase I (150-170 CE) and/or II (170 -185/190 CE). As such, it is contemporaneous with the ash-rich deposits discovered underneath the later phase III *castellum* at Tuin Ds. Vis, the Tuimelsteenstraat, Weide Quataert, and Weide De Smet.[12] These ash layers and the extensive debris zone at the Peurssensstraat suggest that the artisanal activity in the earliest occupation phase was much larger and more important than previously assumed. The simultaneous start of the artisanal activity and the military occupation implies some form of (in)direct military involvement in the local salt exploitation at Aardenburg. This (indirect) military connection could explain the occurrence of, for the area, relatively large quantities of luxurious Cologne colour-coated ware, as well as the presence of the glass beads and the fragments of a glass beaker in the artisanal refuse zone.

As no direct traces or structures related to craft activities were found, the debris layers are not the result of repeated on-site activity. Rather, they represent a refuse zone of one or more artisanal sites operating near the Peurssensstraat site. The ternary plots (Figure 48) clearly showed that the composition of the red-brown and dark-brown debris layers differed slightly. Explaining these differences, however, is not straightforward. Multiple (unknown) factors may have influenced the layers' composition. Large quantities of miscellaneous, undiagnostic fired clay are common on salt production sites and mainly stem from the destruction and disintegration of work floors and heating structures. Given the dominance of fired clay fragments in the red-brown layers, these layers might primarily correspond with the demolition or maintenance and repair of the work floor and heating structures in the work zone. On the other hand, the dark brown–greyish layers contain more vitrified clay fragments. As will be presented in Chapter 8, the larger amorphous greenish-grey, solid vitrified clay fragments represent vitrified hearth bases that formed at the bottom of the salt production hearths. The production hearths might have been cleaned between firing sequences, during which these vitrified hearth base fragments were removed. Following this idea, the dark brown-greyish debris layers might represent debris generated during cleaning activities and maintenance work on the heating structures.

Unfortunately, the exact circumstances in which the material was dumped cannot be deduced from the layers' composition. At the moment, it is impossible to say whether the debris accumulated as part of a pre-determined waste disposal plan in which material was repeatedly dumped over a short period of time or whether these debris layers are the result of a single dump of material following the dismantling and rebuilding of a production site. In any case, it makes sense that in well-managed production centres, debris was removed regularly from the working areas not to hinder production (Hathaway, 2013, 252). The Peurssensstraat site was well suited as a refuse zone since the underlying Pleistocene coversand gradually slopes down eastwards towards an active tidal channel. In addition, the Pleistocene subsoil in the area was quite irregular, forming small micro-depressions in the landscape, which might have been wetter and less accessible. By systematically dumping production

[12] As noted in section 5.2, there are several questions regarding the nature and chronology of the pre-military phase I defined by Van Dierendonck & Vos (van Dierendonck and Vos 2013). Further research is needed to verify whether a distinct pre-military phase existed or if phases I and II should be interpreted together as one longer early military phase.

debris in such micro-depression, they may have tried to level the underlying topography and to desiccate the wet, marshy subsoil improving its accessibility in the process. As the fort of Aardenburg was situated within a dendritic system of waterways (Figure 39), the dump of production waste in wetter areas might have been part of a wider strategy to desiccate and improve access to marshy areas. A similar phenomenon was observed southeast of the *castellum* at the Vestinggrachten, where debris from artisanal activities was used to (partially) fill a depression in the landscape (D'hondt, 2010).

5.5 Identifying craft activities at Aardenburg: a heated debate

To this day, it is unclear whether the craft activities at Aardenburg relate to salt production, metallurgy (iron and/or bronze), pottery production or lime burning (de Visser, 2001; De Clercq and van Dierendonck, 2006; De Clercq, 2011; van Dierendonck and Vos, 2013). The heated ‘salt versus lime production’ debate of artisanal sites in the northern Menapian coastal plain (e.g. Leffinge, Koudekerke, Middelburg and ‘s-Heer Abtskerke) might have been a contributing factor to the overall caution regarding the interpretation of the artisanal activities at Aardenburg. While Leffinge was never contested as a salt production site (Thoen, 1981, 1986, 1987), the other sites were sometimes connected to salt production, then to lime production. The discussion peaked in the late 1980s - early 1990s with several short publications in which each side presented their arguments either in favour of salt production (Ovaa, 1972, 1975, 1987, 1988) or lime production (van den Berg and Hendrikse, 1980; van den Berg, 1988). The debate was never truly resolved. While salt production is often put at the forefront, the other possibilities linger in the background as possible alternatives. The following section presents the expected archaeological evidence of each craft individually and verifies whether (some of) these elements relate to the archaeological evidence discovered at Aardenburg.

5.5.1 Metallurgy

Throughout history, metalworking has received ample attention. This is not surprising given the importance of metal in all aspects of everyday life. Metals can be found in construction materials, craft and agricultural tools, weapons, jewellery, domestic objects, etc. Without going into too much detail,[13] a clear distinction can be made between smelting and smithing activities. The former should be seen as the processing of raw ores into alloys (iron, bronze, brass etc.), while the latter is the fabrication and repair of metal objects by forging on an anvil or welding activities (Tylecote, 1987; Hauptmann, 2020; Rehren, 2020). Both activities are well-attested at Roman sites, leaving distinct imprints in the archaeological record. The remains of certain hearths and furnace constructions used for smelting and smithing can point to a specific craft (iron, bronze etc.). However, more often simple, discrete structures were used. While the heating structures are less indicative, the surrounding debris and objects provide valuable information regarding the nature of the metalworking on site. Metalworking creates heaps of waste, such as different types of slags, moulds, crucibles, tools and

[13] For a detailed discussion of metalworking activities, see Tylecote (1987); (Hauptmann, 2020; Rehren, 2020).

semi-finished productions, of which the type of craft can be derived based on archaeological and (petro-)chemical analyses (Tylecote, 1987; Rehren, 2020).

At Aardenburg, a small zone (approximately 6 by 4 m) south of the road in the artisan quarter (north-eastern corner of Hof Buize I) contained undiagnostic corroded iron scrap material, smithing slags[14] and hammer scale. The lack of smelting slags indicates smithing activities rather than iron ore smelting (van Dierendonck and Vos, 2013, 180). As these finds occur clustered within a well-defined area, and no other traces related to metalworking were found in the 'industrial' zone, the metalworking seems to be limited to a single blacksmithing workshop. The remaining hearths are connected to other craft activities. Hammerscale found during a recent excavation (Aardenburg Draaibrugseweg) might suggest the presence of another blacksmith working from a workshop northwest of the *castellum* (Wattenberghe and van Jole-de Visser, 2012).

A certain amount of blacksmithing near a *castellum* is expected given the constant need to repair military gear and weaponry, manufacture building materials, etc. Several forts along the German and Raetian limes and Hadrian's Wall show evidence of small workshops for metalworking activities (Gralfs, 1994; Allason-Jones and Dungworth, 1997). Soldiers could perform these actions inside the fort in (open) *fabrica* workshops, but independent civilian contractors could also perform these activities working from a workshop district in the *vici* (Reddé, 2006b; Kolbeck, 2018). Closer to home, the late third-century hearths and furnaces inside the Oudenburg fort[15] point towards specialised bronze-alloy brooch production workshops in combination with ironworking (Vanhoutte, 2009, *in press*). Even though the hearths from Oudenburg show similarities to the Aardenburg examples, the lack of metallurgical slags, semi-finished goods and metal objects in most of the artisan quarter at Aardenburg indicates that other craft activities took place here.

5.5.2 Pottery production

Another example of high-temperature artisanal activity is the manufacture of pottery. According to van Dierendonck and Vos (2013), two moulds (one birdlike figure and one Eros-applique) found in the 'industrial zone' implies some form of pottery production at Aardenburg. Additionally, a production centre of northern Menapian handmade ware, found in high quantities in the coastal plain, has been suspected in the vicinity of Aardenburg (De Clercq, 2009c; Vanhoutte et al., 2009b). However, none of the heating structures at Aardenburg resembles known pottery kilns with separate combustion and firing chambers. Furthermore, no misfired pottery, common at pottery production sites, was found near the hearths. Overall, there are only a few indirect indications for pottery production at Aardenburg, which cannot unambiguously be linked to the artisan quarter.

5.5.3 Lime burning

An older, more widely supported hypothesis is that the artisan workshops at Aardenburg, and by extension the workshops situated in the northern Menapian coastal wetlands, produced lime used for

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[14] Van Dierendonck and Vos (2013) mention the presence of so-called 'hearth bottom slags' though this could not be verified.

[15] In Oudenburg, 38 hearths representing 53 hearth levels, two furnaces and three hearth pits were discovered. These heating structures belonged to the first stone fort occupation (fort period 4), which is contemporary with the stone fort at Aardenburg (phase IV) (Vanhoutte, *in press*).

building activities (van den Berg and Hendrikse, 1980; van den Berg, 1988; De Clercq and van Dierendonck, 2006). To manufacture lime, a calcium carbonate ($CaCO_3$)-rich material, preferably a very pure limestone, was burned at temperatures above 900°C until it decomposed into carbon dioxide (CO_2) and calcium oxide (CaO). The calcium oxide, also known as quicklime, was then mixed with water, a process known as 'slaking', to produce hydrated or slaked lime (calcium hydroxide/portlandite). Once hydrated, the product could be stored for a long time if kept in suspension with water or in airtight containers. When exposed to air, which happened when the lime was used to create mortar or plaster,[16] it slowly hardened by storing carbon dioxide (CO_2) and releasing water, followed by the formation of calcium carbonate crystals ($CaCO_3$) (Dix, 1982; Demarez, 2014; Ackermann and Koch, 2015).

Two types of lime kilns can be distinguished for the production of lime: 'clamp kilns' and 'flare kilns'. In the former type, alternating layers of fuel and limestone were stacked into a pit or built into a mound which was then covered with clay or turf (Dix, 1982; Ackermann and Koch, 2015). The end product was of lesser quality because the lime was inevitably mixed with the fuel ash. Besides a heating area of varying dimensions and the remains of unburned (or partly burned) limestone, these features leave few archaeological traces (Dix, 1982). 'Flare kilns' were much more common in Antiquity, and their construction has been described in detail by Cato (Agr. IIXL.1-8). Even though details of the individual lime kilns, such as size, shape and construction method, slightly differ, the archaeological examples largely match Cato's description. Overall, these flare kilns, approximately 1.5-4 m in diameter, consist of a 'calcination chamber' constructed on top of a hearth with a combustion chamber connected to a stoking pit using a firebox (Dix, 1982; Demarez, 2014; Ackermann and Koch, 2015). Preferably, the Romans integrated their lime kilns in a natural slope. This not only thermally insulated the kiln walls but also facilitated loading the limestone and e unloading the produced lime. Both needed to be done from the top of the kiln (Figure 49) (Demarez, 2014, 127-130).

In order to cut transport costs, these lime kilns were located either near limestone and fuel sources or near the construction sites (*villae*, towns, forts etc.). Both Demarez (2014) and Lavergne and Suméra (2000) suggested that production predominantly occurred near the raw materials, after which the quicklime was transported to the construction sites where it was slaked. Arguments in favour of such a lime trade are the lack of lime quenching pits at the production sites, but also the production capacity of the lime kilns, which by far exceeded local needs. Examples of large production sites are the lime kiln battery at Iversheim (Figure 49) and Kempraten (Sölter, 1970; Lavergne and Suméra, 2000; Demarez, 2014). In these lime kilns, the stokehole and combustion chamber were either at the same level, creating a bottom/low-level draft[17] or slightly offset, generating a mid-level draft. The latter changed the airflow; which in turn caused the temperature to rise faster. This method appears to have been developed from the second or third century CE onwards and was used, for example, in the lime kiln battery at Iversheim (Sölter, 1970; Demarez, 2014, 127-129). In any case, kilns with mid-level draft did not replace the bottom/low-level draft kilns, as both techniques continued to be used side by side throughout the Roman period. Overall, lime burning was a slow process that could take up to several weeks and consisted of several sequential phases such as loading of the kiln with limestone, the firing sequence, the cooling down period and the retrieval of the produced lime (Ackermann and Koch, 2015). The loaded 'calcination chamber' was covered with a clay mantle for

[16] Besides producing mortar and plaster, lime could also be used in tanning processes or as a soil improver in agriculture (Dix, 1982).

[17] This type was fairly common, see the lime kilns from Kempraten (CH) (Ackermann and Koch, 2015), in the Ajoie-area (CH) (Demarez, 2014), at Sivry-Courtry (FR) (Suméra and Veyrat, 1997), at Ghislenghien (BE) (Danese and Authom, 2015) etc.

insulation purposes,. Consequently, this mantle had to be removed to retrieve the lime. Together with fuel ash, the remains of this clay mantle, unburned or partially burned limestone and lime residue largely comprise the debris layers surrounding the lime kilns. As the kilns needed to be dismantled to retrieve the lime, only the lower part of the structure (e.g. combustion chamber, hearth and flue) remains preserved *in situ* (Demarez, 2014, 127-139; Ackermann and Koch, 2015).

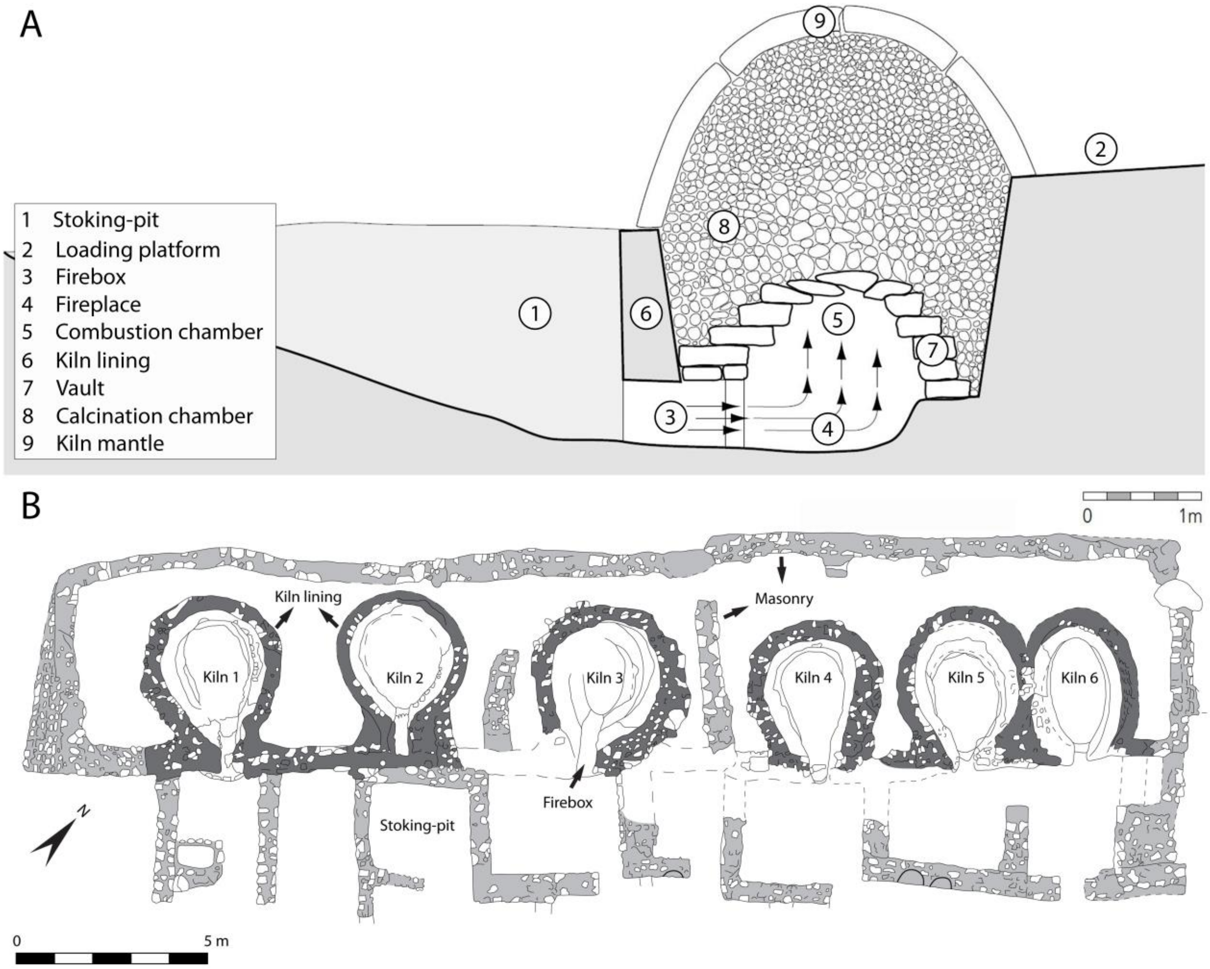

Figure 49 A: schematic reconstruction of a Roman lime kiln (after Demarez, 2014, fig. 141-142) and B: excavation plan of the Roman lime kiln battery discovered at Iversheim (DE) (modified after Sölter, 1970).

Taking the construction of known 'flared lime kilns' into account, the heating structures discovered at Aardenburg differ in several ways. Firstly, the heating structures were much smaller with a maximum external diameter of a few meters and an internal diameter rarely exceeding 1 m. This is significantly smaller than the dimensions of the archaeologically attested lime kilns in the Roman world. Secondly, the level topography of the 'industrial' zone excluded using natural slopes for the construction. Thirdly, a flue was only recorded in a few structures, while this should be an essential, well-constructed element of flared lime kilns. Theoretically, the heating structures could function as small stacked 'clamp kilns' as described by Dix (1982). However, the dimensions do not fit the known examples, and the external kiln walls should be made of stone or brick for which there are no indications on site.[18] Finally, large amounts of unburned or partially burned limestone and lime residue are lacking from the artisan quarter and the debris layers at Aardenburg.

Apart from the archaeological evidence, there are several additional arguments disproving the lime burning hypothesis at Aardenburg. First of all, suitable raw materials are absent as limestone does not naturally occur in the vicinity of Aardenburg. The closest available limestone source can be found in the area of Tournai (Tournai limestone). As Tournai limestone was used as a building material at Aardenburg, the limestone was imported in phase III. The distance between Aardenburg and Tournai is approximately 75 km, but the stones would have been transported by ship using the river Scheldt and the North Sea to save costs. However, several workshops predate the earliest Tournai limestone buildings at Aardenburg (the *principia* and baths) (van Dierendonck and Vos, 2013). In other words, the phase II workshops were active when no limestone was present on site and lime was not needed. Even in phase III, an earth-and-timber fort with a stone *principia* was constructed rather than a stone *castellum* for obvious economic reasons. The large-scale transport of Tournai limestone was too expensive when wood, clay and peat were readily available. As imported limestone was considered a too-costly building material, why would they use this precious resource as a raw material in lime kilns? If this argument already applies to Aardenburg, imaging using limestone as raw materials at all artisanal sites in the Menapian coastal plain (e.g. Middelburg, Koudekerke and 's-Heer Abtskerke), where no stone constructions occur (De Clercq, 2009c, 2011).

Alternatively, van den Berg (1980) and van Dierendonck and Vos (2013) suggested the use of shells (mussels, cockles, oysters etc.) as a raw material since these occur in relatively large quantities at Aardenburg and the other artisanal sites. Little is known about shell lime production during Roman times in northwestern Europe, but for the medieval period, shell lime production is certainly attested in the Netherlands (Janse, 1981). However, in Roman times, the presence of shells could easily denote consumption practices or shell processing activities. Large concentrations of shells were frequently found at regional non-artisanal habitation sites in the coastal plain as well, for example, at Serooskerke (Dijkstra and Zuidhoff, 2011) and Ramskapelle (Verwerft et al., 2019b). Also, in the case of lime production, one would not expect to find such large quantities of shells at the habitation sites. Since the lime burning process would require a large amount of shells, these shells would have been a valuable resource and would not have been thrown away.

Even if the hypothesis of shell lime production stands, the question remains what this lime was used for. The multiple workshops at Aardenburg (27 hearths in total), combined with the artisanal sites of Middelburg and 's-Heer Abtskerke, would have produced a significant amount of lime for which there was only a small local or regional market.[19] Except for the military infrastructure at Aardenburg, no stone buildings occur near the artisan quarter (van Dierendonck and Vos, 2013). In addition, the local building traditions (wooden farmsteads) in the Menapian sandy hinterland also exclude export to regional markets (De Clercq, 2009c, 2011).

[18] Clamp kilns could also be constructed underground in large pits, but there are no indications that this was the case at Aardenburg

[19] A certain amount of lime might have been required to produce mortar and plaster for stone buildings in military *castella* (e.g. Aardenburg, Oranjezon and Roompot) and central places (Wenduine, Colijnsplaat and Domburg). Still, this would not explain why these large production sites occurred far from the raw materials and the supposed consumption sites. Since the production conditions near the consumption sites in the coastal plain would have been practically the same, there are no advantages to producing lime in isolated locations far from the required resources and the consumers.

5.5.4 Salt production

Given Aardenburg's location at the edge of the coastal plain, it has been suggested that the hearths were involved in the production of salt and derivative products such as fish sauce (de Visser, 2001; De Clercq and van Dierendonck, 2006; van Dierendonck and Vos, 2013). The Menapian coastal wetlands have a long tradition of salt production dating back to the middle Iron Age. In the vicinity of Aardenburg, several Roman salt production sites are known (see, Chapter 4). These production sites were situated near (side branches of) tidal inlets supplying the necessary saltwater for salt production. Peat was exploited as a fuel source, and the clay was used to construct the hearths. At Aardenburg, the artisan quarter was located in a soggy area close to the Ee river basin connecting the site with the salt marshes and the North Sea. A macrobotanical analysis of a water well on the outskirts of the industrial zone indicated a freshwater environment with nearby a brackish/saltwater environment (R. Van Heeringen, 1989, 133-134; van Dierendonck and Vos, 2013, 38-39). Unfortunately, no water management infrastructure was found near the hearths, which would unambiguously have pointed towards salt production.

While lime and pottery production required an enclosed kiln with separate combustion and firing chamber, salt production called for open hearths with accessible salt containers or pans. In these hearths, the salt containers were placed above the fire using so-called briquetage elements (pedestals, stabilisers, pinch-props, slabs etc.). The hearths of Aardenburg could have functioned in this regard as they were constructed with an inner diameter rarely exceeding 1 m. However, large amounts of salt container fragments and diagnostic briquetage elements were lacking in the artisan quarter and in the debris depositions. Instead, only large amounts of miscellaneous, undiagnostic fired clay fragments were present. This phenomenon is often encountered on salt production sites due to the destruction and disintegration of clay-built heating structures, work floors etc. (Lane and Morris, 2001; Hathaway, 2013). The absence of both salt containers and briquetage elements is often considered problematic for the identification of salt production. Yet, this could also signify changing production mechanisms as observed in Roman Britain.

In Droitwich (Worcestershire, GB), Hurst (1997, 149) observed a significant increase in production capacity from the second century onwards, which he connected to technological improvements. Arrowsmith and Power (2012) noted a similar evolution in Nantwich (Cheshire, GB). At that site, they also found fragments of lead sheeting, indicating the use of lead evaporation pans from the middle of the second century onwards. Similar fragments dating to the end of the second century were also found in Middlewich (Cheshire, GB), confirming the transition from clay to lead evaporation vessels in a specific salt production area (Zant, 2016). According to Zant (2016, 142), this improved evaporation technique using lead evaporation vessels was well established in Cheshire by the end of the second century at the latest. In the northern Menapian territory, the lack of salt containers at the production sites and the introduction of hearth batteries (e.g. Leffinge, 's-Heer Abtskerke and Middelburg) suggests a similar technological innovation taking place roughly at the same time (Chapter 7). Instead of lead, which was not as readily available as in Britain, iron or copper-alloyed vessels could have been introduced.[20] These metals were very valuable in Roman times and would have been recycled, leaving little archaeological trace. As these metal vessels probably required

[20] The use of large iron salt pans have been attested in the area during medieval times (Leenders, 2007).

different support mechanisms, it might explain as to why no briquetage elements were recovered at Aardenburg, except for large amounts of undiagnostic fired clay fragments (cfr. 7.5.3).

Similar to Roman Britain, this transition from clay to metal evaporation pans could have been a way to increase production to meet an increased salt demand. However, this transition could not be observed at all production sites in the Menapian *civitas*. Ceramic containers continued to be used well into the third century alongside metal evaporation pans. For example, in the southern part of the Menapian *civitas* along the French coast, multiple sites such as Looberghe (late second, early third century CE), Pitgam (first – early third century CE) and Steene (first – early third century CE) contained large amounts of ceramic salt containers and small circular pillar fragments (Hannois, 1999; Donnadieu and Willems, 2015; Faupin, 2017b; Teysseire, 2020). Unfortunately, no heating structures were preserved *in situ* at these sites, making it impossible to reconstruct the hearth dimensions and to determine how these heating structures functioned exactly.

In addition, the 0.5 m thick debris layer found at the site 'Tuin Ds. Vis' consisted primarily of calcium-rich ash (JROB, 1979). As noted above (section 5.3.2), this ash-rich debris layer might have been present underneath a large part of the later *castellum*. Large ash deposits are not uncommon on artisanal sites, and similar calcium-rich ash layers were noted at Koudekerke, Middelburg, 's Heer-Abtskerke and Leffinge.[21] Analyses of comparable ash layers from medieval salt production centres such as Steenbergen (NL), Hulst (NL) and Tholen (NL) also revealed large calcium concentrations (Leenders, 2007; Mientjes, 2015). According to Leenders (2007), the high calcium content in the debris might result from removing calcium-rich salts[22] during the evaporation process. Similarly, in Roman times, these calcium-rich salts could have been removed, resulting in calcium-rich debris layers on site.

Furthermore, the composition of the debris depositions discovered at Aardenburg (e.g. Peurssensstraat and Vestinggrachten) is comparable to the debris layers of the known salt production site discovered at Leffinge. On both sites, the red-brown and dark brown-greyish debris layers largely consisted of fired clay fragments, vitrified clay fragments and fuel ash slag. The high amount of vitrified clay elements recovered at both sites was rather surprising as vitrification is indicative of high-temperature activities (ca. 900°C). Traditionally salt production has been interpreted as a long-lasting process occurring at relatively low to medium temperatures. For a detailed discussion of these vitrified clay fragments, see Chapter 8. Yet, the transition from clay to metal evaporation vessels and the introduction of a new type of heating structure (hearth batteries) might have changed the salt production mechanisms and how the heating structures functioned. Although these vitrified fragments are not indicative of a specific craft, the fact that these fragments occur both at the known salt production site of Leffinge and Aardenburg is an argument in favour of salt production activities.

Overall, the known presence of nearby salt production sites, the availability of natural resources, the presence of suitable hearth infrastructure, and the similarities between the debris depositions at Aardenburg and other known salt production sites, make it rather likely that at least some (if not all) of the hearths at Aardenburg were involved in salt production.

[21] For the study of ash recovered from Middelburg, 's Heer-Abtskerke, 's-Gravenpolder and Leffinge, see APPENDIX6.

[22] Next to sodium chloride, the brine always contains a set of other salts (calcium carbonate, calcium sulphate, magnesium chloride etc.) naturally present in seawater. As these salts have a different solubility, they will crystalise at different moments during the evaporation process (McCaffrey et al., 1987; Babel and Schreiber, 2014). (CHAPTER 3)

5.6 Economic implications of salt production at Aardenburg and the northern Menapian territory

In the late second century, the military occupation shifted from the more inland-oriented fort of Maldegem towards Aardenburg (Thoen, 1991; De Clercq, 2009c; Dhaeze, 2011). A *castellum* was built (ca. 170-185/190) at a strategic position at the intersection of terrestrial and maritime connections. As such, the site was favourably positioned to control the flow of goods and people. Additionally, the military presence stimulated local salt production for military use and/or trade. Several debris depositions, ash layers and hearths dated to this earliest military occupation are known. The lack of civil occupation traces near the artisan quarter and the simultaneous start of the artisanal activity and the military occupation, implies some form of active military involvement in the local salt exploitation. Positioning salt exploitation sites near the fort ensured the military apparatus of a constant supply of a vital commodity used to preserve and prepare provisions, tanning etc. (Tsigarida, 2012a, 2014a, 2014b; Dekoninck and De Clercq, 2022). As discussed in Chapter 4, a relationship between the Menapian *civitas* and the Roman army was already well established in the second half of the first century CE, as evidenced by the *salinatores* inscriptions. In these inscriptions, the *salinatores* of the *civitas Menapiorum* and *Morinorum* honoured *Lucius Lepidius Proculus*, a centurion of *legio VI Victrix* stationed at *Novaesium* (Neuss), who was a provisions officer responsible for the legion's salt supply (Thoen, 1986; Dekoninck and De Clercq, 2022).

Next to a local military supply, salt was also an integral part of larger regional military (and civilian) supply networks. In Britain, next to providing salt to the local residents, several salt-producing areas have been closely linked to military supply networks.[23] The fact that these supply systems could be quite extensive has been suggested by Gerrard (2008), who demonstrated that the Dorset Black Burnished 1 pottery industry might be an army-controlled supply line of pottery and salt(ed products) stretching from south-west Britain to the northern frontier (Hadrian's Wall). In *Gallia Belgica*, the *Nehalennia* altars provide evidence for a thriving salt trade from the late second century onwards. The provenance of these merchants[24] and the origin of the stones suggest strong connections between the Rhineland, the northern Menapian territory and *Britannia* for salt and fish sauce (Stuart and Bogaers, 2001; De Clercq, 2011). The consumption of fish sauce has been attested at Aardenburg by a dolium rim fragment bearing the scratch mark ALIIC XI S, indicating that this storage vessel was filled with 11.5 *amphorae* of *allec* (De Clercq and van Dierendonck, 2006; van Dierendonck and Vos, 2013). Through private contracts with garrisons stationed at the Rhine limes or contracts with the Roman administration of *Germania Inferior*, these *negotiatores* might have been used to supply the Roman army stationed at the Rhine with salt and fish sauce (Tsigarida, 2014a, 2014b).

Changing supply mechanisms and/or an increased demand stimulated production, and, in addition to the Aardenburg workshops, multiple salt production sites from this period (e.g. Leffinge, 's-Heer Abtskerke and Middelburg) are known. Just as at Aardenburg, these workshops are

[23] For several salt production regions in Britain, a connection to the Roman military supply network has been assumed. For example, salt production in Central Somerset has been linked to the supply of the Roman legion stationed at Caerleon (Hathaway, 2013). Also, the 'industrial salt production centres' in Cheshire county (e.g. Nantwich) have been connected to the salt supply of the Roman troops stationed at Hadrian's Wall (Arrowsmith and Power, 2012, 179-182). Fincham (2002) even interpreted the Fenlands as a specific taskscape aimed at producing salt and salted meat for the Roman army.

[24] Most merchants came from Cologne (Stuart and Bogaers, 2001).

characterised by a lack of briquetage elements and the omnipresence of vitrified clay fragments which might represent technological improvements of an ancient technique. The introduction of metal evaporation vessels and of the linear succession of heating structures (so-called hearth batteries) would have pushed the production capacity of the area to unprecedented levels with major economic implications. As suggested in Chapter 4, the Menapian coastal wetlands were intensively exploited in Roman times as a specific taskscape or a productive landscape, focused on the exploitation of salt, to meet the increasing local and (supra) regional salt demand.

5.7 Conclusion

From the 1970s onwards, multiple artisanal sites have been discovered in and at the edge of the northern Menapian coastal wetlands suggesting an intense exploitation during Roman times. The nature of these heated crafts has been debated for decades. Over the years, metallurgical activities, pottery manufacturing, lime burning and salt production have been suggested as interpretation. The ambiguous position towards these craft activities slightly downplayed the area's significance in the wider economic network of northern Gaul.

In this chapter, we have attempted to attach the evidence of artisanal activity at Aardenburg to certain craft activities. After reviewing the available evidence from archaeological structures and debris layers, we conclude that the workshops at Aardenburg were probably related to salt production. From a landscape-based point of view, the site is well-positioned to produce salt as the raw materials were readily available and the location very well accessible to the transport network – both maritime and terrestrial. From the middle Iron age onwards, salt has been produced along the southern North Sea basin, and in the vicinity of Aardenburg, multiple Roman salt production sites are known.

Furthermore, as the composition of debris depositions discovered at Aardenburg is highly similar to the debris layers of known salt production sites in the area, for instance, at Leffinge, similar crafts activities might have taken place at both sites. The lack of clay salt containers and briquetage elements, one of the major arguments against salt production, might represent technological innovations, as seen in Cheshire, Britain. The Roman drive for technological optimalisation might have replaced the small individual clay vessel in favour of larger, better heat-conducting materials. Nevertheless, as exemplified by salt production sites in northern France, ceramic containers continued to be used well into the third century alongside metal evaporation pans. While a multifaceted use of the heating structures cannot be excluded, all evidence suggests that at least some (if not all) the workshops at Aardenburg were involved in salt production. Consequently, the 'marginal' coastal wetlands surrounding Aardenburg were intensively exploited in Roman times as a specific taskscape or productive landscape focused on the exploitation of salt. As was to be expected in the vicinity of a Roman *castellum,* metallurgical activities occurred in a specific zone in the artisan quarter, but evidence suggests this would have been of minor importance at Aardenburg.

Chapter 6 Late first – early second century salt production sites in the northern Menapian territory

6.1 Introduction

On the northwestern shores of the Roman Empire, salt was produced by artificially evaporating brine above heating structures. This production technique is often called the briquetage technique after the specific ceramic elements used on the production sites to manufacture salt. The overall shape and function of these different ceramic elements changed over time and therefore provided information on the technological choices made by the salt producers. In the northern Menapian territory, briquetage material is frequently found at late first- early second salt production sites (Figure 50). Yet, it is noticeably absent from some late second-early third-century sites within the same area. Before exploring this transition in the following chapters, it is important to thoroughly grasp the typo-technological characteristics of the briquetage material and the nature of the production sites at which it occurs.

This chapter addresses these questions by first presenting a detailed overview of the late first-early second century sites in the northern Menapian territory containing briquetage material. Several of these sites were the result of A.W.N excavation campaigns in the 60s and 70s and were never published in their entirety. Additionally, the typo-technological aspects of the briquetage material found at these sites were studied.[1] The use of different archaeometric techniques (petrography, XRF etc.) might, in the future, significantly enhance our understanding of this material, but this fell beyond the scope of this study. Finally, the briquetage material from the northern Menapian territory will be compared to similar briquetage material from late Iron Age-Roman production sites in northern Gaul and *Britannia.*

[1] The Microsoft Excel database registering the briqueatage material is presented in APPENDIX 3.

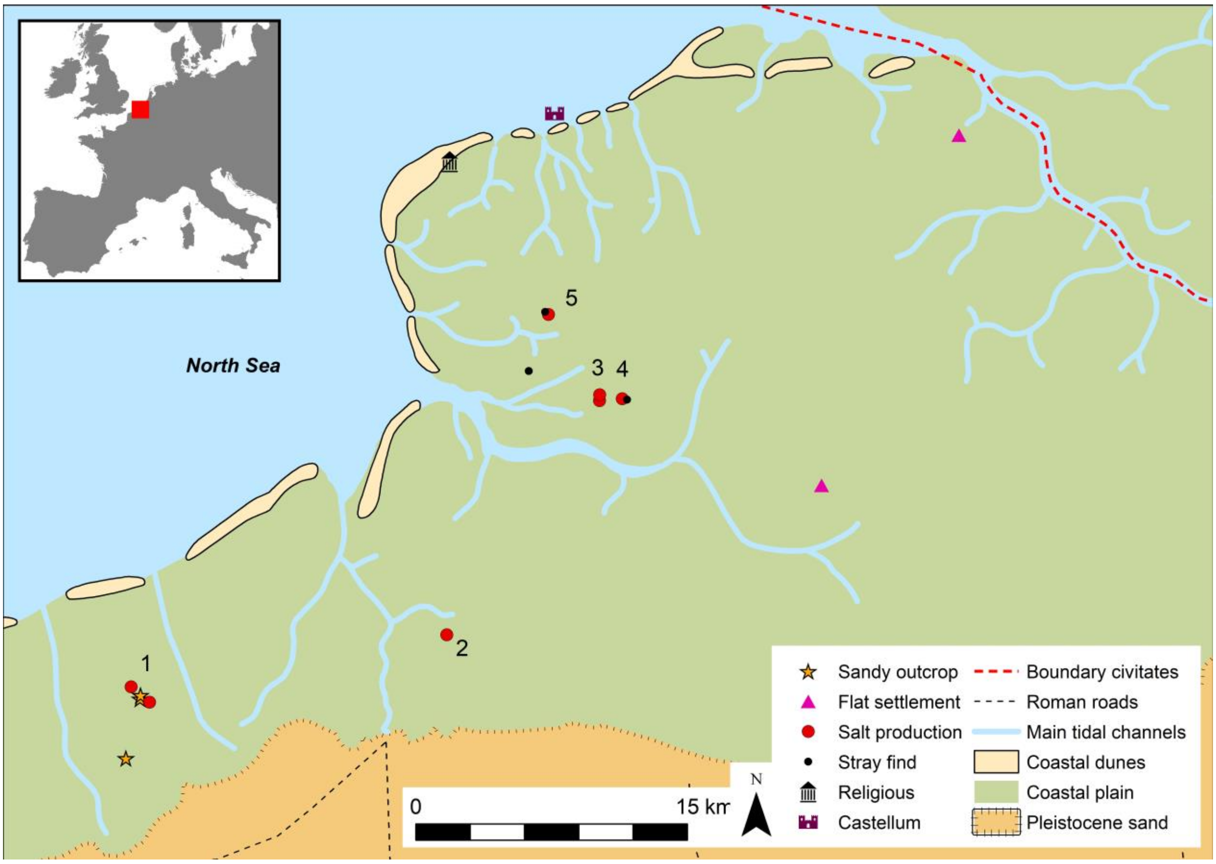

Figure 50 Roman occupation of the northern Menapian coastal plain during the late first – early second century CE depicting the salt production sites mentioned in the text. 1: Zeebrugge-Dudzele, 2: Oostburg 't Vestje, 3: Ritthem Havenweg, 4: Ritthem Schotteweg, 5: Koudekerke Meinersweg

6.2 Presentation of the sites

6.2.1 Zeebrugge-Dudzele

During the 1980s, the harbour of Zeebrugge expanded tremendously. During the construction of its inner port, multiple large docks with logistic centres to store and distribute cargo were built. These infrastructure works threatened several archaeological sites, and therefore, these works were monitored by Hollevoet and Hillewaert. Unfortunately, no legal framework for archaeological interventions existed yet, and documentation of the sites solely depended on the goodwill of the contractors. The observations occurred under difficult circumstances, and most often, archaeology was limited to observing soil conditions/landscape settings (e.g. presence of tidal channels) and collecting pottery fragments. Although the information is sometimes limited, as Hollevoet and Hillewaert themselves recognised, the sites provide valuable insights into the Roman exploitation of the coastal plain that would otherwise have been lost (Hillewaert and Hollevoet, 1987; Hollevoet, 1989; Hollevoet and Hillewaert, 1989).

During their campaigns, Hollevoet and Hillewaert recorded approximately ten locations with briquetage material *in situ* (Figure 51). Interestingly, all of these findspots were located alongside branches of an extensive gully network which would have provided the necessary salt water for salt production (Hollevoet, 1989; Hollevoet and Hillewaert, 1989). Dating these findspots is problematic as the contexts contained no diagnostic material. Hillewaert and Hollevoet (Hollevoet, 1989; Hollevoet and Hillewaert, 1989) dated these findspots at the end of the second - early third century CE but provided no arguments to support their claim. As the briquetage material is very similar to the late first century briquetage fragments discovered on other sites in the area (Achterhaven Geuldepot and Donk 1), these findspots might date from the late first century CE. Therefore, a more cautious dating that spans the late first – early third century might be more appropriate.

In the 1980s, *ex situ* briquetage material was discovered during construction work along the Boudewijn canal (Dudzele Boudewijnkanal) (Figure 51). Unfortunately, the exact context in which the material was found is unclear, and the finds could not be dated. Based on similarities with the material from the Achterhaven, Hillewaert and Hollevoet (1986b, 1986a) dated the context to the middle of the first – middle of the third century CE. At the same time, Hollevoet (1988) came across a small concentration of briquetage pottery at Ramskapelle Heistlaan while monitoring the construction of a drainage ditch. Although the context was disturbed, Hollevoet (1988) interpreted the material as the remains of a salt production site situated along a side branch of a larger northwest-southeast tidal channel. By using the prospection in the Achterhaven as a parallel, Hollevoet dated the assemblage in the third century CE. However, as the dating of the material from the Achterhaven lacks solid argumentation, a more cautious dating spanning the middle of the first – early third century might be more appropriate. Hollevoet (1988) acknowledged this fact when he stated that an older dating could not be excluded due to the lack of chronological indicators.

Furthermore, several briquetage concentrations were discovered during the construction of the Distrigas pipelines (Hillewaert and Hollevoet, 1986c, 1986b; Hillewaert, 1996). Unfortunately, the exact location of these sites is unknown, and, except for the 1992 campaign, the material did not preserve. The literature shows that the briquetage concentrations mainly consisted of salt containers with few salt pillar fragments. Due to the lack of diagnostic material, a conservative dating between the middle of the first – middle of the third century CE was proposed (Hillewaert and Hollevoet, 1986c, 1986b; Hillewaert, 1996).

The Geuldepot is a collective of about ten Roman pottery concentrations observed close together, mostly *in situ,* after the topsoil had been mechanically removed. The material was collected by hand, and three larger concentrations were manually deepened to recover as much material as possible. However, these concentrations might not represent the site as a whole. Only the surface material was collected, and quite a bit of material could have been lost while removing the topsoil. In addition, no context information was recorded, and the relation between the concentrations was not investigated (Patrouille, 2013). The sheer amount of briquetage material (3165 fragments) suggests the presence of one or multiple salt production sites near the Geuldepot. The Geuldepot was located at the edge of the tidal network, so it might represent a deliberate off-site dump of waste material from a nearby salt production site. However, during the 1999-2001 observations, no archaeological features related to salt production activities were found. In part, this might be explained by the limited nature of both the 1999-2001 and the 1980s' observations as well as the meandering activity of the tidal network which could have eroded most of the sites. De Clercq (2009b) dated the material of the Geuldepot in the late first century CE based on the presence of a Drag. 18, Drag. 27 and Drag. 37 fragments from southern Gaul and several terra nigra fragments (Holw. 26 or 27).

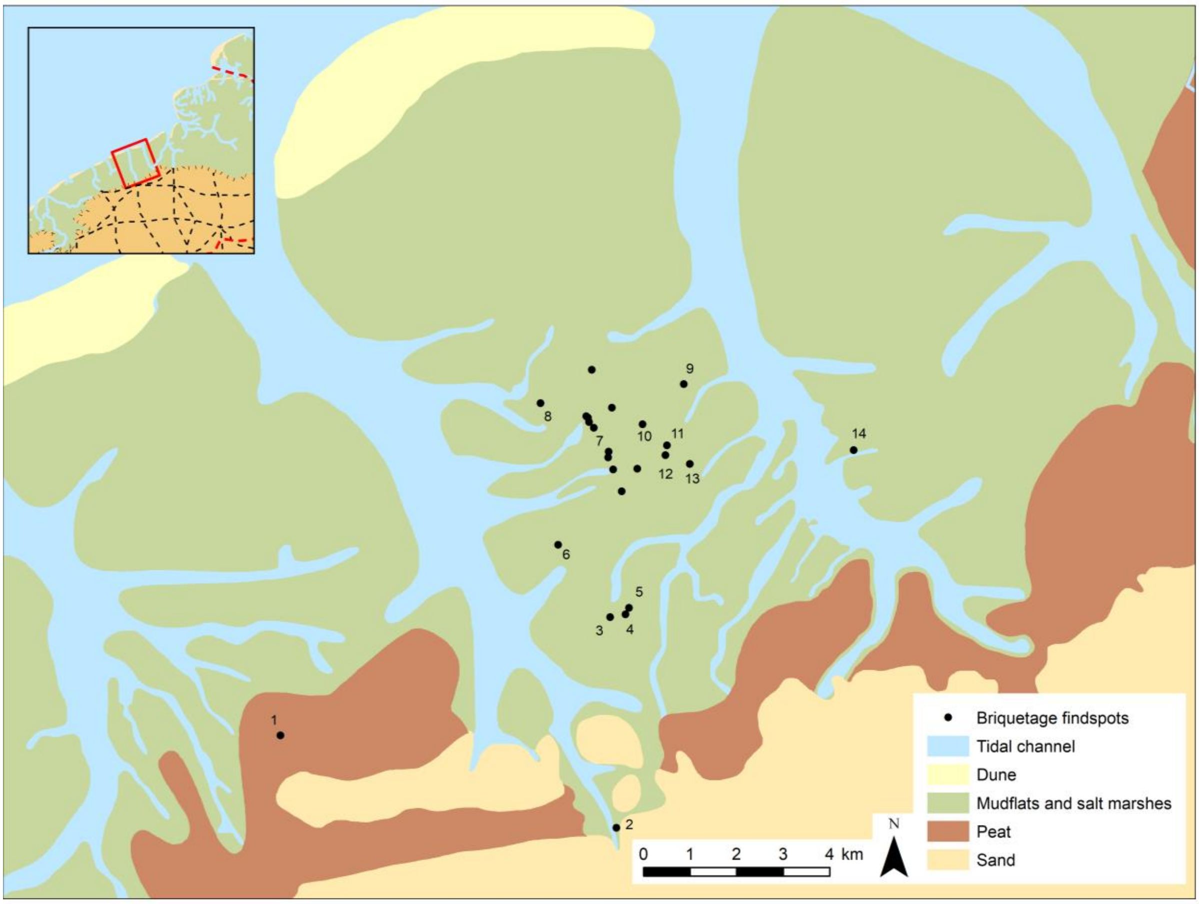

Figure 51 Detailed palaegraphic reconstruction of the Roman coastal plain in the Bruges area depicting all briquetage findspots. Houtave (1) Brugge Fort Lapin (2) Dudzele Landslag west (3) Dudzele Landslag oost 1 (4) Dudzele Landslag oost 2 (5) Dudzele Boudewijnkanaal (6) Hollevoet & Hillewaert's prospection finds (7) Zeebrugge Zeevaartstraat (8) Ramskapelle Heistlaan (9) Zeebrugge Achterhaven Geuldepot (10) Zeebrugge Achterhaven donk 2 (11) Zeebrugge Achterhaven donk 1 (12) Dudzele Zonnebloemweg (13) Hoeke Zwinnevaart (14) (palaeographic reconstruction based on Raakvlak map)

Approximately one kilometre south of the Geuldepot, Patrouille (2013) recorded three Pleistocene sandy outcrops containing heavily eroded traces of Roman occupation (Figure 51). A recurring element was a dark humic layer situated at the base and partly on top of these sandy outcrops. This humic layer contained most of the recovered material. Interestingly, donk 1 contained a large concentration of briquetage material, while no briquetage fragments were recovered on donk 2 and 3. De Clercq (2009b) dated donk 1 and 2 in the Flavian period and donk 3 at the end of the second-early third century CE. It is still unclear whether the briquetage material recovered from Donk 1 represents the dump of production material from a nearby salt production site or whether salt processing activities are taking place at a Roman habitation site. The occurrence of briquetage material at habitation sites is not uncommon as small amounts were found in debris layers on similar sandy outcrops, such as Dudzele Landslag west; Dudzele Landslag oost 1 (second century CE) and Dudzele Landslag oost 2 (second - third century CE). These outcrops were discovered during the construction of the VTN pipeline approximately five km south of Donk 1 (In 't Ven and De Clercq, 2005; In 't Ven et al., 2005a; In 't Ven et al., 2005b).

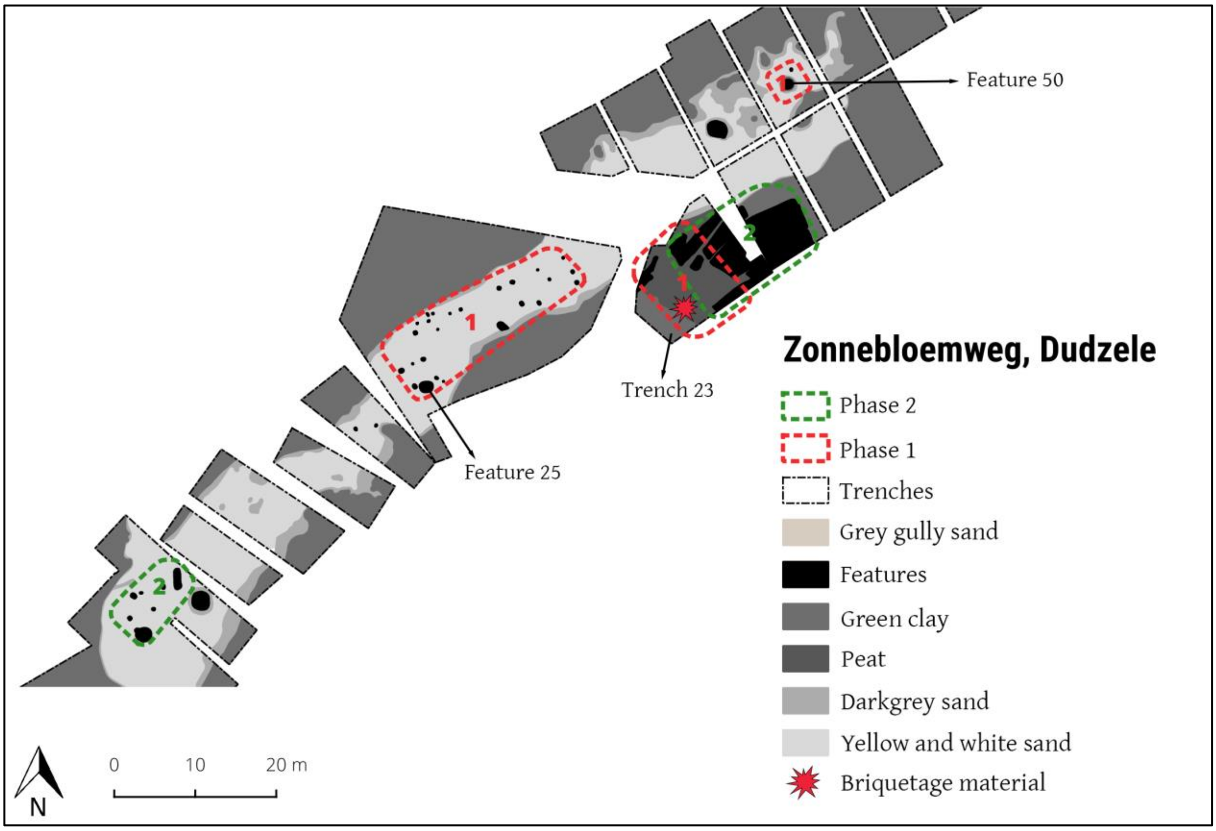

Figure 52 Excavation plan of Dudzele Zonnebloemweg depicting the occupation phases and the features mentioned in the text (after Verwerft et al., 2022).

In 2013, a new (possible) salt production site was discovered at Dudzele Zonnebloemweg (Figure 51) (Verwerft et al., 2013; Verwerft et al., 2014; Verwerft et al., 2022). At Dudzele Zonnebloemweg, the Roman occupation could be separated into two distinct phases: phase 1 dates to the second half of the first century CE and phase 2 dates to the late second - early third century CE (Figure 52). In the first phase, both the top as well as the southern flank of the outcrop were occupied. In addition to several postholes (23 in total) in which no configuration could be recognized, two features measuring 1.6 x 1.3 m (feature 25) and 2.1 x 2.1 m (feature 50) were discovered. These features with a sunken floor were interpreted as possible turf-walled[2] constructions (Verwerft et al., 2022). The exact function of these structures is still unclear, but given their limited size, they may not have functioned as residential buildings. Instead, they could be interpreted as a secondary building with or without artisanal function or a small sheep/goat stable. On the southern flank of the outcrop in excavation trench 23, a thin layer of black clay was deposited in a calm sedimentary environment on top of peat containing most of the pottery fragments. Next to ‘regular’ pottery, the assemblage including many briquetage fragments (356 pieces), suggesting either salt production activities in the vicinity of the site or salt processing activities at the site (Verwerft et al., 2022). In phase two, the occupation was mainly situated on the southwestern extremity of the outcrop. It consisted of a small building (type De Clercq IIB) accompanied by a well, constructed from a woven basket and clay sods. No briquetage pottery was found among the material belonging to this second occupation phase

[2] As noted by Postma (2010, 58), the terms ‘turf’ and ‘sod’ are often used interchangeably. However, depending on the origin of the researcher the words might have a slightly different meaning. Following Postma (2010, 58), the generic term turf is used to describe turf or earth/clay constructions.

(Verwerft et al., 2022). Finally, a small concentration of briquetage pottery dated to the Roman period has been discovered *in situ* in a Roman ditch at Zeebrugge Zeevaartstraat (Verwerft et al., 2017) and *ex situ* in a medieval peat extraction pit at Hoeke Zwinnevaart (Claus, 2020).

6.2.2 Oostburg

While monitoring large-scale sewage works at Oostburg between 2013-2016, Roman features were discovered on top of the peat near the Stadhouderslaan (trench 2) (Figure 50). These features mainly consisted of a 6 m long and approximately 5 to 10 cm thick debris layer, and three small parallel northeast-southwest oriented ditches. Two of these ditches connect at a shallower section in a U-shape and could have had a drainage function. The debris layer had an ash-like, charcoal-rich composition and contained quite a lot of salt container fragments (Figure 53). Due to the poor preservation of the pottery fragments, the debris layer was collected in bulk and then sieved (Dekoninck et al., 2019; Diependaele, 2019).

Figure 53 Profile 21 at the site of Oostburg, viewed from the northeast with the 5-10 cm thick Roman debris layer (circled in red) on top of the peat (Dekoninck et al., 2019)

The site contained 1878 potsherds, of which 1808 fragments of briquetage and 70 (9 MNI) pieces of ‘regular’ pottery. Based on the south-Gallic fragment of Samian ware (Drag. 37), two fragments of terra nigra (Holw. 27), and a Cologne colour-coated beaker fragment with a typical first-century orange-brown coating, the site could be dated to the end of the first century CE (Dekoninck et al., 2019; Diependaele, 2019). The number of salt containers, the ratio between base and rim fragments and the presence of support material suggest that salt production took place in the site’s immediate vicinity. After one or more production cycles, the salt producers discarded their waste which accumulated in distinct debris depositions. At Oostburg, part of such debris deposition might have been excavated (Dekoninck et al., 2019).

6.2.3 Koudekerke

6.2.3.1 Introduction

During the summer of 1975, members of the A.W.N. conducted a small rescue excavation at Koudekerke near the Meinersweg under the supervision of Trimpe Burger (Figure 50). According to van den Berg and Hendrikse (1980), the excavation consisted of three trenches with a total area of 570 m². During the excavation, the remains of four 'kilns' were discovered. The kilns were situated on top of the Holland peat approximately 0.6 m under surface level near a 40 m wide post-Roman creek. Van den Berg and Hendrikse (1980) described these kilns and a selection of the finds in a small publication. In this publication, they hypothesised that the heating structures at Koudekerke and, by extension, at all artisanal sites in Zeeland should be interpreted as lime-burning kilns. However, several arguments can be made against this lime production hypothesis in favour of salt production. These arguments are discussed in Chapter 5. In this study, the excavation archive and the briquetage material were (re)examined.[3] This allowed us to interpret the site based on complete information and to provide a meaningful contribution to the debate. Nevertheless, it should be noted that extensive descriptions of the features are lacking. Therefore, the overview presented below is based on what could be inferred from the excavation plans and the short publication by van den Berg and Hendrikse (1980).

6.2.3.2 Structures and features

Van den Berg and Hendrikse (1980) described three trenches covering 570 m². Yet, the plans indicate that these trenches only amount to 350 m² instead of 570 m² (Figure 54). An extensive refuse layer characterised the excavation with four distinct heating structures in the centre. In the eastern part of the excavation, this refuse layer was approximately 0.15 m thick. It increased to ca. 1 m in the central area, after which it decreased to 0.3 m in the western part of the excavation. The exact composition and possible internal stratification have not been recorded. Van den Berg mentioned that the greyish debris layer primarily consisted of white-grey chalky ash interspersed with charcoal and shell fragments. In profiles A-B and C-D (Figure 55), the eastern part of the refuse zone was coloured darker on the original drawing, which might indicate a slightly different composition. In the western part, prominent parallel NNE-SSW linear clay bands interspersed with shell layers were part of the refuse zone. This alternation of clay, shells and ash-rich debris is clearly visible in profile A-B, and the interval between the clay bands measured approximately 2 m.

During the initial excavation, van den Berg paid little attention to these alternating parallel bands of clay, shells and production debris, making it difficult to reconstruct the exact nature of these layers. Van den Berg and Hendrikse (1980, 224) interpreted the clay bands as locally extracted clay to be used as a clay supply for the construction and repair of the heating structures. However, all evidence suggests that these bands were, in fact, part of an artificial elevation, perhaps even a terp-like structure. This terp could have been constructed from alternating, inclined layers of production debris, clay and shells. Post-depositional processes, such as ploughing, could have capped this elevation. As a result, the inclined layers manifested as parallel bands in the horizontal plane. At

[3] In consultation with Erfgoed Zeeland, we decided to focus solely on the briquetage material as a separate study of the rest of the pottery was in progress at that time. In addition, the handmade pottery of this site was studied by De Clercq (2009c, 2009a) in his doctoral dissertation.

Ramskapelle Heistlaan, a similar phenomenon was observed (Verwerft et al., 2019a; Verwerft et al., 2019b). In the horizontal plane, several parallel bands occurred, which, in profile, corresponded with inclined layers. These layers were deposited against a larger wall to create an artificial dwelling mound or terp. Several layers of clay contained large amounts of mollusc shell fragments. Verwerft et al. (2019b) interpreted these shell-rich layers as reinforcing layers rather than the result of shell processing activities like Dijkstra and Zuidhoff (2011) suggested at Serooskerke. In the case of Koudekerke, van den Berg and Hendrikse (1980) connected the shell layers to the lime-burning process. They interpreted them as raw materials yet to be used or as unburned fragments deposited as waste material.

In any case, it is unclear whether the layers formed a deliberately raised terp/artificial dwelling mound for habitation purposes or if the elevation was a secondary result of the production activities in which shells and clay covered the white-greyish ash-rich production debris. Whatever the reason, it resulted in a more stable, slightly elevated position in a marshy area where the production activities could continue.

In the northwestern part of the excavation, four related postholes (KO-5) can be observed in the debris layers (Figure 54). The two southern postholes have a diameter of about 0.2 m. The two northern postholes are slightly smaller with a diameter of 0.1 m. The east-west distance between the posts is approximately 1.3 m, and the north-south distance measures 0.8 m. These postholes were not recognised during the initial excavation and, therefore, were not sectioned to study the posthole profile and depth. These postholes might be part of a small secondary building that extended beyond the limits of the excavation. The exact function is unclear, but a storage function related to artisanal activities is one of the possibilities.

The main features are the remains of four heating structures (KO1-4) situated at the centre of the excavation area (Figure 54). According to van den Berg and Hendrikse (1980, 224), the kilns were constructed on top of a circular clay bed with a diameter of approximately 2.5 m deposited on top of a shell layer. The hearth lining ran trumpet-shaped to the top and was preserved up to 0.6 m. At the height of 0.6 m, the circular hearth measured 0.7 m in diameter. Unfortunately, it is unknown which of the heating structures van den Berg and Hendrikse described and if this description applies to all four heating structures. In addition, it is unclear how they determined the height and course of the kiln wall since no section of the heating structures has been recorded.

A more nuanced description of each heating structure can be deduced from the original excavation plan. The first, northernmost, heating structure (KO-1) has an oval-shaped combustion chamber (0.65 m wide and 0.95 m long) surrounded by a ca. 0.15 m thick hearth wall. This hearth appears to be constructed on top of a clay bed measuring 1.8 m in width and 2 m in length. A second heating structure (KO-2) was situated close to the southern trench wall and had a circular heating chamber (1.15 m in diameter) surrounded by a ca. 0.15 m thick hearth wall. The third (KO-3) and fourth (KO-4) hearths are slightly bigger and are composed of a circular combustion chamber (1.3 m in diameter) with a 0.25 m thick hearth lining. KO-3 and KO-4 appear to be constructed on top of a circular clay bed of 2.5 m and 3 m in diameter.

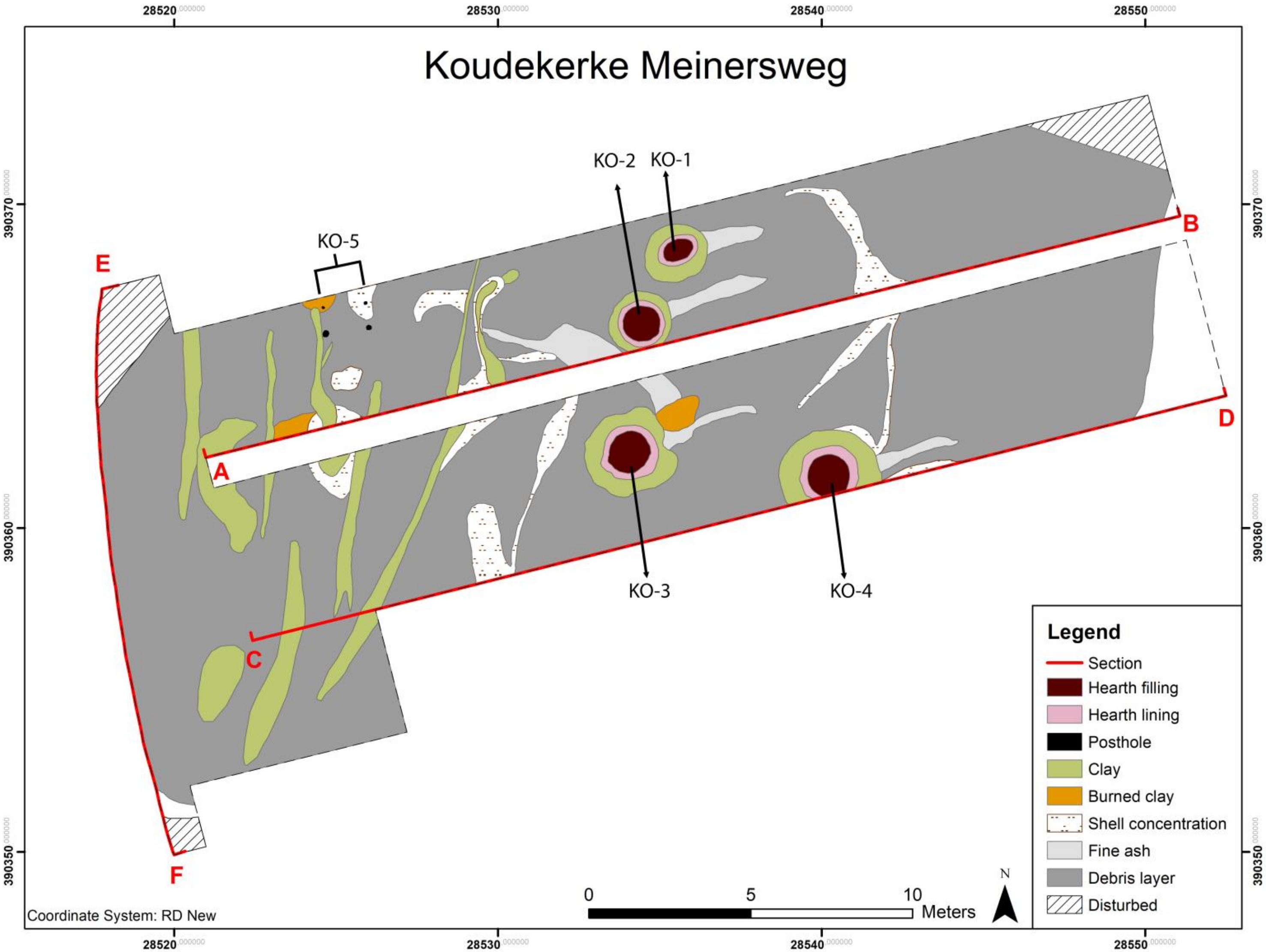

Figure 54 Excavation plan of Koudekerke Meinersweg.

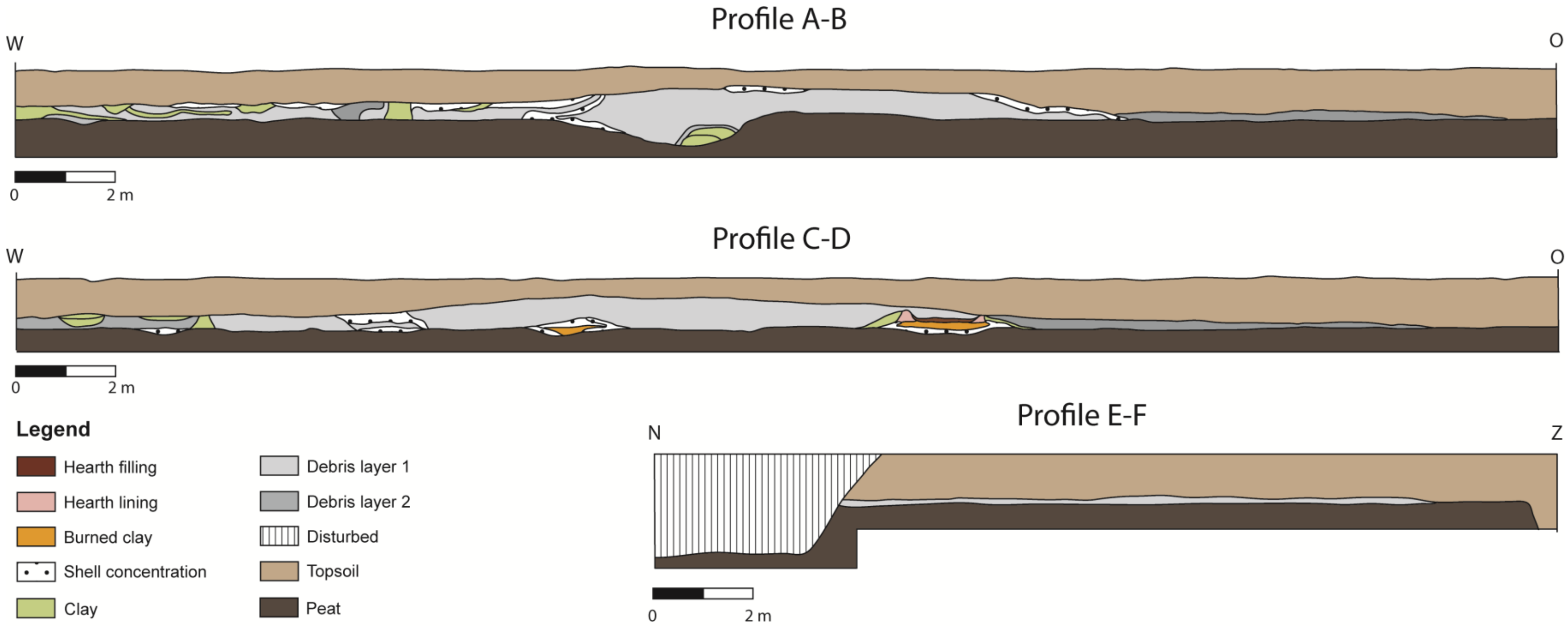

Figure 55 Trench profiles of Koudekerke Meinersweg

On the eastern side of each heating structure, a tongue-shaped feature with a distinctly different composition than the surrounding debris layer could be discerned (Figure 54). The dimensions of each feature slightly differ, and the feature near KO-1 was 1.8 m long and 0.6 m. The feature near KO-2 measured 3.2 m in length and 0.4 m in width. In addition, the feature near KO-3 measured 3 m in length and 0.4 m in width, and the feature near KO-4 was 2.5 m long and 0.4 m wide. As the tongue-shaped elements were composed of a calcium-rich material[94], van den Berg and Hendrikse (1980, 225) interpreted them to be rake-out zones. These rake-out zones were used to remove the produced lime from the heating structures. Since the lime-burning function of these hearths is a matter of debate, the tongue-shaped features most likely do not result from extracting lime from the kiln. Nevertheless, these features could still resemble rake-out zones from which the ash and other debris were cleaned from the bottom of the hearths. If this hypothesis is correct, the hearths had an east-facing entrance designed to clean the hearths and add fuel to the fire (stoke-hole).

Where the southern wall of trench two cuts KO-4, an E-W cross-section of KO-4 has been recorded in profile C-D (Figure 55). This cross-section (in part) confirmed van den Berg and Hendrikse's idea (1980) that the hearths were constructed on a shell-rich basis (0.1 m thick) deposited on top of the peat. The remains of a 0.15 m thick clay layer are visible at both sides of the hearth lining. This clay layer corresponds with the clay bed on top of which all four hearths were built. The bottom of the hearth was composed of a 0.15 m thick burned clay layer. The hearth lining (ca. 0.2 m thick) was preserved up to 0.2 m. However, van den Berg and Hendrikse's (1980) assumptions about the trumpet-shaped course of the hearth lining and the preserved height of 0.6 m could not be verified based on this section.

6.2.3.3 The finds

The pottery is part of a separate study,[95] and De Clercq (2009c, 2009a) already studied the handmade ware. The main results of these studies have been included to date the site and to emphasise the site's privileged position.

Several fragments of south-Gallic samian ware from *La Graufesenque* (types Drag. 18, 27, 35/36 and Curle 11) date the site in the Flavian period. The Rhineland colour-coated ware with the typical first-century orange-brown coating confirms this date (type Hofheim 25 or 26)(De Clercq, 2009a). The amount of colour-coated beakers is surprising, and van den Berg and Hendrikse (1980, 221) estimated that the fragments belong to 50 to 60 individuals. However, De Clercq (2009a) counted at least 601 sherds representing about 90 individuals during a quick assessment. In addition, quite a few flagons and *mortaria* individuals imported from the Rhineland were also present. The handmade pottery (781 fragments representing 120 individuals) mainly consisted of open (cooking) pots type De Clercq P2, followed by pots type De Clercq P6 and bowls type De Clercq K6 (De Clercq, 2009a, 2009c).[96]

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[94] In their article, van den Berg and Hendrikse (1980, 227) published the results from ash analyses performed on samples from Middelburg, Ritthem, 's-Heer Abtskerke and Koudekerke. These results concluded that the carbonate (54%) calcium and magnesium (35,7%) concentration in the ash samples was very high which strengthened their beliefs that these sites were involved in lime burning. However, as presented by Dekoninck et al. (In prep), the high calcium and magnesium concentrations can be explained in other ways. In addition, from a methodological point of view, these analyses are of little value for multiple reasons. Firstly, the technique and equipment used to determine the composition are not specified. Secondly, the data is presented as a percentage, but they do not mention whether the data has been processed or how it was processed exactly. And thirdly, the precise context of the samples is never specifically mentioned.

[95] The regular pottery is currently being studied by Erfgoed Zeeland.

[96] For more information regarding the handmade pottery, see De Clercq (2009c, 2009a).

Apart from pottery, Van den Berg and Hendrikse (1980, 224-225) mentioned "greenish, glass-like slags", which they interpret as the remains of hearth lining and over-heated lime. Unfortunately, the amount in which these 'slags' occur has not been specified, and only a few fragments have been collected. Similar objects were found in large quantities on the late second - early third-century salt production sites at Leffinge, 's-Heer-Abtskerke/'s-Gravenpolder and Middelburg. These objects will be discussed in detail in Chapter 8.

Such a high amount of Rhenish drinking vessels is unusual for Flavian sites in the Menapian coastal plain. In comparison, the contemporaneous settlement of Ellewoutsdijk, which was occupied for three generations contained less than ten colour-coated individuals (De Clercq, 2009a). According to De Clercq (2009c, 2009a), these high numbers indicate either a one-time large delivery of such material or the consumers' desire to use this specific type of drinking vessel for an extended period of time. In both cases, the material must have been (easily) accessible through merchants, middlemen or the military. Following Pitts'(Pitts, 2004, 2005) observations on Belgic drinking vessels in South-East Britain, De Clercq (2009c) suggested that these imported Rhenish beakers were mainly used to express their privileged status in society and their relationship with the Roman military.

In 2002, a new site was excavated at Koudekerke Breeweg, a few hundred meters from Koudekerke Meinersweg. The site itself has yet to be published, but as presented by De Clercq and Van Dierendonck (2006, 49-53), the remains of a heating structure and a large concentration of shells were discovered. De Clercq (2009a) studied the pottery and concluded that the material, dated to the Flavian period, was highly similar to that of Koudekerke Meinersweg.

6.2.4 Ritthem

6.2.4.1 Ritthem Schotteweg

During Walcheren's large-scale soil mapping campaigns in 1949, Ovaa and De Buck observed fragments of Roman pottery in the drainage ditches on both sides of a newly constructed road at Ritthem (Figure 50). Van der Feen checked their notification and concluded that the sherds originated from an *in situ* preserved 0.5-1 m thick Roman debris layer deposited on top of the peat. In 1968-69, the R.O.B commissioned a trial trench along the Schotteweg (Ritthem, NL) to determine the exact nature of the debris layer. A.W.N members dug this trench under Trimpe Burger's supervision. However, the trench cannot be located exactly. In addition, only Trimpe Burger's original profile drawing and the material finds preserved at the provincial depot of Erfgoed Zeeland.

In a short note, Trimpe Burger (1970) described the profile as a 40 to 80 cm thick layer of ash. Many porous handmade, thick-walled, cylindrical pottery vessels, later interpreted as salt containers, were found in this ash layer. However, from the drawn profile, it is clear that the situation was much more complex. Several superimposing ash layers can be observed in the trench profile, sometimes containing shells and other debris (Figure 56). Most likely, these 'ash layers' represent debris layers containing clay, ash, pottery etc., that accumulated during the production process. In addition, several layers contained large amounts of burned clay fragments. It is unclear if these layers represent an *in situ* heating structure or if this material was dumped in the refuse zone. Given the nature of the surrounding deposits, the latter hypothesis seems more likely.

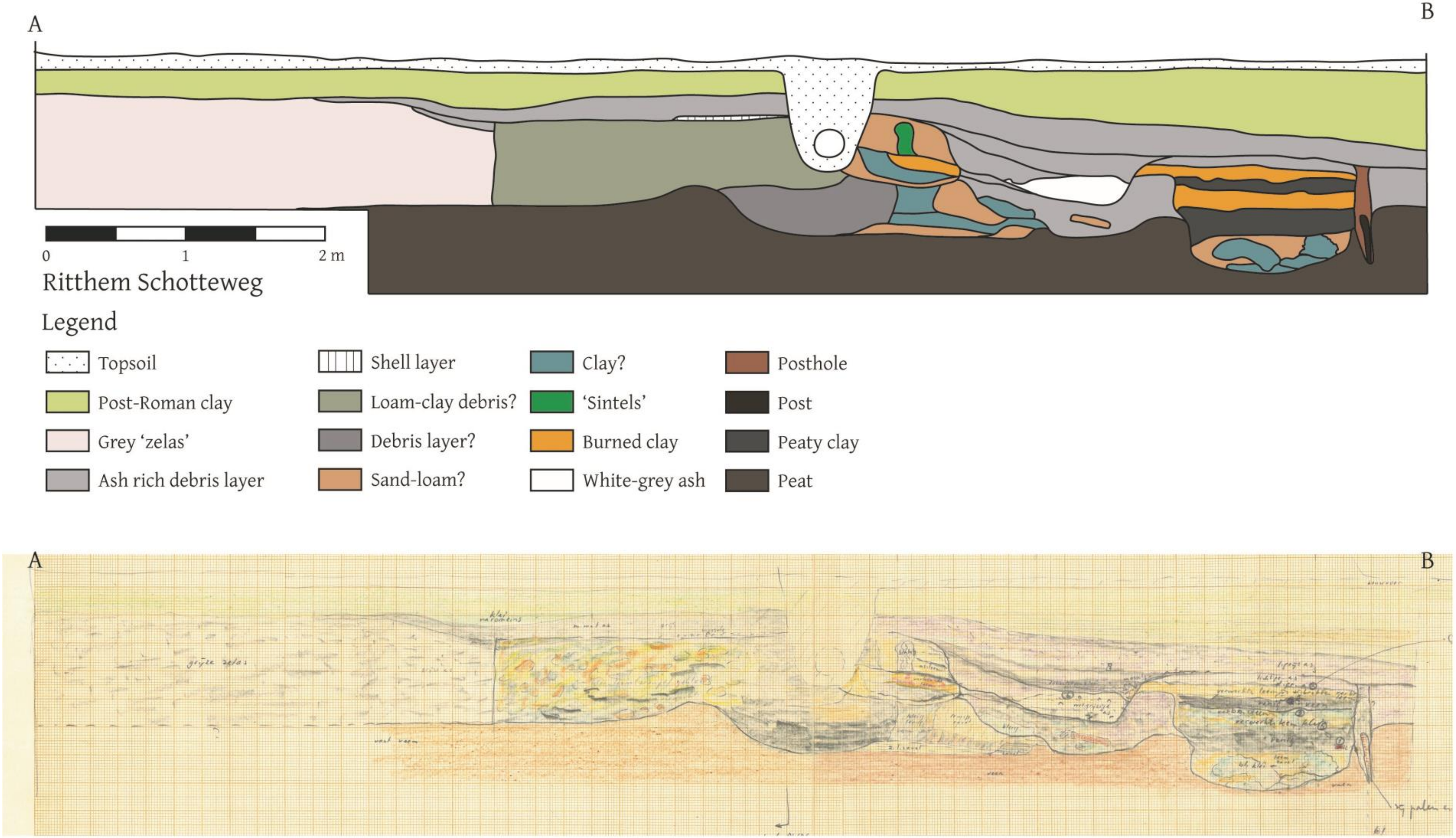


Figure 56 Trench profile of Ritthem Schotteweg excavated by members of the A.W.N in 1968-69 under supervision of Trimpe Burger (original plan drawn by Trimpe Burger).

At the end of the profile, a distinct feature, measuring 1.14 m in width and 0.76 m high, can be recognised (Figure 56). This feature appeared to be deliberately dug through the debris layer into the underlying peat and was filled with alternating layers of processed (burned) clay/loam and peaty clay material. The fill of this feature thus clearly deviates from the surrounding ash-rich debris layers. On the right side of the feature, a row of posts was observed. These posts might be part of some sort of revetment (Figure 56). As the feature was not recorded in plan, it is nearly impossible to determine its exact function. If the posts were, in fact, part of a revetment, then a water-related function (e.g. storage tank) could be assumed.

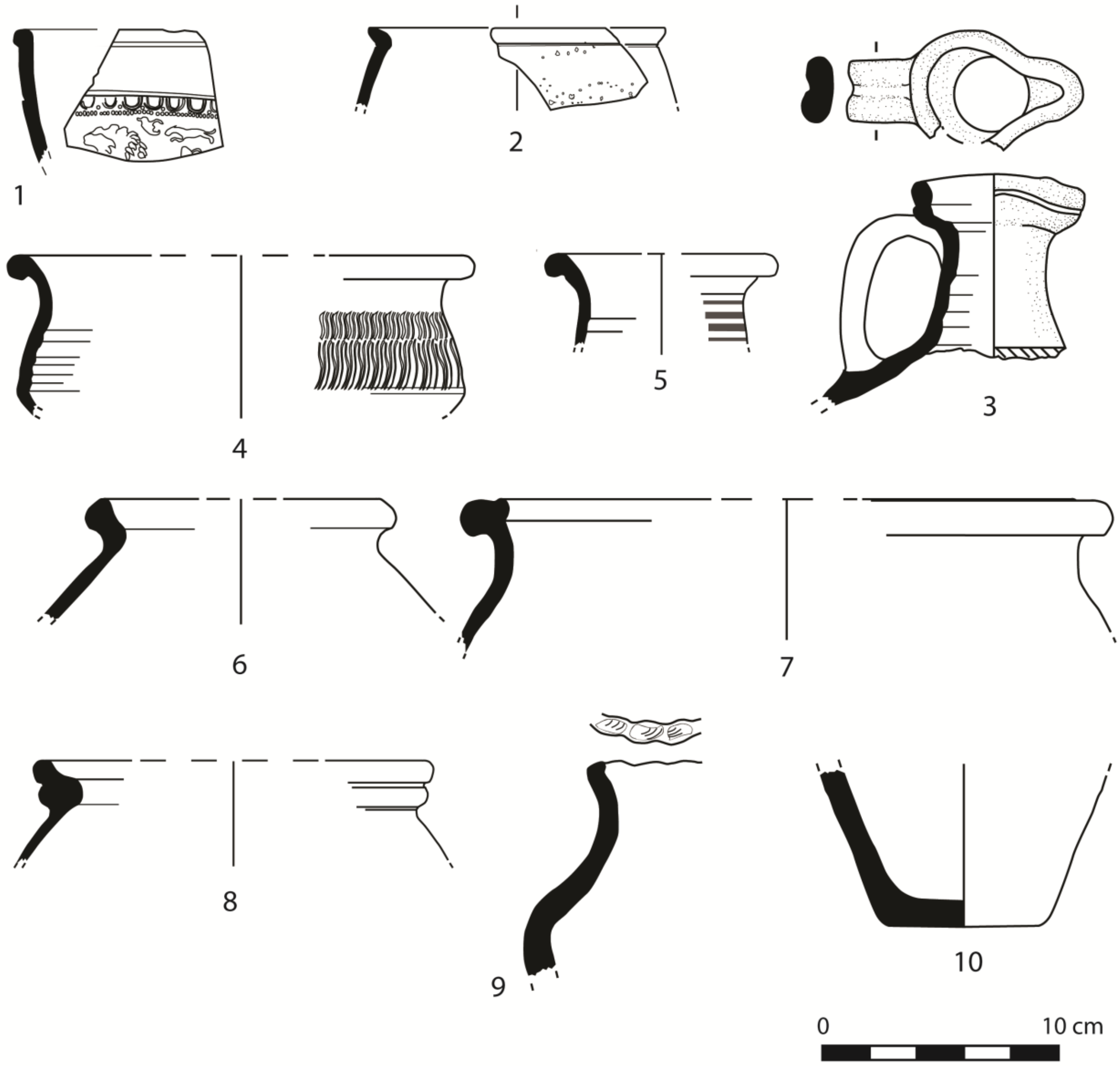


Figure 57 Roman pottery from Ritthem Schotteweg.

In total, 2567 pottery fragments were recovered: 2395 fragments of briquetage and 172 sherds of ‘regular’ pottery (APPENDIX 3). These 172 fragments (35 MNI) can be divided into several categories. Two pieces of Samian ware (2 MNI) were present: a body sherd of a Central Gallic Drag. 18 plate dated to the second half of the first century CE, and a fragment of a small Drag. 37 bowl in Lezoux fabric (Figure 57:1) decorated with the head of a lion. Stylistically, this lion head is part of a hunting scene which can be ascribed to the workshop of the Central Gallic potter Attianus ii (115-145 CE). The distribution of Attianus ii's products shows a strong trade network between the Rhineland and the coastal zone making use of the Rhine estuary. As a result, almost no finds occur on hinterland sites (Vanderhoeven, 1975).

Next to Samian ware, 20 fragments of Cologne colour-coated Hees 2 beakers (5 MNI) with roughcasting decoration were present (Figure 57: 2). These cups can be dated to the first half of the second century CE (Brulet et al., 2010, 335). The fine reduced category (24 sherds, 5 MNI) mainly consisted of tableware with well-finished (polished) exterior walls resembling a terra nigra-like fabric. Concerning the vessel shapes, two beakers, one jar and one pot/jar in fine reduced pottery can be identified. The flagons can easily be divided into two large subcategories based on fabric: orange-red flagons (19 sherds, 3 MNI) and white flagons (11 sherds, 2 MNI) from the Meuse valley or the Rhineland. Interestingly, the neck, rim and handle of a jug are preserved (Figure 57: 3). Unfortunately, the exact type of jug could not be determined. The coarse reduced (11 sherds, 4 MNI) and coarse oxidised ware (25 sherds, 6 MNI) have not been studied in detail, and only a Holwerda 140 storage vessel (Figure 57: 7) and Stuart 203/Vanvinckenroye 478 pot (Figure 57: 8) could be identified. The largest group of pottery is the handmade ware (60 sherds, 8 MNI) which contains a few simple rim fragments and a weak S-shaped rim profile (type De Clercq P4). Based on the Samian and colour-coated ware, the site of Ritthem Schotteweg can be dated in the second half of the first century – the first half of the second century CE.

6.2.4.2 Ritthem bij de Molen

During several prospection campaigns, members of the A.W.N. found similar material at 'Ritthem bij de Molen' near Ritthem Schotteweg. However, as both the prospections and the excavation cannot be located exactly, it is unclear whether these sites were perhaps part of the same complex. In any case, these finds indicate that either one large or multiple smaller salt production sites were active at Ritthem in the second half of the first century CE.

6.2.4.3 Ritthem Havenweg

In 1979 members of the A.W.N. conducted another small excavation at Ritthem under the supervision of van den Berg (Figure 50). Apart from a copy of the original excavation plan, no information about the excavation is preserved. From the excavation plan (Figure 58), it is clear that the A.W.N. excavated an area of 88 m² (16 x 5.5 m) with few archaeological features. Besides two shell concentrations, a feature located at the northeastern edge of the trench was interpreted as the possible remains of a hearth. Unfortunately, the trench profiles were not recorded, making it impossible to check the validity of their interpretations. Based on the material, van den Berg dated the site in the last quarter of the first century CE. Unfortunately, these finds did not preserve. Consequently, it is unclear whether salt production-related material was present.

In 2016, RAAP dug trial trenches near the excavation trench of Ritthem Havenweg. Apart from the remains of a post-Roman creek, several layers of ash, burned clay and second-century formed an artificial elevation of at least 85 m long, 60 m wide and 0.5-0.7 m high (site RAAP-3). De Groot (2016, 75) interpreted this elevation as the remains of a Roman terp. Though the site has not been excavated yet, similarities with the debris layers discovered at Ritthem Schotteweg and 's-Gravenpolder (cfr. 7.3) suggest that the site should be reinterpreted as the refuse zone of a large salt production site rather than the remains of a Roman terp (Figure 59). An additional argument in favour of salt production refuse might be the presence of 'slag fragments' (17 fragments in total) (de Groot, 2016, 84-86). From the description and photographs of these fragments, it is clear that they are highly similar to objects found in large quantities at the known salt production sites of Leffinge, Aardenburg and ‘s-Gravenpolder (sections 7.2 and 7.3). How these debris layers are connected to the 1979 excavation could not be determined. However, the extent of the debris layers suggests that a large salt production complex might have been active at the end of the first – the beginning of the second century CE. At the moment, quite a lot of questions regarding the nature of the site remain, which can only be answered by excavation. An excavation might also (potentially) reveal the relationship between, on the one hand, Ritthem Havenweg and RAAP-3 and the other hand, the nearby complex of Ritthem Schotteweg and Ritthem bij de molen. Do these sites represent separate production entities, or do they form one large ‘industrial’ salt production centre?

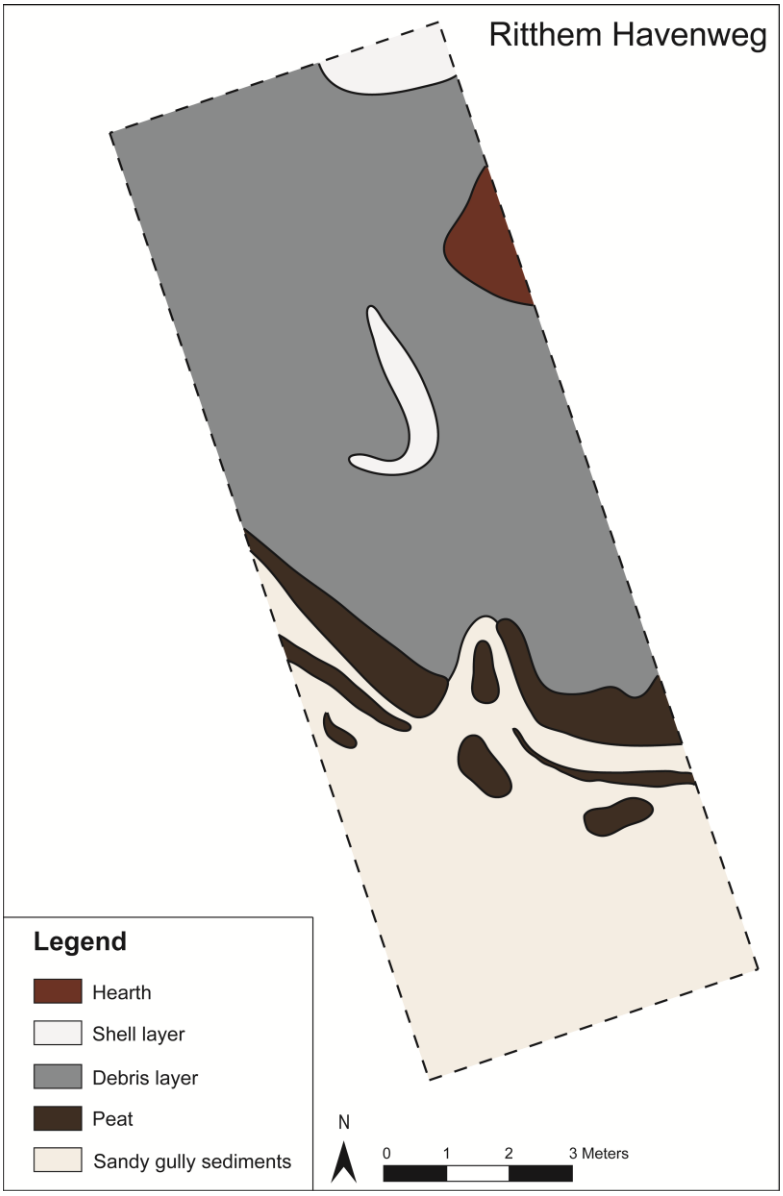


Figure 58 Excavation plan of Ritthem Havenweg excavated by members of the A.W.N in 1979.

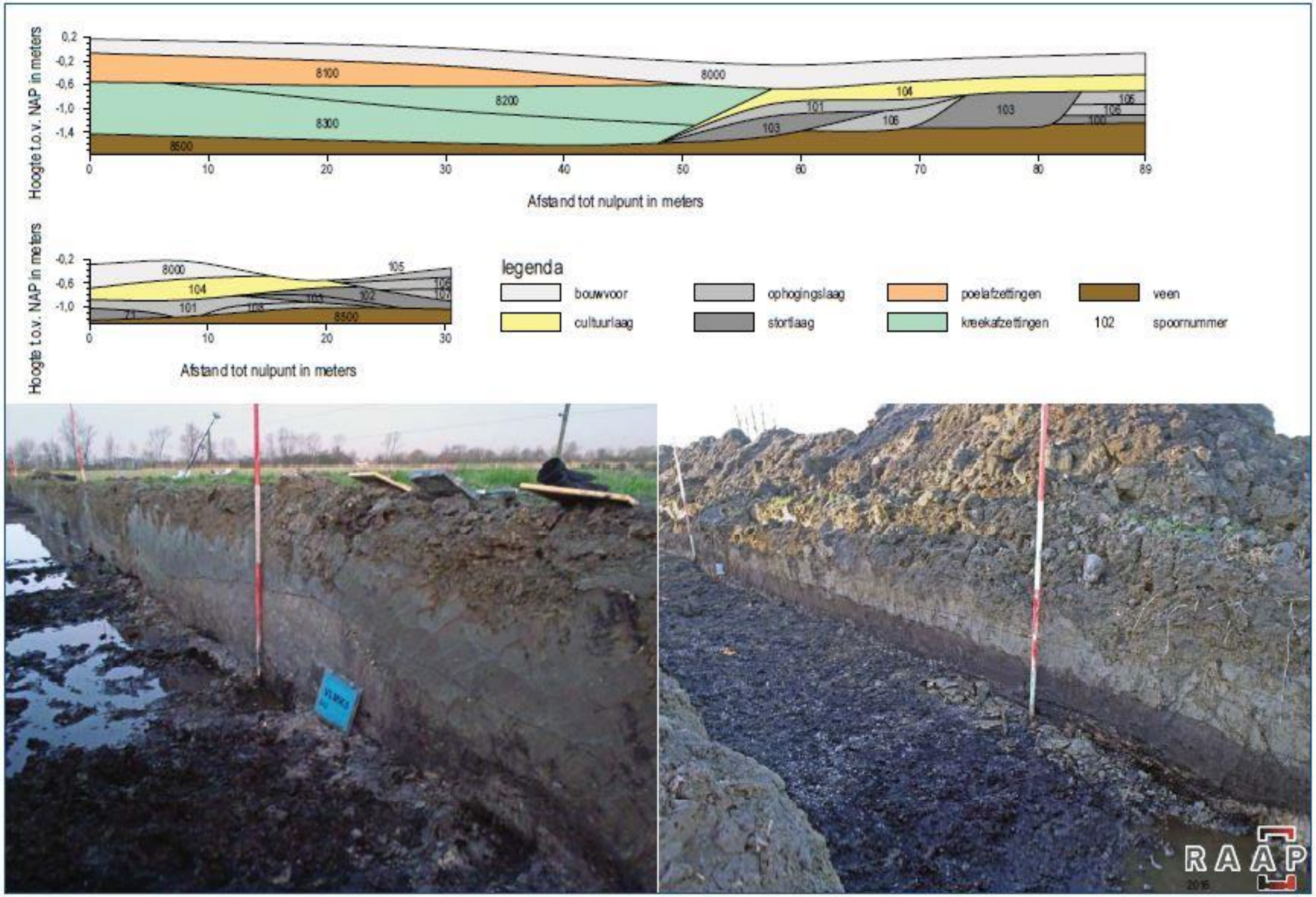


Figure 59 Trench profile and photographs of the second century debris layers discovered during trial trenching at RAAP-3 (Ritthem Plangebied kazerne Korps Mariniers). The debris layers containing refuse such as ash and burned clay fragments are depicted in grey (after de Groot (2016, 76))

6.3 Analysis of the briquetage pottery

6.3.1 Introduction

In this section on briquetage pottery, we first present the current state of research, including references to the most important regional briquetage typologies. After that, the methods used to study the briquetage material are explained in detail. This study focuses on both technological and typological aspects of briquetage, which are presented consecutively in the result section. After presenting the results, the major technological and typological aspects of the northern Menapian, late first - early second-century briquetage material will be discussed and compared to the known regional typologies. To achieve this goal, 9119 pieces of briquetage material (95.2 kg) from ten sites were studied: the Geuldepot (Zeebrugge Achterhaven), Donk 1 (Zeebrugge Achterhaven); Dudzele Zonnebloemweg, Dudzele Distrigas 1992, Dudzele Boudewijnkanaal, Prospectievondsten Achterhaven, Ramskapelle Heistlaan, Oostburg 't Vestje, Ritthem Schotteweg, Koudekerke Meinersweg.[97]

6.3.2 Current state of research

This study of briquetage material fits into a wider research tradition of salt-making practices. The use of briquetage has been intensively studied, and regional typological and chronological syntheses exist in several parts of the world. For this study, we mainly focus on the syntheses regarding the Low Countries and northern France. However, when relevant, parallels will be drawn to major briquetage studies in Britain, such as Lane and Morris (2001) and Lane (2018b) for the Fenlands, Fawn et al. (1990) for Essex, Nevell and Fielding (2005) for Cheshire, or Hathaway (2013) for southern Britain.

In the Low Countries, Van den Broeke (1982, 1986, 1995b, 1995a, 1996, 2007, 2012, 2013) conducted crucial research on briquetage vessels. He devised a regional typo-chronological evolution for salt containers from the early Iron Age to the Roman period based on the material recovered from the multiperiod site of Oss-Ussen (van den Broeke, 1986, 2012). He was also the first to unambiguously link the handmade cylindrical vessels from multiple Roman sites in the hinterland, which in the 1950s and 60s had been interpreted as iron crucibles (Mertens, 1954; Dewulf, 1964) or as shafts of iron furnaces (De Laet and Van Doorselaer, 1969)[98], to salt transport and consumption (van den Broeke, 1995b). In addition, Van den Broeke (1995b) defined the so-called 'Kesteren' type, a cone-shaped salt container with a flared rim, to which the various small fragments of thin-walled pottery occurring on Roman sites in the Netherlands and Belgium belong. Also worth mentioning is the master dissertation of Huys (2005, 2006), who compared the briquetage material from the Iron Age sites of De Panne, Veurne and Brugge.

Along the French Atlantic coast, Coppens (1953) conducted pioneering work on briquetage. Gouletquer (1970) provided the first typo-technological synthesis of briquetage material from Bretagne. Some 20 years later, Daire's dissertation (1994) focused on the Iron Age salt production sites

[97] See APPENDIX 3 for a detailed registration of the briquetage fragments.

[98] In 1978, Bloemers (1978) already suggested that these cylindrical containers might have been used as salt containers. However, contrary to Van den Broeke (1986, 1995b), Bloemers' hypothesis lacks arguments to support this statement or to refute the accepted iron production hypotheses by De Laet and Van Doorselaer (1969), Mertens (1954) and Dewulf (1964).

and briquetage material in that area. In 2003, she published a book summarising the characteristics and typology of briquetage from the Bretagne sites and included then recently discovered Iron Age sites in northern France (Daire, 2003). A more detailed synthesis of these sites (Vignacourt, Sorrus, Pont-Rémy, Arry and Conchil-le-Temple) was published by Prilaux (2000a). This book contained the first typo-chronological evolution of the salt containers, the support material and the heating structures from the early Iron Age until the early Roman period. This overview is still in use today and has recently been complemented with new discoveries (Masse and Prilaux, 2016, 2017). Only recently, more salt-making sites dating to the Roman period have been excavated in the area of Steene, Looberghe and Pitgam. An overview of the briquetage from these sites can be found in Donnadieu and Willems (2015). In addition, the briquetage material of several Iron Age and Roman salt production sites discovered along the southern North Sea basin have been published individually; see, for instance, but not exclusively: De Panne (Kerger, 1997, 1999); Bray-Dunes (Leman Delerive et al., 1996); Looberghe (Teysseire, 2014, 2020); Steene (Faupin, 2017a); Sorrus (Defossés, 2000); Conchil-le-Temple (Lemaire, 2012); Gouy-Saint-André (Masse and Tachet, 2017).

6.3.3 Methods

The term 'briquetage' denotes all ceramic elements found on a salt production site. It includes the ceramic equipment (salt containers, pinch props, pedestals, etc.) as well as larger structural material, such as fragmented debris of heating structures (Fawn et al., 1990; Lane and Morris, 2001, 8; Hathaway, 2013, 31-32). Following Anglo-Saxon tradition (see, amongst others, Fawn et al., 1990; Lane and Morris, 2001; Hathaway, 2013), each piece of briquetage was first assigned to one of four major categories: (salt) containers or briquetage vessels (FR: *moules à sel*; NE: *zoutcontainers*); supports[99] (NE: o*ndersteunend materiaal*); structural or hearth material (NE: *structureel materiaal*) and miscellaneous material (NE*: ondiagnostisch materiaal*). Fragments < 1 cm² are undiagnostic and registered as a miscellaneous material subcategory

6.3.3.1 Technological aspects

This study considers both technological and typological aspects of briquetage material. The main objective of a technological analysis is to understand and reconstruct the successive stages and actions of transforming raw material into finished objects (i.e. the *chaîne opératoire*) (Roux, 2017, 2019). The production of briquetage, and in particular the manufacturing of salt containers and supports, roughly follows the ceramic *chaîne opératoire* consisting of the following steps: clay extraction, processing/preparation, fashioning, finishing and firing (Roux, 2017, 2019).

All sherds were observed macroscopically and assigned to major fabric types based on visible characteristics to study the clays and preparation techniques. Then, a large selection of sherds from each fabric was analysed using an Olympus SZX7 stereo microscope (at magnifications x10 – x40) to make basic fabric descriptions. For this, a fresh fracture was created for each sherd. The methodology used to characterise and describe these fabrics is based on Peacock (1977), Orton et al. (1993), Whitbread (2001) and Quinn (2013). Naturally, as it concerns observations of fresh fractures, not all aspects of each fabric could be described.

[99] The term 'support' denotes all types of objects, such as stabilisers, pedestals, firebars, etc., that have been to support the containers (Lane and Morris, 2001, 42).

On a broad level, a fabric consists of three main components: clay matrix, inclusions and voids. The observations of each component and their mutual relation form the basis of the fabric descriptions. The inclusions (i.e. mineral inclusions and temper) are often the most distinctive aspect of a fabric. Generally, the visible characteristics of the inclusions, such as their nature, colour, size and shape, are documented. Although it is possible to identify some inclusions accurately in hand specimens, such as quartz, shells and grog, some caution is needed as mistakes are easily made (Whitbread, 2017). These inclusions could be naturally present in the clay or deliberately added as a temper to improve the properties of the clay (Rice, 2015).

Often macroscopic fabric descriptions are complemented by ceramic thin-section analysis (Whitbread, 2001; Quinn, 2013). Thin-section petrography is an established technique to study the composition of ceramics, providing insights into pottery provenance and technology. Although initially planned, ceramic petrography was not used to study the briquetage pottery as this was no longer feasible within the time frame of the PhD project. Thin-section petrography should therefore be included in future research as this method enables more detailed fabric descriptions including the identification of mineralogical inclusions, and allows us to study pottery technology in more detail.

In addition to the ceramic composition, several other aspects of pottery technology, such as fashioning and finishing methods, can be studied macroscopically. From ethnographic and ethnoarchaeological research, it is clear that several vessel-shaping techniques existed to produce handmade pottery (e.g. slab building, coiling, moulding etc.). These techniques can be reconstructed by studying visible macro traces at the vessel surface and in the internal clay structure as seen in cross sections (Rye, 1981; Livingstone Smith, 2007). Fashioning techniques of both briquetage vessels and support elements (e.g. pedestals) have been documented by, amongst others, Prilaux (2000a), Lane and Morris (2001), and Hathaway (2013). Unfortunately, the high fragmentation of the briquetage vessels in this study severely limits technological observations. However, identifying how these vessels were made was not the central focus of this study, and as a result, only limited attention was paid to the fashioning methods.

6.3.3.2 Typological aspects and registration

After dividing the briquetage into fabric groups, the material from each fabric group was studied typologically, and the results were registered in an Excel database. Naturally, this database also included contextual information (e.g. site, context etc.), the briquetage category, the fabric etc. In this study, the following variables were documented for each container sherd: the fragment type (base, body, rim), the weight and thickness, the presence and type of decoration and the presence of vitrification. The diameter of the rim and base fragments was measured when possible. Following Lane and Morris (2001) and Van den Broeke (2012), the container sherds were grouped by thickness code. In this study, the following codes with a fixed 3 mm interval were used: 0-2.9 mm; 3-5.9 mm; 6-8.9 mm; 9-11.9 mm; 12-14.9 mm; 15-17.9 mm; 18-20.9 mm; 21-23.9mm. In addition, as Van den Broeke (1995b, 2012) hypothesised that the base of the salt containers was removed at the production sites, the preserved height of all base fragments is also recorded.

Next, the rim and base sherds are grouped into 'rim and base types'. As the briquetage vessels are highly fragmented, complete vessel profiles are absent. This hinders the typological classification of vessel shapes (bowls, beakers, jars etc.) as this classification is often based on metrics such as the ratio between diameter and height (Rice, 2015, 232-244; Teetaert, 2020, 18). This means that the 'container types' defined in this study are solely based on the present rim and base typology. Therefore, it must be stressed that these container types remain hypothetical, and future research is needed to confirm their validity. Nevertheless, defining possible container types was necessary to enable comparison with known briquetage vessel types from previous studies on Iron Age and Roman pottery from the Low Countries (van den Broeke, 1986, 1995b, 1995a, 1996, 2007, 2012), northern France (Prilaux, 2000a; Donnadieu and Willems, 2015) and the UK (Fawn et al., 1990; Lane and Morris, 2001; Pool, 2012; Hathaway, 2013) (see 6.4.2).

The briquetage vessels were quantified using two parameters: sherd count and weight (Orton et al., 1993, 169). Both numbers are easily extracted from the database, but they cannot be used to estimate the number of vessels represented at each site. The minimum number of individuals (MNI) or the estimated vessel equivalent (EVE) are more suitable methods to estimate the number of vessels. Both methods, however, have the disadvantage of being less suitable for highly fragmented pottery categories such as salt containers (Orton et al., 1993, 169; Poulain, 2013). This explains why MNI and EVE are practically never used to study briquetage material (Lane and Morris, 2001; Pool, 2012; Hughes et al., 2017). Therefore, these methods have not been used in this study as well.

Besides briquetage vessels, the ceramic assemblages include support, structural and miscellaneous material. For the support material, the following variables have been registered: the type of fragment (pedestal, bar, wedge, slab, platform, spacer, pinch-prop etc.); weight; the 'completeness' (complete; archaeologically complete profile, corner fragment etc.); the preserved height, length and width and the presence of vitrification. Unfortunately, complete objects and profiles of support material are largely absent. This complicates the typological classification of the different types of supports and their comparison with known types from literature (Prilaux, 2000b; Lane and Morris, 2001; Hughes et al., 2017; Masse and Prilaux, 2017). Both categories are quantified by counting the number of fragments present and measuring their weight. Following Lane and Morris (2001), only the miscellaneous material's total weight has been registered.

6.3.4 Group Zeebrugge-Dudzele-Oostburg

The group Zeebrugge-Dudzele-Oostburg consists of eight sites: the Geuldepot (Zeebrugge Achterhaven), Donk 1 (Zeebrugge Achterhaven); Dudzele Zonnebloemweg, Dudzele Distrigas 1992, Dudzele Boudewijnkanaal, Prospectievondsten Achterhaven, Ramskapelle Heistlaan and Oostburg 't Vestje. These sites are geographically clustered between present-day Bruges and Oostburg in the northern Menapian territory. Four sites (Geuldepot, Donk 1, Dudzele Zonnebloemweg and Oostburg 't Vestje) are firmly dated in the Flavian period. Context-wise, it is noted that neither of these four well-dated sites contained *in situ* features such as hearths or water management structures related to salt production activities. Given the lack of archaeological features, the sites probably represent (part of) debris zones of nearby salt production or processing activities.

The briquetage material from the remaining four sites (Dudzele Distrigas 1992, Dudzele Boudewijnkanaal, Prospectievondsten Achterhaven and Ramskapelle Heistlaan) was recovered either *ex situ* during construction works or as prospection finds indicating the presence of a possible production site. Either way, the latter sites do not provide information on the context in which the salt production activities occurred. Furthermore, these sites lacked diagnostic material to securely attribute them to a specific time period, and a more conservative dating between the middle of the first – middle of the third century CE has been proposed.

6.3.4.1 Composition of the briquetage assemblage

The eight sites together yielded a total of 6394 briquetage fragments (ca. 18.5 kg). The largest amount of material came from the Geuldepot (3165 fragments, ca. 50%) and Oostburg 't Vestje (1808 fragments, ca. 28%). Smaller concentrations of briquetage were recovered at Donk 1 (439 fragments), Zonnebloemweg (355 fragments) and Distrigas 1992 (382 fragments), forming ca. 7%, 5% and 6% of this group respectively. The remaining material originates from the sites of Dudzele Boudewijnkanaal (87 fragments, ca. 1%), Prospectievondsten Achterhaven (42; fragments, ca. 1%) and Ramskapelle Heistlaan (116 fragments, ca. 2%). The briquetage from these last three sites was recovered either during prospection or infrastructural works. This explains why the assemblages of these sites are so small. These three smaller concentrations were primarily included for the sake of completeness. Yet, considering how the material was collected, some caution is required when interpreting and comparing the material from these sites.

The Geuldepot is the largest briquetage assemblage in this group and consists of 3165 fragments weighing 9549 g. Among these are 2597 salt container fragments (8182 g), 50 pieces of support material (638 g) and 518 miscellaneous fragments (729 g). Oostburg 't Vestje yielded 1808 briquetage fragments (4789 g). These include 1787 salt container fragments (3095 g), 27 support fragments (194 g) and 1500 g of miscellaneous material. As this latter category mainly concerns sieve residue, the amount of fragments was not quantified. The distribution of the briquetage material across the different briquetage categories of the remaining sites is shown in Table 9.

From Table 9, it is clear that the briquetage assemblages are dominated by salt container sherds (> 50%, typically around 80%) with a varying amount of miscellaneous material (between 10-50%). Except for the 'Prospectievondsten', the support material makes up less than 5% of the ceramic assemblage. Again, this discrepancy might be related to the collection strategy as typically larger fragments are retrieved during prospection campaigns. This distribution slightly changes when the fragments' weight is considered. Indeed, the support material is generally heavier, and miscellaneous material often consists of a combination of a lot of small fragments (fragments < 1 cm^2, also called pottery gravel) and a few amorphous, larger fragments. This affects the ratio between the different categories. While salt containers still dominate the assemblage (> 65%), the relative amount of support material increases (between 4-12%, with an outlier of 33% attributed to the 'Prospectievondsten') in favour of the miscellaneous material (< 20%). None of the sites yielded fragments of structural material. This is not surprising as none of the excavated sites contained *in situ* hearth infrastructure. In addition, the retrieved fragments were quite small and larger fragments are needed to correctly identify pieces of hearth infrastructure.

The material is generally well-preserved but highly fragmented. This was to be expected from dumped waste briquetage. An indication of the degree of fragmentation is the small mean piece weight (Table 9). The average piece weight of the container sherds is only 2.69 g, and the support material is, on average, 11.59 g. Again, the collection strategy on-site plays an important role. Naturally, material collected through sieving (specifically Oostburg) is smaller than material retrieved by hand during excavation or prospection.

Table 9 Distribution of the briquetage fragments from all eight sites (group Zeebrugge-Dudzele-Oostburg) in major briquetage categories: salt containers, support, structural and miscellaneous material.

	Salt container			Support			Structural		Miscellaneous		Total	
	N	wt. (g)	wt./N (g)	N	wt. (g)	wt./N (g)	N	wt. (g)	N	wt. (g)	N	wt. (g)
Geuldepot	2597	8182	3.15	50	638	12.76	--	--	518	729	3165	9549
Donk 1	263	746	2.84	13	127	9.77	--	--	163	205	439	1078
Zonnebloemweg	309	792	2.56	5	69	13.80	--	--	41	78	355	939
Boudewijnkanaal	41	161	3.93	--	--	--	--	--	46	32	87	193
Distrigas 1992	322	1036	3.22	6	88	14.67	--	--	54	103	382	1227
Heistlaan	100	368	3.68	--	--	--	--	--	16	18	116	386
Prospectievondsten	32	242	7.56	6	124	20.67	--	--	4	9	42	375
Oostburg	1781	3095	1.74	27	194	7.19	--	--	--	1500	1808	4789
Total	5445	14622	2.69	107	1240	11.59	0	0	842	2674	6394	18536

6.3.4.2 Fabrics

In the group Zeebrugge-Dudzele-Oostburg, the fabrics from seven sites were examined. Unfortunately, the fabrics from Oostburg 't Vestje could not be systematically studied due to time constraints. Nevertheless, a quick macroscopic examination suggested that the fabrics at Oostburg were highly similar to those from the other sites. The analysis resulted in the definition of three major fabric types: Zeebrugge Fabric 1 (ZF1), Zeebrugge Fabric 2 (ZF2) and Zeebrugge Fabric 3 (ZF3). These types were defined based on the clay matrix's characteristics, and the inclusions either naturally present in the clay or deliberately added as temper. These fabrics may represent real differences created by the salt producers but could also signal geological variations in the exploited clay source or (microscopic) variations observed during analysis. In the following section, the fabric types are described in more detail. The quantity (number of pieces and percentage by number of pieces) of each fabric type per site is presented in Table 10.

Zeebrugge FABRIC 1 (ZF1): A very coarse, soft heterogeneous fabric with a light grey reduced core and white-yellow oxidized surface (Figure 60). A dense network of meso- to macro (0.05-2 mm) planar and vesicle voids can be observed. Often, larger amorphous mega (> 2 mm) vughs are present. These voids result from burned-out vegetal inclusions and/or shrinkage and drying processes. In the reduced core area of the sherd, some vegetal material was preserved as charred material. In addition, very few mineralogical inclusions are present. These inclusions are identified as very fine to fine sand (< 0.1 – 0.2 mm), white-grey, subangular to subrounded quartz inclusions.

Figure 60 Photomicrograph of the main fabric types present in the group Zeebrugge-Dudzele-Oostburg.

Zeebrugge FABRIC 2 (ZF2): A coarse, soft to moderately hard, heterogeneous fabric with a light to dark grey reduced core and reduced or oxidised light grey/white/yellow surfaces (Figure 60). A dense network of meso- to macro (0.05-2 mm) planar and vesicle voids can be observed. These voids result from burned-out vegetal inclusions and/or shrinkage and drying processes. In the reduced core area, some vegetal material is still preserved as charred material inside the voids. In addition, the very fine to fine sand (< 0.1 – 0.2 mm mineral inclusions are observed: few to common, white-grey, subangular to subrounded quartz grains and possibly very few plate-like (possible) mica inclusions.

Zeebrugge FABRIC 3 (ZF3): A coarse, oxidised, soft to moderately hard heterogeneous fabric with a yellow-orange core and orange-brown surfaces (Figure 60). A dense network of meso- to macro (0.05-2 mm) planar and vesicle voids can be observed. These voids result from burned-out vegetal inclusions and/or shrinkage and drying processes. In addition, frequently, very fine to medium sand (< 0.1 – 0.5mm), white-grey, subangular to subrounded quartz inclusions are present.

Though highly similar, each of these three fabrics has specific characteristics. All fabrics have a well-developed pore network consisting of meso- to macro (0.05-2 mm) planar and vesicle voids. Often larger amorphous mega (> 2 mm) vughs could also be observed. Although some vegetal material was probably naturally present in the clay, the amount and size of the voids suggest that the vegetal material was added as temper. The evidence for this is more pronounced in fabric ZF1. Fabric ZF 2 and 3 contain noticeably fewer voids which could be related to the amount of vegetal material (ZF2 > ZF3). Furthermore, the void size suggests that the vegetal material in these fabrics was also finer.

The opposite is true for the presence of quartz. In fabric ZF1, quartz is only marginally present, but the amount increases in fabric ZF2 and even more so in fabric ZF3. Potentially the quartz was deliberately added as temper, but it is equally possible that a more sandy clay was exploited. This question can be answered by studying the quartz grain size distribution of the fabric in thin-section (Quinn, 2013, 83-89). In addition, some mica inclusions appear to be present in fabric ZF2. Mica could not be identified with the stereomicroscope in the other fabrics. That being said, mineral inclusions are tricky to identify at low magnification, and their presence needs to be verified by thin-section petrography. Finally, and very noticeably, the core of fabric ZF3 was completely oxidized while fabrics ZF1 and 2 were reduced with sometimes an oxidized surface. This suggests that not all briquetage material was subjected to the same firing conditions.

Table 10 Quantification of briquetage fragments by fabric type (both number of pieces and percentage by number of pieces) of seven sites (group Zeebrugge-Dudzele-Oostburg).

	ZF1		ZF2		ZF3		n.v.t.		Total	
	N	%	N	%	N	%	N	%	N	%
Geuldepot	590	*19%*	1239	*39%*	818	*26%*	518	*16%*	3165	*100%*
Donk 1	80	*18%*	62	*14%*	134	*31%*	163	*37%*	439	*100%*
Zonnebloemweg	19	*5%*	165	*46%*	130	*37%*	41	*12%*	355	*100%*
Boudewijnkanaal	21	*24%*	17	*20%*	3	*3%*	46	*53%*	87	*100%*
Distrigas 1992	22	*6%*	241	*63%*	65	*17%*	54	*14%*	382	*100%*
Heistlaan	83	*72%*	7	*6%*	10	*9%*	16	*14%*	116	*100%*
Prospectievondsten	32	*76%*	1	*2%*	5	*12%*	4	*10%*	42	*100%*

The distribution of the fabrics across the different sites is shown in Table 10. Interestingly, fabric ZF1 dominates in the smaller assemblages of Dudzele Boudewijnkanaal, Prospectievondsten Achterhaven and Ramskapelle Heistlaan. As this concerns *ex situ* concentrations of briquetage or prospection finds, the recognisability of this material can perhaps explain the dominance of fabric ZF1. At Dudzele Zonnebloemweg and Dudzele Distrigas 1992, fabric ZF2 is more frequently present, followed by fabric ZF3. Fabric ZF1 is only marginally present at these sites. The fabrics are more evenly distributed at the Geuldepot and Donk 1 with no clear preferences. However, explaining these apparent differences is rather difficult as all three fabrics are present in varying amounts at all sites. Furthermore, no noticeable patterns emerge when these fabrics are correlated to forms. All three fabrics were used varyingly to manufacture salt containers and support material. The interpretation is further complicated by the fact that the material derived from isolated debris layers rather than from well-defined salt production ateliers. As there does not seem to be a functional, geographical or temporal explanation, the differences might signify individual choices by the salt producers regarding the exploitation and preparation of the clay. However, it must be stressed that this remains hypothetical and that further (petrographic) research is required to explain the observed macro-and microscopic differences in the fabrics.

6.3.4.3 Salt containers

Briquetage vessel composition

The eight sites together yielded a total of 5445 salt container fragments (ca. 14.6 kg), forming the bulk of the briquetage material at all sites (see Table 9). Among these are 169 rim (656 g), 4525 body (10775 g) and 721 base fragments (3146 g). At Oostburg 't Vestje, some heavily fragmented pieces could either be interpreted as a base or a rim and were grouped as a separate category (30 fragments, 48 g). Table 11 shows rim, body and base fragments distribution across the different sites. As presented in section 6.3.3.2, estimating the minimum number of individuals (MNI) is rather difficult due to the fragmentation and the lack of complete vessel profiles. Given the small average piece weight (2.69 g), the MNI method would overestimate the amount of briquetage vessels present at each site. Moreover, there are no complete vessels that could be used to determine the mean vessel weight and to estimate the number of vessels based on the total weight of the fragments.

Table 11 Quantification of the salt container sherds by class (rim, body, base and base or rim) of all sites in the group Zeebrugge-Dudzele-Oostburg.

	Rim		Body		Base		Base or Rim		Total	
	N	wt. (g)	N	wt. (g)	N	wt. (g)	N	wt. (g)	N	wt. (g)
Geuldepot	102	400	2156	5871	339	1911	0	0	2597	8182
Donk 1	7	29	247	696	9	21	0	0	263	746
Zonnebloemweg	7	22	250	506	52	265	0	0	309	793
Boudewijnkanaal	1	2	32	132	8	27	0	0	41	161
Distrigas 1992	0	0	282	838	40	199	0	0	322	1037
Heistlaan	1	7	86	317	13	44	0	0	100	368
Prospectievondsten	4	53	25	163	3	27	0	0	32	243
Oostburg	47	143	1447	2252	257	652	30	48	1781	3095
Total	169	656	4525	10775	721	3146	30	48	5445	14625

When taking a closer look at the rim-body-base distribution at all sites (Table 11; Figure 61), there is a noticeable discrepancy in the rim and base fragments ratio. In assemblages of 'regular' pottery, rim fragments are well represented; typically, more rim than base fragments occur. Yet, the opposite is true for the briquetage vessels at the salt production sites. Substantially more base fragments are recovered here. Except for Donk 1 and the Prospectievondsten, base fragments represent more than 10%, and less than 20% of the pottery, while less than 5% of the sherds are rims (Figure 61). The exact rim-base ratio differs between sites and is at least 1:3 or higher. The overrepresentation of base sherds is not uncommon at salt production sites, and this phenomenon has previously been attested at Iron Age and Early Roman sites in northern France, for example, at Pont-Rémy (Prilaux, 2000b), Arry

(Prilaux, 2000a) and Conchil-le-Temple (Lemaire, 2012, 193-197). Prilaux (2000b) connects this phenomenon to the overall fragility of the rim fragments, which affected their preservation in the archaeological record.

Interestingly, in the area of Droitwich (UK), Morris (1985) observed that the rim-base ratio shifted between Iron Age production and consumption sites. At production sites, base fragments dominate, whereas at consumption sites, the amount of bases decreases in favour of rims. Van den Broeke (1995b, 200; 2012, 173) discovered a similar pattern at Roman salt consumption sites in the Low Countries. The bases of briquetage vessels are underrepresented at these sites, and the rims dominate significantly. The fact that rim fragments do occur in larger quantities at consumption sites indicates that Roman salt container rims preserve in the archaeological record. So, while Prilaux's explanation of rim preservation can be true for Iron Age salt production sites in northern France, it cannot be used to adequately explain the rim-base discrepancy observed in this dataset. In turn, Van den Broeke (1995b, 200; 2012, 173) suggests that the base of the vessels was removed at the production sites before being transported to the hinterland. This hypothesis fits the current evidence at both the production and consumption sites rather nicely. The reasons why the salt producers would decide to remove the base at the production sites will be further discussed below.

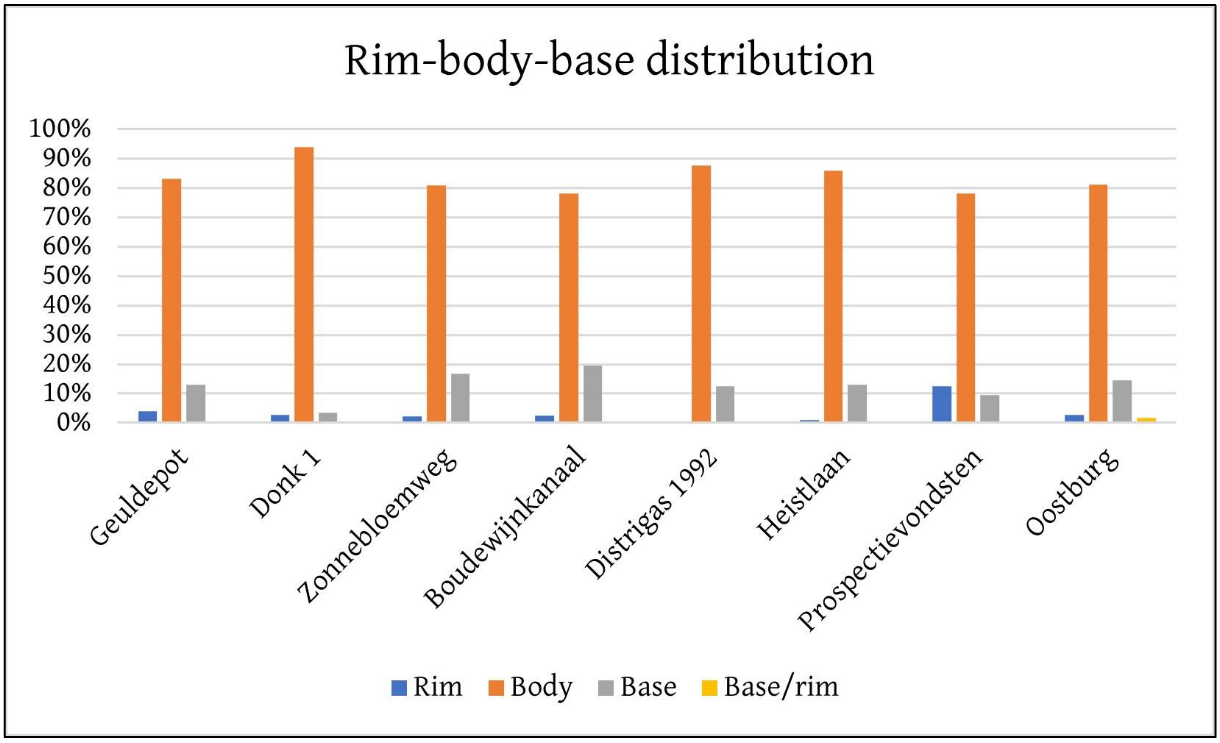


Figure 61 Rim-body-base distribution (in percentage) across the different sites in the group Zeebrugge-Dudzele-Oostburg. Data used to create the graph is presented in Table 11.

Rim & base morphology

In total, 169 rim fragments were recognised at seven sites of the Zeebrugge-Dudzele-Oostburg group (Table 12). These rims were often heavily fragmented, which made the rim identification quite difficult. In Zeebrugge-Dudzele-Oostburg, primarily two types of rims occurred: a straight to slightly everted rounded rim (R1) and a straight to slightly everted flattened rim (R2) (Figure 62). The top of both rim types was sometimes decorated with thumb or fingertip impressions, resulting in a wavy rim pattern. At the Geuldepot, two fragments with a slightly grooved rim were also observed

(Figure 62). As these rims clearly deviate from R1 and R2, they were categorised as a separate rim type: R3. The distribution of the rim types across the different sites is shown in Table 12.

Table 12 Rim type distribution across the different sites in the group Zeebrugge-Dudzele-Oostburg.

	R1		R2		R3		INDET		Total	
	N	%	N	%	N	%	N	%	N	%
Geuldepot	39	*38%*	61	*60%*	2	*2%*	0	*0%*	102	*100%*
Donk 1	2	*33%*	4	*67%*	0	*0%*	0	*0%*	6	*100%*
Zonnebloemweg	3	*38%*	4	*50%*	0	*0%*	1	*13%*	8	*100%*
Boudewijnkanaal	0	*0%*	1	*100%*	0	*0%*	0	*0%*	1	*100%*
Distrigas 1992	0	*0%*	0	*0%*	0	*0%*	0	*0%*	0	*0%*
Heistlaan	1	*100%*	0	*0%*	0	*0%*	0	*0%*	1	*100%*
Prospectievondsten	2	*50%*	2	*50%*	0	*0%*	0	*0%*	4	*100%*
Oostburg	5	*11%*	40	*85%*	0	*0%*	2	*4%*	47	*100%*
Total	52	*31%*	112	*66%*	2	*1%*	3	*2%*	169	*100%*

The base fragments were more easily distinguishable than the rims. The eight sites together yielded a total of 721 bases categorised into two major types, each with an A and B variant. Type B1A is a simple, flat base in which the vessel wall joins the base at an angle between 80-90°. The exterior surface forms a sharp angle at this join (Figure 62). The B1B variant is similar to type B1A, but some flaring or splaying occurs at the underside of the base, where it joins with the vessel wall. As a result, the base platform remains visible as a slightly protruding element (Figure 62). Type B2A is a simple, flat base with a slightly everted wall that joins the base at an angle between 60-80° (Figure 62). In the B-variant (type B2B), some flaring or splaying occurs at the underside of the base, where it is joined to the slightly everted wall (Figure 62). Quite a few small or severely worn base fragments lacked diagnostic features and were categorised as INDET (not illustrated).

Base type B1A is dominant within Zeebrugge-Dudzele-Oostburg, as almost half of the bases (46%) could be assigned to this category. Type B2A is the second largest category (19%). The flared base types (B1B and B2B) are less frequent and represent 10% and 6% of the bases in the dataset. The large proportion of INDET is striking but not that surprising given the high degree of fragmentation (cfr. 6.3.4.1). In addition, the collection strategy plays an important role as more than half of the INDETS was recovered at Oostburg, where the material was collected through sieving. The distribution of the base types across the different sites is shown in Table 13.

Table 13 Base type distribution across the different sites in the group Zeebrugge-Dudzele-Oostburg.

	B1A		B1B		B2A		B2B		INDET		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Geuldepot	163	*48%*	23	*7%*	95	*28%*	29	*9%*	29	*9%*	339	*100%*
Donk 1	4	*44%*	0	*0%*	3	*33%*	0	*0%*	2	*22%*	9	*100%*
Zonnebloemweg	19	*37%*	3	*6%*	18	*35%*	3	*6%*	9	*17%*	52	*100%*
Boudewijnkanaal	2	*25%*	0	*0%*	3	*38%*	0	*0%*	3	*38%*	8	*100%*
Distrigas 1992	11	*28%*	7	*18%*	3	*8%*	6	*15%*	13	*33%*	40	*100%*
Heistlaan	7	*54%*	0	*0%*	2	*15%*	1	*8%*	3	*23%*	13	*100%*
Prospectievondsten	2	*67%*	1	*33%*	0	*0%*	0	*0%*	0	*0%*	3	*100%*
Oostburg	124	*48%*	37	*14%*	13	*5%*	7	*3%*	76	*30%*	257	*100%*
Total	332	*46%*	71	*10%*	137	*19%*	46	*6%*	135	*19%*	721	*100%*

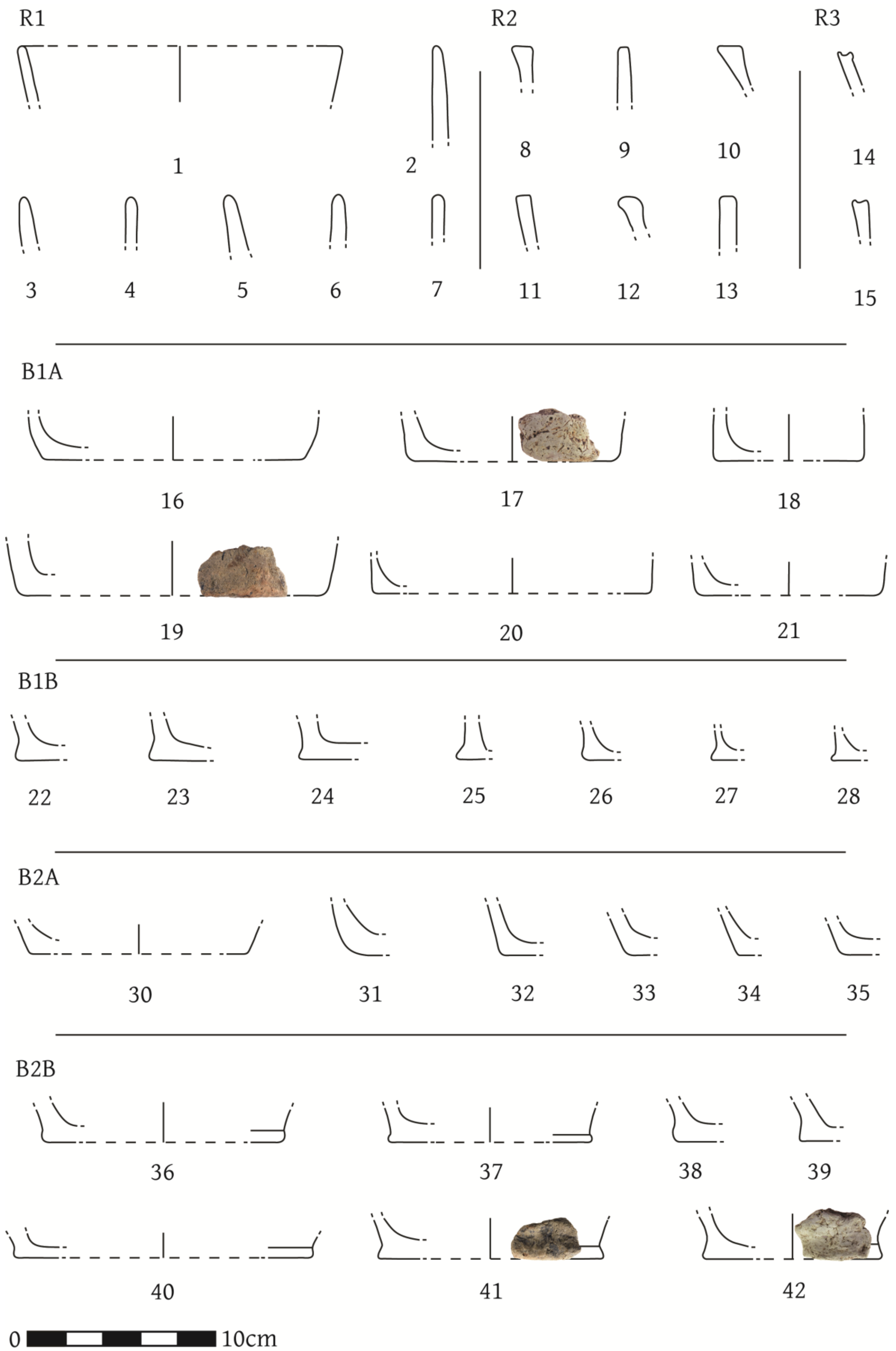


Figure 62 Rim and base typology of the group Zeebrugge-Dudzele-Oostburg (Briquetaga from Geuldepot)

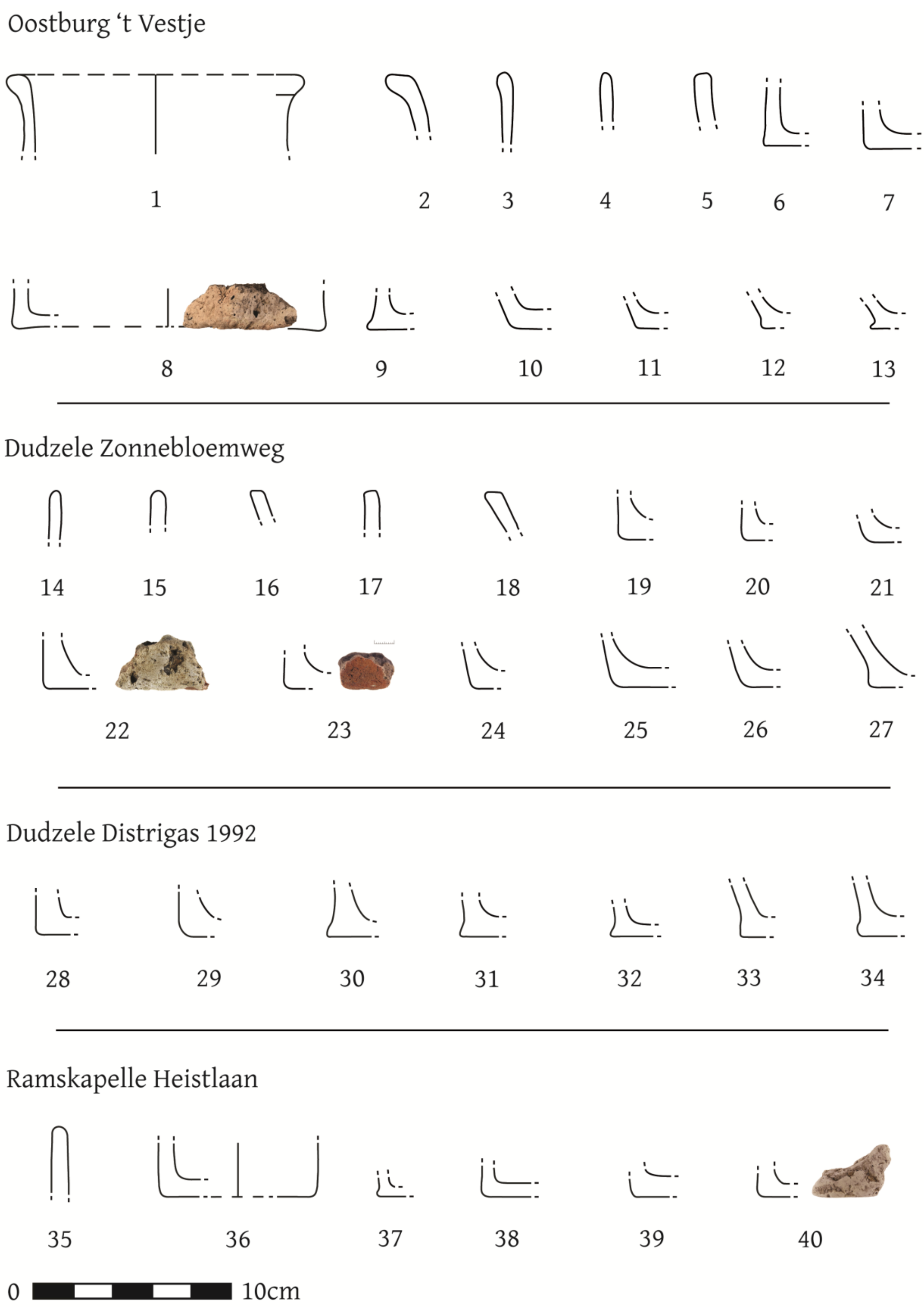


Figure 63 Briquetage vessel fragments from Oostburg 't Vestje, Dudzele Zonnebloemweg, Dudzele Distrigas 1992 and Ramskapelle Heistlaan (scale 1:3).

Vessel shapes

The identification of vessel shapes is hampered because no complete vessel profiles were present. Currently, we lack information on how the different rims connect to bases, and whether the rim and base typology corresponds to different vessel shapes or rather represent small variations of the same vessel form (Figure 62, Figure 63). Based on the base morphology, two large vessel categories might be present: rectangular (?) and cylindrical vessels.

The potential presence of rectangular briquetage vessels is largely based on the occurrence of larger type B1A and B2A base fragments without any curvature. These bases appear straight which is not consistent with the circular base of most vessel types. However, the presence of these rectangular briquetage vessels remains hypothetical as the evidence is quite scarce, and counterarguments can be put forward. For instance, the briquetage vessels were heavily fragmented, and it is common for smaller fragments of circular bases to appear straight. In addition, all briquetage containers were handmade and straight smaller fragments might still be part of circular bases as these hand-shaped bases are not always perfectly circular. Unfortunately, no corner fragments were recovered, which would have been an additional, strong argument in favour of rectangular vessels.

Examples of rectangular flat-based salt pans are known from multiple Iron Age and Roman salt production sites in the Fenlands (Lane and Morris, 2001) and southern Britain (Hathaway, 2013). In the study area, Thoen (1975a) described some nearly complete, small rectangular 'salt cake moulds' from Zeebrugge and Raversijde. However, more recent research showed that these objects stem from the late medieval period instead of the Roman period (van den Broeke, 2012, 292, noot 299). Further research with a more extensive dataset, including more complete vessel profiles, is therefore required to verify the presence of these rectangular salt pans at the production sites.

However, the largest number of bases definitely belongs to vessels with a flat, circular base. As indicated above, some minor differences in base morphology occurred, but it is unclear whether this corresponds with different vessel shapes. The flaring that occurs in the B-variant at the underside of the base is likely the result of the primary or secondary forming of the vessel. During the vessel's construction, the base platform and the wall slabs or coils were pressed together by which, if not smoothed, the base platform remained visible as a protruding element. Base types B1 and B2 might represent different vessel shapes. However, as there is no information on the vessel profiles, there is no way of knowing for sure. Given the vessel's function, simple, open vessel forms can be expected.

The base morphology of the group Zeebrugge-Dudzele-Oostburg shows similarities with the slightly everted, cylindrical briquetage vessels recovered at the Iron Age and early Roman salt production sites in northern France (for examples, see Prilaux, 2000a). In addition, cylindrical salt container fragments have been found at Roman salt consumption sites in the Belgian and Dutch hinterland (van den Broeke, 1995b, 2012) (see section 6.4.2). As such, cylindrical vessels might also have been the dominant vessel shape in the area of Zeebrugge-Dudzele-Oostburg.

Even though the height of the vessels cannot be reconstructed, 16 base and 2 rim diameters provide some information about vessel sizes. The distribution of the vessel diameter values is shown in Figure 64. The vessel diameter varies between 8 cm and 16cm with an average diameter of 12.6cm.

The wall thickness of the container sherds is quite restricted in range, and 98% of the sherds fall between 3-11.9 mm (Table 14). More specifically, 54% fall into the category 6-8.9 mm, 29% into the category 3-5.9 mm and 15% into the category 9-11.9 mm. Some small differences are noticeable between the various sites, but none of the sites deviates from the general pattern (Table 14). The significance of the container wall thickness is further discussed in section 6.4.2.

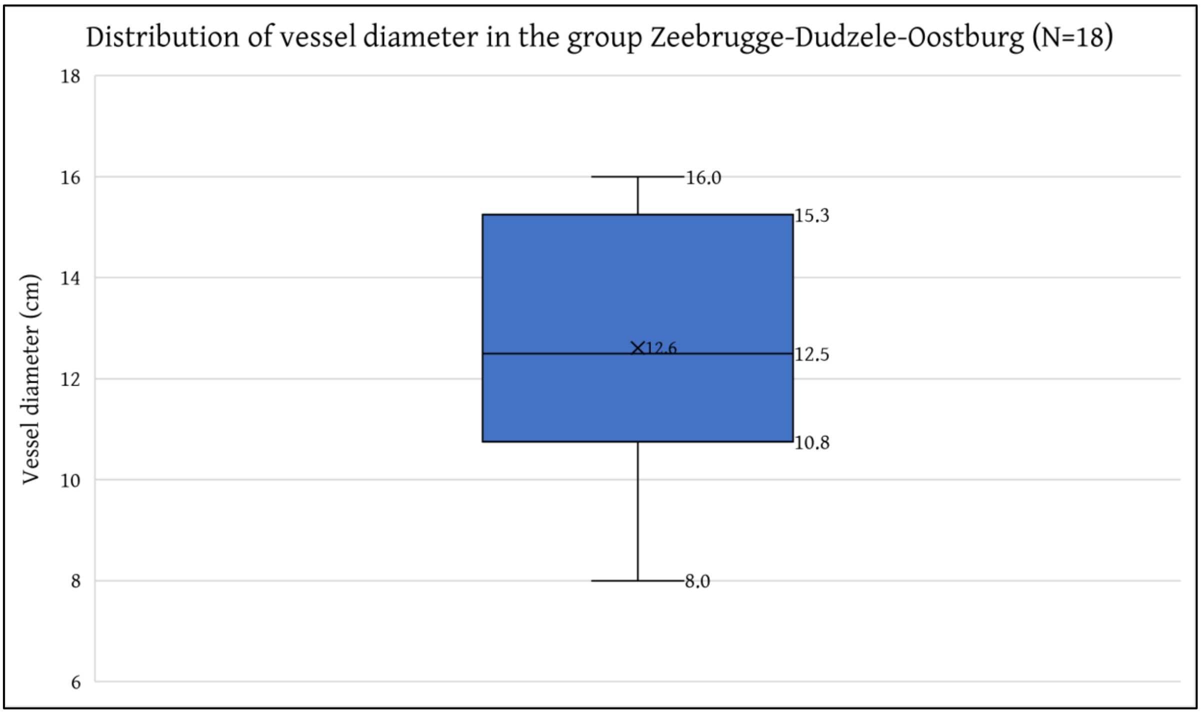


Figure 64 The distribution of the vessel diameter values in the group Zeebrugge-Dudzele-Oostburg.

Table 14 Quantification of the briquetage container sherds (wall fragments only) by thickness, for all archaeological sites included in this study.

	3-5.9mm		6-8.9mm		9-11.9mm		12-14.9mm		15-17.9mm		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Geuldepot	530	*25%*	1179	*55%*	415	*19%*	31	*1%*	1	*0%*	2156	*100%*
Donk 1	59	*24%*	153	*62%*	32	*13%*	3	*1%*	0	*0%*	247	*100%*
Zonnebloemweg	58	*23%*	164	*66%*	27	*11%*	1	*0%*	0	*0%*	250	*100%*
Boudewijnkanaal	8	*25%*	22	*69%*	1	*3%*	1	*3%*	0	*0%*	32	*100%*
Distrigas 1992	7	*2%*	142	*50%*	106	*38%*	27	*10%*	0	*0%*	282	*100%*
Heistlaan	15	*17%*	51	*59%*	17	*20%*	3	*3%*	0	*0%*	86	*100%*
Prospectievondsten	1	*4%*	9	*36%*	13	*52%*	2	*8%*	0	*0%*	25	*100%*
Oostburg	627	*43%*	745	*51%*	75	*5%*	0	*0%*	0	*0%*	1447	*100%*
Total	1305	*29%*	2465	*54%*	686	*15%*	68	*2%*	1	*0%*	4525	*100%*

As previously discussed (section 1.3.4.3), base fragments are overrepresented at the studied production sites compared to rim fragments (Figure 53). Interestingly, the opposite phenomenon has previously been observed at consumption sites, prompting van den Broeke (1995b, 200; 2012, 173) to suggest that the bases of briquetage vessels were removed at the production sites before their transport to the hinterland. The predominance of base fragments encountered here and the preserved height of the bases appear to support van den Broeke's assumption. Figure 65 and Table 15 compare the preserved height of the base fragments across the different sites, which includes the group as a whole. It is clear that the preserved height of the base fragments is highly similar across the different sites. Discarding the outliers, the height of the base fragments was between 8 mm (min.) and 28 mm (max.). The interquartile range shows that the height of 50% of all base fragments was between 13 and 19 mm, and, on average, the bases were 16.1 mm high. The fact that the preserved base height is quite restricted in range indicates that the base of the vessels could indeed have been removed at a fixed height. This fixed height is roughly the equivalent of one *digitus*, a Roman measurement unit of approximately 18.5mm.

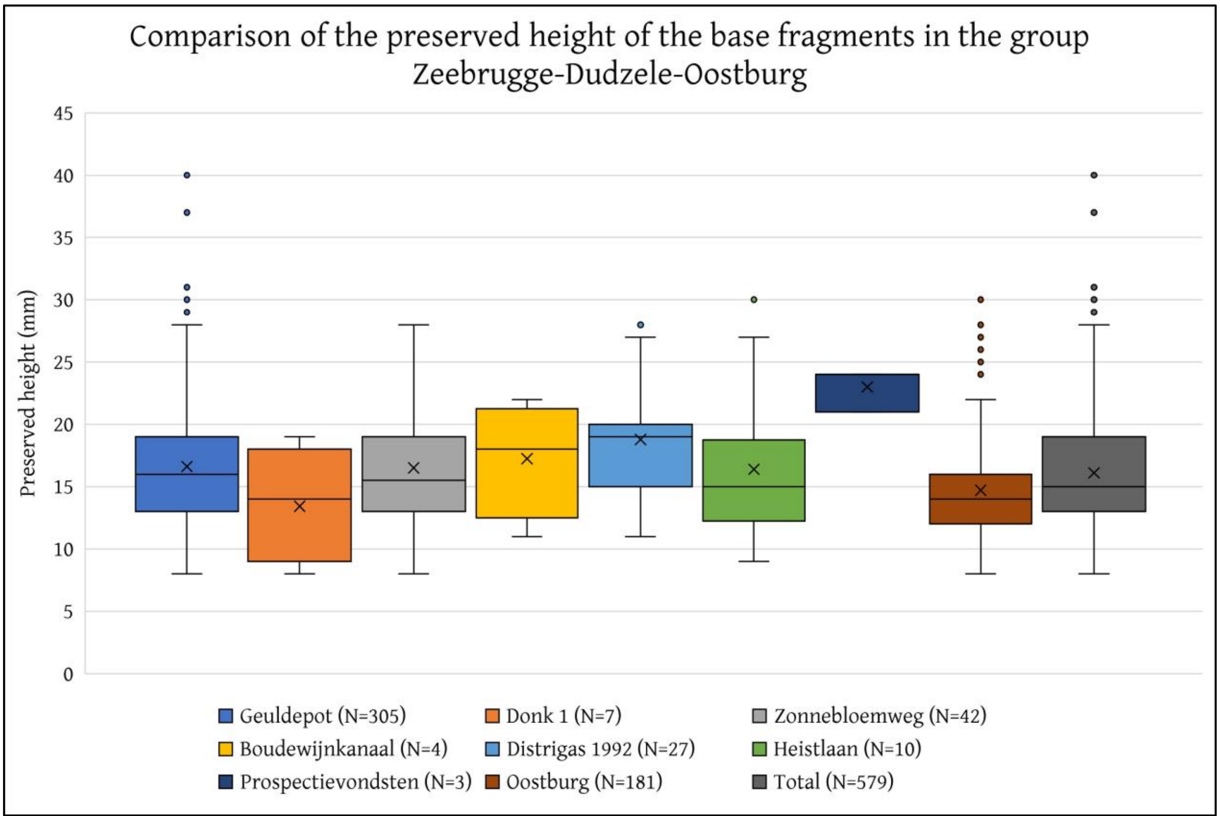


Figure 65 Comparison of the preserved height of the base fragments per site including the group as a whole (= total). Data complementing the boxplot has been presented in Table 15.

Table 15 Complementary data of Figure 65 which presents the values used to create the different boxplots. The preserved base height is expressed in mm.

	Min	Q1	Median	Q3	Max	IQR	Mean
Geuldepot (N=305)	8	13	15	19	28	6	16.6
Donk 1 (N=7)	8	9	14	18	19	9	13.4
Zonnebloemweg (N=42)	8	13	15.5	19	28	6	16.5
Boudewijnkanaal (N=4)	11	12.5	18	21.3	22	8.8	17.3
Distrigas (N=27)	11	15	19	20	27	5	18.8
Heistlaan (N=10)	9	12.3	15	17.8	27	5.5	16.4
Prospectievondsten (N=3)	21	21	24	24	24	3	23
Oostburg (N=181)	8	12	14	16	22	4	14.7
Total (N=579)	8	13	15	19	28	6	16.1

Why salt producers would have removed the base of the vessels is still debated. Van den Broeke (1995b, 200; 2012, 173) suggested that the base was removed to transport the salt with as little ballast as possible to the hinterland. It is true that the dried salt no longer needed support at the base as the salt mass adhered to the vessel walls during the evaporation process. While reducing the ballast was a pleasant side effect, it was likely not the main reason. Salt containers were already quite light because of their porous fabric, and the 'profit' gained by removing the base would have been relatively small. In addition, some disadvantages associated with baseless vessels need to be taken into account, such as the stacking potential of the vessels, the need to protect the product from dirt and other contaminants, etc.

As it offered few practical advantages, it seems more likely that the removal of the vessel base is linked to aspects of the production process. For instance, Riehm (1961) observed that salt is best dried at lower temperatures (ca. 60-70°C) because, at greater temperatures, the salt forms blisters and loses its structural integrity (Hathaway, 2013, 34). Most briquetage vessels were probably subjected to higher temperatures for longer periods of time, during which the crystallised salt accumulated in the containers. At the vessel base, the crystallised salt thus was exposed to higher temperatures for a longer time. If Riehm's assumptions are correct, this might have caused the salt at the bottom to scorch/burn/blister. The salt producers could then have easily removed the contamination by cutting off the vessel base.

A second possible explanation concerns the removal of undesired salts. As explained in Chapter 3, seawater contains different salt minerals that follow successive crystallisation sequences. At the start of evaporation, less soluble minerals such as carbonates (calcite or aragonite) and gypsum will precipitate first. If these minerals settle at the bottom of the briquetage vessels (Fawn et al., 1990, 19), these undesired salts could also have been removed easily by getting rid of the vessel base. Perhaps not the intended purpose, but an added benefit was that without the vessel base, the salt producers and consumers could verify the quality of the salt on both sides of the briquetage vessel.

However, currently, both explanations remain hypothetical, as the crystallisation processes that occurred inside the briquetage vessels are still poorly understood. To this day, a lot of the processes described in literature are purely theoretical, and experimental data on the crystallization of salt minerals inside ceramic briquetage vessels is lacking. Further (experimental) research is thus required to verify the aforementioned hypotheses or to come up with possible alternative explanations.

Decoration?

Although the rims of the briquetage vessels were sometimes decorated with thumb or fingertip impressions, their walls remained largely unadorned. Only on 71 fragments (1.3% of all sherds), possible traces of decoration were observed (Figure 66). These traces can be described as small grooves of variable length, approximately between 1 and 3 mm wide. The preserved groove length clustered between 7 and 10 mm. Yet, often their exact length could not be determined as they had not been completely preserved. Some of these grooves might result from vegetal temper that burned away from the vessel surface during firing. However, most grooves have a rectangular cross-section and a well-defined start and end point, indicating that they were deliberately incised with a knife or spatula (?) before firing when the clay was still slightly moist.

The reason why these grooves were made on the vessels is unclear. As they occur both on base and body sherds, they do not appear to have any specific function. On the other hand, the grooves are quite small, so they do not really stand out on larger vessels which seems to contradict a decorative function. At present, there is no unequivocal answer to explain the presence of these grooves on the vessel surfaces. A more extensive dataset, including inland salt containers and more complete briquetage vessels, is needed to make more informed assumptions. For the time being, it is sufficient to draw attention to this phenomenon, and until more data is available, these grooves are considered a type of briquetage decoration.

The lack of decoration on the briquetage vessel walls is not surprising given the vessels' function. These salt containers were used to boil brine and functioned as packaging material to transport the salt to the hinterland. As such, the briquetage vessels had a specific purpose with a very short lifespan which might have rendered decoration superfluous.

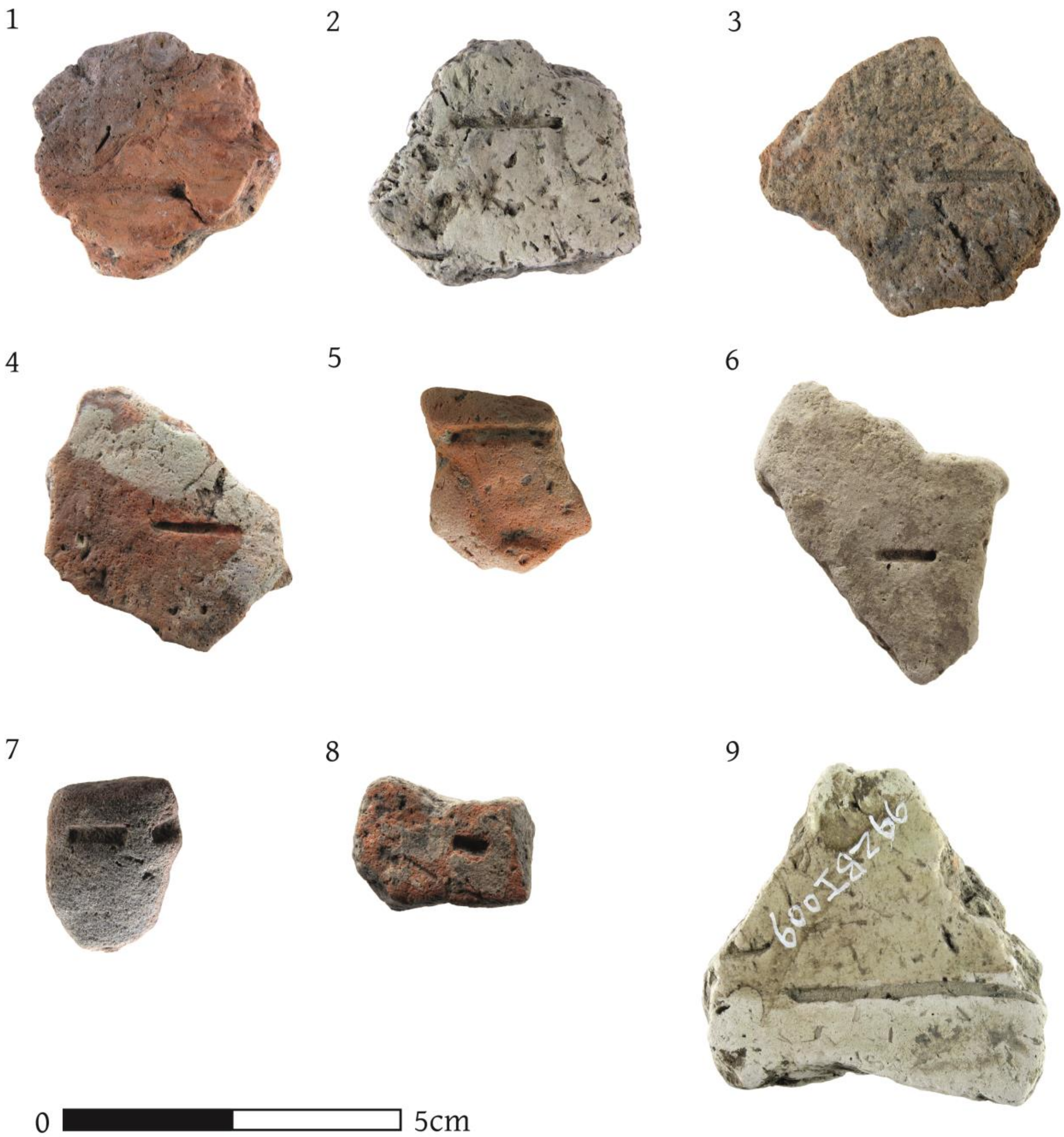


Figure 66 Examples of grooves present on briquetage vessel walls (scale 1:1).

6.3.4.4 Support material

At all sites, the assemblages are dominated by salt container fragments. Support material typically forms less than 5% of the briquetage finds. As the name suggests, support material was used to support briquetage vessels above a heat source. A wide variety of types exist in literature, see Prilaux (2000a), Lane and Morris (2001), Hathaway (2013) etc. In the group Zeebrugge-Dudzele-Oostburg, possibly two distinct support categories were recognised: pedestals and possible stabilisers. Overall, the amount of support material is relatively low, and only 45 fragments of pedestals, 21 potential stabilisers and 23 indeterminable support fragments were present across the different sites (Table 16). Just as no complete vessel profiles were present, no complete pedestals or stabilisers occurred in the dataset. This not only hampers their identification but also makes it difficult to estimate their dimensions and to understand how they may have functioned.

Table 16 Quantification of the support material by category and type across the different sites in the group Zeebrugge-Dudzele-Oostburg.

	Pedestals			Stabilisers?	INDET
	P1	P2	P indet		
Geuldepot	15	--	7	19	7
Donk 1	--	--	1	--	8
Zonnebloemweg	1	1	2	--	1
Boudewijnkanaal	--	--	--	--	--
Distrigas 1992	3	1	--	--	2
Heistlaan		--	--	--	--
Prospectievondsten	1	2	--	2	1
Oostburg	8		3	--	4
Total	28	4	13	21	23

Pedestals

Pedestals are the largest category of support material in the dataset (N=45). Primarily two types of pedestals occurred: a rectangular pedestal of unknown dimensions with a square or rectangular cross-section (type P1) and a cylindrical pedestal of unknown dimensions with a circular cross-section (type P2). Only fragments with a clear corner (approximately 90°) and two smoothed sides were classified as type P1 (Figure 67). There appears to be some variation within this type, as some fragments have a more flanged base/profile Figure 67: 7-8). Unfortunately, the exact height of P1 pedestals could not be determined. Pedestal fragments with a curvature were classified as type P2, and based on this curvature, the diameter of some of these pedestals could be determined (Figure 67: 9-11). The remaining fragments with only one smooth side and no clear curvature were assigned to a separate group P. INDET. The distribution of the pedestal types across the different sites is shown in Table 16.

At this time, the limited dataset prevents far-reaching interpretations of how the pedestals were used in the group Zeebrugge-Dudzele-Oostburg. From the data, it seems that both the rectangular (P1) and cylindrical pedestals (P2) were simultaneously in use. Whether this reflects a personal preference of the producers or if these pedestals had different functions, however, remains unclear.

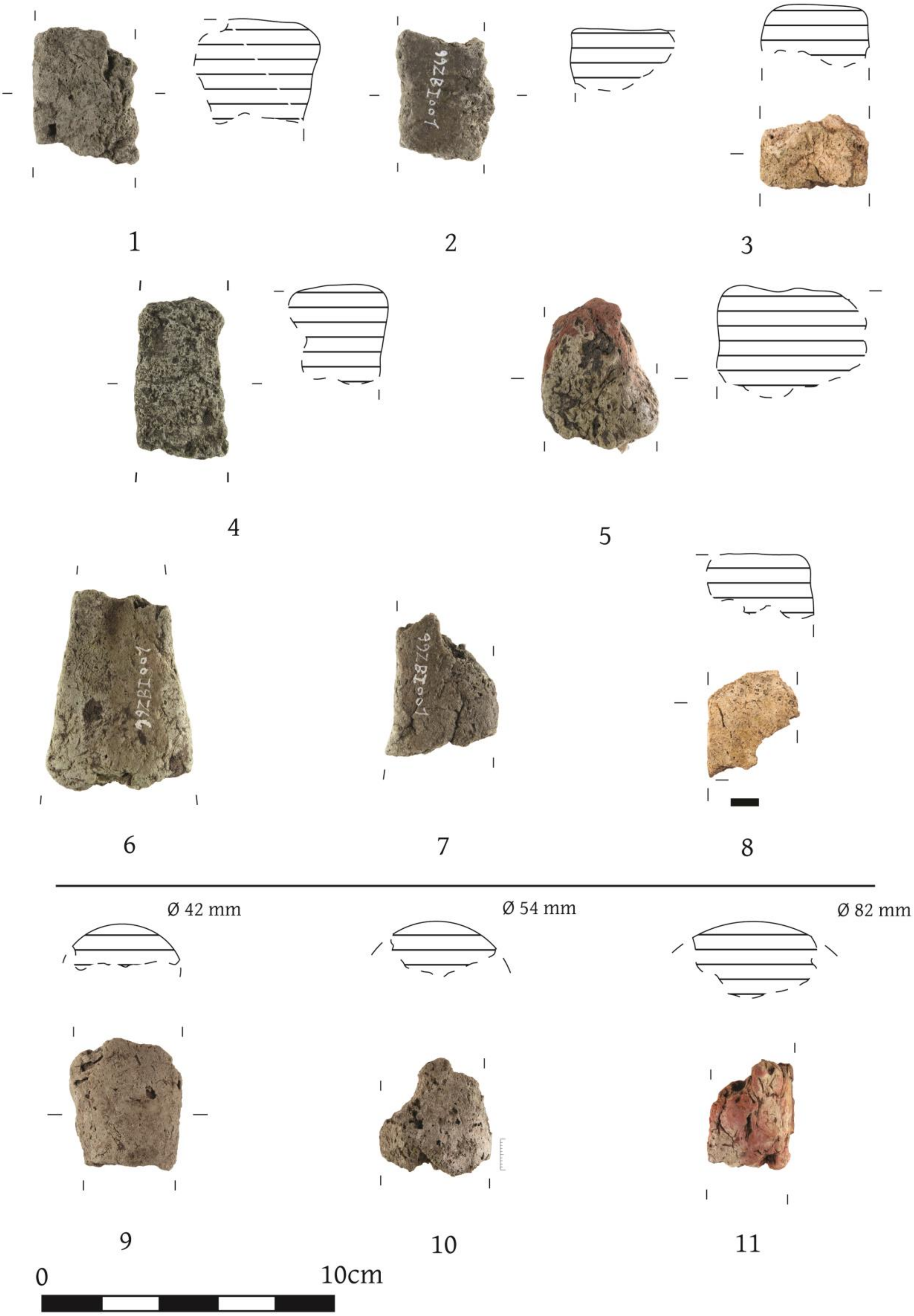


Figure 67 Briquetage pedestal typology for the group Zeebrugge-Dudzele-Oostburg. Type P1: 1-8 and type P2: 9-11 (scale 1:2).

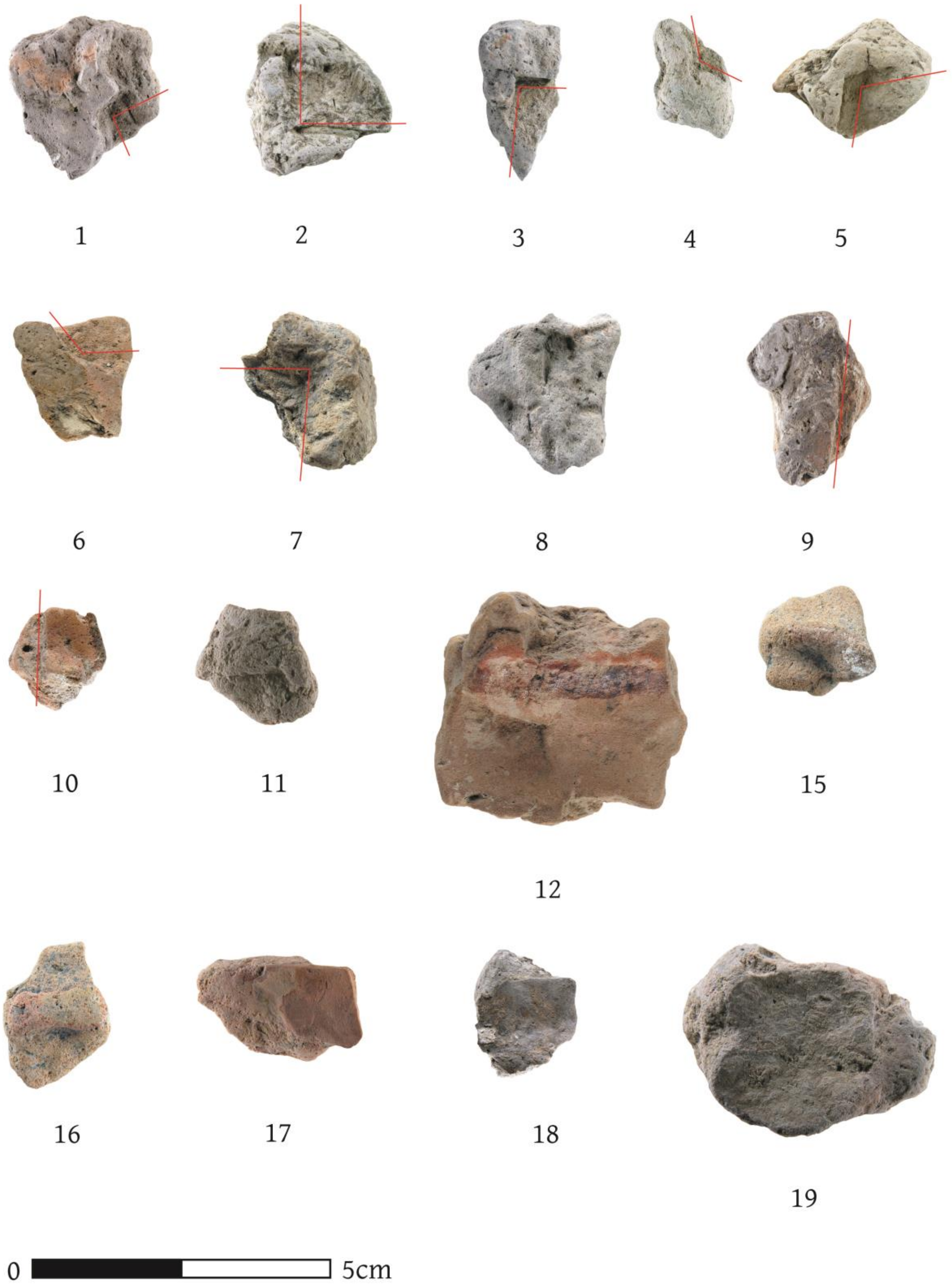


Figure 68 Examples of possible briquetage stabilisers present in the group Zeebrugge-Dudzele-Oostburg (scale 1:1)

Stabilisers?

Stabilisers were manufactured ad-hoc during the production process. They were pushed in a soft state into position, securing the vessels to the various supports. As such, no specific form types were deliberately created, and different types are mainly distinguished depending on the position in which they were used (Lane and Morris, 2001, 370; Hathaway, 2013, 152-154). For instance, Lane and Morris (2001, 370) described different types of 'spacer-clips', while Hathaway (2013, 152) prefers the terms 'platforms', 'spacers' and 'pinch-props'. As these stabilisers were made ad-hoc, they are quite amorphous and not easily recognisable in briquetage assemblages. In the dataset, 21 potential stabiliser fragments were identified mainly from the Geuldepot (Table 16). Most of these fragments have an impression that might result from pressing a wet ball of clay between a pedestal and a container (Figure 68, 1-19). However, the identified stabiliser fragments are quite small compared to most examples in literature (Lane and Morris, 2001; Hathaway, 2013, 152). Further research and well-excavated sites with *in situ* features are needed to confirm the use of stabilisers within the study area.

6.3.5 Group Walcheren

The group Walcheren consists of two sites: Ritthem Schotteweg and Koudekerke Meinersweg. At Koudekerke Meinersweg, the *in* situ remains of four heating structures surrounded by ash and calcium-rich debris layers were discovered. The finds from Ritthem are more difficult to interpret as only the original profile drawing with brief annotations has been preserved. From this drawing, it is clear that the site consisted of a thick debris layer containing large quantities of ash and briquetage material. The site of Koudekerke Meinersweg is firmly dated to the Flavian period. The site of Ritthem Schotteweg can be dated to the second half of the first century – the first half of the second century CE. More detailed information on these sites can be found in sections 6.2.3 and 6.2.4.

6.3.5.1 Composition of the briquetage assemblage

The two sites together yielded 2705 briquetage fragments (ca. 78.5 kg). The majority of the material was recovered at Ritthem Schotteweg (2479 fragments, weighing 68741 g) and includes 2293 salt container fragments (93%), 102 pieces of support material (4%) and 84 miscellaneous fragments (3%). The remaining 8% of the briquetage material (229 fragments, weighing 9924g) is derived from Koudekerke Meinersweg and primarily consists of salt container fragments (99%), complemented by a few pieces of miscellaneous material (1%). For a detailed overview of the composition of the briquetage material, see Table 17.

The lack of support and structural material at Koudekerke Meinersweg was unexpected, considering the presence of *in situ* heating structures. This phenomenon is most likely the result of two (complementary) factors. In the first place, these more amorphous categories of material might have been overlooked or considered less important. As a result, they might not have been recovered during the excavation. There is something to be said for the latter statement since van den Berg and Hendrikse (1980, 225) mentioned in their initial report the presence of vitrified, slag-like material, which they interpreted as hearth lining material. However, only a few of these fragments were present in the assemblage, suggesting that most of them might not have been collected.[100] Secondly,

[100] For a detailed discussion on this vitrified slag-like material, see Chapter 8

it is possible that the salt producers dumped the majority of their waste further from the hearths outside the excavated area. This would also explain why so few salt containers were found at this site.

The briquetage material of both sites is in good condition and is not as fragmented as the material from Zeebrugge-Dudzele-Oostburg. The mean piece weight of the container sherds is 28 g, and the support fragments weigh, on average, 60 g (Table 17). The relatively good preservation of the material can be partially explained by the fact that the sites were preserved below the plough depth and that all fragments were recovered by hand selection.

Table 17 Quantification of the briquetage remains of Koudekerke Meinersweg and Ritthem Schotteweg (group Walcheren) according to the major briquetage categories.

	Salt container			Support			Structural		Miscellaneous		Total	
	N	wt. (g)	wt./N (g)	N	wt. (g)	wt./N (g)	N	wt. (g)	N	wt. (g)	N	wt.
Koudekerke	226	9833	43.51	--	--	--	--	--	3	91	229	9924
Ritthem	2293	61103	26.65	102	6076	59.57	--	--	84	1562	2479	68741
Total	2519	70936	28.16	102	6076	59.57	--	--	87	1653	2708	78665

6.3.5.2 Fabrics

The fabrics from both Koudekerke Meinersweg and Ritthem Schotteweg were examined. This analysis resulted in the definition of two major fabric groups: Walcheren Fabric 1 (WF1) and Walcheren Fabric 2 (WF2). The fabric types are described in detail below. The quantification of the different fabric types is shown in Table 18.

Walcheren FABRIC 1 (WF1): A very coarse, hard, heterogeneous fabric with a reduced dark grey core and oxidised orange-red surfaces (Figure 69). This oxidation layer occurs on the in- and outside of the vessel but is typically more pronounced on the outside. The oxidation does not penetrate deep into the fabric and is usually less than 1 mm thick. The fabric is heavily tempered with vegetal material (grass?). Most of the vegetal inclusions have completely burned out during firing, resulting in a dense network of meso-mega (0.05 > 2 mm) planar and vesicle voids. Often, larger amorphous mega (> 2 mm) vughs could also be observed. The void size indicates that predominantly coarser and fewer fine vegetal material was used. In the reduced core, some vegetal temper was not completely burned out and was preserved as charred material. In addition, very fine-medium sand (< 0.1 – 0.5 mm), consisting of white-grey, subangular to subrounded quartz inclusions, is commonly present. Sporadically, very few orange-red grog fragments can be observed.

Walcheren FABRIC 2 (WF2): A very coarse, hard, heterogeneous fabric with a reduced light grey core and slightly oxidized light grey/white-yellow surfaces (Figure 69). The fabric was tempered with mainly fine vegetal material and the vegetal inclusions, commonly to frequently present, completely burned out during firing, resulting in a network of meso-macro (0.05-2 mm) planar and vesicle voids. In addition, very fine-medium sand (<0.1 – 0.5 mm), consisting of white-grey, subangular to subrounded quartz inclusions, is commonly present.

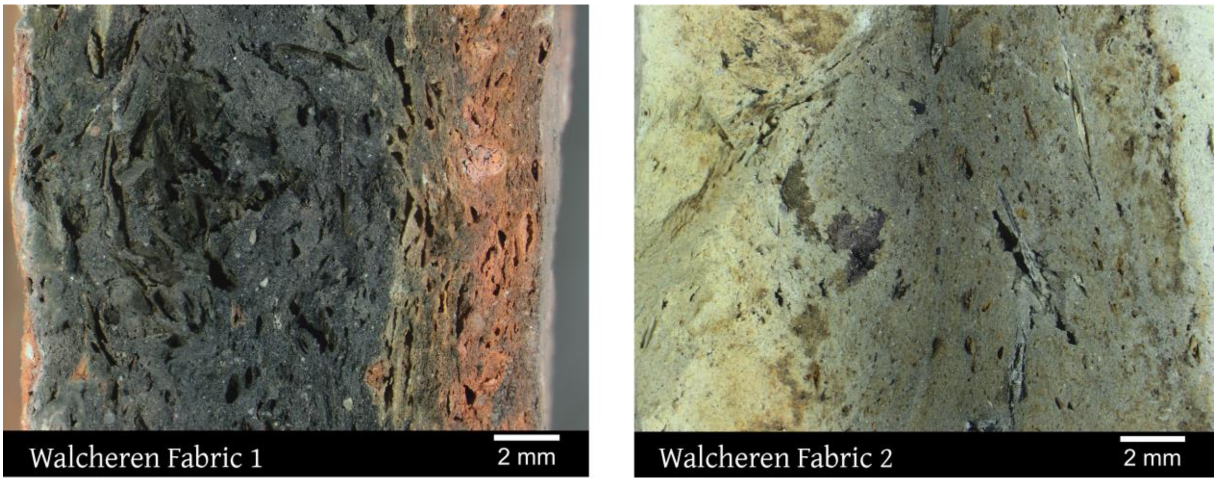


Figure 69 Photomicrograph of the main fabric types represented in the group Walcheren.

Both fabrics are highly similar, but some minor differences occur. While vegetal material was added as temper in both fabrics, this is more pronounced in fabric WF1. In addition, when considering the void size, it appears that predominantly coarser vegetal material was used in fabric WF1 compared to fabric WF2. Furthermore, grog fragments were occasionally used as additional temper in fabric WF1. However, the main difference is the different oxidation surface colours. An orange-red colour is often associated with the abundance and oxidation state of iron. At temperatures above ca. 600°C, iron is oxidized to 'ferric' minerals such as hematite (Fe_2O_3) which produces red or reddish brown colours (Quinn, 2013, 200; Rice, 2015, 281). Yet, as this orange-red zone is very thin (< 1 mm thick), it is possible that other factors or processes played a role. More geochemical and mineralogical research is needed to verify if hematite minerals are present in the orange-red zone of fabric WF1 or if other processes are responsible for the orange-red surface colour of the vessels. The fact that no red or reddish brown colour appears on the surface of fabric WF2 suggests that either clay with no or a very low amount of iron was used or that the firing conditions were significantly different.

The distribution of the fabrics across the different sites and the major briquetage categories is shown in Table 18. At Koudekerke Meinersweg, more salt containers were constructed using fabric WF2, though fabric WF1 is still well represented. At Ritthem Schotteweg, practically all salt containers were made in fabric WF1, and fabric WF2 was only used to create a minority of the containers. Interestingly, all support material was exclusively made in fabric WF2. As this fabric was tempered with less and finer vegetal material, it was perhaps better suited to construct pedestals than fabric WF1.

Table 18 Quantification of briquetage fragments of Koudekere Meinersweg and Ritthem Schotteweg (group Walcheren) by category and fabric type.

	WF1		WF2		n.v.t.		Total	
	N	%	N	%	N	%	N	%
Koudekerke								
Salt container	53	*23%*	171	*76%*	2	*1%*	226	*100%*
Miscellaneous	--	--	--	--	3	*100%*	3	*100%*
Site subtotal	53	*23%*	171	*76%*	5	*2%*	229	*100%*
Ritthem								*100%*
Salt container	2207	*96%*	80	*3%*	6	*0%*	2293	*100%*
Support	--	--	81	*79%*	21	*21%*	102	*100%*
Miscellaneous	--	--	--	--	84	*100%*	84	*100%*
Site subtotal	2207	*89%*	161	*6%*	111	*4%*	2479	*100%*
Total	2260	*83%*	332	*12%*	116	*4%*	2708	*100%*

6.3.5.3 Salt containers

Briquetage vessel composition

The group Walcheren consists almost exclusively of salt container fragments; in total, 2219 sherds (ca. 71 kg) were recovered. Among these are 290 rim (15698 g), 1661 body (47791 g) and 121 base fragments (3320 g). In addition, the assemblage contained 447 fragments (4127 g) of so-called flakes. According to Lane and Morris (2001, 34), the flaking effect is primarily a post-depositional process related to the susceptibility of vegetal tempered ceramic to freeze-thaw conditions in moist environments. Table 19 shows the distribution of rim, body, base and flake fragments in the assemblages of Koudekerke Meinersweg and Ritthem Schotteweg. Similar to group Zeebrugge-Dudzele-Oostburg and in correspondence with section 6.3.3.2, no MNI was determined.

At Koudekerke Meinersweg, the 226 pottery fragments represent the number of sherds after refitting. The original amount of sherds was 266, but 36 body and 13 rim fragments could be refitted into eight larger vessel parts. Often these are a only few body sherds that fit together, but a few larger vessel profiles could be reconstructed (Figure 70: 1-2). No sherds of Ritthem Schotteweg could be refitted.

Table 19 Quantification of the salt container sherds by class (rim, body, base and flake) of Koudekerke Meinersweg and Ritthem Schotteweg (group Walcheren).

	Rim		Body		Base		Flake		Total	
	N	wt. (g)	N	wt. (g)	N	wt. (g)	N	wt. (g)	N	wt. (g)
Koudekerke	21	3182	169	6157	12	343	24	151	226	9833
Ritthem	269	12516	1492	41634	109	2977	423	3976	2293	61103
Total	290	15698	1661	47791	121	3320	447	4127	2519	70936

When considering the rim-body-base distribution (2.5:14:1), no discrepancy in the rim-base ratio favouring the base fragments occurred. On the contrary, more than twice as many rims compared to bases were recovered at both sites. This is rather unexpected and does not really fit with the assumption that the base of briquetage vessels was removed at the production sites before transport to the hinterland (section 6.3.4.3). If this had been the case, bases should dominate in the assemblage as in the group Zeebrugge-Dudzele-Oostburg. This situation is further complicated by the fact that Van den Broeke (1995b, 200) noticed this rim-base discrepancy mainly in type B cylinders which strongly resemble the material from Koudekerke and Ritthem.

Currently, the observed rim-base ratio cannot be explained satisfactorily. Although the data suggest that the base of the vessels was not removed at Koudekerke and Ritthem, this does not necessarily discredit the hypothesis as a whole. These sites may not be representative of the wider production area. Indeed, at neighbouring production sites with similar briquetage vessels, the bases of these vessels might well have been removed before transport, explaining the rim-base discrepancy in the hinterland. Again, it should be noted that, at the moment, the reason why the salt producers removed the base is still unclear. As such, the removal of the base could have been a choice not dictated by practical necessity, but instead was an action dictated by social and/or cultural traditions, which could explain why the phenomenon does not occur at all sites.

That being said, removing the bases cannot be completely ruled out as too many unknown factors play a role. For instance, it is unclear whether the ceramic assemblage is representative for the entire site. In addition, briquetage vessels that broke during the production process would have been dumped on site affecting the rim-base ratio. Furthermore, the low degree of fragmentation coupled with the recognisability of the rims would also have influenced the rim-base ratio. Therefore, a more extensive dataset of both production and consumption sites is required to further test and investigate this hypothesis.

Rim & base morphology

The group Walcheren yielded 290 rim fragments, of which 7% was recovered at Koudekerke Meinersweg and 93% at Ritthem Schotteweg. Except for two heavily fragmented undeterminable pieces, all rims can be described as straight to slightly everted flatted rims (R2). The top of these rims is always decorated with thumb or fingertip impressions. These thumb and fingertip impressions were applied in such a manner that they created a wave-like pattern (Figure 70, Figure 71 and Figure 72). Similar to the rim fragments, most base fragments (64%) belonged to a single base type (B1A). Type B1A is a simple, flat base in which the exterior surfaces form a sharp angle at the join, and the wall is set at an angle between 80-90° (Figure 71: 11-13). The remaining 34% of the base fragments were either too small or severely worn and were therefore categorised as INDET.

Figure 70 Briquetage vessel fragments from Koudekerke Meinersweg – Fabric WF1 (1-2); Fabric WF2 (3; 5-7) and heavily burned (4) (scale 1:4).

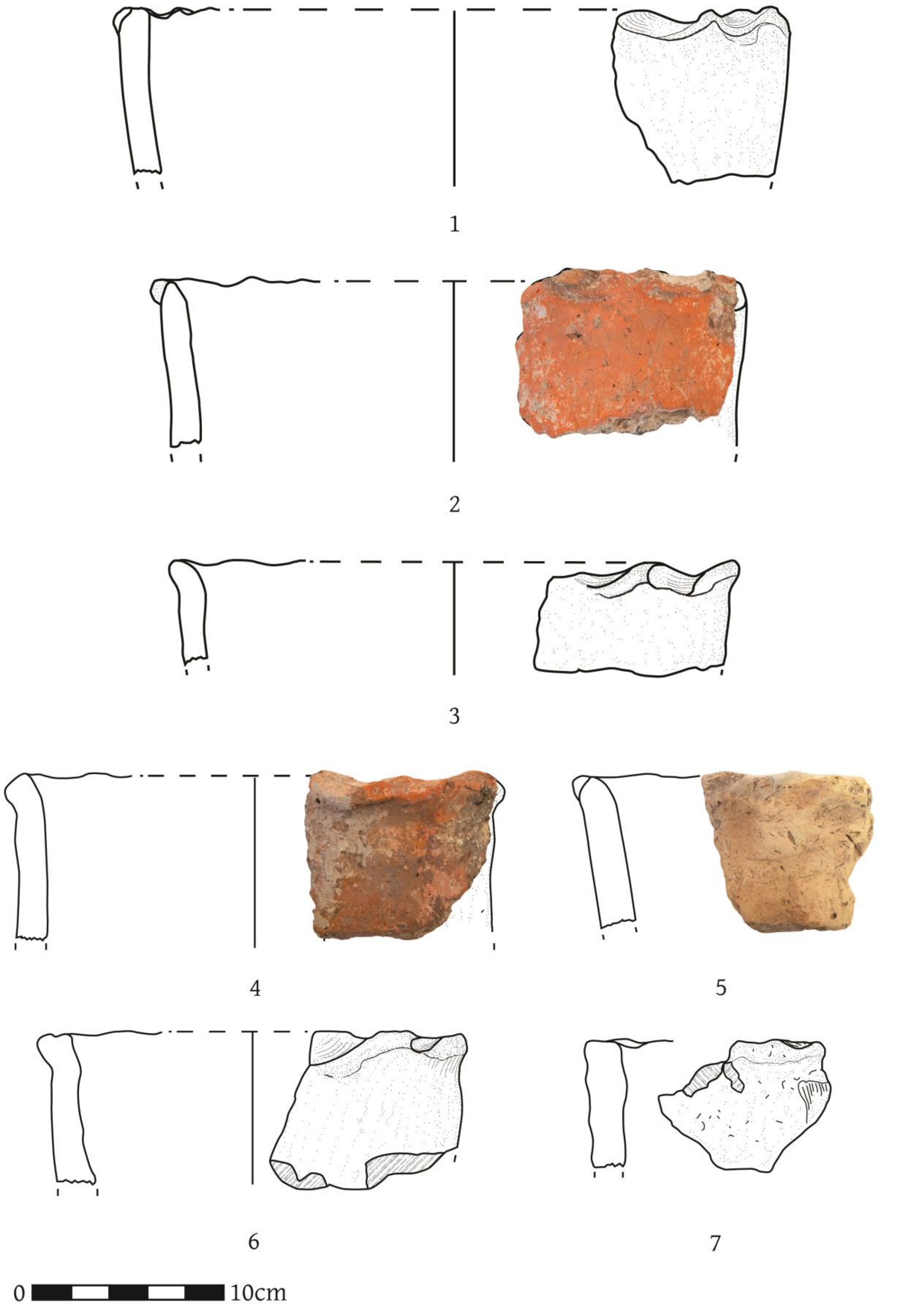


Figure 71 Briquetage vessel fragments from Ritthem Schotteweg – Fabric WF1 (1-4; 6-7) and Fabric WF2 (5) (scale 1:3).

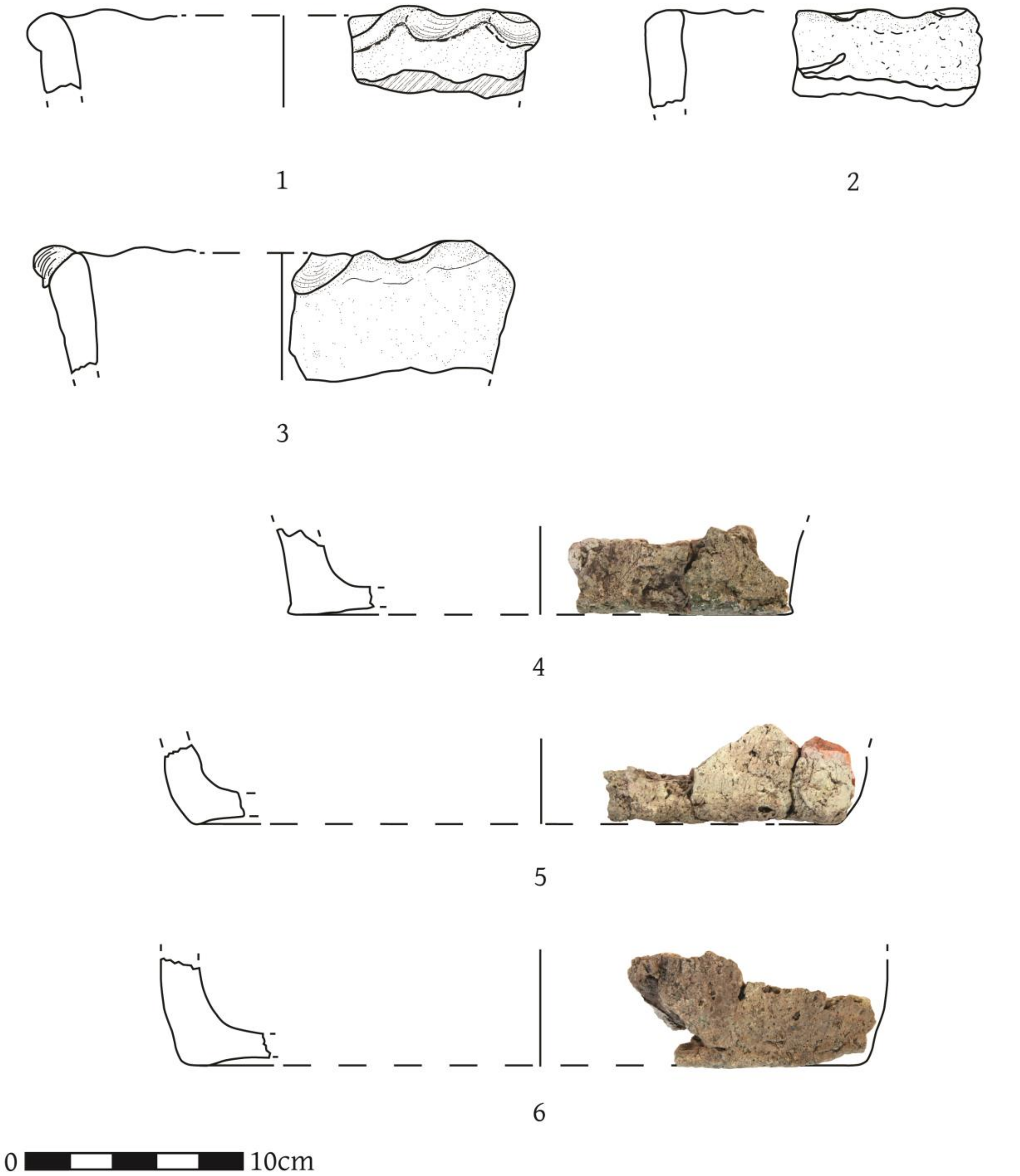


Figure 72 Briquetage vessel fragments from Ritthem Schotteweg – Rim (1-3) and Base (4-6) (scale 1:3).

Vessel shapes

Complete vessel profiles, including the base, could not be reconstructed for these sites. At Koudekerke Meinersweg, two large vessel profiles (rim to body) (Figure 70: 1 -2) and four large body sherds provided additional information on the vessel's construction and shape. The first one (Figure 70: 1) is a large cylindrical, bucket-shaped vessel. It has a rim diameter of 52 cm and is at least 34.5 cm high. The exact height of the vessel could not be reconstructed as the connection to the base was not preserved. Second, there is a cylindrical, bucket-shaped vessel (Figure 70:2) with a rim diameter of 38 cm and preserved height of 16.3 cm. The four large body sherds (not illustrated) are also part of cylindrical vessels with a diameter of 47, 47, 33 and 28 cm. These two large body sherds with a diameter of 47 cm might have been part of the same vessel.

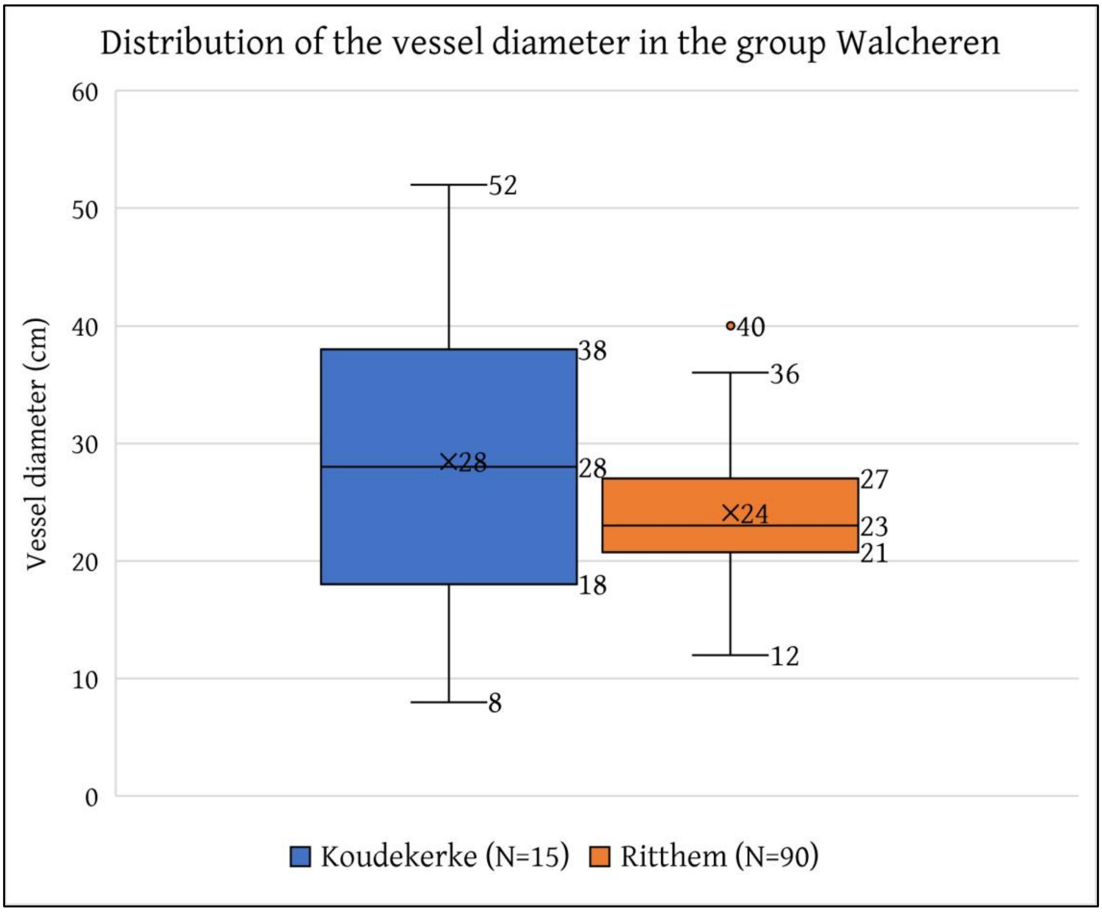


Figure 73 Distribution of vessel diameter values in the group Walcheren.

The remaining, more fragmented rim and base fragments are similar to these larger vessel profiles, suggesting that only cylindrical, bucket-shaped briquetage vessels are represented. One exception is a small vessel with a diameter of 8 cm in fabric WF2 found at Koudekerke Meinersweg (Figure 70: 3). Of the remaining fragments, the rim or base diameter of 105 fragments (15 from Koudekerke and 90 from Ritthem) could be determined. Figure 73 shows the distribution of vessel diameter values for Koudekerke and Ritthem. Discarding the outlier (40 cm), the vessel diameter at Ritthem Schotteweg is between 12 cm (min) and 36 cm (max). The interquartile range shows that 50% of the vessel diameter values lie between 21 and 27 cm. The average diameter of the vessels is 24 cm. At Kouderkerke, no outliers could be defined due to the limited dataset, and the vessel diameter ranges between 8 cm (min) and 52 cm (max). 50% of the values were between 18 and 38 cm, and the average diameter of the vessels was 28 cm. However, it should be noted that a few very large, but also a few very small vessels significantly influence the observed pattern at Koudekerke.

Although little attention was paid to the fashioning, forming and finishing methods, it is clear that these bucket-shaped vessels were built up by coiling (Rye, 1981, 66; Livingstone Smith, 2007; Teetaert, 2020). This is evident from the sherd fracture patterns, as these quadrangular fractures are typically associated with the coiling technique. Because the junctures between two horizontal coils are weak points in the vessel, cracks will more easily occur here and create these typical four-sided sherds (Teetaert, 2020). These quadrangular fractures were noted at Koudekerke and Ritthem and are visible in Figure 70: 1, Figure 71: 1-7 and Figure 72: 1-3. In addition, the separate coils used to build the vessels could occasionally be distinguished as diagonal or subcircular configurations in the internal clay structure (Livingstone Smith, 2007).[101]

The thickness of the vessels (body sherds only) varies between 9 and 20.9 mm, and small differences are noticeable between the sites (Table 20). At Koudekerke Meinersweg, 87% of the sherds fall between 9-14.9 mm and only a small portion of the sherds (11%) was assigned to category 15-17.9 mm. The briquetage vessels from Ritthem are clearly coarser, as 71% of the sherds are between 15 and 20.9 mm thick. The remaining 29% of the fragments were between 12-14.9 mm thick, and no sherds belonged to category 9-11.9 mm.

Table 20 Quantification of the briquetage containers sherds (wall fragments only) from the sites of Koudekerke and Ritthem by thickness category.

	9-11.9mm		12-14.9mm		15-17.9mm		18-20.9mm		Total	
	N	%	N	%	N	%	N	%	N	%
Koudekerke	73	*43%*	75	*44%*	18	*11%*	3	*2%*	169	*100%*
Ritthem	0	*0%*	427	*29%*	701	*47%*	362	*24%*	1490	*100%*
Total	73	*4%*	502	*30%*	719	*43%*	365	*22%*	1659	*100%*

As mentioned above, no discrepancy in the rim-base ratio favouring the base fragments occurred. This was rather unexpected as it does not exactly fit the hypothesis that the bases were removed, just as in the group Zeebrugge-Dudzele-Oostburg (sections 6.3.4.3 and 6.3.5.1). However, the preserved height of the base fragment might be an argument in favour of said hypothesis. Figure 74 compares the preserved base height at both Koudekerke and Ritthem. At Ritthem, the height of the base fragments was between 19 mm (min) and 58 mm (max). The interquartile range shows that 50% of the base fragments had a preserved height between 28 and 41 mm. On average, the bases were 36 mm high, and the median value was 35 mm. Although the minimum and maximum values are more widely spaced, the interquartile range is quite restricted, which might support the idea that the bases of at least some vessels were removed at a fixed height. Based on the mean and median values, the base might have been removed at a height roughly the equivalent of two *digitus* (37 mm). At Koudekerke, this pattern is less clear, which might be due to the limited dataset. The interquartile range is more widely spaced between 20 and 42 mm, but the mean and median value, respectively 35 cm and 33 cm, is highly similar to Ritthem. This suggests that the bases of some vessels might have been removed at the same height as at Ritthem.

[101] This was noted by dr. D. Teetaert when we asked his opinion on the construction methods

Even though the salt producers had a fixed height of two *digitus* in mind, the actual height at which the base broke off was influenced by the position of the clay coils that were used to construct the vessels. The juncture between two horizontal coils is typically the vessel's weak point, making it much easier to remove the base. This could explain why the preserved height of many base fragments cluster around two *digitus* and why there is still a fair amount of variation. In addition, it is possible that, compared to the vessels in group Zeebrugge-Dudzele-Oostburg, the increased vessel thickness and size made it more difficult to remove the base. Interestingly, quite a few base fragments (8% at Koudekerke and 35% at Ritthem) show signs of vitrification. The vitrification illustrates that the vessels were definitely used in the production process, but also that the temperature at the base of the containers was quite high for a longer period of time (Figure 70:4; Figure 71: 12-13). This indicates that a direct heating method was used in which the vessels were exposed to/were in direct contact with the heat source.

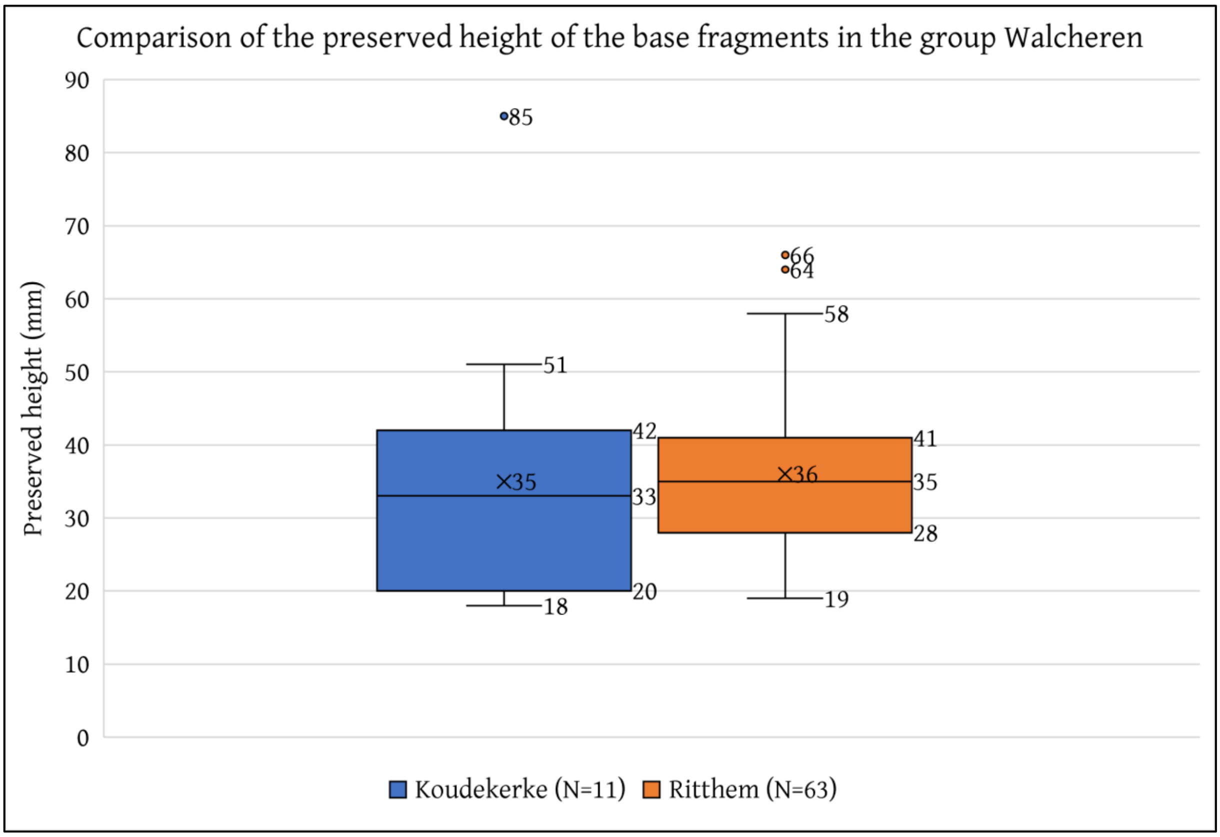


Figure 74 Comparison of the preserved height of base fragments within the group Walcheren.

6.3.5.4 Support material

In the group Walcheren, support material was only attested at Ritthem Schotteweg. At Ritthem Schotteweg, 81 fragments of pedestals and 21 underminable support fragments are present. All pedestal fragments could be assigned to a single type: P3. This type can be described as a large, rectangular, brick-like pedestal with a rectangular cross-section and a rectangular to slightly trapezoid lengthwise profile (Figure 75: 1-6). Only fragments with an (almost) complete cross-section have been classified as type P3 (N=17). Fragments with at least one corner (approximately 90°) and at least two smoothed sides have been classified as P3? (N=64). In the group Zeebrugge-Dudzele-Oostburg, smaller fragments with these characteristics were assigned to type P1 (section 6.3.4.4). Yet, these fragments are much larger in this assemblage, suggesting that they belong to P3 instead of P1 pieces. From the completely preserved cross-sections, it is clear that the length and width were not fixed and varied between 4.8-7.4 cm and 3.8-5.1 cm respectively. The preserved height of some larger fragments indicates that the height of the P3 pedestals could be at least 10 cm. Unfortunately, no complete pedestal fragments were recovered, making it difficult to estimate their dimensions correctly.

In Anglo-Saxon literature, bricks are sometimes considered to represent a different category of support material than pedestals (Lane and Morris, 2001; Hathaway, 2013). According to Lane and Morris (2001, 372), these bricks were designed to support the base of the containers. In the Fenlands, bricks were commonly used from the early Roman period onwards. In addition, they are often associated with larger flat-bottom evaporation vessels and more complex heating structures. Similarly, in Ritthem Schotteweg, the connection between larger briquetage vessels and the introduction of brick-like pedestals is evident.

Apart from pedestal fragments, a small amount of undeterminable support material has been observed for the group Walcheren (N=21). These fragments with no or one smoothed surface are most likely pedestal fragments, but they may belong to a different type of support material. Therefore they are grouped as an INDET category.

6.3.5.5 Miscellaneous material

At Koudekerke Meinersweg and Ritthem Schotteweg, a small amount of amorphous material was categorised as miscellaneous. As indicated above (section 6.3.5.1), they only represent a fraction of the material present on site, as not all fragments were collected. In total, 39 fragments of amorphous low-fired clay and 45 fragments of amorphous vitrified clay were recovered at Ritthem. At Koudekerke, three fragments of vitrified material were collected. Objects from both sites were selected for geochemical analyses, the results of which are discussed in Chapter 8.

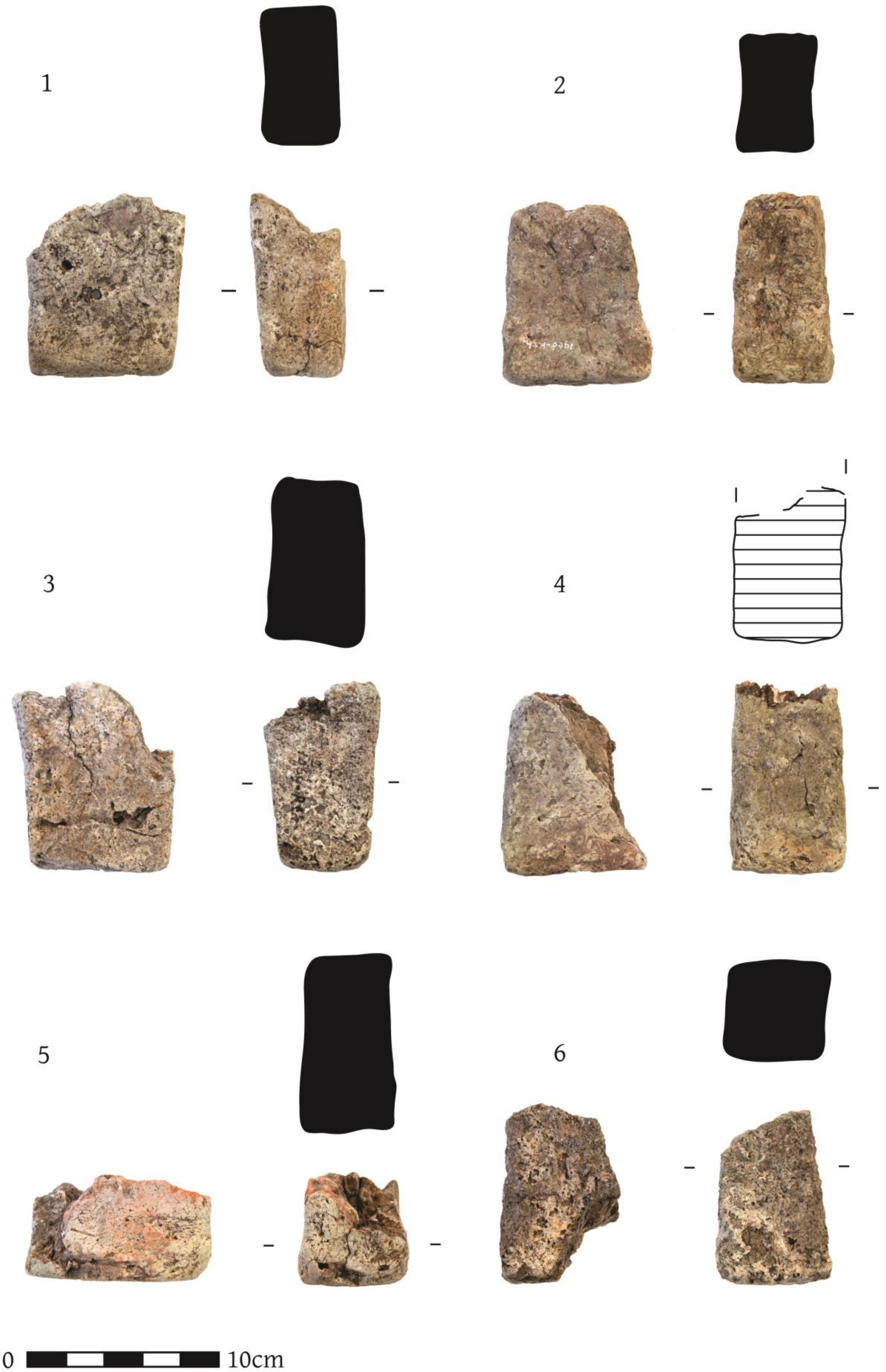


Figure 75 Briquetage pedestal fragments (type P3) from Ritthem Schotteweg.

6.4 Discussion

6.4.1 Fabrics

This section compares the macro-and mesoscopic observations of the briquetage fabrics for both groups and tries to connect them to known fabric types. For a detailed description and discussion of the individual fabrics within a group, see sections 6.3.4.2 and 6.3.5.2.

Across the different groups, five fabric types are defined based on the characteristics of the matrix and the dominant inclusions that are either naturally present in the clay or are deliberately added as temper. The raw materials are similar and mainly consist of silty-sandy (marine) clays. Minor differences occur in firing conditions, amount and size of vegetal temper, amount of quartz and other sporadic inclusions (mica, grog etc). As it concerns only minor differences, it is possible that some of these fabrics are petrographically similar (i.e. have a similar mineralogical composition) and may be variants within the same group.

In all fabrics, a varying amount of voids are present. These voids are not only the result of the shrinkage during drying, but can be linked to the disappearance of vegetal material during the initial firing of the objects. In the reduced core, some vegetal material was not completely burned out and persevered as charred material. Unfortunately, the species could not be determined, but grass or halophytic plants are possibilities.[102] The amount of voids suggests that most vegetal material was deliberately added as temper. It is unclear whether the larger quantities of quartz in some of the fabrics were added as (sand) temper or was naturally present in the clay. This question could be answered by studying the quartz grain size distribution of the fabric in thin-section.

Adding temper to clay mixtures not only reduces the plasticity of the clay but also increases the workability. In addition, specific types of temper can, to a varying degree, affect several key physical characteristics such as permeability, heating effectiveness, thermal shock resistance and toughness (Quinn, 2013, 158). The addition of vegetal temper typically results in highly permeable vessels with a strong resistance to thermal shocks due to the increased porosity. This would have been an important factor as (cold) brine was continuously added to these vessels causing sudden temperature changes. Conversely, the increased porosity significantly reduces the thermal conductivity, i.e. the rate at which heat from an external source passes through a specific material (Quinn, 2013, 158). In other words, the brine inside the briquetage vessels will heat up and evaporate less quickly due to the larger amount of pores. On the other hand, the increased porosity might have been an added benefit as it produced lighter-weight vessels that are easier to transport (Rice, 2015, 81).

The presence of numerous briquetage vessels in the hinterland indicates that these vessels were definitely used to transport salt to the consumers. The only information on Roman briquetage vessels in the hinterland stems from van den Broeke (1986, 1995b, 2012). He distinguishes between yellow (A) and orange-red (B) wares. Yellowish-white, yellow or light orange surface colour and a vegetal temper characterise the yellow ware (A). The orange-red (B) ware has an orange-red, slightly purple or brown surface colour with a reduced core and is tempered with vegetal material. These groups were further divided based on fabric hardness: soft-fired (A1/B1) and moderately hard-fired (A2/B2) (van den Broeke, 2012, 159-160). If these parameters are applied here, then ZF1 and ZF2 look like A1; ZF3 like

[102] Samples of the briquetage vessels are included in the Brain-be 2.0 project 'Identification and 14C Dating of Organic Materials in Archaeological Ceramics'. These analyses will help to determine the preserved charred vegetal material.

B1; WF1 like B2 and WF2 like A2. However, at the moment, connecting the fabrics at the production sites to the fabrics at the consumption sites is difficult solely based on macro-and mesoscopic information. Extensive petrographic and geochemical research on briquetage vessels of both production and consumption sites is required to adequately match these fabrics. Even then, it might be difficult to determine or distinguish production areas as the briquetage fabrics are highly similar.

6.4.2 Briquetage vessel morphology

In both groups, salt containers dominate the briquetage assemblage. However, the lack of complete vessel profiles makes assessing the present vessel shapes difficult. Figure 76 presents an overview of the briquetage morphology of the group Zeebrugge-Dudzele-Oostburg and the group Walcheren. As discussed in section 6.3.4.3, larger base fragments without curvature might suggest the presence of rectangular briquetage vessels in the group Zeebrugge-Dudzele-Oostburg (Figure 76: 1-2). Yet, evidence for this hypothesis is somewhat feeble and more data, especially in the form of more complete vessels, is required to support this claim. Nonetheless, if such rectangular vessels are present, it has repercussions for how these salt production sites may have functioned. Parallels in the Fenlands and southern Britain indicate that larger rectangular, flat-based salt pans were mainly used to evaporate brine and that the salt crystals were removed from these vessels upon crystallisation. Salt drying then took place in open-air or in differently shaped briquetage vessels above the fire (Lane and Morris, 2001; Biddulph et al., 2012, 167-168; Hathaway, 2013, 126-128).

On the other hand, if the rectangular containers were smaller, the evaporation and drying process may have occurred in one and the same briquetage vessel, which is more in line with the Iron Age continental tradition of salt making. Smaller, rectangular briquetage vessels (*augets à sel*) are known from Iron Age salt production sites in Armorica (Bretagne) (Gouletquer, 1970; Daire, 1994, 2003; Carpentier et al., 2012). Yet, no similar vessels are known for the Roman period along the Channel and Atlantic continental shores. For the time being, however, not too much attention should be paid to these rectangular vessels as their presence is still doubtful and needs to be confirmed first.

The majority of sherds of the group Zeebrugge-Dudzele-Oostburg and all fragments of the group Walcheren can be attributed to cylindrical to slightly truncated, conical-shaped vessels. Although the rim and base morphology in the group Zeebrugge-Dudzele-Oostburg indicates that some typological variation might have occurred, the lack of complete vessel profiles makes it difficult to assess the value of these possible types (Figure 76: 3-8). Should they be considered distinct types with possibly a different function, or are they subtle variations of a specific vessel shape related to the vessel's construction? Either way, the overall vessel shape will have been the same and can be described as a cylindrical (to slightly truncated, conical) shape. In the group Walcheren, no variation in rim and base morphology occurred, and all fragments can be attributed to similar cylindrical to slightly truncated, conical-shaped vessels (Figure 76: 9-10).

Even though the briquetage vessels in both groups have the same overall shape, differences can be noted in wall thickness (Figure 77) and vessel size (Figure 78). In the group Zeebrugge-Dudzele-Oostburg, the wall thickness of the vessels varies between 3-11.9 mm, and the average vessel diameter is 12.6 cm. In comparison, the wall thickness in the group Walcheren varies between 12-20.9 mm and the vessel diameter averages 24.6 cm.

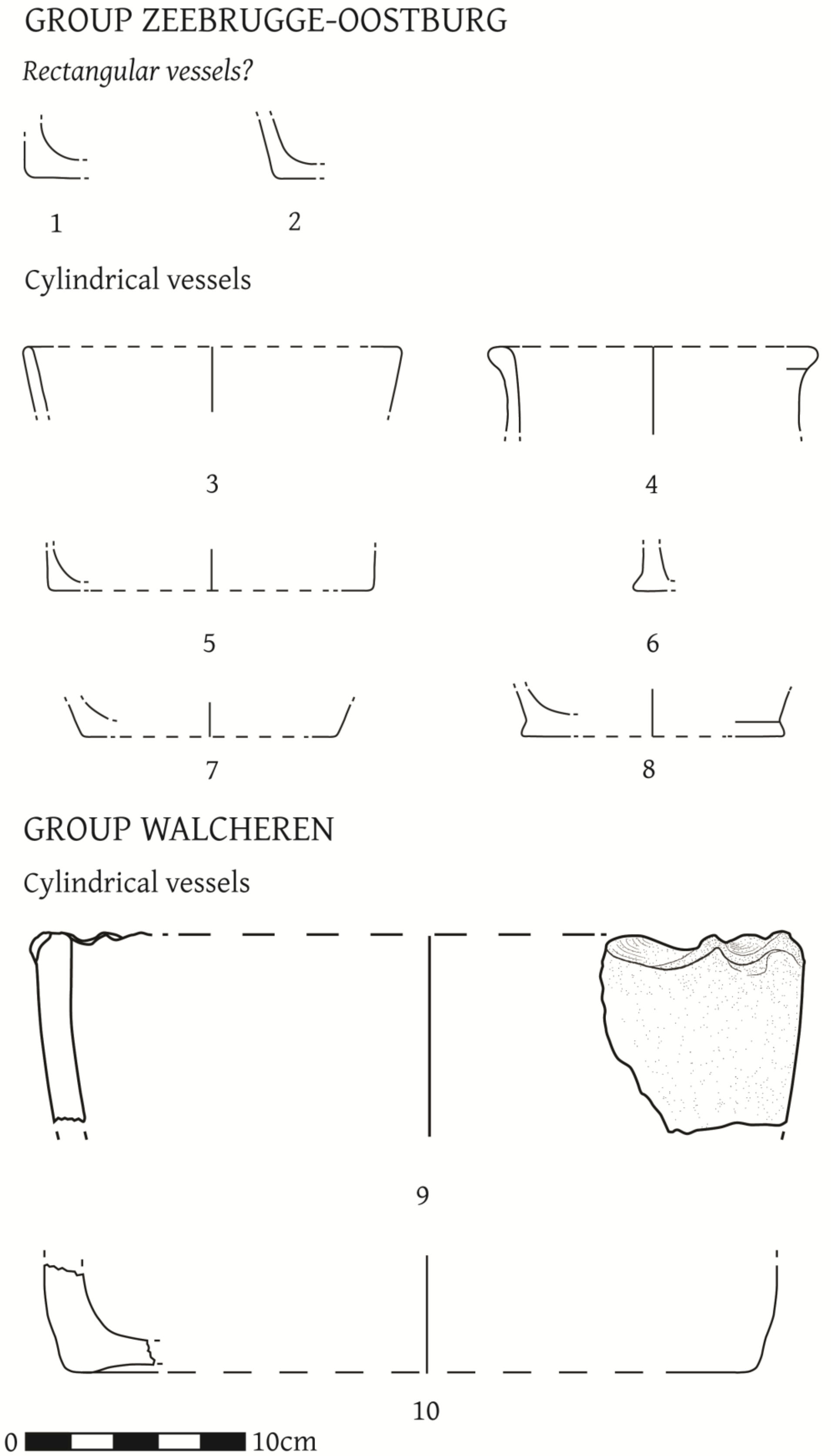


Figure 76 Overview of the briquetage vessel morphology from northern Menapian salt production sites, based on the rim and base morphology from the groups Zeebrugge-Dudzele-Oostburg and Walcheren.

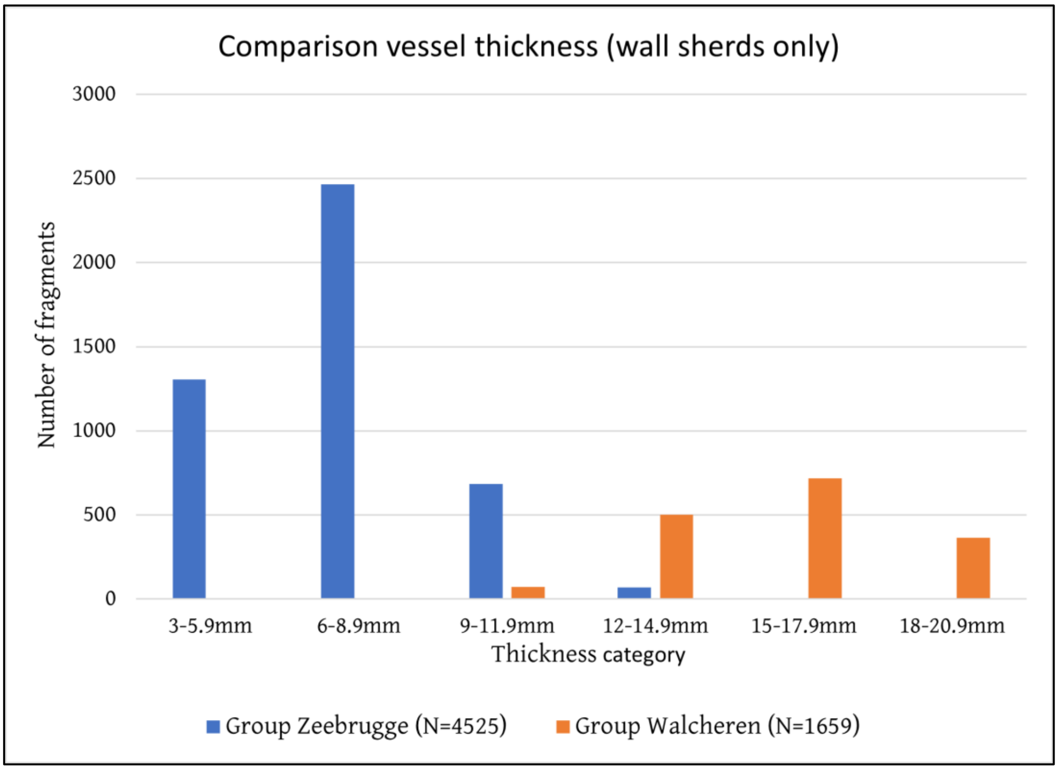


Figure 77 Comparison of the briquetage vessel thickness between the group Zeebrugge-Dudzele-Oostburg and the group Walcheren.

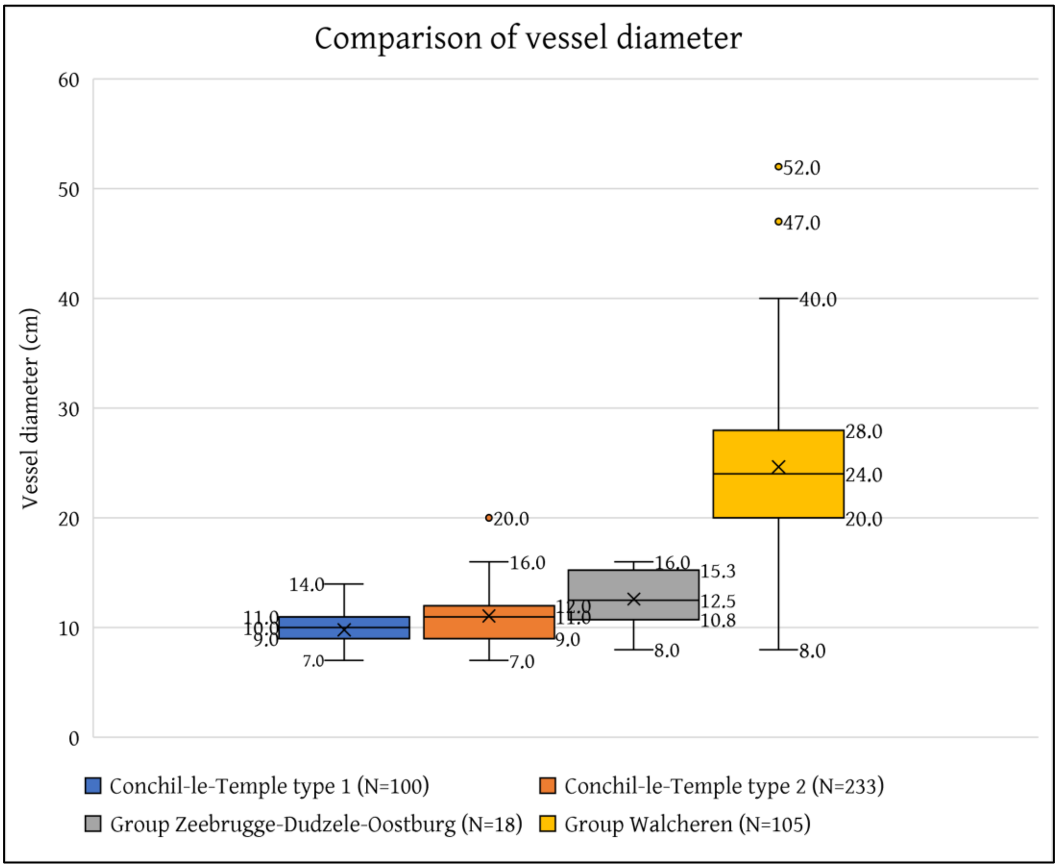


Figure 78 Comparison of the briquetage vessel diameter of the cylindrical vessels recovered at the Augustean-Claudian production site of Conchil-le-Temple and the groups Zeebrugge-Dudzele-Oostburg and Walcheren.

Table 21 Overview of the dimensions of late Iron Age – Roman cylindrical briquetage vessels used to produce salt at production sites in northern Gaul, including an estimation of the vessel's content (l) and the equivalent salt content (kg). Different parameters were used to calculate the vessel's content (l and kg) and therefore these value's might differ from the source publications

	Date	Vessel shape	Height (cm)	Mean diameter (cm)	Content (l)	Salt content (kg)	Reference
Pont-Rémy type 1	La Tène C-D	Cylindrical	> 14.6 cm	Base: 8.5-9.1 cm; upper part 11.3-11.6 cm	> 1.2 l	> 1.44 kg	(Prilaux, 2000a)
Pont-Rémy type 2	La Tène C-D	Cylindrical	> 10 cm	Base: 6.5 cm; upper part: 9.1 cm	> 0.48 l	> 0.58 kg	(Prilaux, 2000a)
Arry type 1	La Tène D	Cylindrical	> 14 cm	Base: 11 cm; upper part: 15 cm	> 1.87 l	> 2.24 kg	(Prilaux, 2000a)
Arry type 2	La Tène D	Cylindrical	> 7.2 cm	Base: 6.25 cm; upper part: 7 cm	> 0.24 l	> 0.29 kg	(Prilaux, 2000a)
Conchil-le-Temple type 1	Augustean-Claudian	Cylindrical	> 7 cm	9.8 cm	> 0.53 l	> 0.64 kg	(Lemaire, 2012)
Conchil-le-Temple type 2	Augustean-Claudian	Cylindrical	26.5 cm	11 cm	ca. 2.52 l	ca. 3.02 kg	(Lemaire, 2012)
Group Zeebrugge	Flavian	Cylindrical	*ca. 20-30 cm?*	12.6 cm	ca. 3.12 l	ca. 3.74 kg	
Group Walcheren	2nd half 1st cent. - 1st half 2nd cent. CE	Cylindrical	*ca. 20-30 cm?*	24.6 cm	ca. 11.8 8l	ca. 14.26 kg	
Type Kesteren	Early-Mid Roman	Conical	ca. 24-29 cm	Base: ca. 6 cm; rim: 16-24 cm	ca. 3.4 l	ca. 4.08 kg	(van den Broeke, 1995b, 2012)

Cylindrical (to slightly truncated, conical) briquetage vessels are not uncommon. Similar vessels have been found at both Iron Age and Roman production sites in northern France (Prilaux, 2000a; Lemaire, 2012; Donnadieu and Willems, 2015) and Roman consumption sites in the Low Countries (van den Broeke, 1995b, 2012).

Van den Broeke (2012, 168-170) studied the cylindrical vessels at the consumption sites in the Low Countries and made a distinction between an A and B variant based on their fabric.[103] Type A is a cylindrical vessel with a yellow-light orange surface and a soft-fired fabric (fabric A1). The wall thickness is usually between 0.6 – 1.2 cm, and the decorated rim diameter varies between 15 and 22 cm. The height of these vessels is between 20-30 cm, which can be inferred from larger and complete vessel profiles (Figure 79: 3-4). Type A vessels were present at consumption sites between the last quarter of the first century – the end of the third century.

On the other hand, type B cylinders (Figure 79: 1-2) have an orange-red surface and a harder fabric (fabric B2). The wall thickness is commonly between 1.0 – 2.5 cm, and larger rim diameters up to 40 cm occur. The exact height of these vessels could not be deduced. However, as they are thicker and wider than type A cylinders, the height of these type B cylinders will be at least equal to those of type A (ca. 20-30 cm). The dating of the type B cylinders is less clear, but they probably occurred from the last quarter of the first century CE and were still present in the second century (van den Broeke, 2012, 168-170).

Based on the description above, it is clear that van den Broeke's type A vessels may be very similar to the vessels in the group Zeebrugge-Dudzele-Oostburg, and the type B cylinders are comparable to the cylindrical vessels in fabric WF1 of the group Walcheren. This morphological parallel was already noted by van den Broeke (1995b; 2012, 168-170), and he suggested that these B cylinders were produced at Walcheren. While the morphological parallel is there, petrographic and geochemical data is needed to confirm the studied sites as production sites of these respective 'vessel types'. These 'vessel types' might have been used in a larger area, and some form of overlap could have existed. Furthermore, more detailed data on the briquetage vessels in the hinterland would have to be included as well as data on the production sites in northern France, where cylindrical containers also occur, for instance at Steene (Donnadieu and Willems, 2015; Faupin, 2017a).

Apart from cylindrical vessels, van den Broeke (1995b; 2012, 168) was the first to define the type Kesteren briquetage vessels. These orange-red vessels are thin-walled (0.2-0.6cm), very porous, and tempered with vegetal material and occasionally calcareous shell (?) fragments. These thin-walled vessels are conical shaped with a globular or small flat base and a flaring rim. The rim diameter varies between 16 and 24 cm. The approximate height of the vessels can be inferred from almost complete vessel profiles recovered at Kesteren (Figure 80: 1) and at Evergem-Kluizendok (Figure 80:2) which are respectively 29 cm and 24 cm high (van den Broeke, 1995b; De Clercq, 2009c, 472; 2012, 168). The clay prop that was used to stabilise the vessel on top of the support material was still attached to the base of the Evergem-Kluizendok example (De Clercq and van Dierendonck, 2006; De Clercq, 2009c, 472).

Since van den Broeke's identification, this briquetage vessel has frequently been found at consumption sites. Worth mentioning is a large amount of very small fragments (ca. 132.862) in the Tiberian-Claudian sanctuary of Tienen (Martens et al., 2002). In addition, Augustean-Tiberian

[103] Van den Broeke integrated the briquetage vessels of some Roman salt consumption sites in the hinterland in his seminal overview of the Iron Age and Roman handmade pottery from Oss-Ussen. In his typology, these cylindrical to slightly truncated, conical-shaped briquetage vessels are categorised as type k-15 which he separates into an A and B variant based on their fabric (van den Broeke, 2012, 168-170).

examples were recovered at the military settlement of Kops Plateau (Van den Broeke, 2014). These finds indicate that this type of briquetage vessel already occurred in the Augustean-Tiberian period and, according to van den Broeke (2012, 168), might have been present until the end of the third century CE.

No fragments of type Kesteren were recovered in the group Zeebrugge-Dudzele-Oostburg and the group Walcheren. Consequently, van den Broeke (1995b; 2012, 161-162; 168) might have been right in assuming a more southern origin for these vessels. He presumed that these salt containers came from the coastal area in the territory of the *Morini* along the Strait of Dover (northern France), as similar vessels were recovered at the production site of Ardres (Florent and Cabal, 2004). Again, although this morphological parallel indicates that Ardres was a production site of these vessels, petrographic and geochemical data is needed to confirm this hypothesis. Furthermore, it is clear from more recent discoveries that the production area might have been larger as type Kesteren vessels were also found at Steene (Faupin, 2017a) and Looberghe (Teysseire, 2014, 2020) in the Menapian territory (Figure 80:3). In addition, similar vessels have been found further south along the Normandy coast, for instance, at the site of Lion-Sur-Mer, dated between the first century BCE and the first century CE, and the site of Caen "Beaulieu" dated between the first and second century CE (Carpentier et al., 2012, 78-82).

In northern France, a chrono-typological evolution of salt containers from the production sites has been proposed by Prilaux (2000a). From the late Iron age onwards (La Tène C and D), cylindrical (to slightly truncated, conical) shaped vessels started to appear, and each site contained a smaller and a larger type (Figure 79: 6-9). The strong standardisation in vessel form and dimensions at each site is remarkable. As a result, Prilaux (2000a, 73; 94) suggested that there was a transition towards a market economy and/or that some form of elite regulation governed the production. In addition, both vessel types appear to have been simultaneously in use. According to Prilaux (2000a, 74; 102), the most plausible explanation is that these smaller and larger vessels were used to produce different kinds of salt: pure white salt and grey magnesium-rich salt.

When these late Iron Age-early Roman cylindrical vessels from northern France are compared to the Roman examples from the Menapian territory, a noticeable pattern towards increasingly larger vessels emerges (Table 21, Figure 78). This pattern appears when the distribution of the vessel diameters at the Augustean-Claudian site of Conchil-le-Temple is compared with those of the vessels within the groups Zeebrugge-Dudzele-Oostburg and Walcheren (Figure 78). These boxplots show that, on average, the diameter of the vessels in the group Walcheren is larger than the diameter of the vessels in the group Zeebrugge-Dudzele-Oostburg, which in turn is slightly larger than Conchil-le-Temple type 2 vessels (24.6 vs 12.5 vs 11 cm). When the average base diameter of the late Iron Age sites of Pont-Remy (8.5-9.1cm) and Arry (11cm) is taken into account (Table 21), it is clear that this gradual increase in vessel diameter already started in the late Iron Age and continued in the Roman period.[104] The overall increase in vessel diameter is quite modest at first, but it suddenly increases hugely in the group Walcheren. The vessel diameter in this group is twice as large as in the Zeebrugge-Dudzele-Oostburg. This is striking since both groups' production started roughly simultaneously in the Flavian period.

[104] In this comparison, only the largest vessel type of the northern French production sites have been taken into account. A similar evolution is noticeable in the smaller containers. On average, the base diameter of Conchil-le-Temple type 1 vessels is larger than the base diameter of Pont-Remy type 2 (6,5 cm) and Arry type 2 (6.25 cm) vessels.

Figure 79 Examples of cylindrical briquetage vessels occuring at Roman consumption sites in the hinterland (1-4) and at late Iron Age – Roman production sites in northern France. 1-4 after van den Broeke (1995b, 194, fig. 192); 5 after Donnadieu and Willems (2015, 318, fig. 318); 6-7 Lemaire (2012, 208, fig. 153) and 8-9 after Prilaux (2000a, 46-47, fig. 30-31) (scale 1:4).

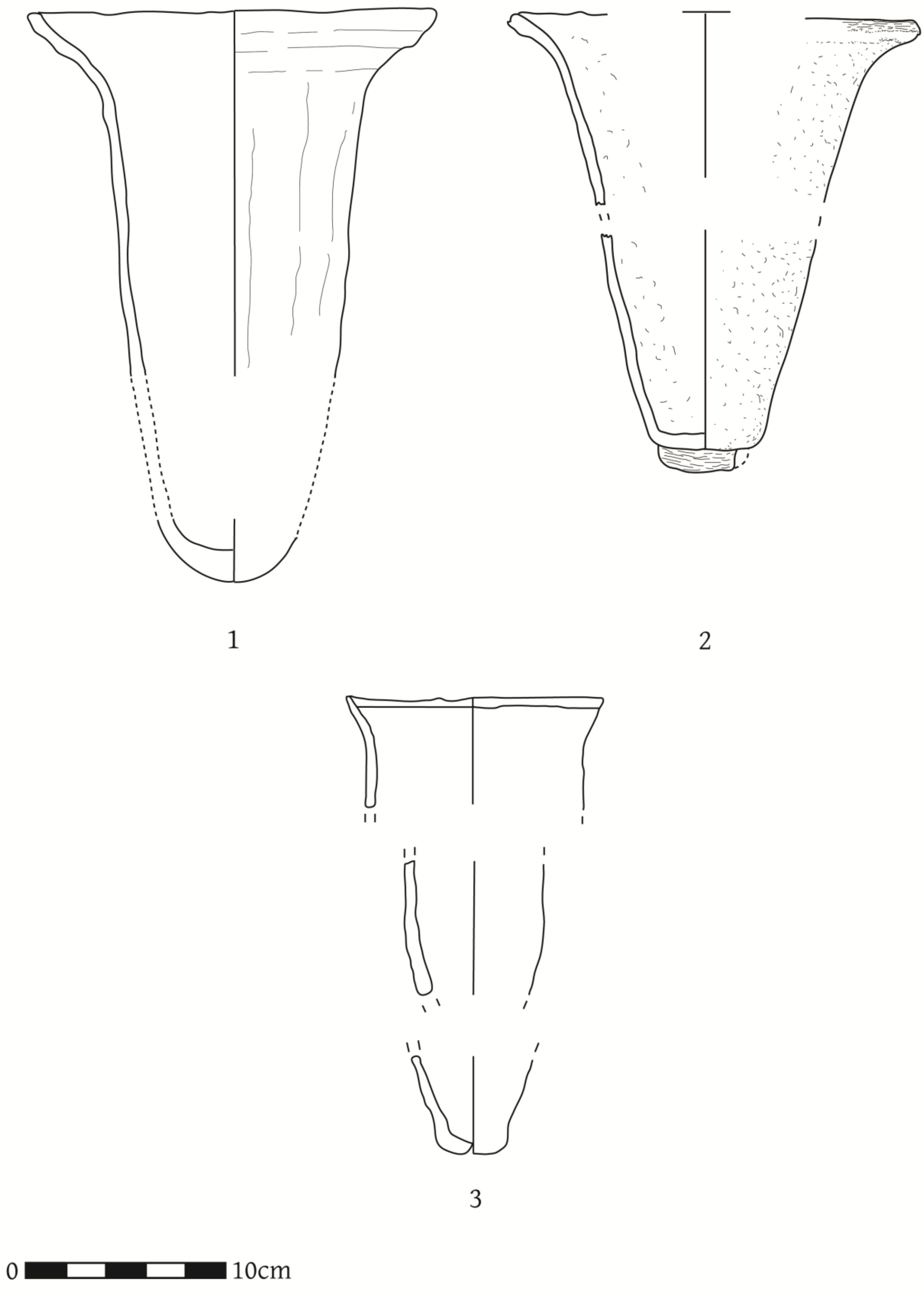


Figure 80 Examples of type Kestern briquetage vessels found at Roman consumption sites in the Low Countries (1-2) and at Roman production sites in northern France (3). 1 after van den Broeke (1995b, 195, fig. 193); 2 after De Clercq (2009c, 472, fig. 414.471) and 3 after Donnadieu and Willems (2015, 318, fig. 318) (scale 1:3).

This pattern was noted in the vessels' volume (see "volumetric content" in Table 21). Based on the average height and rim/base diameter, the approximate volume of the vessels can be calculated (Table 21). As the Pont-Rémy and Arry containers have a slightly truncated - conical shape, the volume was calculated as a truncated cone ($\frac{1}{3} \times \pi \times h \times (R^2 + Rr + r^2)$ with R representing the radius of the base and r the radius of the upper part. In the same way, the volume of the type Kesteren vessels was calculated using the average height and average rim diameter. The approximate volume of the cylindrical vessels at Conchil-le-Temple and the groups of Zeebrugge and Walcheren was calculated as a cylinder ($\pi \times r^2 \times h$). The height of the vessels in the groups of Zeebrugge and Walcheren is unknown. Yet, given their similarities with the cylindrical vessels in the hinterland, a comparable height can be assumed.

It should be noted that the volumetric content does not equal the actual salt content of the vessels, as the mass density of NaCl (2.17 g/cm³) needs to be taken into account. This density, however, refers to the density within a crystal of NaCl and does not account for the interparticle void space (the variable amount of air between the salt crystals), also known as grain packing. As the crystallised salt would have naturally contained a variable amount of air, using a mass density of 2.17 g/cm³ would severely overestimate the salt content of the containers. That is why bulk density, defined as the ratio between the mass of a product and its volume including the void space, is the most accurate way to describe the salt content of the vessels.

Unfortunately, the bulk density differs from situation to situation (the exact composition of the salt, the crystal size, the amount of voids etc.). It is usually calculated in modern-day saltworks on an ad-hoc basis. Therefore, estimating the correct bulk density is difficult, but the published bulk densities of different types of commercially produced salt might offer some guidance. For example, 'Cargill purified sea salt untreated' was harvested from evaporation ponds near the San Francisco Bay and had an approximate bulk density between 1105 (min) and 1345 g/l (max), with a target bulk density of 1185 g/l (Cargill, 2017). Similarly, refined medium coarse Marsel sea salt (Marsel 1-2) has an approximate bulk density between 1150-1300 kg/m³ (Zoutmann, 2019). Based on these commercial examples, an arbitrary bulk density of 1.2 g/cm³ was chosen to determine the salt content of the containers (see "salt content" in Table 21). Naturally, this is a hypothetical value, but it gives an idea of the approximate salt content of the briquetage vessels.[105] Furthermore, these volumetric calculations are influenced by the preserved height of the vessels. No complete vessels were recovered at Pont-Rémy and Arry, and the calculations are therefore based on the maximum preserved height. As such, the volumetric and salt content may have been bigger than presented here.

A trend towards increasingly larger briquetage vessels can be observed in the Roman period. The increase in cylindrical vessel size between the Augustean-Claudian type 2 Conchil-le-Temple vessels and the Flavian group Zeebrugge vessels is quite modest (ca. 2.52 l vs ca. 3.12 l). These vessels' content is similar to the conical-shaped type Kesteren vessels (ca. 3.4 l) that occur in the hinterland from the Augustan period onwards. In the group Walcheren, the vessel size increased significantly, and these containers can contain up to four times as much salt (11.88 l vs 3.12 l). Yet, the difference in vessel

[105] The average height and mean vessel diameter of the Pont-Rémy and Arry vessels were taken from Prilaux (2000a). As all base and rim diameters of the Conchil-le-Temple vessels were published in Lemaire (2012), this data could be used to calculate the distribution of the vessel diameter and the mean vessel diameter. All volumetric calculations are my own using the methodology described above. As such, the hypothetical content of the briquetage vessels differs from the values previously published by Prilaux (2000a)

size cannot be explained as a chronological evolution, as production sites in both groups are dated to the Flavian period.

The use of larger vessels might represent an intensification of the salt production activities and might express the salt producer's desire to increase the production output. The exceptional dimensions of some briquetage vessels recovered at Koudekerke Meinersweg should be mentioned in this regard. The first one (figure 20: 1) has a rim diameter of 52 cm with a preserved height of at least 34.5 cm, equalling a capacity of at least 73.26 l (= ca. 87.91 kg). A second example has a rim diameter of 47 cm and a height of at least 31 cm, corresponding with a volumetric content of at least 53.78 l (= ca. 64.53 kg). A third and final example (figure 20:2) has a rim diameter of 38 cm and a preserved height of 16.3 cm, equalling a capacity of at least 18.49 l (= ca. 22.18 kg). Except for an outlier with a rim diameter of 40 cm, such exceptionally large vessels do not appear to be present at Ritthem Schotteweg (Figure 73).

In the study area, similar briquetage vessels of this size are unknown in Roman times, but medieval parallels exist. For various 10th-11th century sites in northern France (Téteghem, Brouckerque, Saint-Omer, etc.), Routier (2006, 269-270) described the presence of shell tempered, often handmade, cylindrical cauldrons with a vertical body, a flat bottom and a thickened straight or sloping rim. The average dimensions of these so-called cauldrons are as follows: rim diameter between 33-37 cm, base diameter between 24 to 27 cm and height between 23-25 cm. Some variation in rim diameter occurs, and vessels with a rim diameter up to 45 cm are known. Based on their standardised form and their geographical distribution along the northern French coast, Routier (2006, 269-270) hypothesised that these vessels might have been used to produce salt.

More or less contemporaneous larger briquetage vessels, albeit of a different shape and slightly different function, are known from the late Iron-early Roman site of Ingoldmells (Britain). This site has narrow and shallow trapezoidal through-like pans with a length of 47.5 cm, a min width of 15.7 cm, a max width of 23.4 cm and a height of 7.2 cm (Lane and Morris, 2001, 410-419). Given their similarities with the Ingoldmells examples, Lane and Morris (2001, 122-123; 356-358) assume that the flat-based pans discovered in the Fenlands (e.g. early Roman site of Morton Saltern) might be similar in size. These vessels were clearly designed to maximise the evaporation surface and facilitated quick evaporation of the brine. Similar to the late Roman lead evaporation pans, the salt may have been scraped out of these pans as the crystals appeared and left to drain in baskets or dried in very shallow drying pans (Fawn et al., 1990, 20; Lane and Morris, 2001, 123; 192; Biddulph et al., 2012, 163-167). As such, these vessels not only differ in form, but possibly also in function from the containers in the group Walcheren.

How these large briquetage vessels in the group Walcheren were used in the salt production process remains an open question. Two hypotheses can be put forward. In the first scenario, the entire production process, from evaporation to crystallisation and drying, could have taken place in these large vessels. Even though this may have been feasible, its efficiency is questionable as it would have taken a long time for the brine to reach the desired temperature and for the containers to be filled with crystallised salt. In addition, removing these filled salt containers from the hearths would have been a challenge -but not impossible- as these vessels might have weighed over 87 kg. Assuming this production method was used, the question arises as to where these containers were going. Given their supposed salt content (> 50 kg), it seems unlikely that these vessels were intended for small, rural consumption sites. Instead, it seems more likely that this salt was intended for larger towns or Roman military settlements, which had a higher salt consumption. If the Roman military were indeed the intended customers, it might explain how the salt producers at Koudekerke Meinersweg were able to attain such a high quantity of Rhenish beakers (section 6.2.3).

Another possibility is that these large containers were only used as evaporation vessels, and salt crystals were removed when they appeared. This process would have been similar to the abovementioned flat-based pans in the UK. The smaller briquetage vessels at the sites could then have been used to dry the salt. This implies a significant change in how salt was produced. While this method needs to be considered, several aspects do not really fit with this hypothesis. Firstly, the height of the large vessels (up to 34.5 cm) increases their capacity. As a result, it will take longer to evaporate the brine. Shallow vessels with a large evaporation surface are better suited for quickly evaporating the brine. Secondly, even these 'smaller' containers have an average rim diameter between 20-30 cm. Consequently, filling these containers with salt harvested from the evaporation vessels will also take quite some time. Therefore, the question is: what exactly did the salt producers gain by drying the salt in a secondary vessel instead of allowing it to crystallise completely in the large vessels? Is the process more time and energy efficient? Is it related to the removal of impurities? Or do other unknown factors play a role?

Furthermore, this production method would have been restricted to Koudekerke as such large vessels do not exist at Ritthem Schotteweg. Moreover, at Ritthem, several base fragments of larger vessels (diameter up to 32 cm) show signs of vitrification, illustrating that they were subjected to higher temperatures for a longer period of time. This is inconsistent with a drying function and suggests that at Ritthem, evaporation, crystallisation and drying may have taken place in the same vessel. Overall, both hypotheses have their merits and 'problems'. Based on the current data, it is difficult to exclude either one of them.

6.4.3 Briquetage pedestal morphology

Next to salt containers, both groups contained a small amount of support material (less than 5% of the total briquetage assemblage). Given the limited number and lack of completely preserved fragments, the overall information about these support elements is scarce.

Interestingly, different pedestal types are found within the different groups. In the group Zeebrugge, smaller pedestals with a square/rectangular cross-section (P1) occur as well as pedestals with a cylindrical cross-section (P2). In the group Walcheren, larger rectangular brick-like pedestal fragments with a rectangular cross-section (P3) are present. Unfortunately, no complete examples of either type preserved, making it difficult to compare the dimensions of the different types. However, from the preserved fragment sizes, it seems likely that the P3 pedestals are larger than the P1 pedestals. The increase in pedestal size is obviously connected to the increase in vessel size (section 6.4.2) as larger pedestals may have been needed to support the vessels. A similar evolution of increasingly larger pedestals was noted by Lane and Morris (2001) in the Fenlands upon the early Roman transition to larger flat-bottom briquetage vessels at Morton, and the late Roman transition to lead evaporation pans at Middleton.

In the group Zeebrugge, several potential stabiliser fragments were recognised. However, at the moment, their identification is rather hypothetical, and further research is needed to actually confirm the use of stabilisers within the area. No stabiliser fragments were present in the group Walcheren. Although these amorphous fragments may not be collected during the excavation, the increased vessel and pedestal size more likely rendered the use of other support elements, such as pinch-props, platforms, clips etc., obsolete. When filled with brine, these larger vessels would have been thoroughly supported by the large flat-top pedestals without additional support elements. This might have been the case for the containers in the group Zeebrugge as well.

6.4.4 Functioning of the heating structures

The sections above discussed the technical aspects and morphology of the briquetage elements discovered in large quantities at the late first-early second-century salt production sites. Although briquetage follows a long tradition in northern Gaul, it is not a static concept and its morphology evolved through time to fit the salt producers' needs. Mostly, these changes are linked to the nature of the heating structures and the desired output. This section discusses how these late first-early second-century heating structures functioned and how the briquetage vessels were placed above the fire. However, it should be emphasised that this discussion focuses on the Walcheren group since the absence of heating structures in the Zeebrugge-Dudzele-Oostburg group makes it impossible to make informed statements on this topic.

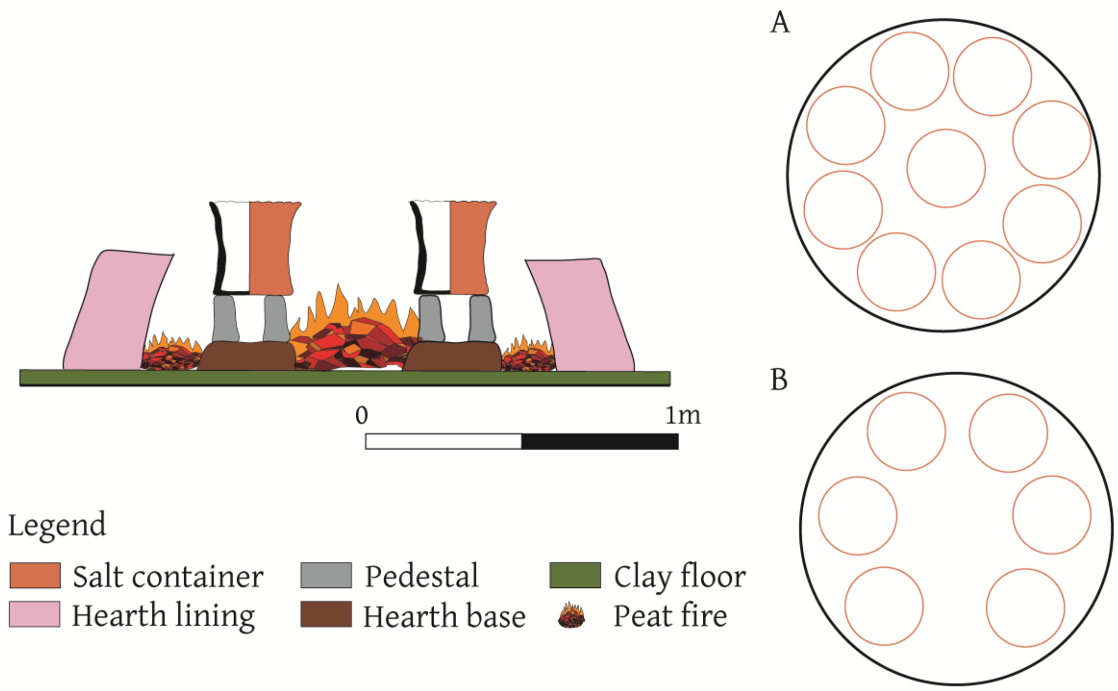


Figure 81 Schematic reconstruction of the Koudekerke hearth. A) maximum number of containers (25 cm diameter). B) conservative number of containers (25 cm diameter).

At Koudekerke Meinersweg, the hearths were constructed above ground on top of a slightly raised clay floor. The heath lining (ca. 15-20 cm thick) slightly curved inward, forming a truncated cone-like structure. The diameter at the base varied between 1.15-1.3 m and decreased towards the top. Unfortunately, the exact height of the heating structures and diameter at the top is unknown.[106] Figure 81 schematically reconstructs these hearths and shows how the briquetage vessels might have

[106] Figure 81 uses the following assumptions: (1) the hearths had a preserved height of ca. 0,5 m and a diameter at the top of ca. 1m. These are generic assumptions based on the available data and are mainly used to give an idea of how these structures may have looked like. (2) The briquetage vessels follow the mean briquetage dimensions of the group Walcheren: height 20-30 cm and 24,6 cm diameter.

been placed on top of the pedestals. As mentioned in section 6.3.5.3, the presence of vitrified vessel base fragments indicates that a direct method of heating was used. Depending on the height of the hearths and the pedestals, some form of platform might have been required at the base to place the pedestals on. At any rate, the producers had to ensure enough room underneath the containers to burn the fuel.

However, determining how many briquetage vessels stood in a hearth at the same time is difficult to answer as it depends on the size of the hearths and the size of the vessels. Yet, this is an important question as it determines the amount of salt one hearth could produce. As shown in Figure 81A, a hearth with a diameter of ca. 1m at the top could hold nine vessels with a diameter of 25 cm. Nonetheless, this option might not be feasible from a practical point of view as the number of supports required to hold these containers significantly reduced the space in the firing chamber. As a result, fuelling and cleaning the hearths during the production phase might be difficult. A second option (Figure 81B) only places six vessels at the edge of the fireplace. This number might be somewhat on the conservative side, but it keeps the centre of the hearth and stokehole free to add fuel to the fire. Again, these are just simulations based on fixed parameters (hearth width ca. 1 m, vessels diameter 25 cm). Changing one of these parameters will lead to a different result. Yet, the presented example does give an idea of the hearth's capacity.

6.5 Summary

In the northern Menapian territory, briquetage material was frequently found at late first-early second-century salt production sites. Unfortunately, most of these sites contained no *in situ* features related to the salt production activities. Especially in the area of Zeebrugge-Dudzele-Oostburg context information is scarce. The sites with *in situ* material probably represent briquetage waste dumps near salt production or salt processing sites. Whether these small concentrations of briquetage material correspond to individual production sites or if they are part of larger production entities is difficult to answer at this moment. At Ritthem, the small-scale excavation and prospection campaigns near the Schotteweg indicate that a larger salt production site was active in the area. As the excavation dates from the 1960s and was not completely documented, it is difficult to grasp the nature of this site. From the data at hand, it is evident that at least an extensive debris zone consisting of multiple waste layers was found. Currently, Koudekerke Meinersweg is the only late first-century site with *in situ* heating structures (four in total) that might provide additional information on how these hearths and briquetage material worked together. A more detailed discussion on how these late first- early second sites may have functioned can be found in Chapter 9.

Despite the lack of features related to the production activities, the briquetage material from these sites offers quite a lot of insights into the salt manufacturing process and the technological choices made by the producers. In this study, 9119 pieces of briquetage material from 10 sites were analysed: Geuldepot (Zeebrugge Achterhaven), Donk 1 (Zeebrugge Achterhaven); Dudzele Zonnebloemweg, Dudzele Distrigas 1992, Dudzele Boudewijnkanaal, Prospectievondsten Achterhaven, Ramskapelle Heistlaan, Oostburg 't Vestje, Ritthem Schotteweg and Koudekerke Meinersweg. Based on macroscopic characteristics, the material could be divided into two groups: Zeebrugge-Dudzele-Oostburg and Walcheren. For convenience's sake, these groups were named after the geographical area where the sites occur. However, this does not mean that the groups are necessarily geographically separated. Future research will need to confirm these groups' existence and whether they are geographically clustered.

In both groups, the macroscopically identified fabrics are highly similar, and minor differences occur concerning the firing conditions, the amount and size of vegetal temper, the amount of quartz and other sporadic inclusions. As such, it is possible that (some of) the identified fabrics are petrographically highly similar and represent variants within larger groups. Characteristic of briquetage material is the large amounts of vegetal material that was intentionally added as temper. This created highly permeable vessels with strong thermal shock resistance. As the vessels were heated for a longer period of time and cold brine was continuously added, the increased ability to withstand thermal shocks would have been of great importance (Quinn, 2013, 158).

At all sites, the briquetage assemblages mainly consist of salt containers with a small amount of support material (< 5%). Regarding the briquetage vessel morphology, there are some indications for rectangular vessels in the group Zeebrugge. However, more data, especially more complete vessel profiles, is needed to confirm their presence. Remarkably, simple cylindrical (to slightly truncated conical) vessels are the predominant, if not the only, vessel form in both groups. Besides some minor variations in base morphology which might be related to the vessel's construction, differences only occur in vessel thickness and size. In the group Zeebrugge, the vessels have an average diameter of 12.6 cm with a wall thickness between 3-11.9 mm. In comparison, the wall thickness in the group Walcheren varies between 12-20.9 mm and the vessel diameter averages 24.6 cm. Reconstructing the height of these containers is difficult, but complete vessel profiles of similar containers in the hinterland suggest a height between 20 and 30 cm. The vessels in the group Walcheren might have been able to contain up to four times as much salt (14.26 kg vs 3.74 kg). Why these vessels drastically increased in size is unknown, but it might be related to increasing the production output.

Furthermore, there is increased evidence that the base of the salt containers was removed at the production sites before their transport to the hinterland. Especially in the group Zeebrugge, several arguments can be put forward supporting this claim. Firstly, the base fragments are overrepresented compared to the rim fragments. And secondly, the preserved height of the base fragments is highly similar across the different sites suggesting that the bases were removed at a fixed height. In the group Walcheren, the data is less clear as base fragments are not overrepresented on the sites, but the preserved height of the base fragments is similar. The reason why the salt producers removed the base is unclear as, at first glance, it served little to no functional purpose. It might be related to the removal of contaminants (either scorched/burned salt at the bottom or undesired salts) which accumulated at the base. Experimental research, however, is required to understand the exact processes that might have occurred at the bottom of these vessels. Equally possible is that removing the base served no functional purpose, but was an action dictated by social and/or cultural traditions.

Lastly, not only the briquetage vessels in the group Walcheren are larger, but also the pedestals appear to be bigger. However, the lack of complete examples, makes it impossible to determine how much larger these pedestals were. This increase in pedestal size is obviously connected to the increase in vessel size since these heavier vessels would have required bigger support elements. Besides pedestals, no other types of support elements were present in the group Walcheren. It is likely that increased vessel and pedestal size rendered additional stabilisers obsolete. In the group Zeebrugge, few potential stabiliser fragments were recognised, but further research is needed to confirm their presence and use in the area.

Chapter 7 Late second – early third century salt production sites in the northern Menapian territory

7.1 Introduction

After the well-attested Flavian boost (Chapter 6), salt production continued in the second century. Yet, the lack of (securely dated) sites makes it difficult to assess the nature and scale of the activities. In the late second century, a new type of salt production site emerges in the northern Menapian territory. Compared to the previously discussed late first – early second-century sites, ceramic salt container fragments are noticeably absent. Instead, the sites are characterised by water management features, a new type of heating structures and large refuse zones. Based on these sites, it is evident that the *chaîne opératoire* changed in the northern Menapian territory at the end of the second century. Before discussing this transition in *chaîne opératoire* in Chapter 9, it is important to have a thorough understanding of the features that occur on these sites.

This chapter discusses the salt production-related features discovered on three late second - early third century sites, e.g. Leffinge, 's-Heer Abtskerke – 's Gravenpolder and Middelburg (Figure 82).[1] The case of Aardenburg has been considered in Chapter 5 and will not be repeated here. Except for the 2020 's Gravenpolder campaign, all three sites were excavated in the 70s and 80s and were never completely analysed nor published. By processing the excavation archive, we aim to present a complete picture of each site. After that, the features of the sites will be discussed and compared to features from known salt production sites in northern Gaul and *Britannia*. This will help to determine how salt was produced on these sites and which innovations took place during the late second – early third century.

[1] Additional information has been presented in appendix. APPENDIX 4A contains the feature lists and digitised profiles (e.g. Leffinge) of the individual sites. APPENDIX 4B presents the Microsoft Excel database used to register the briquetage and regular pottery of the sites.

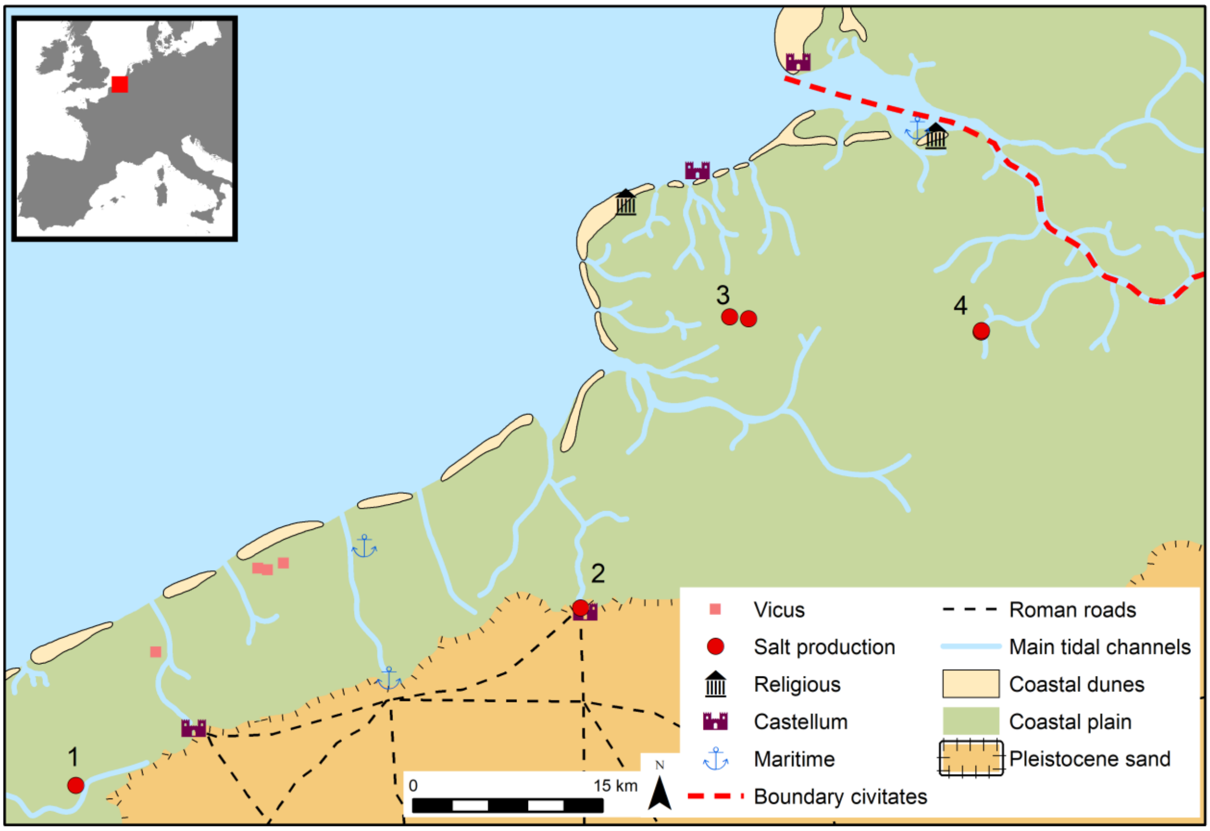


Figure 82 Roman occupation of the northern Menapian coastal plain during the late second – early third century CE depicting the salt production sites mentioned in the tekst. 1: Leffinge, 2: Aardenburg, 3: Middelburg Oude Vlissingseweg, 4: complex 's-Heer Abtskerke – 's Gravenpolder

7.2 Leffinge Zwarte weg

7.2.1 Introduction

7.2.1.1 Research history

During the Calais-Brussel highway (E40) construction in 1973, Depuydt and Vanisacker collected Roman pottery fragments on a plot along the Zwarte weg at Leffinge. Most sherds surfaces were intact, and no rolling was visible on the fractures pointing towards an *in situ* preserved Roman occupation layer (Thoen and Cools, 1975; Thoen, 1977a). In 1974, a Roman layer was recorded *in situ* in the profile of a drainage ditch along the new highway confirming the earlier hypothesis. This layer, more than 10 m in length, contained Roman pottery as well as 'slag' material, suggesting the presence of an artisanal site (Thoen and Cools, 1975). In the autumn of 1974, Thoen and Cools dug the first excavation trench, signalling the start of a multi-year excavation campaign. Five campaigns took place between 1974-1978, and short find reports of each campaign were briefly published (Thoen, 1974, 1975b; Thoen and Cools, 1975; Thoen, 1976; Thoen and Cools, 1976; Thoen, 1977b, 1977a, 1978b).

In addition, Baeteman studied the Holocene geology of the site, and Cleveringa and Verbruggen conducted palynological analyses. Their findings on the palaeoenvironment were published in a separate report (Baeteman et al., 1981). The main results are presented in section 7.2.2. Furthermore, Ooijevaar and Balsem (1975) mapped the ash deposit distribution to determine the site's extent. Similarly, Hus[2] carried out a proton magnetometer survey to detect potential hearths and other features related to the production. Also, Van Strydonck (1987) radiocarbon dated a series of samples obtained from peat and charcoal fragments, and De Paepe (1987) carried out chemical and mineralogical analyses on the 'zelas' fragments.

7.2.1.2 Fieldwork methodology and post excavation processing

The five excavations campaigns resulted in 17 trenches covering an area of 386 m² (Figure 83). The early campaigns (1974-1975) were characterised by small excavation trenches (ca. 10 by 2 m) where the results of each trench determined the location of the next one. Several early trenches (LFZ 75/3-6) were heavily disturbed and, therefore, not further investigated. In 1976, the excavation strategy drastically changed as it became apparent that the small trenches could not grasp the site's complexity. As a result, a large open area (LFZ 76/11) and wider trenches (LFZ 77/12; LFZ 78/15-17) were created during the last campaigns.

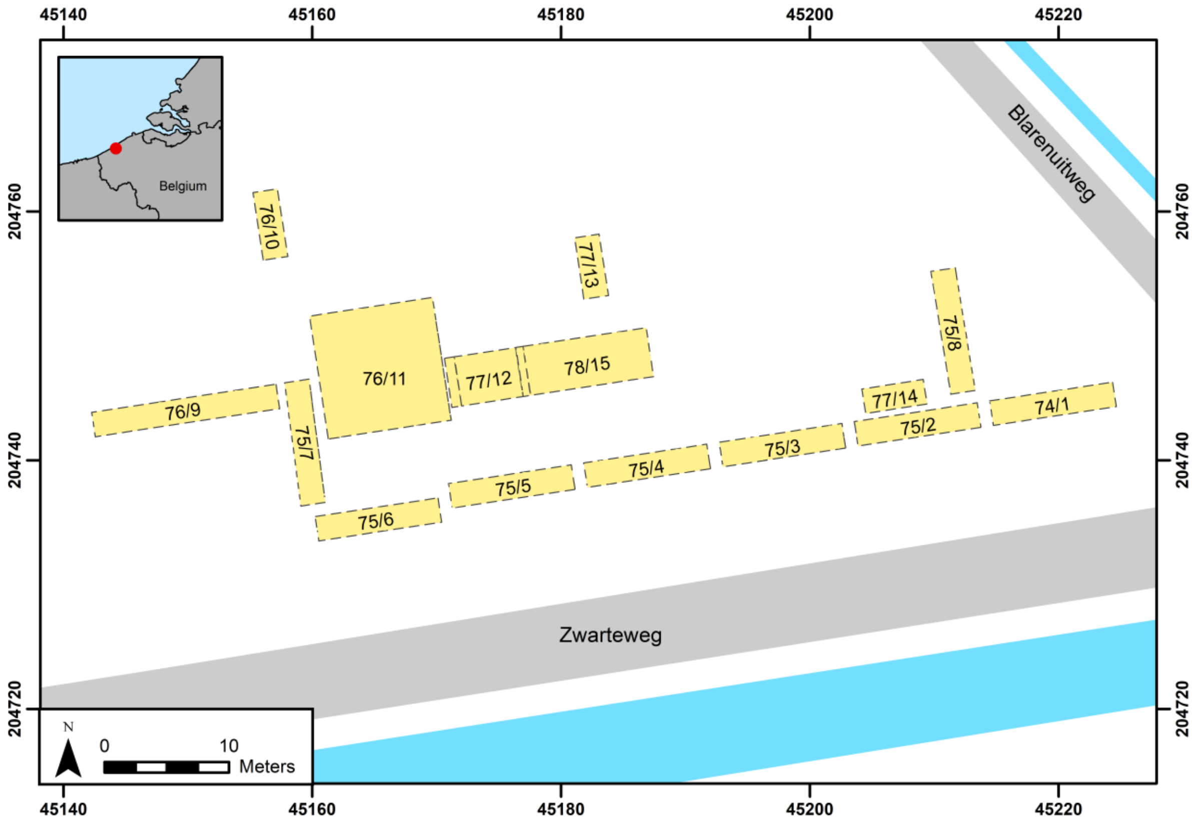


Figure 83 Trench layout of Leffinge Zwarte weg

An excavator with a 2 m wide bucket removed the topsoil exposing the archaeological level. After the topsoil was removed, further excavation of the archaeological layer occurred manually. At regular intervals, excavation plans were drawn up, registering the visible features and structures. Often as many as seven plans were made covering a 35 cm thick archaeological layer. In addition, individual

[2] Unpublished documentation found in the archive

features and profiles were drawn and photographed. The results presented below are derived from consulting the unprocessed excavation archive consisting of the finds, the excavation plans, the trench profiles, the descriptions, the excavation diaries, the original colour diapositives, the black and white negatives, the analyses reports and the correspondence. In addition, the personal archive of the late Etienne Cools[3] (site manager) was consulted to gain insight into the site.

By georeferencing and digitising the excavation plans in ArcGIS, we created an all-feature plan combining the data from all excavation levels. In addition, the features were renumbered to incorporate previously unrecognised features. A detailed feature list, feature plans and described trench profiles are presented in APPENDIX 4A.

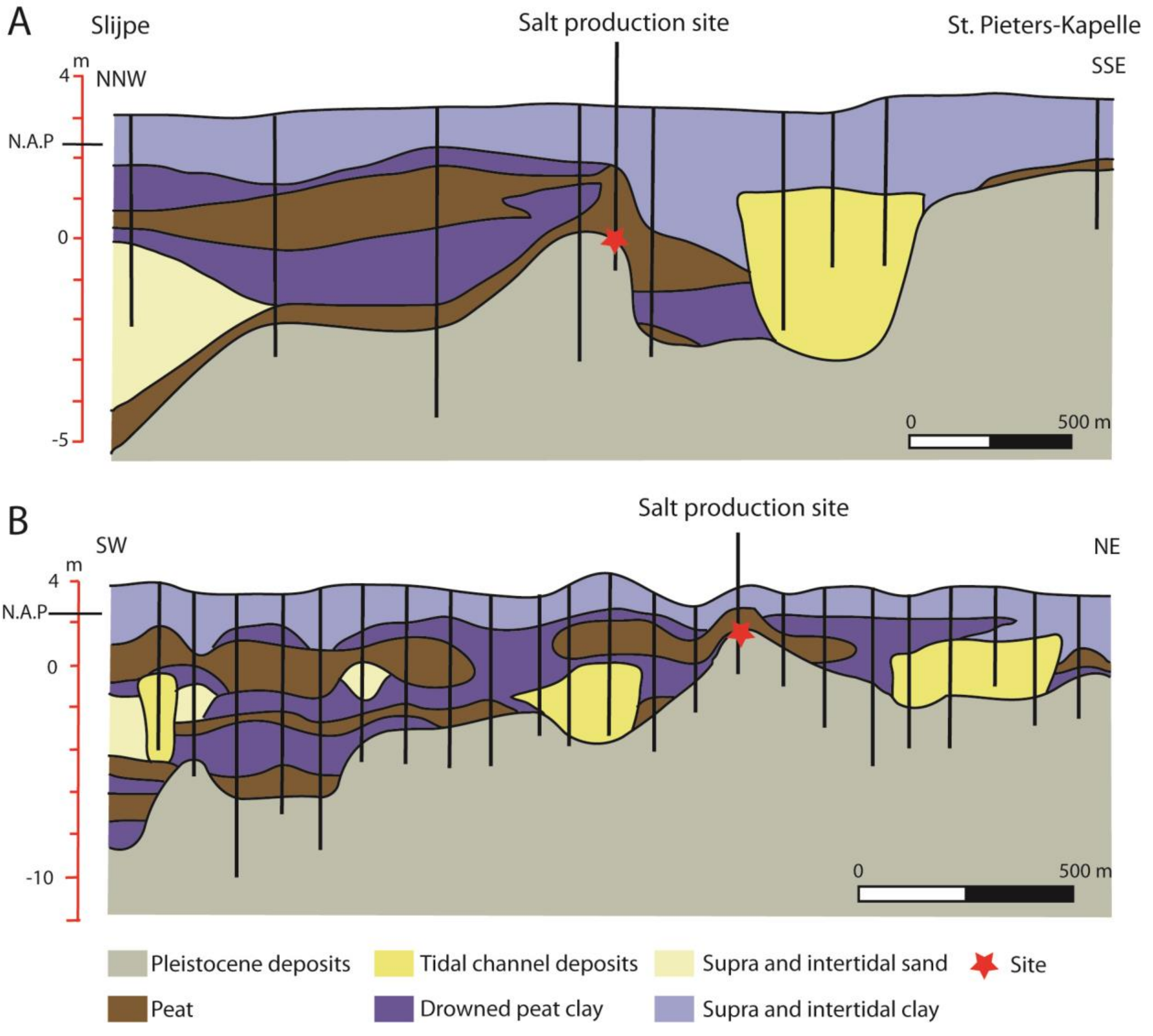


Figure 84 A. NNW-SSE geological profile between Slijpe and St.Pieters-Kapelle situating the salt production site Leffinge Zwarte weg on the edge of a Pleistocene sandy outcrop near the Spermaliegeul (after Baeteman et al., 1981, profile 3; Baeteman, 1987, fig. 14) B. SW-NE geological profile following the Calais-Brussel highway (E40) confirming the site's location on top of a Pleistocene sandy outcrop (after Baeteman et al., 1981, profile 7; Baeteman, 1987, fig. 15).

[3] I would like to thank Ine Demerre and the Agentschap Onroerend Erfgoed for alerting me to and facilitating access to the digitised archive.

7.2.2 Topography and landscape surrounding the site

7.2.2.1 Holocene depositional history of the salt production site

The site of Leffinge was situated on the edge of a small Pleistocene sandy outcrop or ridge with deeper depressions on either side (Figure 84). The ridge was only covered by the basal peat, while the deeper Pleistocene depressions were filled by multiple peat beds separated by clay and sand layers. Samples taken at the base and the top of the peat were dated, indicating that in the vicinity of the site, the peat growth started at approximately 4500 BP and might have ended around 3500-3000 BP (cfr. 2.2). On top of the upper peat bed, a thin, very organic clay layer was deposited in a shallow fresh or brackish marshy environment characterised by quite a lot of vegetation. This environment might be temporarily (or seasonally) wetter or drier depending on the precipitation and surface runoff of the nearby Pleistocene cover sands. This organic clay layer was dated to the Iron Age, but sedimentation probably continued into the Roman period. From the late Roman period onwards, the tidal influence increased and the site was covered by a thick layer of clay (Baeteman et al., 1981).

Geological profiles (Figure 84) indicate that the site was situated near a larger tidal channel. This tidal channel, called the Spermaliegeul, ran westwards from the border of the coastal plain near Gistel. Approximately at Leffinge, the tidal channel ran southwards for a few kilometres, after which it turned westwards again past Mannekensvere and Spermalie. At Nieuwpoort, the tidal channel then flowed into the North Sea. The Spermaliegeul followed an existing Pleistocene depression (approximately -4 m TAW) and was active as a peat river from mid-Holocene times (Baeteman et al., 1981, 5-13).

7.2.2.2 Palaeogeographic reconstruction of the landscape surrounding the site

Based on the collected geological data, Baeteman (1981) reconstructed the palaeography of the landscape surrounding the site at ca. 4500 BP and ca. 2000 BP (Figure 85). Around 4500 BP, the area was characterised by a coastal peat bog intersected by the Spermaliegeul. The eastern (inland) part of the channel probably acted as a peat river draining the fresh water from the sandy hinterland, while the western part was subjected to tidal activity. Mudflats and salt marshes were situated on both sides of the Spermaliegeul, and these tidal flats were more prominently present near the tidal inlet (Baeteman et al., 1981, 14).

Around 3500-3000 BP peat growth near the site ended. Most likely, the tidal activity of the Spermaliegeul increased, allowing salt water to penetrate further into the peat bog. As a consequence, peat growth stopped adjacent to the channel, and the peat lost its potential to store water resulting in peat compaction and subsidence of the land adjacent to the channel. This enlarged the accommodation space where intertidal sediments could be deposited (Baeteman, 2005, 2007a, 2013; 2018, 318). An example of such sediments is the thin organic clay layer deposited on top of the peat in the vicinity of the site. At the start of the Roman period (ca. 2000 BP), the area was characterised by a drowned peat bog intersected by the Spermaliegeul and its side branches. The drowned peat bog should probably be seen as a marshy area with brackish conditions that could be temporarily wetter or drier depending on the season, the precipitation and the surface runoff of the nearby Pleistocene hinterland. It is generally assumed that due to poor drainage, the area was fairly inaccessible in wet periods such as the winter. Contrary to the previous reconstruction, the channel's tidal influence increased and brackish conditions extended landwards (Baeteman et al., 1981).

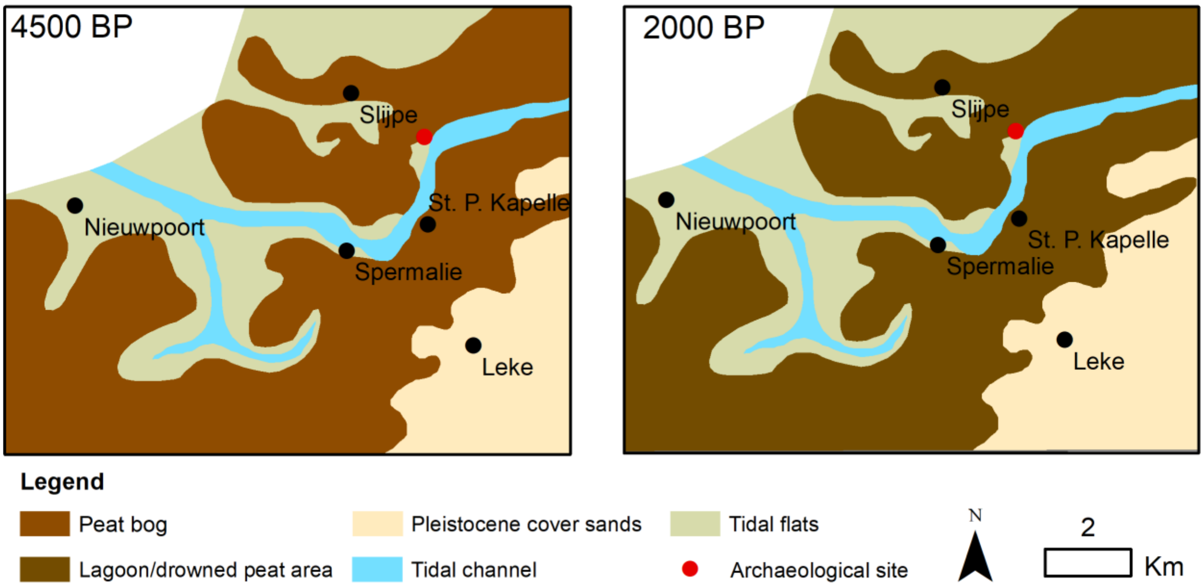


Figure 85 Palaeographic reconstruction of the landscape surrounding the salt production site Leffinge Zwarte weg (after Baeteman et al., 1981, fig.5 and fig. 6)

7.2.2.3 Vegetation surrounding the site

Cleveringa and Verbruggen analysed pollen assemblages taken during the excavation to reconstruct the vegetation history of the site. While Cleveringa focused primarily on the composition of the peat, Verbruggen tried to reconstruct the vegetational environment of the site in the Roman period (Baeteman et al., 1981, 17-30). Verbruggen's pollen sequence covered the top of the peat, the organic clay layer and the artificially raised clay bank in which the hearths were constructed.

Based on the presence of *Carpinus* (birch family) in the clay sediments on top of the peat, Verbruggen determined that the clay was deposited between 3000 BP and the Roman period. Both Cleveringa and Verbruggen noted high *Sphagnum* and *Ericaceae* values in the clay layer, suggesting an open landscape. In addition, the presence of *Chenopodiaceae* (goosefoot family) and *Artemisia* -both halophytic species- indicated a brackish environment prior to the arrival of the salt producers. Furthermore, given the similarities between the pollen spectra from the clay bank and the underlying clay layer, Verbruggen concluded that the clay used to construct the hearth infrastructure was collected on-site or in the site's immediate vicinity. Unfortunately, both Cleveringa and Verbruggen could not identify the Roman surface level and remained quite vague on the vegetation at the time of the salt production activities. They suspected that the landscape in Roman times might have been similar to the Iron Age in which the area surrounding the site was characterised by an open landscape dominated by *Ericaceae* (heathland vegetation) and halophytes species like *Chenopodiaceae* (goosefoot family) and *Artemisia* (Baeteman et al., 1981, 17-30).

7.2.3 Structures and features related to the salt production activities

The excavation at Leffinge revealed the remains of an extensive Roman artisanal site. With the exception of (post-) medieval peat extraction pits and early modern disturbances, the site contained primarily mid-Roman features related to salt production activities. Besides the extensive debris layer of variable thickness that covered the entire surface, the following features/zones were recognised: water management features, heating structures and refuse zones (Figure 86).

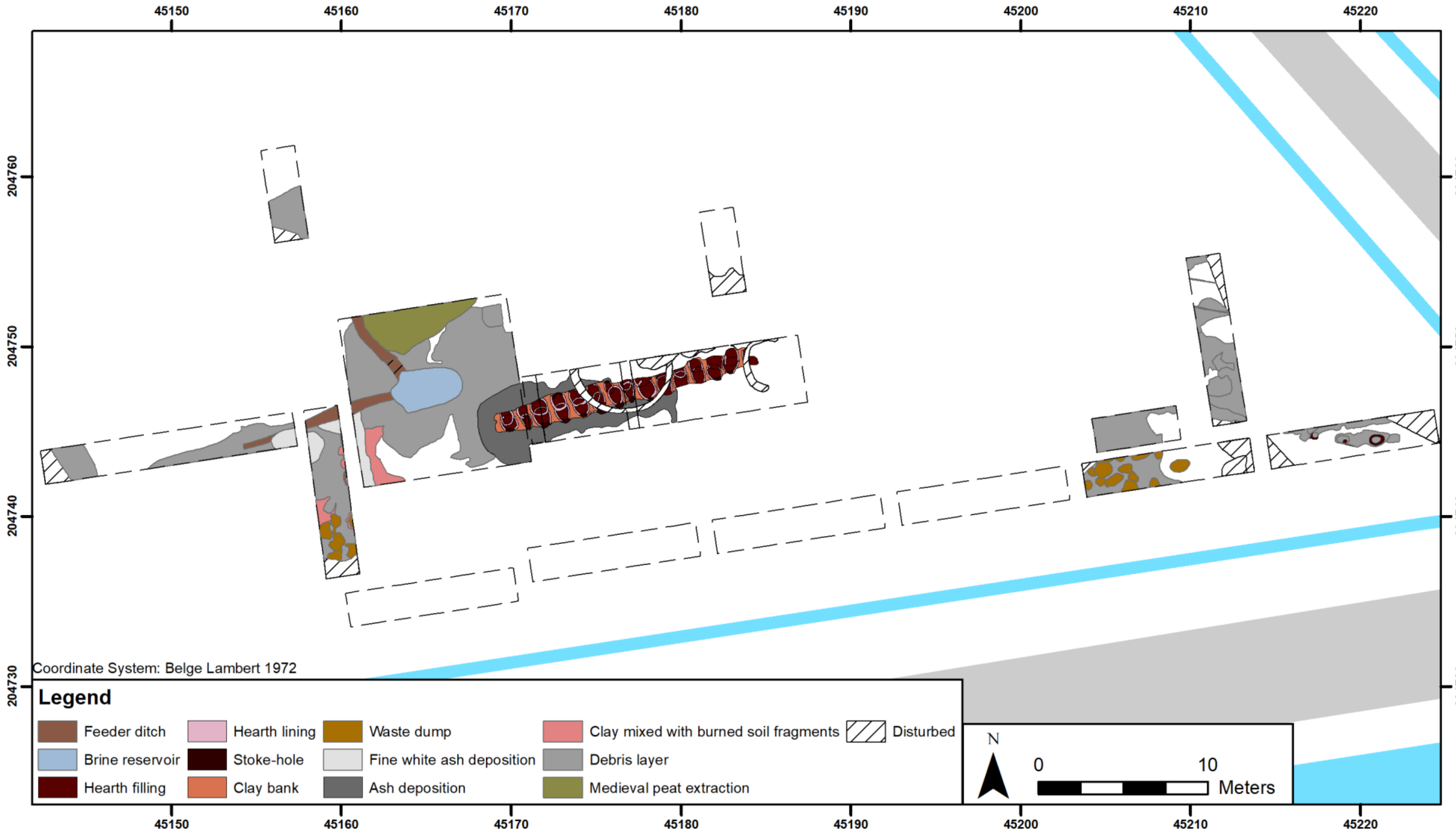


Figure 86 Excavation plan late second-early third century salt production site Leffinge Zwarte weg.

7.2.3.1 Water management structures

A series of ditches (7536; 7607) and a large reservoir or settling tank (7608) (Figure 87), situated in the central and western parts of the excavation, are related to water management activities. The westernmost ditch (7536) with a WSW-ESE alignment measured 9.20 m in length and was up to 0.65 m in width. The ditch with a concave base and rather steep sides was probably recut on at least one occasion and was filled with a mixture of clay, ash, fired clay and 'zelas' fragments (APPENDIX 4A). In addition, the ditch transects features 7610 and 7535 and, in turn, was cut by feature 7534 (Figure 87). Ditch 7607 with an N-SE alignment was approximately 3.25 m in length and 0.60 m in width. Even though the southernmost section of ditch 7607 was not preserved, it is clear that ditch 7607 was associated with water reservoir 7608 (Figure 87).

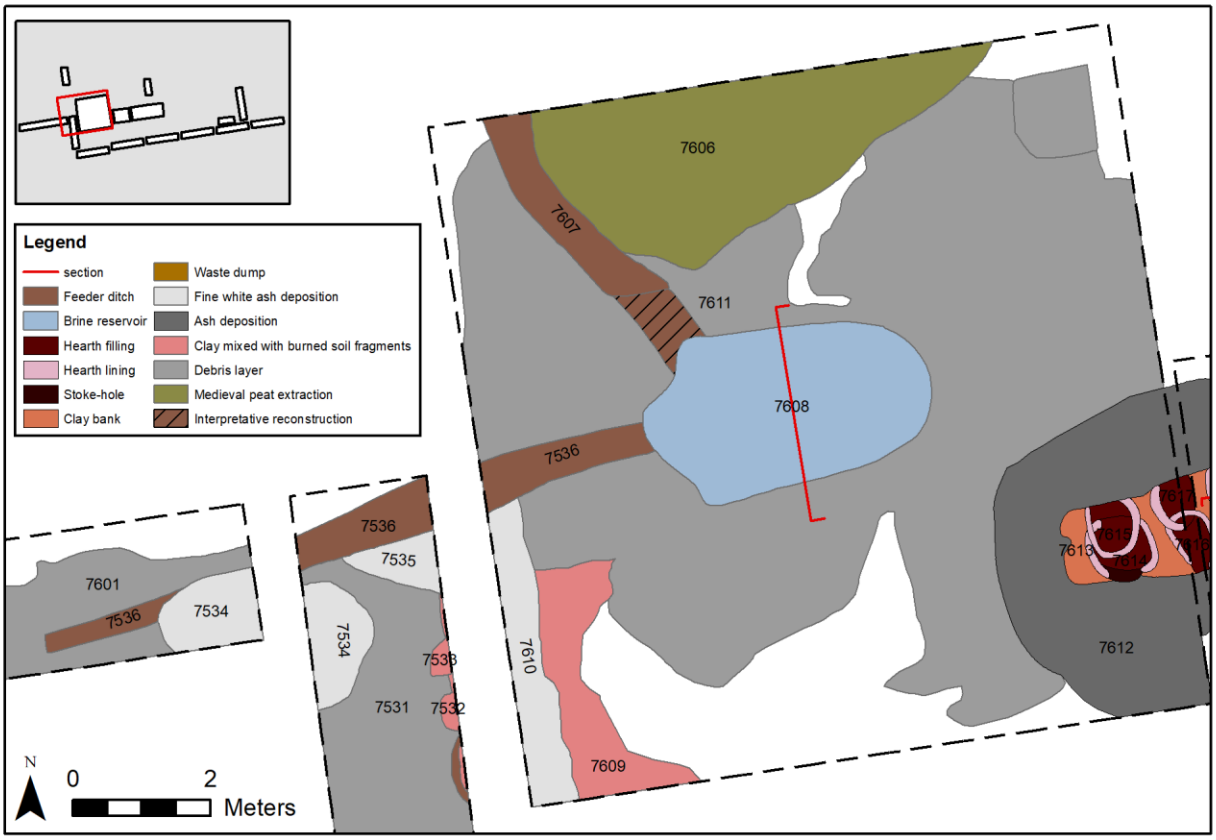


Figure 87 Detailed excavation plan of the water management structures (Leffinge Zwarte weg)

Both ditches acted as feeder ditches and transported the saltwater from a nearby creek to the water reservoir. These ditches represent a multi-phased supply system and may not have been used simultaneously. The fact that ash deposit 7534 cuts ditch 7536 indicates that the site continued to function while the ditch was no longer in use, supporting the idea that the water supply changed at a certain moment in time. As such, ditch 7536 might correspond with phase 1 and ditch 7607 with phase 2. Unfortunately, the proposed phasing is hypothetical as the relationship between reservoir 7608 and ditches 7536 and 7607 was not recognised on-site and, therefore, not investigated.

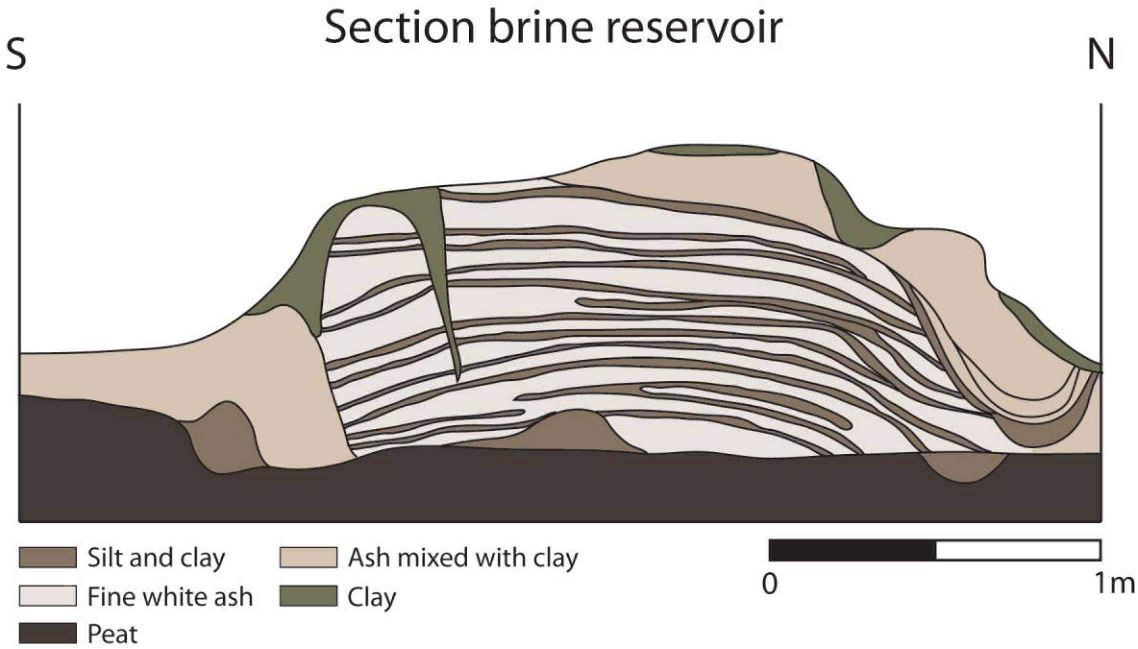


Figure 88 North-south section through brine tank 7608 showing the alternating layers of humic fine white ash and silt.

The brine tank (feature 7608) lay northwest of the heating structures on an east-west alignment and was roughly oval-shaped. The settling tank measured approximately 4.25 m in length, 2.30 m in width and 0.8 m in depth. The reservoir had a maximum capacity of roughly 6.5 m^3, equalling 6500 l. The western end of feature 7608 connected with ditch 7536, while the north-western bulge might have been connected to ditch 7607. In profile (Figure 88), the water reservoir had a flat base dug into the peat with steep sides and filled with alternating layers of humic fine white ash and silt. This infill might represent the final usage of the reservoir before the site was abandoned. The undisturbed nature of the layers suggests a gradual sedimentation from continued use. The silt layers formed when the insoluble sediments (sand, silt and clay) present in seawater settled on the bottom of the reservoir. These silt layers (13 in total) were often covered by ash layers indicating that the ash was not dumped accidentally into the reservoir but most likely was deliberately added (see section 7.5.2).

At first glance, the observed stratigraphy is atypical for a water reservoir as normally more sediment is deposited on the edges of such features, resulting in a concave stratigraphy. However, the somewhat convex infill might be explained by the continued use of the reservoir in the salt production activities. As brine was constantly scooped out at the reservoir's edge to fill the evaporation vessels, the sediments could not settle at the edge or they were partly removed. These processes could explain why the layers curve slightly outwards. In Figure 89, possible traces of timber postholes are visible, which might be the remains of a (wattle?) revetment. Although it cannot be conclusively proven at Leffinge, such revetment would have reinforced the reservoir's edge and created a more impermeable barrier preventing the brine from seeping out of the reservoir (see section 7.5.2).

Figure 89 Digitised colour diapositive of the south-eastern part of the brine tank (7608). Red line delineates the possible traces of revetment. Along the line white coloured polygons might be traces of possible postholes.

7.2.3.2 Heating infrastructure

The heating structures were located in the central/northeastern part of the excavation, approximately 3 m southeast of the water reservoir. The heating infrastructure, of which the eastern end did not preserve, consisted of a clay bank in which 30 hearths were constructed (Figure 90). The sub-rectangular clay bank, aligned WSW-ENE, measured 15.5 m in length, between 1.2 and 1.6 m in width and between 0.4 and 0.5 m in depth (Figure 90, Figure 91). This clay bank was raised on top of the peat, and its construction required at least 10 m³ of locally available clay (section 7.2.2.3).[110] In section (Figure 92), the clay bank consists of several layers with slightly different hues, which might result from the different temperatures near the heating structures rather than different constructing phases.

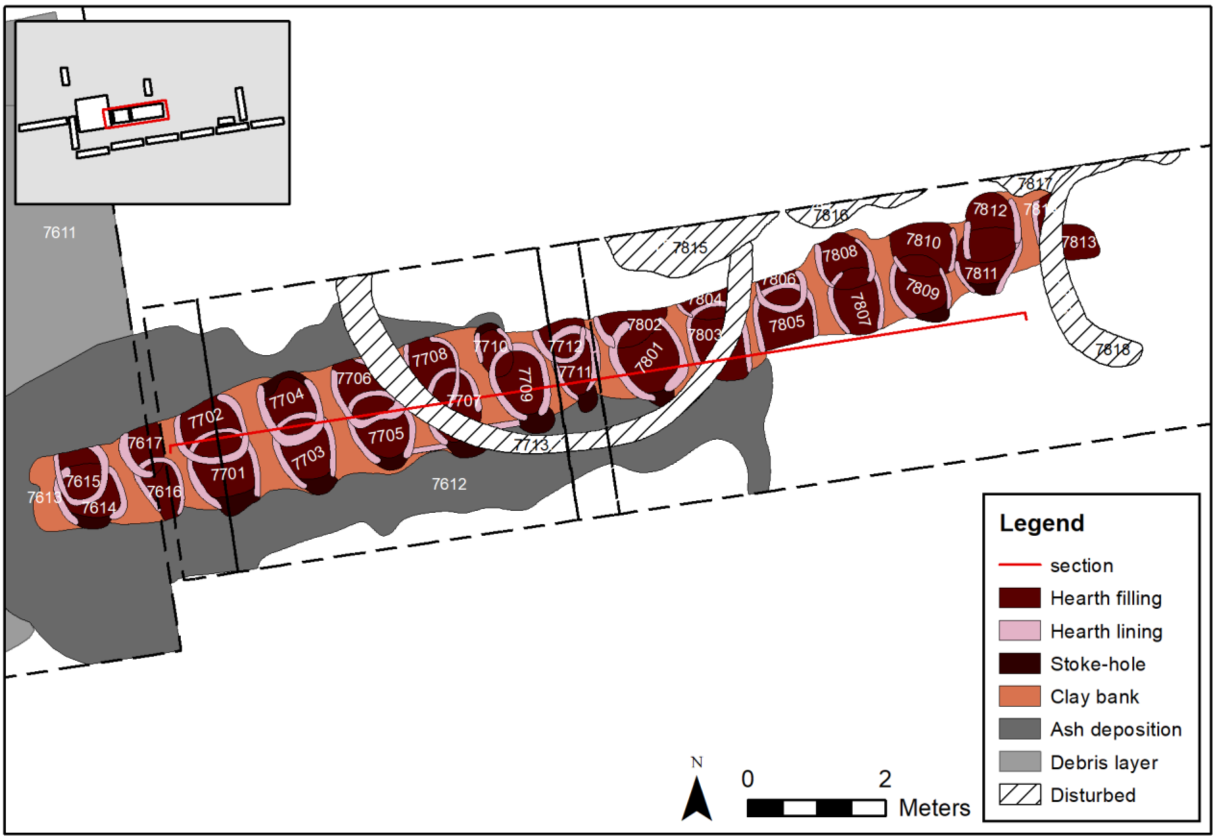


Figure 90 Detailed excavation plan of the heating structures.

In this clay bank, 30 individual heating structures or hearths were constructed in two distinct phases. The first phase consisted of 15 south-facing hearths, which were cut into the clay bank at regular intervals (Figure 90, Figure 91, Figure 93). The western half of the hearths is more widely spaced (approximately 25-30 cm between each hearth), while the eastern half is closer together (approximately 10-15 cm between each hearth). The second phase comprised 15 north-facing hearths with a similar interval (ca. 20-30 cm) between each hearth (Figure 90, Figure 91; Figure 93). These hearths were positioned on top of the earlier hearth battery, and their construction destroyed the

[110] Contra Thoen (1977b), who assumed that first, the hearths were constructed, after which the space between the hearths was filled with clay. During the heating process, the clay oxidised forming a solid clay bank between the hearths. In cross-section, layer 42 clearly contradicts Thoen's hypothesis as this layer, which was part of the clay bank, was found underneath the hearth (lining). This would not have been the case if the clay bank had been constructed afterwards.

northern end of the older phase 1 heating structures. Unfortunately, the phase 2 hearths are less preserved than the phase 1 structures due to post-depositional processes. The stratigraphical relationship between the phase 1 and phase 2 hearths is visible in Figure 92. This cross-section shows that the phase 2 hearths (7702, 7704 and 7706) were positioned on top of the phase 1 hearths (7701, 7703 and 7705).

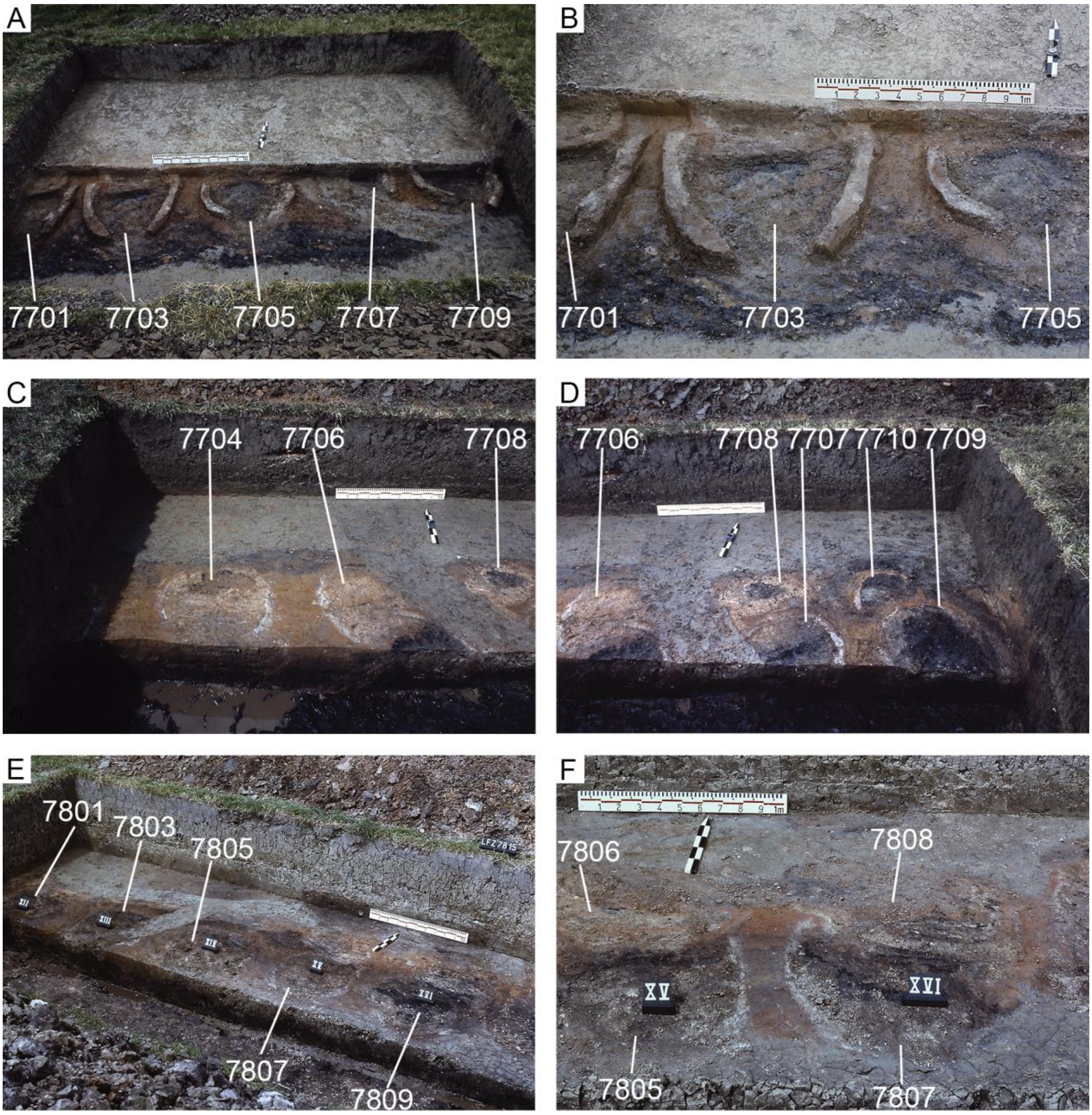
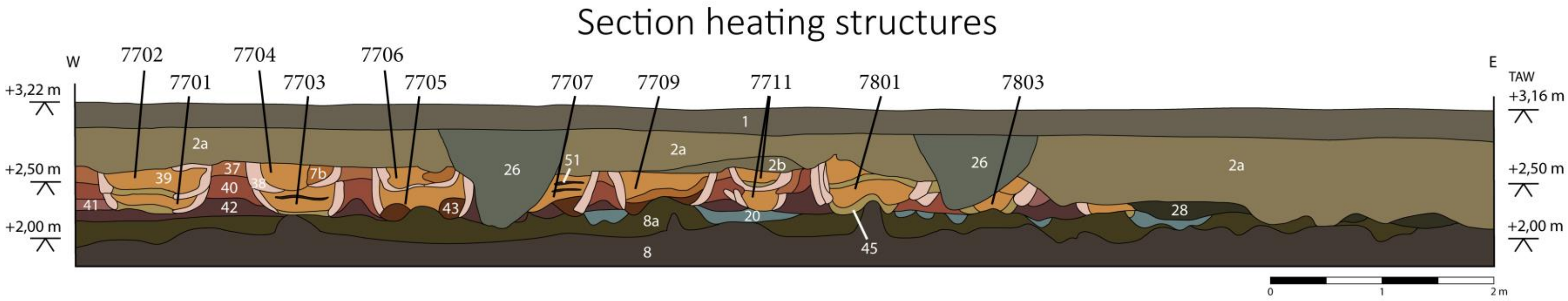


Figure 91 Digitised colour diapositives from the 1977 and 1978 campaign depicting the heating structures. A) Overview of the western end of the phase 1 hearth battery in trench 77/12. B) Detail of phase 1 hearth 7703. C) Overview of the western end of the phase 2 hearth battery in trench 77/12. D) Overview of the eastern end of trench 77/12 showing the phase 1 and phase 2 hearth battery. E) Overview of the eastern part of the phase 1 and 2 hearth battery in trench 78/15. F) Detail of phase 1 and 2 hearths in trench 78/15.



Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
7b	Clay with lots of 'zelas' fragments	Roman occupation layer
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
20	Greenish blue clay (mud)	
26	Greyish green, plastic clay with fragments of 'zelas', hearth furniture etc.	Post-medieval/modern ditch
28	Dark greenish black, very plastic clay with lots of charcoal fragments, 'zelas' fragments etc.	Disturbed ash belonging to the heating structures
37	Orangey brown sandy clay with 'zelas', hearth lining and ash fragments	Raised clay bank
38	Inside: pinkish white; outside: purplish red; sandy clay (heated at high temperature)	Hearth lining
39	Highly dispersed, very hard and very compact material consisting of chunks of crumbled clay mixed with 'zelas' and ash fragments	Hearth filling
40	Orangey red (10 R 4/7) plastic clay	Raised clay bank
41	Reddish brown (7,5 YR 4,5/5,5) plastic clay	Raised clay bank
42	Dark reddish brown (7,5 YR 2,5/3) plastic clay	Raised clay bank
43	Brown compact clay mixed with small 'zelas' chunks	Small ditch
45	Greyish green sandy clay (heated at high temperature); smooth transition with hearth lining	Hearth bottom
51	Dark brownish black ash layer	

Figure 92 West-east section of the heating structures (Leffinge Zwarte weg)

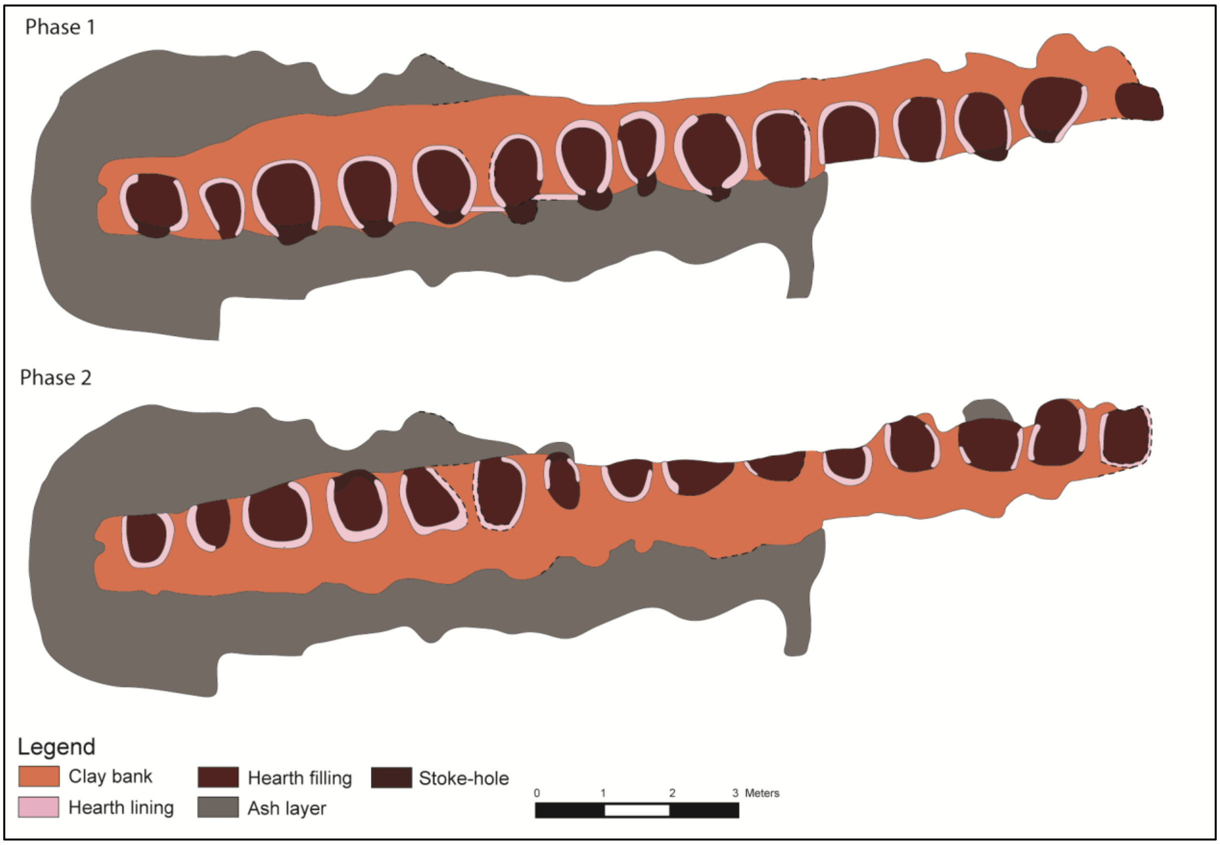


Figure 93 Detailed interpretative excavation plan of the phase 1 and phase 2 heating structures. The dotted line represents a possible reconstruction of the disturbed feature parts.

Taking only the more or less completely preserved hearths[111] into account, it is evident that the dimensions of the hearths were remarkably similar.[112] On average, the hearths measured 94.4 cm in length and 85 cm in width. The variation in hearth length and width is shown in Figure 94. The dimensions of the individual hearths can be found in APPENDIX 4A. The phase 1 and phase 2 hearths had an opposite orientation (south vs north), and at the south-facing entrance of phase 1 hearths, often a stokehole was recorded. In total, 15 stokeholes were recorded, measuring between 20 cm and 50 cm in width (average 35 cm) (Figure 90). These stokeholes were used to fuel the hearths, create an updraft airflow and rake out the ashes.

Each hearth constructed in the clay bank had steep sides and a concave/flat base consisting of greyish-green sandy clay (Figure 92). Often the transition from hearth bottom to hearth lining is relatively smooth, but there are examples where the lining was constructed from a small oval ditch (for example, hearths 7705 and 7709). The hearth lining was pinkish white on the inside and purplish red on the outside and might have tempered with vegetal material. Particularly, the lining of hearths 7701, 7703 and 7705 was well preserved (Figure 91, B). Hearth 7711 and 7801 contained several phases of hearth lining, and two superimposed hearth bases were recorded in hearth 7801 (Figure 92). This suggests that the hearths were used throughout multiple heating or production cycles before they

[111] Less preserved hearths 7710, 7712, 7802, 7804, 7805 and 7806 were excluded from this comparison.

[112] Some margin of error resulting from small measurement errors and other post-excavation mistakes should be taken into account. As such, it is possible that the presented values slightly deviate from the actual situation in Roman times.

were discarded. Debris accumulated around the clay bank and the hearths, forming an ash-rich deposition.

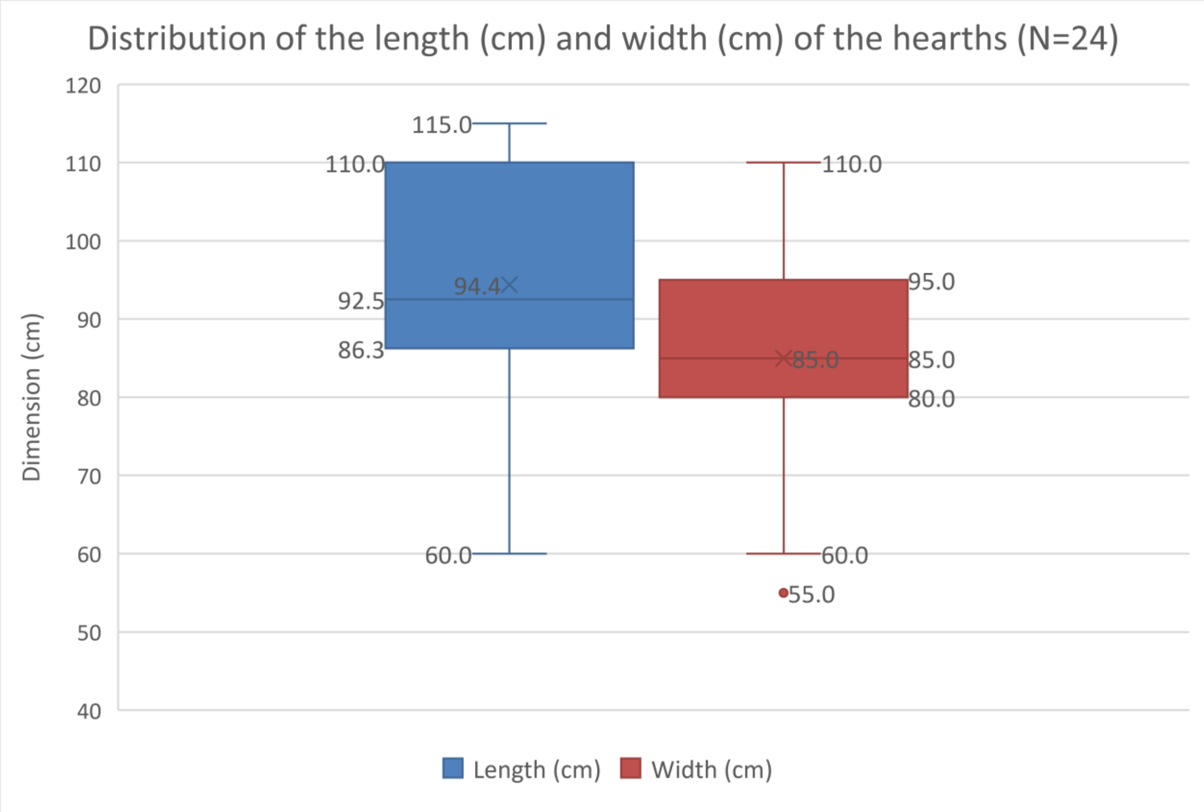


Figure 94 Distribution of the length and width values of the hearths discovered at Leffinge Zwarte weg.

7.2.3.3 Refuse zones

In addition to the extensive debris layer of variable thickness that covered the entire surface, two distinct refuse zones (A and B) containing larger quantities of debris were present at the edge of the site (Figure 96 and Figure 97). Refuse zone A was situated at the southeastern part of the site and consisted of a large, thick, amorphous contiguous mass (feature 7516) of reddish-brown clay mixed with ash, briquetage, pottery and 'zelas' fragments (Figure 95 and Figure 96). This debris layer contained 13 semi-circular or oval-shaped features (7503-7515), which measured between 0.55 and 1.2 m in length, and 0.3-0.65 m in width. Each feature consisted of a thin layer of sand covered by 'zelas' and fired clay fragments. Several of these features (7503.7504.7505, 7508 etc.) extended beyond the limits of excavation, suggesting that the zone continued further south- and northwards. Although the debris layer extended northwards, the layer was definitely thinner in trench 77/14.

Refuse zone B, on the other hand, was situated in the southwestern part of the site (Figure 97) and comprised a large debris layer (7531) containing 6 individual features (7524-7529). The southernmost features (7524 and 7525) were cut by a post-Roman, possibly medieval, creek (feature 7523). Contrary to refuse zone A, these features were more elongated in shape and measured between 0.55 m and 1.1 m in length and 0.4-0.6 m in width. Similar to refuse zone A, each feature consisted of burned soil fragments covered by 'zelas'. In section (APPENDIX 4A), small ditches were recognised underneath some features which might have been older drainage ditches. Several features extended beyond the limits of excavation, suggesting that the refuse zone continued west and eastwards.

Figure 95 Digitised colour diapositives from 1975 depicting the large, thick amorphous, contiguous mass containing multiple individual refuse dumps

In older publications and the excavation archive, Thoen (1975b) interpreted these features as the remains of older salt production hearths which were abandoned and destroyed during the site's continued use. As such, zone A and B were initially interpreted as zones of intense activity where multiple hearths produced salt. However, various arguments can be put forward contradicting this hypothesis. Firstly, the fickle nature of each feature does not correspond with known types of heating structures. In addition, large quantities of 'zelas' and pottery fragments were found in these areas, which correspond with refuse zones rather than heating structures. Furthermore, samian ware found in layer 7516 could be fitted with sherds recovered in the hearth battery. This implies that both zones were active at the same time. The simultaneous character of both zones refutes the idea that the features served as an older stage of the salt production activities. Instead, the features should be interpreted as refuse dumps representing several cleaning episodes. Over time, material accumulated in these zones and merged the individual dumps into a larger amorphous, contiguous mass. It is tempting to connect each of the refuse zones to one of the phases of the hearth battery. While this is a strong possibility, there is insufficient evidence to conclusively prove this hypothesis.

North and northeast of refuse zone B, multiple features (7534, 7535 and 7610) containing fine white ash were identified (Figure 97). Unfortunately, these features were not recognised during the excavation, complicating their interpretation. Feature 7534 measured ca. 3.15 m in length, min 1.85 m in width and between 0.2-0.4 m in depth and consisted of a pale white, light brown ash sporadically containing fired clay and 'zelas' fragments. Features 7535 and 7610, measuring 4 m in length, 0.63 m in width and 0.25 m in depth, were most likely the same feature and comprised of pale white ash mixed with 'zelas' and fired clay fragments. Exactly how these features should be interpreted is unclear. Evidently, the composition deviated from the abovementioned refuse dumps. This suggests that the refuse might have originated from a different stage in the salt production process, for instance, cleaning the settling tank, dumping residual brine etc. Several samples of these white ash layers were selected for further (chemical) analyses. For more information on these analyses and the results, see Dekoninck et al. (In prep)

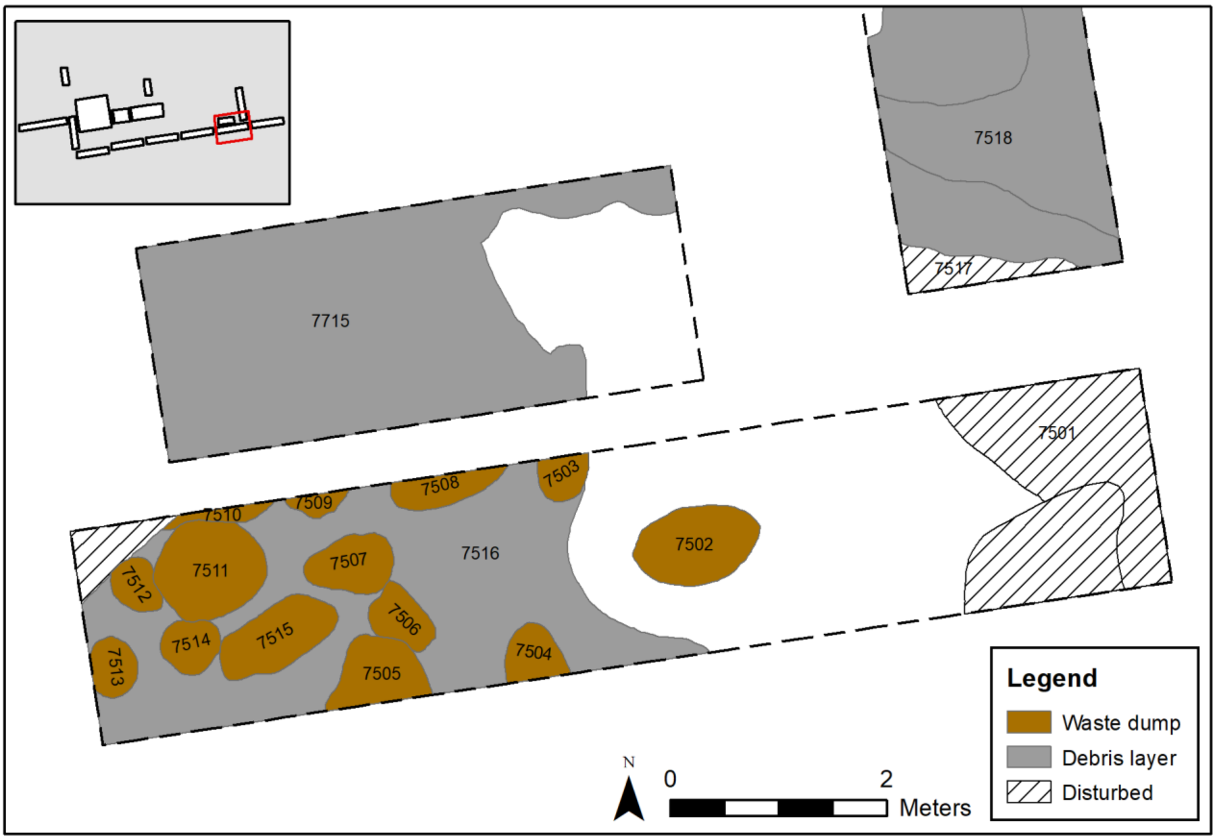


Figure 96 Detailed excavation plan of refuse zone A (Leffinge Zwarte weg)

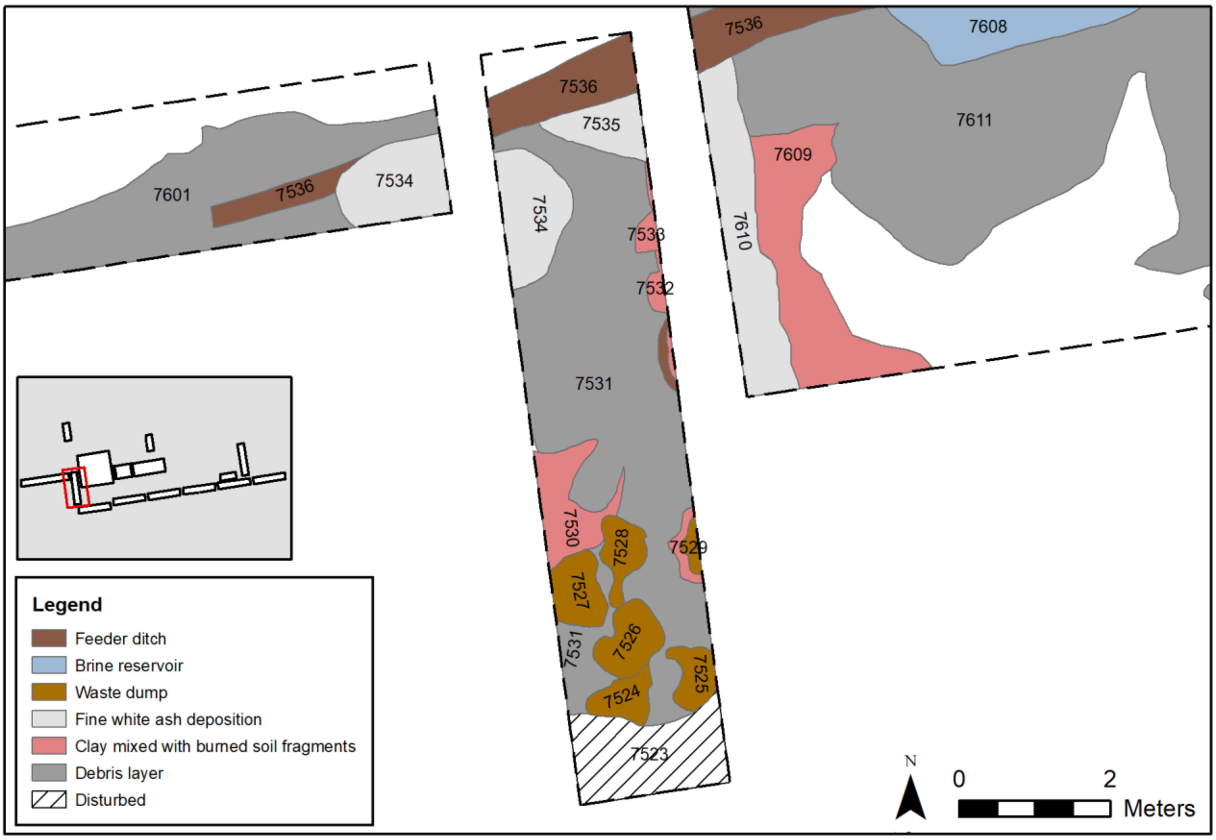


Figure 97 Detailed excavation plan of refuse zone B (Leffinge Zwarte weg)

7.2.4 The finds

7.2.4.1 Pottery

The site of Leffinge contained 767 potsherds representing a minimum number of 77 individuals (MNI) (Table 22) (APPENDIX 4B). Only a minority of the sherds were collected in well-defined features (ditches, water basin, hearth infrastructure), and most were recovered from the debris layers covering the entire site. Most sherds surfaces were intact (little flaking), and no rolling was visible on the fractures indicating a well-preserved pottery ensemble. Multiple cross-fits in fine and coarse ware confirm the homogeneous nature of the pottery assemblage and suggest a short period between vessel breakage and its deposition.

Table 22 Quantification of the pottery fragments recovered at Leffinge

Fabric Group	Sherd count (N)	Percentage (%)	MNI (N)	Percentage (%)
Samian ware	30	*3.9%*	12	*15.6%*
Colour-coated ware	47	*6.1%*	9	*11.7%*
Terra nigra like ware	3	*0.4%*	1	*1.3%*
Fine oxidised ware	3	*0.4%*	1	*1.3%*
Flagons	226	*29.5%*	9	*11.7%*
Amphorae	5	*0.7%*	1	*1.3%*
Dolia	1	*0.1%*	1	*1.3%*
Mortaria	7	*0.9%*	4	*5.2%*
Oxidised ware	43	*5.6%*	3	*3.9%*
Reduced ware	64	*8.3%*	7	*9.1%*
Handmade ware	338	*44.1%*	29	*37.7%*
Total	**767**	**100%**	**77**	**100%**

The assemblage only contained a small amount of samian ware (30 sherds representing 12 MNI) (Table 22; Figure 98). All 25 sherds, excluding the five heavily burned fragments, had a deep orange-brown to orange-yellow fabric with a lustrous, smooth orange-brown slib of good quality. This fabric corresponded with an East-Gaulish, possibly Rheinzabern, provenance (Brulet et al., 2010, 173-191). The following dish or shallow bowl types were present: Drag. 18/31 (3 MNI) (Figure 98, 1 and 3); Drag. 32 (1 MNI); Drag. 32 or 36 (1 MNI) and Drag. 36 (1MNI). Next to dishes, three larger bowls occurred: one flanged bowl type Drag. 38, dated to the second - early third century, and two decorated Drag. 37 bowls. One of the Drag. 37 fragments had a rouletted decoration specifying the bowl as a Drag. 37R type (Figure 98, 5). Finally, fragments of two Drag. 33 cups were present (Figure 98, 2 and 4).

Next to Samian ware, 47 sherds (9MNI) of colour-coated ware were identified (Table 22). One rim sherd had an orange-red, chalk-tempered fabric and a blackish metallic exterior coating originating from Lezoux (Brulet et al., 2010, 345-348). The production of colour-coated ware at Lezoux started in the second half of the second century and continued well into the third century (Brulet et al., 2010, 347-348). The remaining fragments had a white, quartz tempered fabric with olive green to greyish black or orange-brown coating characteristic for colour-coated ware from Cologne.

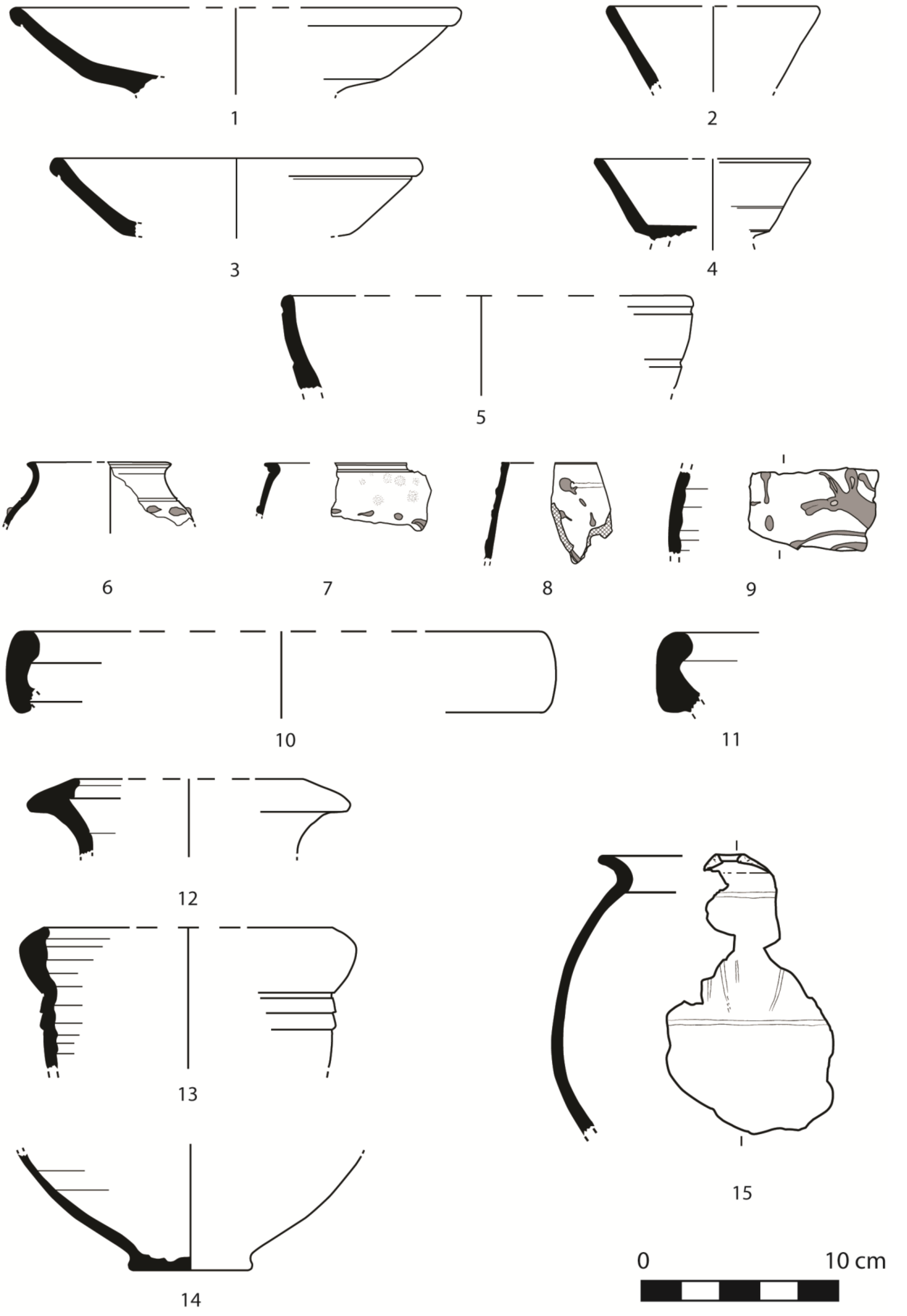


Figure 98 Pottery from Leffinge. Samian ware (1-5); Colour Coated ware (5-8); Mortaria (10-11); Flagons (12-14) and North Menapian handmade (15)

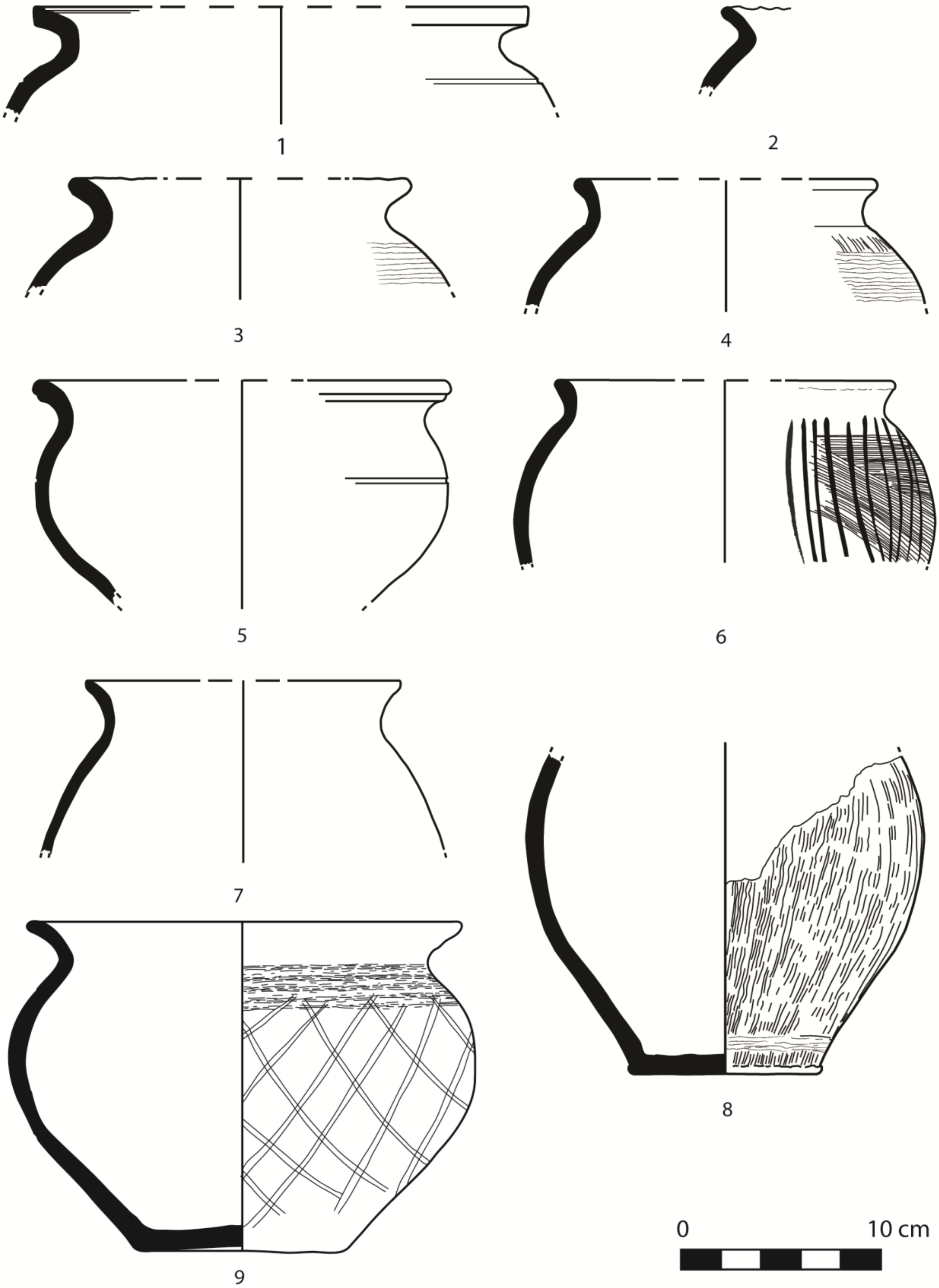


Figure 99 Pottery from Leffinge. North Menapian handmade (1-9).

In the assemblage, the following types of colour-coated ware were present: one Hees 17a/Niederbieber 40 plate, three Hees 3 cups (Figure 98, 8), two Hees 2 cups (Figure 98, 7) and one Niederbieber 32 cup (Figure 98, 6). While the rim sherds were not decorated, some decoration was present on most of the body sherds. The most common decorative element was rouletted bands (14 sherds), closely followed by barbotine dots or figurines (13 sherds). One fragment clearly portrays a running deer (Figure 98, 9), and another depicts a hunting dog's hind leg. These hunting scenes are characteristic of so-called hunting cups, which occur from the second half of the second century onwards (Brulet et al., 2010, 335). Finally, seven fragments showed signs of roughcasting decoration.

Three fragments of grey, fine-walled, smooth pottery with a dark-grey slip were identified as terra nigra like ware (Table 22).[113] No rim sherds or other diagnostic elements were recognised which would allow a more precise identification. Similar pottery fragments were found at Oudenburg and Aardenburg and were interpreted as a possible local/regional imitation of the British London Ware style. Both isolated finds were dated to the first half of the third century but the tradition might have been slightly older (Vanhoutte and Willems, 2018b).

The fine oxidised category contained three smooth body sherds (1 MNI) of so-called saponaceous ware. The fabric and style, typically used to produce flagons or other luxurious ware, is consistent with the Bavay production centres in northern France. This type of pottery appears on consumption sites from the second century onwards (Deru and Vachard, 2002).

The mortaria group consisted of seven sherds (4 MNI) belonging to one of the following fabrics: Soller White Ware (6 sherds, 3 MNI) or Bavay-Famars (1 sherd, 1 MNI). The former fabric has a cream-to-yellow colour and is abundantly tempered with large quartz inclusions (Haupt, 1984). The latter fabric is more light brownish and tempered with chalk inclusions and small quartz grains (Vanhoutte and Willems, 2018a). Unfortunately, the Bavay-Famars fragments could not be assigned to a specific type. The Soller fragments were identified as a type Vanvinckenroye 337 mortaria dated between the middle of the second - first half of the third century (Figure 98, 10 and 11) (Haupt, 1984, 413-414; Vanvinckenroye, 1991; Willems, 2005).

Flagon fragments take up a large part of the pottery assemblage (226 sherds, 9 MNI), and all fragments were attributed to the Scheldt valley flagons (Table 22). Three different rim types were present: a ring-shaped rim (3 MNI), a band-shaped undercut rim (1 MNI) (Figure 98, 13) and a triangular rim (1 MNI). The smaller ring-shaped rims belong to smaller tableware flagons, while the other two rim types most likely represent storage ware flagons. The triangular rim fragment (Figure 98, 12) clearly imitates the known Dressel 20 amphorae and might have been used to store and transport beer or nut oil (Van der Werff et al., 1997). Next to these storage ware flagons, only very few amphorae (5 sherds, 1 MNI) and dolia (1 sherd, 1 MNI) were present (Table 22). The amphorae were identified as the white Gaulish fabric GAL AM 1, produced in Gallia Narbonensis in the second and third centuries CE.

At the site, a rather large amount of northern Menapian handmade ware was present (338 sherds representing 29 MNI). This pottery group could be divided into three main fabric types: NMH1 (42%); NMH2 (27%) and NMH3 (15%). The remaining fragments (16%) were heavily burned and could not be assigned to a fabric group. Typologically, most individuals (Figure 99) corresponded with a De Clercq type P2 cooking pot, the most courant handmade vessel type in the northern Menapian territory. One complete vessel was decorated with a reticulated burnishing pattern (Figure 99, 9). Another vessel

[113] Fragments identified by dr. Sofie Vanhoutte

resembled a so-called stud beaker (Figure 98, 15), of which more preserved examples are known from Oudenburg, Plassendaele, Wenduine and Aardenburg. They were used as drinking vessels and occurred from the late second century onwards, but are more commonly present in the third century (Vanhoutte et al., 2009b, 126-127).

7.2.4.2 Briquetage material and other salt production related finds

In addition to the abovementioned pottery fragments, the site contained several other types of finds[114] (Table 23) (APPENDIX 4B). Following Anglo-Saxon tradition, several of these find categories can be classified as briquetage material. As discussed in section 6.3, the term 'briquetage' denotes all ceramic elements used in the salt production process, including the ceramic equipment (salt containers, pinch props, pedestals, etc.) as well as larger structural material, such as fragmented debris of heating structures (Fawn et al., 1990; Lane and Morris, 2001, 8; Hathaway, 2013, 31-32). Apart from the briquetage, different types of waste material like cemented 'ash slags' and fuel ash slag occurred, which will be discussed as well.

Table 23 Quantification of the briquetage material and other salt production related finds at Leffinge

Find category	Fragments (N)	Weight (g)	Mean piece weight (g)
Briquetage: miscellaneous material			
Fired clay	2922	11381	3.89
Briquetage: structural material			
Vitrified clay fragments	5946	170289	28.64
Waste material			
Cemented 'ash slag'	71	3303	46.52
Fuel ash slag/vitrified clay	213	458	2.15

Remarkably, no fragments of ceramic evaporation vessels or support material like pedestals could be identified. Instead, the debris layers contained large quantities of fired and vitrified clay fragments (Table 23). Most fired clay fragments were initially interpreted as badly worn salt container sherds. Indeed, several thin, plate-like fragments (ca. 59% of the fired clay) resemble vessel fragments at first glance. However, close examination revealed that several aspects of the material do not correspond with the known characteristics of salt containers or pottery in general. For instance, the plate-like fragments are relatively thin (88% < 9 mm thick), have some sort of internal stratification (i.e. some form of layering in the clay) and are not tempered. In addition, no definite shape can be discerned in the larger fragments. Instead of salt container sherds, the fragments are perhaps the remains of a thin clay lining applied in or near the heating structures. Further geochemical and petrographic research is required to evaluate these fragments and to check whether any chemical signatures present could help determine the origin and function of the fragments.

[114] Only the pottery, briquetage and production waste categories are discussed in this dissertation. The site also contained a small assemblage of ceramic building material and faunal remains, but these categories are not addressed here.

At Leffinge, unexpectedly, vitrified clay fragments were dominantly present. In total, 5946 fragments weighing 170 kg were recovered throughout the various excavation campaigns (Table 23). Initially, these fragments were termed ‘zelas’ in Dutch and ‘salt slag’ in English. However, both terms are somewhat ambiguous and create confusion. Especially the term ‘zelas’ does not adequately describe the objects since it is often confused with the term ‘zel’, which is used in Dutch literature to denote the ash from burning salt-impregnated peat in medieval salt production. Technically the word ‘salt slag’ is correct as the term slag can be described as ‘waste discarded or left behind evidence of human activity, difficult to classify and to date, but remarkably resistant to weathering’ (Bachmann, 1982), and thus applies to archaeological material from all sorts of artisanal processes (Dekoninck et al., 2022). Nevertheless, over the years, the term slag has become intrinsically linked to waste products from archaeometallurgical processes (Hauptmann, 2020; Rehren, 2020). The use of this terminology thus might (indirectly) evoke a connotation to metallurgy which should be avoided at all costs since the site was involved in salt production. Therefore, we propose to use the more neutral term vitrified clay fragment to describe the objects. As will become clear later on, the fragments are part of the heating structures, and for this reason, they are classified as structural briquetage material.

Table 24 Quantification and find density of the vitrified clay fragments at Leffinge per excavation trench

Excavation trench	Surface area (m^2)	Number of finds (N =)	Weight of finds (g)	Find density (N/m^2)	Find density (g/m^2)
74/1	20	73	2094	4	105
75/2	20	1708	38464	85	1923
75/7	20	1931	39649	97	1982
75/8	20	351	5935	18	297
76/9	30	486	12916	16	431
76/10	10	34	505	3	51
76/11	100	1153	48757	12	488
77/14	10	2	12	1	1
78/15	40	152	17395	4	435
78/16	3.2	44	3608	14	1128
78/17	2.4	12	954	5	398
Total	275.6	5946	170289	22	618

As shown in Table 24, vitrified fragments were recovered in various excavation trenches. The find density (finds per square meter) of each excavation trench was calculated to study the distribution of the finds across the site. The differences between smaller and larger trenches are cancelled out by using the find density, and the distribution can be studied more objectively. The distribution of the vitrified material across the site is shown in Figure 100, and an interesting pattern emerges. The find density in trench 75/7 (97 finds per m²) and 75/2 (85 finds per m²) is significantly higher than the surrounding trenches confirming their identification as refuse zones (section 7.2.3.3). Given the limited width of the trenches, it is highly probable that these refuse zones occupied a larger area. In this regard, the increased find density in trenches 76/9 and 78/8 adjacent to trenches 75/7 and 75/2 suggest that at least part of these trenches functioned as a refuse zone. However, the absence of vitrified material in trenches 77/12 and 77/14 is rather surprising. Especially considering the position of trench 77/14 adjacent to refuse the refuse zone in trenches 75/8 and 75/2. Furthermore, vitrified fragments recovered from the heating structures in trench 78/15 adjacent to trench 77/12 indicate that the heating structures did contain vitrified material. Based on the available information, it is possible that no fragments were present or, more likely, that they were not collected on-site.

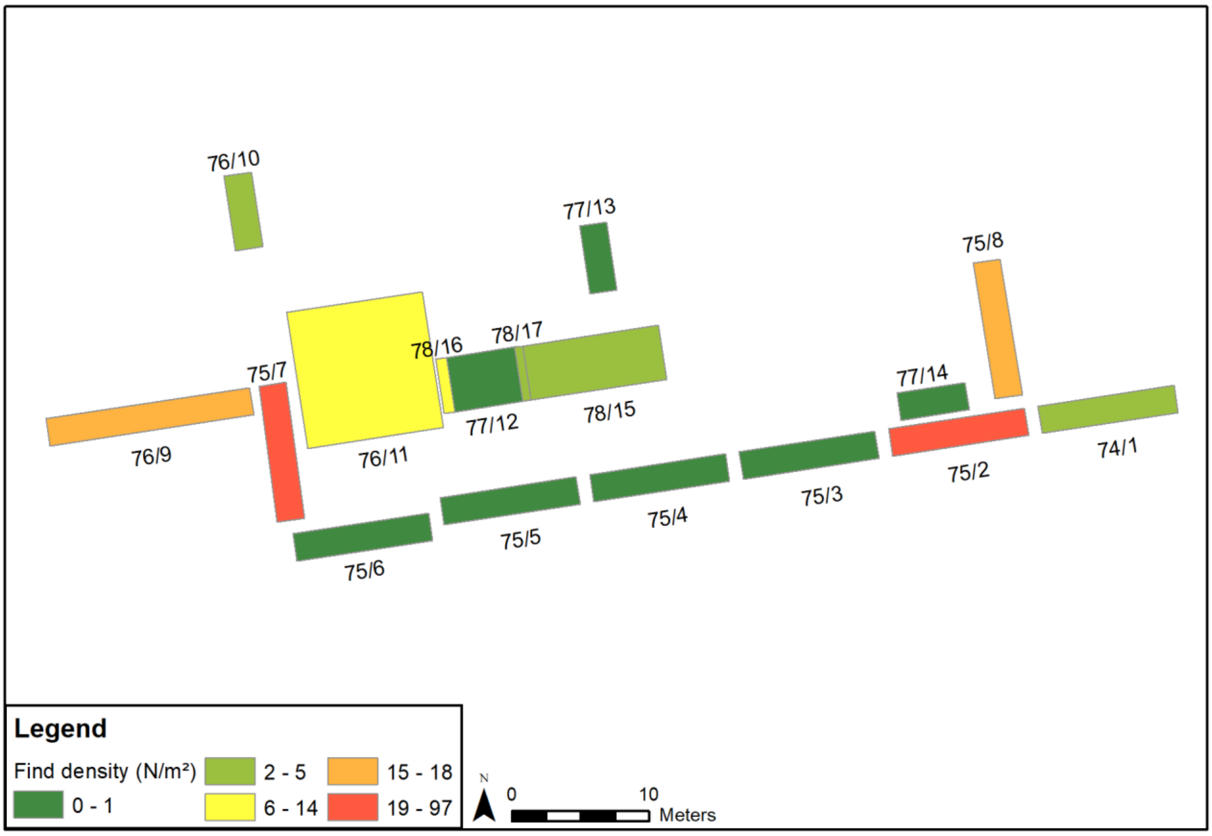


Figure 100 Distribution of the vitrified clay fragments across the site showing that trench 75/2 and 75/7 have a higher density of vitrified material.

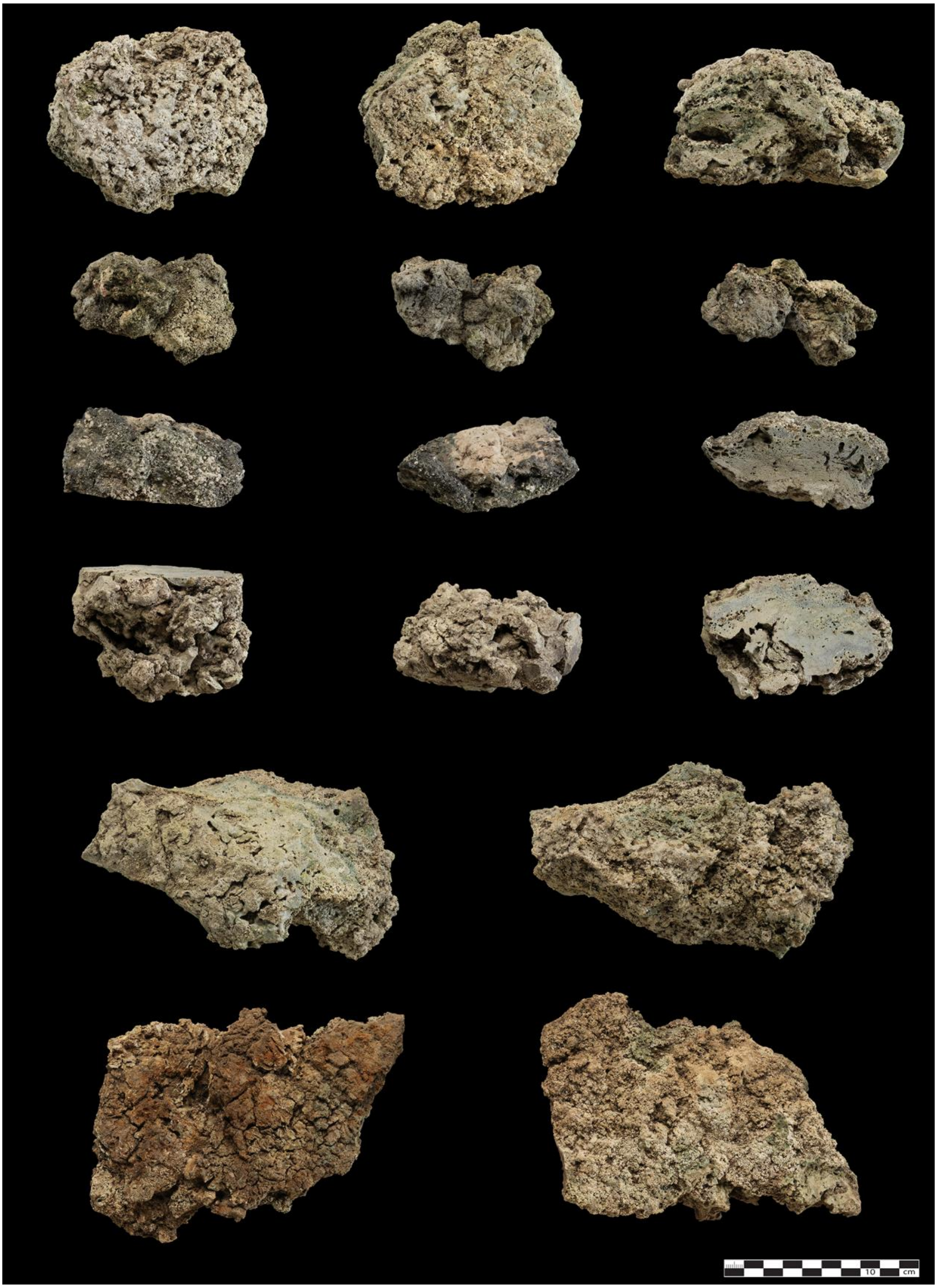


Figure 101 Selection of the vitrified clay fragments discovered at Leffinge. On the top half, the irregular pockmarked vitrified surface exhibiting a fluidal structure of the fragments is shown on the left. In the middle, the flat/slightly plano-convex (vitrified) sandy clay bottom of the fragments is shown. The right image depicts the cross-section. On the bottom half, the front and backside of two larger fragments is shown (© Cedric Verhelst).

Morphologically, these vitrified fragments are highly similar and cannot be divided into different types with distinct characteristics. Overall, the fragments are amorphous with no definitive shape or size and have a greenish-grey colour (Figure 101). Quite often, a transition from a flat/slightly plano-convex (vitrified) sandy clay bottom to a highly vitrified top can be observed in the fragments. At the bottom, the clay structure is often still visible, while the top is entirely glazed and exhibits a fluidal texture. Frequently, this side has an irregular, pockmarked appearance with small dome-like protrusions whose occurrence may be linked to the escape of trapped gases. Larger fragments sometimes have a layered appearance suggesting that multiple vitrification layers have formed during multiple heating sequences. That being said, not all fragments display the abovementioned thermal transition in which the in- and outside are easily discernible. Especially smaller fragments are often completely vitrified and have a pockmarked appearance on both sides. Nevertheless, it is clear that they formed under similar conditions as the larger fragments, but because they are less thick, the vitrification process occurred throughout the entire fragment.

Except for some preliminary observations by De Paepe (1987), these vitrified objects were never studied, and a many questions remained on how these objects formed and related to the salt production process. Multiple samples from several salt production sites, including Leffinge, were analysed using several analytical methods to answer these questions (Dekoninck et al., 2022). This study and the results are further discussed in Chapter 8

Apart from briquetage material, fragments of two other waste categories were present: cemented 'ash slags' and fuel ash slag (Table 23). In the absence of a better word, white, very porous, very soft heterogeneous objects were classified as cemented 'ash slags' (Figure 102). These objects (71 in total, weighing 3.3 kg) were recovered from the ash layers present in the brine reservoir (feature 7608). When pulverised, the material is highly similar to the samples recovered from feature 7534, consisting of pale white, light brown ash. Since it was unclear what these objects were and how they formed, several samples were selected for geochemical analysis and petrography. For more information on these analysis, see Dekoninck et al. (In prep).

Figure 102 Example of a cemented 'ash slag' recovered from the brine reservoir (© Cedric Verhelst).

Finally, several smaller, lightweight, vesicular, highly porous, pale greenish-grey fragments are categorised as fuel ash slag (or vitrified clay) (Table 23). Fuel ash slag formed when alkali-rich fuel ash from the fire chemically reacted with silica-rich material such as sand or clay at high temperatures (Biek and Bayley, 1979; Bayley, 1985). As they can be formed in any sufficiently hot fire, they are not indicative of any specific craft activity, and their presence has been attested on salt production sites

(Hathaway, 2013; Biddulph, 2016) as well as at glass ateliers (Biek and Bayley, 1979) and metallurgical workshops (Bachmann, 1982; Hauptmann, 2020). As this chemical reaction is highly similar to the formation of the abovementioned vitrified clay fragments, it is possible that some of the objects in this group are broken-off pieces of larger vitrified clay fragments.

7.3 Complex 's-Heer Abtskerke - 's Gravenpolder

7.3.1 Introduction

7.3.1.1 Research history

During an augering campaign in 1972, Ovaa registered an ash-rich layer with Roman pottery covering an area of approximately 1 hectare near the recently dug waterway at the 's Heer Abtskerksezandweg (Borsele, NL). On the fifth of June 1972, the ROB excavated a small trench of 40 m² to study the composition of said layer and to determine the nature of the artisanal activities. In the small excavation trench, they discovered the remains of six adjacent heating structures, which were studied in July and August of that year. In the years following the excavation, the preliminary results were presented or incorporated in a series of small publications (Ovaa, 1972; Trimpe Burger, 1973, 1974; Ovaa, 1975, 1987, 1988; van den Broeke, 1996). In his publications, Ovaa (1972, 1975, 1987, 1988) interpreted the site as a Roman salt production site, an interpretation which was heavily contested by van den Berg (1980; 1988). Instead, van den Berg (1980; 1988) suggested that the artisanal sites in Zeeland functioned as lime-burning plants. Chapter 5 thoroughly examined both hypotheses and concluded that the evidence favoured the salt production hypothesis. Recently, Artefact! conducted an excavation approximately 60 m north of the 1972 excavation, revealing a large refuse zone consisting of multiple overlapping ash layers (Figure 103). At the moment, the excavation is still being processed, but preliminary results have been included here.[115]

7.3.1.2 Fieldwork methodology and post-excavation processing

In the 1972 campaign, 40 m² was excavated, but little is known about the fieldwork methodology. The excavation archive contained several excavation plans, which we georeferenced and digitised in ArcGIS to create an all-feature plan of the excavation. In addition, the features were renumbered to incorporate previously unrecognised features. A detailed feature list, feature plans and described trench profiles are presented in APPENDIX 4A.

The 2020 excavation campaign consisted of two trenches covering an area of 1300 m². An excavator with a 2 m wide bucket removed the topsoil exposing the archaeological level. As the archaeological level comprised multiple layers in which potential features could be present, four levels were laid out in which the features were documented. These excavation plans are linked to the 1972 plans in ArcGIS to enable a discussion of all features related to the salt production activities.

[115] We are incredibly grateful to Artefact! for transferring us the unpublished shapefiles, trench profiles, excavation photographs etc. Without this data, we would have been unable to connect the 1972 and 2020 excavations.

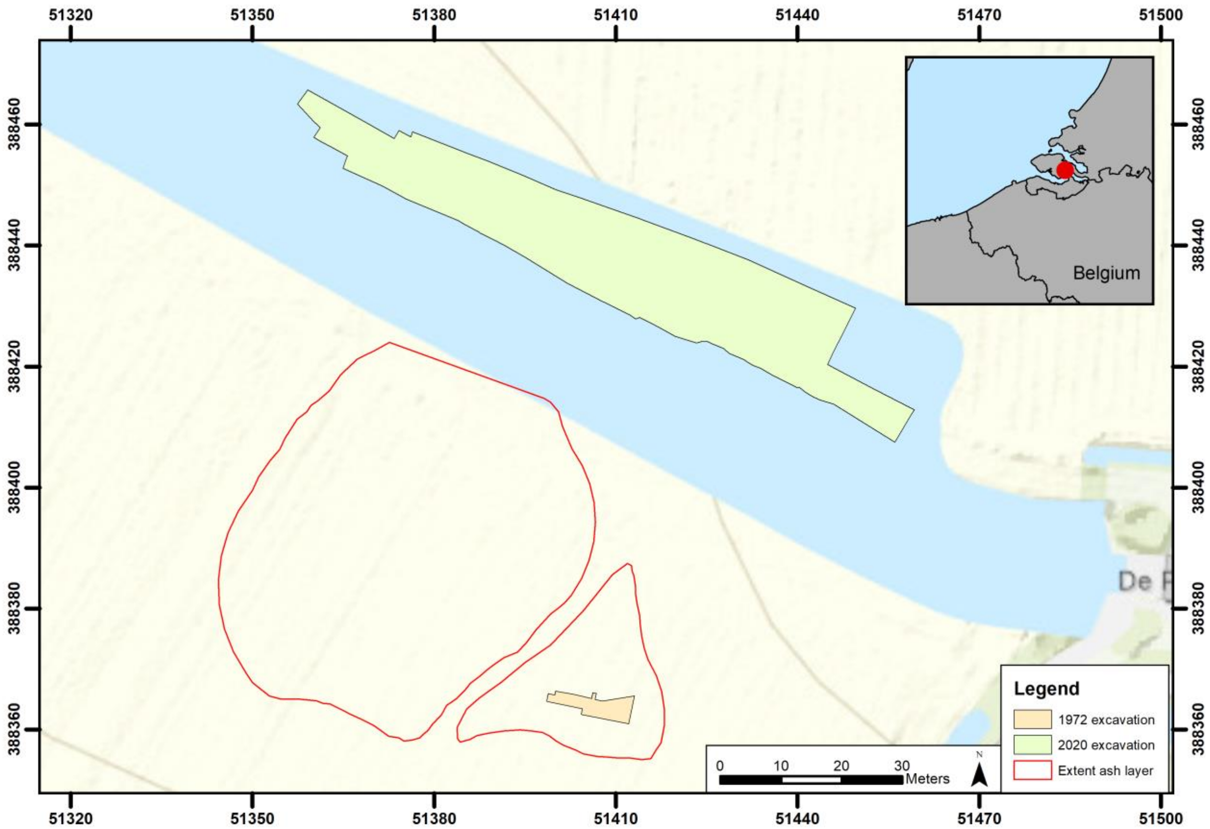


Figure 103 Positioning of the 1972 and 2020 excavation trenches at ’s Heer Abtskerke. The red line visualises the extent of the ash-rich layer as registered by Ovaa in 1972.

7.3.2 Topography and landscape surrounding the site

The salt production complex of ‘s Heer Abtskerke was situated on top of the Holland peat and was surrounded by a network of smaller and larger (tidal) channels (Figure 104). Although Figure 104 depicts the extent of the post-Roman channel network, it is highly likely that some of these channels had a Roman predecessor. For instance, a smaller version of the very large tidal channel east of the site will have been active during Roman times. Furthermore, the origin of several smaller linear creeks might go back to Roman drainage ditches or attempts to control the water flow to artisanal sites. In addition, during the 1972 augering campaign and the 2020 excavation, remains of several (small?) creeks were attested on site (Figure 105). These creeks were active in Roman times and eroded to their current extent due to post-Roman tidal activity. A lot of Roman material was found at the bottom of the westernmost creek, suggesting that the creek was active during the site’s activities (Winterswijk and Coppens, 2022). These creeks supplied the site with the necessary saltwater to conduct the salt production activities. Moreover, during the 2020 excavation, several samples were taken for archaeobotanical analyses (macro and pollen analyses). Preliminary results indicate that the site was situated in a salt marsh environment, for instance, the presence of for instance, samphire and sea lavender. These salt marshes will have developed near the active tidal channels which supplied the salt water. Interestingly, non-salt tolerant species also occurred, suggesting the presence of freshwater reservoirs (Van Beurden et al., in prep). The presence of *Ericaceae* pollen in the ash layers either suggests active ombrotrophic *Ericacae* peat in the vicinity of the site but, more likely, these pollen derived from unburned fuel (peat) that got mixed in the ash layers.

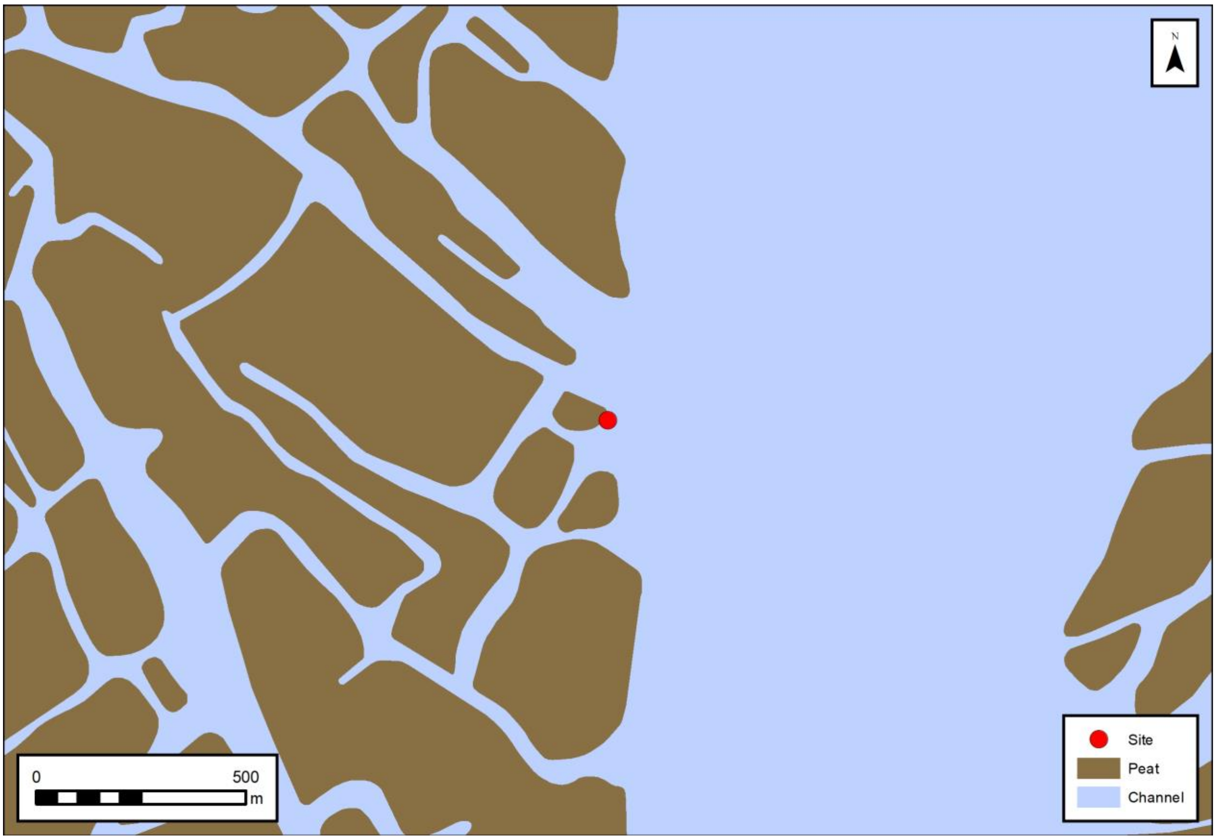


Figure 104 Position of the salt production complex at 's Heer Abtskerke on a simplified version of van der Meer's soil map 'de brede wetering bewesten Yerseke' (van der Meer, 1952) showing the extent of the post-Roman channel network (map made by D. de Ruijsscher).

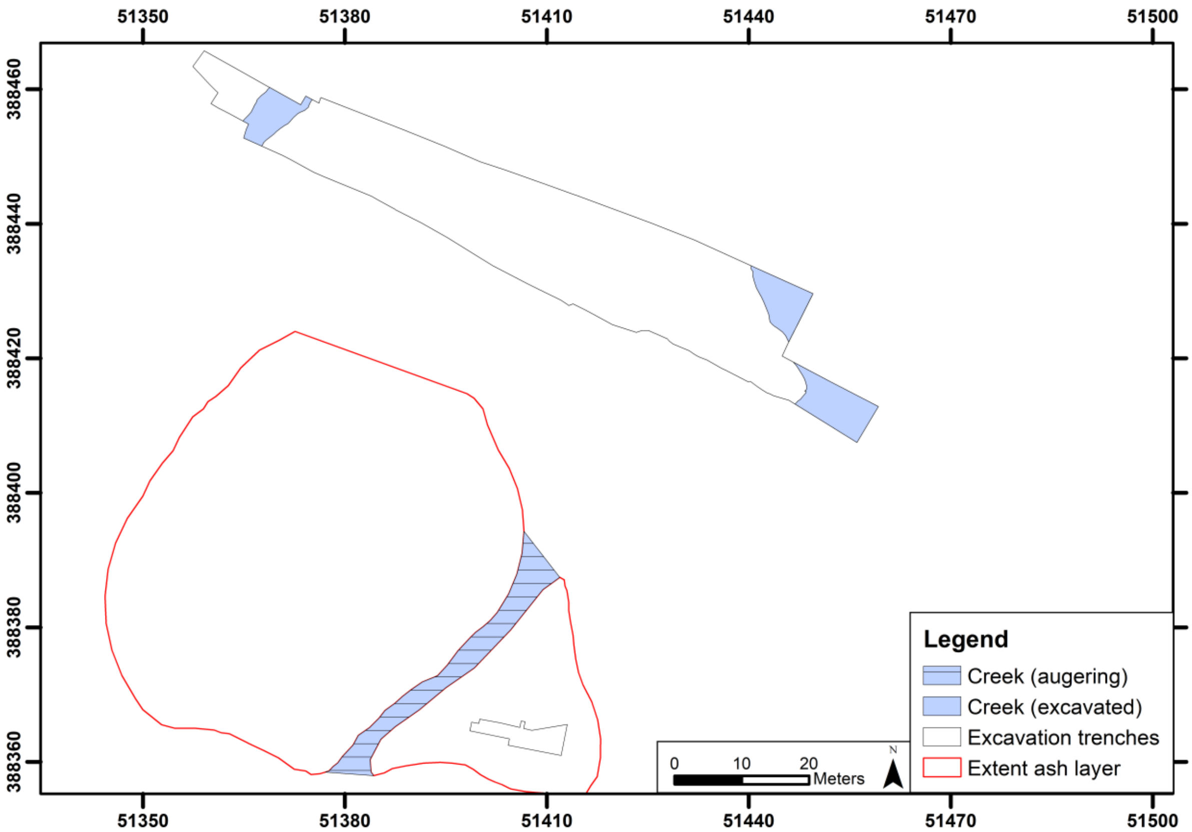


Figure 105 Outline of the creeks discovered during the 1972 augering campaign and 2020 excavation.

7.3.3 Structures and features related to the salt production activities

The 1972 campaign revealed the remains of an artisanal site containing primarily mid-Roman features related to salt production activities. Specifically, the site consisted of an artificially raised work floor with a small row of six hearths constructed in a raised clay bank and surrounded by an ash-rich debris layer. The 2020 campaign, approximately 60 m north of the 1972 excavation, unearthed an extensive refuse zone consisting of multiple debris layers. Partly underneath these debris layers, traces of a small building were discovered. Given the proximity of both excavations and the extent of the ash layer (Figure 103), it is evident that the features were only a small part of a larger salt production complex. Therefore, the features of both excavations are discussed together in the following section.

7.3.3.1 Water management

Apart from the abovementioned active tidal channels that supplied the site with salt water, a few possible ditches were present in the western part of the 1972 excavation. According to Ovaa (Ovaa, 1972, 1975), the western part of the excavation was used to extract peat as fuel for the salt production activities. Indeed, in Figure 108, section A-B, the top of the peat is quite arbitrary with a very angular delineation indicating man-made activity. However, given the amount of peat that would have been required to fuel the hearths, large-scale extraction close to the site rather than on the site would make more sense. As such, the fan-shaped lanes described by Ovaa might also be drainage ditches or feeder ditches. Nevertheless, the reasons behind the angular delineation of the peat remain hypothetical as these features were not observed in plan.

7.3.3.2 Heating infrastructure

The heating structures were the main features of the 1972 excavation and consisted of a clay bank in which six hearths were constructed (Figure 106). The sub-rectangular clay bank (SHA-01), aligned ESE-WNW, measured 6.5 m in length and 1.3 m in width with a persevered height of approximately 0.4 m. This clay bank was raised on top of the peat and its construction required at least 3.5 m^3 of clay, which likely had a local origin. Six individual heating structures or hearths can be identified in this clay bank. These circular or slightly oval-shaped hearths with a north-facing entrance were constructed into the clay bank at regular intervals (ca. 15-25 cm between each hearth). The remarkably similar hearths had a recorded diameter between 0.75-0.80 m with a hearth lining of 0.1 m and a maximum preserved height of 0.3 m. Stokeholes measuring between 0.20-0.25 m in width were recorded at the north-facing entrance. These stokeholes were used to fuel the hearths, create an updraft airflow, and rake out the ashes. In profile, each hearth had steep sides and a flat to concave base. The hearth filling was composed of alternating layers of ash and clay (Figure 108). Around the clay bank, a potential clay work floor was identified on top of the peat. This work floor, consisting of clay cast on top of the peat, was approximately 0.05-0.1 m thick and was only visible in section C-D (Figure 108). Unfortunately, the clay floor was not recognised during the fieldwork making it difficult to estimate the layer's extent. This work floor may have provided a more solid underground for artisanal activities. On top of the clay floor, multiple debris layers were observed, which accumulated during the production activities.

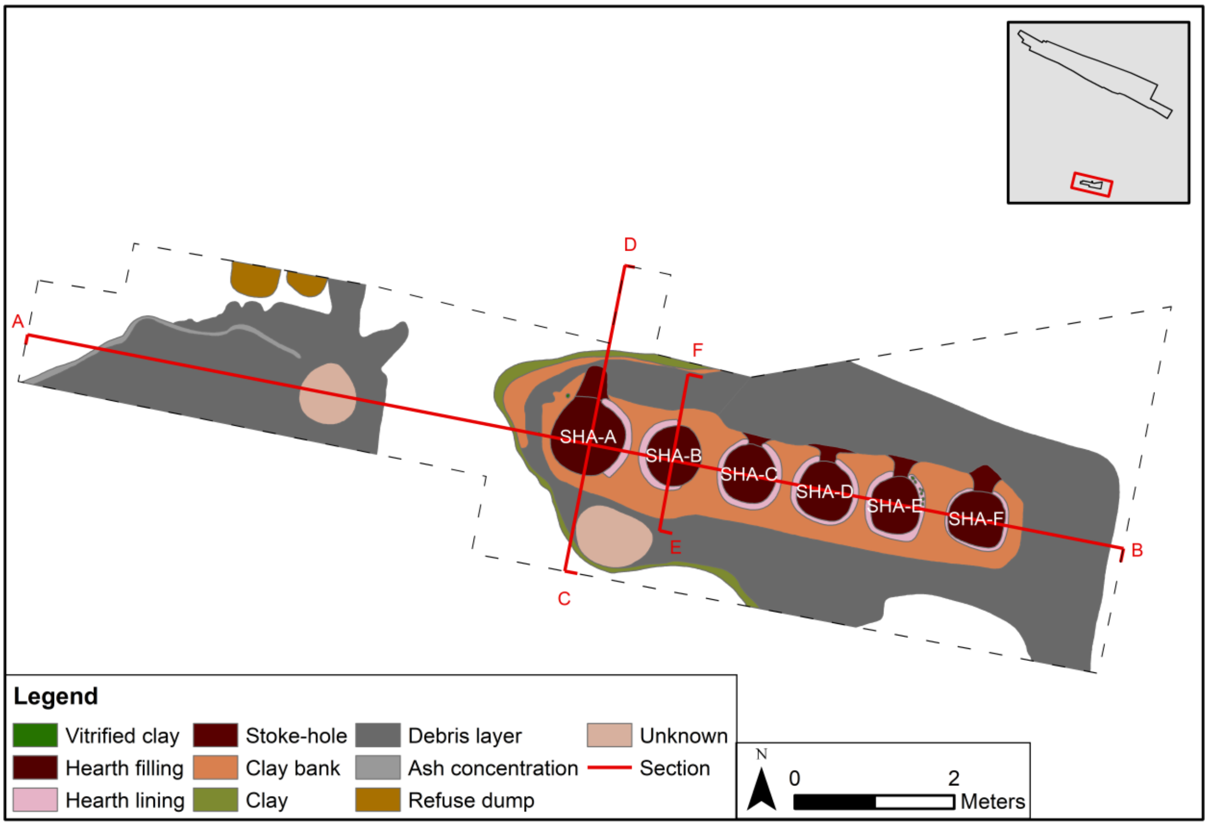
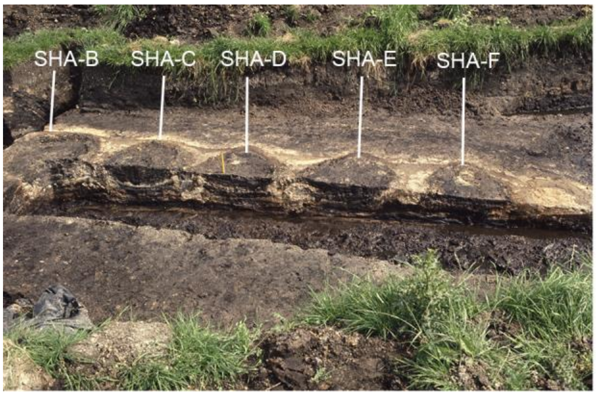


Figure 106 Detailed plan of the heating structures discovered during the 1972 excavations.



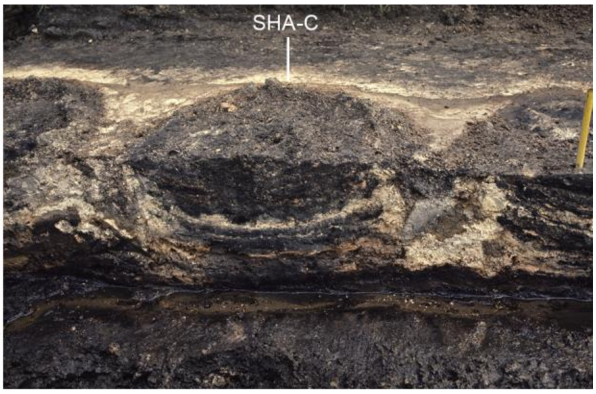


Figure 107 Photographs of the hearth infrastructure at ’s Heer Abtskerke

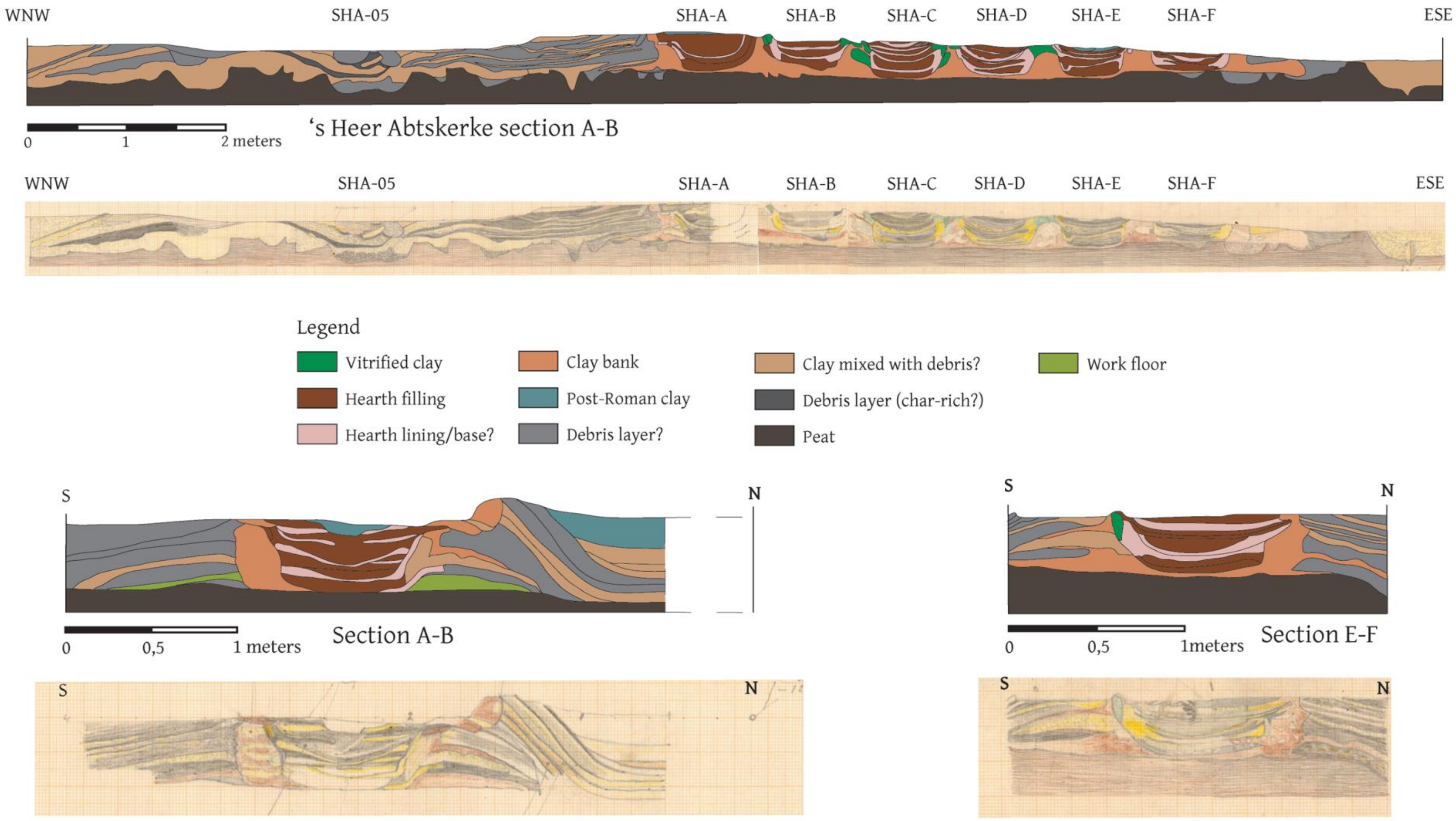


Figure 108 Cross-sections of the heating structure

7.3.3.3 Refuse zone[116]

The 2020 excavation unearthed the remains of an extensive refuse zone approximately 60 m north of the heating structures. The refuse zone consisting of multiple debris layers measured 40 m in length and was at least 12 m in width (Figure 109). Most likely, the refuse zone extended southwards beyond the limits of excavation, but this could not be verified due to the presence of a large modern drainage ditch. The central part of the refuse zone was relatively thick (0.7 m) and became gradually thinner towards the eastern (0.4 m) and western ends (0.15 m). Rough calculations indicate that this refuse zone might have contained 144 m^3 of debris.

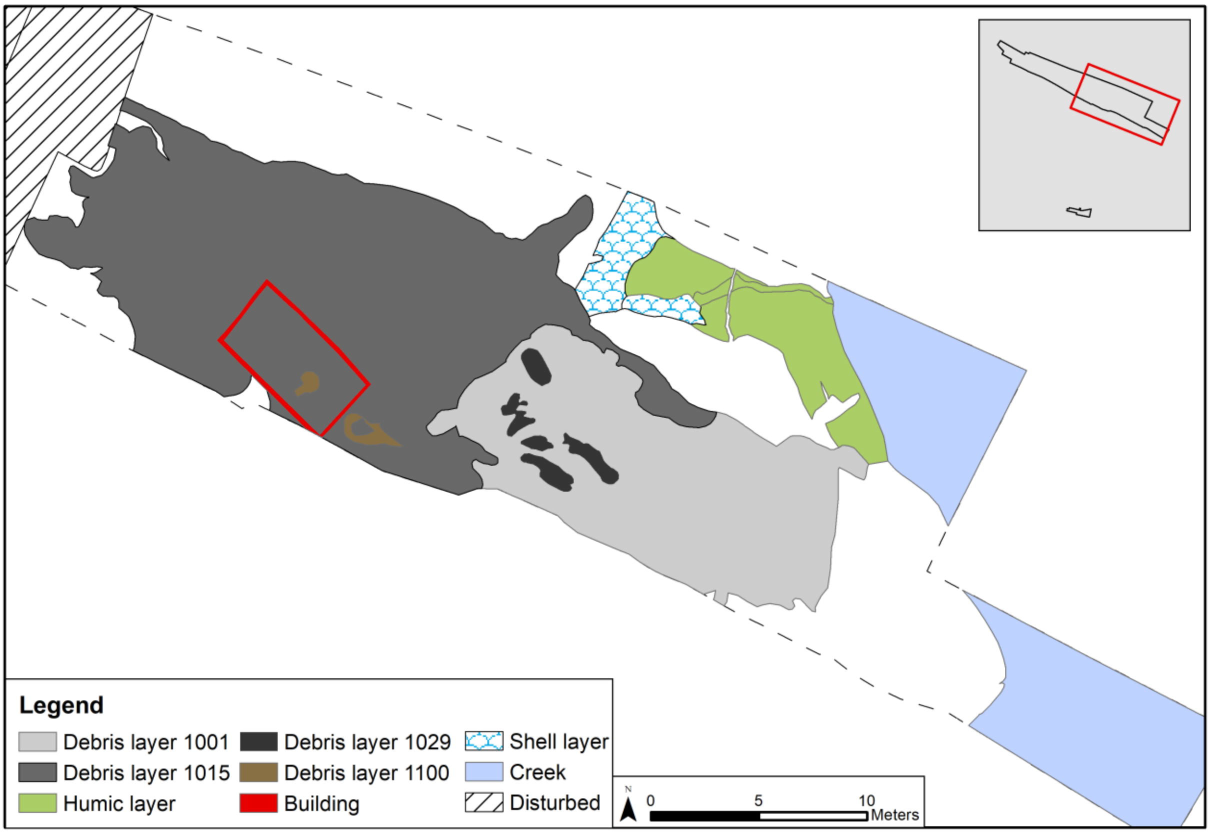


Figure 109 Detailed interpretative excavation plan of the 2020 excavation depicting the refuse zone and the habitation traces.

The refuse zone consisted of three large debris layers situated partly on top of and next to each other. White-light grey heterogenous debris layer 1001 consisted of ash mixed with clay interspersed with char inclusions. This layer primarily occurred in the eastern part of the refuse zone with a maximum thickness of 0.7 m which became thinner towards the eastern extremity (approximately 0.3 m) (Figure 110). The grey-black, very heterogenous debris layer 1015 was interspersed with orange-brown spots of slightly different composition and occurred primarily in the western part of the refuse zone. Since the layer was very heterogenous, the composition varied but generally consisted of a mixture of clay, ash, char, pottery, fired and vitrified clay fragments. At the centre of the refuse zone, this layer measured approximately 0.4 m in depth but became thinner towards the

[116] This section draws upon the description of the refuse zone in Winterswijk and Coppens (2022) and the unpublished excavation results provided by Artefact!

west (ca. 0.15 m) (Figure 111). Dark grey-black heterogeneous debris layer 1029 was situated underneath layers 1015 and 1001 in the central part of the refuse zone. In profile, this layer was relatively well identifiable, but in plan, the transition between layers 1015 and 1029 was diffuse, suggesting a similar composition. Directly on top of the peat, a small debris layer (1100) consisting of dark grey ash, char and large quantities of fired clay was observed (Figure 111). Although this layer was noted at a few locations, the spot within the building is rather conspicuous. Given the large concentrations of char and fired clay, it is possible that this spot represents the remains of a small hearth (section 7.3.3.4).

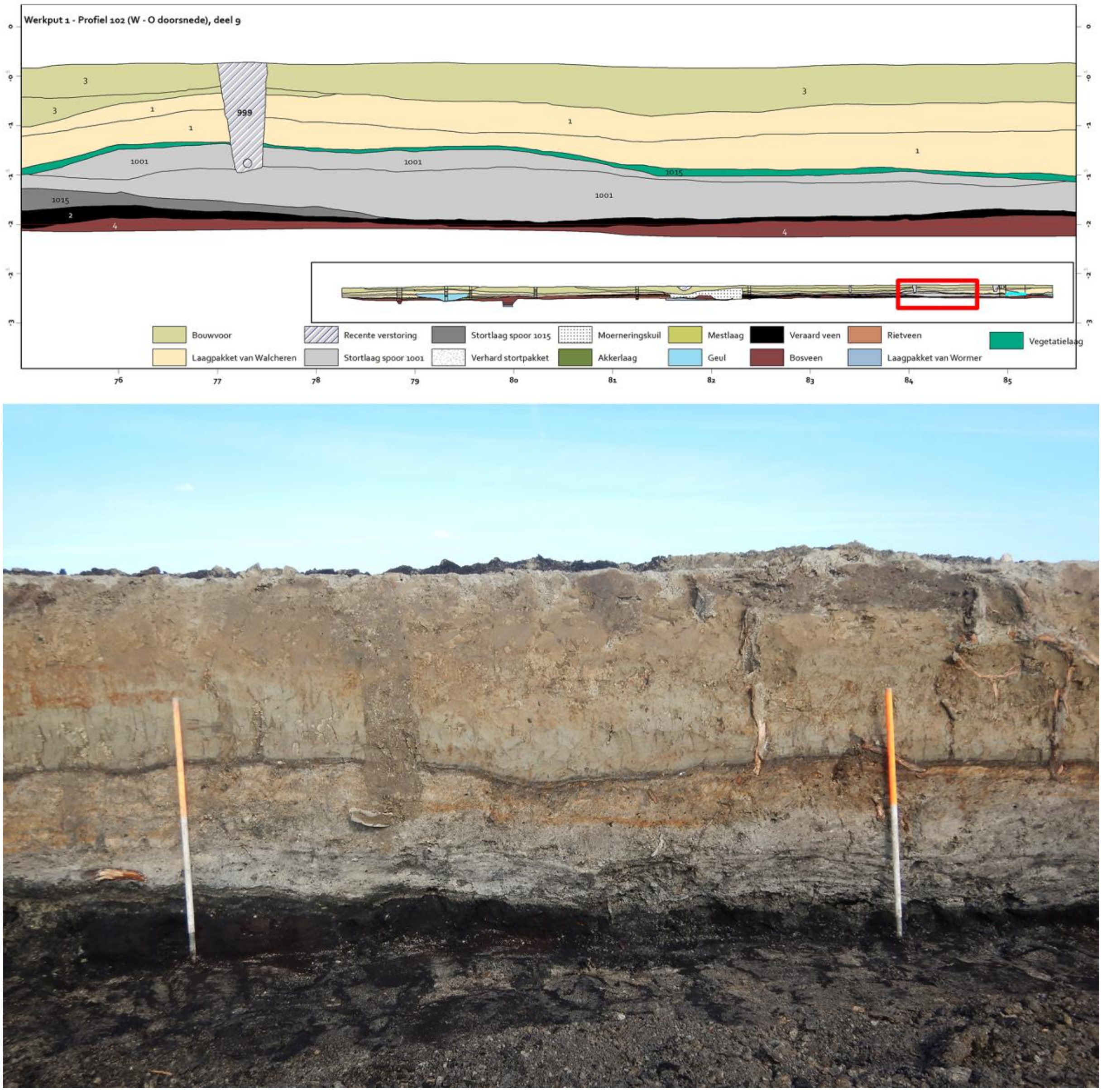


Figure 110 Detail of the west-east cross-section of the refuse zone depcting debris layer 1001 in the central part of the refuse zone (drawn profile and photo courtesy of Artefact).

Stratigraphically, layers 1001 and 1015 are situated on top of layer 1029, but the relation between layers 1001 and 1015 is less clear. At the centre of the refuse zone, there are spots where layer 1001 is positioned on top of layer 1015 and vice versa. In addition, several 'features' were recognised in these layers during the excavation. However, further investigation revealed that these 'features' were local zones with a slightly different composition within the debris layers. In consequence, Figure 109 only depicts the extent of layers 1001 and 1015 and visualises the most important features underneath these layers.

The refuse zone contained waste materials related to the nearby salt production activities. For instance, the ash and char derived from fuelling the hearths and the fired and vitrified clay fragments represent cleaning episodes or the destruction of the hearth infrastructure (section 7.3.4.2). Nevertheless, given the heterogenic character of the debris layers, it is possible that these layers contained waste from other aspects of the production process. Therefore, samples of these layers were integrated into a wider study concerning the identification of the fuel and the nature of the debris layers. Currently, chemical analyses on these samples are pending (Dekoninck et al., In prep). Furthermore, the large quantities of regular pottery found in the debris layers suggest that the refuse zone was not exclusively used to dump artisanal refuse. The communal nature of the dump is confirmed by the large shell concentrations situated at the edge, which can be attributed to consumption practices. Given the refuse zone's dimensions, it is possible that the consumption and artisanal waste originated from a larger settlement and multiple production sites, not just from the hearth battery discovered during the 1972 excavation. However, at this point, this a rather hypothetical as more data is needed on the amount of refuse created by a single production site, the lifespan of a site etc.

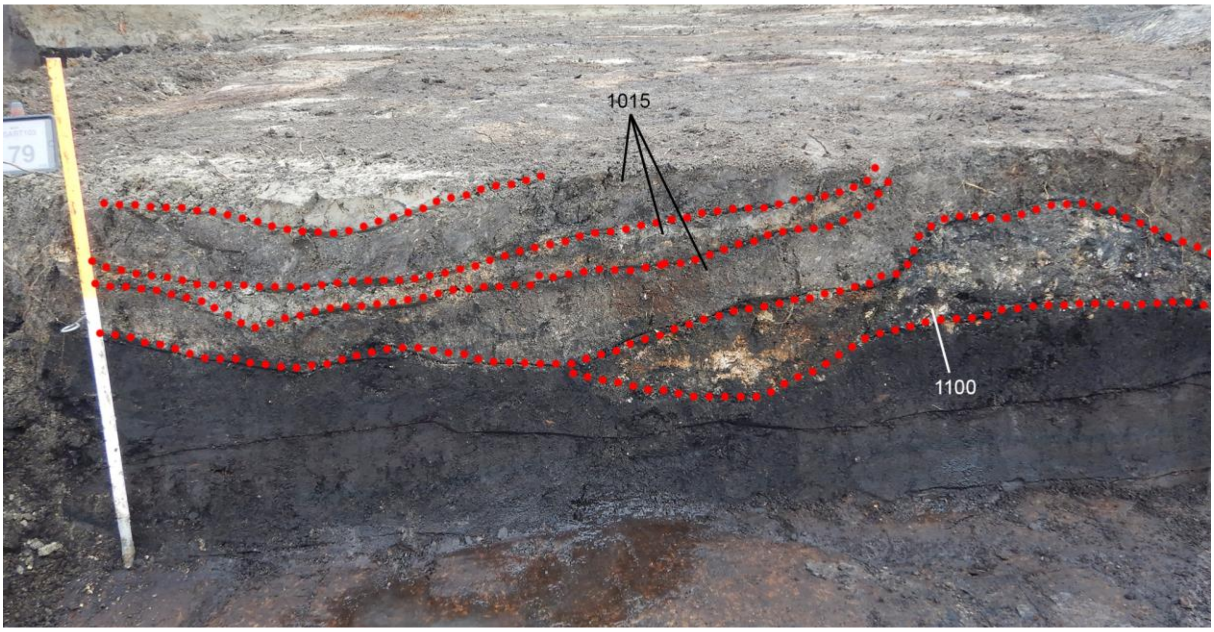


Figure 111 Detail of a west-east cross-section of the refuse zone depicting the heterogenous character of debris layer 1015 as well as a spot of debris layer 1100 (photo courtesy of Artefact).

7.3.3.4 Habitation traces

In the central part of the excavation, the remains of a small building measuring 7 m in length and 4 m in width were discovered on top of the peat underneath debris layer 1015. As only the construction slots and no postholes were recovered (Figure 109), the building might have been built with construction slots and sleeper beams instead of postholes. A building of similar dimensions (9 by 4 m) was excavated at Eke (Vermeulen, 1992), and larger buildings of this type are known from Kappele Smokkelhoek (Bouma and Dijkstra, 2021), Haamstede Brabers (Trimpe Burger, 1995) and Goedereede-Oude Wereld (De Bruin et al., 2012). Nevertheless, the use of timber framing with sleeper beams is rare on civil and especially on rural sites in Flanders (De Clercq, 2009c, 300; Vanhoutte, *in press*).

On the other hand, sleeper beam constructions were standard practice on military sites like the *castellum* of Oudenburg (Vanhoutte, *in press*). Therefore, it is generally assumed that these types of constructions were military-inspired or influenced (De Clercq, 2009c, 300; Vanhoutte, *in press*). As the building was stratigraphically positioned underneath debris layer 1015, it represents an older habitation phase before the area was used as a refuse zone. However, it cannot be ruled out that this building was related to the (nearby) salt production activities and that changes in waste management strategies decommissioned the building, and habitation moved to a new location. Similar to other sites in the coastal plain (see Chapter 2), the large concentration of shells in the refuse zone represents consumption waste from the salt producers working on the site or from a nearby habitation site.

7.3.4 The finds

7.3.4.1 Pottery

In this study, only the pottery from the 1972 excavation was examined (APPENDIX 4B). Van Kerckhove studied the pottery of the 2020 excavation on behalf of Artefact! The 1972 excavation contained 1209 pottery sherds representing a minimum number of 193 individuals (Table 25). Unfortunately, the sherds were collected with little regard to their original context, and no fragments could be assigned to specific features such as the hearth infrastructure, the debris layers etc. Most sherds surfaces were intact (little flaking), and no rolling was visible on the fractures indicating a well-preserved, homogeneous pottery ensemble.

Table 25 Quantification of the pottery fragments recovered during the 1972 campaign at 's-Heer Abtskerke

Fabric Group	Sherd-count (N)	Percentage (%)	MNI (N)	Percentage (%)
Samian ware	71	*5.9%*	30	*15.6%*
Colour-coated ware	33	*2.7%*	9	*4.2%*
Fine oxidised ware	10	*0.8%*	6	*3.1%*
Fine reduced ware	36	*3.0%*	9	*4.7%*
Pompian red ware	1	*0.1%*	1	*0.5%*
Flagons	378	*31.3%*	18	*9.4%*
Amphorae	2	*0.2%*	2	*1.0%*
Dolia	57	*4.7%*	5	*2.6%*
Mortaria	20	*1.7%*	7	*3.6%*
Coarse oxidised ware	63	*5.2%*	16	*8.3%*
Coarse reduced ware	216	*17.9%*	55	*28.6%*
Handmade ware	322	*26.6%*	35	*18.2%*
Total	**1209**	**100%**	**193**	**100%**

The assemblage contained a relatively high amount of samian ware (71 sherds representing 30 MNI) (Table 25), and several fabrics were recognised. The Rheinzabern products (42%) dominate the spectrum, followed by samian ware from Trier (21%), the Argonne (4%) and Central-Gaulish workshops (4 %). The exact production centre in Eastern Gaul could not be determined from 16% of the sherds, and the remaining fragments (11%) were too heavily burned for fabric identification.

Morphologically, the samian ware could be divided into cups (4 MNI), dishes/plates (15 MNI), bowls (5 MNI) and mortaria (5 MNI). Typologically, three Drag. 33 cups and one Déch. 72 cup with incised floral motifs (Figure 112, 3) dating to the second half of the second – early third century could be identified (Déchelette, 1904; Webster, 1996, 61-62; 116). The plates are dominated by Drag. 18/31 (2 MNI), Drag. 18/31 or Drag. 31 (9 MNI) dishes (Figure 112, 4 and 7), followed by Drag. 32 plates (3 MNI) (Figure 112, 2 and 5) and a Lud. Ti' plate (1 MNI) (Figure 112, 1). Both the Drag. 32 and the Lud. Ti' plate occurred from the second half of the second century and is common in the third century (Dragendorff, 1895; Ludovici, 1927; Webster, 1996, 44; Brulet et al., 2010). In addition, five decorated bowls type Drag. 37 (Figure 112, 9) were present in different fabrics (Central-Gaulish; Rheinzabern, Trier and Argonne). Lastly, the assemblage contained two Drag. 45 (Figure 112, 8) and one Drag. 43 (Figure 112, 6) mortaria from Rheinzabern. Several mortaria fragments with trituration grits originated from Trier (1 MNI) or Argonne (1 MNI) fabric. Samian ware mortaria were introduced in the last quarter of the second century and are common in the third century (Dragendorff, 1895; Webster, 1996, 53; 55-56; Vanhoutte et al., 2009b, 106; Brulet et al., 2010).

Next to samian ware, 32 fragments of colour-coated and black-slipped ware in different fabrics were identified: Cologne (2 MNI), Trier (3 MNI) and Argonne (4 MNI). Interestingly, several Trier (2 MNI) and Argonne (2 MNI) examples had a metallic coating which sporadically occurred from the second half of the second century onwards (Brulet et al., 2010, 342-345). Typologically, a complete, indented Nied. 32 cup (Figure 112, 19) and a three Nied. 33 cups (Figure 112, 10-12) in Argonne fabric were present. While Nied. 32 cups are quite courant at the end of the second century - early third century, the Nied. 33 type mainly occurs in third-century pottery assemblages (Oelmann, 1914, 39-42; Brulet et al., 2010, 314; 342-344).

The fine oxidized category contained ten sherds representing six individuals (Table 25). The majority of these sherds were made in high-quality Low Lands Ware, and imitated the more luxurious Rhineland colour-coated/black-slipped ware. Two rim fragments and several body sherds (2 MNI) with a black slip were identified as imitations of Nied. 33 cups (Figure 112, 13). The remaining fragments (3 MNI) had a white-yellowish saponaceous fabric, consistent with the Bavay production centres in northern France (Deru and Vachard, 2002). In addition, 36 fragments representing nine individuals were categorised as fine reduced ware and belonged to one of the following fabrics: Low Lands Ware (21 sherds, 6 MNI) and North Gaulish fine reduced ware (15 sherds, 3 MNI). Similar to the fine oxidised LLW ware, the fine reduced LLW ware mainly imitates Rhinish colour coated/black-slipped ware. For example, one vessel (1 MNI) imitated an indented black-slipped cup, while other fragments (1 MNI) resembled the metallic coating of Rhinish black-slipped ware.

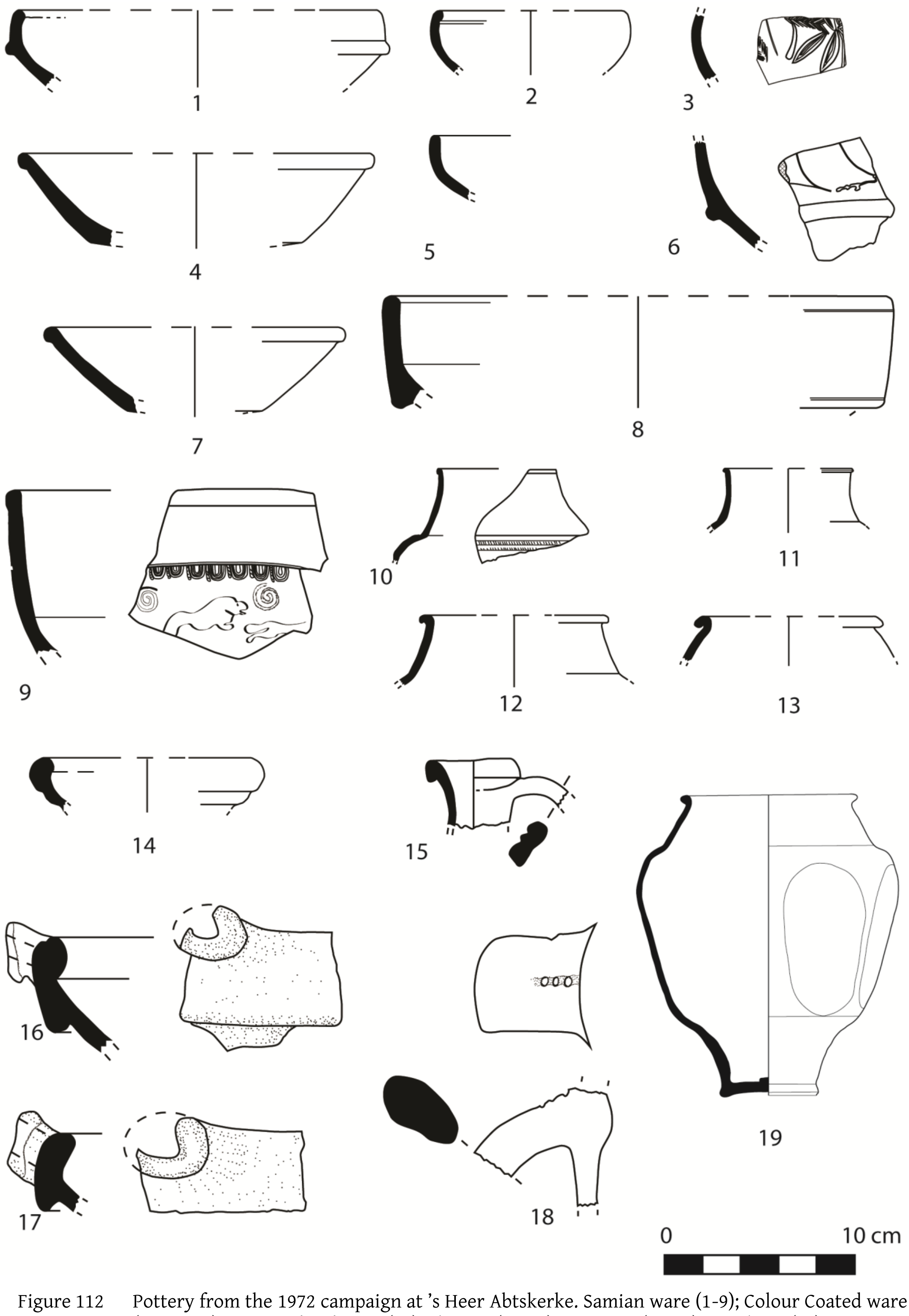


Figure 112 Pottery from the 1972 campaign at 's Heer Abtskerke. Samian ware (1-9); Colour Coated ware (10-11; 19); Fine oxidised ware (13); Flagons (14-15); Mortaria (16-17); Amphora (18).

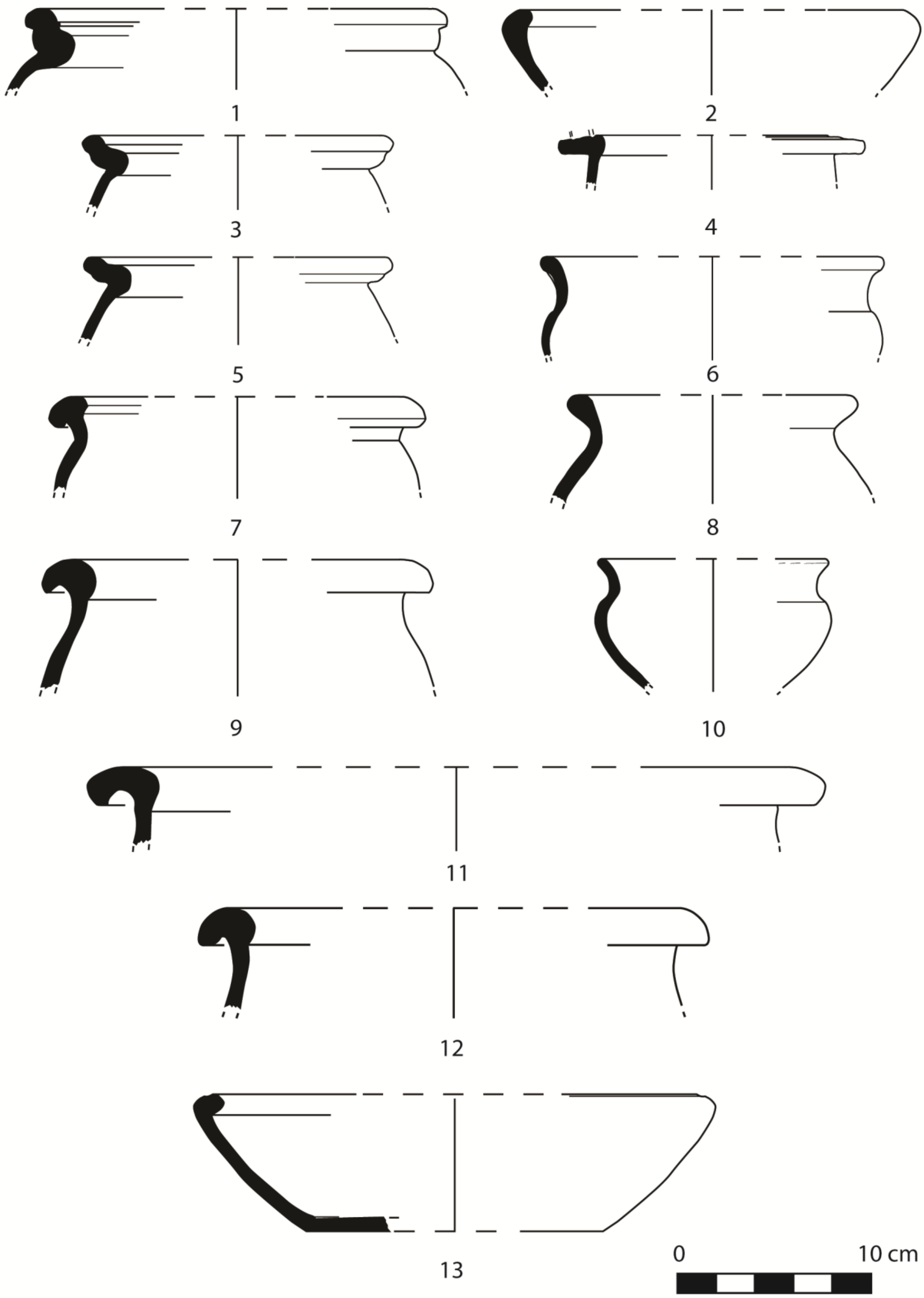


Figure 113 Pottery from the 1972 campaign at ’s Heer Abtskerke. Coarse oxidised ware (1-6); Coarse reduced ware (7-13).

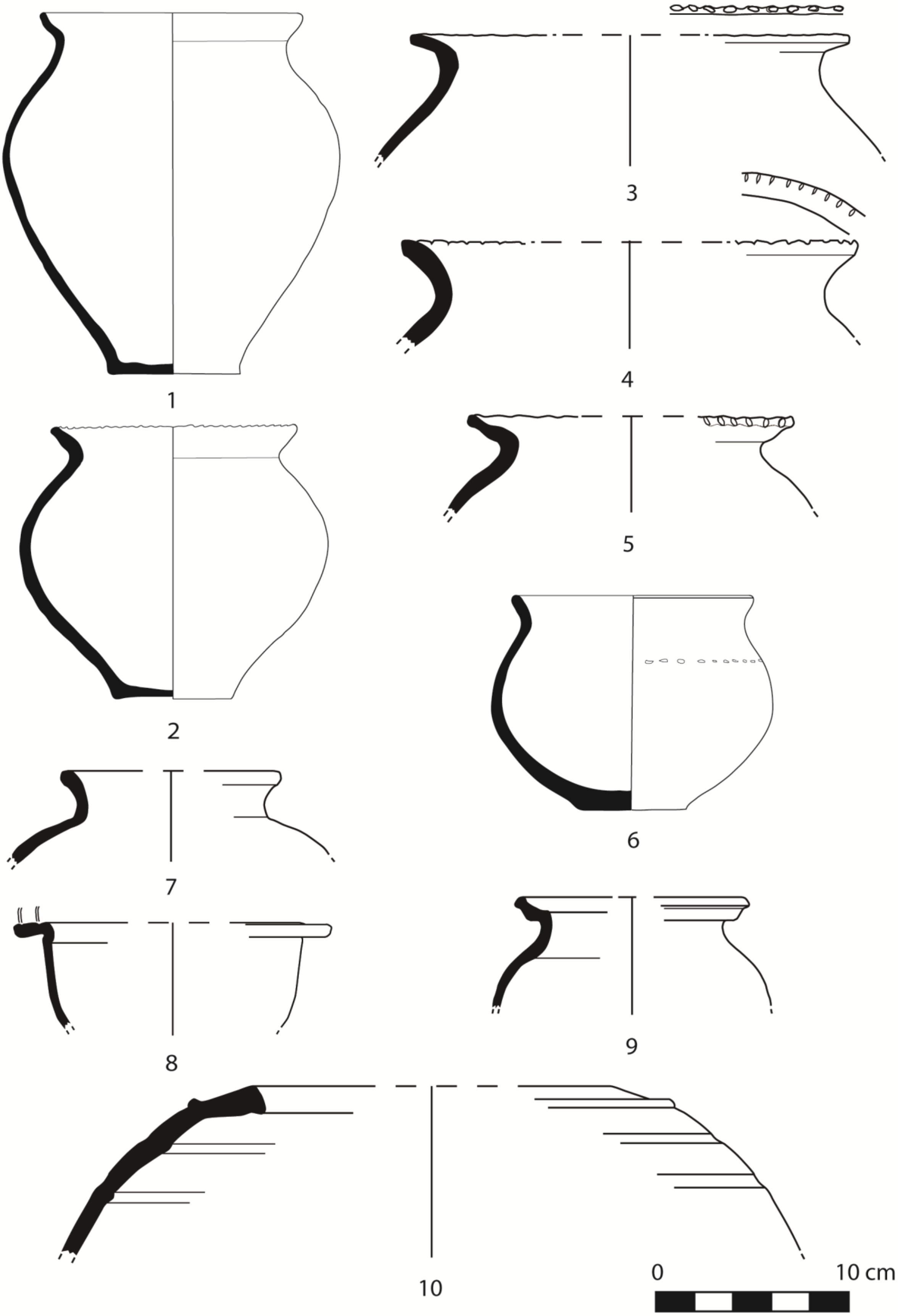


Figure 114 Pottery from the 1972 campaign at 's Heer Abtskerke. North Menapian reduced ware (1-2); North Gaulish reduced ware (7-9); North Menapian handmade (3-6) and Dolia (10)

Flagon fragments take up a large part of the pottery assemblage (379 sherds, 18 MNI), and four large fabric groups were present: Low Lands Ware (154 sherds, 8 MNI); Scheldt valley (90 sherds, 4 MNI); Meuse Valley (51 sherds; 4 MNI) and Rhineland (45 sherds, 1 MNI). Some fragments (38 sherds, 1 MNI) were too heavily burned to assign with certainty to either of the abovementioned fabrics. Several LLW fragments had characteristic ridges with polished surfaces and were sometimes covered with a white slib imitating the Meuse Valley or Rhineland flagons. One LLW handle closely resembled the handles of a Dressel 20 olive oil amphora. These local imitations of Dressel 20 amphorae are fairly common and might have been used to store and transport beer or nut oil (Van der Werff et al., 1997). Unfortunately, very little information could be deduced from the Meuse Valley sherds as no rim fragments were present. Nevertheless, the wall thickness and the exterior surface finish suggest that they were used as tableware rather than storage ware vessels. The Rhineland fragments (46 sherds, 1 MNI) had a high-quality exterior finish and one Niederbieber 62/Stuart 111 type (Figure 112, 15) dating to the end of the second century - early third century was identified (Oelmann, 1914, 58-59; Brunsting, 1937, 96-97; Stuart, 1963, 45).

The assemblage only contained two amphorae fragments: one Gauloise 13 amphora handle (Figure 112, 18) in a north Gaulish fabric imitating a Dr. 20 amphorae (Laubenheimer, 2000) and a fragment with an unknown Iberian fabric. The large storage jars (dolia) are represented by 57 fragments (5 MNI) in three different fabrics: Low Lands Ware (26 sherds, 2 MNI); Meuse Valley (17 sherds; 2 MNI) and North Gaulish (14 sherds, 1 MNI). Similar to the flagons, several LLW fragments had traces of a white engobe. Typologically, one vessel with a flat rounded rim could be interpreted as a small dolia type 'evolution Haltern 89'/Stuart 147 (Figure 114, 10) (Stuart, 1963, 64-65). The mortaria group consisted of 20 sherds (9 MNI) either in Low Lands ware (9 sherds, 4 MNI) or Eifel-Rhine ware (2 sherds, 1 MNI). Again, several of the LLW sherds had the remains of a white engobe imitating the white fabrics from the Meuse Valley or the Rhineland. Typologically, both the LLW and Eifel-Rhine fragments were identified as a type Vanvinckenroye 337, which occurred from the middle of the second century onwards (Vanvinckenroye, 1991, 70-71; Willems, 2005).

The coarse oxidised ware contained 63 fragments (16 MNI) in two fabrics: Low Lands Ware (10 sherds, 4 MNI) and Rhine-Meuse-Eifel group (53 sherds, 12 MNI). In the latter group, fragments from the Meuse Valley (18 sherds; 4 MNI) and Urmitz (2 sherds, 1 MNI) were definitely present. In Low Lands Ware following types were identified: two bowls type Holw. 133-136 (Figure 113, 6), a plate type Holw. 149 and a pot with a lid-seated rim which was possibly a local imitation of a Nied. 89/Stuart 203 type. (Oelmann, 1914, 72; Holwerda, 1923; Stuart, 1963). Fragments from the wider Rhine-Meuse-Eifel region were typologically assigned to a lid-seated pot type Nied. 89 (2 MNI) (Figure 113, 1 and 3), a Stuart 218 type plate (3 MNI) and a lid type Nied. 120 (1 MNI) (Oelmann, 1914; Stuart, 1963). The identified vessels from the Meuse valley corresponded with a lid-seated pot type Nied. 89/Stuart 203 (Figure 113, 5), a bowl with a flat horizontal carinated rim type Stuart 210 (Figure 113, 4), a bowl type Vanvinckenroye 563-65 with a smoked surface (Figure 113, 2) and a lid possible type Nied. 120 (Oelmann, 1914; Stuart, 1963; Vanvinckenroye, 1991). The fragments from Urmitz are part of a lid-type Nied. 120, which is typically dated in the third century (Van Kerckhove, 2014).

The coarse reduced ware comprised 216 fragments representing 55 MNI. The following Low Lands Ware (108 sherds, 29 MNI) vessels were present: sixteen Holwerda 139-142 storage vessels (Figure 113, 7; 9; 11 and 12), three Holwerda 133-136 bowls (Figure 113, 8 and 10), three Holwerda 149 plates (Figure 113, 13) and three lid-seated pots. The latter pots are local imitations of Niederbieber 89/Stuart 203 vessels. The North Menapian reduced ware (68 sherds, 12 MNI) contained one upright rim type NOM RE 1, three carinated bowls with horizontal rim (NOM RE type 13), five globular jar with everted rim (NOM RE type 15), one globular jar with everted lid seated rim (NOM RE type 16) (Figure 114, 1) and a cooking pot type Thoen LOK 2 (Figure 114, 2) (Thoen, 1978a, 182-183; Vanhoutte et al., 2009b). The North Gaulish coarse reduced ware (34 sherds, 12 MNI) consisted of pots with lid-seated rim (3 MNI) (Figure 114, 9), jars with rounded rim (5 MNI) (Figure 114, 7), jar with everted lid-seated rim, carinated bowl with horizontal rim (1 MNI) (Figure 114, 8) and a Nied. 120 lid (1 MNI). Finally, several Rhine-Meuse-Eifel fragments of a type Nied. 89/Stuart 203 vessel were present.

The handmade pottery formed one of the largest groups in the assemblage (322 sherds, 35 MNI). Typologically, cooking pots with everted rims and an S-shaped rim-shoulder evolution (De Clercq type P2/Vanhoutte NOM HA type 10) (Figure 114, 3-5) dominated the handmade assemblage (25 MNI). The rim of most vessels was decorated with fingertips or spatula impressions, while the body sherds showed signs of horizontal, vertical and diagonal comb-scoring decoration. Smaller everted rim fragments with a weak S-shaped rim-shoulder evolution (4 MNI) (Figure 114, 6) corresponded either with a De Clercq type P4 cooking pot or a De Clercq type K4 bowl (De Clercq, 2009c, 406-421). Finally, fragments of several handmade lids (3 MNI) were also present.

7.3.4.2 Briquetage material and other salt production related finds

Apart from the pottery, both the 1972 and the 2020 excavations contained various waste materials. Remarkably, just as at Leffinge, no fragments of ceramic evaporation vessels or support material like pedestals could be identified. Instead, the debris layers contained large quantities of vitrified clay fragments (Table 26). Ovaa (1975) explicitly mentioned that the debris layers of the 1972 campaign contained green-glazed ‘slags’. However, only a small amount (11 fragments weighing 967g) was preserved, suggesting that sampling took place during the excavation. In contrast, 2856 vitrified clay fragments weighing 132 kg were collected during the 2020 campaign (Table 26).[117] As shown by Figure 115, these vitrified fragments are morphologically highly similar to those discovered at Leffinge (section 7.2.4.2). Therefore, the morphological description of these fragments will not be repeated here. Interestingly, none of the fragments had distinct characteristics confirming that these fragments represent an unintentional and unwanted byproduct of the salt production activities. Samples of both campaigns were selected for petrographic and geochemical analyses, which are presented in Chapter 8.

In addition to the vitrified clay fragments, large quantities of the white, very porous, soft heterogeneous cemented ‘ash slags’ were present (Table 26; Figure 116). Except for a few fragments discovered in the 1972 campaign, most objects (350 fragments weighing 71 kg) were recovered in the refuse zone. At first glance, the composition of the objects is highly similar to the composition of debris layer 1001 in which they primarily occurred, suggesting that they formed through some kind of ‘cementation’ process. However, which processes took place and whether the objects were composed of ash or other types of salt production waste is still unclear. That is why several samples were selected for further geochemical analyses. For more information on these analyses, see Dekoninck et al. (In prep).

[117] For a detailed registration of the vitrified material, see APPENDIX 4B

Table 26 Quantification of the briquetage material and other salt production related finds at ‘s-Heer Abtskerke – ‘s Gravenpolder

Find category	Fragments (N)	Weight (g)	Mean piece weight (g)
1972 campaign			
Briquetage: miscellaneous material			
Fired clay	4	286	71.5
Briquetage: structural material			
Vitrified clay fragments	11	967	87.91
Waste material			
Cemented ‘ash slag'	5	452	90.40
2020 campaign			
Briquetage: miscellaneous material			
Fired clay	61	2137	32.03
Briquetage: structural material			
Vitrified clay fragments	2856	132536	46.40
Waste material			
Cemented ‘ash slag'	350	70989	202.82

Figure 115 Selection of the vitrified clay fragments discovered at ’s-Heer Abtskerke – ‘s Gravenpolder. On the left, the flat/slightly plano-convex (vitrified) sandy clay bottom of the fragments is shown above and the the vitrified surface exhibiting a fluidal structure is shown below. The bottom right images depict the cross-section of the top right objects (© Cedric Verhelst).

Figure 116 Example of a cemented ‘ash slag’ recovered during the 2020 excavation (© Cedric Verhelst).

All waste materials from the refuse zone were collected and assigned to a grid of 5 by 2m, except for 33 ‘ash slags’ (10%) and 684 vitrified clay fragments (24%). This collecting strategy enabled a discussion of the find distribution of the different waste categories. To facilitate the comparison with the refuse zone at Leffinge, the vitrified material's find density (finds per square meter) and the ‘ash slags’ were calculated for each rectangle. The distribution of both waste categories across the refuse zone is shown in Figure 117 and Figure 118. Interestingly, vitrified clay fragments exclusively occur in the western and central part of the refuse zone, while the ‘ash slags’ were mainly found in the central and eastern parts of the excavation. The central part of the refuse zone is a transition zone in which both categories occur. This dichotomy matches the distribution of debris layers 1001 and 1015 in the refuse zone. As such, the refuse zone appears to be divided into a western and eastern section. Since the composition of the debris layers differs significantly, each zone might have been used to dispose of waste materials from different steps in the production process.

As will be discussed in Chapter 8, the vitrified material primarily formed at the base of the hearths, which was an unwanted side effect that occurred during production. Therefore, these hearths were regularly cleaned to remove the vitrified material. At ‘s-Heer Abtskerke - ‘s Gravenpolder, the refuse from cleaning and/or repair activities ware then dumped together with ash in the western part of the refuse zone forming debris layer 1015. At the moment, it is still unclear which stage in the production process provided the refuse for debris layer 1001. As indicated above, the chemical composition of the ‘ash slags’ might shed light on how these objects formed, which will help identify the production step from which the refuse emanates. Why the waste from different production steps was dumped in different parts of the refuse zone is difficult to answer. At first glance, this served no functional purpose, and the reasons might be related to how the refuse management was organised at the onset of production.

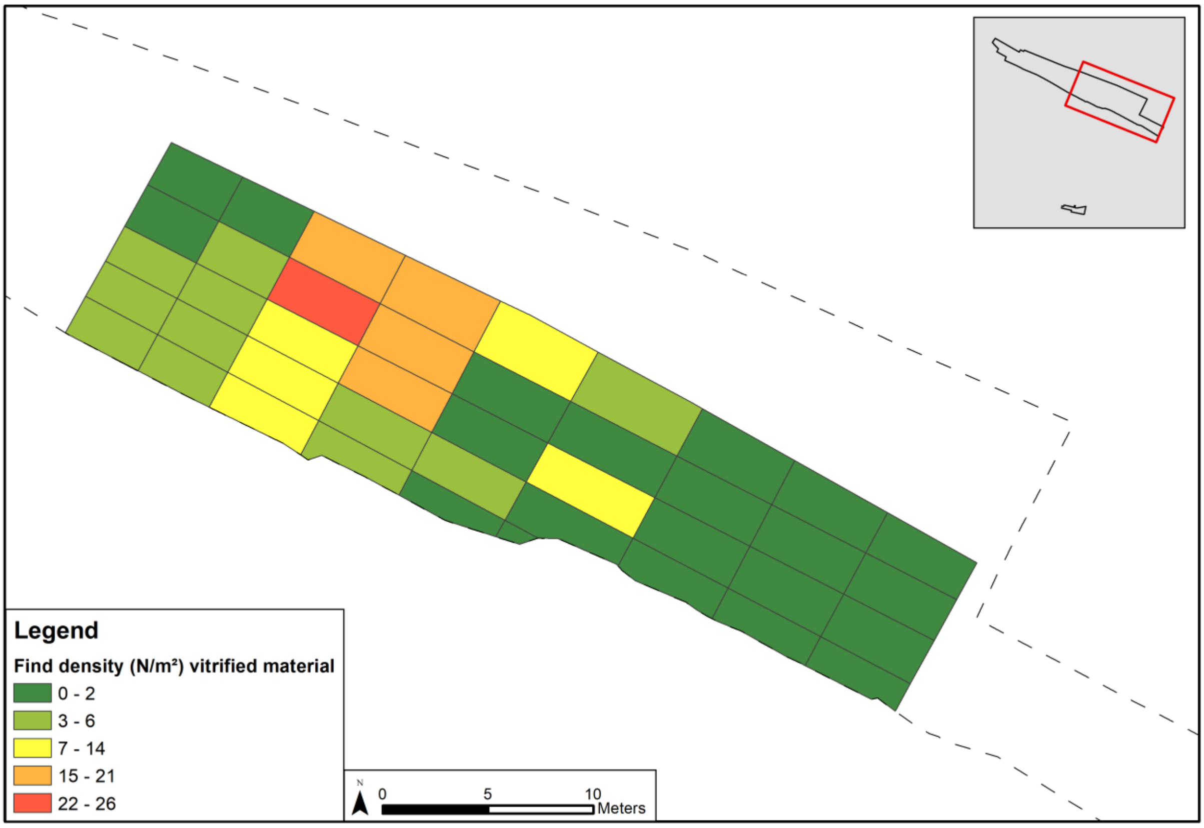


Figure 117 Distribution of the vitrified material in the refuse zone at 's-Heer Abtskerke – 's Gravenpolder

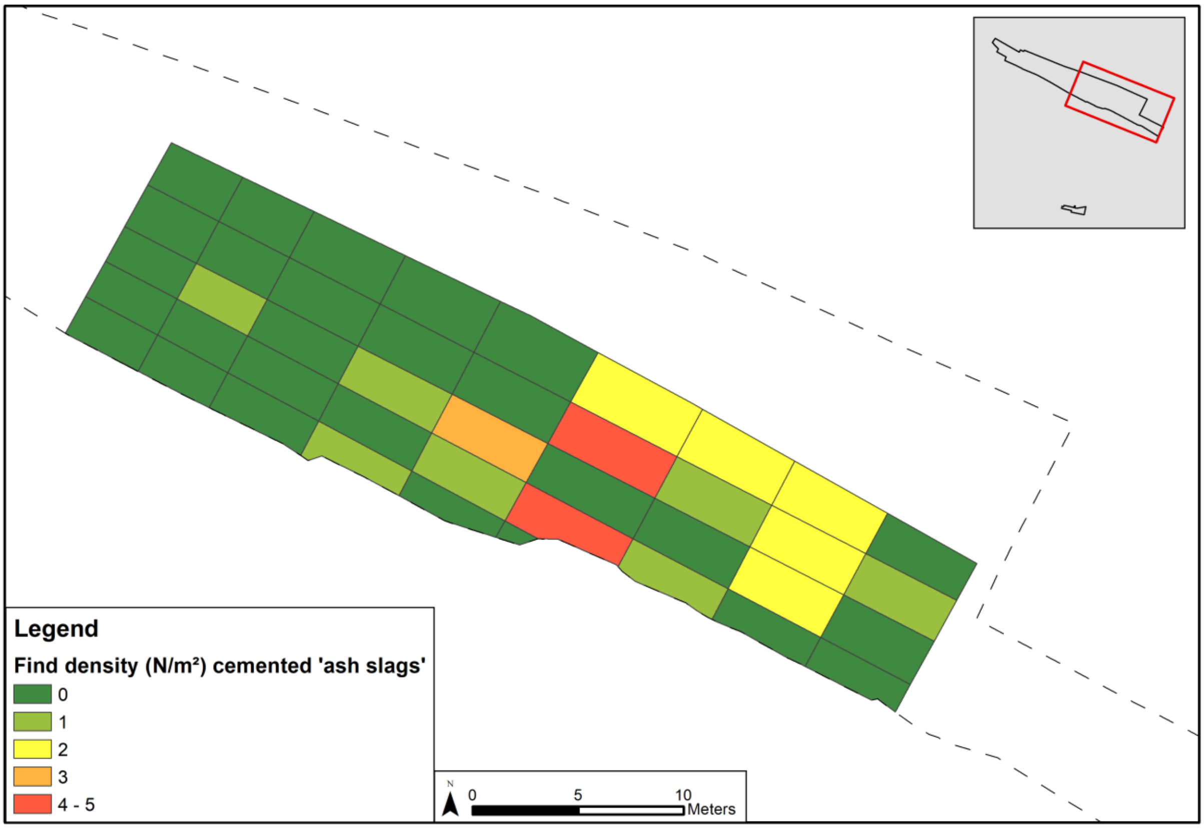


Figure 118 Distribution of the cemented 'ash slags' in the refuse zone at 's-Heer Abtskerke – 's Gravenpolder

7.4 Middelburg Oude Vlissingseweg

7.4.1 Introduction

7.4.1.1 Research history

The site Middelburg Oude Vlissingseweg on the corner of the Gandhistraat and the Amnestylaan (Middelburg) was discovered by members of the AWN in 1967. The first excavations took place in 1981 under the supervision of van den Berg (R. M. Van Heeringen, 1989). The excavation consisted of two trenches and covered an area of 355 m² (Figure 119). In 1988, Van Heeringen (1989) conducted additional excavations and discovered an approximately 40 cm thick ash layer on top of the peat, which he related to the nearby artisanal activities. However, the exact position of the 1988 excavation and its relation to the 1981 excavation is unclear. In addition, the 1988 excavation yielded no archaeological features *in situ*. Therefore, only the 1981 excavation will be discussed from this point onwards.

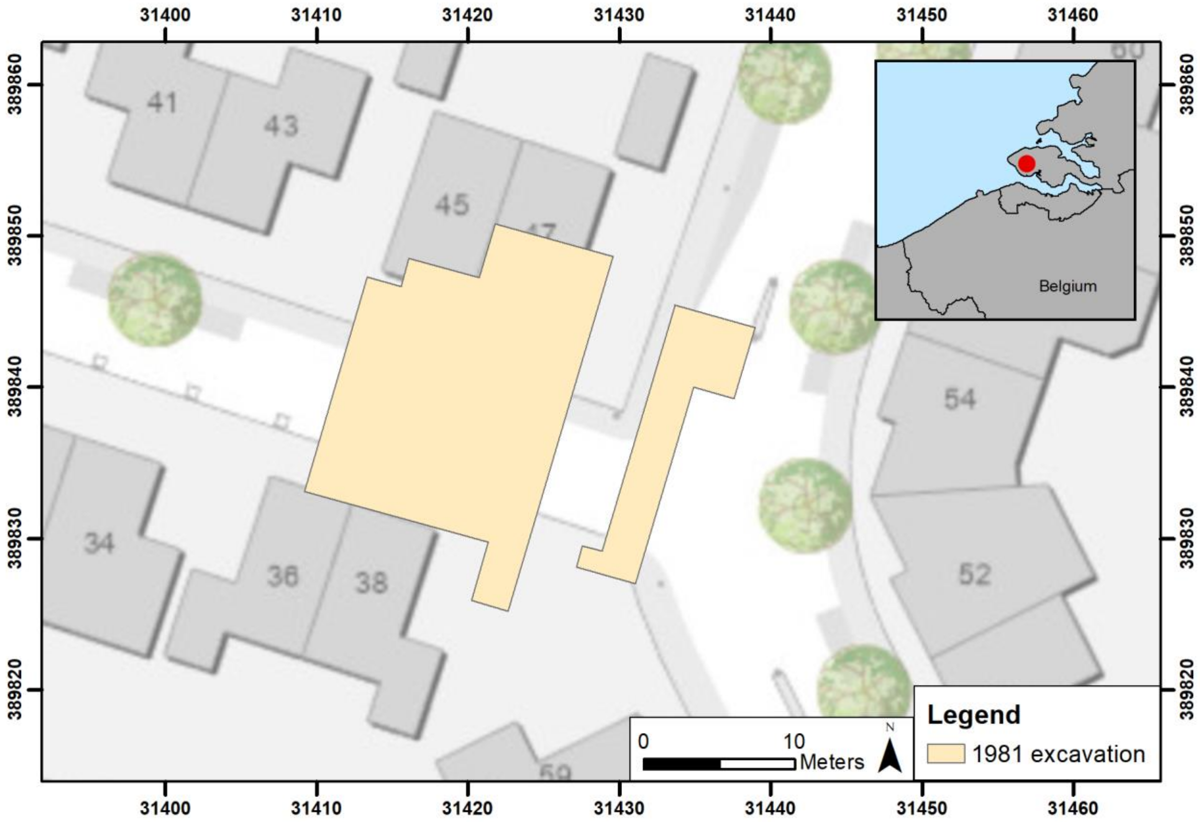


Figure 119 Positioning of the 1981 excavation trenches at Middelburg

Similar to 's Heer Abtskerke, the site of Middelburg Oude Vlissingseweg was at some point interpreted as a lime manufacturing site. Indeed, van den Berg (1988), an ardent defender of the lime production hypothesis, used the site of Middelburg Oude Vlissingseweg to support his main arguments. According to van den Berg (1988), the presence of ash layers with a high Ca-content, the green glazed, vitrified clay slags and shell concentrations are indicative of lime production rather than salt production. As indicated above (7.3.1.1), these arguments are refuted in Chapter 5

7.4.1.2 Fieldwork methodology and post-excavation processing

Little is known about the fieldwork methodology at Middelburg Oude Vlissingsweg. The excavation archive contained several excavation plans drawn by van den Berg, which we georeferenced and digitised in ArcGIS to create an all-feature plan of the excavation. Unfortunately, except for a few annotations on the plans, detailed feature and layers descriptions by the excavators are lacking, complicating the interpretation of the site. Nevertheless, by combing all available information a new feature list, plans and described trench profiles (APPENDIX 4A) were compiled to be used in the following sections.

7.4.2 Topography and landscape surrounding the site

The salt production site of Middelburg Oude Vlissingseweg was situated on top of the Holland peat near the side branch of a larger tidal channel (Figure 120). Although Figure 120 depicts the extent of the post-Roman channel network, it is highly likely that the larger channels had Roman predecessors. This may have been case for the larger channel and the tributary on which the site was located. In addition, the origin of several smaller linear creeks might go back to Roman drainage ditches or attempts to control the water flow to artisanal sites.

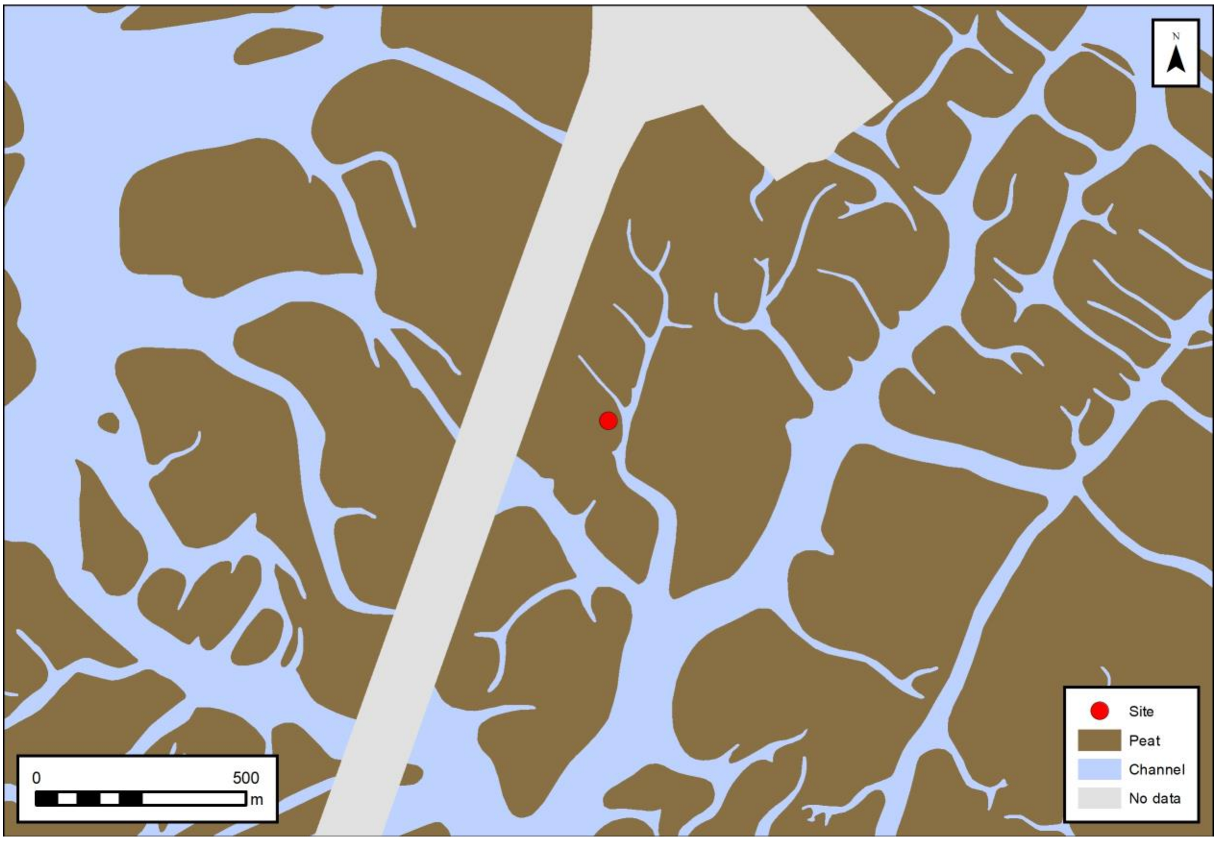


Figure 120 Position of the salt production site Middelburg Oude Vlissingseweg on a simplified version of Bennema and van der Meer's soil map of Walcheren (1947) showing the extent of the post-Roman channel network (map made by D. de Ruijsscher).

7.4.3 Structures and features related to the salt production activities

The excavation at Middelburg Oude Vlissingseweg revealed the remains of an extensive Roman artisanal site. As mentioned in section 7.4.1.2, the absence of detailed feature and layer descriptions complicated the site's interpretation. Except for a few modern disturbances, all identified features stem from the mid-Roman period (Figure 121). The northern part of the excavation contained an artificially raised work floor with a small row of four hearths constructed in a raised clay bank. Two additional heating structures were found outside the clay bank. One hearth was situated immediately east of the clay bank, while the other hearth was found at the southern end of the work area. The southeastern part of the site may have served as a large refuse zone and contained several refuse dumps.[118]

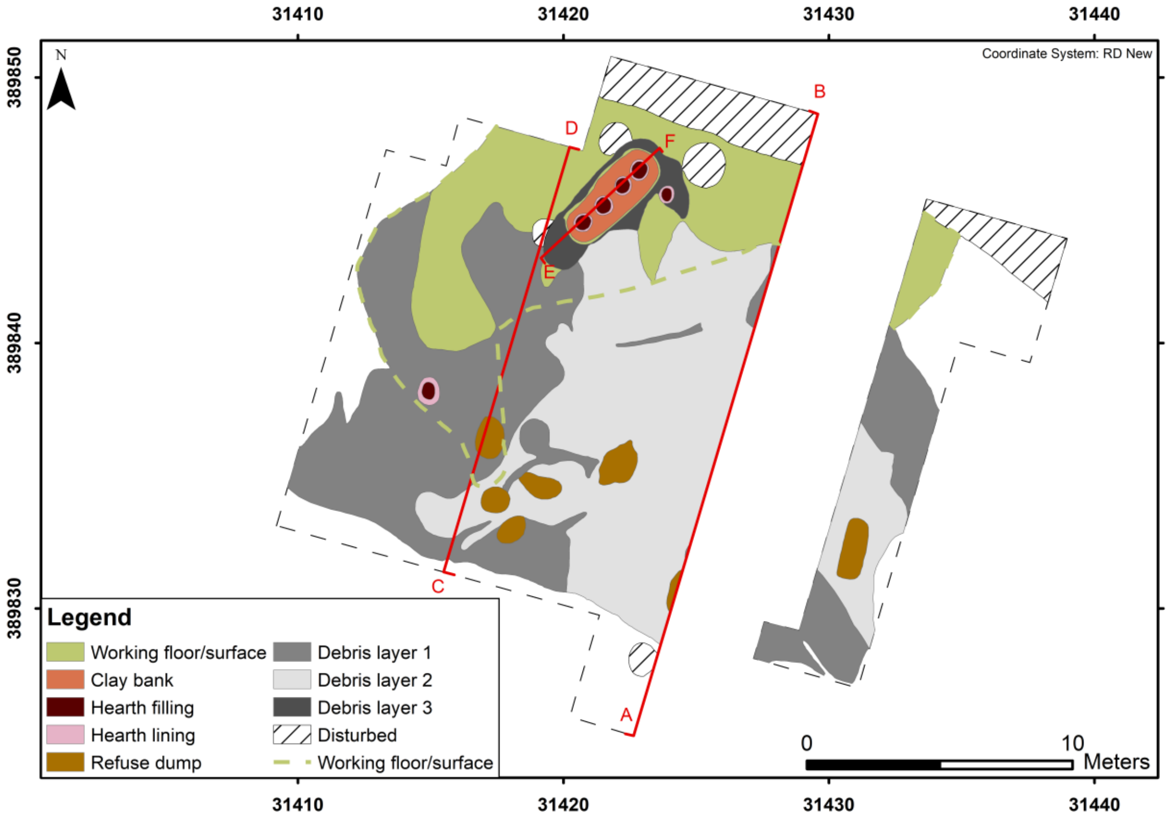


Figure 121 Excavation plan late second-early third century salt production site Middelburg Oude Vlissingseweg

[118] For a detailed feature list, see appendix 4A

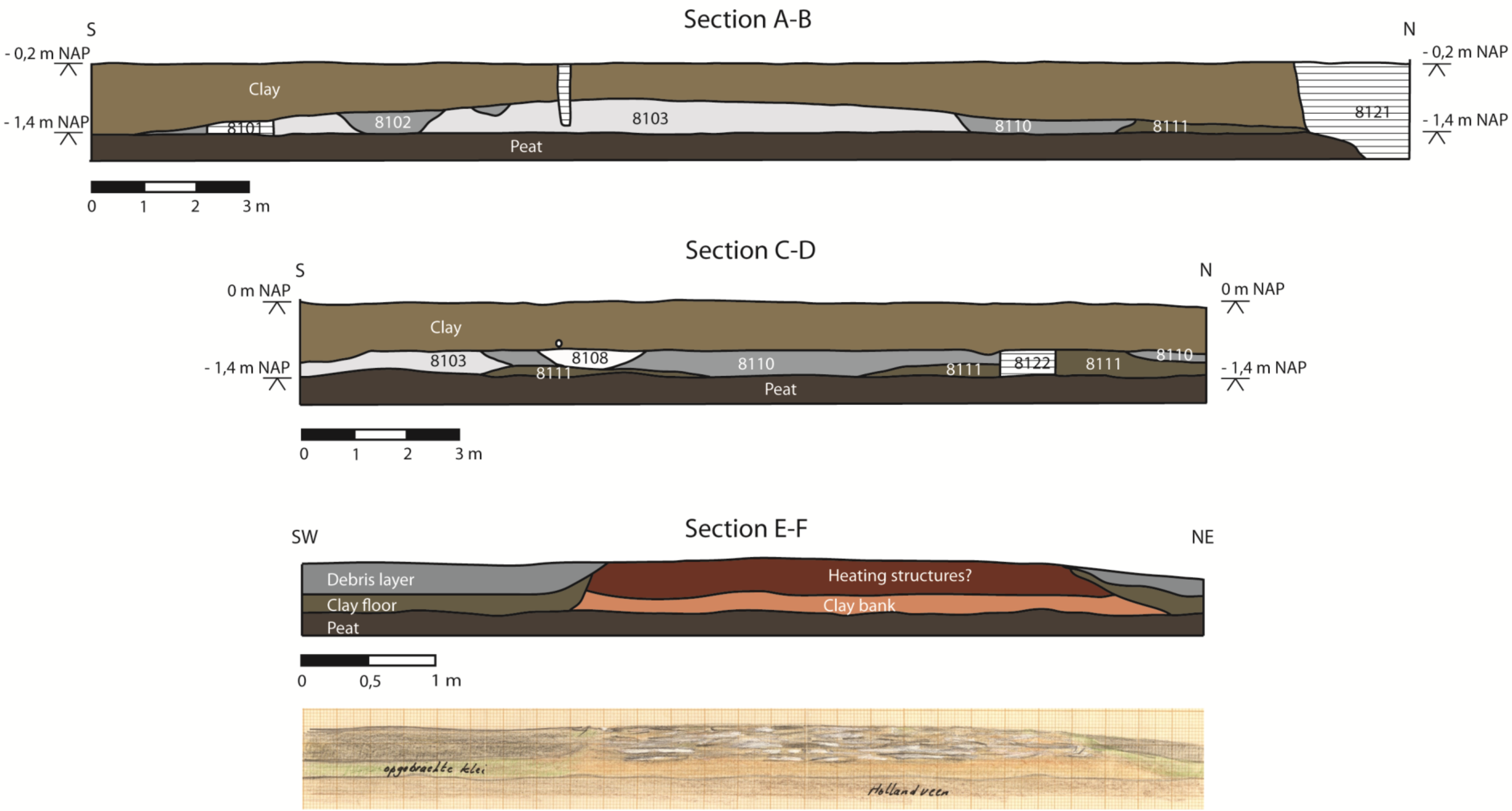


Figure 122 Digitised cross-sections of Middelburg Oude Vlissingseweg. The numbers refer to the individual features and are used throughout the text.

7.4.3.1 Work zone

In the northwestern part of the excavation, a work floor (feature 8111) was identified on top of the Holland peat (Figure 121). This work floor consisted of an approximately 0.2-0.3 m thick clay layer cast on top of the peat (Figure 122, section C-D). The work floor had an amorphous shape and covered an area of ca. 100 m². The construction of this working area required at least 25 m³ of clay, most likely originating from the site's immediate surroundings. As the work floor was cut by a (post)-medieval peat extraction pit, it is plausible that this area extended beyond the limits of excavation. Towards the south, the clay floor was covered by a 0.2-0.5 m thick debris layer (feature 8110). The accumulation of debris on top of the work floor suggests that the workspace was no longer required at some point and gradually became part of the refuse zone. This slightly raised clay platform with debris (ash, pottery, slags etc.) trampled into the surface provided a more solid underground for artisanal activities. Similar working floors were noted by Hathaway (2013, 256-261) on salt production sites in southern Britain.

7.4.3.2 Heating infrastructure

The heating structures were located in the northern part of the excavation and consisted of a clay bank in which four hearths were constructed (Figure 123). The SE-NW aligned, sub-rectangular clay bank measured 4.35 m in length, 1.75 m in width and was preserved up to 0.4 m. Based on the cross-section (Figure 122, section E-F), the clay bank was constructed simultaneously with the working area on top of the peat. The construction required at least 3 m³ of clay which, like the clay floor, most likely had a local origin. Four circular heating structures or hearths can be identified in this clay bank. Unfortunately, these heating structures are not well documented in cross-section (Figure 122, section E-F), and little can be inferred regarding their construction method.

Van den Berg (1988) interpreted this clay bank as a large fireplace (6 by 4 m) where fires burned around circular shell mounds, which the producers covered with clay to encapsulate the heat. The circular features visible in plan would then have formed by heating these circular shell mounds several times. However, based on the similarities with the hearth batteries at Leffinge and 's Heer Abtskerke, it is clear that each circular feature (8117-20) represents an individual hearth constructed into the clay bank at regular intervals (ca. 0.15-0.25 cm between each hearth). No stokeholes were recorded, but minor annotations on the plans indicate a possible east-facing entrance. The four circular hearths had an internal diameter of 0.60 m with a preserved hearth lining measuring between 0.1 and 0.15 m in width (Figure 123). Around the clay bank and the hearths, debris (feature 8815) consisting of clay mixed with char(coal) and vitrified clay fragments accumulated on top of the work floor, forming an ash-rich debris deposition.

Apart from the hearth battery, two additional heating structures were recorded. Hearth 8114 was situated 0.4 m west of the clay bank, while hearth 8109 was constructed on the southern end of the work floor approximately 7.5 m southeast of the hearth battery (Figure 123). Hearth 8114 had a diameter of 0.5 m with a 0.1 m thick hearth lining. Hearth 8109 was slightly bigger, with a diameter of 0.6 m and a hearth lining of approximately 0.2 m. Unfortunately, no stokeholes were attested, and no sections were made on either hearth. This lack of data makes it impossible to deduce the construction technique and interpret their relationship to the ash layers. These additional heating structures raise questions about the site's chronology as all hearths might not have been simultaneously in use. Indeed, if all hearths were used at the same time, they would have been constructed in the clay bank to maximize production efficiency. Alternatively, the hearths might have been used simultaneously, but in different stages of the salt production process or they were involved in other artisanal activities.

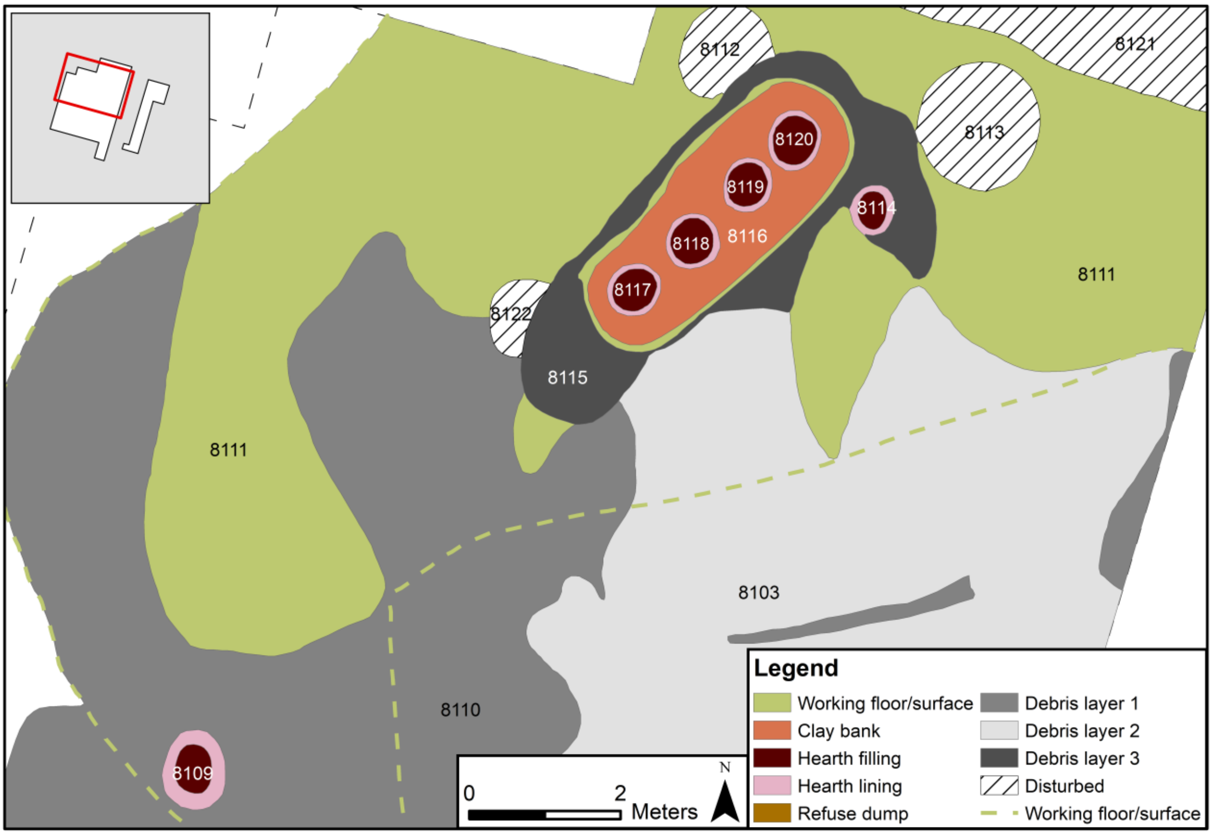


Figure 123 Detailed excavation plan of the heating structures at Middelburg Oude Vlissingseweg

7.4.3.3 Refuse zone

The southern part of the excavation consisted primarily of debris layers and may have acted as a refuse zone. In this refuse zone, two distinct debris layers (8103 and 8810) with slightly different compositions were present as well as several amorphous refuse dumps (8102; 8104-08). Debris layer 8810 consisted of a 0.2-0.5 m thick deposit of clay mixed with ash, charcoal, vitrified clay and pottery fragments. Debris layer 8103, on the other hand, was 0.4-0.65 m thick and made up of white ash, cemented 'ash slags', green glazed vitrified clay fragments, charcoal and pottery fragments. The main difference between both layers thus seems to be the higher white ash content and the presence of cemented 'ash slags'. In addition, several individual refuse dumps (8102; 8104-08) were recognised in the centre of the excavation. The dimensions and shape of these dumps varied between circular features of approximately 1 m diameter and more amorphous dumps of ca. 1.95 m in length and 1.22 m in width. These refuse dumps mainly consisted of large concentrations of mussels, cockles and oyster shells. According to van den Berg (1988), the large concentration of shells in these refuse dumps proves the site's function as a lime manufacturing plant. However, as discussed in section 2.4, these shells can just as easily be attributed to consumption practices as large concentrations of shells are frequently found on non-artisanal habitation sites in the coastal plain as well, for example, at Plassendaele (Vanhoutte and De Clercq, 2007), Steene (Demey et al., 2013) and Serooskerke (Dijkstra and Zuidhoff, 2011).

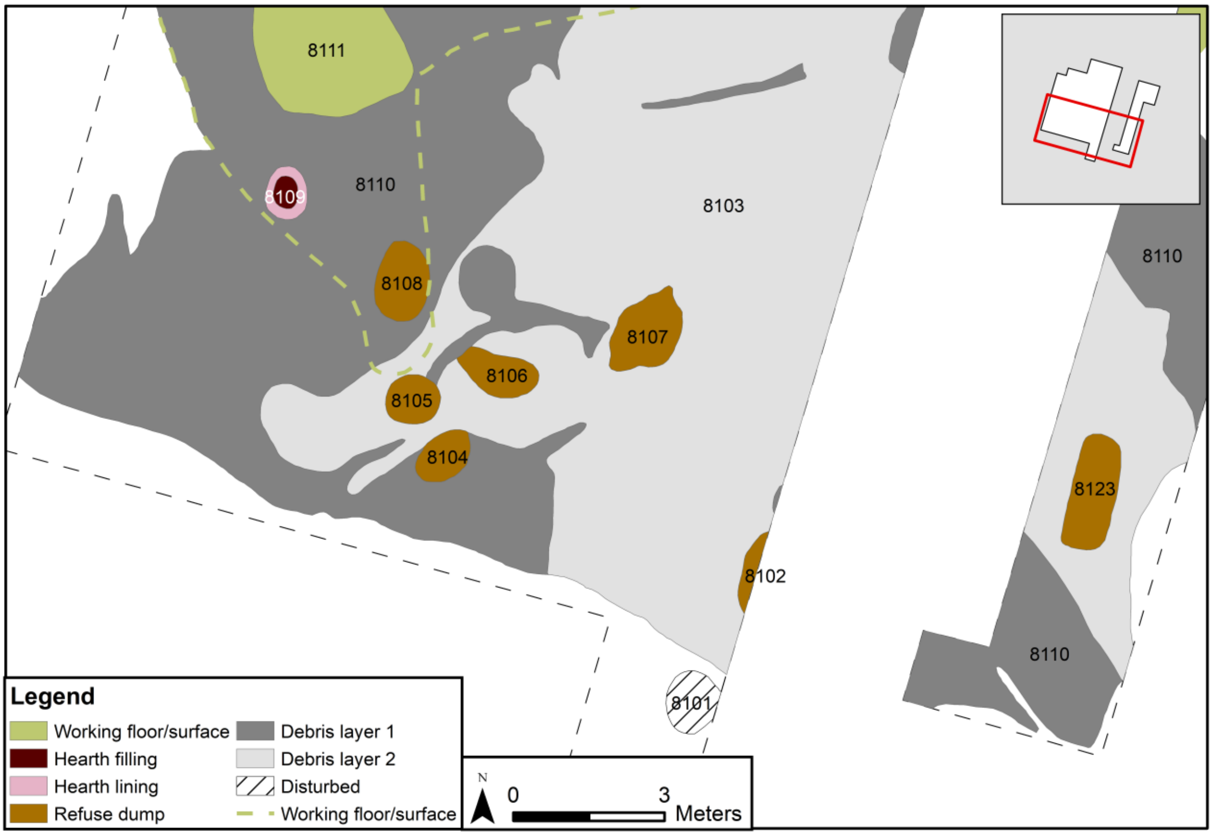


Figure 124 Detailed excavation plan of the refuse zone at Middelburg Oude Vlissingseweg.

7.4.4 The finds

7.4.4.1 Pottery

The pottery of Middelburg Oude Vlissingseweg was examined and integrated into De Clercq's (2009a, 2009c) doctoral dissertation:. De Clercq (2009a) focused primarily on the handmade pottery of the site, but he quantified all fragments in main fabric groups using sherd count and MNI. Therefore, the pottery was not re-examined in detail, and the following section is based on De Clercq's observations (2009a).

In total, the pottery assemblage contained 1938 sherds, representing a minimum number of 265 individuals (Table 27). The relatively high amount of samian ware (6.8% of the sherds, 20.8% of the MNI) with an East-Gaulish provenance (primary production from Rheinzabern and Trier) is remarkable. Typologically, fragments of Drag. 31 (fig. 1 nr. 6), Drag. 33 (fig. 1 nr. 1-3), Drag. 37 (fig 1 nr.9, fig. 2 nr. 1), Drag. 40 (fig. 1 nr. 4), Drag. 43/45 (fig. 1 nr. 7), Drag. 44 (fig. 1 nr. 5) and Drag. 45 (fig. 1 nr. 8) could be recognised. One of the decorated Drag. 37 bowls show a hunting scene of dogs chasing hares (fig 1 nr.9), while another bowl depicts a repeating pattern of i.a. birds (fig. 2 nr. 1). Stylistically, these decorated bowls belong to the '*Censor-Dexter-Criciro Nachfolger*' group which is dated between 180-250 AD (De Clercq, 2009a). The presence of Samian ware mortaria supports this dating (Drag. 43 & Drag. 45), which occur from 170 CE onwards (Brulet et al., 2010).

Table 27 Quantification of the pottery fragments recovered at Middelburg Oude Vlissingseweg

Fabric Group	Sherd-count (N)	Percentage (%)	MNI (N)	Percentage (%)
Samian ware	132	*6.8%*	55	*20.8%*
Colour-coated ware	36	*1.9%*	8	*3.0%*
Terra nigra like ware	7	*0.4%*	1	*0.4%*
Flagons	432	*22.3%*	16	*6.0%*
Dolia	51	*2.6%*	3	*1.1%*
Mortaria	5	*0.3%*	3	*1.1%*
Oxidised ware	63	*3.3%*	27	*10.2%*
Reduced ware	419	*21.6%*	44	*16.6%*
Handmade ware	793	*40.9%*	109	*41.1%*
Total	**1938**	**100%**	**265**	**100%**

Next to samian ware, colour-coated ware from Cologne and Trier formed a small part of the pottery assemblage (6.8% of the sherds, 3% of the MNI). Typologically, several Niederbieber 32 (fig. 2, nr. 2) and Hees 7 (fig. 2, nr. 4) cups were present as well as one type Niederbieber 40 plate (fig. 2, nr. 3). In addition, the assemblage contained small groups of terra nigra, oxidised ware, mortaria and dolium fragments (Table 27). Furthermore, the flagon category consisted of 432 sherds (22.3%), representing 16 individuals (6%). The reduced ware (21.6 % of the sherds, 16.6% of the MNI) comprised the Low Lands Ware and the North Menapian reduced ware. In Low Lands ware fabric, the characteristic Holwerda 142 storage/transport vessel (fig. 2, nr. 10; fig. 3, nr. 1) was present as well as several types of flagons (fig. 3, nr. 3-6). Atypical was a high-quality bowl closely resembling (a prototype of) the late-Roman Chenet 342 type (fig. 2, nr. 6). Similar vessels were found in the Roman fort of Oudenburg in mid-third century contexts (De Clercq, 2009a; Vanhoutte et al., 2009b). Apart from the LLW, a few Urmitz Niederbieber 89 (fig. 3, nr. 2) vessels were identified. In the North Menapian reduced ware, particularly the presence of the carinated bowls with horizontal rim (fig. 2, nr. 8-9) should be emphasised as these vessels are characteristic of the so-called Coastal Ware production (Thoen, 1978a, LOK type 6). According to Vanhoutte et al. (2009b), this type (NOM RE type 13) emerged around the third quarter of the second century and became popular in the first half of the third century.

Finally, a large amount of North Menapian handmade pottery was present (793 sherds representing 109 individuals). Typologically, P2 cooking pots dominate the handmade category (73 MNI), followed by P16 pots (25 MNI). Apart from cooking pots, a small amount of K12 bowls or dishes (9 MNI) and one dish type B10 were identified. Both the identified fabrics, the vessel types and decoration schemes are characteristic of De Clercq's (2009c) coastal group dated between ca. 150/170 – 270 CE. This handmade pottery group occurs on sites in the Menapian coastal plain and/or in the Pleistocene hinterland near tidal landscapes. In Zeeland, this group displaces the so-called 'Zeeland style', which dominated the first century - early second century pottery assemblages (e.g. Ellewoutsdijk, Koudekerke etc.) (De Clercq, 2009c, 423-444).

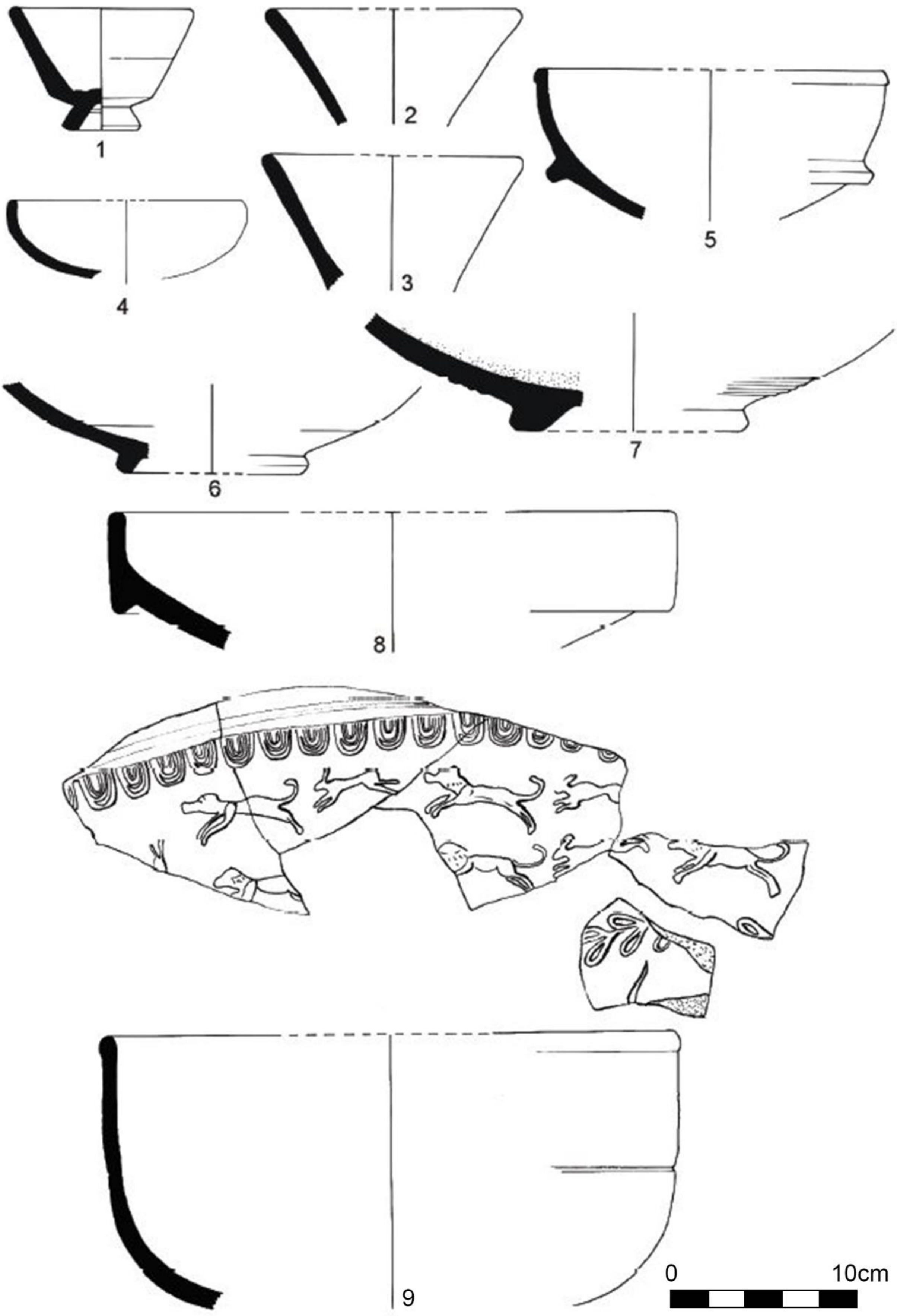


Figure 125 Pottery from Middelburg Oude Vlissingseweg. Samian ware (1-9) (De Clercq 2009a, fig. 79).

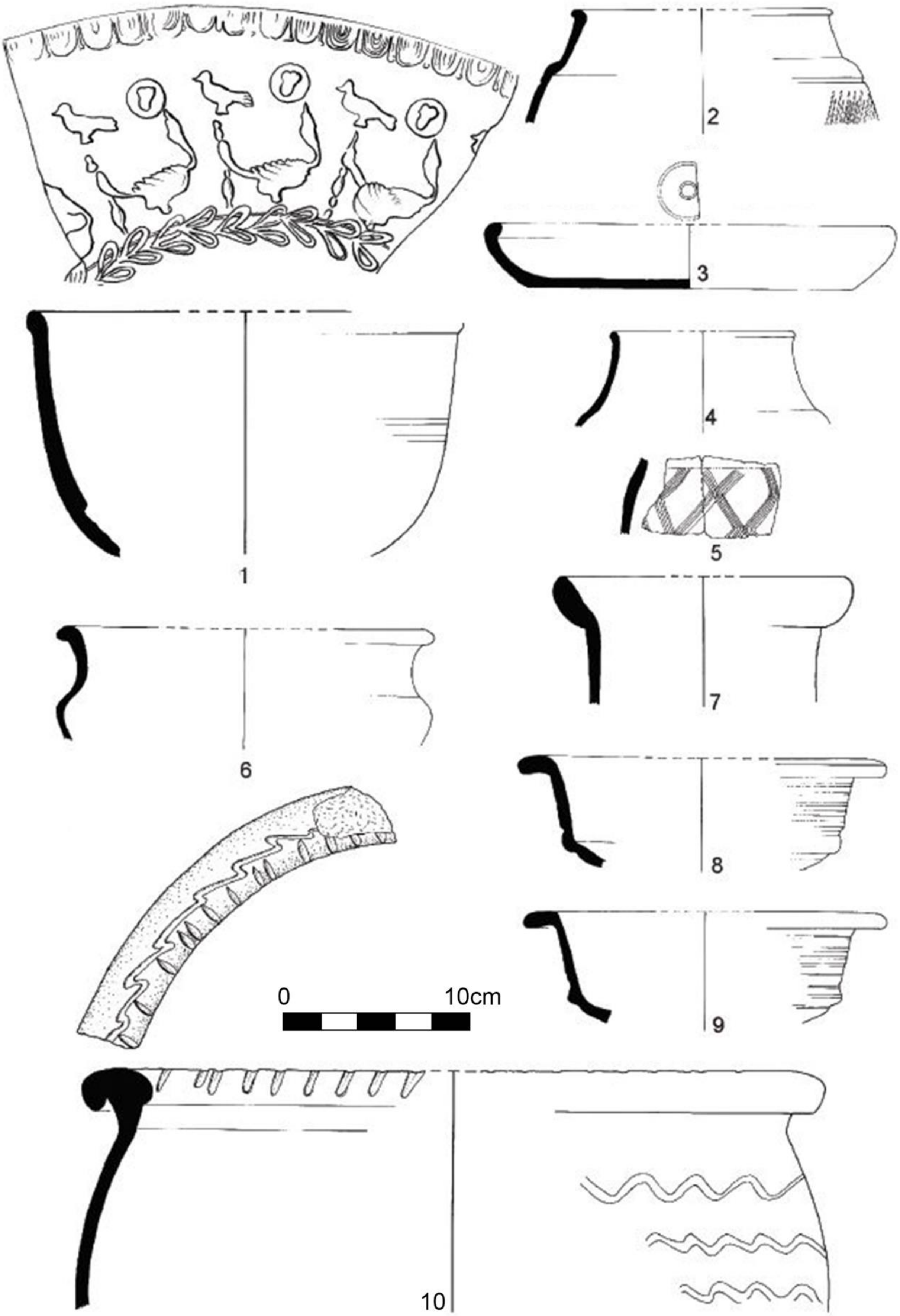


Figure 126 Pottery from Middelburg Oude Vlissingseweg. Samian ware (1); Colour Coated ware (2-4); Terra nigra (5); LLW (6 & 10); North Menapian reduced ware (8-9) (De Clercq 2009a, fig. 80).

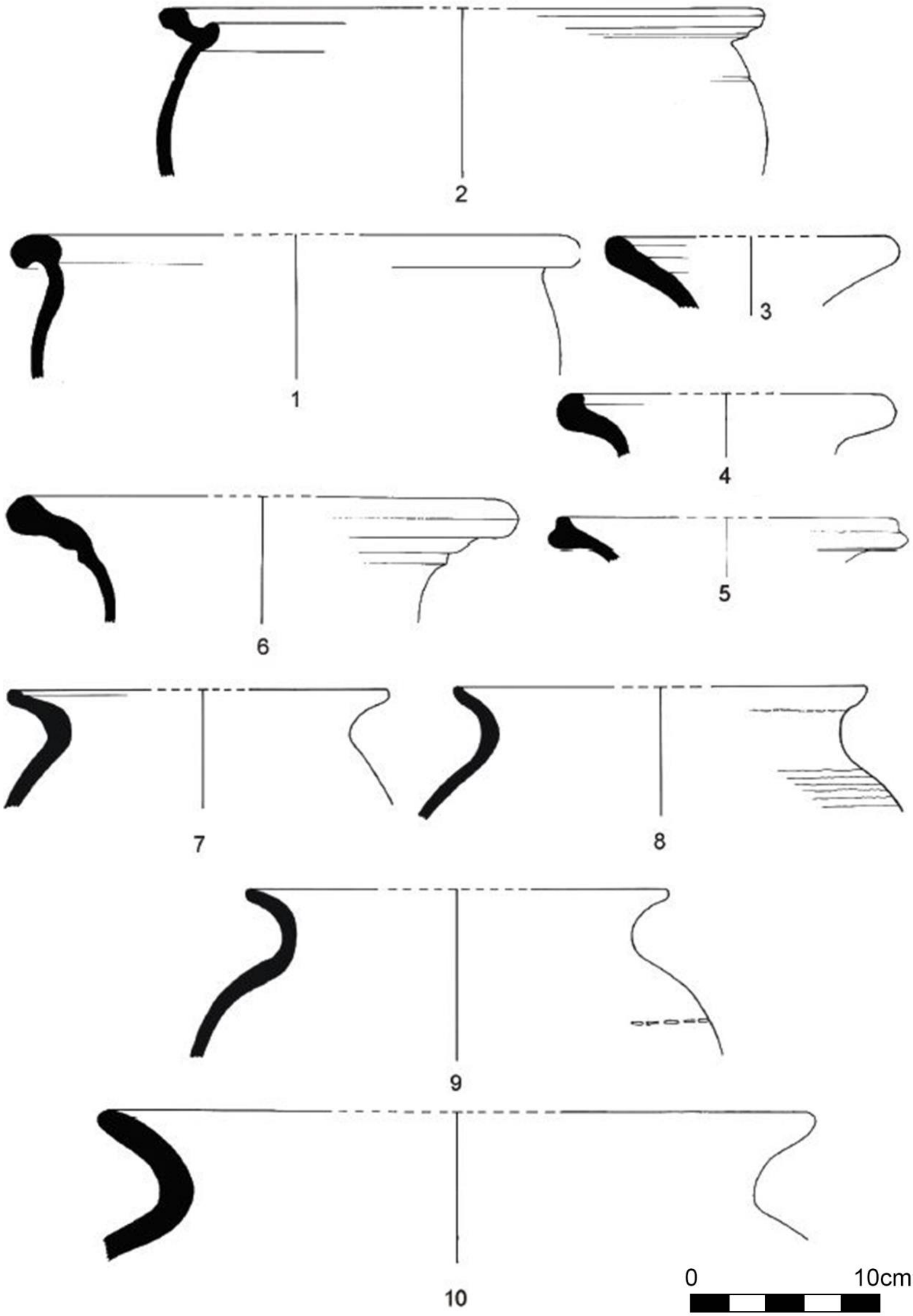


Figure 127 Pottery from Middelburg Oude Vlissingseweg. LLW (1; 3-6); Urmitz ware (2); North Menapian handmade (7-10) (De Clercq 2009a, fig. 81).

7.4.4.2 Briquetage and other salt production related finds

Similar to Leffinge and the complex ‘s-Heer Abtskerke-‘s Gravenpolder no fragments of ceramic evaporation vessels or support material like pedestals were found. Instead, the site contained fragments of fired clay, vitrified clay and cemented ‘ash slags'. Although van den Berg (1988) explicitly mentioned that large quantities of green-glazed ‘slags’ occurred on site, hardly any fragments were preserved, suggesting that only a small sample of the material was collected during the excavation (Table 28). As shown by Figure 128, these vitrified fragments are highly similar to the Leffinge (7.2.4.2) and ‘s-Heer Abtskerke-‘s Gravenpolder (7.3.4.2) examples making a detailed description somewhat redundant here. Two samples were selected for petrographic and geochemical analyses, and these results are presented in Chapter 8.

Table 28 Quantification of the briquetage material and other salt production related finds at Middelburg Oude Vlissingseweg

Find category	Fragments (N)	Weight (g)	Mean piece weight (g)
Briquetage: miscellaneous material			
Fired clay	1	17	17
Briquetage: structural material			
Vitrified clay fragments	6	989	164.83
Waste material			
Cemented ‘ash slag'	22	2939	133.59

The same argument applies to the cemented ‘ash slags’ (Table 28, Figure 129). Based on van den Berg’s (1988) description of the site, more fragments must have been present, but either they were not collected or were not preserved. Unfortunately, the exact context from which the fragments stem is unclear, though the refuse zone is the most likely candidate. Analogous objects were also discovered at Leffinge (7.2.4.2) and the complex ‘s-Heer Abtskerke-‘s Gravenpolder (7.3.4.2). Samples from each site were selected for geochemical analysis. For more information on the analyses, see Dekoninck et al. (In prep).

Figure 128 Selection of the vitrified clay fragments discovered at Middelburg Oude Vlissingseweg. The top half shows the vitrified surface of the fragments is shown, while the bottom half depicts the flat/slightly plano-convex (vitrified) sandy clay bottom (© Cedric Verhelst).

Figure 129 Example of a cemented 'ash slag' recovered from the refuse zone (© Cedric Verhelst).

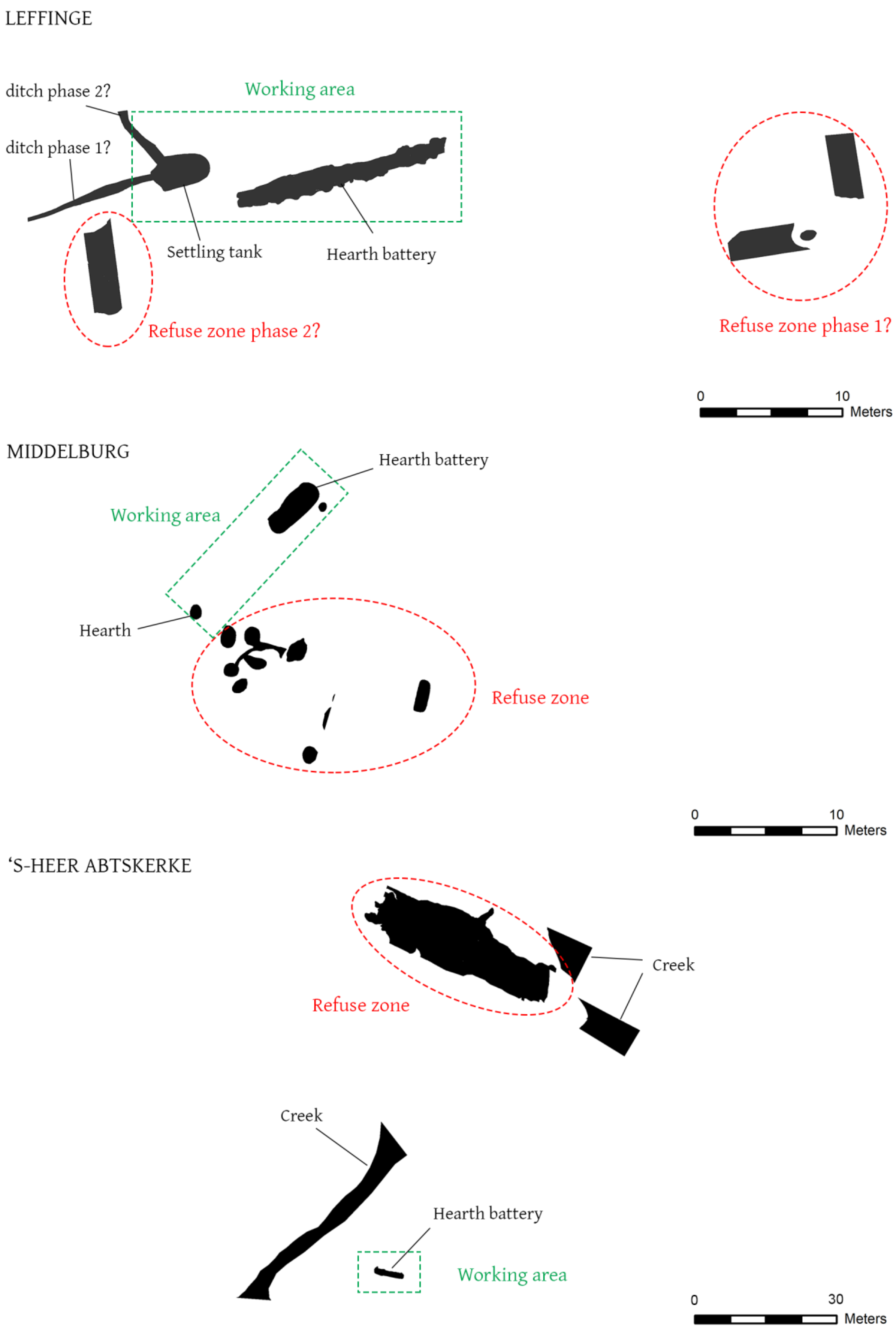


Figure 130 Organisation of the late second-early third salt production sites in the study area

7.5 Comparing the sites and discussing the salt production mechanisms

7.5.1 Organising the salt production site

After deciding on a suitable location, the salt producers organised and divided the space into several zones with specific functions. Figure 130 shows the perceived organisation of the late second - early third-century salt production sites in the study area. Given that the excavated area of the three sites was relatively small, these observations are inevitably rather general. Despite debris being present across the sites, the working area comprising the hearth infrastructure and brine reservoir was clearly distinguishable from the refuse zones suggesting a predefined waste disposal strategy. This strategy seems to consist of depositing debris at the edge of the site relatively close to the heating structures but out of the way to not interfere with the day-to-day activities.

In the case of Leffinge, two distinct phases were identified, and the site's organisation was revisited between the phases. The fact that the westernmost refuse zone partly covered the western feeder ditch indicates that they did not belong to the same phase. Following this hypothesis, it is tempting to connect the easternmost refuse zone to the phase 1 hearth battery and the western refuse zone to the phase 2 hearths. These refuse zones are approximately 30 m and 20 m from the hearth infrastructure. The refuse zone at Middelburg is less well-defined, but more refuse appears to be present south of the heaths which could indicate the start of the refuse zone. At 's-Heer Abtskerke, a refuse zone was discovered approximately 60 m north of the working area. At first glance, this is relatively far, but as the area between the refuse zone and the working area was not excavated, it is impossible to determine where the refuse zone began. In addition, the unexcavated area could hide a second working area or refuse zone. Nevertheless, based on the available data, the working area and refuse zone is interpreted as part of the same complex.

7.5.2 Water management and brine production

Unfortunately, water management features were only recovered at Leffinge, which tells little about how these features were embedded in the sites. At Leffinge, the brine reservoir (4.25 x 2.3 x 0.8 m) with feeder ditches was situated approximately 3 m from the nearest and 16 m from the farthest hearth. This reservoir was used to store and produce brine and had a capacity of ca. 6500 l. The spatial relation between the reservoir and the heating structures makes perfect sense since brine was constantly required to replenish the containers. Multiple examples of settling tanks close to hearths are known, for instance, from various salt-producing regions in Britain (Lane and Morris, 2001; Biddulph et al., 2012; Hathaway, 2013; Lane, 2018b). The absence of brine tanks at Middelburg and 's-Heer Abtskerke can be explained by the fact that the working area was not completely excavated. At both sites, the hearth battery is situated relatively close to the edge, suggesting that the working area continued beyond the limits of excavation.

Similar (large) brine reservoirs were discovered, for instance, at Conchil-le-Temple (FR) (Lemaire, 2012) and Middleton (GB) (Lane and Morris, 2001; Lane, 2018b) (Figure 131). Furthermore, large brine reservoirs are a typical aspect of the inland salt production area of Cheshire (GB), and examples are known from Droitwich (Hurst, 1997), Middlewich (Williams and Reid, 2008; Garner and Reid, 2012; Zant, 2016) and Nantwich (Arrowsmith and Power, 2012). At Roman Nantwich, even larger, completely timber-built brine reservoirs (ca. 11.2 x 3.6 x 1.5 m and 10.5 x 3 x 0.75 m) were constructed to store brine from the nearby brine wells (Arrowsmith and Power, 2012, 18-31). Remarkably, all examples were either lined with clay, revetted with wattle or timber built to prevent brine from seeping into the surrounding soil. At Conchil-le-Temple, the brine reservoir with a capacity of 4000 l (ca. 9 x 0.9 x 1-1.6 m) was built into an artificial chalk bank to prevent brine loss (Lemaire, 2012, 188-189) (Figure 131). As such, it would be logical to assume some form of revetment at the brine reservoir of Leffinge. These large brine tanks differ from the multi-celled tanks that are more commonly found at salt production sites in Essex (Fawn et al., 1990; Biddulph et al., 2012; Biddulph, 2016).

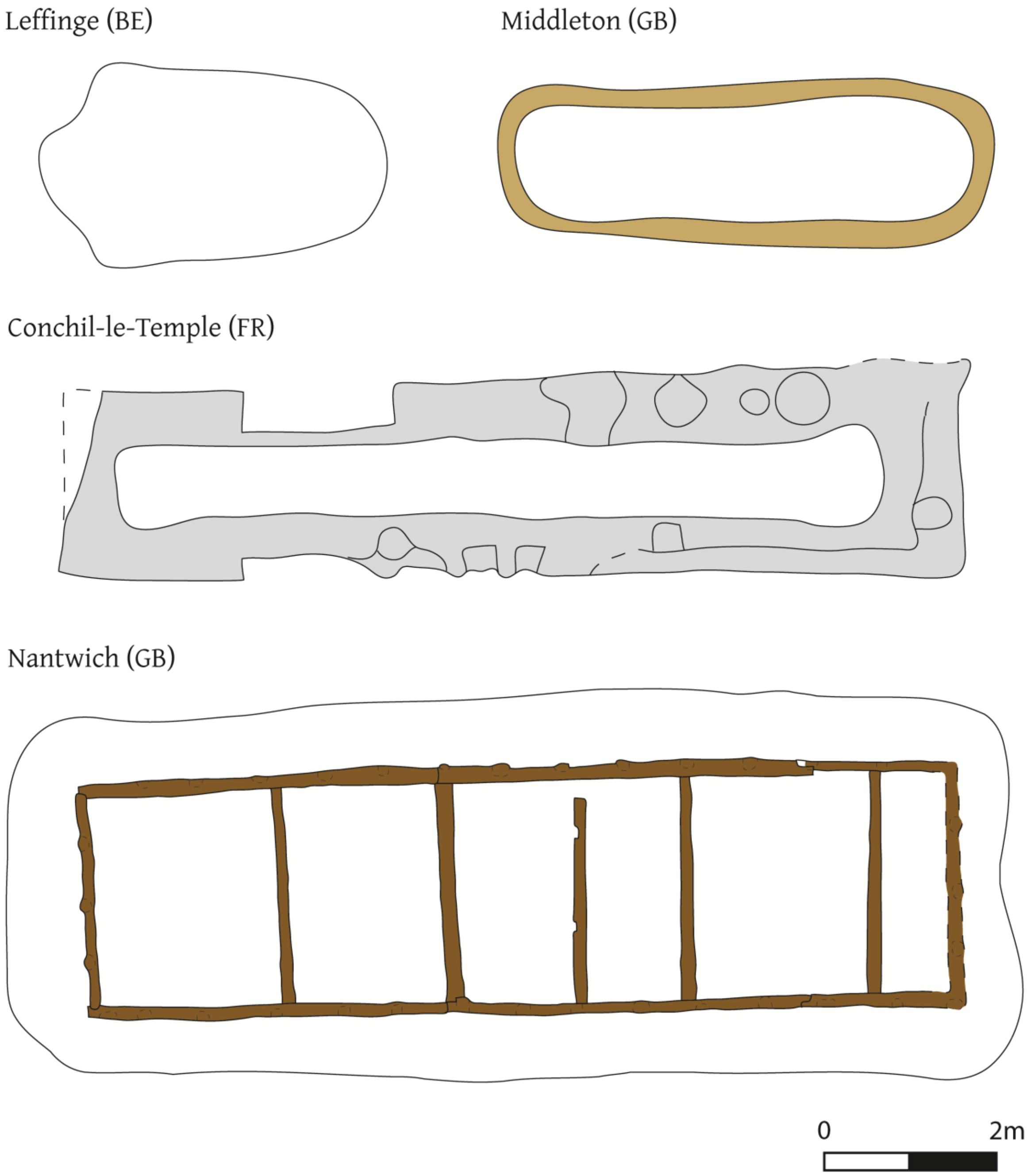


Figure 131 Comparison of large brine reservoirs discovered at Leffinge (4.25 x 2.3 x 0.8 m), Middleton (6 x 1.6 x 0.7 m), Conchil-le-Temple (9 x 0.9 x 1-1.6 m), Nantwich (10.5 x 3 x 0.75 m). Yellow = clay lining; grey = chalk; brown = wood. Redrawn after Lane and Morris (2001, 165), Lemaire (2012, 188) Arrowsmith and Power (2012, 28)

As indicated in section 7.2.3.1, the reservoir at Leffinge was filled with alternating layers of silt and ash. The silt layers formed when the insoluble sediments (sand, silt and clay) present in seawater settled on the bottom of the reservoir. Each of the silt layers was often covered by an ash layer (Figure 7), indicating that the ash was not dumped accidentally into the reservoir but most likely deliberately added to increase the brine strength. This method of leaching salts from plant ash to increase the brine strength was recently proven at the Iron age - Roman salt production site of Stanford Wharf Nature Reserve (Essex) (Biddulph et al., 2012). However, similar to ethnographic examples (Gouletquer, 1975; Antonites, 2013), Biddulph et al. (2012) assumed that the ash was filtered above the settling tanks and not deposited into the brine tank, as was the case at Leffinge. Leenders (2010), on the other hand, assumes that in medieval times the ash from peat (so-called *zel*) was mixed with seawater in a barrel until the salts dissolved and the remaining ash settled at the bottom (cfr. 3.6). The latter technique of mixing and settling instead of filtering might also have been used at Leffinge. In addition, while Biddulph (2012) determined that saltmarsh plants were used in the brine production process, the evidence at Leffinge rather points towards the use of salt-impregnated peat.

7.5.3 A transition towards metal evaporation vessels

Ceramic salt container fragments are noticeably absent at the late second – early third-century sites with hearth batteries. At Leffinge, several thin, plate-like fired clay fragments were initially interpreted as vessel fragments. Yet, closer examination revealed that these fragments did not correspond with the known characteristic of salt containers (section 7.2.4.2). Sporadic salt container fragments were discovered at Aardenburg Peurssensstraat (cfr. 5.4), but not in the expected amount of a large salt production site. The absence of ceramic salt container fragments has long been considered problematic for the identification of salt production activities at the sites (van den Broeke, 1996; Van Heeringen, 1996; van den Broeke, 2007). However, this is not necessarily a problem as it may signify changing production mechanisms, i.e. the transition towards metal evaporation vessels.

Metal vessels have several advantages over ceramic briquetage vessels:

(1) Metal vessels are more durable and, if repaired, can be used for longer periods of time, perhaps even multiple production seasons. Briquetage vessels, on the other hand, had a single use as they were transported with salt to the hinterland.

(2) The physical properties of metals far exceed clay for heating purposes as the thermal conductivity[119] (Table 29) is higher, and they are less prone to thermal shocks (Akridge, 2008).

(3) The production can be organised more efficiently as metal vessels are constantly kept above the fire, and the salt crystals are removed from the brine when they form. Compared to the briquetage vessels that must be replaced when full, production does not come to a standstill during the evaporation process. In addition, no time should be spent on making the briquetage vessels.

(4) Larger vessels can be made from metal, which positively affects the production output.

[119] Thermal conductivity expresses the ability of a material to conduct or transfer heat. Materials with a high thermal conductivity, like copper, allow more heat to transfer through the vessels compared to vessels with low conductivity. In consequence, the brine will heat more quickly in vessels with high conductivity. A small sidenote, the vessel thickness also affects the conductivity and increasing the vessel thickness will reduce the heat transfer (Akridge, 2008)

The biggest downside to metal vessels may have been the large initial investment to produce or procure them.

Table 29 Thermal conductivity coefficient and melting temperature of the different types of material discussed in the text. Data from Nikiforova et al. (2013) (clay) and Davis (1998) (metals)

Material	Thermal conductivity ($W{\cdot}m^{-1}{\cdot}K^{-1}$)	Melting temperature (°C)
Clay	0.5-1.44	N.A.
Lead	34.7	ca. 327
Copper	393.7	ca. 1080
Bronze (90% Cu)	188.28	ca. 980
Yellow brass (65% Cu)	117.2	ca. 930
Iron	74.47	ca. 1535
Cast Iron	46.86	ca. 1175

In Roman Britain, multiple fragments of lead sheeting and solidified lead spills/run-off were discovered at Nantwich (Arrowsmith and Power, 2012, 90-91; 174) and Middlewich (Zant, 2016, 141-142). These discoveries suggest that lead evaporation pans replaced ceramic vessels in Cheshire before the end of the second century. Over the years, more than 20 lead salt pans were found in that area, of which several complete vessels date to the fourth or fifth century (Shotter, 2005; Garner and Reid, 2012, 62). The three examples from Shavington measured 1 x 0.9 x 0.14 m; 1.03 x 1.01 x 0.14 m and 1.08 x 0.98 x 0.12 m (Penney and Shotter, 1996, 2002) and the dimensions of the Nantwich pans were 1 x 1 x 0.13 m and 1 x 0.95 x 0.13 m (Hassall and Tomlin, 1984). Interestingly, the two opposite sides of the pans were centrally pierced to apply lead arcs. These arcs could have been used to lift the pans on and off the heating structures (Penney and Shotter, 1996, 2002). Given the striking similarities between the late Roman pans, it is often assumed that the mid-Roman pans had similar shapes and dimensions. Following the Cheshire examples, the absence of ceramic briquetage vessels on late Roman production sites, for instance, in Somerset, the Fenlands or Essex, prompted researchers to assume a similar transition towards lead evaporation pans in the late Roman period (Lane and Morris, 2001; Biddulph et al., 2012; Hathaway, 2013; Biddulph, 2016; Lane, 2018b).

In the northern Menapian territory, the lack of ceramic salt container fragments on the production sites indicates that a similar transition towards metal evaporation vessels took place roughly at the same time. However, unlike the Cheshire area, other types of metal like brass or bronze may have been used rather than lead. While it is true that lead vessels are easily malleable and repairable, the material has a much lower melting point and a lower thermal conductivity than copper alloys or iron. Especially the melting temperature of lead (327°C) is problematic as the large quantities of vitrified material indicate that the bottom of the hearths regularly reached temperatures of 900°C. At the top of the hearths, the temperature will have been lower, but probably still high enough to melt the lead vessels.[120] Instead, copper alloys like bronze (copper and tin) or brass (copper and zinc) can withstand higher temperatures (> 900°C) and have a higher thermal conductivity (Table 29), making it far more likely that the vessels were made in some sort of copper alloy. Technically, iron recipients could have been used. Iron has an even higher melting point but also a lower thermal conductivity. Although this

[120] Most likely, the lead evaporation vessels were only used in indirect heating systems or above embers instead of open flames.

option cannot be completely refuted, it is difficult to estimate what these containers looked like since very few examples of large iron vessels are preserved.

In general, several types of large copper alloyed vessels existed in the northern territories, of which a derived form could have been used in the salt production process. The first option is the large copper alloyed cauldrons that occurred in Gaul and Britain from the Iron Age onwards (Joy, 2014). The mid- and late Roman examples are often termed Westland cauldrons after the numerous examples that were found in Scandinavia (Hauken, 2005). A complete typology of these cauldrons encompassing various forms exists. However, in general, these 'projecting-bellied' cauldrons have a more or less cylindrical neck above a body with a distinctive shoulder carination and a rounded base. The top of the cauldrons can be reinforced with an iron rim and fitted with iron handles. Often these cauldrons show signs of repairs attesting to their long-term use (Hauken, 2005; Joy, 2014). A recent analysis of Iron Age – early Roman cauldrons in Britain and Ireland indicated that cauldrons with a diameter of 70 cm and a height of 50 cm were no exception (Joy, 2014). In the Menapian *civitas*, examples of such large vessels were found in second and third-century contexts at Oudenburg (Vanhoutte, *in press*), Roeselare (Clerbaut, 2016) and Harelbeke (Clerbaut, 2013).

A second possibility is large, shallow copper alloyed dishes or pans with vertical sides, for instance, type Tassinari O 1112. This is a generic description as relatively few of such objects are known. Two examples were discovered in the vicinity of Nijmegen with diameters of 48.9 cm and 47.3 cm and heights of 7.8 cm and 9 cm, respectively (Figure 132) (Den Boesterd, 1958, 57; Koster, 1997, 52-53). Interestingly, the first example had several holes pierced in the sides. These holes could hold the rivets of an iron ring below the rim (Koster, 1997, 52-53), or they might be holes created when fastening a cover over the pan. Handles on the sides of the pans would make it relatively easy to get them on and off the fire or other structures.

Evidently, these options merely indicate that a tradition of large metal vessels existed and that the knowledge was there to create suitable metal pans adapted to the needs of the salt producers. Since no fragments were discovered on site, it is difficult to estimate the exact shape of the vessels that were used. Following the lead examples of Cheshire, a shallow pan seems preferable to deeper vessels as a small amount of brine spread out across a large evaporation surface will evaporate more quickly. In other words, it will take longer to bring a large amount of brine in deeper cauldrons to a boil compared to a small amount in shallow pans. In addition, removing the crystallised salt is easier from shallow pans than from deep cauldrons. Therefore, it can be hypothesised that the evaporation pans could have a form similar to the Valkenburg examples.[121]

[121] It must be stressed that we do not interpret the Valkenburg examples as salt evaporation pans. We only want to point out that this kind of form (a large, shallow pan) would be ideal to conduct the salt production activities.

Figure 132 Examples of large, shallow copper alloyed dishes or pans with vertical sides discovered in the vicinity of Nijmegen (photo courtesy of Collectie Valkhof Museum, Nijmegen, bruikleen Rijksdienst voor het Cultureel Erfgoed ©).

7.5.4 Introducing the concept hearth battery on salt production sites

The study area's late second – early third century sites are characterised by a new type of heating structure: the 'hearth battery.' As shown in Table 30 and Figure 133, the hearth batteries are remarkably similar, for instance, the width of the clay bank, spacing between the hearths and dimensions of the hearths. These similarities indicate that they were constructed following a pre-defined plan. At first glance, the hearths at Leffinge are slightly larger than those at 's-Heer Abtskerke and Middelburg. However, as the top of the hearths did not preserve, it is possible that the opening above which the evaporation vessels were placed did not differ much. One major difference between the sites is the number of hearths. At Leffinge, two rows of 15 heating structures were present, while the site of 's-Heer Abtskerke and Middelburg contained 6 and 4 hearths (Figure 133).

To this day, this type of heating system in which individual hearths were constructed into an artificial clay bank has yet to attested elsewhere on salt production sites. Also, the number of adjacent hearths is unique to these salt production sites in northern Gaul. Sporadically, adjacent or twin hearths have been discovered at salt production sites in Essex and Kent (Fawn et al., 1990; Hathaway, 2013). Although the principles behind these twin hearths and the benefits are the same, they do not come close to the abovementioned hearth batteries in terms of scale.

That being said, the concept of hearth batteries is not entirely unknown in the Roman world, and examples exist from different types of artisanal activities. A first example is the third-century lime kiln battery discovered at Iversheim (Figure 133). This lime kiln battery was directly exploited by a *vexillatio* of the 30th legion. This battery consisted of six lime kilns which worked in a rotating sequence to maximise the production output (Sölter, 1970). A second example is the bread kiln batteries discovered in the forts of Saalburg (Jacobi, 1930) (Figure 133) and Strasbourg (Monteix and Noûs, 2021). Quite often, a series of adjacent bread ovens were built into the rampart of the fortification at the edge of the *via sagularis*. These ovens were used for baking bread for the centuries stationed in the camp (Johnson, 1987, 220-222). Though the hearth/kiln batteries worked differently in the various industries the overarching benefits are the same: increasing production efficiency and output. Furthermore, the raised clay bank acted as an insulator preventing heat loss during firing. In addition, the joint firing of adjacent hearths through the individual stoke holes will further reduce heat loss. This way, a 'heat island' was created, encapsulating the heat of the individual hearths and decreasing the efforts to maintain the temperature.

Table 30 Comparison of the late second – early third century hearth batteries in the study area

	Leffinge	**s Heer Abtskerke**	**Middelburg**
Clay bank	15.5 m long 1.2-1.6 m wide 0.4 m high	6.5 m long 1.3 m wide 0.4 m high	4.35 m long 1.75 m wide 0.4 m high
Number of hearths	2x15	6	4
Hearth spacing (mean)	30	25	20
Hearth dimensions (mean)	94 cm long; 85 cm wide	diameter 75-80 cm	diameter 60 cm

Although ethnographic examples should be treated with caution when extrapolated across continents and through time, the similarities cannot be ignored. At Bo Kluea (northern Thailand), a very similar type of heating structure is still in use today (Figure 134). This heating structure consisted of two evaporation pans placed side by side on top of a raised clay bank with a single stoke hole to fuel the fire underneath the pans. The raised clay bank encapsulated the heat, increasing the thermal efficiency. The production sites often contained a second 'hearth' adjacent to the first and these 'hearths' were separated by a small corridor (Figure 134). Merging these structures into a single hearth battery would have further increased the thermal efficiency and made the resemblance to the Roman examples in the study area more striking. Moreover, this ethnographic parallel can offer unique insight on how these 'hearths' functioned (section 7.5.5).

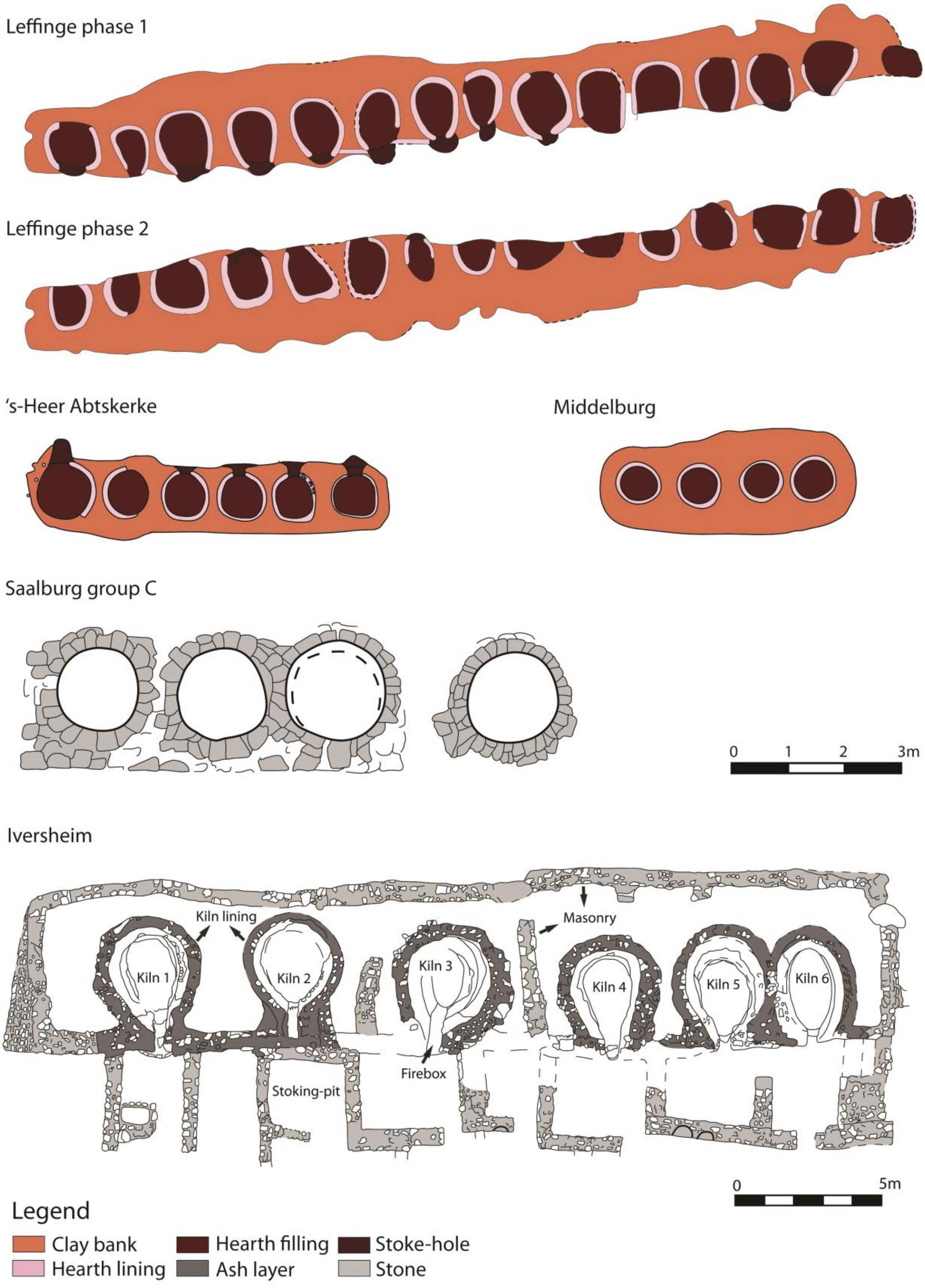


Figure 133 Comparison between the hearth batteries discovered at the late second-early third salt production sites in the northern Menapian territory and examples from other 'industries' in the Roman world, for instance, the bread kiln batteries of Saalburg (redrawn after Jacobi, 1930) and the lime kiln battery of Iversheim (redrawn after Sölter, 1970)

Figure 134 Etnographic examples of salt hearths at Bo Kluea, northern Thailand. Each hearth consisted of two adjacent evaporation pans placed on top of a raised clay bank with a single stoke hole to the side to fuel the fire. © think4photop, 123RF (A) and tuanjai, 123RF (B).

7.5.5 Functioning of the heating structures

The sections above described the innovations that occurred at the study area's late second-early third century salt production sites. The consequences of these innovations are discussed in this section. Specifically, the following aspects will be considered: the heating system, the placement of the vessels above the hearths and the hearth battery as an operating entity.

Concerning the heating system, the large quantities of vitrified material in the refuse zones and the presence of *in situ* vitrified base fragments at the bottom of the hearths at Leffinge indicate that the fire burned inside the hearth chamber. Fuel was continually added to the fire through the stoke hole to maintain the temperature within these hearths. The absence of briquetage support material demonstrates that no raised floor or other types of barrier was present separating the vessels from the heat source (e.g. direct heating system). Furthermore, the absence of support elements like pedestals affected how the evaporation pans could be placed above the fire. Indeed, in the hearth chamber, no supports were present on which the vessels could rest. In consequence, alternative methods were required of which the various options are summarised in Figure 135.[122]

The first example (Figure 135, A) uses a suspension system with iron chains to hold the metal vessels above the fire. Although suspension could be achieved with perishable materials, this seems improbable given the heat that emanated from the hearths. However, this method has serious disadvantages making it unlikely that this technique was used. For example, the wooden or metal tripod frame holding the suspension chains needs to be long and sturdy enough to bear the weight of the brine-filled vessels (see note 122). In addition, as these materials might not be readily available, this would require an additional investment on top of procuring the metal vessels. More importantly, the suspension frame affects the salt producers' ability to harvest the salt and replenish the brine. The second example (Figure 135, B) largely solves this problem by placing the vessels on top of a metal tripod. Some drawbacks are the considerable span of the tripod across the hearths and the heat loss that will occur by placing the pans higher above the fire. Also, similar to the suspension frame, procuring or producing these metal tripods would require an additional investment.

Alternatively, the third and fourth example (Figure 135, C and D) has no other requirements besides the locally available clay. Both examples are variations on the same theme where the hearth lining supports the evaporation pans. In example C, the lining at the top of the hearth forms an inwardly protruding lip to support the vessels. This principle is similar to the flattened kiln lip that was used to support the bars of a pottery kiln (Swan, 1984, 31). In the other example, the hearth lining gently slopes inwards, integrating the vessel base into the lining. A similar technique was used to support cauldrons on top of the second-century curved firedogs in northern Gaul (van Zoolingen, 2018). The low material cost, the sturdiness of the set-up and the relatively close position of the pans to the fire make it probable that one of the latter techniques was introduced on the salt production sites.

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[122] Figure 135 uses the following assumptions: (1) the actual height of the hearth battery was higher than the preserved height. A maximum height of 0,8-0,9 m can be suspected (the dotted line represents the preserved height). The hearths could not have been much higher as this would have made harvesting the salt and replenishing the brine too difficult. (2) The salt producers used a shallow copper alloyed pan. Based on the width of the hearths, a pan with the following dimensions is used in this example: diameter of 75 cm and a height of 10 cm. Using the material density of bronze (8,9 g/cm³), a 10mm thick vessel would weigh approximately 50,5 kg, and a 5 mm vessel would weigh 25.25 kg. The capacity of such a vessel would be approximately 40 l. Completely filled with brine, this hypothetical vessel thus weighs between 65 and 90 kg. Naturally, this is only an example to illustrate some choices, but it remains one of many possibilities as, for example, the type of material and the dimensions of the vessels are unknown.

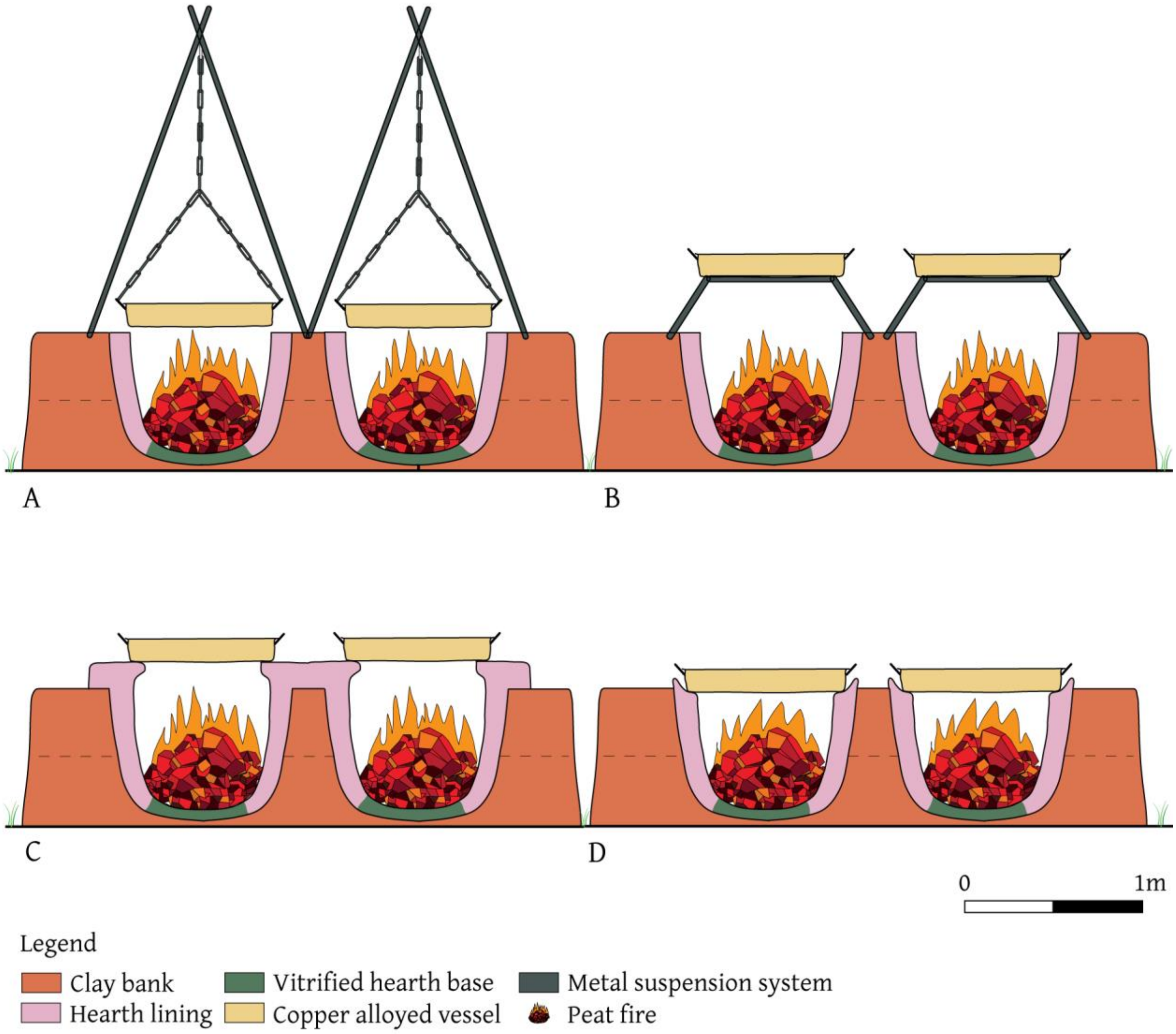


Figure 135 Summary of the different possibilities to place the copper alloyed evaparation pans on top of the heating structures.

Another (hypothetical) scenario to consider is that a suspension system could have existed to support a basket above the evaporation pans (Figure 136). These baskets were used to collect the harvested, wet salt, which was then drained into the pans. The main advantage of this system is that the brine that leaked out of the harvested salt was not irrevocably lost, but was 'reintroduced' into the evaporation process. This made the evaporation process more efficient and increased the output. This kind of suspensions systems are known from late medieval prints, for instance, De Re Metallica (Agricola, 1556, 552-554) or ethnographic examples, for instance, Bo Kluea (Thailand) (Figure 136). Yet, based on the current evidence, it is a stretch to presume such a system at the late second - early third century sites. Ethnographic observations at Kibiro (Uganda) (Connah et al., 1990) show that the harvested salt could just as easily be dumped on the work floor to solidify into cones. Another possibility is that the harvested salt was collected in baskets or other recipients next to the heating structures. Whatever the case, the harvested salt had to drain and dry before it could be packaged for transport to the consumption sites.

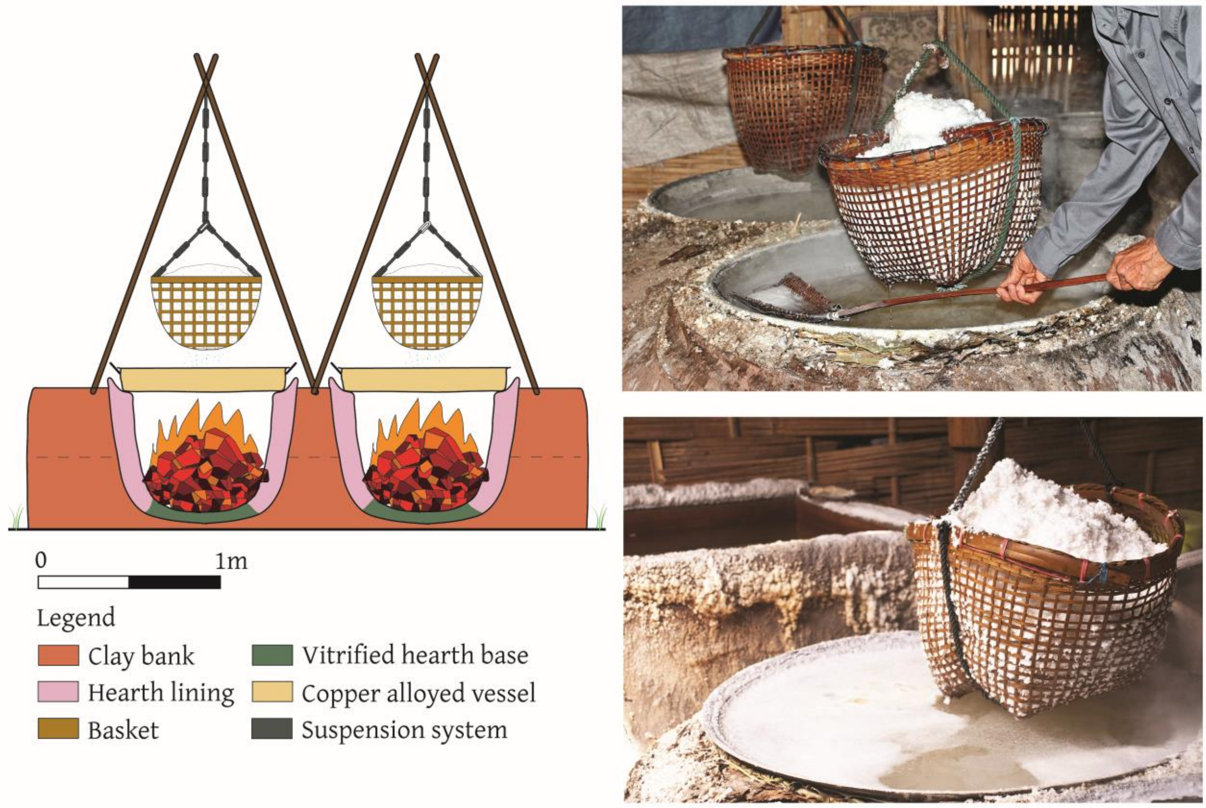


Figure 136 Hypothetical scenario based on ethnographic observations in which the harvested salt crystals are ladled in baskets hanging above the evaporation pans to drain the remaining moisture. Ethnographic photo's © smilekorn & yuri2011, 123RF

How these hearth batteries worked as a production unit is more difficult to answer, and two possibilities need to be considered. Either all hearths were in use at the same time, or a rotating sequence existed in which only a few hearths worked simultaneously. This question mainly arose from the battery of 15 hearths discovered at Leffinge, as both hypotheses would seriously affect the site's productivity. Overall, this question boils down to the availability of labour and resources. Enough people had to be present to fuel the hearths, harvest the salt and replenish the brine to keep all 15 hearths running continuously. In addition to the workforce, sufficient supplies had to be available in stock or had to be prepared to prevent a production standstill. In this scenario, the bottleneck might be the brine production as it takes time to bring the brine up to strength and let the sediments settle at the bottom. This might be particularly problematic when only one reservoir is present since it is not feasible to use and produce brine from the same reservoir at the same time. However, more data is required on how long it takes to prepare a suitable brine to estimate the consequences. If, for instance, the sediments and the ash settle overnight, this might not have affected production that much. Returning to the Leffinge example, the 15 hearths could certainty be used simultaneously as long as sufficient personnel and raw materials were available.

7.6 Summary

In the late second-early third century, a new type of salt production site emerges in the northern Menapian coastal plain. These sites are characterised by the absence of ceramic evaporation vessels and support material, the introduction of hearth batteries, the existence of water management features and the presence of extensive refuse zones containing large quantities of vitrified material and cemented 'ash slags'. Examples of this type of site have been excavated at Leffinge, Middelburg and 's-Heer Abtskerke - 's-Gravenpolder.

At the moment, the only water management system was discovered at Leffinge. Although this data should not be unequivocally extrapolated to the other sites, it indicates how brine was produced and stored on these mid-Roman sites. At Leffinge, the basin (4.25 x 2.3 x 0.8 m) had a capacity of 6500 l, and the feeder ditches supplied the reservoir with saltwater from the nearby tidal channel(s). The layered fill of silt and ash suggests that peat ash was deliberately added to increase the brine strength. This method is highly similar to the technique that was used to produce salt in medieval times in the Low Countries (Leenders, 2007, 2010). Besides water management features, the concept of a 'hearth battery' was introduced. A hearth battery consists of a series of individual hearths that were constructed in an artificial clay bank. The similarities between Leffinge, Middelburg and 's-Heer Abtskerke indicate that these hearth batteries were built following a pre-defined plan and that a larger strategy of organising the production sites existed. One major difference between the sites is the number of hearths. At Leffinge, two rows of 15 hearths were present, while the sites of 's-Heer Abtskerke and Middelburg contained 6 and 4 hearths. The concept of hearth batteries is unique to salt production in northern Gaul, and this phenomenon is yet to be discovered elsewhere. Known examples stem from other types of artisanal activities and were introduced to increase productivity.

The absence of ceramic evaporation vessels on these sites was long considered problematic for salt production. However, similar to second-century salt production in Britain, this signifies a transition towards metal evaporation vessels. Not only are metal pans more durable, but they also transfer heat more efficiently and increase production efficiency and output. Unlike the Cheshire area, most likely, a transition towards copper alloyed vessels instead of lead pans occurred in northern Gaul. The vitrified material at the bottom of the hearths indicates that the salt pans needed to withstand higher temperatures. As such, lead with a melting point of 327°C is unsuitable for evaporation pans in these heating structures. In northern Gaul, large metal vessels occurred from the Iron Age onwards, so the knowledge was there to create suitable copper alloyed evaporation pans. Since no fragments were discovered on site, it is difficult to estimate what these vessels looked like. Based on completely preserved lead examples, large and shallow pans are preferred because the brine will evaporate more quickly in these vessels. There are several possibilities for placing these containers above the fire. Most likely, these vessels rested on top of an inwardly protruding lip or were integrated into the hearth lining. This way, the evaporation pans rested stable on top of the hearths and were close to the fire without needing additional support.

These innovations increased the production efficiency and the site's salt output, and significantly changed the way salt was produced in northern Gaul. This transition in the *chaîne opératoire* will be more thoroughly explored in Chapter 9. This chapter also paid very little attention to the socio-economic consequences of said innovations. These innovations required a considerable investment which indicates that new players were involved in organising the production. Who these potential investors are and several other issues will be discussed in Chapter 9.

Chapter 8 Geochemical and mineralogical characterisation of vitrified waste material discovered in large quantities on Roman salt production sites along the southern North Sea coast.

The content of this chapter is published in:
Journal of Archaeological Science

Dekoninck, M., Goemaere, E., Dewaele, S., De Grave, J., Leduc, T., Vandenberghe, D., De Clercq, W. *Geochemical and mineralogical characterisation of vitrified waste material discovered in large quantities on Roman salt production sites along the southern North Sea coast*, Journal of Archaeological Science 146, 105665

Credit roles:
Michiel Dekoninck: Conceptualization, Methodology, Investigation, Writing – Original Draft; Writing – Review & Editing, Project administration, Funding acquisition
Eric Goemaere: Conceptualization, Methodology, Investigation, Writing – Original Draft; Writing – Review & Editing
Stijn Dewaele: Resources; Writing – Review & Editing
Johan De Grave: Resources; Writing – Review & Editing
Thierry Leduc: Resources
Dimitri Vandenberghe: Resources; Writing – Review & Editing
Wim De Clercq: Supervision, Writing – Review & Editing, Project administration, Funding acquisition

Abstract

Along the southern North Sea coast, Roman salt production sites are characterised by extensive refuse zones containing large quantities of what has been described as 'salt slags'. These 'salt slags' are in fact amorphous, heavily vitrified waste materials. This is rather surprising since large-scale vitrification has never been associated with the salt production process. In this paper, these materials are for the first time systematically studied macroscopically, mineralogically and geochemically to determine their composition, formation and relation to the salt production process. To achieve these objectives, 30 samples from 7 Roman salt production sites were analysed by combining several analytical methods (thin-section petrography using Polarised Light Microscopy, Scanning Electron Microscopy coupled with Energy Dispersive X-Ray Spectroscopy and X-Ray diffraction). This approach enabled a detailed characterisation of the vitrification process in the waste materials, as well as the identification of high temperature mineral transformations formed in specific (archaeological) conditions. Based on these results, the amorphous waste materials should be interpreted as vitrified hearth base fragments. This study shows that the current interpretations regarding the firing conditions on Roman salt production sites needs major adjustments. In addition, this paper demonstrates the value of geochemical and mineralogical research on discarded waste materials to study poorly understood aspects of not only the salt production process, but artisanal activities in general

8.1 Introduction

Throughout history, salt was the preferred preservative of premodern societies enabling them to prepare provisions for the winter or military campaigns and to transport perishable products (e.g. fish and meat) over long distances (Tsigarida, 2012b; Marzano, 2013; Moinier and Weller, 2015). In the northern part of the Roman Empire, climatological conditions prevented the natural evaporation of seawater in open air saltpans, as attested archaeologically on sites across the Mediterranean (Carusi, 2008a; Currás, 2017; Garcia Vargas and Martinez Maganto, 2017). Instead, a high concentration solution of salt minerals, referred to as a brine, was heated in evaporation vessels above hearth-like structures (Harding, 2013, 2021). This technique, often called the 'briquetage' technique, already dates from the Neolithic (Bánffy, 2015; Weller, 2015; Sherlock, 2021) and has been widely documented in Europe (Nenquin, 1961; Harding, 2013, 2021), as well as in Asia (Chen, 2008; Flad, 2011; Kawashima, 2015), in America (McKillop, 2002; Watson and McKillop, 2019) and in Africa (Antonites, 2013, 2016).

Over the last decade, geochemical research has been introduced to help to characterize the premodern salt production process and the associated artefacts and structures. Several studies (Flad et al., 2005; Horiuchi et al., 2011; Sandu et al., 2012; Raad et al., 2014; Tencariu et al., 2015; Alessandri et al., 2019) focused on the concentrations of sodium and chlorine in ceramic 'briquetage' vessels to verify their use in the salt production process. Other studies (Flad et al., 2005; Macphail et al., 2012; Sills et al., 2016; Graham et al., 2017; Sordoillet et al., 2018; Sevink et al., 2021) analysed the chemical composition of sedimentary deposits to determine their relationship to the salt production activities. However, with the exception of some preliminary observations by De Paepe (1987), no studies paid attention to heavily vitrified 'salt slags' frequently occurring on late second-early third century CE salt production sites in northern Gaul. To this day, it was still unclear what these objects are, how they formed and how they relate to the salt production process. Here, in this paper, several analytical methods are applied to unravel the nature, composition and formation of these 'slags', in order to better understand the Roman period salt-making process.

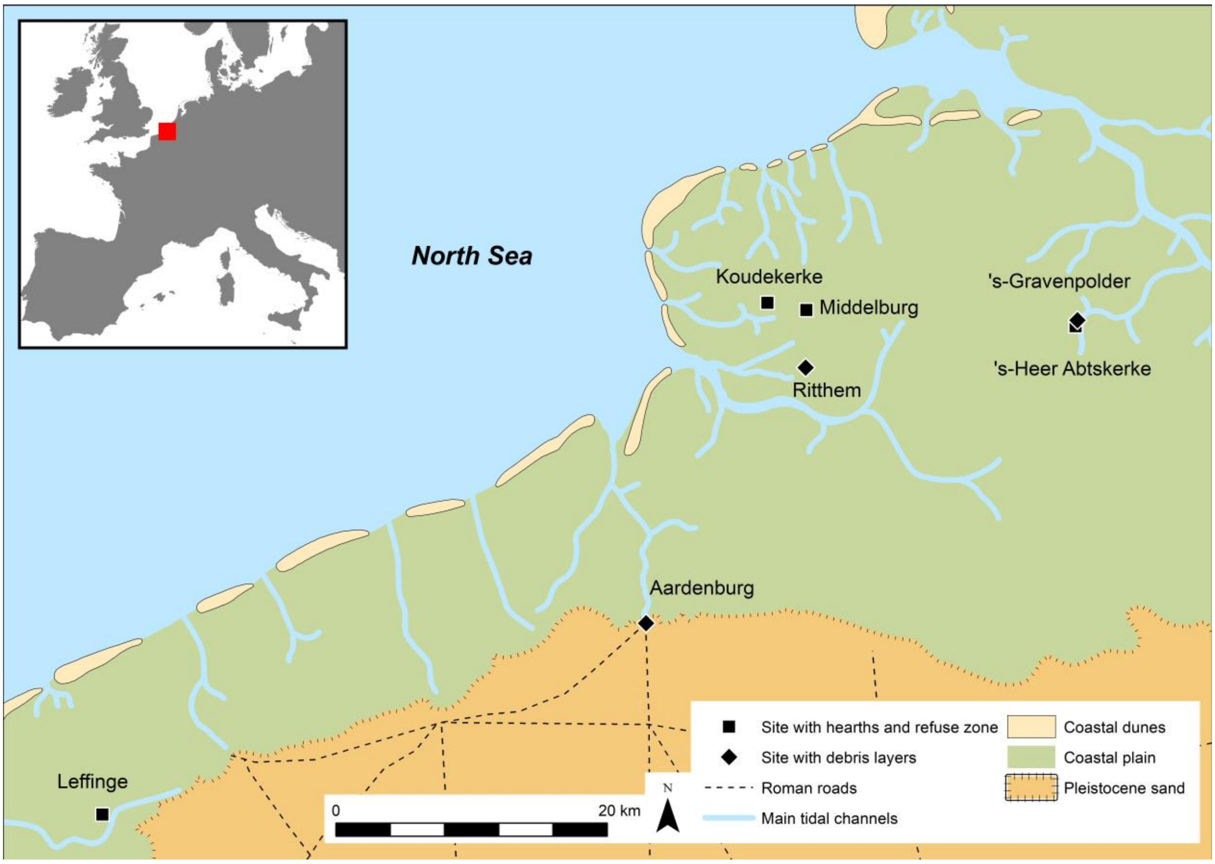


Figure 137 Simplified paleogeographic map of the Belgian coast and Zeeland (NL) in Roman times situating the sites mentioned in the tekst

8.2 Sites and study area

In the 1970s, multiple salt production sites dating to the late second-early third century CE have been discovered along the coast of Belgium and southern part of the Netherlands (Figure 137) (Ovaa, 1975; 1977a, 1978a, 1981, 1986). The production site of Leffinge (BE) contained a large water reservoir with a capacity of 6500l and a two-phased hearth battery consisting of 15 hearths to evaporate the brine. A large refuse zone consisting of multiple waste layers containing fragments of pottery, fired clay and large quantities of heavily vitrified 'salt slags' surrounded these heating structures (Figure 138). A similar hearth battery surrounded by debris layers was discovered at 's-Heer Abtskerke (NL) and at Middelburg (NL) comprising 6 and 4 hearths respectively. In 2020, two additional debris layers were uncovered at 's Gravenpolder (NL), approximately 200m west of 's Heer Abtskerke, and near the Roman military camp of Aardenburg (NL). Next to these sites, very few vitrified fragments were found on the late first century sites of Koudekerke (NL) and Ritthem (NL) (Figure 137). Remarkably, on all mid-Roman sites the debris layers were characterised by a lack of ceramic briquetage evaporation vessels and a high quantity of amorphous 'salt slags'. Taking the spatial arrangement of the sites into account, there is a striking correlation between refuse zones containing large amounts of vitrified waste material and so-called hearth batteries. As large amounts of these vitrified waste products and hearth batteries are lacking on earlier salt production complexes in northern Gaul, this may point to a technological shift within the tradition of Roman salt-making practises.

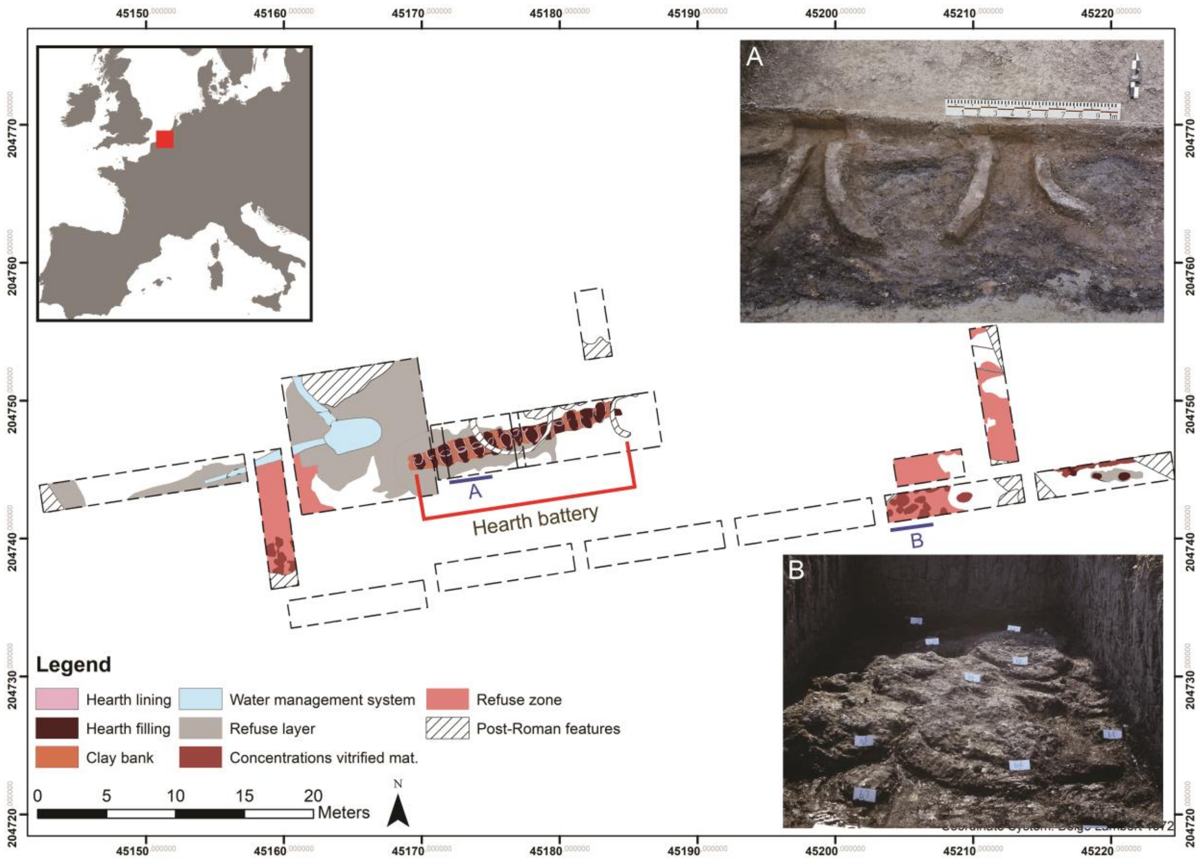


Figure 138 Simplified plan of the late second-early third century CE salt production site of Leffinge (BE) depicting the hearth battery, water management systems and the refuse zones

8.3 Materials and methods

8.3.1 Sample selection of the 'salt slags'

In this study, 17 'salt slags' from 5 late second-early third century CE sites (Leffinge, Aardenburg, 's-Heer Abtskerke, 's Gravenpolder and Middelburg) were sampled for analysis. As the fragments across the different sites were highly similar, primarily larger, 'complete' fragments with a visible internal stratification were selected. To enable comparison with earlier, late first-early second century CE sites, 2 fragments from Koudekerke and 3 fragments from Ritthem were included in this study as well. Unfortunately, no unfired clay samples were available from the selected sites, but as a substitute low fired objects were used to characterise the mineralogical and chemical composition of the source material.

These low fired objects can be considered a valid reference material because, like the 'salt slags', they are waste products removed during cleaning or demolition of the heating structures. As it is unlikely that different types of clay were used to construct the heating structures, one can assume that both the low and high fired objects were made from the same locally available marine clay. This assumption was later confirmed petrographically as both types of objects contained calcareous microfossils which pointed towards a similar marine source clay (see section 8.4.2). In total, 8 low-fired fragments from 4 sites (Leffinge (4), Aardenburg (2), 's Gravenpolder (1) and Ritthem (1)) were selected from the debris layers. In the case of Leffinge, one preserved sample originated from the artificially raised clay bank in which the heating structures were constructed and one other sample was taken closer to what in the field was considered to be hearth lining (for a detailed sample list see APPENDIX 5).

8.3.2 Methods

After documenting all 30 samples, cross-sections were made by using a water cooled diamond-coated saw. Each sawed fragment was embedded in an epoxy resin which was used to manufacture uncovered polished thin-sections. These thin-sections were then studied using an Olympus BX41 polarising light microscope (PLM) to determine the texture and the mineralogical composition. Thin-section petrography is an established technique to characterize, identify and study objects found in archaeological contexts like ceramics. The petrographic description and classification of all thin-sections is based on several reference works regarding ceramic petrography (see, amongst others, Whitbread, 2001; Reedy, 2008; Quinn, 2013). In a second phase, samples were selected for Scanning Electron Microscopy coupled with Energy Dispersive X-Ray Spectroscopy (SEM-EDS) and X-Ray Diffraction (XRD).

The elementary oxide composition of 8 samples (5 'salt slags'; 2 low-fired and 1 outlier) was determined by analysing the uncovered thin-sections with a FEI Quanta 200 SEM (voltage 23 kV, current 3.2 μA, spot size 6-7), in combination with an EDAX Apollo 10 EDS system with Silicon Drift Detectors (SDD). In addition, SEM-EDS was used to identify unknown mineral phases which were observed during the petrographic description of the samples.

XRD was used to analyse the bulk mineralogy and to identify the high temperature crystalline phases occurring in the samples. In total, 8 'salt slags', 3 low fired fragments and 2 possible outliers were selected for analysis. In cross-section, different zones could be observed in these 'salt slags'. As the mineralogy of these zones might differ, two samples, one from each zone, were taken per 'salt slag'. The 21 subsamples were collected on the cross-cut material by using a Dremel 4000 equipped with a diamond-coated drill head. The XRD analyses were performed using a Bruker D8 Advance (current 25mA, voltage 40kV), equipped with a copper anode X-ray tube, at a 2-theta angle of 3° to 70°. The step size was set at 0.01° with a time per step of 48s. The obtained spectra were interpreted using X'Pert Highscore software (PANalytical), and the Joint Committee of Powder Diffraction Standards database (JCPDS) was used to identify the mineral phases present in the samples.

8.4 Results

Although Bachmann's (1982) definition of slags as "waste discarded or left behind evidence of human activity, difficult to classify and to date, but remarkably resistant to weathering", is widely applicable to archaeological materials from different artisanal processes, over the years the term slag has been mainly used to denote waste products from archaeometallurgical processes (Miller and Killick, 2004; Hauptmann, 2020; Rehren, 2020). To avoid any connotations to archaeometallurgical waste products commonly known as 'slags', the more neutral term 'vitrified clay fragments' will therefore be used throughout the rest of the paper to describe the 'salt slags'.

8.4.1 Macroscopic characterisation of the vitrified clay fragments

The debris layers of the studied sites largely consisted of an unknown category of waste products: i.e. the aforementioned vitrified clay fragments. Throughout the different sites, these amorphous greenish-grey objects are highly similar and occur in various forms and sizes. However, due to their amorphous nature, they cannot be separated into different groups with distinct characteristics. Quite often a transition from flat/slightly plano-convex (vitrified) sandy clay bottom (outer surface) to a highly vitrified top (inner surface) can be observed in the fragments (Figure 139). The inner surface, sporadically exhibiting a fluidal texture, is very irregular with small dome-like protrusions whose occurrence may be linked to the escape of trapped gases. Larger fragments sometimes contain multiple vitrification layers which indicate multiple heating sequences. Moreover, the thickness of these layers varies considerably throughout the objects, as both thin, planar-like and thicker variants can be discerned.

8.4.2 Mineralogical and chemical characterisation of the vitrified clay fragments

A more detailed progressive thermal transformation can be observed petrographically (for a summary, see Table 31). In general, the observed transformation consists of four successive stages: low fired/Raw Material (RW), Vitrified impure Sand (ViS), Vitrified impure Sand with Neoformed minerals (ViS-NM) and Glass with Neoformed minerals (GNM).

The low fired/raw material (Table 31; Figure 140A) is composed of semi-homogeneous coarse silt-sandy clay with a high SiO_2 and moderate Al_2O_3 content (Table 32). Na_2O is only marginally present and the CaO content – originating from sporadically observed calcareous marine microfossils (foraminifera, filamentous algae and occasional shell bioclasts) that are naturally present in the clay – is relatively low, indicating a non or very low calcareous marine source clay. Mineralogically, a high concentration of medium silt-very fine sand, monocrystalline (occasionally polycrystalline) sub-rounded to subangular anisometric well-sorted quartz grains occur. Additionally, mica flakes (muscovite, biotite), chlorite flakes, plagioclase, K-feldspars, and opaque minerals (mainly iron oxides) can be identified. Rarely, glauconite grains and heavy detrital minerals (tourmaline, zircon, rutile and amphibole) are present (Figure 140A).

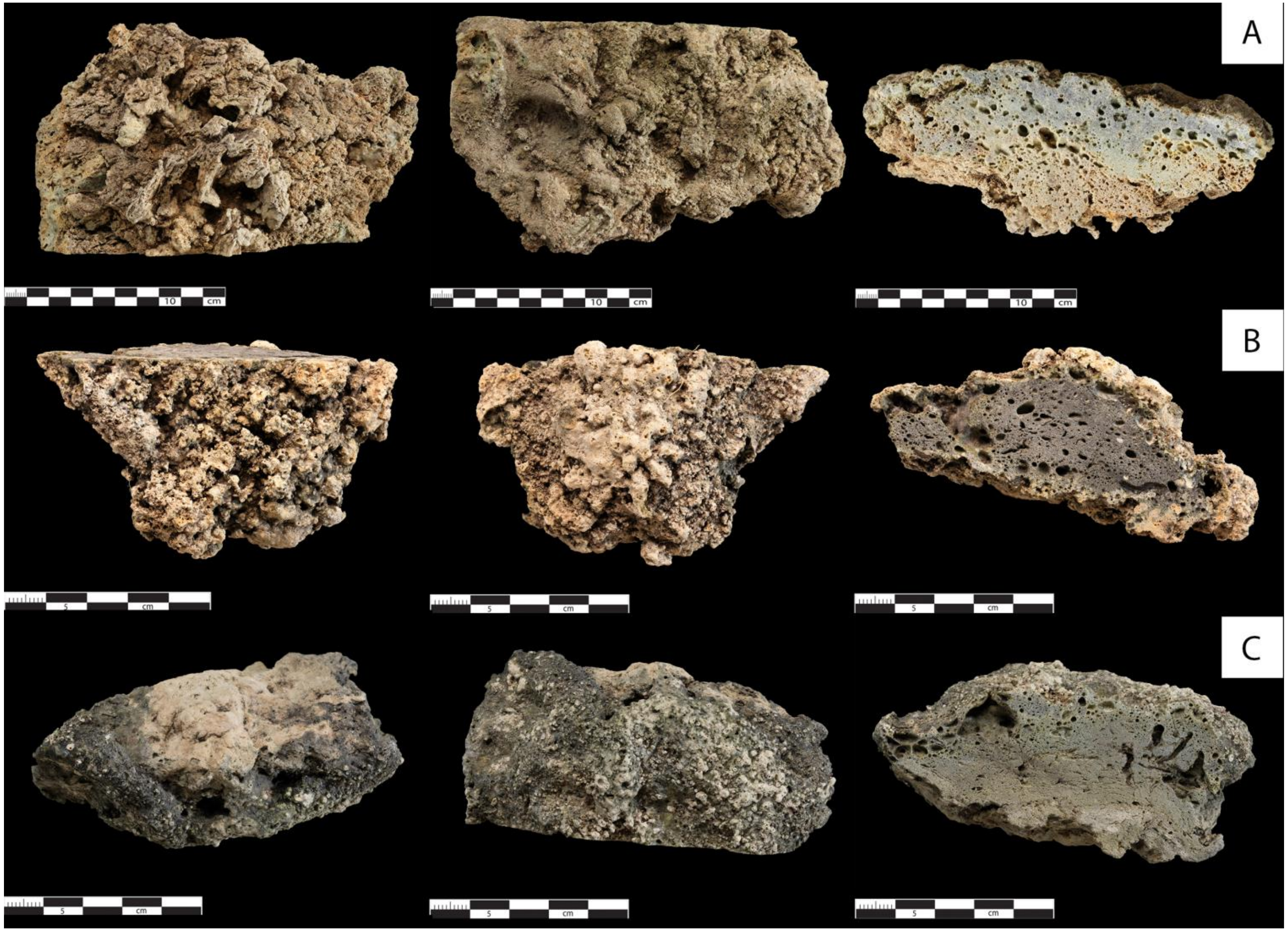


Figure 139 Examples of vitrified clay fragments discovered at Aardenburg (A) and Leffinge (B-C). On the left, the lightly modified outer surface of each fragment is shown and the highly vitrified irregular inner surface with dome-like protrusions of each fragment is visible in the middle. In the cross sections on the right, the progressive thermal transformation can be clearly observed. © C. Verhelst and Ugent

Table 31 The characteristics of each petrographic entity. Legend: ++ = abundant; + = frequent; +- = common; - = sparse; – = rare.

Petrographic group	Low fired *(n=6)*	Vitrified impure sand *(n=7)*	Vitrified impure sand with neominerals *(n=20)*	Glass with neominerals *(n=17)*	Group A *(n=2)*	Individual B *(n=1)*
Samples	LFZ-clay bank; LFZ-mantel; AB-99-AB3; AB-116-AB4; SHAZ-1; R-1	LFZ-6; LFZ-11; AB-63-AB5; MB-1; SHAZ-467; KO-1; KO-2	LFZ-6; LFZ-7; LFZ-8; LFZ-10; LFZ-11; LFZ-12; LFZ-13; AB-63-AB6; MB-1; MB-2; SHA-1; SHA-2; SHAZ-467; SHAZ-780-1; SHAZ-780-2; KO-1; KO-2; R-2; R-3; R-4	LFZ-6; LFZ-7; LFZ-8; LFZ-10; LFZ-11; LFZ-12; LFZ-13; AB-63-AB6; MB-2; SHA-1; SHA-2; SHAZ-467; SHAZ-780-2; KO-1; KO-2; R-2; R-3	LFZ-3; LFZ-4	SHAZ-481
Sites	Leffinge, Aardenburg, 's-Gravenpolder, Ritthem	Leffinge, Aardenburg, Middelburg, 's-Gravenpolder, Koudekerke	Leffinge, Aardenburg, Middelburg, -'s-Heer Abtskerke 's-Gravenpolder, Koudekerke, Ritthem	Leffinge, Aardenburg, Middelburg, -'s-Heer Abtskerke 's-Gravenpolder, Koudekerke, Ritthem	Leffinge	s-Gravenpolder
Matrix (PPL)	dight brown - grey	darkbrownish - grey	darkbrownish - grey	translucent	black	light brown
Matrix (XP)	dark grey	dark grey - black	dark grey - black	translucent	black	calcareous; grey-black
% Matrix	60% (est.)	50% (est.)	50-60% (est.)	55-65% (est.)	75% (est.)	60-70% (est.)
Matrix composition	silty/sandy clay	silty/sandy clay	silty/sandy clay	glass		recarbonated' lime and sandy clay
Dominant minerals	quartz (++)	quartz (++)	quartz (++)	Neoformed minerals (++)	quartz (-)	quartz (+)
Accessory minerals	opaque minerals (-); muscovite (-); feldspar (-); biotite (--); tourmaline (--); rutile (--); zircon (--); amphibole (--); glauconite (--)	opaque minerals (-); muscovite (--); feldspar (--); tourmaline (--); zircon (--)	neoformed minerals (+-); opaque minerals (-); muscovite (--); feldspar (--); tourmaline (--); zircon (--); rutile (--)	quartz (--)	opaque minerals (-)	opaque minerals (-); muscovite (--)
% Inclusions	25% (est.)	25-30% (est.)	25-30% (est.)	20-30% (est.)	< 10 % (est.)	10-15% (est.)
Inclusion size	med. silt -very fine sand	med. silt - very fine sand	med. silt -very fine sand	med. silt -very fine sand	med. silt - very fine sand	med. silt - very fine sand
Clay pellets	(--)					
Grog	(--)					(-)
Allochems	(--)	(--)	(--)			
Plant						(--)
Porosity	vesicles (+); vughs (+); planar (+-)	planar (+); channel (+); vesicles (+-); vughs (+-)	ring voids (+); vesicles (+-); vughs (+-); planar (-); channel (-)	ring voids (++); vesicles (-); vughs (-)	vesicles (+); vughs (+); planar (-); channel (-)	planar (+); vesicles (+-); vughs (-)
Void size	meso (+); macro (+-); mega (--)	meso (+); macro (+-); mega (--)	meso (+); macro (+); mega (-)	meso (+-); macro (+); mega (-)	meso (+-); macro (+); mega (+-)	meso (+-); macro (+); mega (+-)
% Porosity	15% (est.)	20% (est.)	15-20% (est.)	15% (est.)	15-20% (est.)	20% (est.)

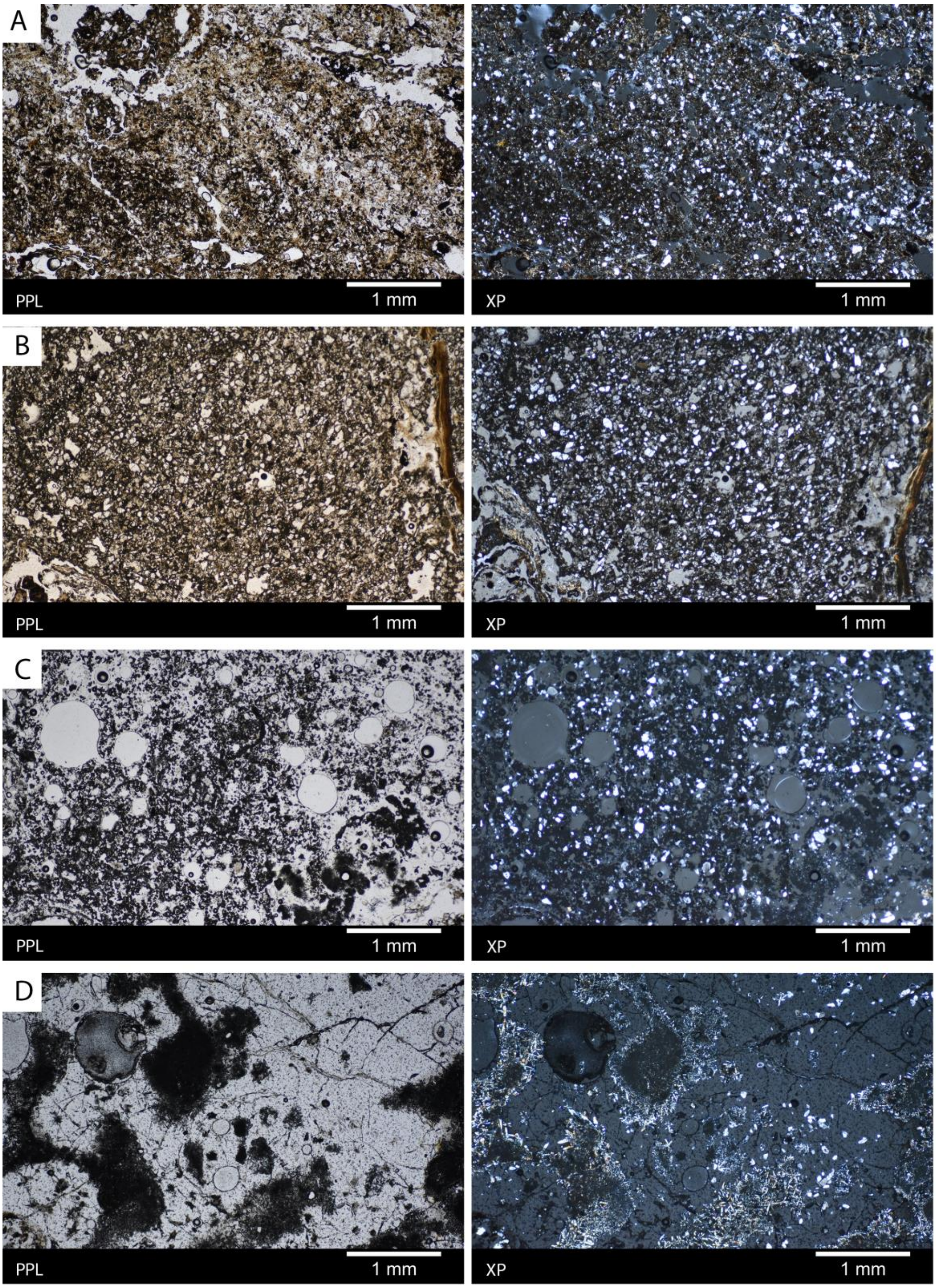


Figure 140 Thin-section photomicrographs of each petrographic entity in plain polarised light (PPL) and crossed polars (XP). A) A light brown (PPL) – grey (XP) non-vitrified matrix dominated by medium silt-very fine quartz grains (RW); B) A dark brown (PPL) – dark grey (XP) well sintered matrix dominated by medium silt-very fine quartz grains (ViS); C) Grey (PPL) – black (XP) continuous vitrified matrix dominated by quartz grains with newly formed, black micro-acicular mineral phases floating between the quartz grains (ViS/NM); D) Translucent matrix (glass) dominated by clusters of newly formed mineral phased with few detrital quartz grains (GNM).

Table 32 The total elementary oxide composition of the samples as determined by SEM/EDS (oxide wt%. contents normalised to 100%). The global composition comprises both the matrix and the minerals present in the sample, while the matrix refers to the matrix of the samples without minerals

Sample code	Na_2O (wt%)	MgO (wt%)	Al_2O_3 (wt%)	SiO_2 (wt%)	P_2O_5 (wt%)	K_2O (wt%)	CaO (wt%)	TiO_2 (wt%)	MnO_2 (wt%)	Fe_2O_3 (wt%)
Global composition Raw/low fired clay										
LFZ-mantel	1.83	9.66	12.53	62.91	0.00	3.31	3.74	0.81	0.00	5.20
LFZ-clay bank	0.84	4.70	12.74	71.29	0.00	2.99	1.12	0.71	0.00	5.60
Global composition ViS/NM										
LFZ-10	9.39	1.90	10.61	68.81	0.00	1.96	4.02	0.49	0.00	2.81
SHA-2	6.86	1.30	9.73	72.51	0.00	0.64	6.57	0.32	0.00	2.08
SHAZ-467 (1)	9.50	2.00	8.48	70.23	0.00	2.83	4.04	0.40	0.00	2.52
SHAZ-467 (2)	6.60	1.34	17.45	68.49	0.00	2.11	0.96	1.23	0.00	1.84
Global composition GNM										
AB-63-AB6	10.45	7.60	6.97	64.82	0.00	0.95	6.35	0.43	0.00	2.43
LFZ-7	11.59	7.46	8.98	63.10	0.00	1.93	3.77	0.70	0.00	2.47
LFZ-10	11.22	6.52	9.70	62.57	0.00	2.07	5.02	0.52	0.00	2.38
SHA-2	7.00	1.41	7.23	77.28	0.00	1.27	2.99	0.36	0.00	2.46
Matrix Raw/low fired clay										
LFZ-mantel	0.37	3.17	20.99	60.77	0.00	3.54	1.15	0.46	0.00	9.56
LFZ-clay bank	0.40	6.13	19.48	59.42	0.00	3.56	1.16	0.55	0.00	9.31
Matrix ViS/NM										
LFZ-10	10.28	1.38	8.74	71.10	0.00	2.73	2.58	0.73	0.00	2.46
SHA-2	5.79	0.87	11.12	74.50	0.00	1.07	3.39	0.41	0.00	2.84
SHAZ-467 (1)	10.49	2.08	7.35	71.14	0.00	2.97	3.15	0.40	0.00	2.42
SHAZ-467 (2)	5.72	1.78	9.21	72.74	0.00	5.82	1.61	0.78	0.00	2.34
Matrix GNM										
AB-63-AB6	13.14	4.74	7.72	68.04	0.00	1.31	1.97	0.54	0.00	2.53
LFZ-7	10.33	5.33	9.85	68.11	0.00	2.31	0.66	0.74	0.00	2.68
LFZ-10 (2)	15.94	4.49	10.54	63.41	0.00	2.62	0.86	0.48	0.00	1.65
SHA-2 (2)	12.23	2.65	10.19	65.08	1.54	1.40	4.48	0.55	0.00	1.88

The ViS-zone consist of a well sintered matrix (no birefringence), with a high concentration of medium silt-very fine sand mineral inclusions. Monocrystalline (occasionally polycrystalline) subrounded to subangular well-sorted quartz grains are dominantly present, with occasionally some opaque minerals (mainly iron oxides) and rarely plagioclase, K-feldspars and heavy detrital minerals (tourmaline, zircon and rutile) (Table 31, Figure 140B). Petrographically, the ViS/NM zone is highly similar to the ViS zone. The main differences are the advanced continuous vitrification (glass) and the newly formed mineral phases between the quartz grains (Table 31, Figure 140C). The amount and size of these unidentifiable black micro-acicular crystals vary considerably in the samples and increase progressively towards the GNM zone. Remarkably, the concentration of newly formed minerals is higher along the borders of the elongated voids indicating that the heat was transferred more efficiently through the pore network. Also, due to the release of gases related to the dehydration and dehydroxylation of phyllosilicates and the decomposition of organic material and carbonates, spherical voids (bloating pores) appear, in which occasionally secondary calcite has crystallised. In the GNM zone, predominantly high temperature newly formed mineral phases are visible. These mineral phases cannot be identified petrographically and often occur in clusters or nuclei in the matrix (Table 31, Figure 140D). In addition, a few detrital, partially melted, quartz grains that coalesced at the edge can be observed.

This progressive thermal transformation (RW – ViS – ViS/NM – GNM) can also be observed by SEM. In the low fired/raw clay samples, quartz, feldspars (K-feldspar and plagioclase), muscovite, chlorite etc. are present in a non-vitrified clay matrix (Figure 141A). Upon firing, the minerals in the clay undergo chemical and structural modifications influenced by several factors, such as the chemical composition, the temperature, the duration of firing and the firing atmosphere (Moropoulou et al., 1995; Trindade et al., 2009; Rice, 2015). First, the clay dehydrates after which the organic material oxidizes and the clay minerals decompose by the removal of the hydroxyl groups from the silicate lattice (dehydroxylation) (Maniatis and Tite, 1981; Rice, 2015). With increasing temperature, these spots of partially melted clay minerals steadily increase in size until they form a continuous vitrified matrix, as observed in Figure 141B-F (Maniatis and Tite, 1981). At different temperatures, the remaining mineral phases (feldspars, quartz, etc.) decompose enriching the viscous 'liquid' glass in silica (SiO_2) and other oxides. Both the vitrification process, as well as the dissolution of quartz, is largely influenced by the presence and concentration of fluxing agents (Na, K, Ca, Mg and Fe). These are either inherent of the source material or can be introduced during the heating process. When fluxing agents are present, Maniatis and Tite (1981) observed that the vitrification process started at approximately 800°C and Trindade et al. (2009) and Shelby (2005) noticed that quartz gradually dissolves between 800° to 1100°C. In the GNM zone, few to common relict quartz grains can be observed locally in a continuous vitrified matrix (Figure 141E-F) indicating that the dissolution of quartz was incomplete.

In the viscous 'liquid' glass, different chemical reactions occur between the elements to form new mineral phases. When the melt cools down, these neoformed minerals will crystallise, often showing distinct crystal shapes, and the remaining melt will solidify into glass. In the ViS/NM zone, mineral phase transformations primarily take place locally at the quartz borders due to a chemical reaction between the quartz and the Si-poor glass forming new Si-richer phases (Figure 141B-C). EDS-measurements (APPENDIX 5) indicate that these neoformed grains either correspond with tabular wollastonite ($CaSiO_3$) crystals or acicular clinopyroxene crystals. These newly formed clinopyroxene minerals are dominantly present, while wollastonite only rarely occurs in the vicinity of decomposed calcareous microfossils.

As shown by Figure 142, the observed clinopyroxene minerals in the ViS/NM and GNM zone form a solid solution between augite [(Ca, Na)(Mg, Fe, Al)(Al, Si)$_2$O$_6$] and diopside ($CaMgSi_2O_6$) in which the Mg-content is similar, but the CaO/MgO ratio changes. The decomposition of clay and other silicate minerals forms a melt rich in Na_2O, MgO, Al_2O_3, SiO_2, and CaO (Table 32). From this melt, primarily clinopyroxene minerals nucleate and crystallise. As the outer surface is exposed to higher temperatures for a longer period of time, larger clinopyroxene minerals form at the edge of the object and the size of these minerals significantly decreases towards the ViS/NM zone (Figure 141C, E-F). The lack of orientation in the neoformed minerals indicates a rather high viscosity of the melt which did not create noticeable macro- and microscopically visible flow patterns. Next to clinopyroxenes, sporadically zones of elongated newly formed plagioclase crystals, of which some can be chemically assigned to albite, are observed (Figure 141D). As indicated by the diopside-albite-anorthite system, diopside and plagioclase can coexist and crystallise together in a cooling glass. The observed zonation of plagioclase may be the result of fractional crystallization in the glass (magnesium and calcium depletion in the glass due to pyroxene crystallization) (Okrusch and Frimmel, 2020).

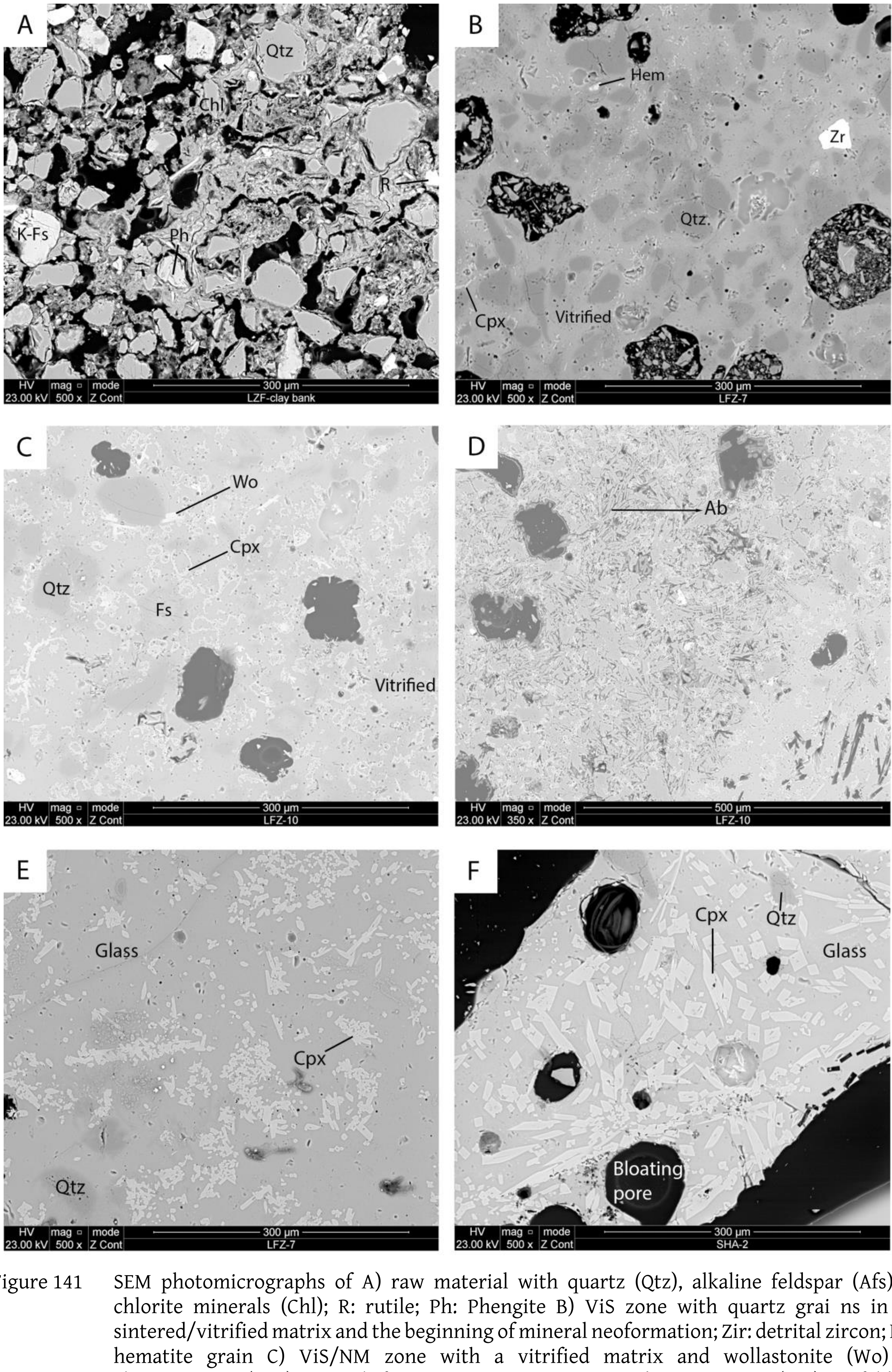


Figure 141 SEM photomicrographs of A) raw material with quartz (Qtz), alkaline feldspar (Afs) and chlorite minerals (Chl); R: rutile; Ph: Phengite B) ViS zone with quartz grai ns in well sintered/vitrified matrix and the beginning of mineral neoformation; Zir: detrital zircon; Hem: hematite grain C) ViS/NM zone with a vitrified matrix and wollastonite (Wo) and clinopyroxene (Cpx) minerals forming a reaction rim around quartz grains (Qtz); Fs: feldspar, D) elongated newly formed plagioclase (Ab: albite) crystals in a vitrified matrix E) glass with newly formed automorphic crystals of clinopyroxene minerals (Cpx) and relict quartz (Qtz) F) well-developed glass with large newly formed automorphic crystals of clinopyroxene minerals and relict quartz (EDS point measurements of minerals, see APPENDIX 5).

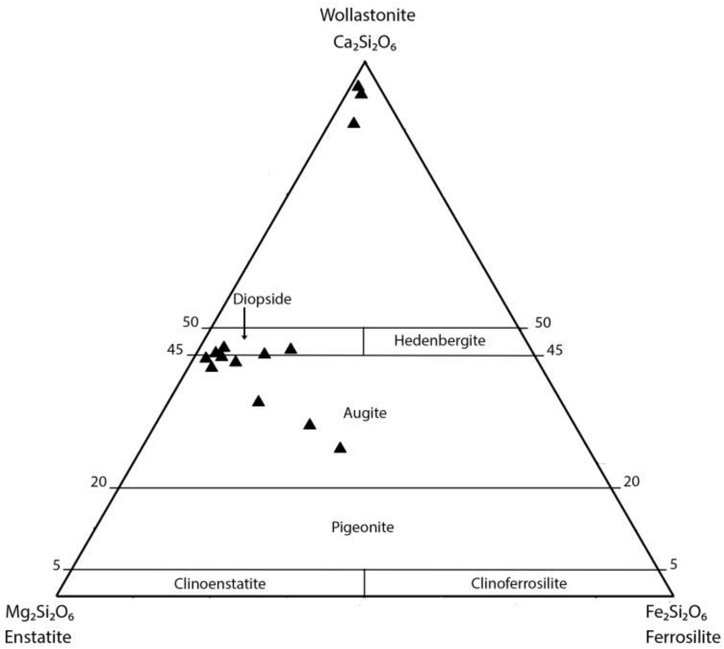


Figure 142 Ternary plot Wo-En-Fs for the pyroxene minerals in the ViS/NM and GNM zone indicating that they form a solid solution between augite and diopside (EDS point measurements of pyroxene minerals see APPENDIX 5).

The petrographic observations and the SEM/EDS mineralogical identifications are confirmed by the XRD analysis (Figure 143). The RW diffractogram attests to the dominance of quartz, as well as the presence of muscovite, hematite and feldspars (both K-feldspar and plagioclase). In the ViS/NM diffractograms (Figure 143), several high intensity peaks correspond with quartz. Next to quartz, several peaks can be assigned to Ca-Fe-Mg clinopyroxenes. Due to the non-stoichiometric composition, variations in crystal structure occur that cause a slight shift and asymmetry of the diffraction peaks. In addition to clinopyroxene, newly (and residual) plagioclase minerals can be identified as well as wollastonite. In the GNM samples (Figure 143), the decrease in intensity of the diffraction peaks and the increase in background noise indicate the presence of an amorphous/vitreous phase. Similar to the ViS/NM samples, quartz, clinopyroxene and plagioclase are observed. Although the minerals in the samples are not quantified, the relative intensity of diffraction peaks and the petrographic and SEM observations indicate a higher amount of clinopyroxene in the GNM-samples compared to the ViS/NM samples.

Chemically, the composition of the different stages (RW, ViS/NM and GNM) reveals a gradual enrichment of Na_2O, MgO and to lesser extent CaO towards the GNM zone (e.g. the inside of the heating structure) (Table 32, Figure 144). Interestingly, the low fired material, used as a substitute for the local source material, contains relatively low concentrations of Na_2O and CaO, indicating that sodium and calcium are introduced during the heating process. As shown by Fig. 8, the pattern of CaO enrichment is less clear compared to Na_2O and might, in part, be explained by local variations in the marine clay and minor differences between the sites. Regarding the Mg-content, it is striking that the MgO levels of the ViS/NM samples are significantly lower than the low fired material (RW) and that the MgO content of the low fired samples was in line with the GNM samples (Figure 144). Although a magnesium depletion in the ViS/NM is not impossible, this seems rather improbable and may suggests that similar processes caused a magnesium enrichment in both the GNM zone and low fired material.

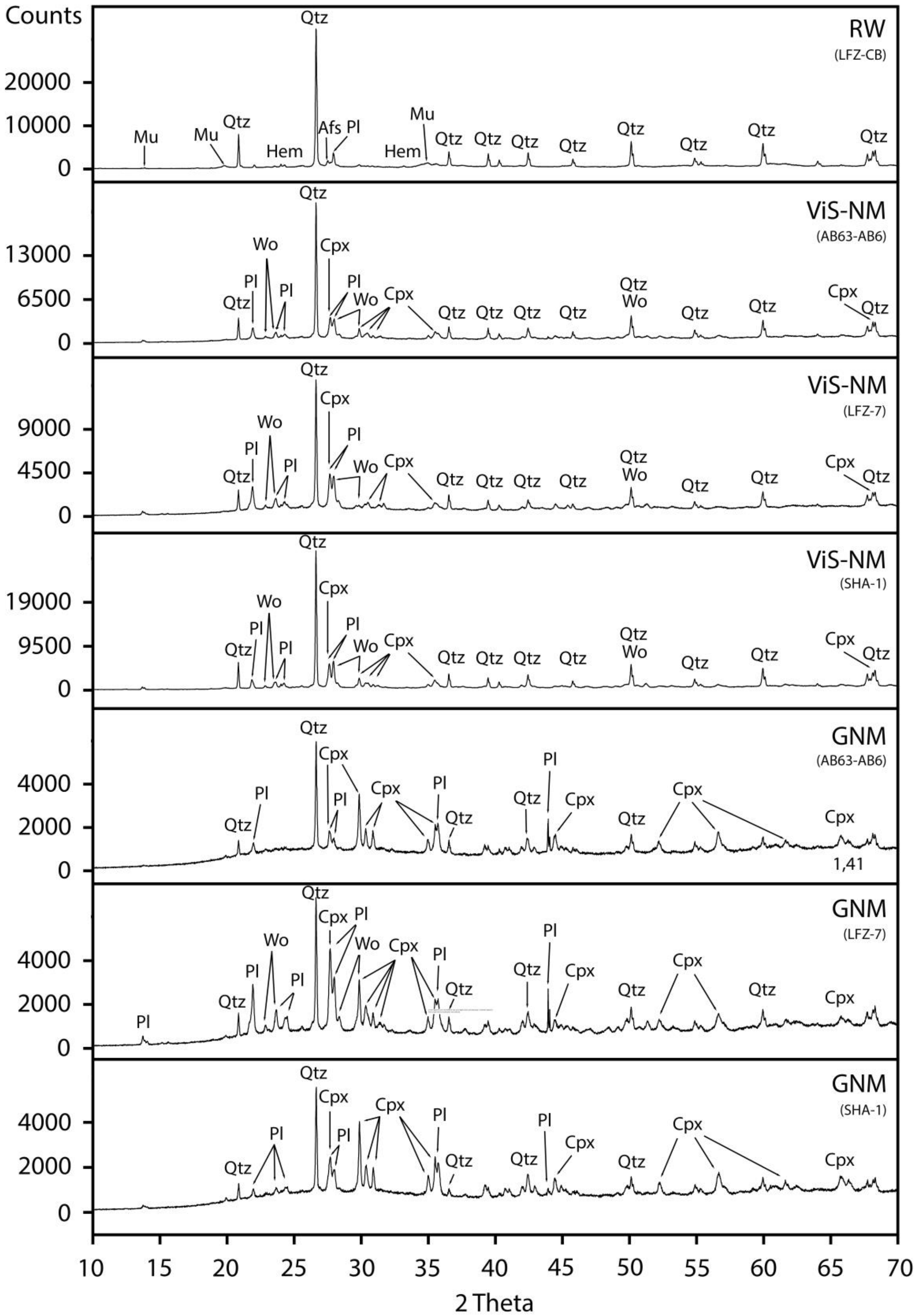


Figure 143 Powder XRD patterns of selected samples from the raw/low fired samples, the ViS-NM zone and GNM zone. Abbreviations: Qtz = quartz, Mu = muscovite; Hem = hematite; Afs = alkali feldspar; Pl= plagioclase; Wo= wollastonite and Cpx = clinopyroxene (overview of all XRD-data see APPENDIX 5).

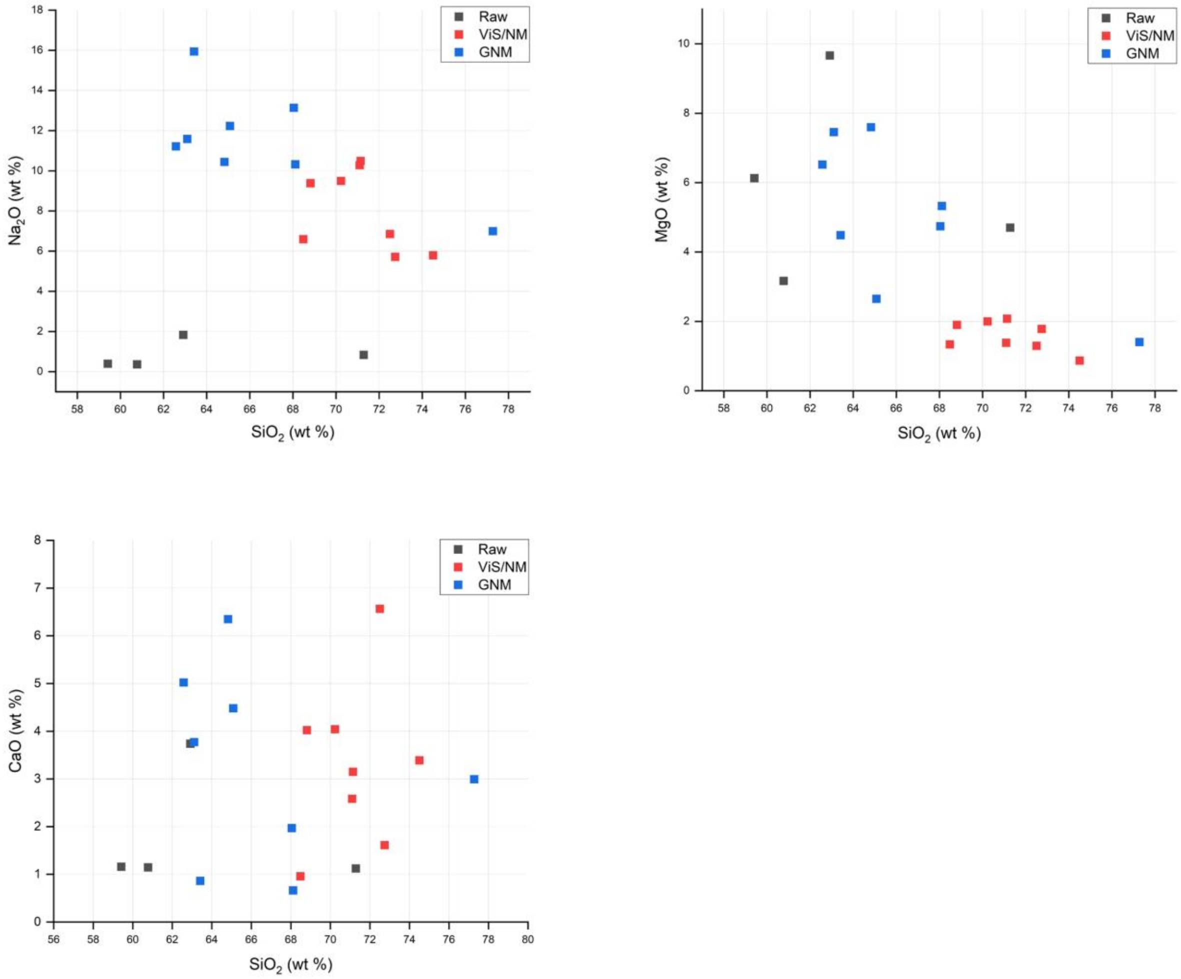


Figure 144 Bivariant plots Na2O versus SiO2; MgO versus SiO2 and CaO versus SiO2 of the raw/low fired, ViS-NM and GNM samples indicating a sodium enrichment towards the glass zone, a magnesium enrichment of the GNM and raw/low fired samples and a slight increase in calcium towards the glass zone (based on data presented in Table 32).

8.5 Discussion

8.5.1 Identifying the external fluxes that facilitate the vitrification process

In this study, the low fired samples contain relatively little CaO indicating a non or low calcareous source material (Table 32, Figure 144). As demonstrated by, amongst others, Maniatis and Tite (1981), Cultrone et al. (2001), Trindade et al. (2009, 2010) and El Ouahabi et al. (2015) the firing of non-calcareous and calcareous clay is considerably different and affects the vitrification process as well as the formation of high temperature mineral phases. Upon firing, the low amount of fluxes in Ca-poor clay inhibits vitrification and, depending on the chemical composition, essentially the Al- and Si-content, primarily spinel, mullite, hematite and/or cristobalite will form (Moropoulou et al., 1995; Trindade et al., 2009; El Ouahabi et al., 2015). However, none of these neoformed mineral phases are identified here. Instead, Ca- and/or Mg-rich high temperature mineral phases, such as wollastonite and clinopyroxene have crystallised which can only be explained by an enrichment of Ca-poor source material with external fluxing agents as attested in the ViS/NM and GNM zones (Table 32, Figure 144).

These chemical elements or fluxes can be deliberately added in the form of natron or plant ashes to facilitate the melting of quartz, which is an established practice in ancient glass production activities (Henderson, 2013). In the case of glass manufacturing, adding fluxes is an intentional step in the *chaîne opératoire* which serves a deliberate technological purpose. However, the large amount of vitrified objects found discarded on Roman salt production sites in northern Gaul indicate that the reactions occurring in these hearths is unintentional and unwanted. The fluxes will therefore not have been deliberately added to create additional waste material which indicates that the presence of these fluxes must be explained by the processes occurring in the hearth structures: the combustion of fuel and the production of salt. The combustion of fuel (wood, peat or dung) produces ash which primarily provides Ca, K and to a lesser extent Mg. The amount and ratio between these fluxing agents largely depend on the type of fuel and the combustion temperature (Misra et al., 1993; Braadbaart et al., 2012; 2017; Karkanas, 2021). In view of the landscape context, peat will probably have been used to fuel the salt production hearths in northern Gaul.

Next to fuel, several actions occurring during the salt production activities, for instance the replenishment of the evaporation vessels with brine, boiling over and leaking of these containers etc., may have introduced Na-, Mg- and to lesser extent Ca- and K-fluxes. These elements are present as soluble salt minerals in seawater and during evaporation their concentration in the brine will steadily increase until the different salts crystallize based on their solubility (McCaffrey et al., 1987; Babel and Schreiber, 2014). It is generally assumed that, next to accidental spilling, boiling over and leaking, the undesired salts such as calcite ($CaCO_3$), gypsum (($CaSO_4$)·$2H_2O$), epsomite (($MgSO_4$)·$7H_2O$), kaïnite ($KMg(SO_4)Cl·3H_2O$), sylvite (KCl), etc. were deliberately disposed of during the production process to prevent contamination of the finalised product (Hathaway, 2013; Babel and Schreiber, 2014; Harding, 2021).

Although calcium occurs in the brine, it is dominantly present in all fuel ash compositions suggesting that fuel ash may be the dominant source of Ca-flux. The Na_2O and MgO levels are anomalously high in the GNM zone which must have originated primarily from the brine, as the Na- and Mg-content in fuel is typically quite low (Steenari et al., 1999; Braadbaart et al., 2012; Babel and Schreiber, 2014; Vassilev et al., 2017; Karkanas, 2021).

These external fluxes provide the necessary Na, Mg and Ca to cause similar mineral transformation as observed in calcite and dolomite rich clays (Cultrone et al., 2001; Trindade et al., 2009, 2010; El Ouahabi et al., 2015). Trindade et al. (2009); (2010) report that in these Ca and Mg rich clays both wollastonite and diopside minerals crystallize at 900°C and that forsterite, mullite and cristobalite form at 1000°C, 1100°C and >1100°C respectively. The absence of these latter minerals, the presence of wollastonite and Ca-Fe-Mg clinopyroxenes, the continuous vitrification and the melting of quartz observed here may indicate that the clay fragments inside the hearths reached temperatures between 900-1000°C

A similar phenomenon was observed by Macphail et al. (2012) who studied the siliceous green glaze on briquetage fragments from Stanford Wharf (Essex, Britain). They concluded that the green glaze formed at temperatures between ca. 700-1000°C and contained significantly higher quantities of sodium which can only be explained by their role in the salt making process. Next to sodium, the green glaze also contained higher levels of phosphorus, iron and zinc which might have originated from plant-derived fuel ash waste (Macphail et al., 2012). Just as for the vitrified clay fragments, the presence of external fluxes, originating from the brine used to produce the salt and the fuel, facilitated the vitrification process in the briquetage fragments.

However, it is important to note that the reference studies used to characterise the mineral transformations are conducted with calcite and/or dolomite rich source clays that are heated under laboratory conditions (Trindade et al., 2009, 2010; El Ouahabi et al., 2015). Further (experimental) research is needed to verify whether external fluxes, originating from the fuel or the brine, cause in fact comparable mineral transformations in non/low calcareous clays at the same temperature intervals.

8.5.2 Implications for the salt production process and wider archaeological significance

Compared to other waste categories, vitrified clay fragments are often considered undiagnostic elements with little explanatory potential. As recently proven by Kropáč and Dolníček (2013), identifying the mineralogical phases and determining the chemical composition of non-metallurgical vitrified clay fragments can provide new insights into the firing conditions of a lime burning kiln. Similarly, Young (2012) analysed non-metallurgical vitrified clay slags of unknown origin from a late Iron Age farmstead at Bornais (Scotland) and determined that they formed through the fluxing action of ash and the silicate substrate.

Macroscopically, the vitrified clay fragments resemble vitrified hearth lining and base fragments. To this day, vitrified hearth lining has only been frequently described on other high temperature artisanal sites involved in metallurgy and lime burning (Bachmann, 1982; Kropáč and Dolníček, 2013; Hauptmann, 2020). As a result, despite their prominent place in the coastal landscape near tidal channels, the interpretation of ‘s Heer Abtskerke, Aardenburg and Middelburg was debated for decades and a variety of heated crafts such as metallurgy and lime burning were suggested (Dekoninck et al., in press). However, the anomalously high Na_2O and MgO levels that decrease away from the GNM zone should be viewed as supporting a salt making origin for the vitrified clay fragments.

It is clear that the occurrence of high quantities of vitrified material might be unique to mid-Roman salt production in northern Gaul, as this phenomenon is yet to be discovered elsewhere in the northern parts of the empire. Nevertheless, the amount of vitrified material on these salt production sites is rather surprising as traditionally salt production has been interpreted as a long-lasting process occurring at relatively low to medium temperatures (Hathaway 2013). The vitrified material indicates that inside the hearths temperatures between 900-1000°C were regularly reached. As shown by Livingstone Smith (2001), a maximum temperature above 900°C is not uncommon in bonfires and in simple updraft kilns. However, the maximum temperature is not the only parameter that needs to be considered as the heating rate, the duration of firing and firing atmosphere also played an important role (Maniatis and Tite, 1981; Rye, 1981; Livingstone Smith, 2001; Rice, 2015). An experimental study by Aldeias et al. (2016) demonstrated that inside the hearth the heat preferentially travels downwards and not laterally, meaning that the temperature will be highest just below the fire at the hearth base. In addition, they observed that the surface of the sediment beneath the fire heated rather quickly and progressively slowed as the heat travelled downwards (Aldeias et al., 2016). This principle resembles the observed progressive thermal transformation (GNM-ViS/NM-ViS) in the analysed objects.

As the temperatures were highest just below the fire, the analysed objects may have formed primarily at the base of the hearths, and should therefore be interpreted as vitrified hearth base fragments. In the case of Leffinge, remains of the vitrified hearth base were preserved *in situ* at the bottom of the hearths indicating that the fire burned directly underneath the evaporation vessels. Through the stoke-hole, fuel was then continually added to the hearth chamber to maintain the temperature. Inside the raised clay bank, the individual hearths were well insulated which prevented heat loss during firing, and consequently, may have facilitated higher temperatures. Moreover, the joint firing of adjacent hearths will have further minimised heat loss and may have had a significant impact on the temperatures inside the hearths.

On mid-Roman salt production sites in northern Gaul, vitrification was a common, unwanted side effect during the salt making activities. Therefore, between production cycles, the hearths were either cleaned and relined removing the vitrified material or immediately reused. In the latter case, the hearth base might have re-melted forming objects with multiple vitrification layers. For instance, multiple levels of superimposed vitrified hearth bases were recorded *in situ* on the late Iron Age - early Roman salt production site at Peldon (Essex, Britain) (de Brisay, 1978). This shows that cleaning the hearth might be a deliberate choice to prolong the life cycle of the hearths, but as demonstrated by the Peldon complex, the salt producers could just as easily have relined the hearth covering the old vitrified base.

To remove the hearth base, it had to be broken up in manageable pieces creating amorphous fragments of various shapes and sizes with sharp edges. Consequently, these detrital pieces were discarded outside the work area in refuse zones situated at the edge of the sites. The large amount of fragments recovered, for instance, at Leffinge indicates that the hearth battery was repeatedly cleaned and reused. However, as multiple factors might have influenced the functioning of the heating structures, it is difficult to estimate whether the large amount of objects was generated during a single production season or in fact represented a repeated use of the site over a longer period of time. At this time, the reasons as to why the salt producers put in the (extra) effort to reach these temperatures is unclear. Nevertheless, it is evident that, for whatever reason, reaching vitrification temperatures was not a haphazard incident, but occurred systematically on these mid-Roman salt production sites along the southern North Sea coast.

The introduction of these hearth batteries in the late second-early third century completely transformed the way in which the salt production sites operated in northern Gaul. This heating system is thoroughly different from the rectangular hearths with a griddle (*fourneau à grille*) in late Iron Age northern France. These hearths consisted of elongated pits covered with a griddle on which the ceramic briquetage vessels were placed. At the extremities were one or two open-air stoke-pits which were used to fuel the hearths (Prilaux, 2000a; Masse and Prilaux, 2017). Similarly, in Iron Age and Roman Britain, several other types of salt production hearths using direct and indirect heat are known (Lane and Morris, 2001; Biddulph et al., 2012; Hathaway, 2013). Indirect heating systems using adjacent stoke-pits, as was the case in late Iron Age northern France and certain areas of Britain, might not have been able to reach sufficiently high temperatures or lacked sufficient fluxes to enable large-scale vitrification. Similar arguments apply for smaller isolated hearths in which direct heating systems were used. The different nature and functioning of the heating systems might explain why vitrified clay fragments are rare at best in other Roman salt production areas, like Essex (EN) or Somerset (EN). Recently, fragments of vitrified hearth bases have been recorded on late Saxon-early medieval salterns in Norfolk (UK), but these are yet to be systematically studied (Clarke, 2016; Knight and Clarke, 2019).

8.6 Conclusion

The present study demonstrates that the geochemical and mineralogical study of discarded, undiagnostic waste materials can provide valuable new insights to poorly understood aspects of the Roman salt making practices in the most northern part of the empire. The large amount of amorphous, undiagnostic waste material frequently encountered on mid-Roman salt production sites in northern Gaul represents vitrified hearth base fragments. The high similarity between the objects from different sites suggest that salt production occurred in a technologically very uniform way and under similar conditions. In the hearth, external fluxes ($Na2O$, MgO and CaO) - originating from the brine and the fuel - induced a (unintentional) vitrification process with specific mineral transformations in a non or low calcareous source material. The newly formed high temperature mineral phases, the amount vitrification and the melting of quartz indicate that the area underneath the fire at a certain point may have reached temperatures of approximately 900-1000°C.

This first study on salt production related vitrified materials clearly indicates that current interpretations regarding the functioning of salt production hearths and the firing conditions needs major adjustments. Salt production was clearly not always a low temperature activity and, through time, regional technological innovations might have profoundly changed the way in which salt was produced. In the case of northern Gaul, the Roman drive for technological optimalisation and increasing productivity may have introduced hearth batteries on late second-early third century CE salterns providing unique production conditions, yet to be discovered elsewhere in the Roman Empire. Inside the raised clay bank, the hearths were well insulated preventing heat loss during firing which in turn may have facilitated higher temperatures leading to an unintentional and even unwanted by-product: i.e. vitrified hearth base fragments.

The analysis of these undiagnostic, vitrified waste materials will enable future discussions of how these enigmatic salt production hearths functioned and how the Romans adapted and further developed existing salt production techniques. This study, together with those by Young (2012) and Kropáč and Dolníček (2013), also demonstrates the potential value of future geochemical and mineralogical research on previously discarded waste categories to better understand certain aspects of high temperature artisanal processes.

Part 3 Towards a new understanding of the technical and social organisation of Roman salt production in the Menapian *civitas*

Chapter 9 Towards a new understanding of salt production in the *civitas Menapiorum*

9.1 Introduction

The dissertation's main objective was to acquire insight into how salt as a basic resource was extracted from the sea on the shores of the *civitas Menapiorum*, situated at the northern fringe of the Roman Empire. Furthermore, this study aims to explore and acquire insight into the social actors involved in the production, and assess the wider economic impact of the production activities. These objectives were concretised through a set of research questions which structured the research. The first research question was defined as follows:

> How was salt as a basic resource extracted from the sea in the study area throughout the Roman period, and how are the salt production activities reflected in the archaeological record?

This overarching research question was broken down into three topics which were subsequently studied in Part 2 of this dissertation. Chapter 4 describes the salt production's chronological and geographical development in northern Gaul. Chapters 5, 6 and 7 assess the archaeological evidence of Menapian salt production. Finally, Chapter 8 evaluates the potential of archaeometrical analyses on salt production related artefacts. Each of these chapters presents, analyses and answers a specific set of research questions defined in Chapter 1. Furthermore, these chapters touch upon and pave the way to answer the second overarching research question:

> Who were the social actors involved in salt production, how was the production organised, and what was the socio-economic and cultural impact of the production activities in the study area and the wider region?

Two additional questions can concretise this general question:

1) Which social actors were involved in salt production and how do those relate to other salt production regions in northwestern Europe?
2) What role does salt production play in the socio-economic development of the study area?

This chapter aims to integrate and historically and economically contextualise the results presented in the individual chapters. Furthermore, it provides a comprehensive answer to the overarching research questions presented above. Early on, it became apparent that the way salt was produced in the study area drastically changed towards the end of the second century CE. These technological changes significantly impact but also reflect the socio-cultural and economic sphere in which the activities took place. To answer the research questions satisfactorily and to study the socio-cultural and economic implications of the technological innovations, it was necessary to separate the salt production activities into two chronologically distinct phases: late first – early second century and late second – early third century salt production. The first sections (sections 9.2.1 and 9.2.2) attempted to reconstruct the *chaîne opératoire* of the salt production activities in each phase by considering the technological choices made by the salt producers. These choices are inferred based on the data presented in chapters 6, 7, 8 and 9. In the following sections (0 and 9.4), the socio-cultural and economic aspects of the research questions will be explored.

9.2 Reconstructing the salt production process in the Menapian *civitas*

9.2.1 Late first-early second century salt production

This section attempts to reconstruct the late first - early second-century *chaîne opératoire* by mapping the different choices of the producers at each of the six salt production stages (cfr. 3.4). The reconstructed process draws heavily on the data presented in Chapter 6. In that chapter, the following late first - early second century sites were studied: the Geuldepot (Zeebrugge Achterhaven), Donk 1 (Zeebrugge Achterhaven); Dudzele Zonnebloemweg, Dudzele Distrigas 1992, Dudzele Boudewijnkanaal, Prospectievondsten Achterhaven, Ramskapelle Heistlaan, Oostburg 't Vestje, Ritthem Schotteweg and Koudekerke Meinersweg (Figure 50). However, with the exception of Koudekerke Meinersweg, these sites primarily consist of briquetage refuse and lack distinct salt production features like heating and water management structures. Yet, the briquetage material from these sites offers quite a lot of insights into the salt manufacturing process and the technological choices made by the producers. Based on macroscopic characteristics, the briquetage could be divided into two groups: Zeebrugge-Dudzele-Oostburg and Walcheren. The latter group comprises the sites of Ritthem Schotteweg and Koudekerke Meinersweg. The remaining sites are part of the Zeebrugge-Dudzele-Oostburg group (Chapter 6).

The reconstructed *chaîne opératoire* of the late first - early second century salt production activities (phase 1) is shown schematically in Figure 145. Figure 146 illustrates how these late first - early second century salt production activities may have taken place. Although it is an essential aspect of the *chaîne opératoire*, the manufacture and use of briquetage only explains a fraction production process. The majority of the production process consists of preparatory steps, which can only be deduced by studying the sites holistically, including the salt production features like heating and water management structures. Consequently, certain aspects of the *chaîne opératoire* are solely based on the heating structures discovered at Koudekerke Meinersweg. Although not contradicted by the material on other sites, it is possible that aspects of the reconstructed *chaîne opératoire* are not representative of the entire study area. In addition, some choices are inferred based on data from the later period and have not yet been conclusively proven for the late first - early second century.

9.2.1.1 Stage 1: raw material procurement

Access to locally available raw materials was a determining factor in selecting suitable locations to perform salt production activities. As each studied site was located in a dynamic mudflat-salt marsh environment, brackish or salt water from nearby tidal channels was abundantly available. Exactly how the salt water from the tidal channels was transported to the sites is unclear and can only be hypothesised. Depending on the distance to the site, the salt water could be collected by hand directly from the tidal channel or from supply ditches. The collected water was then stored in (large) settling tanks on site.

Besides salt water, a steady fuel supply was essential to heat the salt production hearths. Palynological studies on Roman sites in the coastal plain (cfr. 2.2.4) indicate an open mudflat-salt marsh-salt meadow landscape dominated by grassland and herbaceous plants. Given the scarcity of trees, peat is the only local, abundantly available type of fuel. Roman peat extraction pits have been found at multiple sites in the study area (section 2.4.1.3) (Figure 23) (Baeteman, 2007b; Pieters, 2013). Unfortunately, no ash samples of late first – early second century sites were preserved for analyses. Just as for the later period, these analyses might have removed any lingering doubts about the nature of the fuel. However, based on the landscape and parallels with the later phase and medieval salt production in the same area, the use of peat can be suspected with a relatively high amount of certainty. The extraction of peat is a *chaîne opératoire* on its own as it had to be cut, laid out to dry for an ample amount of time, turned at regular intervals to facilitate the drying process, transported and stacked at the production sites (Gerding, 1995). Each of these steps had specific labour requirements that had to be met. In addition, peat drying took several months before it could be used as fuel (Borger, 1992). Consequently, a well-thought-out fuel collection strategy must have been in place to guarantee a stable fuel supply throughout the salt production season.

Subsequently, a potential clay source was located, and the clay necessary to create the briquetage elements and hearth infrastructure was collected. Most likely, the clay was collected in the site's immediate vicinity since one of the main requirements of the clay might have been its availability. As discussed in Chapter 6, the briquetage vessels were heavily tempered with vegetal material. At this time, it is unclear which plants were used as temper[1], but whatever plants were used, somebody had to harvest and dry them before they could be added to the clay.

9.2.1.2 Stage 2: site preparation

After a suitable location was chosen, the site had to be organised. This involved defining and creating a working area where the main activities took place. The working area, delimited or not, comprised elements of the water management system like the settling tanks and the heating structures necessary to produce salt. The only evidence of site preparation activities stems from Koudekerke.

At Koudekerke, the partly excavated working area contained four individual heating structures, of which the base's diameter varied between 1.15-1.3 m. Whether these hearths were used simultaneously or were part of different site phases cannot be said for certain. The hearths were constructed above ground on top of an artificial clay surface, and the hearth lining slightly curved inwards forming a structure resembling a truncated cone (cfr. 6.4). Similar to pottery kilns, the hearths will have been pre-fired before their actual use to strengthen the lining. Again, this type of heating structure might not be representative of the study area as a whole, and different, more ephemeral types could have existed in the Bruges area and, by extension, the *civitas*. Either way, any type of heating structure had to be constructed and probably pre-fired before use. This could be carried out in conjunction with pre-firing the briquetage pottery (section 9.2.1.3).

[1] Samples of the briquetage vessels are included in the Brain-be 2.0 project 'Identification and 14C Dating of Organic Materials in Archaeological Ceramics'.

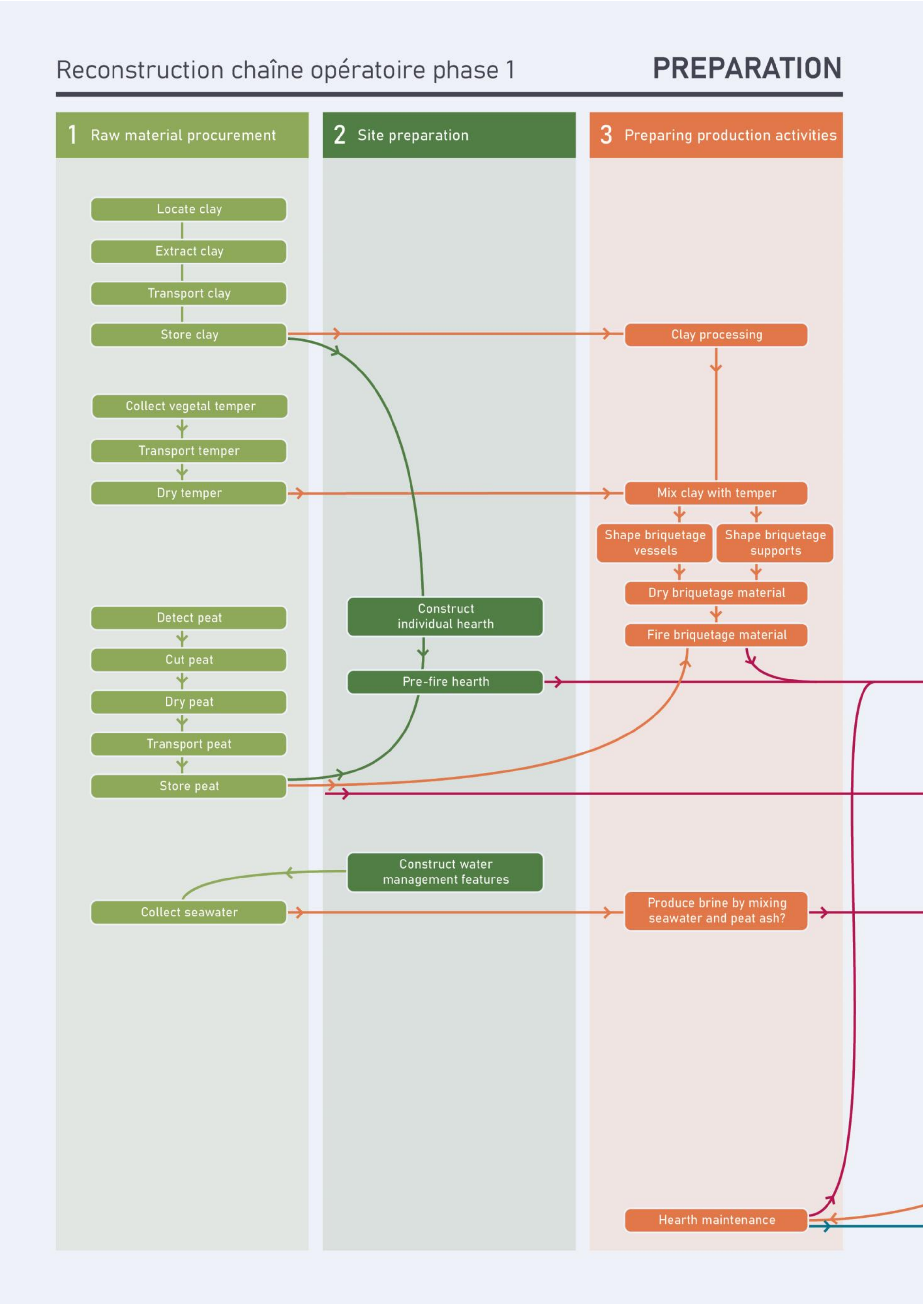
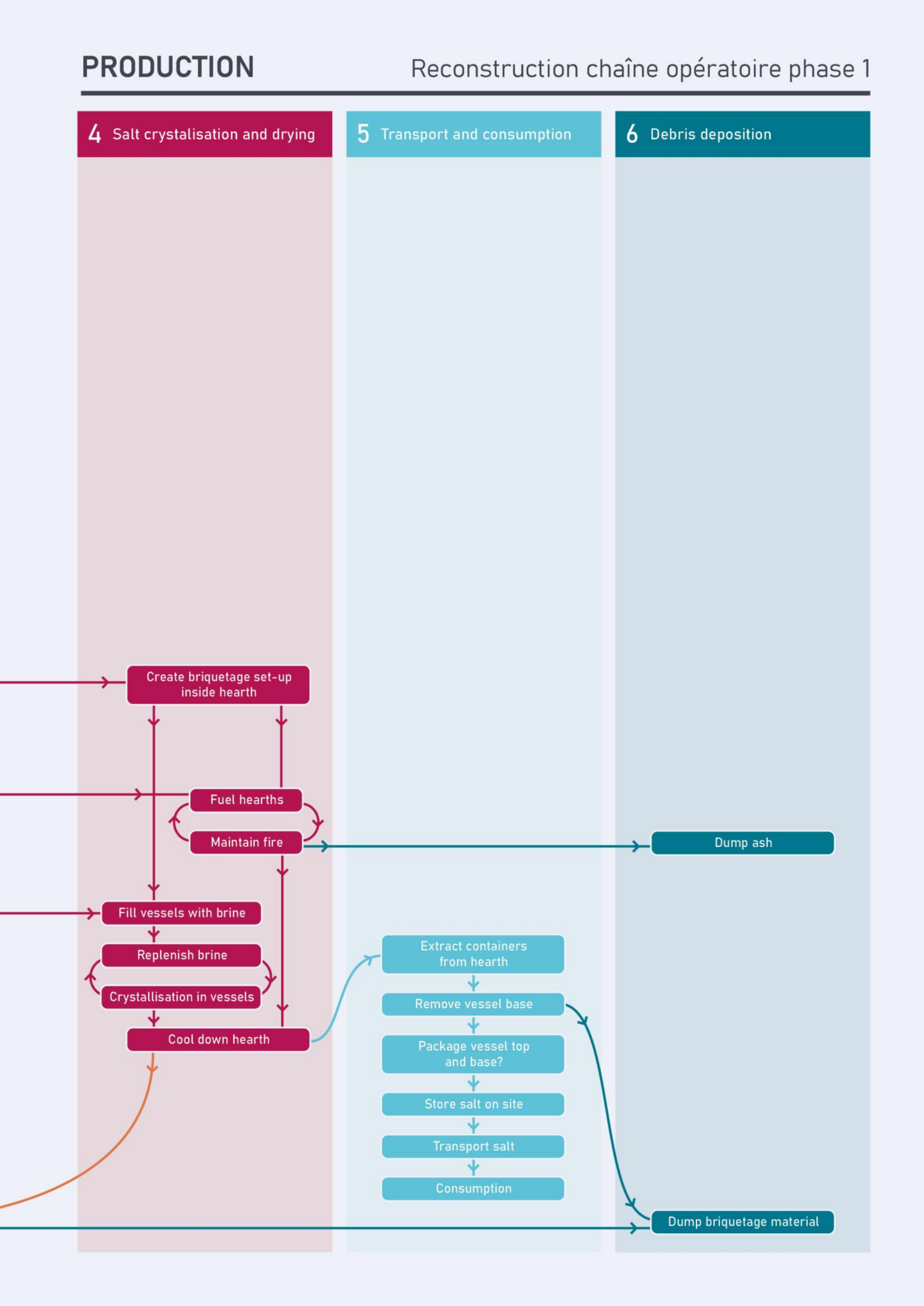


Figure 145 Reconstruction of the salt production *chaîne opératoire* in the late first– early second century (phase 1) (©Yannick De Smet (graphic design) and Michiel Dekoninck/Ugent (content))


PRODUCTION
Reconstruction chaîne opératoire phase 1
4 Salt crystalisation and drying
5 Transport and consumption
6 Debris deposition
Create briquetage set-up inside hearth
Fuel hearths
Maintain fire
Dump ash
Fill vessels with brine
Replenish brine
Crystallisation in vessels
Cool down hearth
Extract containers from hearth
Remove vessel base
Package vessel top and base?
Store salt on site
Transport salt
Consumption
Dump briquetage material

None of the sites provided evidence of how the water supply and storage were organised. Given the crucial role of brine in the production process, some form of settling tanks or brine reservoirs must have existed in the vicinity of the hearths. Consequently, these features had to be constructed and maintained, but, for the moment, their shape and capacity is anyone's guess. Another possibility is that the brine was produced in wooden barrels above ground, which would leave little archaeological traces.

9.2.1.3 Stage 3: preparing the salt production activities

After the stage 2 activities, the raw materials were processed in preparation of the brine boiling process. This stage primarily consists of producing the briquetage material and creating the brine. However, the absence of water management features like settling tanks makes it difficult to make informed statements about brine production in this period. Since the salinity of seawater is typically quite low (31-35‰) (Babel and Schreiber, 2014), there is little doubt that the salt producers attempted to increase the salinity of the seawater/brine before the evaporation process. This had a significant effect on the process' efficiency as it saved the producers not only fuel but also time and labour. Similar to the later period (infra) and medieval times (Leenders, 2007, 2010), it can be hypothesised that the brine was made by mixing seawater with the ash from salt-impregnated peat. Yet, to confirm this hypothesis, analyses on new sites are required.

The necessary briquetage elements were also produced at this stage: vessels to evaporate the brine and support elements to support the salt containers above the fire. The production of briquetage roughly follows the ceramic *chaîne opératoire* consisting of the following stages: clay extraction, clay processing/preparation, fashioning, drying and firing (Roux, 2017, 2019). Naturally, each major stage could consist of a series of smaller mandatory or optional steps, which are not discussed here. As briquetage vessels had a single use and a practical purpose, clay processing/preparation will have been kept to a minimum. As discussed in Chapter 6, one of the preparatory steps was adding and mixing (large) amounts of vegetal material as a temper to the clay. This created highly permeable vessels with strong thermal shock resistance. This would have been important since (cold) brine was continuously added to these containers.

Subsequently, the vessels and the support elements were crudely fashioned/shaped by hand. In the Zeebrugge-Dudzele-Oostburg and Walcheren group, the simple cylindrical to slightly truncated conical containers were built up by coiling, and the rim was often finished with fingertip decoration. The pedestals were also shaped by hand into the desired form ('brick-like', cylindrical etc.). Important differences between the two briquetage groups are the vessel thickness, size and the pedestal's dimensions. In the group Zeebrugge, the vessels have an average diameter of 12.6 cm with a wall thickness between 3-11.9 mm. In comparison, the wall thickness in the group Walcheren varies between 12-20.9 mm and the vessel diameter averages 24.6 cm. Reconstructing the height of these containers is difficult, but complete vessel profiles of similar containers in the hinterland suggest a height between 20 and 30 cm. The vessels in the group Walcheren might have been able to contain up to four times as much salt (14.26 kg vs 3.74 kg). The observed increase in pedestal size is obviously connected to the increase in vessel size as these heavier vessels will have required bigger support elements.

After the briquetage elements were formed, the material was left to dry in order to evaporate some of the moisture prior to the firing process (Rye, 1981, 21-23). Firing the briquetage elements could be done in bonfires or the already built salt production hearths.

9.2.1.4 Stage 4: salt crystallisation and drying

With the preparatory steps completed, the evaporation process could commence. First of all, the container-pedestal setup was constructed inside the hearths. Naturally, what this setup looked like depended on the briquetage morphology and the nature of the heating structure. In addition, the observed variability in vessel diameter will require minor adjustments of the setup between production cycles within the same site. Next, the briquetage vessels were filled with brine and the fuel, stacked at the hearth base, was set on fire. Gradually, the brine heated up, and the undersaturated solution was brought into a (super)saturated state through evaporation. This required a lot of energy and, therefore, the fire had to be maintained throughout this evaporation process. The ash was raked out of the firing chamber to maintain the fire, and the fuel, more precisely peat, was added through the stokehole. The raked-out ash was then either kept to the side to produce a new batch of brine or dumped in the refuse area.

The vessels were constantly monitored and replenished with brine during evaporation to prevent production downtime. As explained in detail in section 3.1.2, different salt minerals crystalised from the brine at successive intervals based on their solubility. First, the carbonate minerals crystallised, followed by gypsum. Subsequently, the desired halite (NaCl) formed, followed by the K-Mg salts, also referred to as bitterns (Babel and Schreiber, 2014). Most likely, these salt crystals were not harvested from the vessels but left to accumulate inside the containers. Arguments for this are the unsuitability of deep containers for harvesting salt, the use of briquetage vessels as packaging material and the long-standing north Gaulish tradition of letting the crystallised salt accumulate inside the containers (Prilaux, 2000a; Masse and Prilaux, 2017). However, it remains an open question whether the salt accumulated in or was harvested from the large briquetage vessels (Ø 40-52 cm) at Koudekerke (section 6.4). Finally, when the vessels were full, the producers extinguished the fire and the hearth and the containers cooled down. After a cool-down period, the briquetage vessels could then be lifted out of the hearth chamber.

An unresolved issue of the 'accumulation' method relates to the removal of impurities or undesired salts. When the crystallised salt accumulates inside the vessels, the carbonate minerals and bitterns will also precipitate, 'contaminating' the end product. Sevink et al. (2021) recently suggested that the evaporation process was halted before the majority of bitterns precipitated and that the residual brine enriched in Mg and K was decanted from the vessels after removing them from the fire. A similar method might have been used here, but more (experimental) research and chemical analyses are required to verify the feasibility of this technique. In addition, experimental research might shed new light on salt minerals' crystallisation and accumulation process inside these briquetage vessels.

9.2.1.5 Stage 5: transport and consumption

Given the (potential) capacity of a single hearth, it is evident that the majority of the produced salt was intended for the local and regional consumer markets. Numerous finds of briquetage vessel fragments in the hinterland (see, Van den Broeke, 1995a, 1995b, 2012) indicate that the salt was extracted from the briquetage vessels at the consumption and not the production sites. Hence, after the briquetage vessels were removed from the hearths, they were prepared for transport. This involved removing the vessel base at a fixed height (one *digitus* in the group Zeebrugge-Dudzele-Oostburg and two *digitus* in the group Walcheren). The reason why the salt producers removed the base is still debated. At first glance, removing the base served little to no functional purpose. It might be related to the removal of contaminants (scorched/burned salt at the bottom or undesired salts), but it can also be an action dictated by social and/or cultural traditions (see 6.4). Furthermore, an added benefit was that without the vessel base, the salt producers and consumers could verify the quality of the salt on both sides of the briquetage vessel. Some kind of organic cover (textile, vegetal material etc.) could have been applied to protect the exposed salt at the top and bottom of the container during transport. The nearby tidal channels provided easy access to and from the sites to ship the briquetage vessels to the hinterland. At the consumption sites, the briquetage vessels were broken to retrieve the salt, which could then be used for various purposes (section 6.4). The social actors involved in the salt trade will be more thoroughly explored in section 9.4.

9.2.1.6 Stage 6: debris deposition

The salt production process created a significant amount of waste that had to be cleared from the sites at regular intervals. The debris consisted of the ash raked out of the heating structures, sediments from the settling tanks, fragments of briquetage vessels that broke during production, hearth (briquetage) debris from cleaning, maintaining and repairing the hearth infrastructure and regular 'domestic' waste like pottery, shells etc. To prevent the accumulation of waste at the work zone, a waste management strategy with predefined refuse zones would have been in place.

In the Bruges area, the briquetage debris might have been deposited away from the actual production sites, which partially explains the lack of features. In addition, these refuse zones stretched out over a larger area with fewer large debris concentrations. At Koudekerke, a different strategy might have been used as the debris accumulated around the heating structures, forming a large white-greyish ash-rich debris layer. At Ritthem, the limited excavation does not allow any statements on the position of the refuse zone in relation to the work zone. Yet, it appears that the refuse (ash, fired clay, briquetage elements) accumulated and formed a thick white-greyish ash-rich debris layer at the edge of a larger site complex.

Figure 146 Reconstruction painting of the late first – early second century salt production activities in the Menapian coastal plain (©Yannick De Smet, www.de-smet.me, Michiel Dekoninck/UGent)

9.2.2 Late second-early third century salt production

Based on the data presented in chapters 7 and 8, it is clear that the salt production process drastically changed towards the end of the second century CE. These changes were attested on several late second - early third century salt production sites: Aardenburg, Leffinge Zwarte weg, the complex 's-Heer Abtskerke – 's Gravenpolder and Middelburg Oude Vlissingseweg. This section attempts to reconstruct the late second - early third century chaîne opératoire by mapping the different choices of the producers at each of the six salt production stages. Nevertheless, although the excavated features at the sites provided valuable insights into the process, certain aspects or choices leave no archaeological traces and are therefore inferred based on medieval or ethnographic examples. Similar to phase 1, the reconstructed chaîne opératoire of the late second- early third century salt production activities (phase 2) is shown schematically in Figure 147. Figure 148 illustrates how these late first - early second century salt production activities may have taken place.

9.2.2.1 Stage 1: raw material procurement

Similar to the previous period, the accessibility of raw materials was a determining factor in selecting suitable salt production locations. The nearby tidal channels provided the necessary brackish or salt water that, most likely, was transported to the sites through a series of ditches. At some point, these larger ditches connected to so-called feeder ditches that supplied the brine reservoirs. Next to salt water, a local clay source was located and extracted. At the late second - early third century sites, quite a large volume of clay was necessary to create the above-ground clay bank in which the heating structures were constructed. In addition, clay was required to create work floors (for instance, at Middelburg and 's-Heer Abtskerke), to reline the heating structures between production cycles and to conduct repairs. At Leffinge, preliminary analyses indicated that the clay used to build the heating structures came from the site's immediate vicinity.

Besides salt water and clay, a local fuel supply was essential given the energy-consuming nature of the salt production process and the number of active heating structures at each site. Multiproxy analyses on ash samples from Middelburg, the complex of 's-Heer Abtskerke - 's Gravenpolder and Leffinge have unequivocally proven that oligotrophic peat, more specifically *Ericacae* and *Sphagnum* peat, was extracted as the main fuel source (Dekoninck et al., In prep). Most likely, in the vicinity of the sites, the *Ericacae* and *Sphagnum* peat was still visible on the surface or was covered by only a thin layer of clay. Either way, detecting potential peat sources required relatively little effort. As indicated above (section 9.2.1.1), the peat extraction is a *chaîne opératoire* on its own and consists of peat cutting, drying, transporting and stacking (Gerding, 1995).

Interestingly, pre-industrial peat cutting was a seasonal activity occurring from April onwards. Apparently, peat extraction could not start much earlier as the wet peat could still freeze, causing it to disintegrate and not burn properly (Gerding, 1995). According to Borger (1992, 150), the drying process could take between 8 to 12 weeks, depending on the weather conditions. In order to speed up the drying process, the peat was turned multiple times and stacked in open, small heaps to allow wind circulation. Once dry, weather conditions no longer mattered, and peat could be stored outdoors over a longer period of time. These rectangular or circular peat stacks were created either at the extraction or consumption sites, and consisted of a systematically stacked peat-brick wall in which peat bricks were dumped (Gerding, 1995, 29-35).

As the peat extraction and salt production season overlapped, a strategy had to be in place to guarantee a sufficient fuel supply during the entire salt production season. Moreover, taking the drying time of peat into account, a multi-year peat collection strategy was required to commence salt production before June (on the issue of seasonality, see 9.4.4.2). Furthermore, a considerable amount of time had to be spent on fuel preparation depending on the requirements of the site. As a result, the individuals involved in fuel collection were not 'free' to participate in other salt production activities. Yet, this does not necessarily pose a problem as the labour force on the production sites could have been large enough to include a peat extraction crew. In addition, this crew would not be continuously involved in peat extraction as the drying process required primarily time and little labour.

Another possibility is that the salt producers did not extract the peat themselves to save labour and time. Instead, they acquired the fuel either from specialised 'peat farms' that supplied artisanal and habitation sites or from small farmers that extracted peat as a subsidiary activity. Although 'peat farms' occurred in Medieval times (see Leenders, 1989; Borger, 1992; Gerding, 1995; Leenders, 2004, 2007), this scenario is deemed less likely for the Roman period as large peat markets are absent. In Medieval times, peat was the main fuel source of larger cities like Bruges, Ghent and Antwerp (Jongepier et al., 2011), but these large cities, who were the motor of this system, did not yet exist in Roman times. Small farmers that extracted peat as a subsidiary activity to gain an additional source of revenue in a 'hostile' landscape cannot be dismissed. Yet, whether such farmers were actually used to supply fuel to the salt producers is impossible to say.

Furthermore, it cannot be excluded that other combustibles were used as an additional, subsidiary fuel source. For instance, at Aardenburg and Middelburg, coal fragments with an unknown provenance were recovered (Dekoninck et al., In prep). However, coal does not occur locally and, therefore, had to be imported from Britain or another outcropping, continental source. Why coal was combined with the locally available peat at Aardenburg and Middelburg is difficult to answer. Is coal more efficient than peat? And if so, where did the coal come from and did importing this fuel type not reduce the salt producer's profit margins?

Finally, the lack of briquetage vessels meant shallow metal vessels had to be procured at the start of production. This required a large investment and was probably used for several production seasons. The reason why the salt producers introduced these metal vessels has been discussed in 7.5.3.

9.2.2.2 Stage 2: site preparation

The site preparation stage consisted of creating a work area with water management features and heating structures necessary to conduct the salt production activities. At Middelburg, this working area was well-defined and constructed from a thin layer of clay deposited on top of the peat.

Currently, the only evidence of water management features stems from Leffinge. At Leffinge, feeder ditches were constructed to supply an elliptical reservoir (4.25 x 2.3 x 0.8 m) with salt water. Both the ditches and the reservoir were partly dug into the underlying peat. In addition, some form of revetment and/or lining might have surrounded the reservoir to prevent brine from seeping into the surrounding soil. An often overlooked aspect is that ditches silted up and/or crumbled. As a result, somebody had to maintain/clean these ditches regularly throughout the production season. Although these features cannot be extrapolated to the other sites, a similar type of brine reservoir might have existed in the vicinity of the hearths to produce and store the brine.

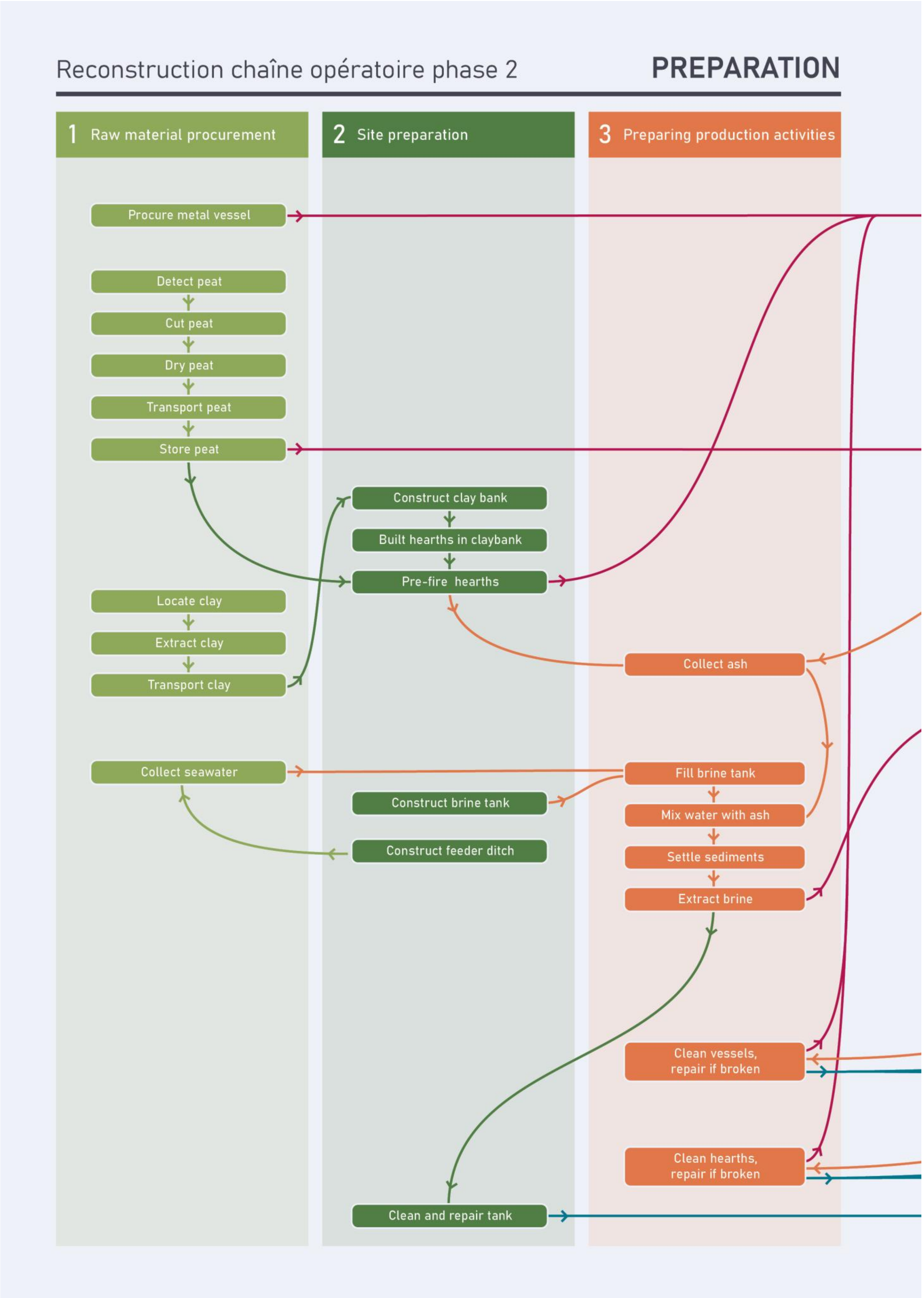
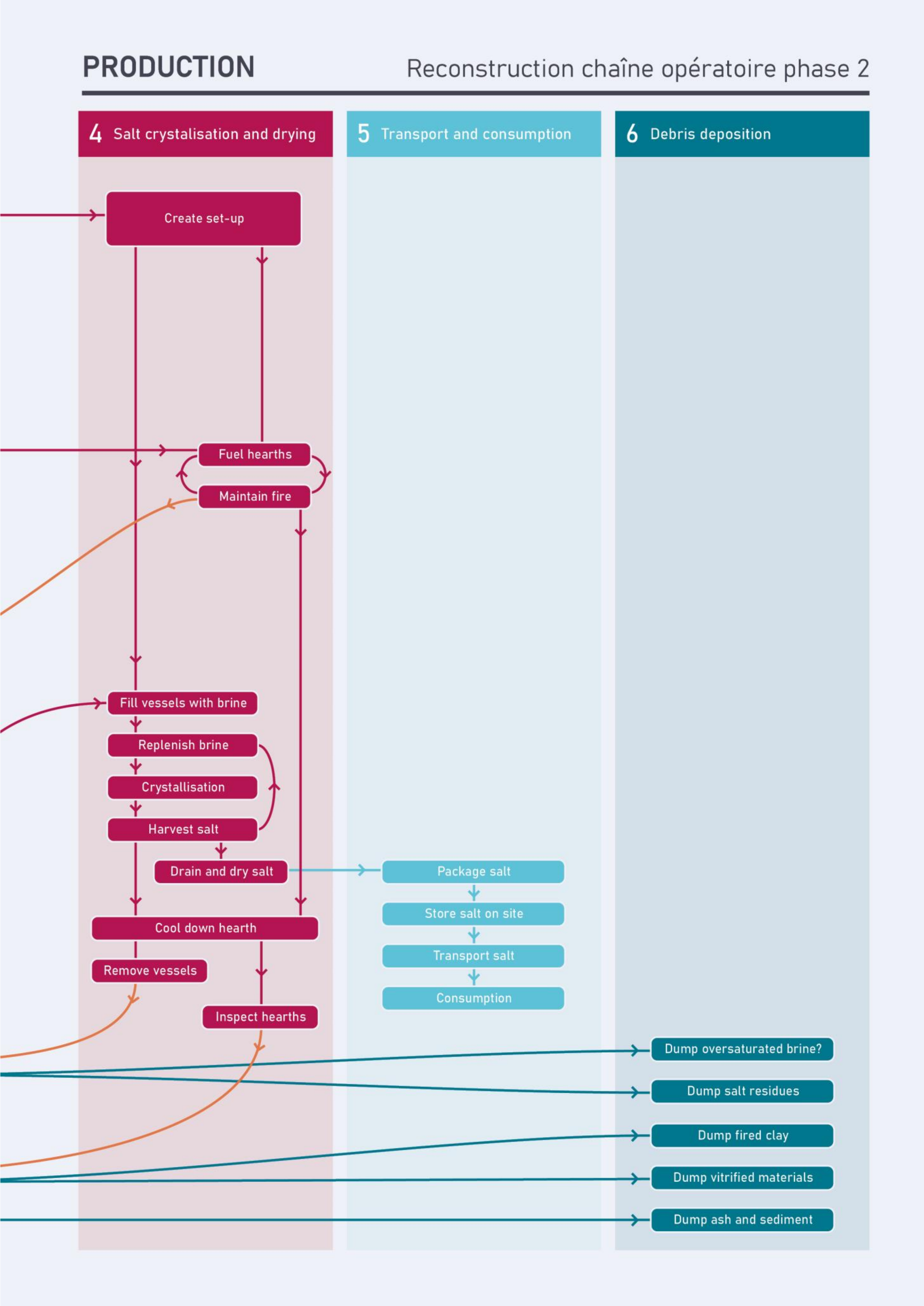


Figure 147 Reconstruction of the salt production *chaîne opératoire* in the late second– early third century (phase 2) (©Yannick De Smet (graphic design) and Michiel Dekoninck/Ugent (content))


PRODUCTION
Reconstruction chaîne opératoire phase 2
4 Salt crystalisation and drying
5 Transport and consumption
6 Debris deposition
Create set-up
Fuel hearths
Maintain fire
Fill vessels with brine
Replenish brine
Crystallisation
Harvest salt
Drain and dry salt
Cool down hearth
Remove vessels
Inspect hearths
Package salt
Store salt on site
Transport salt
Consumption
Dump oversaturated brine?
Dump salt residues
Dump fired clay
Dump vitrified materials
Dump ash and sediment

At Leffinge, the complex of ‘s-Heer Abtskerke - ‘s Gravenpolder and Middelburg, the work area comprised a hearth battery consisting of 2 phases of 15, 6 and 4 individual hearths, respectively. First, a clay bank of varying sizes was raised on top of the peat to construct the hearth battery. Subsequently, the circular to elliptical-shaped hearths were dug into this bank with individual stoke holes added to the side. Furthermore, a thin clay lining might have been applied as a finishing layer. Just as in the previous period, the heating infrastructure will have been pre-fired before their initial use. Remarkably, the concept of hearth batteries is unique to salt production in northern Gaul as this phenomenon is yet to be discovered elsewhere. In addition, the high similarities between these sites suggest that these hearth batteries were built following a pre-defined plan (7.5.4).

9.2.2.3 Stage 3: preparing the salt production activities

After preparing the site, the raw materials were processed in preparation of the brine evaporation process. Since briquetage was no longer produced, this stage primarily consisted of creating the brine. As discussed in section 9.2.1.3, there is little doubt that the salt producers attempted to increase the brine strength before the evaporation process to save fuel, time and labour. This brine manufacturing process consisted of several steps. First, the feeder ditches filled the reservoir with brackish/salt water from a nearby tidal channel. As these ditches were directly connected to the basin, the salt producers must have been able to control the water intake and flow by lowering or lifting a wooden partition. Once the reservoir was full, the insoluble sediments (sand, silt and clay) present in seawater settled on the bottom of the reservoir and ash from salt-impregnated peat was added to strengthen the brine. Subsequently, these ash particles sank to the bottom, creating alternating layers of silt and ash, as observed at Leffinge. If the brine was stored in the reservoir for a sufficient amount of time, the salinity would have increased further through natural evaporation.

Although this process is fairly straightforward, certain aspects of the brine production method require further research to better understand the overall implications for the salt production activities on site. As the site of Leffinge only contained one reservoir, the brine production forms a serious bottleneck for continuous production as it is impossible to use and produce brine at the same reservoir at the same time. In other words, estimating the time it took to produce the brine, the frequency with which it had to be produced, and its salinity would allow an assessment of the workflow and the site’s efficiency.

Furthermore, several maintenance activities occurred between production cycles, like inspecting, cleaning and relining the heating structures or cleaning and repairing the metal evaporation pans (section 9.2.2.4). As a result, these actions are technically stage 2/3 activities. Yet, conducting these actions might have depended on the situation after the salt crystallisation and drying stage. Therefore, these actions might not always have taken place in preparation for a new production cycle.

9.2.2.4 Stage 4: salt crystallisation and drying

With the preparatory steps completed, the evaporation process could commence. First, the shallow metal pans were positioned above the individual hearths in the clay bank. The absence of briquetage support elements indicates that the hearth chamber contained no pedestals on which the vessels could rest. Section 7.5.5 explored the different alternatives and concluded that the vessels either rested on top of an inwardly protruding hearth lining or were integrated into an inwardly sloping hearth lining. Consequently, the width of the hearths may have been tailored to the size of the copper-alloyed pans. A very similar type of heating structure is still in use today at Bo Kluea (Thailand). Yet, as the top of the hearths did not preserve, the actual width of the hearths and, by extension, the dimensions of the vessels are difficult to ascertain.[1] In addition, questions arose about whether all hearths were used simultaneously or if a rotating sequence existed. Especially at Leffinge, this would have significant resource and labour implications, and affect the site's productivity. However, if the resource requirements are met - the bottleneck being the brine production- then there are few arguments to dispute the simultaneous use of all hearths.

Next, the evaporation pans were filled with brine from the reservoir, and the peat, stacked at the hearth base, was set on fire. Gradually, the brine heated up and the undersaturated solution was brought into a (super)saturated state through evaporation. Although the thermal conductivity of metal is considerably higher than clay, heating the brine still required a significant amount of energy. Hence, the fire was constantly monitored, and fuel was added when necessary to maintain the temperature. Furthermore, the large quantities of vitrified material - formed at the bottom of the hearths at temperatures above 900°C - suggest that the salt producers deliberately pursued high temperatures (Chapter 8). Why salt producers put in the extra effort to reach these temperatures when the process already requires a large amount of energy and could occur at lower temperatures is still unclear. While it is true that the clay bank acted as an insulator facilitating higher temperatures and reduced heat loss, it remained a conscious decision to increase the temperature. Perhaps higher temperatures made the process more efficient as the vessels heated up faster and caused the brine to evaporate faster. However, more research is required to determine the impact of these high temperatures.

At regular intervals, the ash was raked out of the firing chamber and stored on the side to produce a new batch of brine. The vessels were constantly monitored and replenished with brine during evaporation to prevent production downtime. Ethnographic observations at Kibiro (Uganda) record that salt crystals appeared in steel evaporation pans after 1.5 to 2 hours of brine boiling (Connah et al., 1990, 34). Yet, Connah et al. (1990) do not mention the time it took to produce a certain amount of salt. In addition, the evaporation rate will depend on vessel size, the temperature of the fire, the brine concentration etc. (Biddulph et al., 2012, 167). As these parameters are site and process depended, it is extremely difficult to estimate how long it took to produce a certain amount of salt.

When the brine reached a (super)saturated state, the salt minerals crystallised at successive intervals based on their solubility ($CaCO_3 < CaSO_4\ 2H_2O < NaCl < MgSO_4\ 7H_2O < KCl$) (Babel and Schreiber, 2014). Contrary to the previous period, the salt crystals were harvested from the shallow pans. These shallow pans are preferable to deeper vessels as the large evaporation surface will evaporate the brine more quickly. Similar to ethnographic and medieval examples, the harvested wet salt could have been ladled in baskets hanging above the evaporation pans (section 7.5.5). In these baskets, the remaining moisture leaked out of the salt and was gradually dried by the heat emanating from the fire. The main advantage of this setup was that the brine that leaked out of the salt was captured in the evaporation vessels and was 'reused'. Alternatively, comparable baskets could have been placed at the edge of the clay bank to drain the moisture from the harvested salt. The radiant heat from the clay bank dried the salt, but the brine that leaked out of the salt would be irrevocably lost. Both options are credible, yet hypothetical, as there is no direct evidence for either option at the sites.

[1] In this study, a fictitious pan with a diameter of 75 cm and a height of 10 cm (capacity 40 l) is used as an example. Yet, it should be emphasised that the dimensions of this fictitious pan are based on a few assumptions (see 7.5). Therefore, it should be emphasised that this is only a theoretical example, and the dimensions of the pans that were actually used might be somewhat different.

Ideally, the salt producers would have tried to keep the salinity within the halite (NaCl) crystallization zone. As long as the salinity fell in this zone, salt harvesting continued undisturbed, and the precipitation of the undesired bitterns (K-Mg salts) was suppressed. Harvesting the salt crystals thus created a 'purer' salt with fewer contaminants. Yet, constantly topping off the vessels inevitably increased the K and Mg content creating an exhausted brine (Babel and Schreiber, 2014). Consequently, the harvesting process was probably halted before the bitterns crystallised to prevent 'contamination'. The vessels were then removed from the hearths to dump the exhausted brine into the refuse zone. This could partially explain the increased Mg content in the ash layers (Dekoninck et al., In prep).

Whether the pans were removed during production or only after the hearth cooled down is impossible to ascertain. The latter option seems more likely since removing hot vessels is more challenging compared to cold ones. Furthermore, ethnographic observations (Connah et al., 1990, 34) and historical sources (Brownrigg, 1748, 147) record that after each use, hard salt residues composed of carbonates and sodium chloride formed at the bottom and sides of the pan.[2] Evidently, these residues were scraped from the evaporation vessels before reusing them in a new production cycle. Finally, the cooled hearth allowed the salt producers to remove the vitrified materials and inspect the hearth infrastructure. If needed, the hearth lining was repaired or replaced at this point. As explained in section 9.2.2.3, executing these maintenance tasks would have depended on the situation.

9.2.2.5 Stage 5: transport and consumption

The observed technological innovations make it abundantly clear that the sites produced salt for a larger regional market. The strategy of harvesting and drying loose salt crystals meant that the salt had to be packaged before transport to the hinterland. In the absence of briquetage pottery, the salt producers might have resorted to organic containers like leather or linen bags, baskets, barrels, etc. Afterwards, the packaged salt was stored temporarily at the site until it was shipped to consumers via the tidal channels. The actors involved in the salt trade and distribution mechanisms are discussed in section 9.4.

9.2.2.6 Stage 6: debris deposition

As previously mentioned (Chapter 7), the salt production process created a significant amount of waste like sediment, ash, fired and vitrified clay etc. If not properly dealt with, the accumulating refuse would obstruct the movement at the site and affect the production activities. Consequently, a waste management strategy with predefined refuse zones was clearly in place to prevent such a scenario. At the late second-early third century sites, this strategy consisted of depositing the debris at the edge of the site relatively close to the heating structures, but far enough not to impede the day-to-day activities. Yet, these strategies did not differ much from the previous period.

[2] Leenders (2007, 124; 2010, 29) called these carbonate salt deposits 'keetspek' when describing the medieval salt production process in Zeeland (NL).

Figure 148 Reconstruction painting of the late second – early third century salt production activities in the Menapian coastal plain (©Yannick De Smet, www.de-smet.me, Michiel Dekoninck/UGent)

9.3 Salt production in transition: gradual adoption of change and innovations

9.3.1 Late first century Menapian salt production: a continuation of local Iron Age traditions?

In the early Roman period, salt production geographically shifted from *Ambiani* territory to the Menapian *civitas.* The exact cause requires further debate, but Caesar's campaigns, Augustus' administrative reforms and the influx of Mediterranean salted products may have played an important role (Dekoninck and De Clercq, 2022). The Augustan sites of Conchil-le Temple (Lemaire 2012) and Croixrault La Dériole (Duvette 2017) are the last remnants of the Iron Age production tradition. Rectangular hearths with a griddle characterise this tradition, and these hearths are often situated within an enclosure-type habitat (Masse and Prilaux, 2016; Dekoninck and De Clercq, 2022). As the *Ambiani* elite probably centralised and controlled the production in the coastal area, this would have prevented the dissemination of this heating structure to neighbouring tribes like the *Menapii* or the *Morini*. In the late Iron Age, these latter areas were characterised by so-called 'pillar or pedestal hearths,' which are rather modest compared to these *Ambiani* production centres (Dekoninck and De Clercq, 2022).

This local tradition formed the basis for and further developed into the late first – early second century northern Menapian salt production technique discussed in section 9.2.1 (see also Chapter 6). Although the information on the heating structures is limited, it is evident that the vessel and pedestal size increased compared to their Iron Age counterparts. This increase is rather modest in the group Zeebrugge-Dudzele-Oostburg but is more pronounced in the group Walcheren (Chapter 6). These changes are clearly **bottom-up innovations** introduced by autochthonous salt producers to increase the site's productivity. Most likely, an increased internal (local population growth) and external (taxation, trade and/or military supply) demand motivated the producers to find new ways to make the process more efficient and to enlarge the output. The *salinatores* inscriptions (section 9.4.1) indicate a military supply of Menapian salt, which might be reflected in the material culture on the production sites. Especially the high number of Rhenish imports at Koudekerke and the decorated Samian vessel at Ritthem from a Central Gaulish producer known to use the military network to deliver products to the Rhineland and Britain suggests at least a trade connection with (military) sites on the Rhine. Consequently, the large increase in vessel size in the Walcheren group might partly express a desire to supply this (new?) Rhenish market.

Yet, despite these innovations, the known late first – early second century Menapian hearths were considerably smaller than their late Iron Age – early Roman *Ambiani* counterparts. This suggests that the production capacity per hearth could be significantly smaller in the Menapian examples. However, this does not necessarily mean that the output per site per production season was lower in the study area. Moreover, this comparison should be approached with caution as the social organisation of the salt production activities, and the number of sites within a certain area could have differed. Furthermore, several other unknown parameters, like the number of hearths per site and the number of production sequences per season, determine the production output. Nevertheless, this comparison raises serious questions as to why hearths with a griddle were never adopted/introduced in the northern *civitates* after production ended in the *civitas Ambianorum*. It appears that together with the geographical shift towards the Menapii and Morini *civitas*, the production was again organised on a more domestic scale (Figure 146).

9.3.2 Late second century innovations: a new 'industrialised' way of producing salt

9.3.2.1 A top-down technological change?

When comparing the salt production chaîne opératoire of the two phases, it is evident that a new way of producing salt was introduced in the late second century CE (Table 33). Several of these changes, like the clay bank with adjacent heating structures and the metal vessels, clearly represents a scale-up of the production activities, which inevitably led to an increased output per site. Furthermore, the transition towards continuous production by harvesting the salt crystals prevented production downtime and made the process more efficient. In other words, these innovations increased the productivity and efficiency of the salt production process (Figure 148). Unfortunately, assessing how much the output increased compared to the previous period is difficult. The transition towards continuous production introduced several variables that affect the theoretical production output of a site like Leffinge or 's-Heer Abtskerke. These variables consist of, but are not limited to, the number of active hearths, the brine concentration, the temperature of the fire and the production time. At this time, the impact of these parameters are insufficiently understood, and further experimental research is needed to make informed statements on the potential output of these sites.

Table 33 Late second – early third century innovations in the salt production *chaîne opératoire*

Late first – early second century	Late second – early third century
Cylindrical briquetage vessels	Large, shallow metal pans
Isolated, individual hearths	Clay bank with multiple heating structures
Accumulation of salt crystals inside vessels	Harvest salt crystals from vessels
Batch production	Continuous production
Refuse zone dominated by briquetage and ash	Refuse zone dominated by vitrified material and ash

Although these innovations have roots in the local traditions, the transition was not gradual and broke with the previous production method in several key aspects like the use of metal vessels, new heating structures and a new extraction method. In addition, scaling-up required an unprecedented increase of investment in resources and labour. Especially the acquisition of the large copper-alloyed pans required a considerable influx of capital. Besides capital, a sufficiently large labour force was necessary to collect and prepare the raw materials and to conduct the evaporation process. These arguments advocate a **top-down technological change** in which wealthy members of higher social standing implemented new inventions into the community. Contrary to the local population/salt producers, these actors could afford the risks of a sizeable investment that pays off in the long run. Who had the capital to invest and benefited from these changes is discussed in section 9.4.2.

9.3.2.2 An increased salt demand as the driving factor behind the technological change?

At this time, there is no definitive answer as to why these innovations took place at the end of the second century CE. Most likely, since these changes increased the production output, it was a response to meet an increased salt demand. Simply put, there are four main reasons why the demand for salt could increase: population growth, changing supply mechanisms, a new application of the product[1] and increased taxes on the product.

In Chapter 4, a sharp decline in early Roman salt production sites was observed. This decline was rather unexpected as the Roman troops stationed at the Rhine would have significantly increased the demand (external population growth). As previously suggested by Tsigarida (2014b, 2014a), the soldier's salt requirements could be met by establishing a long-distance trade in salt and salted products, like *garum* and *salsamenta*, from the Mediterranean. Alternatively, import from Britain needs to be considered as Hathaway (2013, 605-610) observed a considerable increase in salt production sites in southern Britain during the first century BCE – first century CE. According to Hathaway (2013, 605-610), these sites could have produced enough salt to supply mainland Gaul. Whether salt was imported from the Mediterranean or Britain, the supply was definitely complemented by small-scale local production, attested by the presence of locally produced briquetage vessels in the hinterland (Martens et al., 2002; Van den Broeke, 2013).

From the Flavian period onwards, the rural and urban population grew exponentially in northern Gaul (De Clercq, 2009c, 196; van Lanen et al., 2018; Verhagen et al., 2019). This population growth increased demand and triggered a local response in the form of new production sites to meet these requirements. In addition, the Batavian revolt may have highlighted the fragility of the military supply lines resulting in a gradual change towards cost-efficient local supply (Dekoninck and De Clercq, 2022). Thus, at the end of the first century – the first half of the second century, a combination of local production and long-distance trade will have supplied the inhabitants of northern Gaul.

From the late second century, the population gradually declined, and this trend continued throughout the third century[2] (De Clercq, 2009c, 196; 2011; Verhagen et al., 2019). It is interesting that the abovementioned innovations in the salt production process take place at a time when the settlement pattern in the Menapian *civitas* profoundly changes. At the late second century, the population appears to have shifted from the hinterland towards the coast. This is reflected in the archaeological record as in the Pleistocene hinterland, the majority of farms were abandoned before 200 CE, and the surviving farms were downsized, restructured and/or defended (De Clercq, 2009c, 2011). This local population increase might have resulted directly from the heightened military presence and the observed economic revival (section 9.3.2.3). Despite the local population boost, the population growth will have stagnated and even declined on a regional scale in the third century.

As a result, the stagnating population growth would not have significantly altered the salt demand compared to the previous period and is, most likely, not the driving force behind said innovations. As a combination of local production and long-distance trade might have supplied northern Gaul in the previous period, changes in this long-distance supply of salted products could significantly affect the

[1] For instance, the introduction of gibbing ('haringkaken') drastically increased the local salt demand in Zeeland (NL) during the late medieval period (Degryse, 1966-67).

[2] This decline is mainly inferred based on settlement numbers. At this time, no palaeodemographic model of Flanders exists to estimate population numbers. Van Lanen et al. (2018) modelled the demographic changes in the Rhine-Meuse delta, but, unfortunately, this study lacked the chronological resolution to determine the population changes between the late first and third century CE.

local salt demand. Interestingly, towards the end of the first- beginning of the second century CE, the number of imported Mediterranean amphorae containing salted products drastically declined (Martin-Kilcher, 1990; Van Neer et al., 2010). As salt production and salting were interwoven industries, this could also denote a significant drop in long-distance Mediterranean salt import. Furthermore, southern Britain's salt production sites drastically declined throughout the second century (Hathaway, 2013). Consequently, the potential salt import from Britain would have declined as well.

In other words, the observed innovations at the local sites could have been a response to changing supply mechanisms. So, because the import of salt and salted product dwindles, the demand for locally produced salt goes up. In order to meet the demand, innovations were introduced that increased the productivity and efficiency of the production process. Together with a general upscaling, this resulted in a significantly larger output per site. Furthermore, an increased supply may have been necessary to further develop the local *garum* and *allec* industry (see section 2.4).

One aspect not yet discussed that could have an impact is the taxation burden. Typically, newly integrated territories like the *civitas Menapiorum* had to pay a *tributum* to the Roman authorities. Presumably, the *civitas Menapiorum* paid their tribute largely in kind in the form of commodities such as animal products (Roymans, 1996; De Clercq, 2011). According to De Clercq (2011), external demands such as taxes and commodities for non-local consumers like the army resulted in an economic intensification of the region. This is illustrated by farms with deepened byre sections on the Pleistocene sandy soils and the production of salt. That salt was used to fulfil part of the taxation requirements makes sense. Yet, while taxation could have been a contributing factor, it is doubtful that this was the driving force behind the intensification and the observed innovations of the salt production activities. Exactly how the production and/or sale of salt was taxed in the Menapian *civitas* is unknown. Did the *salinatores* play a role in the organisation of the salt tax? Collected the provincial *procurators* a 'salt tax' by leasing the salt production exploitation rights? Or was salt integrated into the *civitas* tax and not subjected to a separate taxation regime? Unfortunately, the answer to these questions will remain speculative as the data to support hypotheses is lacking.

9.3.2.3 Political-economic context of the late second century innovations

The observed changes in the salt production *chaîne opératoire* appear to have been part of a larger transition period in the Menapian coastal plain. In the middle of the second century, a period of what resembles consistent economic growth was disrupted. This disruption may have been partly caused by a combination of different subsequent political-economic disturbances, including the Antonine plague, the succession war between *Clodius Albinus* and *Septimus Severus*, the revolt of *Maternus* (*Bellum Desertorum*), the *Marcomanni*- wars, the *bagaudae* and the *Chauci* raids (De Clercq, 2009c, 488-495).

Furthermore, the second half of the second century might have been a period of ecological stress, for instance, the increased tidal influence in the coastal plain (Baeteman, 2013, 2018) and potentially disastrous floods? (Jansma, 2020). The latter could be deduced from Jansma's (2020) analysis of the hydrological disasters in the Low Countries during the first millennium. This study shows a distinct period of inundation stress/higher likelihood of floods in the Rhine-Meuse delta during the mid-second century (Jansma, 2020). Together with the increased tidal influence caused by the lateral migration of channels and creeks (Baeteman, 2018), this could explain why, for instance, the settlement of Ellewoutsdijk was abandoned around 150 CE and was quickly covered by marine sediments.

After this period of stress, new military sites like Oudenburg and Aardenburg suddenly appeared at the edge of the coastal plain and the immediate hinterland (van Dierendonck and Vos, 2013; Vanhoutte, *in press*). The increased military presence could thus express the central authorities' desire to regain control in the area after a period of turmoil (De Clercq, 2009c). The role the Roman military could have played in introducing the observed innovations in the salt production process is discussed in section 9.4.3.

9.3.2.4 The Menapian transition in salt production mechanism : a wider second century trend?

The second century was clearly a transition period as changes in salt production activities not only occurred in northern Gaul but were also attested in various areas of Roman Britain. For instance, the number of production sites drastically declined in several key first-century CE salt production areas like Dorset and Essex. Furthermore, salt production shifted from small sites in the abovementioned areas to better organised, larger centres in Somerset, Kent, and inland centres like Cheshire (Hathaway, 2013, 634-650). In addition, several technological changes have been attested, like the introduction of lead evaporation pans and the construction of large timber-built brine reservoirs (Williams and Reid, 2008; Arrowsmith and Power, 2012; Garner and Reid, 2012; Zant, 2016, 141-142). Based on the current evidence, Hathaway (2013, 646) concluded that the abovementioned changes resulted from a deliberate centralisation/regionalisation attempt in response to an initial breakdown of the salt production activities.

Interestingly, centralisation involves the introduction of larger site complexes (Hathaway's mode 4 sites). These sites are characterised by more 'industrial-sized hearths', a uniform technology and an expertly managed use of space. All of this suggests that a well-organised and highly specialist group of salt producers was involved (Hathaway, 2013, 648). Just as the late second-century innovations in the Menapian *civitas*, the organisation of these sites would require a large investment. Hence, a future comparison between these areas and sites can provide valuable insights into which causes underlie the transition, which social actors were involved and exactly what the outcome/impact was for the salt production activities in the wider area.

9.3.3 The parallel occurrence of the early briquetage phase and a new production mechanism

As Dobres and Hoffman (1994) pointed out, there is a clear distinction between the invention of a technique and its acceptance by the community. Indeed, it takes time for innovations to be widely accepted by society. Rogers (2003) describes how innovations spread as well as the decision-making process that precedes the acceptance or refusal of the innovation. This theoretical framework was discussed in detail in section 1.4. It suffices to say that innovation is a gradual process, and it takes a while before, if ever, the innovations are accepted and become part of daily practice.

This view also applies to the salt production activities in the Menapian *civitas*. At the end of the second century CE, there was no breakdown of the briquetage technique in which all sites switched to metal evaporation pans and produced salt in hearth batteries. On the contrary, the phase 1 and phase 2 production technique coexisted well into the third century CE. This is evidenced by the presence of briquetage vessels at the late second century - early third century site of Middelburg

Mortiere (group Walcheren vessels)[3]. In addition, numerous briquetage containers and pedestals were discovered at Looberghe (late second - early third century CE), Pitgam (first – early third century CE) and Steene (first – early third century CE) (Teysseire, 2014; Donnadieu and Willems, 2015; Faupin, 2017b; Teysseire, 2020). However, this does not necessarily mean that salt production at these sites followed the exact same *chaîne opératoire* as presented above. The overall process will be the same, but local changes in fuel, brine production strategy and types of briquetage are possible.

Interestingly, continuation primarily occurs in northern France, where no phase 2 sites have been discovered to this day. This may reflect a state of research, but could also indicate a more reserved attitude towards the innovations. However, only new discoveries can provide an answer to this question. Another possibility to consider is that the new technique represents specialised groups that produce for a specific consumer market, for instance, the Roman military, while the traditional briquetage technique represents a local population producing for a local/regional market. Definitely the social actors involved in the production are different as the phase 2 sites requires a larger investment compared to the phase 1 briquetage (cfr. 9.4). Yet, whether specific consumer markets existed that were only supplied by a specific type of site is highly doubtful.

9.4 Social actors involved in salt production and wider economic implications

This section briefly discusses the social actors that were involved in salt production. The first part considers the role of the *salinatores* and aspects of ownership in the late first century CE. The second part discusses exactly who the late second-century innovators were and their impact on how salt production and -trade was organised. A third section discusses the potential role of the Roman military apparatus. Finally, the nature and organisation of the labour force are debated.

9.4.1 *Salinatores* and late first-century salt production

At the end of the nineteenth century, the *salinatores* inscriptions were discovered near the Porta Sant' Andrea in Rimini (IT). These inscriptions, in which the *salinatores* of the *civitas Menapiorum* and *Morinorum* honour centurion *Lucius Lepidius Proculus*, led 20th-century historians (Will, 1962) to assume that the area played an important role in provisioning the Rhine legions. Yet, the interpretation of these inscriptions has been a matter of debate for decades (Hocquet, 1994; De Clercq, 2009c). In Chapter 4, various possible interpretations were discussed in detail; therefore, these perspectives are only briefly summarised here. All the same, the precise role and identity of these *salinatores* remain a difficult question to answer as the data is lacking to make informed statements.

The first hypothesis is that the *salinatores* were local operators who leased the exploitation rights of the salt production centres owned by the state or the *civitas* (Napoli, 2007; Marzano, 2013; Lowe, 2018). However, there are several problems regarding this hypothesis.

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[3] These observations were made on prospection material from Middelbrug Mortiere

(1) A leasing system might imply a certain degree of monetisation as a percentage of the acquired revenue, a result of Augustus' administrative reorganisations, had to be paid based to obtain the exploitation rights from the *procurator's* office (Günther, 2016; Gutiérrez and Martínez-Esteller, 2022). Although the collection of exploitation rights in kind cannot be excluded, the limited monetarisation of the area might pose a problem. It is generally assumed that relatively little monetary capital was present in the *civitas Menapiorum* (Aarts, 2000; De Clercq, 2009c). In addition, the archaeological finds in the coastal plain indicate a slow and different adaptation of (new) Roman ways of living (De Clercq, 2009c). Both aspects would make it more difficult to appropriate a leasing system in the Menapian *civitas* for salt production.

(2) At Minturnae, a *societas salinatores* (CIL I, 2691; 2693; 2698 and 2703) most likely leased the rights to exploit the salt pans during the first century BCE (Cébeillac-Gervasoni and Morelli, 2014). Although this example could be used as a parallel strengthening Napoli's and Marzano's arguments, there is a distinct chronological and geographical difference, and the local context cannot be ignored. For instance, the data presented in Chapter 4 indicates that salt production occurred at small, individual sites in the Menapian *civitas* at the end of the first century CE. As these sites operated on a more 'domestic' level, it is unlikely that these producers formed a collective to lease exploitation rights. Even if the argument is turned, it is equally unlikely that a collective of investors would produce salt in individual domestic sites and not try to centralise and scale up production. As such, the relatively small sites argue for individual, local producers working on a domestic scale.

A second, more likely, hypothesis is that the first-century *salinatores* were a group of officials operating at a *civitas* level who controlled salt production and trade, and collected part of the profits as a form of tax for the state treasury (Hocquet, 1994; De Clercq, 2009c, 2011). Although this hypothesis explains how these *salinatores,* as members with higher social standing, could interact with a centurion and erect an honorific inscription in his home region, some aspects require further consideration.

(1) Taxation was an integral part of the Roman economic system, yet there are many uncertainties about how taxes were organised and collected in the northern provinces. It is generally assumed that (I) the taxes from *Gallia Belgica* were primarily used to support the troops stationed at the Rhine, and (II) the *civitas Menapiorum* paid their tribute largely in kind in the form of commodities such as wool, salted meat, salt etc. (Aarts, 2000; De Clercq, 2009c, 2011). Most likely, the salt tax was embedded in the *civitas* tax, which was imposed on the *civitas* upon their integration into the Roman Empire (*civitas stipendaria*). If salt was indeed part of the *civitas* tax, it seems unlikely that an additional or separate tax on the exploitation and trade of salt existed. The *salinatores*, as a type of 'tax farmer', may then be specifically tasked to collect salt in kind as part of the *civitas* tax and transfer the proceeds in kind to the state. In the absence of centralised markets and a presumed exploitation by multiple small, domestic producers, a collection in kind might be the most logical taxation method. As taxes from the Menapian *civitas* were used to support the troops at the Rhine, the salt could have been directly transported to that area using the military supply network. This would explain the *salinatores* their relationship with the centurion *Proculus*. A similar system was in place in Roman Sicily to collect the *decuma* (the 10% grain tax). This grain tax was collected by tax farmers in kind, who passed the proceeds in kind, minus their profit margin, to the state (Erdkamp, 2005).

(2) To what extent the *salinatores* were involved in the salt trade remains an open question. As Hocquet (1994) pointed out, the nomenclature suggests they were more than mere merchants/traders. If the *salinatores* indeed acted as 'tax farmers' (as suggested above), then part of the collected salt would be their profit margin. As the salt was collected in kind, they would have to market the salt to cash their profit. So, in a way, the *salinatores* would also have been traders in salt. Yet, trading salt might not have been their core business when *negotiatores* and local merchants were present in the wider area (*Gallia Belgica* and *Germania Inferior*) (Verboven, 2007b, 2007a). Granted, there is no direct evidence of their involvement in the salt trade for this specific period. Yet, private traders (*negotiatores*) are known to supply the Rhine legions with basic necessities from an early date (Verboven, 2007b). It would be logical if this involved salt as well. In addition, similar to the Iron Age, local traders could have played an important role in supplying salt to the rural population.

However, the labels *salinator* and *negotiator* do not have to be exclusive. *Negotiator* is a very general term, meaning almost literally 'businessman.' Only in Imperial times the connotation shifted more toward 'merchant' (section 9.4.2) (Verboven, 2007a). However, as 'businessmen' they could be involved in various activities and, for instance, bid for state contracts. In doing so, a *negotiator* could thus become (also) a *salinator*. As such, the expression what's in a name definitely applies here.

(3) The altar of *Catius Drousus*, a Menapian *sal(inator?)*, discovered in *Atuatuca Tungrorum* (capital of the *civitas Tungrorum*) (Vanvinckenroye, 1994) is particularly interesting as it suggests that *salinatores* were still present at the end of the second - early third century. Yet, this discloses little about the system in which these late second-century *salinatores* worked. The meaning of the term *salinatores* could have changed over time, or *Catius Drousus* could portray himself with an archaic term *salinator* to enhance his status. Again, the expression what's in a name is applicable. However, it is possible that the proposed late first - century taxation system, in which the *salinatores* were used to collect salt in kind as part of the *civitas* tax, continued in the late second century.

In conclusion, a variation of the latter hypothesis in which the *salinatores* were tax farmers operating at a *civitas* level seems most likely. Yet, without new data, the 'identity' and 'role' of the *salinatores* are difficult to determine. Moreover, the available data are insufficient to address the issue of ownership and taxation. At this time, the evidence suggests that small individual, domestic producers manufactured salt (section 9.4.4). Most likely, these producers had to pay taxes on the product to the central authorities, which could have been embedded into the overarching *civitas* tax. The *salinatores*, as a type of 'tax farmer', may then be specifically tasked to collect salt as part of the *civitas* tax and transfer the proceeds in kind to the state.

9.4.2 Late second century innovations: private entrepreneurs (*negotiatores*) leading the change?

Section 9.3.2 described the late second-century innovations and concluded that the transition was not gradual and broke with the previous production method in several key aspects. Furthermore, the observed changes (i.e. acquisition of metal vessels) required a considerable investment which advocates a top-down technological change. Interestingly, these innovations coincide with increased epigraphic evidence for a thriving trade in salt and derivative products. At the Nehalennia sanctuaries, four *negotiatores salarii* and four *negotiatores allecarii* erected a votive stone honouring their pledge to Nehalennia who protected them, their cargo and their ships on their voyage (Stuart and Bogaers, 2001; Derks, 2014). The *negotiatores salarii* were *M. Exgingius Agricola* (altar A1), *C. Iulius Florentius* (altar A 26), *C. Iulius Ianuarius* (altar A 49) and *Q. Cornelius Superstis* (altar B1). And the *negotiatores allecarii* were called *[.] A[. .]ius G[r]atus* (altar A34), *C. Catulinius Secco* (altar B44), L. *Secundius Similis* and *T. Carinius Gratus* (both altar A39) (Stuart and Bogaers, 2001; Derks, 2014). Since the names follow Roman patterns (*tria nomina*), the *negotiatores* clearly enjoyed Roman citizenship (Verboven, 2007b; Derks, 2014). In addition, two *negotiatores salarii* came from Cologne (*Colonia Claudia Ara Agrippinensium*), and one *negotiator salarius* and one *negotiator allecarius* were a citizen of Trier (Derks, 2014).

The provenances of these *negotiatores* indicate strong trading connections between the Rhineland and the coastal area of the *civitas Menapiorum*. As multiple *negotiatores Britannicianus* are also known, the province of *Britannia* will have been an integral part of the *negotariores*' trade network (Stuart and Bogaers, 2001; De Clercq and van Dierendonck, 2006; De Clercq, 2009c). Hassall (1978) assumed that these inscriptions reflected merchants passing through the area and crossing the Channel to import merchandise (e.g. salt, fish sauce, pottery etc.) from *Britannia* to the Rhineland. Yet, these new 'industrialised' salt production sites in the Menapian *civitas* indicate that locally produced salt could form a substantial part of regionally produced goods that were exported to the Rhine and *Britannia*. According to Tsigarida (2014b, 2014a), the salt trade to the Rhine army and the redistribution to the rural hinterland was organised from Cologne, the capital of *Germania Inferior.* Given that Cologne was the administrative heart of the province, Tsigarida (2014b, 2014a) assumes that the salt merchants were granted their lease to conduct their business in the provincial capital and, consequently, controlled their business from Cologne.

However, while it is true that the salt merchants' association of Tebtunis was granted a concession to sell salt in a wider area (Boak, 1937; Carusi, 2008a), it is unclear if a similar method was used in the northern provinces. Furthermore, Broekaert (2019) believes that these concessions in Egypt should be seen as a means to facilitate tax collection rather than a desire to control the trade of a certain product. In other words, it is doubtful that merchants required a lease to trade in salt in the northern provinces. Especially if the primary goal of the lease was to collect taxes since taxation could be organised in a number of different ways. More likely, the *negotiatores* entered into 'government contracts' with the Roman army to supply them with commodities such as salt. The procurator could award these contracts, but as each military unit was in charge of its own supply, they could negotiate their own contracts with these *negotiatores* (Verboven, 2007b). A prime example is Hadrian's Wall, where the Vindolanda tablets indicate that officers employed civilian businessmen to supply the fort with basic necessities (Whittaker, 2002; Verboven, 2007b).

To return to the *negotiatores salarii*, it is highly likely that these *negotiatores* were contracted by several military units to supply them with salt. In addition, they could have supplied civil markets together with smaller indigenous merchants. Hence, their role in the late second - early third-century salt trade in the northwestern provinces is undeniable. However, it would be incorrect to characterise the *negotiatores salarii* as mere salt merchants. As Verboven (2007a, 113-115) pointed out, the term *negotiator* has a broad meaning which encompasses a variety of activities (producer, wholesale merchants, financier etc.) and products (rural, artisanal, commercial, financial etc.). In a sense, they are a 'business class' of private 'entrepreneurs' whose emergence in the northwestern provinces was closely linked to the emergence and growth of a new military market. According to Verboven (2007b, 297), these private 'entrepreneurs' are personally committed to derive pecuniary profits by engaging in market exchange for which they are willing and prone to take risks. Accordingly, their patrimonies consist primarily of capital assets and liquidities.

These characteristics make the *negotiatores* the ideal candidates to implement the abovementioned technological changes. They have the necessary capital to acquire the metal evaporation vessels, to prepare the sites, and to cover the labour costs. Their incentive to invest in the production sites derives from the need to increase the local productivity due to changing supply mechanisms to fulfil their contractual obligations to the Roman army and other partners. Furthermore, once the *negotiatores* established the sites, they could fulfil more and larger orders increasing their profits. That *negotiatores* were actively involved in the salt production activities in the Menapian *civitas* should not be surprising since there are several examples of *negotiatores* being engaged in the production of different types of goods. For instance, *negotiatores* are known to be involved in the manufacture of tiles, the production of flour and quarrying activities. As such, their involvement in the production was a conscious decision where they invested money in a business whose products they then marketed (Verboven, 2007a, 99-100).

Though dismissed for the earlier period, it is possible that the *negotiatores* now had to lease the exploitation rights to conduct their business. Now that enough monetised capital was present, such a leasing system could have been introduced as an alternative to taxation in kind. However, as *salinatores* were present in the late second century, it is equally possible that these *salinatores* collected part of the *negotiatores*' salt harvest in kind as tax. Off course, at this point, both scenarios are purely hypothetical since the evidence to support taxation is lacking.

Another aspect that remains difficult to answer is where these *negotiatores* obtained the knowledge to implement these innovations. As discussed in section 9.3.2, these innovations break with the known traditions, so the knowledge is most likely exogenous. Currently, examples of hearth batteries are primarily known from military sites (cfr. 7.5.4). Whether this signalises a technology transfer from the military sphere, known for scaling up production processes, is difficult to say. Yet, *negotiatores* and the military are closely connected through their contracts and/or family ties as attested at Vindolanda (Whittaker, 2002). Furthermore, veterans, who received a large sum of money upon discharge, could become *negotiatores* (Verboven, 2007b). Consequently, a military origin of some of the innovations cannot be excluded.

9.4.3 The role of the state and the Roman military in Menapian salt production

In the early Roman period, salt production shifted from *Ambiani* territory towards the *civitates* of the *Menapii* and the *Morini*. This shift coincided with Augustus' administrative reforms like the installation of self-governing *civitates* and the introduction of a new taxation system (Aarts, 2000, 11-18; Carroll, 2001, 41-43; Raepsaet and Raepsaet-Charlier, 2013; Dekoninck and De Clercq, 2022). Part of these reforms could have included assigning (exclusive?) salt production rights to the *civitas Morinorum* and *Menapiorum*. Such an exclusivity clause could explain why the 'industrial' Late Iron age Ambiani production disappeared, and why, throughout the Roman period, no production sites were present outside Morini or Menapian territory. If salt production as a lucrative business was not regulated, sites would have sprung up in neighbouring areas as the environmental conditions are highly similar and well suited for salt production. Furthermore, if such privileges were indeed granted, this would signal a close relationship between the *civitates* and the Roman authorities. This coveted relationship could partly explain why both *civitates* sided with Rome during Civilis' revolt and why he sent insurgents to ravage their territories (Tacitus, hist. IV.28; De Clercq, 2009c). Off course, these statements only present a likely scenario and remain hypothetical.

In Flavian times, a close relationship between the Menapian and Morini *civitates* and the Roman army can be deduced from the *salinatores* inscriptions (9.4.1). The contacts between the *salinatores* and centurion *Lucius Lepidius Proculus* date shortly after *Civilis*' defeat somewhere between 70-75 CE (Thoen, 1986; Dekoninck and De Clercq, 2022). Scholars agree that *Proculus* (Will, 1962; Thoen, 1986; Napoli, 2007; De Clercq, 2009c) was a provisions officer responsible for the legion's and, by extension, perhaps the Rhine army's salt supply. Moreover, Rhenish imports at Koudekerke suggest a reciprocal trading relationship. All of this indicates that the Roman army was an important customer who might have encouraged salt production in these areas to ensure their own supply. As a result, the coastal area became a taskscape or productive landscape focused on salt production and derivative products (De Clercq, 2011; Dekoninck and De Clercq, 2022). The military demand stimulated production in Flavian times, but there is no evidence to suggest that they were actively involved in the production themselves.

Interestingly, the observed late second-century innovations coincide with an increased military presence at the edge of the coastal plain and the immediate hinterland. New forts were erected at Maldegem, Oudenburg and Aardenburg, and the military occupation at Aalter was renewed (Thoen, 1991; De Clercq, 2009c; Dhaeze, 2011; van Dierendonck and Vos, 2013; Dhaeze, 2021; Vanhoutte, *in press*). Often the construction of these forts is seen as a military response following the *Chauci*-raids (170-174 CE) (Thoen, 1991; Dhaeze, 2021). Yet, as De Clercq (2009c, 2011) already noted, these raids are a symptom/result of a larger late second-century political-economic crisis rather than an isolated event (9.3.2.3). The increased military presence thus expresses a desire to regain control in the area after a period of turmoil. In addition, they provided a safe haven for investors to swoop in and rebuild the production that would have suffered from the political instability and the seaborn raids. In other words, the military offered stability and protected these private entrepreneurs' investments and economic interests in the area. This was also in their own interest as the military most likely contracted these businessmen to supply them with salt (section 9.4.2). By protecting the *negotiatores*' investment, they protected their own supply of a necessary product.

One could wonder why the military relied on these businessmen and did not produce the salt themselves. Granted, the military had the necessary capital to implement the observed changes but, compared to these private entrepreneurs, they may have lacked the incentive to do so. Why spend precious resources (capital and labour) producing your own salt when this could be outsourced? While it is true that the army produced a wide variety of products in *fabricae* (shoes, ceramics, etc.) (Bishop, 1985; Johnson, 1987; Reddé, 2006a) or detached *vexillatio's* to procure or produce, for instance, lime (Sölter, 1970) or ceramic building material (Schmidts, 2018), there is no evidence to suggests that this was the case here. None of the production sites contained conclusive evidence of a military presence or involvement. Furthermore, the production sites are situated in the wider vicinity but not close to the military sites. In the case of military production, this would be rather illogical as the environmental conditions near these military sites are suitable for salt production. Only at Aardenburg salt production activities have been attested near the *castellum,* suggesting a more active military role.

The question of what role the Roman military played in salt production is not unique to the Menapian *civitas*. It is a problem that several authors studying salt production in Britain also struggle with (Lane and Morris, 2001; Arrowsmith and Power, 2012; Hathaway, 2013; Zant, 2016). For instance, Hathaway (2013, 648) assumes a more direct military involvement in the third – fourth-century salt production in Central Somerset. Yet, while the salt could be largely intended for military supply, active involvement of the Roman army in the production remains hypothetical as no conclusive evidence supports this. In addition, Zant (2016) recently came to similar conclusions regarding the salt industry in Cheshire (GB). At Cheshire, the introduction of lead evaporation pans and the general upscaling was often connected to a direct military involvement in the production. However, Zant (2016) concluded that there is little evidence to support a direct military involvement in the salt industry. Alternatively, he suggested that private entrepreneurs implemented the innovations while leasing the production rights from the provincial authorities. This would make the Cheshire situation highly comparable to the Menapian *civitas*.

To conclude, direct military involvement in Menapian salt production cannot be ruled out, but there is also no evidence to suggest that this was definitely the case.

9.4.4 Identifying and organising the labour force

This section attempts to answer the question of who exactly was the labour force that carried out the actions described in the *chaîne opératoire*. However, data to answer this question is often lacking, and consequently, answers usually remain hypothetical. The first part discusses how the production was organised, followed by more ambiguous topics such as seasonality, gender and status.

9.4.4.1 Transition towards specialised labour?

Production can be organised in different ways depending on the availability of raw materials and labour, the nature of the technology, economic needs, and so on. (Costin, 1991, 2001, 2005). As a production context can take many forms, there are several ways to approach the variation in production systems. A common technique is to categorise the production systems hierarchically into what Peacock (1982) described as 'modes of production' (see 1.4 for more information). Though examples do not always fit into the typology, a problem that Peacock (1982, 8) himself recognised and acknowledged, it can be used to describe the organisation of the salt production activities.[4]

Given the complexity of the *chaîne opératoire* and the market-oriented output, it is clear that salt production in the Menapian *civitas* exceeds the more basic mode of 'household production'. The archaeological evidence for late first - early second century salt production compares best to household industry or individual workshop level. The division between both modes is fine and depends on the level of specialisation and how much time was devoted to pursuing salt production (Peacock, 1982). Both aspects are difficult to measure from the archaeological record. Lane and Morris (2001, 396-397) suggested that the late Iron Age – early Roman salt production in the Fenlands was at the level of individual workshops given the use of more specialised types of briquetage and the care spent on the site's infrastructure, like the hearths and the water management features. Similarly, the hearths and large briquetage vessels might indicate that (some of) the Menapian sites operated at an

[4] Contra Hathaway (2013, 509-524) who signals various problems applying Peacock's modes of production to salt production. The main problems are: 1) assigning modes depends on the quality of the archaeological record. 2) lack evidence to estimate output. 3) issue of part-time versus full-time labour due to seasonality 4) issue link between technology and a more complex production mode. In response, Hathaway created new modes to classify salt production sites based on 1) organisation and use of space, 2) site location, 3) focused industrial activity and 4) site infrastructure. Hathaway validly points out that not all characteristics of a certain mode can be assigned to the salt production activities. Yet, even if not all aspects fit, Peacock's modes of production are used by archaeologists worldwide to describe production systems, making them very accessible and comparable.

'individual workshop' level. At these sites, the production could have been family-based (single or extended family?), and the larger vessels indicate that salt production might have formed a considerable part of the family income (mainly market-oriented production). However, as the salt production season coincides with the agriculture season, production might not have been a full-time activity. Unless, of course, extended families divided the labour so that production could continue undisturbed (Figure 146).

The situation drastically changed in the late second century as a substantial investment was made in specialised tools (metal pans) and the site's infrastructure (hearth batteries and a large settling tank). This provides evidence for a considerable upscale of the salt production activities and signals a more complex production system. Consequently, the late second-century production sites might be considered a '**workshop industry'** where skilled labourers worked together to produce salt. The investor would not have produced the salt himself but appointed a site manager who ran the day-to-day activities. In turn, the site manager could use his family network or hire unrelated labourers to conduct the salt production activities. However, as an external investor is involved, the possibility of forced labour always needs to be considered. There is no evidence to substantiate this, but it can never be completely ruled out. In addition, some of these labourers could have a well-defined role or function in the production process, for instance, harvesting the salt or managing the fires (Figure 148)

Furthermore, the increased output and efficiency, and the fact that the sites may have formed a considerable source of income for the investors indicate that salt production was a full-time activity during the production season. As the salt production and agricultural season are simultaneous, this would mean that the labourers were full-time salt producers (specialised labour) and could be exempt from agricultural labour. Similarly, Lane and Morris (2001, 397) connected the late Roman appearance of metal pans and the improved heating structures at Middleton to the more complex workshop industry.

9.4.4.2 Seasonality

It is generally accepted that salt production was not a year-round activity but carried out seasonally (Lane and Morris, 2001; Biddulph et al., 2012; Kinory, 2012; Hathaway, 2013). Yet, there is little consensus on the actual length of the production season. Based on meteorological data, Gurney (1986, 141-142) assumes ideal salt production conditions between March and June. Bradley (1975), on the other hand, estimates that salt production largely took place between May and August/September based on similar meteorological data. Both assumptions found their way into more recent publications, see Hathaway (2013, 29-30) and Lane and Morris (2001, 62). At Stanford Wharf, Biddulph et al. (2012, 82; 171-172) identified the remains of salt marsh plants harvested during their growing season between the end of May/June to the end of September. As these plants were used to produce the brine, this implies that salt was produced at the site throughout that period.

The abovementioned studies suggest that salt production could have occurred between the end of March and the end of September. Yet, as the analyses at Stanford Wharf demonstrate (Biddulph et al., 2012), the actual production season will also depend on technological choices like the type of fuel and local environmental conditions. In addition, there is a scheduling conflict between the salt production and the agricultural season (Bradley, 1975; Lane and Morris, 2001). If the salt producers were involved in arable farming, ploughing, sowing and harvesting periods need to be considered. This could have significantly reduced the time spent on salt production. Lane and Morris (2001, 62) suggested that salt production could have been combined with more extensive agricultural production techniques like grazing. This type of agriculture was highly suitable in coastal wetlands and provided more time for salt production activities. Consequently, salt production might not have a fixed timeframe, and the season's length will vary depending on the technological choices, environmental conditions, labour requirements etc.

These reasons make narrowing down the production season in the Menapian territory difficult. One aspect that the salt producers definitely had to consider was the fuel supply (section 9.2.2.1). If the peat was cut at the start of April and dried for three months, salt production could only start at the end of June. Thus, if they wanted to start earlier in April or May, a sufficiently large fuel supply had to be collected at the end of the previous season and stored over winter to start production activities in the spring. As the late first-century salt production occurred on a more domestic scale, the producers could have been involved in some form of agricultural production. This would have shortened the salt production season considerably. On the other hand, the observed late second-century intensification and upscaling suggest that more time was now spent producing salt. From an investor's point of view, it would be only logical to make the most of the production season to maximise the site's output and profit. This would only be possible if salt producers were indeed full-time specialists exempt from agricultural labour (section 9.4.4.1).

9.4.4.3 Gender and status of the labour force

In the study area, there is no evidence of a specific gender-based division of labour. As shown by ethnographic examples, for instance, Uganda (Connah et al., 1990) and Niger (Gouletquer, 1975), both men and women are physically able to carry out production activities. As denoted by Kinory (2012, 125-126), social custom rather than physical necessity will have determined the gender of the salt producers. Furthermore, besides the analysis of fingerprints on the briquetage material, there is very little that archaeology can contribute to this debate. Laing (2022) recently conducted a fingerprint analysis on the briquetage material from several late Iron Age-early Roman salt production sites in Britain. Given the preponderance of late teenage and adult male prints on the support material, Laing (2022) concluded that briquetage manufacturing was predominantly a male activity. Though cautious in her assumptions, Laing (2022) suggested that late Iron Age salt production in Britain could have been a male-dominated practice to which young men were introduced through a rite of passage. However, this study only conclusively proves that teenagers and males were involved in the production of briquetage pottery. The remainder of the argument remains hypothetical. Following Peacock's modes of production model (Peacock, 1982), Morris (2007) considers it possible that when salt production in the Fenlands intensified, men took over the production. However, Morris (2007) stresses that this is only a possibility, and both sexes could just as easily be involved in more complex production systems. As it stands, men, women and children could have worked together to complete the variety of tasks necessary to produce salt.

Another more ambiguous topic is the status of the salt producers. Were the salt producers able to accumulate wealth, resulting in a higher standing in society? This is difficult to answer as the data is limited to the material culture recovered on the production sites. Unfortunately, no habitation traces were found, which could help to identify if and how salt producers expressed their status. This is somewhat different compared to late Iron Age northern Gaul, where several large hearths were found nearby a contemporaneous settlement (Prilaux, 2000a; Masse and Prilaux, 2016). Yet, none of the inhabitants of the late Iron Age salt production sites of Pont-Rémy, Sorrus and Rue displayed their status through material and infrastructural wealth. This suggests that the salt producers in late Iron Age northern Gaul did not have a privileged status and might not have benefitted much from the salt trade (Prilaux, 2000a, 94-95).

Returning back to the Menapian *civitas*, the material culture on the late first – early second century production sites is not extremely rich. In addition, the amount of luxurious imports on late first century habitation sites in the coastal plain is fairly limited (see Chapter 2). All of this suggest that salt production did not lead to accumulation of wealth in the area or it must have been expressed in an archaeologically less visible manner (De Clercq, 2009c; Dekoninck and De Clercq, 2022). An exception could be Koudekerke, where the amount of Rhenish imports is abnormally high (De Clercq and van Dierendonck, 2006; De Clercq, 2009c, 2009a). These Rhenish beakers could have been used to express a more privileged status in society and their trading relationship with the Roman military (De Clercq, 2009c).

The variety of import material at the late second-early third century salt production sites illustrates that the salt producers were well-connected and were able to acquire some high-status goods. Yet, whether this means that the labour force had a higher standing is difficult to ascertain. In the late second century, the Menapian coast experienced an economic revival, and 'luxurious' imports might have been more commonly available. In addition, the material could partly reflect the investor's or manager's status instead of the labour force. The labourers might have earned some money with which they could acquire some prestige goods, but most of the profits will have landed in the investors' coffers. If these investors were indeed the proposed *negotiatores*, they would be more likely to express their business success in their hometown and in the public domain. The Nehalennia-altars could therefore represent a local expression of their business success.

Chapter 10 Conclusions and prospects for future research

Building on centuries of popular interest and decades of academic research, this dissertation offers a long overdue synthesis on salt production in the *civitas Menapiorum*. This additional piece of the puzzle transforms the area from a 'blind spot' into a 'hot spot' that, hopefully, stimulates further international discussion. Furthermore, it hopes to offer a stepping stone for future interdisciplinary studies on salt production. To reveal new insights into ill-understood aspects of the salt production process, this dissertation has tried to integrate various archaeological, historical and archaeometric techniques. This project's main contribution has been to describe how salt as a basic resource was extracted from the North Sea in Roman times, and how the *chaîne opératoire* evolved to meet the increasing salt demand. The previous chapter laid out and integrated the main results of this dissertation. This chapter, therefore, will offer final conclusions on salt production on the northern fringe of the Roman Empire and considers further lines of research.

Salt and the Menapian coastal plain

In the early Roman period, salt production shifted from *Ambiani* territory to the *civitates Morinorum* and *Menapiorum*. The exact cause of this geographical production shift requires further debate, but a combination of different socio-political and administrative decisions could have been at the root of this transition. At any rate, the 'industrial' late Iron Age *Ambiani* production disappeared, and throughout the Roman period, no production sites were present outside Morini or Menapian territory. Although very few early Roman salt production sites are known in those latter areas, the production most likely occurred in modest 'pillar or pedestal hearths'.

From Flavian times onwards, the Roman occupation of the Menapian coastal plain steadily increased. Large habitation sites exceeding the character of rural sites appeared, for instance, at Wenduine and Bredene, and the rural occupation was well documented at Ellewoutsdijk, Stene, Zeebrugge and many other locations. At the same time, Flavian salt production boomed in the northern part of the *civitas Menapiorum*. Although this trend follows the general Flavian rural and urban population growth in northern Gaul, this intense exploitation of what is typically considered a marginal landscape is rather remarkable. Possibly a combination of internal (local population growth) and external (taxation, increased military and local salt demand) factors drove the local population toward the opportunities - and thus the exploitation - of these so-called 'marginal' coastal wetlands.

At this stage, the salt production activities were firmly rooted in the local Iron Age tradition, which formed the basis for and further developed into the late first – early second century northern Menapian salt production technique. This phase is characterised by the use of briquetage material that gradually increased in size and the occurrence of isolated, individual hearths. At these sites, the small-scale salt production was most probably organised on a more 'domestic' level (potentially 'individual workshop' level) in which the entire (extended) family worked together to complete the variety of tasks necessary to produce salt.

Furthermore, in this period, the *salinatores* inscriptions demonstrate that the Roman army was an important customer of Menapian salt. However, the precise role of these *salinatores* in Menapian salt production is still controversial. In this dissertation, we proposed that these *salinatores* were higher officials operating at a *civitas* level who may have been specifically tasked to collect some of the produced salt in kind as part of the overarching *civitas* tax. Whatever the case, the relation between salt from the Menapian *civitas* and the Roman military was a major incentive to the local population to further develop the 'salt industry' in the area. Moreover, this triggered a bottom-up innovation in which the autochthonous salt producers increased the briquetage vessel size to enhance the site's productivity. As a result, the coastal area became a taskscape or productive landscape focused on salt production and derivative products aimed at the supply of salt for the Roman Rhine army and the adjacent civil hinterland. The increased economic activity could have attracted new settlers, which, in turn, led to further socio-economic development.

In the middle of the second century, this period of what appears to be consistent economic growth was disrupted by a combination of political-economical events and ecological stress. After this tumultuous period, new military sites like Oudenburg and Aardenburg suddenly appeared at the edge of the coastal plain and the immediate hinterland. Therefore, the increased military presence could express the central authorities' desire to regain control of the area after a period of turmoil. This military presence is accompanied by a huge economic upturn which could have been largely driven by external investors, for instance, the *negotiatores*. These private businessmen took advantage of the opportunities presented to them by the abovementioned economic crisis. For instance, their investment in the salt production industry could have derived from a need to increase the local productivity to fulfil their contractual obligations with the Roman army. By investing in the tools and the site's infrastructure, they enhanced the site's efficiency and productivity, increasing their profit margin. Yet, besides private investment, some form of direct military involvement in salt production cannot be excluded at this time.

These investments drastically changed the salt production *chaîne opératoire* in the Menapian *civitas* from the late second century CE onwards. Not only did the salt producers implement a clay bank with multiple adjacent heating structures (hearth battery), but they also switched to metal evaporation pans which are more durable. Furthermore, these innovations signalled a transition from a batch production in briquetage vessels towards a continuous production in metal vessels from which the salt crystals were harvested. This prevented production downtime and made the process more efficient. This considerable upscale in salt production activities also signals a transition towards a more complex production system. Consequently, these new late second-century production sites might be considered a 'workshop industry' where skilled labourers worked together on a 'full-time' basis to produce salt. However, the introduction of this new way of producing salt did not lead to a breakdown of the briquetage technique. The old and the new production process coexisted well into the third century CE.

Besides the significant scale-up of the salt production activities, larger trading settlements like *Ganuenta* (Colijnsplaat) and Wenduine further developed and reached their heyday at the end of the second - early third century. Besides the general economic upturn of the area, it is possible that these private investors, as important trading partners, played a more direct role in the development of these settlements. Especially at Colijnsplaats, the Nehalennia altars attest to the presence of *negotiatores salarii* and *allecarii,* who traded salt and salted products from the Menapian *civitas* to the Rhineland and *Britannia.*

The military protection and the economic revival created a safe haven which boosted population numbers. Interestingly, the population not only increased but appears to have shifted from the hinterland towards the coast. This is reflected in the archaeological record as in the Pleistocene hinterland, the majority of farms were abandoned before 200 CE, and the surviving farms were downsized, restructured and/or defended. However, it should be noted that this transition is not necessarily a linear process, but rather a result of mutually enforcing processes in which economic development stimulated a population increase and vice versa.

In terms of rural habitation, the late second century was also a transition period in which native coastal communities gradually adapted to changing circumstances. Terp-sites were constructed to cope with regular tidal inundations, and Pleistocene sandy outcrops still offered attractive, drier locations well-suited for habitation. This process already started at the end of the first century CE, but now gathered momentum and superseded the flat settlements situated on top of the peat. Furthermore, there are clear indications that the coastal communities actively tried to intervene and shape the coastal landscape by constructing large dykes. These dykes could have been attempts to reclaim land or to minimize the tidal influence in specific areas, for instance, close to habitation sites or near fields and meadows. Their construction required a considerable investment and affected the coastal landscape in a wide area. It remains an open question of who financed these constructions. Were they coordinated by the local/regional authorities, the military or saw private business this as an interesting investment opportunity? Whatever the case, it does not necessarily have to be one or the other, as they might have been the result of a combined effort.

In other words, the late second century was a transition period in the Menapian coastal plain during which new social actors introduced military and economic changes after a period of crisis, and the autochthonous community gradually adapted to a changing landscape. This heyday is reflected in the archaeological record by a considerable increase of findspots and a new type of habitation site. Moreover, the salt production sites transformed into 'proto-industrial' complexes, which might have formed the motor of the coastal economy. Yet, this 'golden age' may not have lasted very long as both the population and the salt production dwindles towards the end of the third century. Again, the political instability caused by i.a. *Postumus' Imperium Galliarum* and the increasing tidal influence had a devastating effect which significantly reduced the economic interest in the area.

Prospects for future research

By revisiting old or unfinished research and introducing archaeometry to answer ill-known aspects of the salt production process, we tried to rekindle international interest in the production of a historically important resource in a remote part of the Roman Empire. Obviously, this research should not be seen as a conclusive study on salt production in the Menapian *civitas*, but as a stepping stone towards future research. Throughout this dissertation, several potential avenues for further research have been suggested. Though much remains to be elucidated, we propose the following directives for future research on (Roman) salt production in northern Gaul.

The first aspect that would significantly enhance our understanding of the salt production activities is 'more data.' One of the greatest shortcomings of this study is the limited number of sites and the absence of recently excavated sites containing water management features and heating structures. Processing more (recently) excavated sites could help to substantiate the reconstructed salt production phases and to strengthen the observed transition in salt production mechanisms. Furthermore, processing more briquetage assemblages from a wider geographical area could strengthen the typological insights. These briquetage assemblages include, for instance, the material from northern France production sites, but also the briquetage vessels from salt consumption sites in the hinterland. Moreover, mapping the distribution of briquetage pottery on inland sites could provide insights into the salt supply and consumption patterns of various social groups (Roman army, rural and urban populations).

A second aspect relates to the first one and concerns the use of archaeometry. Two pilot studies in this dissertation, one on the vitrified material (Chapter 8) and one on the ash (Dekoninck et al., In prep), have shown the potential of archaeometry to answer specific questions on more ephemeral aspects of salt production. For instance, Chapter 8 used a multiproxy approach to study the firing conditions of the salt production hearths. Dekoninck et al. (In prep) used different analytic techniques to identify the type of combustible used to fuel the hearths. One avenue worth pursuing is thin-section petrography and SEM/EDS analysis on briquetage material. These analyses would enable more detailed fabric descriptions, including the identification of mineralogical inclusions, but also allow more detailed observations of the manufacturing technology. A second avenue could be a more thorough chemical analysis of soil samples to identify the removal of salt impurities during the crystallisation stage.

A third research path would be an extensive experimental research project coupled with geochemical analyses. Throughout the dissertation, it became apparent that crucial phases of the salt production process leave no archaeological traces. Better understanding the effects of these actions would significantly aid the interpretation of the archaeological and historical data. Hypothesis-based experimental research with positive feedback loops can help to adjust and nuance archaeological models of the production process. Furthermore, geochemical data collected during the experiments could be instrumental in understanding the results from geochemical analyses on archaeological samples.

A fourth and final aspect relates to detecting new salt production sites in the coastal landscape. Despite the increase of developer-led archaeological research, only a few new salt production sites have been discovered in the study area. This is rather remarkable as the knowledge of the habitation structures in that same area increased tremendously. This suggests that the current fieldwork methodology of trial trenches is less suited to detect artisanal sites and large site complexes in a complex sedimentary landscape like the coastal plain. Instead, a methodological transition in which geophysical surveys are integrated to detect landscape features, like gullies and water management features, heating structures and/or refuse dumps, is strongly recommended to enhance our capabilities of finding new sites.

To conclude, new cross-disciplinary initiatives offer the best way forward to enhance our knowledge of the salt production technology, the distribution mechanisms and the consumption patterns.

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Appendices

The appendices of this dissertation are only included in the digital, not the printed version of the dissertation. The dataset containing the registered archaeological material (briquetage and regular pottery) of the studied sites (appendix 3 and 4B) has not been included here, but can be requested from the author. The figures and maps are available in high resolution upon request.

APPENDIX 1: Dataset chapter 4

APPENDIX 2: Dataset chapter 5

APPENDIX 3: Dataset archaeological material (briquetage and regular pottery) chapter 6

APPENDIX 4A: Dataset (feature lists and profiles) chapter 7

APPENDIX 4B: Dataset archaeological material (briquetage and regular pottery) chapter 7

APPENDIX 5: Dataset chapter 8

Appendix 1: dataset chapter 4

This appendix contains the dataset of salt production sites collected in the framework of this study. This dataset has been used to create the figures in chapter 4.

Table 1. Inventory of the Iron Age and Roman salt production sites along the southern North Sea coast. Reliability relates to how accurately the location could be determined with 1) exact location and 2) approximate location.

SN-ID	Site name	F Con	Y	X	Reliabilit	IRA	ROM	E-IRA	M-IRA	L-IRA	Erom	Mrom	Lrom	References
SN001	Monster Het Geestje	Excavation	52,032120	4,177567	2	1	0	1	0	0	0	0	0	van den Broeke (1986); Van Heeringen (1989); van den Broeke (1996)
SN002	Monster Poeldijk A	Excavation	52,025716	4,227734	1	1	0	0	1	0	0	0	0	(Vos, 2000b, 2000a)
SN003	Leiden Bosch-Gasthuispolder	Excavation	52,144712	4,473383	1	1	0	0	1	0	0	0	0	(Modderman, 1960-1961; Nenquin, 1961; van den Broeke, 1982, 1986; Van Heeringen, 1989)

SN004	Den Haag - Wateringse Veld (Noordhof & Boezemland)	Excavation	52,036107	4,286683	1	1	0	1	1	0	0	0	0	(Bulten, 2009; Meurkens, 2014; Siemons and Bulten, 2014)
SN005	Den Haag - Wijndaelerplantsoen	Excavation	52,062671	4,233427	1	1	0	1	1	0	0	0	0	(Stokkel, 2012)
SN006	Westmaas - Maaszicht	Excavation	51,790708	4,492798	1	1	0	1	0	0	0	0	0	(Van Heeringen et al., 1998)
SN007	Wateringen	Excavation	52,026486	4,262614	1	1	0	0	1	0	0	0	0	(Koot, 1996; van den Broeke, 2007, 2012)
SN008	Rockanje-Oud Rockanje (vindplaats 08-06)	Excavation	51,872288	4,068941	1	1	0	0	0	1	0	0	0	(Wind, 1970)
SN009	Rockanje vindplaats 08-54	Excavation	51,870057	4,063982	1	1	0	0	0	1	0	0	0	(Van Trierum, 1992, 2005)
SN010	Rockanje vindplaats 08-52	Excavation	51,869482	4,063215	1	1	0	0	0	1	0	0	0	(Van Trierum, 1992, 2005)
SN011	Santpoort - Spanjaardsberg	Excavation	52,435554	4,637383	1	1	0	0	1	1	0	0	0	(Modderman, 1960-1961)
SN012	Velsen - Velserbroekpolder	Excavation	52,434324	4,671078	1	1	0	1	0	0	0	0	0	(Perger and Hendrichs, 1991; van den Broeke, 2012)
SN013	Assendelft vindplaats 39	Excavation	52,449791	4,704353	1	1	0	1	0	0	0	0	0	(Helderman, 1967a, 1967b; Van Heeringen, 1989)
SN014	Assendelft vindplaats 60	Excavation	52,465751	4,711920	1	1	0	1	0	0	0	0	0	(Van Heeringen, 1989; van den Broeke, 2012)

SN015	Valkenburg – Ommedijksche polder (vindplaats 5)	Excavation	52,158060	4,433651	1	1	0	1	0	0	0	0	0	(Van Heeringen, 1998)
SN016	Wassenaar - Huis ter Weer	Excavation	52,147569	4,414735	1	1	0	1	0	0	0	0	0	(Van Heeringen, 1989)
SN017	Spijkenisse vindplaats 17-34	Excavation	51,850671	4,301844	1	1	0	0	1	0	0	0	0	(Van Trierum, 1992)
SN018	Vlaardingen	Prospection	51,909792	4,303627	2	1	0	0	1	1	0	0	0	(van den Broeke, 1996, 2007)
SN019	Poortugaal vindplaats 12-03	Excavation	51,868236	4,408173	1	1	0	0	1	0	0	0	0	(Van Trierum, 1992)
SN020	Leidschendam-Voorburg	Excavation	52,101199	4,422618	1	1	0	1	0	0	0	0	0	(Molthof, 2018)
SN021	Koudekerke Meinersweg	Excavation	51,488422	3,566451	1	0	1	0	0	0	0	1	0	(van den Berg and Hendrikse, 1980), this volume
SN022	Koudekerke Breeweg	Excavation	51,490196	3,562606	1	0	1	0	0	0	0	1	0	This volume
SN023	Middelburg-Mortiere	excavation	51,483228	3,629972	1	0	1	0	0	0	0	1	0	(Jongste, 2002)
SN024	Middelburg-Oude Vlissingseweg	Excavation	51,484391	3,608227	1	0	1	0	0	0	0	1	0	(van den Berg, 1988); this volume
SN025	Middelburg-Kruitmolenlaan	Excavation	51,493445	3,630197	1	0	1	0	0	0	0	1	0	(van den Berg and Hendrikse, 1980)
SN026	Ritthem - Havenweg	Excavation	51,445904	3,607716	1	0	1	0	0	0	1	1	0	(van den Berg and Hendrikse, 1980)
SN027	Ritthem - Schotteweg	Excavation	51,446988	3,625803	1	0	1	0	0	0	0	1	0	(Trimpe Burger, 1970)

SN028	Ritthem - bij de Molen	Prospection	51,446990	3,627850	1	0	1	0	0	0	0	1	0	Pers. Com. A. Feldbrugge
SN029	s Heerabtskerke	Excavation	51,474748	3,895231	1	0	1	0	0	0	0	1	0	(Ovaa, 1972; Trimpe Burger, 1974; Ovaa, 1975); this volume
SN030	Oostburg 't Vestje	Excavation	51,327849	3,488212	1	0	1	0	0	0	0	1	0	(Dekoninck et al., 2019; Diependaele, 2019); this volume
SN031	Aardenburg Peurssenstraat	Excavation	51,275402	3,443327	1	0	1	0	0	0	0	1	0	this volume
SN032	Oostkapelle Bos Schoonoord	Excavation	51,567325	3,541744	1	1	0	0	1	0	0	0	0	Pers. Com. G. Besuijen
SN033	Domburg Strand Westhove	Prospection	51,574452	3,514664	2	1	0	0	0	1	0	0	0	(van Heeringen, 1988, 1994)
SN034	Vlissingen Paauwenburg	Excavation	51,460427	3,550821	2	0	1	0	0	0	0	1	0	Pers. Com. A. Feldbrugge
SN035	Ramskapelle Heistlaan	Prospection	51,309300	3,250500	1	0	1	0	0	0	0	1	0	(Hollevoet, 1988)
SN036	Dudzele Zonnebloemweg	excavation	51,293900	3,252700	2	0	1	0	0	0	0	1	0	(Verwerft et al., 2022); this volume
SN037	Dudzele Boudewijnkanaal	Prospection	51,277900	3,212600	1	0	1	0	0	0	0	1	0	(Hillewaert and Hollevoet, 1986a, 1986b, 1987)
SN038	Zeebrugge Achterhaven Geuldepot	Excavation	51,301400	3,238000	1	0	1	0	0	0	0	1	0	(De Clercq, 2009; Patrouille, 2013); this volume
SN039	Zeebrugge Achterhaven Donk 1	Excavation	51,295500	3,245200	1	0	1	0	0	0	0	1	0	(De Clercq, 2009; Patrouille, 2013); this volume

SN040	Zeebrugge Achterhaven Donk 2	Excavation	51,297400	3,245600	1	0	1	0	0	0	0	1	0	(De Clercq, 2009; Patrouille, 2013); this volume
SN041	Zeebrugge Prospectievonst 1	Prospection	51,288400	3,231900	2	0	1	0	0	0	0	1	0	(Hollevoet, 1989; Hollevoet and Hillewaert, 1989)
SN042	Zeebrugge Prospectievonst 2	Prospection	51,292800	3,236600	2	0	1	0	0	0	0	1	0	(Hollevoet, 1989; Hollevoet and Hillewaert, 1989)
SN043	Zeebrugge Prospectievonst 3	Prospection	51,292600	3,229200	2	0	1	0	0	0	0	1	0	(Hollevoet, 1989; Hollevoet and Hillewaert, 1989)
SN044	Zeebrugge Prospectievonst 4	Prospection	51,294900	3,227600	2	0	1	0	0	0	0	1	0	(Hollevoet, 1989; Hollevoet and Hillewaert, 1989)
SN045	Zeebrugge Prospectievonst 5	Prospection	51,296000	3,227700	2	0	1	0	0	0	0	1	0	(Hollevoet, 1989; Hollevoet and Hillewaert, 1989)
SN046	Zeebrugge Prospectievonst 6	Prospection	51,300600	3,223000	2	0	1	0	0	0	0	1	0	(Hollevoet, 1989; Hollevoet and Hillewaert, 1989)
SN047	Zeebrugge Prospectievonst 7	Prospection	51,301700	3,221500	2	0	1	0	0	0	0	1	0	(Hollevoet, 1989; Hollevoet and Hillewaert, 1989)
SN048	Zeebrugge Prospectievonst 8	Prospection	51,302500	3,221200	2	0	1	0	0	0	0	1	0	(Hollevoet, 1989; Hollevoet and Hillewaert, 1989)
SN049	Zeebrugge Prospectievonst 9	Prospection	51,302800	3,220600	2	0	1	0	0	0	0	1	0	(Hollevoet, 1989; Hollevoet and Hillewaert, 1989)
SN050	Zeebrugge Prospectievonst 10	Prospection	51,304500	3,228500	2	0	1	0	0	0	0	1	0	(Hollevoet, 1989; Hollevoet and Hillewaert, 1989)
SN051	Zeebrugge Prospectievonst 11	Prospection	51,311800	3,222100	2	0	1	0	0	0	0	1	0	(Hollevoet, 1989; Hollevoet and Hillewaert, 1989)
SN052	Zeebrugge Zeevaartstraat	Excavation	51,305200	3,206500	1	0	1	0	0	0	0	0	0	(Verwerft et al., 2017)

SN053	Hoeke Zwinnevaart	Excavation	51,296494	3,304379	1	0	1	0	0	0	0	0	0	(Claus, 2020)
SN054	Brugge Fort Lapin	Excavation	51,223400	3,231900	2	1	0	0	1	0	0	0	0	(Rutot, 1902-1903; Thoen, 1973, 1975a, 1978a, 1986; Huys, 2005)
SN055	Houtave Loweg	Excavation	51,240200	3,128100	2	0	1	0	0	0	0	1	0	(Hollevoet, 1987)
SN056	Leffinge Zwarte Weg	Excavation	51,143300	2,870600	1	0	1	0	0	0	0	1	0	(Thoen, 1974, 1975a, 1975b; Thoen and Cools, 1975; Thoen, 1976; Thoen and Cools, 1976; Thoen, 1977a, 1977b, 1977c, 1978a, 1978b, 1986); this volume
SN057	Veurne Stabelincksleed	Excavation	51,081700	2,669300	1	1	1	0	0	1	1	0	0	(De Ceunynck and Termote, 1987; Huys, 2005)
SN058	De Panne Oosthoekduinen	Excavation	51,090700	2,615300	1	1	0	0	0	1	0	0	0	(Dewilde and Wyffels, 2003; Bot, 2005)
SN059	De Panne Westhoekduinen (De Panne 1-2)	Excavation	51,086298	2,553000	1	1	0	0	1	0	0	0	0	(de Loë, 1901-02, 1906, 1908; Thoen, 1973, 1975a, 1978a; Kerger, 1997, 1999; Huys, 2005; Lehouck and Thoen, 2012)
SN060	Bray-Dunes	Excavation	51,082381	2,543187	1	1	0	0	0	1	0	0	0	(Cabuy et al., 1990; Delmaire et al., 1996; Leman Delerive et al., 1996)
SN061	Steene Rue du Chateau	Excavation	50,950523	2,373157	1	0	1	0	0	0	1	1	0	(Donnadieu and Willems, 2015; Faupin, 2017)
SN062	Steene Ducrocq S11	Prospection	50,951000	2,379300	1	0	1	0	0	0	0	1	0	(Ducrocq, 1999; Hannois, 1999)
SN063	Steene Ducrocq S10	Prospection	50,950900	2,375400	1	0	1	0	0	0	0	1	0	(Ducrocq, 1999; Hannois, 1999)

SN064	Steene Ducrocq S4-2	Prospection	50,948600	2,359200	1	0	1	0	0	0	0	1	0	(Ducrocq, 1999; Hannois, 1999)
SN065	Steene Ducrocq S4-3	Prospection	50,950900	2,356400	1	0	1	0	0	0	0	1	0	(Ducrocq, 1999; Hannois, 1999)
SN066	Steene Ducrocq S4-4/8-1	Prospection	50,953000	2,355900	1	0	1	0	0	0	0	1	0	(Ducrocq, 1999; Hannois, 1999) (Ducrocq, 1999; Hannois, 1999)
SN067	Steene Ducrocq S8-2	Prospection	50,954400	2,358200	1	0	1	0	0	0	0	1	0	(Ducrocq, 1999; Hannois, 1999)
SN068	Steene Ducrocq S8-3	Prospection	50,956000	2,358500	1	0	1	0	0	0	0	1	0	(Ducrocq, 1999; Hannois, 1999)
SN069	Steene Ducrocq S991	Prospection	50,956400	2,360300	1	0	1	0	0	0	0	1	0	(Ducrocq, 1999; Hannois, 1999)
SN070	Steene Ducrocq S993	Prospection	50,955000	2,364000	1	0	1	0	0	0	0	1	0	(Ducrocq, 1999; Hannois, 1999)
SN071	Pitgam Ducrocq S2	Prospection	50,947800	2,347900	1	0	1	0	0	0	0	1	0	(Ducrocq, 1999; Hannois, 1999)
SN072	Pitgam Ducrocq S3	Prospection	50,947400	2,351900	1	0	1	0	0	0	0	1	0	(Ducrocq, 1999; Hannois, 1999)
SN073	Pitgam Ducrocq S9	Prospection	50,944200	2,346300	1	0	1	0	0	0	0	1	0	(Ducrocq, 1999; Hannois, 1999)
SN074	Pitgam Schulle Veld	Excavation	50,926200	2,315200	1	0	1	0	0	0	0	1	0	(Bouche and Michel, 2004; Elleboode, 2011, 2013)
SN075	Looberghe B1473	Excavation	50,917400	2,262400	1	0	1	0	0	0	0	1	0	(Oudry, 2006)
SN076	Looberghe Chemin de la mairie	Excavation	50,914700	2,272600	1	0	1	0	0	0	0	1	0	(Oudry, 2008)
SN077	Looberghe Route de Bergues	Excavation	50,918500	2,269600	1	0	1	0	0	0	0	1	0	(Faupin, 2009a)
SN078	Looberghe Rue de Cassel, près du Moulin	Excavation	50,916108	2,270678	1	0	1	0	0	0	0	1	0	(Faupin, 2009b)

SN079	Looberghe Rue de Cassel	Excavation	50,915500	2,277100	1	0	1	0	0	0	0	1	0	(Teysseire, 2014, 2020)
SN080	Cappelle-Brouck	Prospection	50,895700	2,219500	2	0	1	0	0	0	0	1	0	(Delmaire et al., 1996)
SN081	Ardres la Cauchoise	Prospection	50,901300	1,989300	2	0	1	0	0	0	1	1	0	(Cabal, 1973; Cabal and Thoen, 1985; Delmaire, 1994; Florent and Cabal, 2004)
SN082	Ardres les Terres Brugnobois	Prospection	50,885500	1,967700	2	0	1	0	0	0	1	1	0	(Cabal, 1973; Cabal and Thoen, 1985; Delmaire, 1994; Florent and Cabal, 2004)
SN083	Ardres les Noires Terres	Prospection	50,876100	1,964100	2	0	1	0	0	0	1	1	0	(Cabal, 1973; Cabal and Thoen, 1985; Delmaire, 1994; Florent and Cabal, 2004)
SN084	Balinghem le Vieux bac	Prospection	50,877700	1,952900	2	0	1	0	0	0	1	1	0	(Cabal, 1973; Cabal and Thoen, 1985; Delmaire, 1994; Florent and Cabal, 2004)
SN085	Les Attaques le Banc des Loups	Prospection	50,881800	1,939200	2	0	1	0	0	0	1	1	0	(Cabal, 1973; Cabal and Thoen, 1985; Delmaire, 1994; Florent and Cabal, 2004)
SN086	Marcq en Calaisis	Excavation	50,952700	1,949929	2	1	0	0	1	0	0	0	0	(Boisson et al., 2015)
SN087	Camiers	Prospection	50,568223	1,588745	2	1	0	0	1	0	0	0	0	(Dilly, 1988; Thoen, 1990; Delmaire, 1994)
SN088	Etaples	Excavation	50,525977	1,625380	2	1	0	0	1	0	0	0	0	(Mariette, 1970, 1972; Thoen, 1990; Delmaire, 1994)
SN089	Sorrus - La Bruyère	Excavation	50,462064	1,702039	1	1	0	0	1	0	0	0	0	(Defossés, 2000; Prilaux, 2000a; Weller and Desfossés, 2002)
SN090	Sorrus - La pâture à vache	Excavation	50,459356	1,699962	1	1	0	0	1	0	0	0	0	(Defossés, 2000; Prilaux, 2000a; Weller and Desfossés, 2002)

SN091	Airon-Saint-Vaast	Excavation	50,425536	1,649654	2	1	0	0	1	0	0	0	0	(Dilly et al., 1986)
SN092	Waben	Excavation	50,386630	1,650188	2	1	0	0	0	1	0	0	0	(Weller and Desfossés, 2002)
SN093	Conchil-le-Temple	Excavation	50,378429	1,696815	1	0	1	0	0	0	1	0	0	(Lemaire, 1997; Prilaux, 2000a; Lemaire, 2012)
SN094	Gouy-Saint-André	Excavation	50,371814	1,926430	2	1	0	0	1	1	0	0	0	(Masse et al., 2011; Masse and Tachet, 2017)
SN095	Nampont-Flexicourt	Excavation	50,344100	1,734700	2	1	0	0	0	1	0	0	0	(Defossés, 2000; Ben Redjeb, 2012)
SN096	Vron	Excavation	50,322009	1,750917	2	1	0	0	1	0	0	0	0	(Gosselin et al., 1984; Defossés, 2000)
SN097	Rue “Le chemin des Morts”	Excavation	50,284046	1,685355	2	1	0	0	0	1	0	0	0	(Rougier and Blancquaert, 2001; Ben Redjeb, 2012; Masse and Prilaux, 2016)
SN098	Arry ‘Le Trou Bernache’	Excavation	50,289197	1,731288	2	1	0	0	0	1	0	0	0	(Prilaux, 2000a; Ben Redjeb, 2012)
SN099	Pont-Remy	Excavation	50,081196	1,926515	1	1	0	0	1	1	0	0	0	(Prilaux, 2000a, 2000b)
SN100	Vignacourt	Excavation	50,011585	2,154878	2	1	0	1	0	0	0	0	0	(Prilaux, 2000a)
SN101	Arras Actiparc	Excavation	50,315000	2,828600	1	1	0	0	1	1	0	0	0	(Jacques and Prilaux, 2003)
SN102	Croixrault La Dériole	Excavation	49,810501	1,979396	1	0	1	0	0	0	1	0	0	(Duvette, 2017)
SN103	Croixrault L'Aérodrom	Excavation	49,807777	1,970023	1	1	0	0	1	1	0	0	0	(Ben Redjeb, 2012)
SN104	Saint-Quentin-La-Motte-Croix-au-Bailly	Excavation	50,066369	1,474840	1	1	0	0	0	1	0	0	0	(Lascour, 2016)
SN105	Campagne Le Muid	Excavation	49,647771	2,949487	1	1	0	0	1	1	0	0	0	(Sarrazin and Louesdon, 2017)
SN106	La Calotterie	Prospection	50,468163	1,739491	2	1	0	0	1	0	0	0	0	(Delmaire, 1994)

SN107	Ruminghem	Excavation	50,847168	2,198764	1	0	1	0	0	0	0	1	0	(Desoutter, 2019)

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Appendix 2: dataset chapter 5

This appendix contains the raw data collected during the excavation Aardenburg Peussensstraat and includes:

1) Excavation plan
2) Description of the sections
3) Composition of the bulksamples

Characterising the debris layers

In order to collect the samples, eight cross-sections were made on the different debris layers enabling a decent description of said layers. A selection of cross-sections is presented in **Fout! Verwijzingsbron niet gevonden.**.[130] In addition to these cross-sections, a large north-south profile stretching the entire width of the excavation was made to study the debris zone (Figure 44). In this profile, two different debris layers of approximately 15cm thick can be observed: S87 and S91. Dark brown/dark grey debris layer S87 was composed of heterogeneous sandy clay with frequent char (mm-wide), fired clay and vitrified clay inclusions (cm-wide). Red-brown/brown/dark brown debris layer S91 on the other hand was dominated by multicoloured fired - and vitrified clay inclusions (cm-wide). Both of these debris layers were deposited on top of a dark grey – greyish buried topsoil (Ah horizon) (Figure 44; 8003 and 8005) which in turn lay upon an dark beige, sandy eluviated subsoil (Figure 44; 8002). On the bottom of the profile, the homogenous, beige parent material can be observed consisting of sandy aeolian deposits of Weichselian age (Figure 44; 8000). The anthropogenic debris depositions were covered by two greenish yellow marine clay deposits (Figure 44; 6000).

[130] Due to time restrictions, sections 5 to 8 in the eastern part of the excavation were only photographed and the decision was made not to incorporate these sections in **Fout! Verwijzingsbron niet gevonden.**.

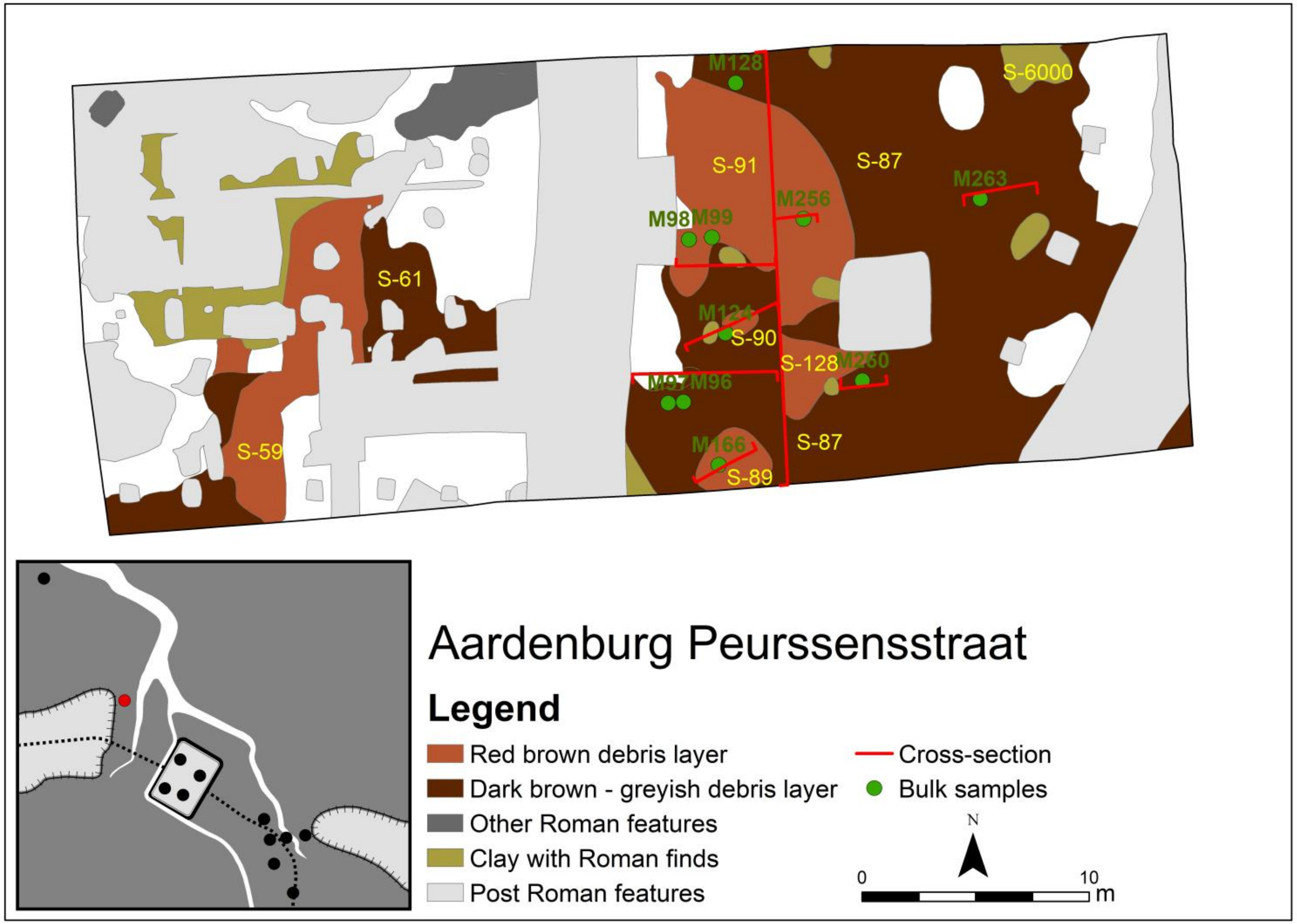
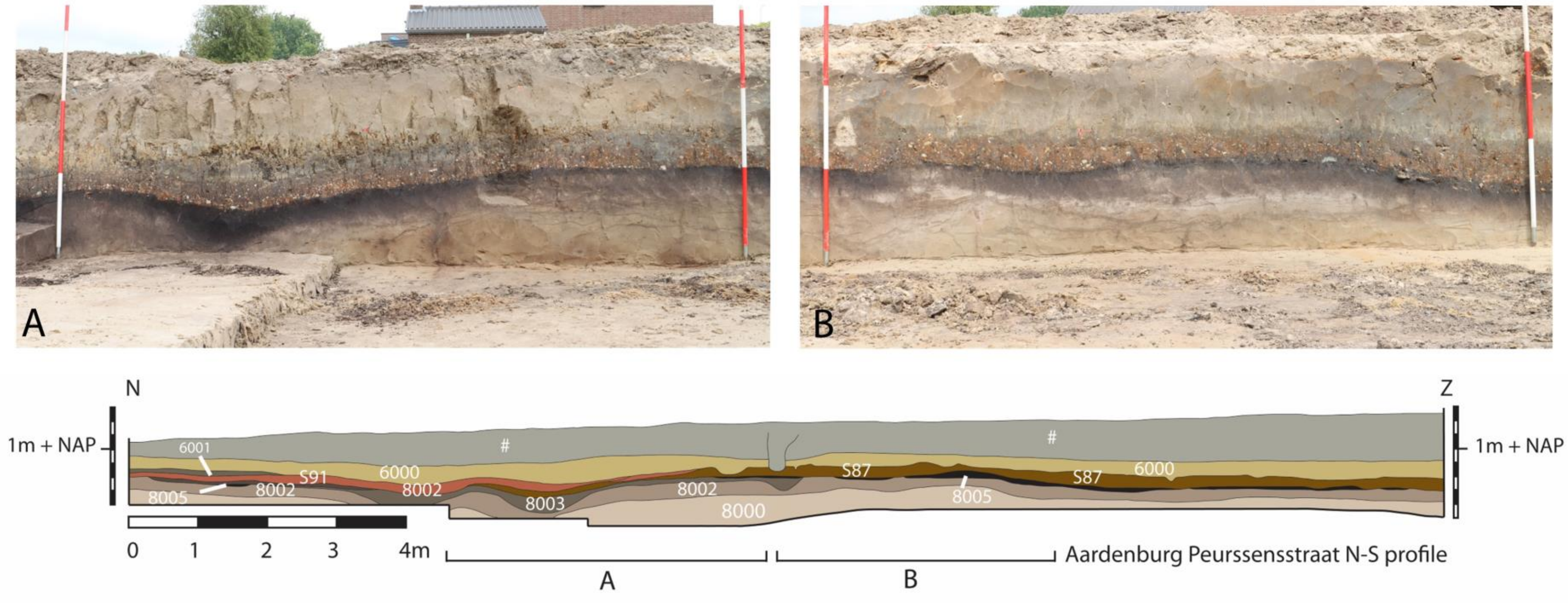


Figure 1 Excavation plan of Aardenburg Peurssensstraat depicting the red-brown and dark brown–greyish debris layers as well as the location of the cross-section and bulk samples.



Layer	Description
8000	Parent material C, Pleistocene sand, 'flamed' browned to yellow-brown
8002	Eluviated subsoil B/E, sand, brown
8003	Buried topsoil with accumulation of organic matter (Ah), sand, dark grey- greyish black
8005	Buried topsoil with accumulation of organic matter (Ah), sand, greyish black
6000	Parent material C, marine clay, greenish yellow
6001	Parent material C, marine clay, greenish yellow with common baked clay and charcoal inclusions (cm-wide).
S87	Dark brown/dark grey heterogeneous sandy clay with frequent char, baked clay and vitrified clay inclusions (cm-wide)
S91	Red-brown/Brown/dark-brown heterogeneous sandy clay dominated by multicoloured baked clay and vitrified clay inclusions (cm-wide)
#	plough soil

Figure 2 North-south profile across the entire debris zone showing and describing the stratigraphy of the Aardenburg Peurssensstraat site.

Table 1 Percentage ratio of the different sieve fractions form each bulksample (data used to create ternary plot)

	Fraction 2-5 mm (g)		Fraction 5-10 mm (g)		Fraction > 10m (g)	
	Number	**%**	**Number**	**%**	**Number**	**%**
Sample 96	2726	21%	3178	24%	7265	55%
Sample 97	1949	22%	1978	23%	4804	55%
Sample 98	6822	38%	5195	29%	5977	33%
Sample 99	3442	28%	3568	29%	5160	42%
Sample 116	1467	40%	865	24%	1325	36%
Sample 124	1251	20%	1293	21%	3606	59%
Sample 128	672	20%	720	21%	2036	59%
Sample 256	824	31%	777	30%	1019	39%
Sample 260	650	22%	732	25%	1569	53%
Sample 263	33	11%	66	21%	208	68%
Total	19836		18372		32969	

Table 2 Distribution of the three main find categories of each bulk sample (data used to create the ternary plots in chapter 5)

	Pottery		Fired clay		Sintered clay	
	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)
Sample 96	37%	41%	31%	19%	32%	39%
Sample 97	22%	24%	34%	16%	44%	60%
Sample 98	17%	24%	56%	47%	27%	29%
Sample 99	22%	31%	58%	47%	20%	22%
Sample 116	9%	24%	63%	49%	28%	27%
Sample 124	9%	13%	48%	26%	43%	61%
Sample 128	46%	73%	43%	19%	12%	8%
Sample 256	9%	12%	65%	56%	26%	32%
Sample 260	24%	31%	46%	38%	30%	31%
Sample 263	44%	62%	26%	13%	29%	24%

Table 3 Classification and quantification of the archaeological material recovered from sieve fraction > 10mm.

Sample	Sample size (l)	Pottery		Baked clay		Vitrified clay		CBM		Stone		Metal		Glass		Animal bone		Shell		Char		TOTAL	TOTAL
		no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt. (g)	no.	wt (g.)
M. 96	1000	602	2964	510	1377	533	2820			7	58	4	14			9	27			5	5	**1670**	**7265**
M. 97	1000	197	1086	300	732	396	2672			34	273					18	34	4	6	1	1	**950**	**4804**
M. 98	1000	315	1332	1014	2627	41	338			41	338	4	7			8	20			5	6	**1428**	**4668**
M. 99	1000	315	1545	850	2386	299	1109			14	68	4	15			7	36	2	1			**1491**	**5160**
M. 116	100	32	285	212	587	95	325	4	97	4	25	2	6									**349**	**1325**
M. 124	100	47	314	260	621	230	1450	3	1184	4	29			1	1	3	7					**548**	**3606**
M. 128	100	204	1425	191	362	52	152			5	49	2	8	3	3	4	40					**461**	**2039**
M. 256	100	26	118	196	544	79	305	2	50	2	2											**305**	**1019**
M. 260	100	71	370	138	448	90	369	5	315	10	64	1	3									**315**	**1569**
M. 263	100	15	79	9	17	10	31			22	78	1	3									**57**	**208**
TOTAL	**4600**	**1824**	**9518**	**3680**	**9701**	**1825**	**9571**	**14**	**1646**	**143**	**984**	**18**	**56**	**4**	**4**	**49**	**164**	**6**	**7**	**11**	**12**	**7574**	**31663**

Table 4 Classification and quantification of the pottery fragments discovered in sieve fraction > 10mm.

Category		TS.	C.C.	C.C.	C.C.	TN	Flag.	Flag.	Amp.	Dol.	Mort.	Mort.	Ox.	Ox.	Red.	Hand.	Salt	Ind.	TOTAL
Subcategory			KOL	TRI	Ind.		RME	Ind.	BAT	Ind.	Ind.	BAV	RME	Ind.	Ind.	NOM			
M. 96	**Sherds**	4	119				52	25	1		1		10	89	22	79	78	122	602
	MNI	2	8				2	3	1		1		3	7	1	9	6		43
M. 97	**Sherds**	3	17		1		14	10	1	5			2	49	38	33	24		197
	MNI	3	3		1		1	1	1	1			1	2	3	5	1		23
M. 98	**Sherds**	3	46				3	30		2		2	2	41	87	74	11	14	315
	MNI	1	5				1	2		1		1	1	2	8	7	1		30
M. 99	**Sherds**	1	34				8	27		5				50	51	122	9	8	315
	MNI	1	3				1	1		1				3	7	17	1		35
M. 116	**Sherds**		3										4	7	5	13			32
	MNI		1										1	1	2	3			8
M. 124	**Sherds**		1					1	5				2	8	16	14			47
	MNI		1					1	2				2	1	2	1			10
M. 128	**Sherds**	2	10					8		1			1	39	20	53	62	8	204
	MNI	1	2					1		1			1	2	2	6	2		18
M. 256	**Sherds**		4					5					1	3	4	8	1		26
	MNI		2					1					1	1	3	1	1		10
M. 260	**Sherds**		7			2		6		3			5	18	13	16	1		71
	MNI		3			1		1		2			1	2	1	1	1		13
M. 263	**Sherds**	1	1	2				4						1	3	2	1		15
	MNI	1	1	1				1						1	1	1	1		8
TOTAL	**Sherds**	**14**	**242**	**2**	**1**	**2**	**77**	**116**	**7**	**16**	**1**	**2**	**27**	**305**	**259**	**414**	**187**	**152**	**1824**
	MNI	**9**	**29**	**1**	**1**	**1**	**5**	**12**	**4**	**6**	**1**	**1**	**11**	**22**	**30**	**51**	**14**		**198**

Appendix 4A: dataset chapter 7

This appendix contains the supplementary information to chapter 7, namely the detailed feature lists of Leffinge, 's-Heer Abtskerke and Middelburg Oude Vlissingseweg. In addition, the digitised profiles of Leffinge have been included. A second appendix (Microsoft Excel database) contains the registration of the pottery, fired clay and vitrified clay fragments.
These features list were created after consulting, processing and digitising the unpublished excavation archives of the sites. This digitised archive has been transferred back to the depots to preserve for future researchers.

To consult the digitised excavation archive of the sites contact the following institutions

Leffinge: Regionaal Archeologisch Museum aan de Schelde (RAMS)/V.O.B.o.W.,
'S-Heer Abtskerke and Middelburg Oude Vlissingseweg: Erfgoed Zeeland

Leffinge Zwarte weg

Feature list

Feature	Trench	Interpretation	Dating	Description
7401	74/1	Ditch	PME/MOD	Ditch 7401 extended NW from the south-eastern corner of trench 74/1, on a NW-SE alignment. The structure extended well beyond the limit of excavation, only the western end could be recorded, and was approximately 1,35 m in depth filled with greyish brown clay.
7402 +7501	74/1	Ditch	PME/MOD	Ditch 7402/7501, on a NW-SE alignment, defined the western end of trench 74/1 and the eastern end of trench 75/2, measuring approximately 2,25 m in width and 1,4 m in depth. The ditch, dug into the underlying peat, contained multiple fills of brownish-greenish clay mixed with peat and sods. The exact length could not be recorded.
7403	74/1	Debris deposition?	ROM	Sub rectangular deposit (7403), roughly 0,5 m long and 0,6 m wide, consists of charred peat mixed with ash. A few fragments of briquetage and zelas were recovered.
7404	74/1	Heating structure?	ROM	Feature 7404 was part of layer 7405 and may have been a heating structure. This feature consisted of an oval shaped core of charred peat, measuring 0,6 m in length and 0,4 m in width, with charcoal, ash and zelas fragments surrounded by a 0,10 to 0,2 m wide band of hearth lining fragments.
7405	74/1	Debris layer	ROM	Layer 7405 was amorphous in plan (somewhat oval-shaped) and comprised a ca. 0,20 m thick deposit of peat mixed with ash, charred peat and 'zelas', measuring approximately 0,8 m in length and 3 m in width. The deposit appeared to have formed from dumping and trampling ash and other industrial waste into the top of the underlying peat, most likely corresponding with the Roman surface level.

7406	74/1	Heating structure? Debris dump?	ROM	Feature 7406 was sub rectangular in plan, measuring 0,75 m in length and 0,45 m in width, and may have been a heating structure or a dump of industrial waste. The south-eastern side had a tapered end which consisted primarily of hearth lining fragments.
7407	74/1	Heating structure?	ROM	Feature 7407 was part of layer 7408 and may have been a heating structure. The feature comprised a subcircular core of charred peat, 0,35 m in diameter, with ash and 'zelas' fragments surrounded by a 0,10 m wide band of hearth lining fragments at the western end
7408	74/1	Debris layer	ROM	Layer 7408, on a E-W alignment, was amorphous in plan, measuring approximately 5,6 m in length and 0,35 m in width. The northern most end of the layer extended beyond the limit of excavation and the eastern terminus was cut by the post-medieval/modern ditch 7401. The layer comprised a 0,10 m thick deposit of peat mixed with pottery-, ash-, charred peat- and 'zelas'- fragments. The deposit appeared to have formed from trampling ash and other industrial waste into the top of the underlying peat, most likely corresponding with the Roman surface level.
7409	74/1	Debris deposition?	ROM	Feature 7409 was semi-oval in plan and ca. 0,35 m long and 0,55 m wide. The northern end extended beyond the limit of excavation. It comprised primarily of charred peat mixed with peat, hearth lining- and briquetage fragments
7502	75/2	Refuse dump?	ROM	Dump 7502 was oval shaped (1,2 m long, 0,8 m wide) and consisted of ash and zelas fragments.
7503	75/2	Refuse dump	ROM	Semi-oval shaped refuse dump 7503, approximately 0,40 m long, 0,45 m wide and 0,1 m deep, defined the north eastern edge of refuse zone 7516. At the bottom, a glazed burned clay deposit ca. 0,05 m was detected, topped by charcoal-, briquetage-, and 'zelas' fragments
7504	75/2	Refuse dump	ROM	Refuse dump 7504, semi-oval shaped, was situated in the southern part of refuse zone 7516, measuring 0,55 m in length, 0,50 m in width and 0,1 m in depth. It comprised a mixture of small and bigger zelas chunks and burned clay-, pottery- and briquetage fragments.
7505	75/2	Refuse dump	ROM	Refuse dump 7505, measuring approximately 0,85 m in length, 0,65 m in width and 0,2 m in depth, was part of refuse zone 7516. At the bottom, the excavators recorded a deposit of burned clay mixed with burned sand (ca. 0,1 m thick) which was respectively covered by numerous fragments of 'zelas' and briquetage. Also several pottery fragments were recovered.
7506	75/2	Refuse dump	ROM	Refuse dump 7506, part of refuse zone 7516, lay north of refuse dump 7505. It consisted of a 0,08m thick deposit of briquetage- and zelas fragments

7507	75/2	Refuse dump	ROM	Refuse dump 7507, roughly pear shaped in plan, was situated to the north of feature 7506 and 7515. It consisted of a mixture burned clay, - sand, pottery-, briquetage and smaller and larger zelas fragments.
7508	75/2	Refuse dump	ROM	Semi-oval shaped refuse dump 7508, part of refuse zone 7516, was situated at the western end of refuse dump 7503. In its surviving form, the feature was 1,05 m long, 0,30 m wide and 0,2 m deep and consisted of a tight mixture of burned clay, briquetage- and 'zelas' fragments
7509	75/2	Refuse dump	ROM	Refuse dump 7509 was semi-circular in plan, measuring 0,5 m in length, 0,2 m in width and 0,15 m in depth. It comprised a deposit of zelas fragments mixed with burned clay and briquetage fragments
7510	75/2	Refuse dump	ROM	Feature 7510, ca. 1 m long, 0,1 m wide and 0,1 m deep, was situated at the north western corner of trench 75/2, north of refuse dump 7511. It extended beyond the limit of excavation and only a small part was recorded in plan. Fragments of zelas, briquetage and pottery were recovered.
7511	75/2	Refuse dump	ROM	Refuse dump 7511, circular in plan with a diameter of 1 m, was not excavated, but preserved in situ for future generations.
7512	75/2	Refuse dump	ROM 11	Oval shaped refuse dump 7512, measuring 0,55 m in length, 0,40 m in width and 0,15 m in depth, lay next to feature 7511. It comprised a mixture of burned clay and zelas fragments
7513	75/2	Refuse dump	ROM 12	Oval shaped refuse dump 7513, measured 0,6 m long, 0,45 m wide and 0,20 m deep and was situated at the western end of trench 75/2. The feature contained a mixed deposit of burned clay, zelas- and briquetage fragments, respectively covered by zelas and briquetage fragments
7514	75/2	Refuse dump	ROM 10	Feature 7514 was circular in plan and measured 0,50 m in diameter and 0,15 m in depth. It comprised a deposit of burned clay, respectively covered by zelas- and briquetage fragments.
7515	75/2	Refuse dump	ROM 4	Refuse dump 7515 was roughly rectangular in plan with a SW-NE alignment, measuring 1,2 m in length, 0,5 m in width and 0,2 m in depth. The feature consisted of a mixture of burned sand and -clay, respectively covered by zelas and briquetage fragments. Also, several pottery fragments were recovered.
7516	75/2	Debris layer	ROM	Layer 7516, amorphous in plan, covered the western half of trench 75/2 and extended beyond the limits of excavation. The layer comprised a 0,25 m thick deposit of reddish brown clay with inclusions of briquetage, pottery and zelas-fragments. This layer was sealed by a post Roman clay deposit. In this layer, semi distinguishable refuse dumps (13 in total) were discernible. The

				deposit and refuse dumps appeared to have formed from episodes of dumping of industrial waste which might have formed a refuse zone with semi distinguishable refuse dumps (13 in total).
7517	75/8	Ditch	PME/MOD	Ditch 7517 defined the southern edge of trench 75/8 and measured 0,4 m in length, 1,55 m in width and 0,4 m in depth. Ditch 7517 was dug into the underlying peat and is most likely a segment of post-medieval/modern ditch 7402/7501
7518	75/8	Debris layer	ROM	Layer 7518 was amorphous in plan and was situated in the southern half of trench 75/8. It clearly extended beyond the limits of excavation to the east and the west. The layer consisted of a several centimetres thick deposit of peat (clay) mixed with ash and scarcely 'zelas' fragments. The amount of ash mixed with the underlying peat deposits varied considerably from scarce to abundant. The deposit appeared to have formed from trampling ash and other industrial waste into the top of the underlying peat, most likely corresponding with the Roman surface level
7519	75/8	Small drainage ditch	ROM	A small drainage ditch was situated in the central part of trench 75/8. This ditch, aligned NW-SE, was cut into the underlying peat and measured 2,07m in recorded length by 0,1 m in width and 0,1 m in depth. The extent to north-west and south-east is unknown. This shallow, flat-based and steep sided ditch lay parallel to drainage ditch 7520 and was filled with reddish brown clay and 'zelas' fragments.
7520	75/8	Small drainage ditch	ROM	A small drainage ditch was situated in the central part of trench 75/8. This ditch, aligned NW-SE, was cut into the underlying peat and measured 1,60 m in recorded length by 0,1 m in width and 0,1 m in depth. The extent to north-west is unknown and the south-eastern end was cut by modern ditch 7522. This shallow, flat-based and steep sided ditch lay parallel to drainage ditch 7520 and was filled with reddish brown clay and 'zelas' fragments.
7521	75/8	Debris layer	ROM	Layer 7521 was situated in the northern part of trench 78/8 and extended beyond the limits of excavation. The recorded length was approximately 0,65 m and the layer was 0,65 m wide and 0,15 m deep. No clear features were discernible and it concerns most likely a debris layer formed by a 0,15 m thick deposit of peat mixed with ash, briquetage- and zelas fragments. The deposit appeared to have formed from trampling ash and other industrial waste into the top of the underlying peat, most likely corresponding with the Roman surface level
7522	75/8	Ditch	PME/MOD	Ditch 7522 extended SSE from the north-eastern corner of trench 75/8, on a NNW-SSE alignment. The structure extended well beyond the limit of excavation, only the western end could be

				recorded, and was at least 3,75 m long, 0,85 m wide and 1,75 m deep. The ditch was filled with several deposits of (light) olive grey, slightly sticky clay with iron reduction.
7523	75/7	Channel deposit	MED?	Feature 7523 (2 m long, 1,1 m wide and 0,65 m deep) was recorded in the southern part of trench 75/7 and extended beyond the limits of excavation. It clearly cut through the Roman layers and was sealed by a clay deposit which also covers a small medieval feature. The greenish grey clay filling was interpreted as channel deposits which might indicate the presence of a nearby medieval (tidal) channel.
7524	75/7	Refuse dump	ROM F4	Refuse dump 7524 was recorded south of refuse dump 7526 and was cut by feature 7523. The surviving feature, triangular in plan measuring 0,55 m long and 0,65 m wide, comprised a deposit of zelas fragments mixed with burned soil-, briquetage fragments, mussel shells and animal bones.
7525	75/7	Refuse dump	ROM	Refuse dump 7525 was recorded south east of refuse dump 7526 and was cut by feature 7523. The surviving amorphous feature, approximately 0,8 m long and 0,45 m wide, comprised a 0,15 m thick deposit of zelas fragments mixed with burned soil-, briquetage fragments and mussel shells. The deposit covered small ditches that were found at the southern and northern edge, but these could not be recorded in plan. These ditches were only seen in section and their exact function is unknown.
7526	75/7	Refuse dump	ROM	Sub rectangular refuse dump 7256, measuring 0,90 m long, 0,60 m wide, was recorded north of refuse dump 7524. It comprised of a 0,10 m thick deposit of ash mixed with zelas-and briquetage fragments. The deposit covered small ditches that were found at the north-western and south eastern edge, but these could not be recorded in plan. These ditches were only seen in section and their exact function is unknown.
7527	75/7	Refuse dump	ROM	Refuse dump 7527 was recorded north west of refuse dump 7526. The surviving amorphous feature, approximately 0,95 m long and 0,65 m wide, comprised a 0,10 m thick deposit of zelas fragments mixed with burned soil-, briquetage fragments and mussel shells. The deposit covered small ditches that were found at the southern and northern edge, but these could not be recorded in plan. These ditches were only seen in section and their exact function is unknown.

7528	75/7	Refuse dump	ROM	Refuse dump 7527 was recorded north of refuse dump 7526. The surviving amorphous feature, approximately 1,15 m long and 0,60 m wide, comprised a 0,10 m thick deposit of zelas fragments mixed with burned soil- and briquetage fragments.
7529	75/7	Refuse dump	ROM	Refuse dump 7528 was recorded east of refuse dump 7528 and measured ca. 1 m in length and 0,4 m in width. It comprised of a burned soil deposit covered by zelas- and briquetage fragments
7530	75/7	Debris layer	ROM	Layer 7530, 1,40 m long, 0,50 m wide, consists of a 0,10 m thick deposit of clay mixed with burned soil- and briquetage fragments.
7531	75/7	Debris layer	ROM	Layer 7531 comprised in the northern part of trench 75/7 a 0,2 m thick deposit of clay mixed with sticky pale ash, briquetage and zelas-fragments. In the southern end of trench 75/7 more zelas fragments were recorded and semi distinguishable refuse dumps (6 in total) were discernible. The deposit and refuse dumps appeared to have formed from episodes of dumping of industrial waste which might have formed a refuse zone with primarily ash dumping in the north and zelas refuse dumps in the south.
7532	75/7	Unknown	ROM	Feature 7532 extended beyond the limits of excavation and measured 0,55 m in length, 0,25 m in width and 0,2 m in depth. It comprised of a 0,05 m thick deposit of burned clay, respectively covered by a 0,15 m thick deposit of pale yellowish white ash and briquetage fragments
7533	75/7	Unknown	ROM	Feature 7533 extended beyond the limits of excavation and measured 0,45 m in length, 0,35 m in width and 0,2 m in depth. It comprised of a 0,05 m thick deposit of burned clay, respectively covered by a 0,15 m thick deposit of pale yellowish white ash and briquetage fragments.
7534	75/7 + 76/9	Ash deposition?	ROM	Feature 7534 was recorded in trench 75/7 and 76/9 and measured approximately 3,15 m in length, minimum 1,85 m in width and between 0,2 m and 0,4 m in depth. It comprises a thick deposit of pale white-light brown ash sporadically mixed with briquetage and zelas fragments. The north-western end of the feature cuts ditch 7536.
7535	75/7	Ash deposition?	ROM	Most likely feature 7535, north of feature 7533, was part of feature 7610 which extends N-S from the south western corner of trench 76/11 and was cut by ditch 7536.
7536	75/7	Feeder ditch	ROM	Ditch 7536, on a WSW-ESE alignment, extended across trench 76/9, 7536 and 76/1. The ditch cut features 7610 and 7535, respectively in trench 76/11 and 75/7, though it was in turn cut by feature 7534 in trench 76/9. In its surviving form, the feature was 9,20 m long, between 0,5 m and 0,65 m wide and 0,35 m deep. The eastern end connected with the western end of water tank 7608, while

				the ditch western terminus could not be traced in plan. In profile this feature had a concave base and rather steep sides. One profile indicates that the feature may have been recut at least once in a later stage.
7601	76/9	Debris layer	ROM	Layer 7601, amorphous in plan, covered the south eastern half of trench 76/9 and to the south extended beyond the limits of excavation. It comprises a 0,15 m thick deposit of reddish brown clay peat (clay) with inclusions of ash, briquetage, pottery and zelas-fragments. The deposit appeared to have formed from trampling ash and other industrial waste into the top of the underlying peat, most likely corresponding with the Roman surface level.
7602	76/9	Debris layer	ROM	Layer 7602, amorphous in plan, was cut by post-medieval/modern ditch 7603 and extended beyond the limits of excavation. It comprises a 0,15 m thick deposit of reddish brown clay peat (clay) with inclusions of ash, briquetage, pottery and zelas-fragments. The deposit appeared to have formed from trampling ash and other industrial waste into the top of the underlying peat, most likely corresponding with the Roman surface level.
7603	76/9	Ditch	PME/MOD	Ditch 7603, on a NW-SE alignment, defined the western end of trench 76/9, measuring approximately 2 m in length, 1,1 m in width and 1,20 m in depth. The ditch, dug into the underlying peat, contained multiple fills of brownish-greenish clay.
7604	76/10	Ditch? Pit?	PME/MOD	Feature 7604 was situated in the south western corner of trench 76/10 and may have been part of a post-medieval or modern ditch or pit. Only a small part of the feature was visible in plan, measuring approximately 0,75 m in length, 1,55 m in width and 1,1 m in depth.
7605	76/10	Debris layer	ROM	Layer 7605 was situated close to the southern limit of trench 76/10 and to the west and east extended beyond the limit of excavation. It comprised a 0,15 m thick deposit of peat (clay) mixed with ash and scarcely 'zelas' fragments. The deposit appeared to have formed from trampling ash and other industrial waste into the top of the underlying peat, most likely corresponding with the Roman surface level
7606	76/11	Peat extraction pit	ME/PME	Feature 7606, measuring 6,80 m long, 6,50 m wide and 1,20 m deep, may have been a (post-) medieval peat extraction pit with steep sides and an highly irregular base. At the base spade marks and a small peat extraction bank are discernible
7607	76/11	Feeder ditch	ROM	Ditch 7607 extended SE from the north-western corner of trench 76/11, on a on a N-SE alignment. The feature was cut by (post-)medieval peat extraction pit 7606 and in its surviving form,

				measured 3,25 m in length, 0,60 m in wide and 0,15 m in depth. Even though the south eastern end doesn't connect to water tank 7608 in plan, this was clearly the case in the Roman period.
7608	76/11	Water reservoir	ROM	Water reservoir 7608, a roughly oval shaped feature aligned E-W, was situated in the central part of trench 76/11. The reservoir was approximately 4,25 m long, 2,30 m wide and 0,8 m deep. The western end connects with ditch 7536, while in Roman times a north western bulge might have been connected to ditch 7607. In profile, this flat-bottom feature had a very fine multi-layered fill alternating fine white ash and mud. The feature may have been used as a water reservoir to store water or brine.
7609	76/11	Unknown function	ROM	Feature 7609, 3,40 m long, between 0,5 m and 1,5 m wide, was recorded in the south western corner of trench 76/11. It comprised a 0,20 m thick deposit of reddish brown clay with lots of burned clay fragments and ash, briquetage and zelas chunks. The deposit appeared to have formed from dumping industrial waste on top of the underlying peat
7610	76/11	Ash deposition?	ROM	Feature 7610 extended north from the south western corner of trench 76/11, on a N-S alignment. The feature was cut by feeder ditch 7536 and in its surviving form, measured 4,4 m long, 0,65 m wide and 0,25 m deep. It comprised a thick deposit of pale white sticky ash sporadically mixed with briquetage and zelas fragments. The deposit may have formed from episodes of dumping industrial waste, specifically fine white ash on top of the peat.
7611	76/11	Debris layer	ROM	Layer 7611, amorphous in plan, was recorded in trench 76/11. It consisted of a 0,1 m thick deposit of peat (clay) mixed with ash, pottery-, briquetage- and zelas fragments. The deposit appeared to have formed from trampling ash and other industrial waste into the top of the underlying peat, most likely corresponding with the Roman surface level
7612	76/11 +77/12 +78/5-17	Ash deposition	ROM	Ash deposit 7612, amorphous in plan, was recorded in trench 76/11, 77/12 and 78/15-17. It consisted of a 0,1 m-0,35 m thick dark brownish black deposit of clay mixed with huge amount of ash, charcoal and zelas fragments. The deposit appeared to have formed from episodes of cleaning out the heating structures which accumulated in front of the heating structures. Most likely the northern, eastern and southern part of the feature was eroded in later periods.
7613	76/11 +77/12	Clay bank	ROM	Clay bank 7613, sub-rectangular shaped, extended ENE from the south eastern corner of trench 76/11, on a WSW-ENE alignment, across trench 77/12 and 78/15-17. The northern, eastern and southern part of the eastern half of the feature was eroded and the central part was cut by modern

	+78/5-17			ditch 7713. In its surviving form, the feature measured 15,5 m in length, between 1,2 m and 1,6 m in width and approximately between 0,4 and 0,5 m in depth. In this artificially raised clay bank 30 heating structures were constructed. The northern and southern part of the western half of the feature are surrounded by ash deposit 7612
7614	76/11	Hearth	ROM	Hearth 7614 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance connected to a small stoke-hole/flue. In its surviving form, the feature measured 0,90 m in length, 1 m in width and a maximum persevered height of 0,40 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,50 m across. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7615 and no profile was recorded.
7615	76/11	Hearth	ROM	Hearth 7615 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance. The northern end of the feature was eroded and no stoke-hole/flue could not be recorded in plan. In its surviving form, the feature measured 0,80 m in length, 0,80 m in width and a maximum preserved height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7614. No profile was recorded.
7616	76/11	Hearth	ROM	Hearth 7616 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance. In its surviving form, the feature measured 0,90 m in length, 0,60 m in width and a maximum persevered height of 0,40 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,25 m across. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7617 and no profile was recorded.
7617	76/11	Hearth	ROM	Hearth 7617 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance. The northern end of the feature was eroded and no stoke-hole/flue could not be recorded in plan. In its surviving form, the feature measured 0,75 m in length, 0,65 m in width and a maximum persevered height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width. The clay lining of the eastern part of the structure could

				not be recorded in plan. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7616. No profile was recorded.
7701	77/12+ 78/16	Hearth	ROM	Hearth 7701 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance connected to a small stoke-hole/flue. In its surviving form, the feature measured 1,10 m in length, 1 m in width and a maximum persevered height of 0,40 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,50 m across. In profile, the hearth had a flat bottom and steep concave sides and was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7702.
7702	77/12+ 78/16	Hearth	ROM	Hearth 7702 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance. The northern end of the feature was eroded and no stoke-hole/flue could not be recorded in plan. In its surviving form, the feature measured 0,95 m in length, 1 m in width and a maximum persevered height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width. In profile, the hearth had a flat bottom and steep concave sides and was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7701.
7703	77/12	Hearth	ROM	Hearth 7703 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance connected to a small stoke-hole/flue. In its surviving form, the feature measured 1,10 m in length, 0,90 m in width and a maximum persevered height of 0,40 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,40 m across. In profile, the hearth had a flat bottom and steep concave sides and was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7704.
7704	77/12	Hearth	ROM	Hearth 7704 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance connected to a small stoke-hole/flue. In its surviving form, the feature measured 1,05 m in length, 0,90 m in width and a maximum persevered height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,6 m across. In profile, the hearth had a flat bottom and steep concave sides and

				was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7703.
7705	77/12	Hearth	ROM	Hearth 7705 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance connected to a small stoke-hole/flue. In its surviving form, the feature measured 1,10 m in length, 0,95 m in width and a maximum persevered height of 0,40 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,35 m across. In profile, the hearth had steep concave sides and was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7706 and modern ditch 7713.
7706	77/12	Hearth	ROM	Hearth 7706 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance. In its surviving form, the feature measured 0,95 m in length, 0,80 m in width and a maximum persevered height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,35 m across. Ditch 7713 cut through the eastern part of hearth 7707 disturbing the clay lining. In profile, the hearth had a flat bottom and steep concave sides and was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7705.
7707	77/12	Hearth	ROM	Hearth 7707 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance connected to a small stoke-hole/flue. In its surviving form, the feature measured 1,10 m in length, 0,80 m in width and a maximum persevered height of 0,40 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1m in width. Ditch 7713 cut through the south western part of hearth 7707 disturbing the clay lining and the entrance. In profile, the hearth had a flat bottom and steep concave sides and was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7708.
7708	77/12	Hearth	ROM	Hearth 7708 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance. In its surviving form, the feature measured 1 m in length, 0,80 m in width and a maximum persevered height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,30 m across. Ditch 7713 cut through the south western part of hearth 7707 disturbing the clay lining. The hearth was filled

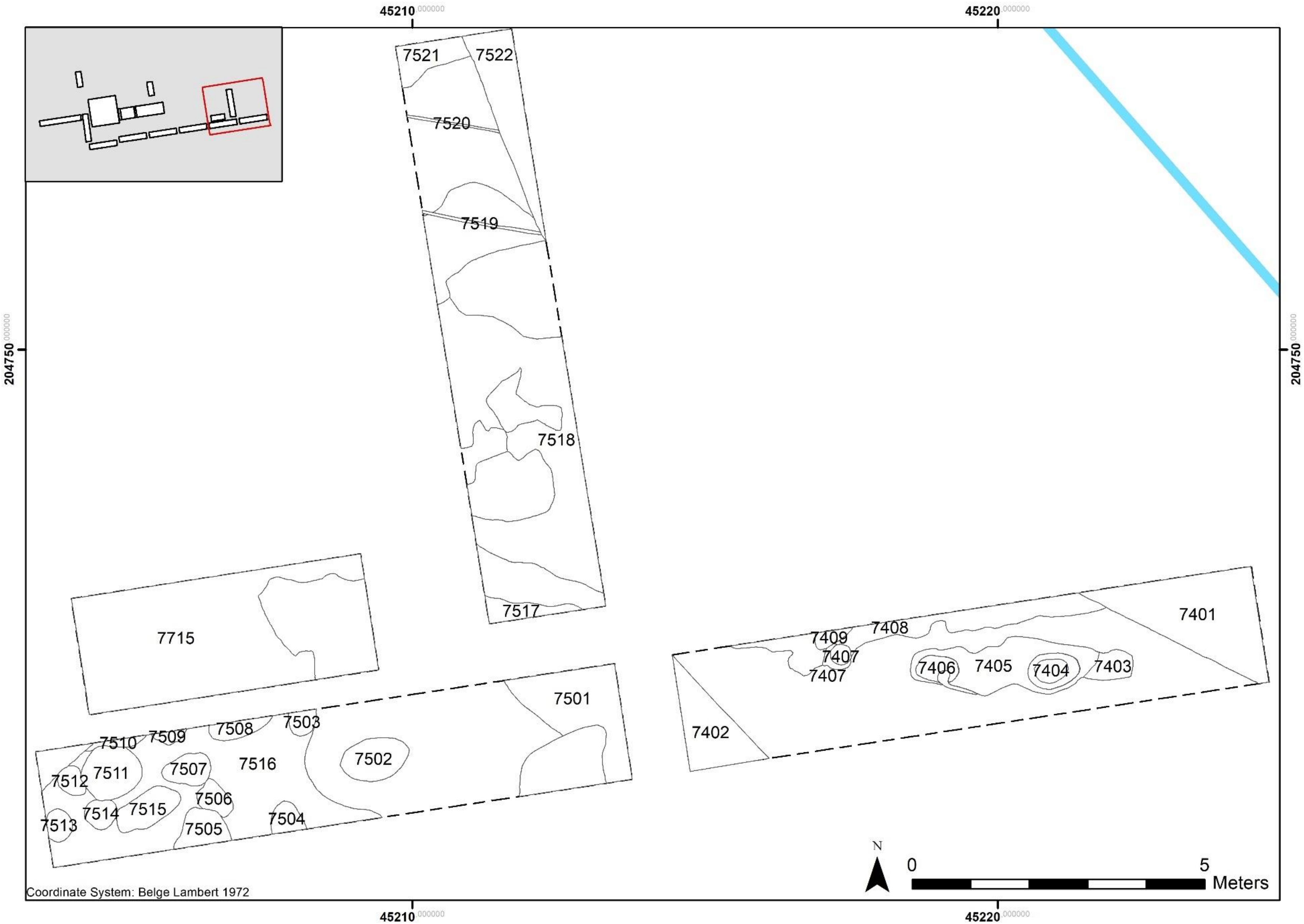
				with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7707.
7709	77/12	Hearth	ROM	Hearth 7709 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance connected to a small stoke-hole/flue. In its surviving form, the feature measured 1,10 m in length, 0,85 m in width and a maximum persevered height of 0,40 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,20 m across. In profile, the hearth had a flat bottom and steep concave sides and was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7709.
7710	77/12	Hearth	ROM	Hearth 7710 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance connected to a small stoke-hole/flue. In its surviving form, the feature measured 0,6 m in length, 0,55 m in width and a maximum persevered height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,25 m across. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7709.
7711	77/12+ 78/17	Hearth	ROM	Hearth 7711 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance connected to a small stoke-hole/flue. In its surviving form, the feature measured 1 m in length, 0,70 m in width and a maximum persevered height of 0,40 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,20 m across. In profile, two flat hearth bottoms, belonging to the same heating structure, and episodes of relining were recorded which might indicate repairs or a multiphased use of the hearth. It was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7712.
7712	77/12+ 78/17	Hearth	ROM	Hearth 7712 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance. The northern end of the feature was eroded. In its surviving form, the feature measured 0,60 m in length, 0,70 m in width and a maximum persevered height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7711. No profile was recorded.

7713	77/12+ 78/15	Ditch	PME/MOD	Ditch 7713, curved semi-circular in plan, extended across trench 77/12 and 78/15 and clearly cuts through multiple Roman features. It measures 9 m in length, 0,5 m in width and 0,8 m in depth and consist of a single fill of greenish grey clay.
7714	77/13	Peat extraction pit	PME?	Feature 7714, 1 m deep with a relatively flat base and steep sides, defined the southern edge of trench 77/13 and may have been a post medieval peat extraction pit.
7715	77/14	Debris layer	ROM	Layer 7715 was situated in the western part of trench 77/14 and extended beyond the limits of excavation with the exception of the eastern terminus. The layer comprised an approximately 0,10 m thick deposit of peat (clay) mixed with ash, pottery-, briquetage- and zelas fragments. The deposit appeared to have formed from trampling ash and other industrial waste into the top of the underlying peat, most likely corresponding with the Roman surface level
7801	78/15	Hearth	ROM	Hearth 7801 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance connected to a small stoke-hole/flue. In its surviving form, the feature measured 1,15 m in length, 1,10 m in width and a maximum persevered height of 0,40 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,15 m in width, with an entrance approximately 0,20 m across. In profile, two flat hearth bottoms, belonging to the same heating structure, and episodes of relining were recorded which might indicate repairs or a multiphased use of the hearth. It was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7802.
7802	78/15	Hearth	ROM	Hearth 7802 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance. The northern end of the feature was heavily eroded. In its surviving form, the feature measured 0,45 m in length, 1,05 m in width and a maximum persevered height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width. The clay lining of the north eastern part of the structure could not be recorded in plan. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7801. No profile was recorded.
7803	78/15	Hearth	ROM	Hearth 7803 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance. In its surviving form, the feature measured 1,15 m in length, 0,90 m in width and a maximum persevered height of 0,35 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width. Ditch 7713 cut through the south western and north eastern part

				of hearth 7707 disturbing the clay lining and the entrance. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7804.
7804	78/15	Hearth	ROM	Hearth 7804 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance. The northern end of the feature was heavily eroded. In its surviving form, the feature measured 0,30 m in length, 0,80 m in width and a maximum persevered height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width. Ditch 7713 cut through the eastern part of hearth 7804 disturbing the clay lining. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7803. No profile was recorded.
7805	78/15	Hearth	ROM	Hearth 7805 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance. The southern end of the feature was eroded and no stoke-hole/flue could not be recorded in plan. In its surviving form, the feature measured 0,90 m in length, 0,90 m in width and a maximum persevered height of 0,35 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7806 and no profile was recorded.
7806	78/15	Hearth	ROM	Hearth 7806 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance. The northern end of the feature was eroded. In its surviving form, the feature measured 0,55 m in length, 0,75 m in width and a maximum persevered height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7805. No profile was recorded.
7807	78/15	Hearth	ROM	Hearth 7807 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance. The southern end of the feature was eroded and no stoke-hole/flue could not be recorded in plan. In its surviving form, the feature measured 0,90 m in length, 0,80 m in width and a maximum persevered height of 0,35 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,40 m across. The hearth

				was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7808 and no profile was recorded.
7808	78/15	Hearth	ROM	Hearth 7808 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance. The northern end of the feature was eroded. In its surviving form, the feature measured 0,75 m in length, 0,80 m in width and a maximum persevered height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width. The clay lining of the southern part of the structure could not be recorded in plan. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7807. No profile was recorded.
7809	78/15	Hearth	ROM	Hearth 7809 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance connected to a small stoke-hole/flue. In its surviving form, the feature measured 0,85 m in length, 0,85 m in width and a maximum persevered height of 0,35 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,45 m across. The clay lining of the north eastern part of the structure could not be recorded in plan. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7808 and no profile was recorded.
7810	78/15	Hearth	ROM	Hearth 7810 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance. The northern end of the feature was heavily eroded. In its surviving form, the feature measured 0,75 m in length, 0,95 m in width and a maximum persevered height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width. The clay lining of the western and southern part of the structure could not be recorded in plan. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7809. No profile was recorded.
7811	78/15	Hearth	ROM	Hearth 7811 comprised a simple penannular or horseshoe shaped structure, with a south facing entrance connected to a small stoke-hole/flue. In its surviving form, the feature measured 0,90 m in length, 0,95 m in width and a maximum persevered height of 0,35 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width, with an entrance approximately 0,30 m across. The clay lining of the north western part of the structure could not

				be recorded in plan. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The northern end of the structure was cut by hearth 7812 and no profile was recorded.
7812	78/15	Hearth	ROM	Hearth 7812 comprised a simple penannular or horseshoe shaped structure, with a north facing entrance. The northern end of the feature was heavily eroded. In its surviving form, the feature measured 0,90 m in length, 0,85 m in width and a maximum persevered height of 0,25 m and consisted of a pinkish white-purplish red fired clay lining measuring 0,1 m in width. The clay lining of the southern part of the structure could not be recorded in plan. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments. The southern end of the structure cut hearth 7811. No profile was recorded.
7813	78/15	Hearth	ROM	Hearth 7813, with a south facing entrance, was heavily eroded. Ditch 7818 cut through the western part of the hearth 7814 disturbing the clay lining and hearth filling. Only part of the heart filling, diameter of 0,5 m preserved consisting of a compact mixture of ashy material, zelas- and burned clay fragments.
7814	78/15	Hearth	ROM	Hearth 7814, with a north facing entrance, was heavily eroded. Ditch 7818 cut through the eastern and southern part of the hearth 7814 disturbing the clay lining and hearth filling. In its surviving form, the feature measured 0,65 m in length with a maximum persevered height of 0,15 m. The hearth was filled with a compact mixture of ashy material, zelas- and burned clay fragments
7815	78/15	Pit	PME/MOD	Pit 7815 was situated at the northern edge of trench 78/15 and extended beyond the limits of excavation. It measured 2,25 m in length, 0,75 m in width and 0,9 m deep.
7816	78/15	Pit	PME/MOD	Pit 7816 was situated at the northern edge of trench 78/15 and extended beyond the limits of excavation. It measured 1,9 m in length, 0,30 m in width and 0,9 m deep.
7817	78/15	Pit	PME/MOD	Pit 7815 was situated at the northern edge of trench 78/15 and extended beyond the limits of excavation. It measured 2,50 m in length, 0,26 m in width and 0,9 m deep.
7818	78/15	Ditch	PME/MOD	Ditch 7818, situated on the eastern edge of trench 78/15, was slightly curved on a NE-SE alignment. It measured 3,25 m in length and 0,40 m in width.



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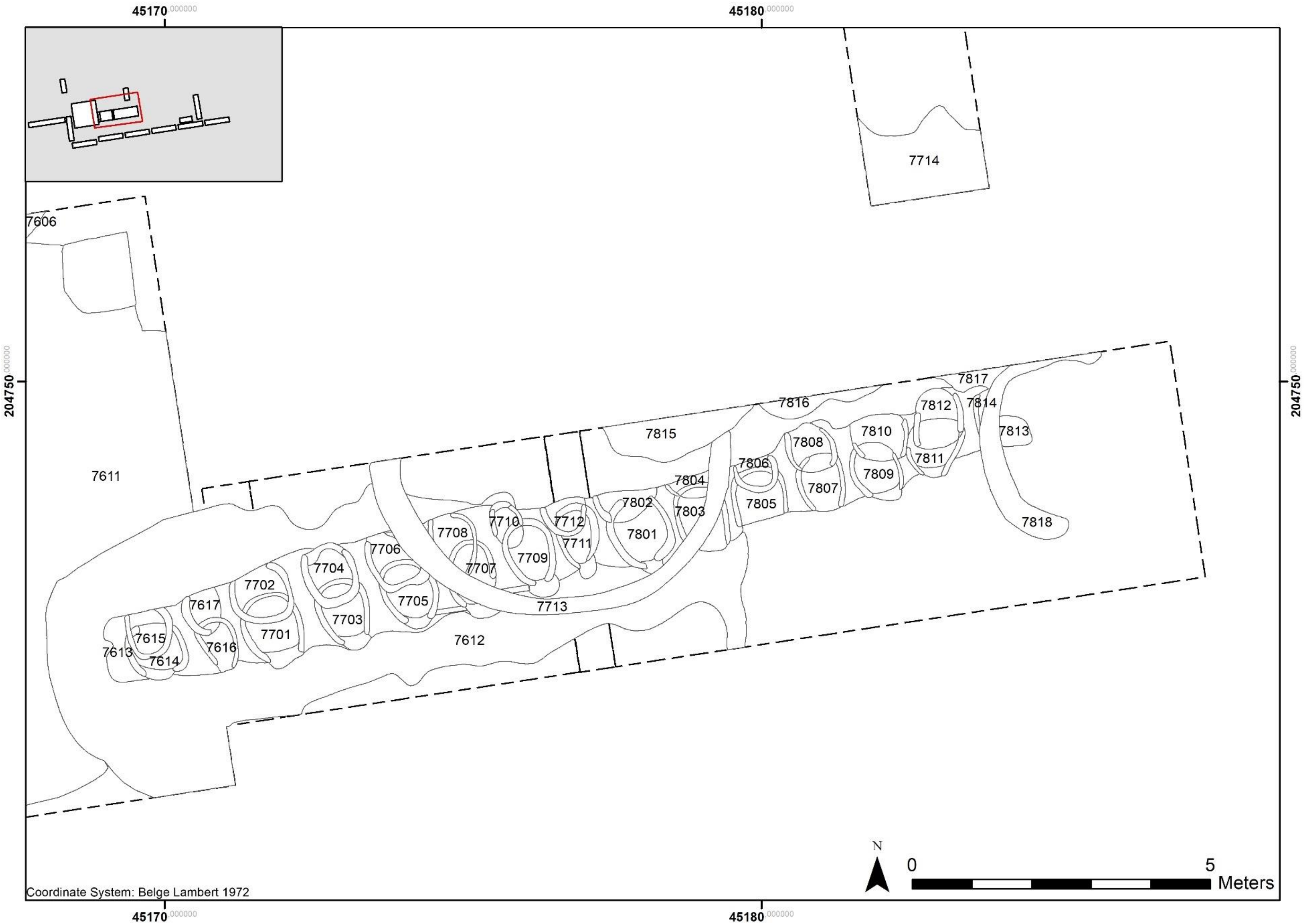
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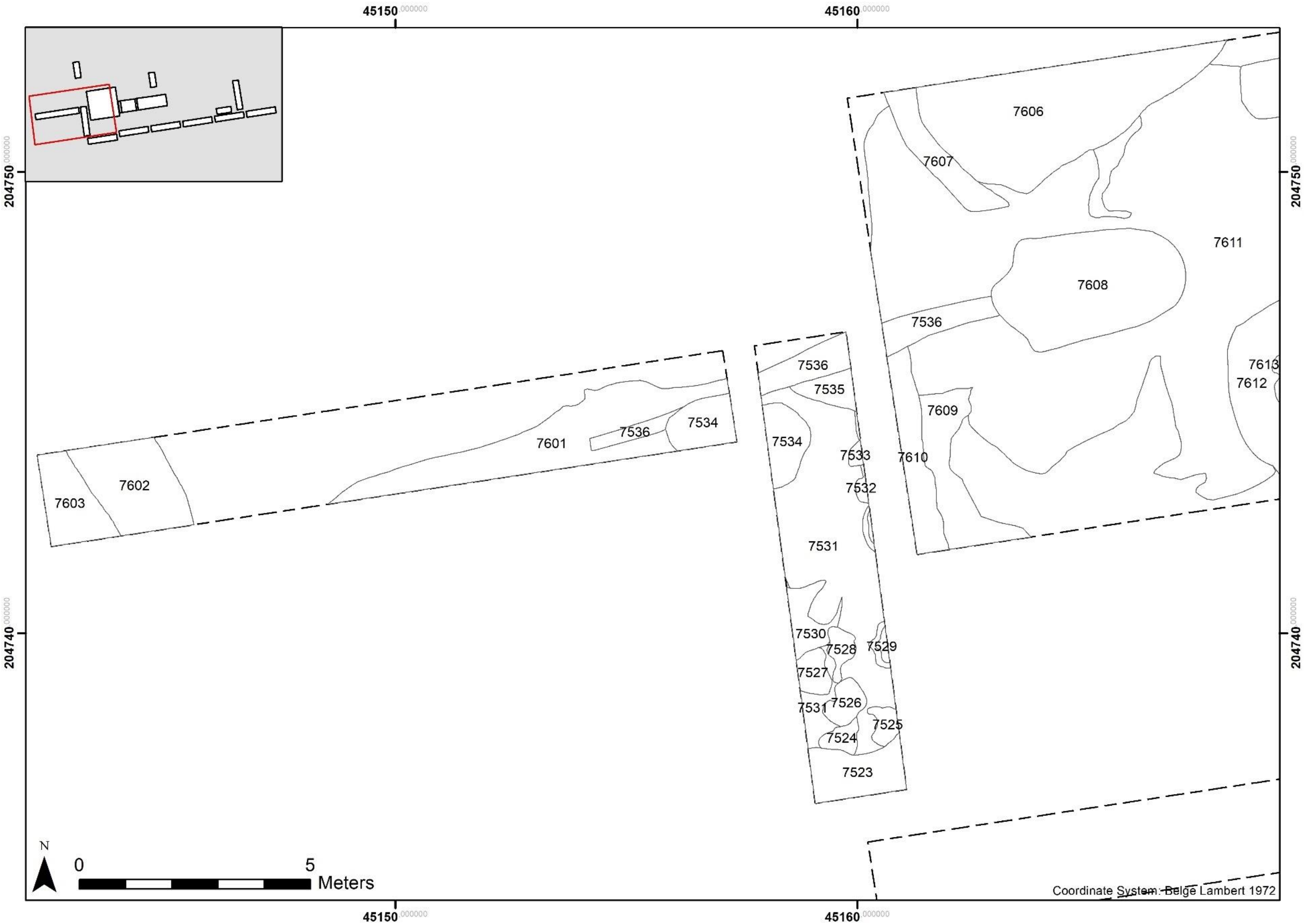

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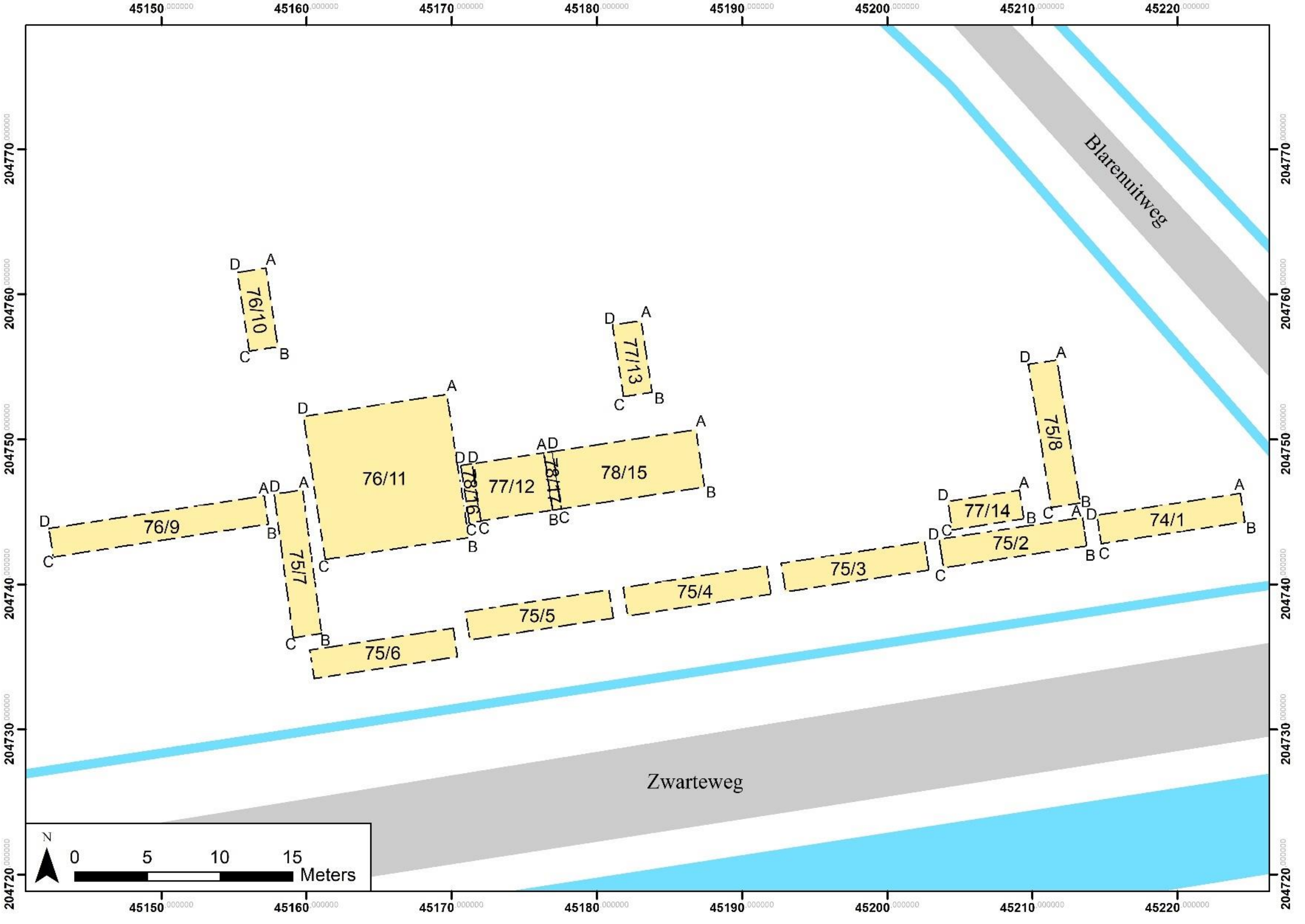
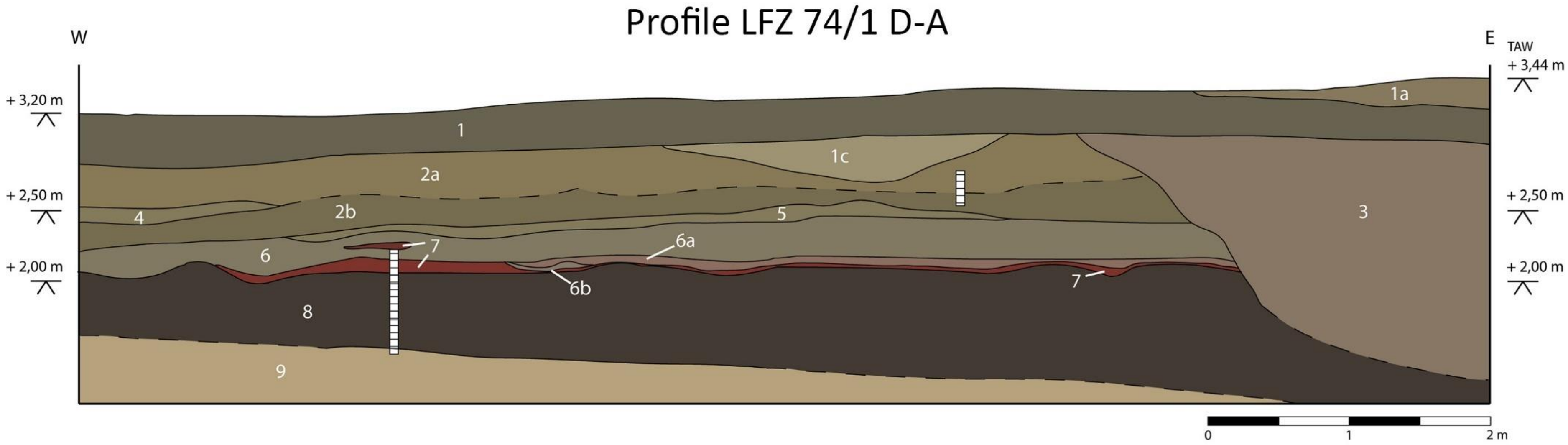
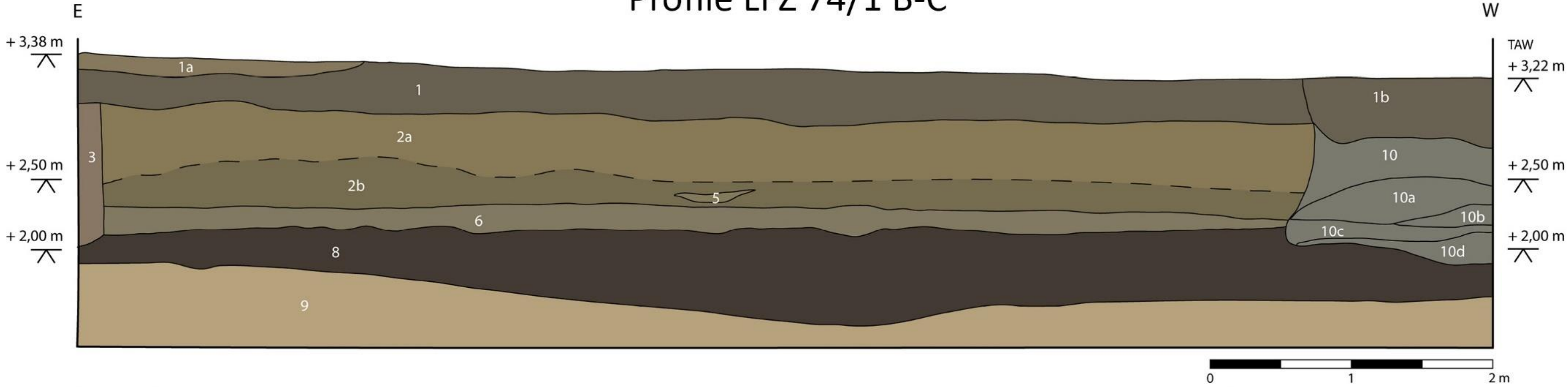
Digitised profiles





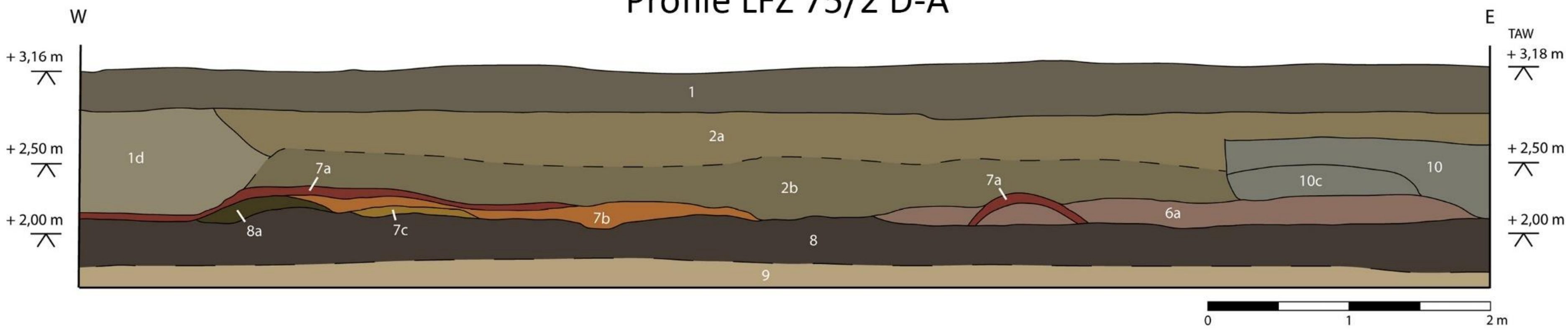
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
1a	Light olive brown (3,5 Y 5/2,5), non sticky clay with a granular texture and roots are common	Reworked earth on plough soil
1c	Dark yellowish brown clay with a high humus content	Local modern disturbance
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
3	Greyish brown clay with a blocky texture, a low humus content and many deep penetrating roots	Post-medieval ditch
4	Olive grey (5 Y 5/2,5), slightly sticky clay with a blocky texture	
5	Olive grey (5 Y 5/2,5), slightly sticky, very plastic clay with a blocky texture and locally small lime concretions	
6	Olive grey (5 Y 5/2), slightly sticky, plastic clay with a fine granular texture and sporadically peat chunks. Many sandy flow lines were discernible	
6a	Light reddish brown clay with a crumbly structure, many rust spots and peat and ash chunks	
6b	Olive brown peatish clay	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, ‘zelas’, briquetage and charcoal fragments	Roman occupation layer
8	Dark greyish peat	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand

Profile LFZ 74/1 B-C



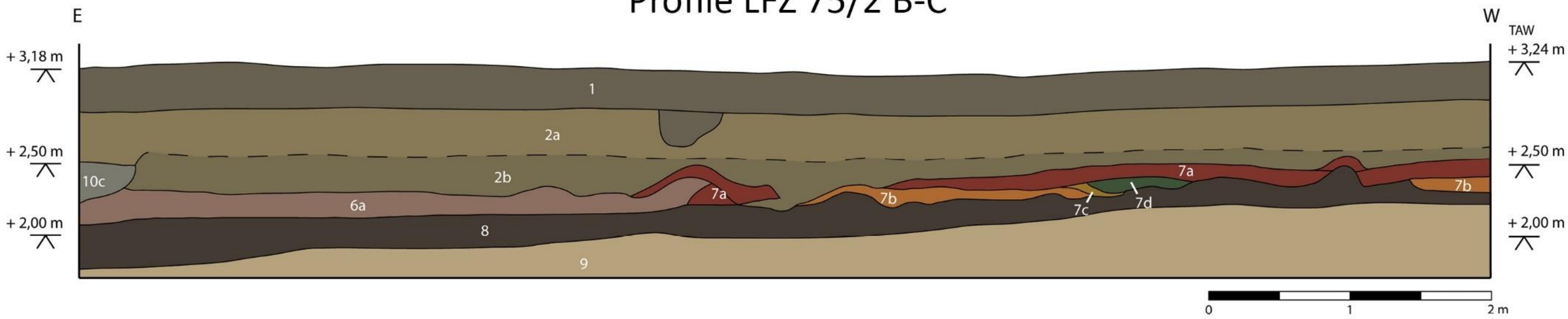
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
1a	Light olive brown (3,5 Y 5/2,5), non sticky clay with a granular texture and roots are common	Reworked earth on plough soil
1b	Dark brownish grey, slightly sticky clay with many roots and bone fragments	
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
3	Greyish brown clay with a blocky texture, a low humus content and many deep penetrating roots	Post-medieval ditch
5	Olive grey (5 Y 5/2,5), slightly sticky, very plastic clay with a blocky texture and locally small lime concretions	
6	Olive grey (5 Y 5/2), slightly sticky, plastic clay with a fine granular texture and sporadically peat chunks. Many sandy flow lines were discernible	
8	Dark greyish peat	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand
10	Very light brownish grey clay with a blocky texture	Post-medieval/modern ditch
10a	Very light brownish grey clay with a blocky texture and local phosphate enrichment	Post-medieval/modern ditch
10b	Light greenish grey, slightly sticky clay with a blocky texture and rust spots	Post-medieval/modern ditch
10c	Light greenish grey clay with a crumbly structure, many rust spots and peat chunks	Post-medieval/modern ditch
10d	Light greenish grey, sticky clay with a blocky texture and small lime concretions	Post-medieval/modern ditch

Profile LFZ 75/2 D-A



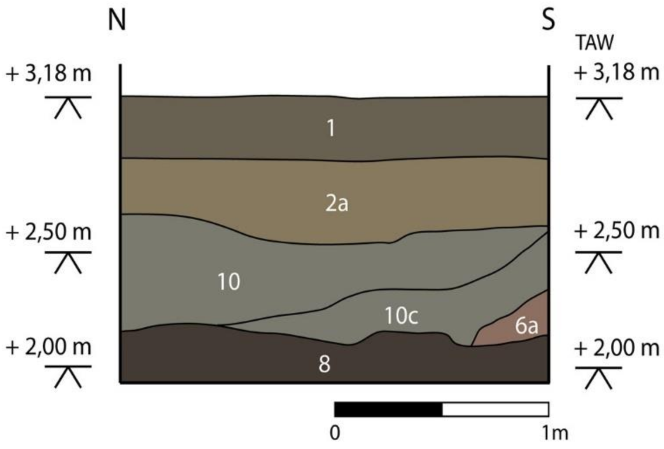
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
1d	Light olive grey (5 Y 5,5/2), non sticky clay with a blocky texture and a low humus content	(Post)-medieval peat extraction pit?
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
6a	Light reddish brown clay with a crumbly structure, many rust spots and peat and ash chunks	
7a	Clay with lots of briquetage fragments	Roman occupation layer
7b	Clay with lots of ‘zelas’ fragments	Roman occupation layer
7c	Burned sand layer	Roman occupation layer
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand
10	Very light brownish grey clay with a blocky texture	Post-medieval/modern ditch
10c	Light greenish grey clay with a crumbly structure, many rust spots and peat chunks	Post-medieval/modern ditch

Profile LFZ 75/2 B-C



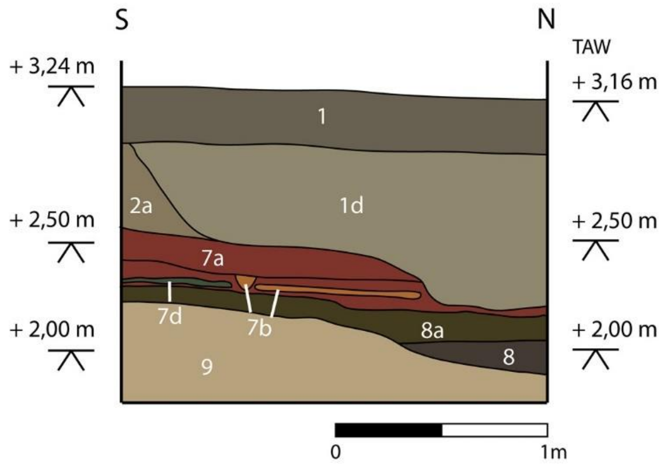
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
6a	Light reddish brown clay with a crumbly structure, many rust spots and peat and ash chunks	
7a	Clay with lots of briquetage fragments	Roman occupation layer
7b	Clay with lots of 'zelas' fragments	Roman occupation layer
7c	Burned sand layer	Roman occupation layer
7d	Burned clay layer	
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand
10c	Light greenish grey clay with a crumbly structure, many rust spots and peat chunks	Post-medieval/modern ditch

Profile LFZ 75/2 A-B



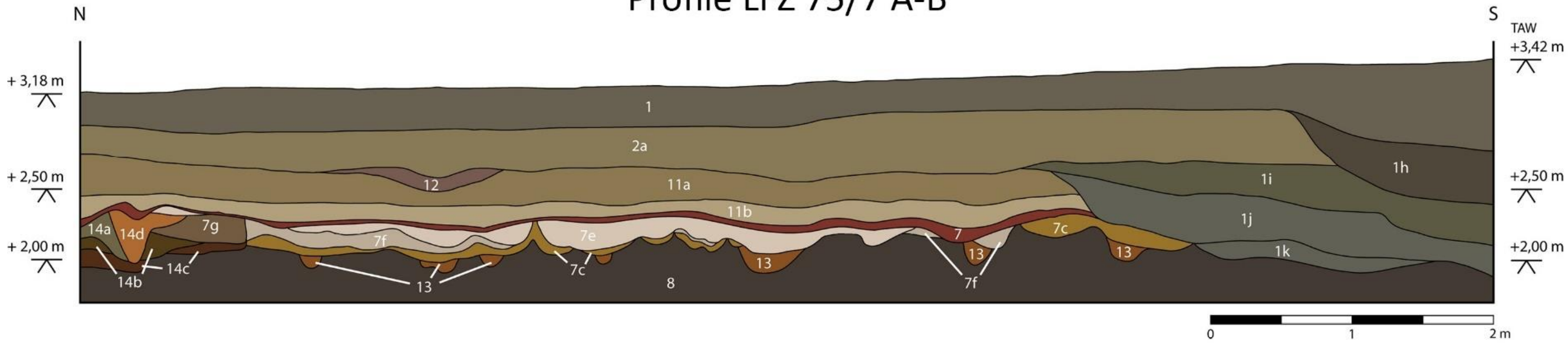
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
6a	Light reddish brown clay with a crumbly structure, many rust spots and peat and ash chunks	
8	Dark greyish peat	
10	Very light brownish grey clay with a blocky texture	Post-medieval/modern ditch
10c	Light greenish grey clay with a crumbly structure, many rust spots and peat chunks	Post-medieval/modern ditch

Profile LFZ 75/2 C-D

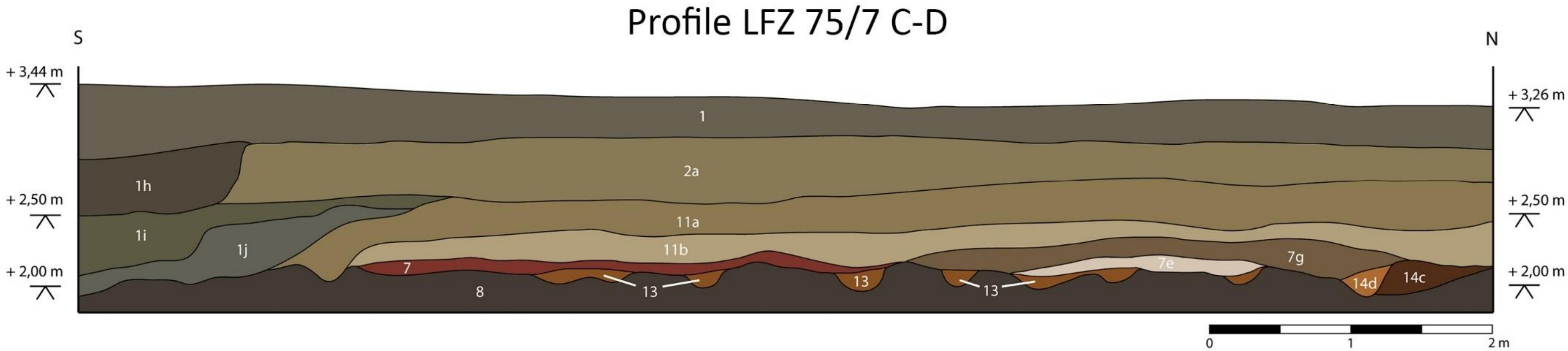


Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
1d	Light olive grey (5 Y 5,5/2), non sticky clay with a blocky texture and a low humus content	(Post)-medieval peat extraction pit?
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
7a	Clay with lots of briquetage fragments	Roman occupation layer
7b	Clay with lots of 'zelas' fragments	Roman occupation layer
7d	Burned clay layer	Roman occupation layer
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand

Profile LFZ 75/7 A-B

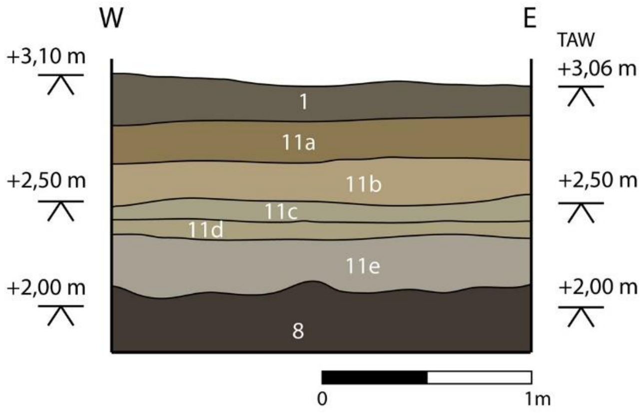


Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
1h	Very dark greyish brown (2,5 Y 3/1,5) clay with a high humus content, lots of roots and few reed stems	Post-medieval/modern ditch
1i	Greenish brown, slightly sticky, slightly plastic clay with a blocky texture, a medium humus content and lots of roots	Channel deposit
1j	Light greenish grey, very sticky, very plastic clay mixed with sandy clay (reworked natural levee deposit) at the bottom	Channel deposit
1k	Light greenish grey clay mixed with peat clay and reworked ash deposits	Channel deposit
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
7c	Burned sand layer	Roman occupation layer
7e	Pale yellowish white, very sticky, slightly plastic ash layer with a very fine structure, a low humus content and sporadically briquetage fragments and 'zelas' chunks	Roman occupation layer
7f	Yellowish white clayish ash layer with a fine texture and a high humus content	Roman occupation layer
7g	Light brownish ash layer	Roman occupation layer
8	Dark greyish peat	
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
11b	Light yellowish brown (2,5 Y 6,5/3) well layered fine sand and clay lenses with a fine granular texture and sporadically ash fragments	Natural levee deposit
12	Light reddish brown clay with a burned soil fragments and a high humus content	Medieval layer
13	Orangey brown (2,5 YR 3,5/7,5), very sticky, very plastic clay. Sometimes mixed with peat clay fragments	Small ditch
14a	Light brownish grey clay mixed with ash fragments and lots of briquetage fragments	Ditch (water management)
14b	Brown peat clay with sporadic clay lenses and briquetage fragments	Ditch (water management)
14c	Dark brown peat clay with local rust spots and briquetage fragments	Ditch (water management)
14d	Orangey brown clay with a high humus content, lots of ash fragments and lots of 'zelas' fragments	Ditch (water management)



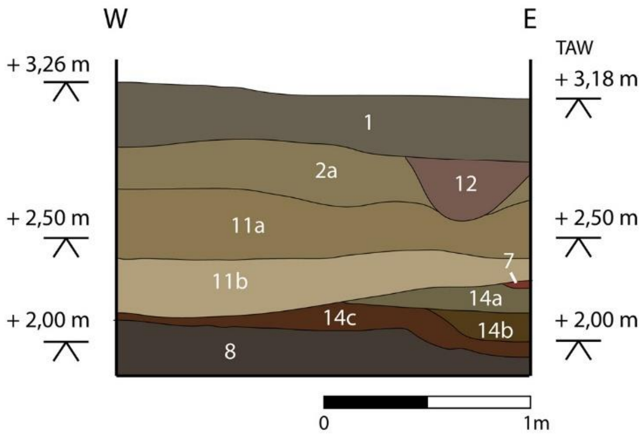
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
1h	Very dark greyish brown (2,5 Y 3/1,5) clay with a high humus content, lots of roots and few reed stems	Post-medieval/modern ditch
1i	Greenish brown, slightly sticky, slightly plastic clay with a blocky texture, a medium humus content and lots of roots	Channel deposit
1j	Light greenish grey, very sticky, very plastic clay mixed with sandy clay (reworked natural levee deposit) at the bottom	Channel deposit
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, ‘zelas’, briquetage and charcoal fragments	Roman occupation layer
7e	Pale yellowish white, very sticky, slightly plastic ash layer with a very fine structure, a low humus content and sporadically briquetage fragments and ‘zelas’ chunks	Roman occupation layer
7g	Light brownish ash layer	Roman occupation layer
8	Dark greyish peat	
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
11b	Light yellowish brown (2,5 Y 6,5/3) well layered fine sand and clay lenses with a fine granular texture and sporadically ash fragments	Natural levee deposit
13	Orangey brown (2,5 YR 3,5/7,5), very sticky, very plastic clay. Sometimes mixed with peat clay fragments	Small ditch
14c	Dark brown peat clay with local rust spots and briquetage fragments	Ditch (water management)
14d	Orangey brown clay with a high humus content, lots of ash fragments and lots of ‘zelas’ fragments	Ditch (water management)

Profile LFZ 76/10 D-A



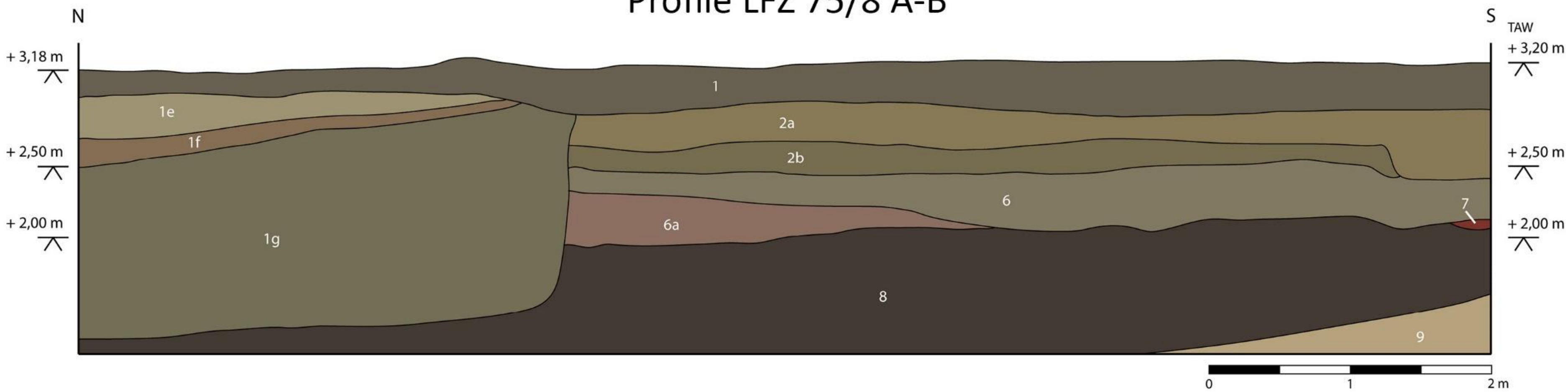
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
8	Dark greyish peat	
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
11b	Light yellowish brown (2,5 Y 6,5/3) well layered fine sand and clay lenses with a fine granular texture and sporadically ash fragments	Natural levee deposit
11c	Light greenish grey (7,5 Y 6,5/2) clay with a fine granular texture and many lime concretions	Natural levee deposit
11d	Pale olive grey (5 Y 6,5/3), fine sand with very unclear clay lenses and a crumbled iron reduction horizon at the bottom	Natural levee deposit
11e	At the top: large light grey fine sand lenses with brown iron reduction horizons and small dark grey clay lenses. At the bottom: large dark grey clay lenses with brown iron reduction horizons and small light grey sand lenses	Natural levee deposit

Profile LFZ 75/7 D-A



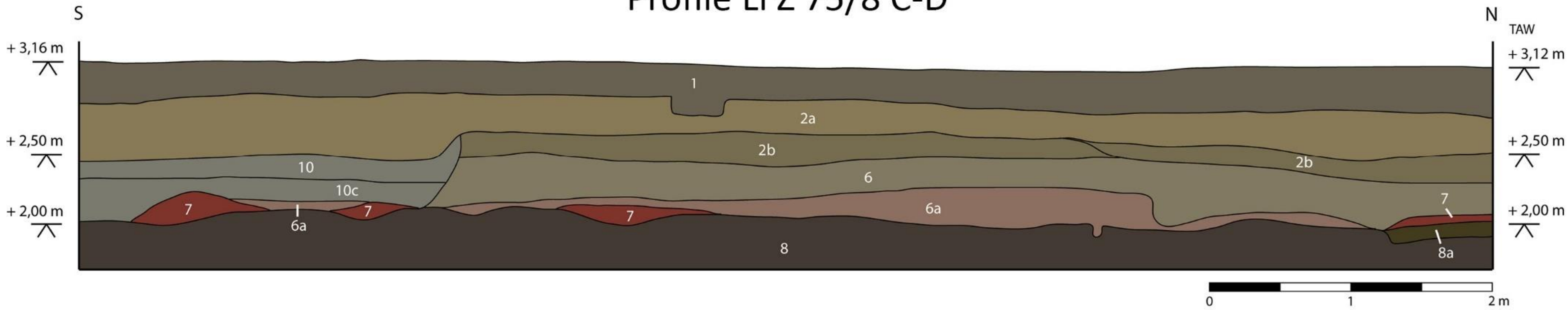
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
8	Dark greyish peat	
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
11b	Light yellowish brown (2,5 Y 6,5/3) well layered fine sand and clay lenses with a fine granular texture and sporadically ash fragments	Natural levee deposit
12	Light reddish brown clay with a burned soil fragments and a high humus content	Medieval layer
14a	Light brownish grey clay mixed with ash fragments and lots of briquetage fragments	Ditch (water management)
14b	Brown peat clay with sporadic clay lenses and briquetage fragments	Ditch (water management)
14c	Dark brown peat clay with local rust spots and briquetage fragments	Ditch (water management)

Profile LFZ 75/8 A-B



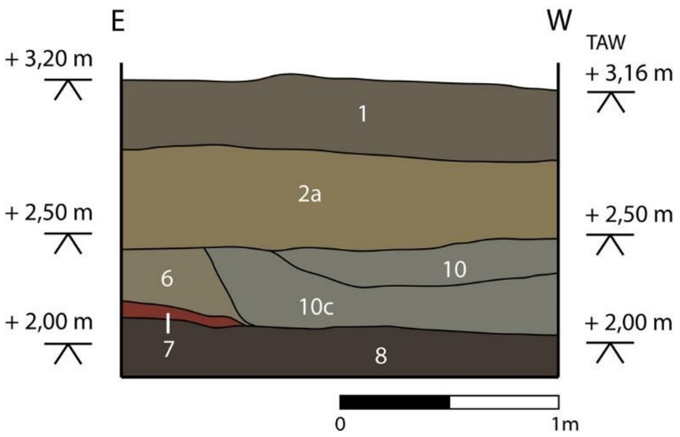
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
1e	Light olive grey (5 Y 6/2), slightly plastic clay with a granular texture	Post-medieval/modern ditch
1f	Light brown, slightly sticky clay with a very high humus content	Post-medieval/modern ditch
1g	Olive grey (7,5 Y 4,5/2), slightly sticky clay with a blocky texture and iron reduction horizons	Post-medieval/modern ditch
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
6	Olive grey (5 Y 5/2), slightly sticky, plastic clay with a fine granular texture and sporadically peat chunks. Many sandy flow lines were discernible	
6a	Light reddish brown clay with a crumbly structure, many rust spots and peat and ash chunks	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
8	Dark greyish peat	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand

Profile LFZ 75/8 C-D



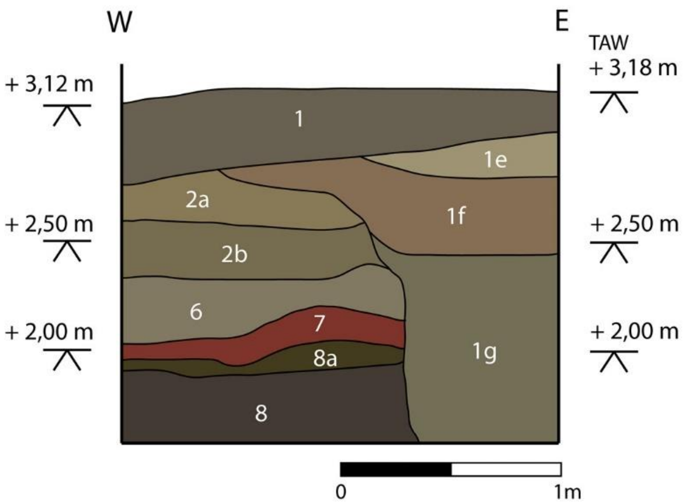
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
6	Olive grey (5 Y 5/2), slightly sticky, plastic clay with a fine granular texture and sporadically peat chunks. Many sandy flow lines were discernible	
6a	Light reddish brown clay with a crumbly structure, many rust spots and peat and ash chunks	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
10	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	Post-medieval/modern ditch
10c	Light greenish grey clay with a crumbly structure, many rust spots and peat chunks	Post-medieval/modern ditch

Profile LFZ 75/8 B-C



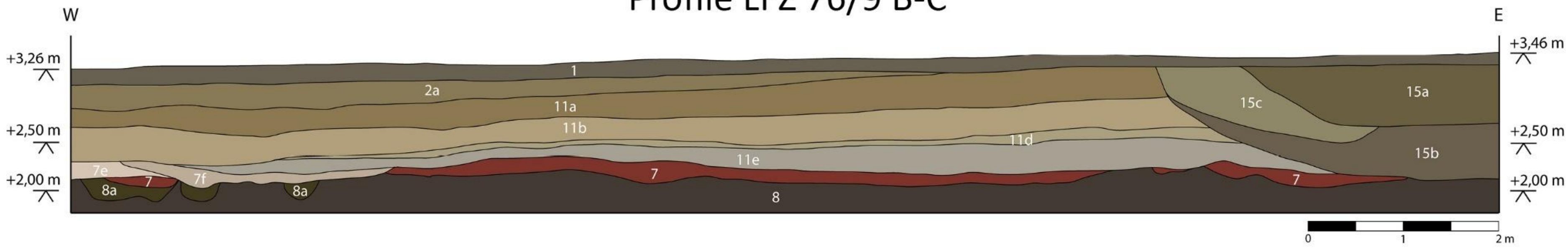
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
6	Olive grey (5 Y 5/2), slightly sticky, plastic clay with a fine granular texture and sporadically peat chunks. Many sandy flow lines were discernible	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
8	Dark greyish peat	
10	Very light brownish grey clay with a blocky texture	Post-medieval/modern ditch
10c	Light greenish grey clay with a crumbly structure, many rust spots and peat chunks	Post-medieval/modern ditch

Profile LFZ 75/8 D-A



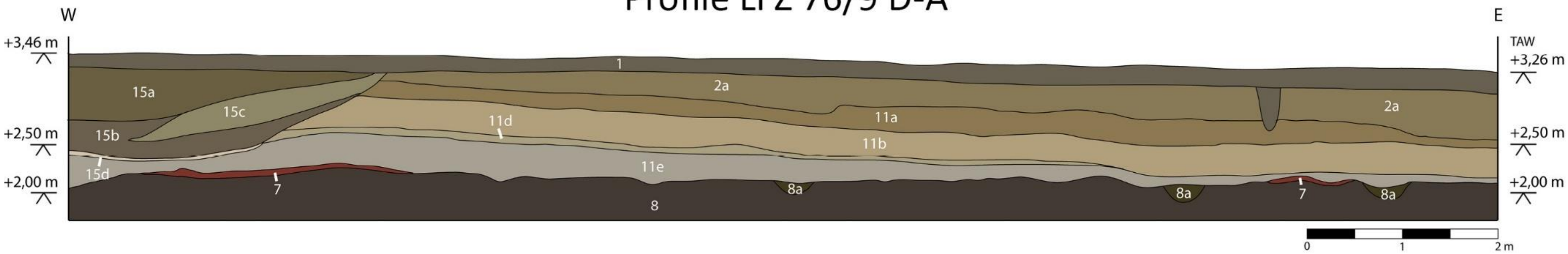
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
1e	Light olive grey (5 Y 6/2), slightly plastic clay with a granular texture	Post-medieval ditch
1f	Light brown, slightly sticky clay with a very high humus content	Post-medieval ditch
1g	Olive grey (7,5 Y 4,5/2), slightly sticky clay with a blocky texture and iron reduction horizons	Post-medieval ditch
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
6	Olive grey (5 Y 5/2), slightly sticky, plastic clay with a fine granular texture and sporadically peat chunks. Many sandy flow lines were discernible	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
8	Dark greyish peat	

Profile LFZ 76/9 B-C



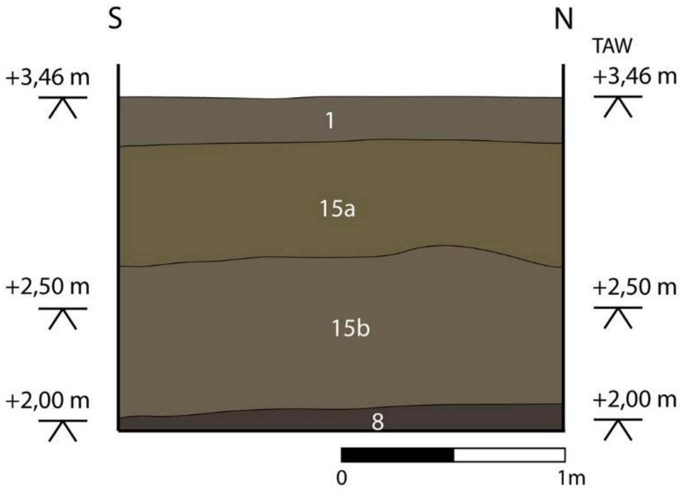
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
7e	Pale yellowish white, very sticky, slightly plastic ash layer with a very fine structure, a low humus content and sporadically briquetage fragments and 'zelas' chunks	Roman occupation layer
7f	Yellowish white clayish ash layer with a fine texture and a high humus content	Roman occupation layer
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
11b	Light yellowish brown (2,5 Y 6,5/3) well layered fine sand and clay lenses with a fine granular texture and sporadically ash fragments	Natural levee deposit
11d	Pale olive grey (5 Y 6,5/3), fine sand with very unclear clay lenses and a crumbled iron reduction horizon at the bottom	Natural levee deposit
11e	At the top: large light grey fine sand lenses with brown iron reduction horizons and small dark grey clay lenses. At the bottom: large dark grey clay lenses with brown iron reduction horizons and small light grey sand lenses	Natural levee deposit
15a	Olive brown (5 Y 4/2,5), slightly sticky clay with a blocky texture	Post-medieval/modern ditch
15b	Brownish grey, slightly sticky clay with greyish sand lenses	Post-medieval/modern ditch
15c	Greenish grey (7,5 Y 5,5/2,5) clay with a blocky texture	Post-medieval/modern ditch

Profile LFZ 76/9 D-A



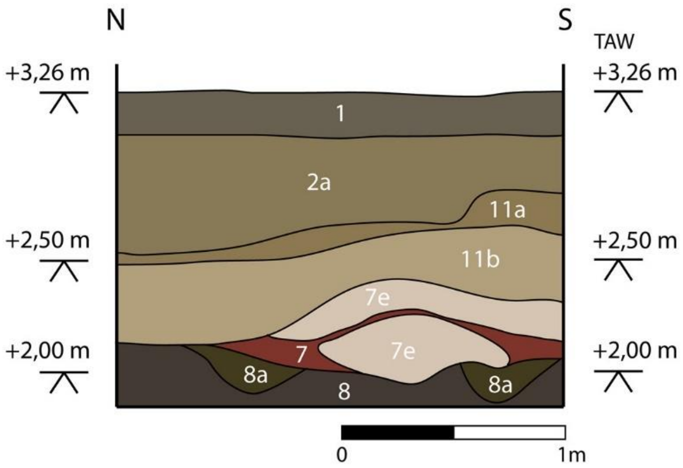
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
11b	Light yellowish brown (2,5 Y 6,5/3) well layered fine sand and clay lenses with a fine granular texture and sporadically ash fragments	Natural levee deposit
11d	Pale olive grey (5 Y 6,5/3), fine sand with very unclear clay lenses and a crumbled iron reduction horizon at the bottom	Natural levee deposit
11e	At the top: large light grey fine sand lenses with brown iron reduction horizons and small dark grey clay lenses. At the bottom: large dark grey clay lenses with brown iron reduction horizons and small light grey sand lenses	Natural levee deposit
15a	Olive brown (5 Y 4/2,5), slightly sticky clay with a blocky texture	Post-medieval/modern ditch
15b	Brownish grey, slightly sticky clay with greyish sand lenses	Post-medieval/modern ditch
15c	Greenish grey (7,5 Y 5,5/2,5) clay with a blocky texture	Post-medieval/modern ditch
15d	Pale yellowish white, fine sand with local iron reduction horizon	Post-medieval/modern ditch

Profile LFZ 76/9 C-D



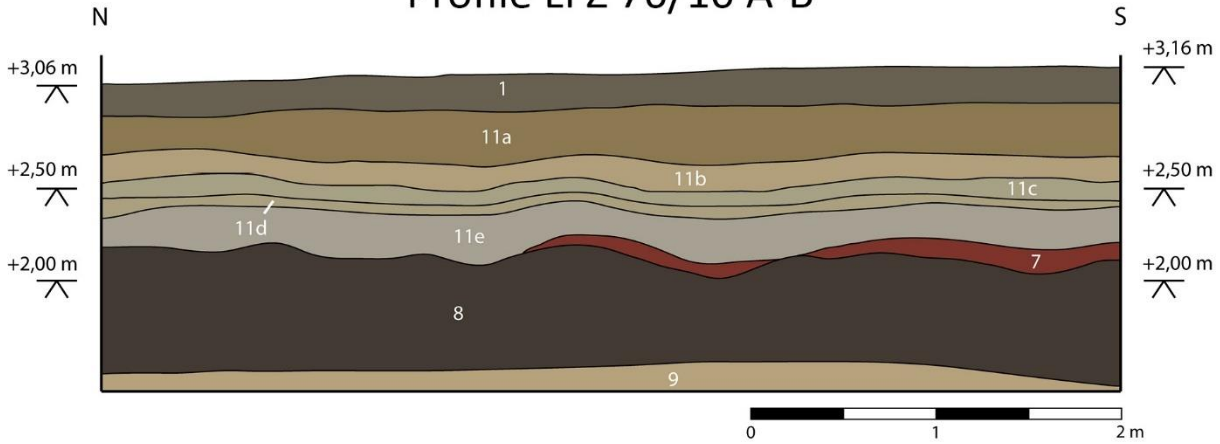
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
8	Dark greyish peat	
15a	Olive brown (5 Y 4/2,5), slightly sticky clay with a blocky texture	Post-medieval/modern ditch
15b	Brownish grey, slightly sticky clay with greyish sand lenses	Post-medieval/modern ditch

Profile LFZ 76/9 A-B



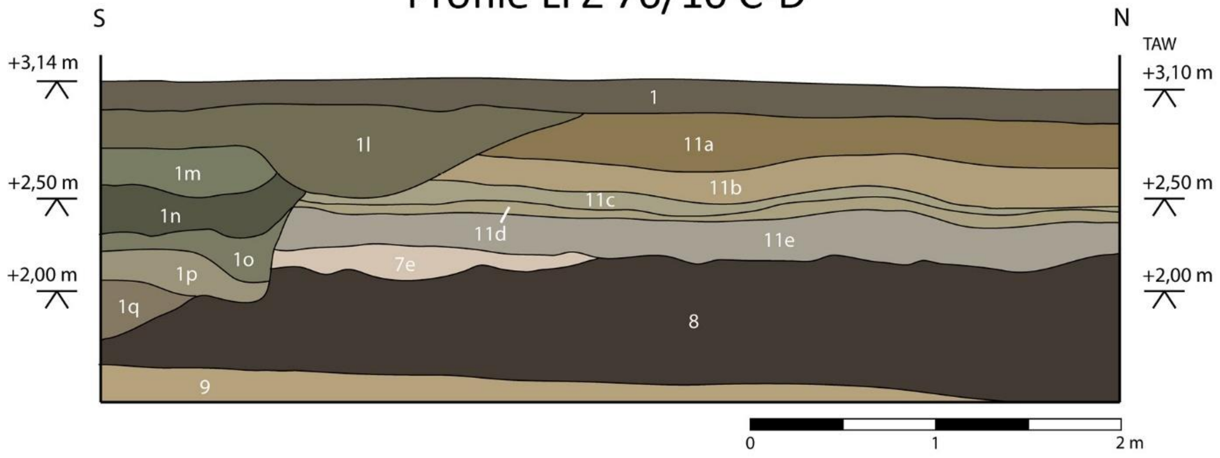
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
7e	Pale yellowish white, very sticky, slightly plastic ash layer with a very fine structure, a low humus content and sporadically briquetage fragments and 'zelas' chunks	Roman occupation layer
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
11b	Light yellowish brown (2,5 Y 6,5/3) well layered fine sand and clay lenses with a fine granular texture and sporadically ash fragments	Natural levee deposit

Profile LFZ 76/10 A-B



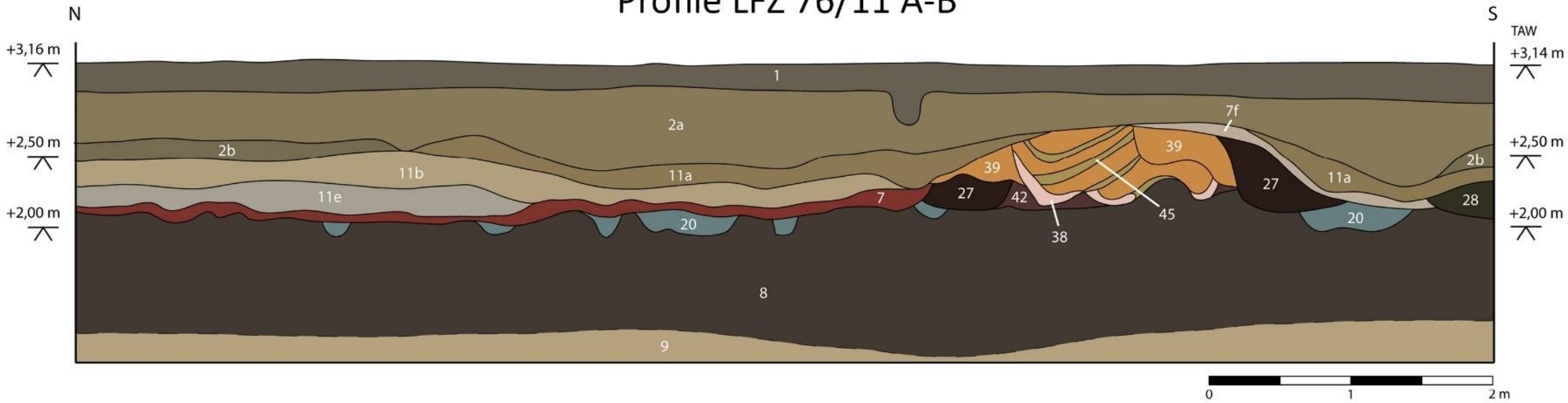
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
8	Dark greyish peat	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
11b	Light yellowish brown (2,5 Y 6,5/3) well layered fine sand and clay lenses with a fine granular texture and sporadically ash fragments	Natural levee deposit
11c	Light greenish grey (7,5 Y 6,5/2) clay with a fine granular texture and many lime concretions	Natural levee deposit
11d	Pale olive grey (5 Y 6,5/3), fine sand with very unclear clay lenses and a crumbled iron reduction horizon at the bottom	Natural levee deposit
11e	At the top: large light grey fine sand lenses with brown iron reduction horizons and small dark grey clay lenses. At the bottom: large dark grey clay lenses with brown iron reduction horizons and small light grey sand lenses	Natural levee deposit

Profile LFZ 76/10 C-D

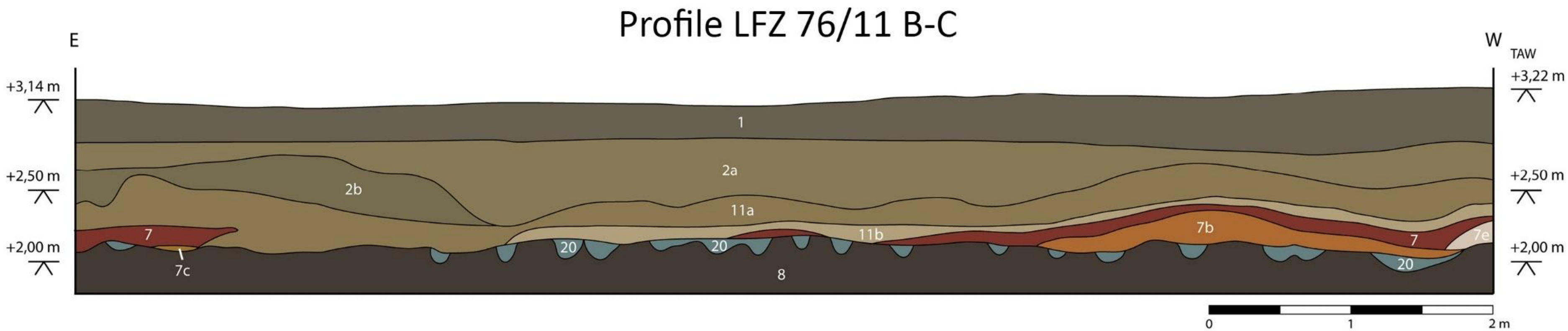


Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
1l	Olive grey (7,5 Y 4,5/2), non sticky clay with a blocky texture and few roots	Local modern disturbance
1m	Greenish grey (7,5 Y 4/2), slightly sticky clay with a blocky texture, lots of roots and many rust spots	Post-medieval/modern ditch
1n	Dark greenish grey (10 Y 3,5/1,2), slightly sticky sandy clay with a blocky texture, many lime concretions and many rust spots	Post-medieval/modern ditch
1o	Greenish grey, slightly sticky, slightly plastic sandy clay	Post-medieval/modern ditch
1p	Very light olive grey, sticky, plastic sandy clay with sporadically ash fragments	Post-medieval/modern ditch
1q	Light brownish grey sandy clay	Post-medieval/modern ditch
7e	Pale yellowish white, very sticky, slightly plastic ash layer with a very fine structure, a low humus content and sporadically briquetage fragments and 'zelas' chunks	Roman occupation layer
8	Dark greyish peat	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
11b	Light yellowish brown (2,5 Y 6,5/3) well layered fine sand and clay lenses with a fine granular texture and sporadically ash fragments	Natural levee deposit
11c	Light greenish grey (7,5 Y 6,5/2) clay with a fine granular texture and many lime concretions	Natural levee deposit
11d	Pale olive grey (5 Y 6,5/3), fine sand with very unclear clay lenses and a crumbled iron reduction horizon at the bottom	Natural levee deposit
11e	At the top: large light grey fine sand lenses with brown iron reduction horizons and small dark grey clay lenses. At the bottom: large dark grey clay lenses with brown iron reduction horizons and small light grey sand lenses	Natural levee deposit

Profile LFZ 76/11 A-B

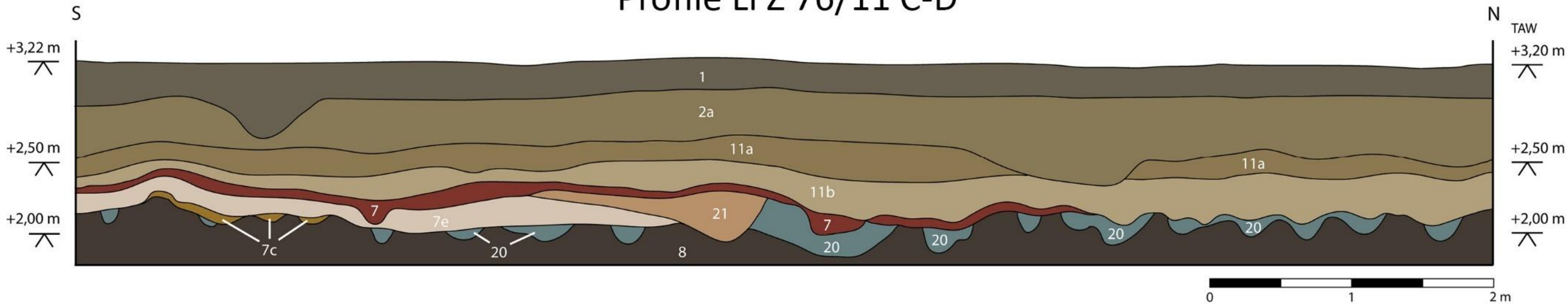


Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
7f	Yellowish white clayish ash layer with a fine texture and a high humus content	Roman occupation layer
8	Dark greyish peat	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
11b	Light yellowish brown (2,5 Y 6,5/3) well layered fine sand and clay lenses with a fine granular texture and sporadically ash fragments	Natural levee deposit
11e	At the top: large light grey fine sand lenses with brown iron reduction horizons and small dark grey clay lenses. At the bottom: large dark grey clay lenses with brown iron reduction horizons and small light grey sand lenses	Natural levee deposit
20	Greenish blue clay (mud)	
27	Dark brownish black, very plastic clay with lots of charcoal fragments, 'zelas' fragments etc.	Ash deposit belonging to the heating structures
28	Dark greenish black, very plastic clay with lots of charcoal fragments, 'zelas' fragments etc.	Disturbed ash deposit belonging to the heating structures
38	Inside: pinkish white; outside: purplish red; sandy clay (heated at high temperature)	Hearth lining
39	Highly dispersed, very hard and very compact material consisting of chunks of crumbled clay mixed with 'zelas' and ash fragments	Hearth filling
42	Dark reddish brown (7,5 YR 2,5/3) plastic clay	Raised clay bank
45	Greyish green sandy clay (heated at high temperature); smooth transition with hearth lining	Hearth bottom

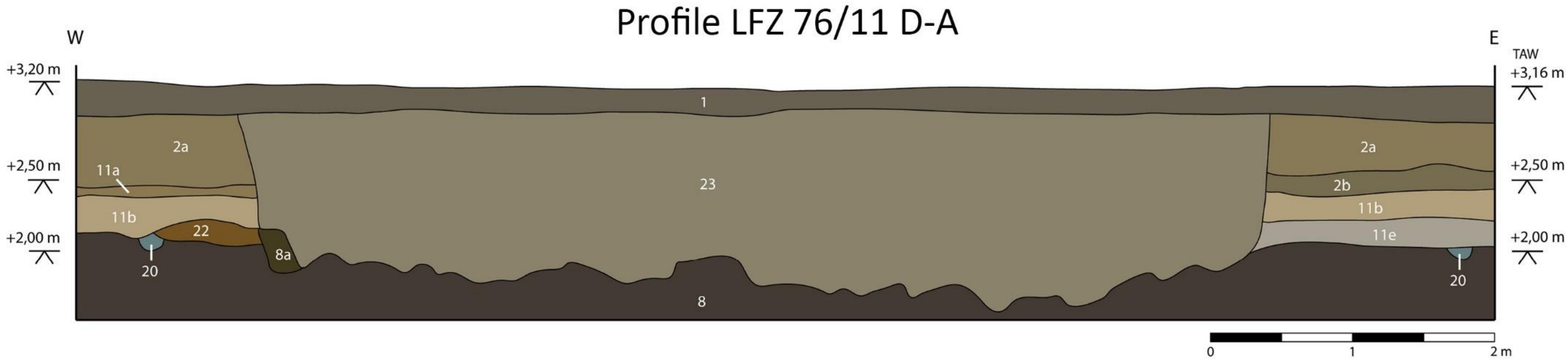


Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
7b	Clay with lots of 'zelas' fragments	Roman occupation layer
7c	Burned sand layer	Roman occupation layer
7e	Pale yellowish white, very sticky, slightly plastic ash layer with a very fine structure, a low humus content and sporadically briquetage fragments and 'zelas' chunks	Roman occupation layer
8	Dark greyish peat	
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
11b	Light yellowish brown (2,5 Y 6,5/3) well layered fine sand and clay lenses with a fine granular texture and sporadically ash frag- ments	Natural levee deposit
20	Greenish blue clay (mud)	

Profile LFZ 76/11 C-D

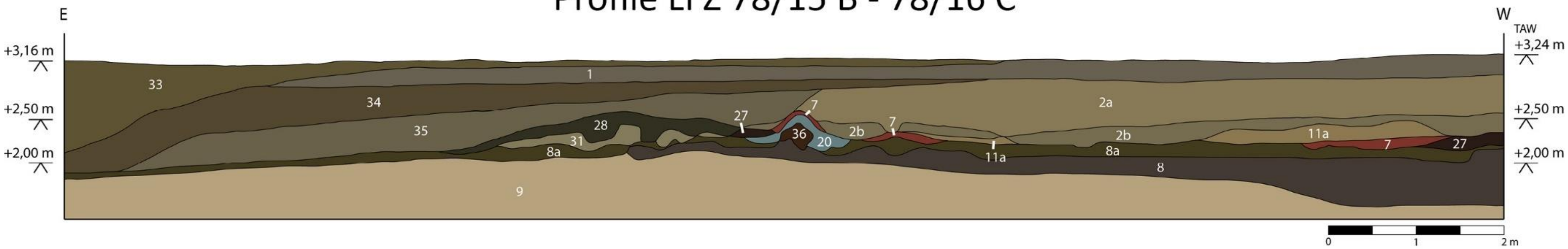


Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
7c	Burned sand layer	Roman occupation layer
7e	Pale yellowish white, very sticky, slightly plastic ash layer with a very fine structure, a low humus content and sporadically briquetage fragments and 'zelas' chunks	Roman occupation layer
8	Dark greyish peat	
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
11b	Light yellowish brown (2,5 Y 6,5/3) well layered fine sand and clay lenses with a fine granular texture and sporadically ash fragments	Natural levee deposit
20	Greenish blue clay (mud)	
21	Light orangey brown clay with ash fragments, 'zelas' chunks and briquetage material	Ditch (water management)



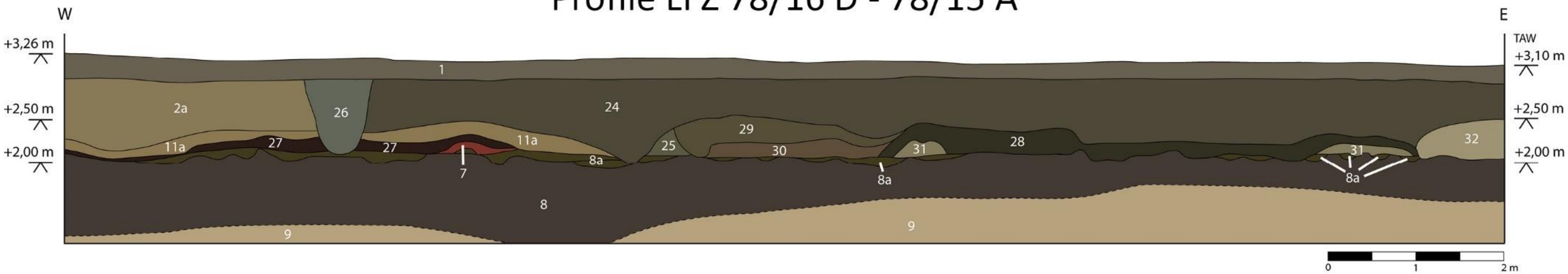
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
11b	Light yellowish brown (2,5 Y 6,5/3) well layered fine sand and clay lenses with a fine granular texture and sporadically ash fragments	Natural levee deposit
11e	At the top: large light grey fine sand lenses with brown iron reduction horizons and small dark grey clay lenses. At the bottom: large dark grey clay lenses with brown iron reduction horizons and small light grey sand lenses	Natural levee deposit
20	Greenish blue clay (mud)	
22	Brown clay with ash fragments and 'zelas' chunks	Ditch (water management)
23	Light greenish grey clay with a blocky texture and reworked 'zelas' fragments'. At the bottom spade marks and a small peat bank are discernible	Medieval peat extraction

Profile LFZ 78/15 B - 78/16 C



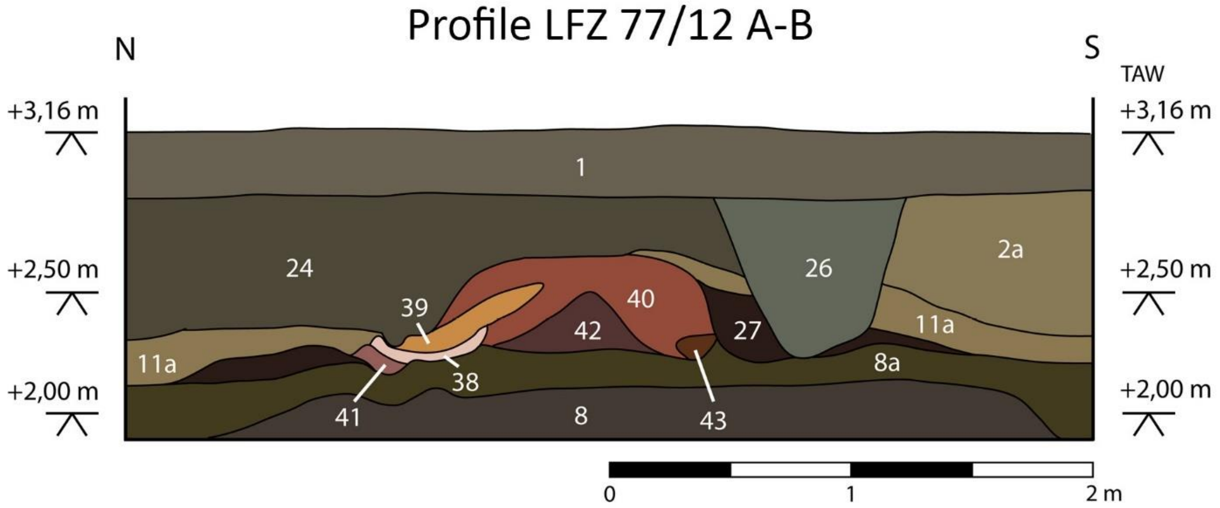
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b		
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
20	Greenish blue clay (mud)	
27	Dark brownish black, very plastic clay with lots of charcoal fragments, 'zelas' fragments etc.	Ash deposit belonging to the heating structures
28	Dark greenish black, very plastic clay with lots of charcoal fragments, 'zelas' fragments etc.	Disturbed ash belonging to the heating structures
31	Olive grey (5 Y 5/2,5), sticky, plastic clay with lots of rust spots	
33	Olive brown clay	Modern parcel ditch
34	Brown (2,5 Y 3/2), slightly plastic, non sticky clay with a blocky texture, a high humus content and lots of roots	Modern parcel ditch
35	Brownish grey (5 Y 4/2), slightly sticky ,slightly plastic clay with a blocky texture, a high humus content and lots of roots	Modern parcel ditch
36	Peat tree stump	

Profile LFZ 78/16 D - 78/15 A



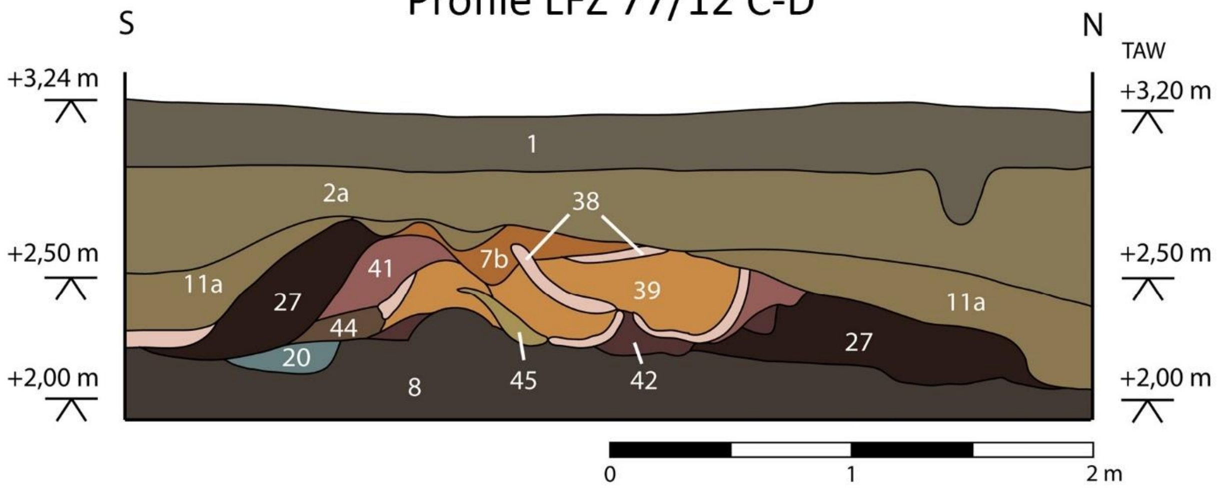
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
24	Grey (5 Y 5/1,5), slightly sticky clay with a blocky texture and lots of roots (disturbed)	
25	Olive grey, slightly sticky, very plastic clay with a high humus content, peat chunks and fine ash fragments (disturbed)	
26	Greyish green, plastic clay with fragments of 'zelas', hearth furniture etc.	Post-medieval/modern ditch
27	Dark brownish black, very plastic clay with lots of charcoal fragments, 'zelas' fragments etc.	Ash deposit belonging to the heating structures
28	Dark greenish black, very plastic clay with lots of charcoal fragments, 'zelas' fragments etc.	Disturbed ash belonging to the heating structures
29	Light greenish brown, slightly sticky clay with fine ash fragments, 'zelas' chunks and briquetage fragments	Post-medieval/ modern pit
30	Light brownish, slightly sticky clay mixed with peat and peat clay	Post-medieval/ modern pit
31	Olive grey (5 Y 5/2,5), sticky, plastic clay with lots of rust spots	
32	Light olive grey (5 Y 6/1), sticky clay with a granular texture, reworked peat and 'zelas' fragments and lots of rust spots. Local spots of very sandy clay discernible	

Profile LFZ 77/12 A-B



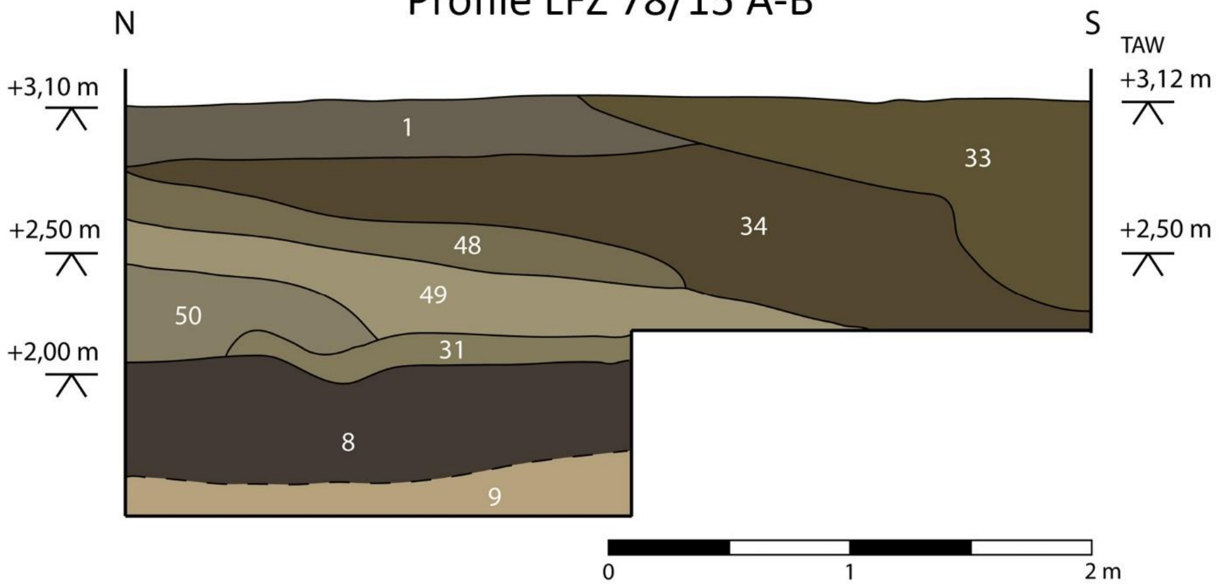
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
24	Grey (5 Y 5/1,5), slightly sticky clay with a blocky texture and lots of roots (disturbed)	
26	Greyish green, plastic clay with fragments of 'zelas', hearth furniture etc.	Post-medieval/ modern ditch
27	Dark brownish black, very plastic clay with lots of charcoal fragments, 'zelas' fragments etc.	Ash deposit belonging to the heating structures
38	Inside: pinkish white; outside: purplish red; sandy clay (heated at high temperature)	Hearth lining
39	Highly dispersed, very hard and very compact material consisting of chunks of crumbled clay mixed with 'zelas' and ash fragments	Hearth filling
40	Orangey red (10 R 4/7) plastic clay	Raised clay bank
41	Reddish brown (7,5 YR 4,5/5,5) plastic clay	Raised clay bank
42	Dark reddish brown (7,5 YR 2,5/3) plastic clay	Raised clay bank
43	Brown compact clay mixed with small 'zelas' chunks	Small ditch

Profile LFZ 77/12 C-D



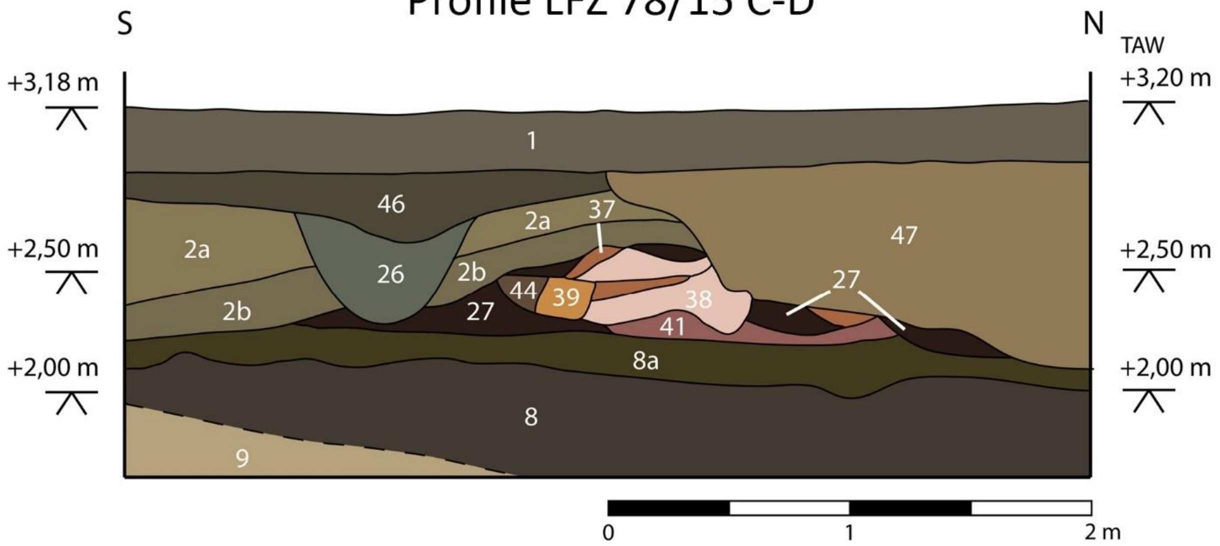
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
7b	Clay with lots of 'zelas' fragments	Roman occupation layer
8	Dark greyish peat	
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
20	Greenish blue clay (mud)	
27	Dark brownish black, very plastic clay with lots of charcoal fragments, 'zelas' fragments etc.	Ash deposit belonging to the heating structures
38	Inside: pinkish white; outside: purplish red; sandy clay (heated at high temperature)	Hearth lining
39	Highly dispersed, very hard and very compact material consisting of chunks of crumbled clay mixed with 'zelas' and ash fragments	Hearth filling
41	Reddish brown (7,5 YR 4,5/5,5) plastic clay	Raised clay bank
42	Dark reddish brown (7,5 YR 2,5/3) plastic clay	Raised clay bank
44	Brown sandy clay mixed with small 'zelas' chunks	Hearth flue
45	Greyish green sandy clay (heated at high temperature); smooth transition with hearth lining	Hearth bottom

Profile LFZ 78/15 A-B



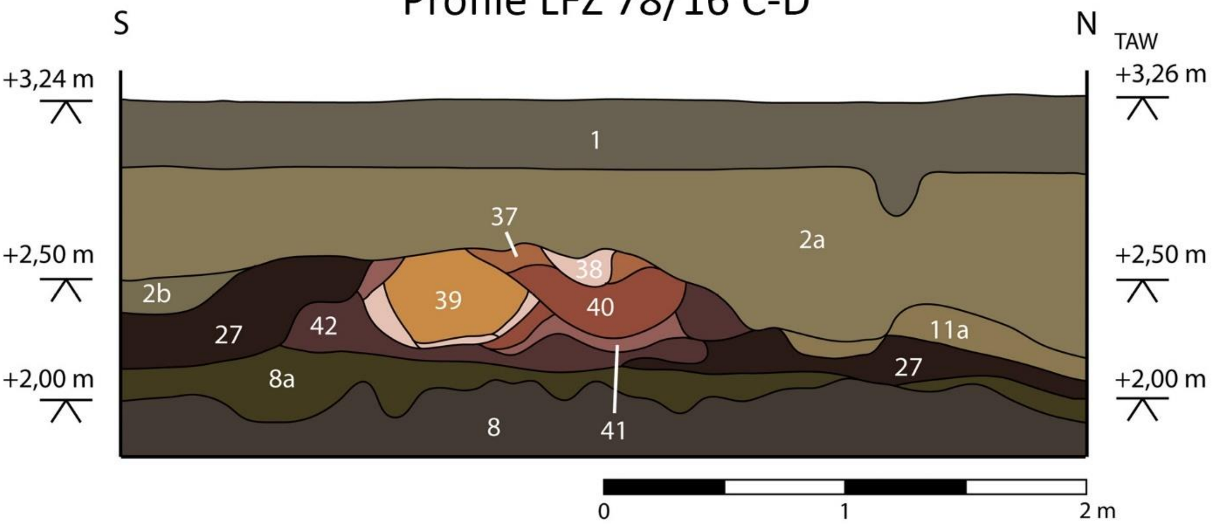
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
8	Dark greyish peat	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand
31	Olive grey (5 Y 5/2,5), sticky, plastic clay with lots of rust spots	
33	Olive brown clay	Modern parcel ditch
34	Brown (2,5 Y 3/2), slightly plastic, non sticky clay with a blocky texture, a high humus content and lots of roots	Modern parcel ditch
48	Olive grey (5 Y 5/2,5), non sticky, non plastic clay with a blocky texture, many rust spots and lots of roots	
49	Light greenish grey (5 Y 6/2), slightly sticky clay with a blocky texture and lots of roots	
50	Olive grey (5 Y 5,5/2,5), very sticky, slightly plastic clay mixed with reworked peat and 'zelas' fragments. Local spots of very sandy clay discernible	

Profile LFZ 78/15 C-D



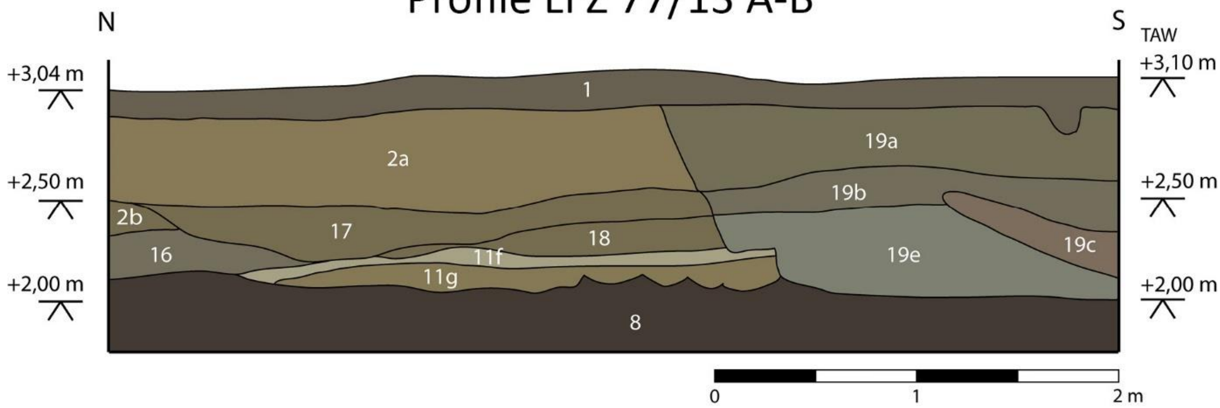
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand
26	Greyish green, plastic clay with fragments of 'zelas', hearth furniture etc.	Post-medieval/ modern ditch
27	Dark brownish black, very plastic clay with lots of charcoal fragments, 'zelas' fragments etc.	Ash deposit belonging to the heating structures
37	Orangey brown sandy clay with 'zelas', hearth lining and ash fragments	Raised clay bank
38	Inside: pinkish white; outside: purplish red; sandy clay (heated at high temperature)	Hearth lining
39	Highly dispersed, very hard and very compact material consisting of chunks of crumbled clay mixed with 'zelas' and ash fragments	Hearth filling
41	Reddish brown (7,5 YR 4,5/5,5) plastic clay	Raised clay bank
44	Brown sandy clay mixed with small 'zelas' chunks	Hearth flue
46	Dark grey (5 Y 3/1,5), slightly sticky clay with a blocky texture, medium humus content and lots of roots	Post-medieval/ modern ditch
47	Yellowish brown clay with a blocky texture	Post-medieval/ modern ditch

Profile LFZ 78/16 C-D

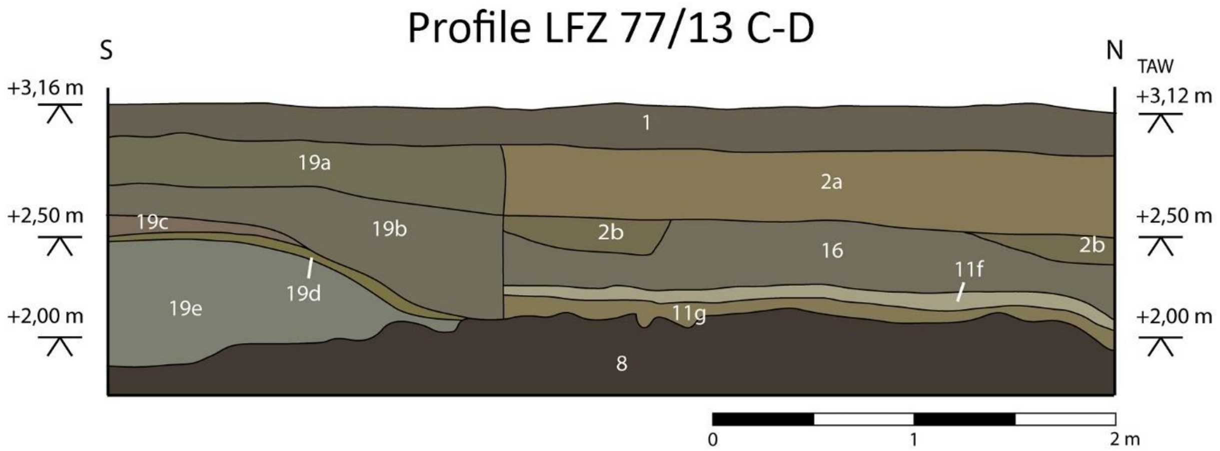


Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
11a	Light olive brown (2,5 Y 5/3,5) fine layers of sand and clay with a fine granular texture, very few roots and sporadically iron reduction horizons	Natural levee deposit
27	Dark brownish black, very plastic clay with lots of charcoal fragments, 'zelas' fragments etc.	Ash deposit belonging to the heating structures
37	Orangey brown sandy clay with 'zelas', hearth lining and ash fragments	Raised clay bank
38	Inside: pinkish white; outside: purplish red; sandy clay (heated at high temperature)	Hearth lining
39	Highly dispersed, very hard and very compact material consisting of chunks of crumbled clay mixed with 'zelas' and ash fragments	Hearth filling
40	Orangey red (10 R 4/7) plastic clay	Raised clay bank
41	Reddish brown (7,5 YR 4,5/5,5) plastic clay	Raised clay bank
42	Dark reddish brown (7,5 YR 2,5/3) plastic clay	Raised clay bank

Profile LFZ 77/13 A-B

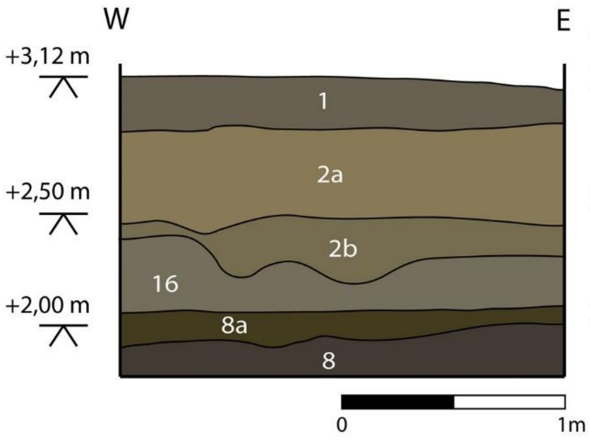


Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
8	Dark greyish brown peat with clear spade marks at the top of the layer	Traces of Roman peat extraction
11f	Light greenish grey, sticky sandy clay with brown iron reduction horizons, many rust spots and few roots	Natural levee deposit
11g	Olive grey (5 Y 4,5/2), sticky sandy clay with distinguishable sand lenses	Natural levee deposit
16	Light olive grey (5 Y 4,5/1), sticky sandy clay with multiple thin sand lenses and local rust spots	Natural levee deposit
17	Olive brown (5 Y 4,5/2,5), sticky clay with a blocky texture and few roots	Natural levee deposit
18	Olive brown (5 Y 4,5/2,5), very sticky sandy clay with few roots	Natural levee deposit
19a	Olive grey (7,5 Y 4,5/2) clay with a blocky texture, a high humus content and lots of roots	Post-medieval peat extraction?
19b	Light brownish grey, sticky clay with a blocky texture and few roots	Post-medieval peat extraction?
19c	Greyish brown, slightly sticky clay with many rust spots and many roots	Post-medieval peat extraction?
19e	Light bluish grey, slightly sticky, sandy clay with sporadic humus lenses and many rust spots	Post-medieval peat extraction?



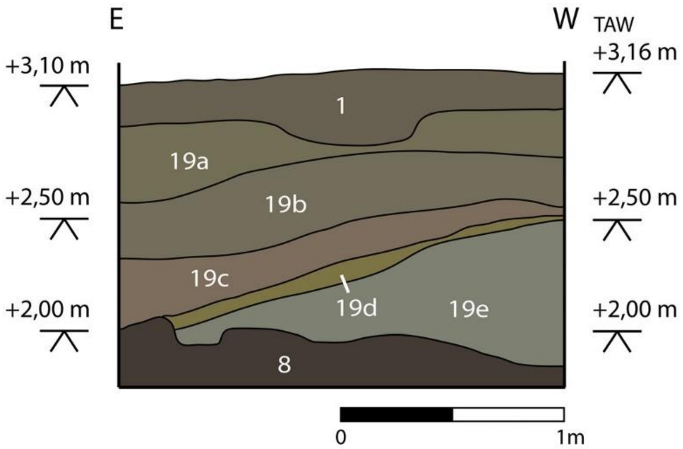
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
8	Dark greyish peat	
11f	Light greenish grey, sticky sandy clay with brown iron reduction horizons, many rust spots and few roots	Natural levee deposit
11g	Olive grey (5 Y 4,5/2), sticky sandy clay with distinguishable sand lenses	Natural levee deposit
16	Light olive grey (5 Y 4,5/1), sticky sandy clay with multiple thin sand lenses and local rust spots	Natural levee deposit
19a	Olive grey (7,5 Y 4,5/2) clay with a blocky texture, a high humus content and lots of roots	Post-medieval peat extraction?
19b	Light brownish grey, sticky clay with a blocky texture and few roots	Post-medieval peat extraction?
19c	Greyish brown, slightly sticky clay with many rust spots and many roots	Post-medieval peat extraction?
19d	Dark greenish brown, non sticky clay with humus lenses, reworked peat fragments and 'zelas' fragments	Post-medieval peat extraction?
19e	Light bluish grey, slightly sticky, sandy clay with sporadic humus lenses and many rust spots	Post-medieval peat extraction?

Profile LFZ 77/13 D-A



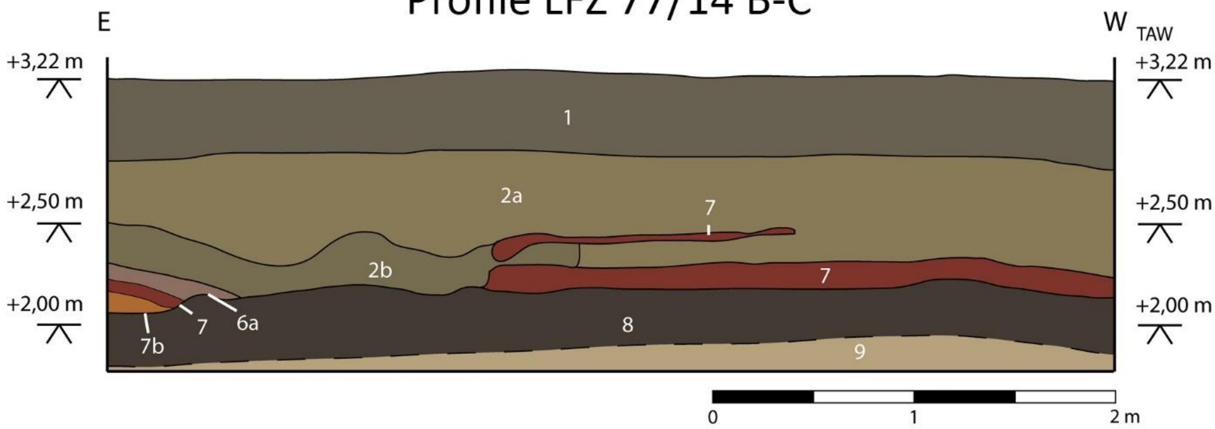
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
8	Dark greyish peat	
8a	Dark olive grey, slightly sticky peat clay with a fine texture and sporadically ash fragments	
16	Light olive grey (5 Y 4,5/1), sticky sandy clay with multiple thin sand lenses and local rust spots	Natural levee deposit

Profile LFZ 77/13 B-C



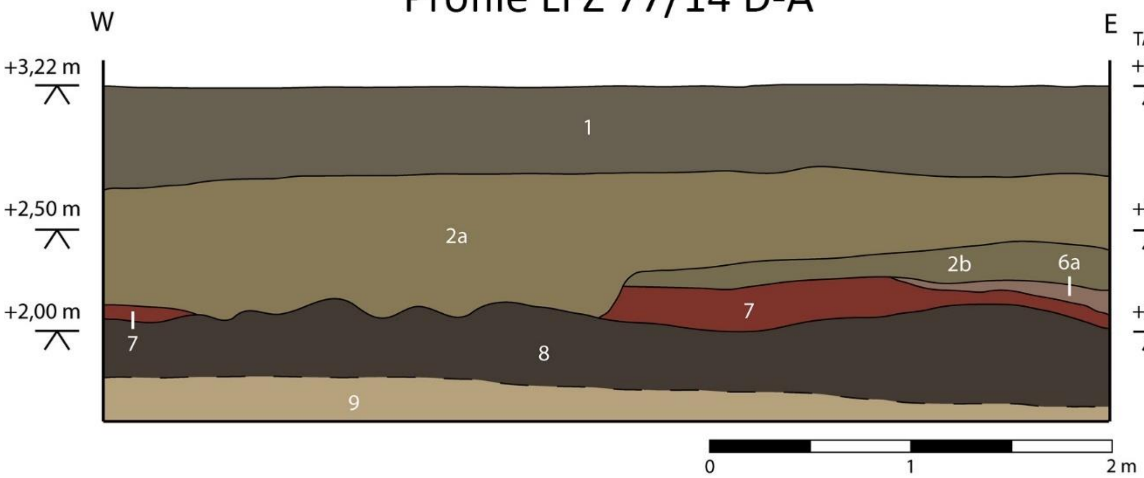
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
8	Dark greyish peat	
19a	Olive grey (7,5 Y 4,5/2) clay with a blocky texture, a high humus content and lots of roots	Post-medieval peat extraction
19b	Light brownish grey, sticky clay with a blocky texture and few roots	Post-medieval peat extraction
19c	Greyish brown, slightly sticky clay with many rust spots and many roots	Post-medieval peat extraction
19d	Dark greenish brown, non sticky clay with humus lenses, reworked peat fragments and 'zelas' fragments	Post-medieval peat extraction
19e	Light bluish grey, slightly sticky, sandy clay with sporadic humus lenses and many rust spots	Post-medieval peat extraction

Profile LFZ 77/14 B-C



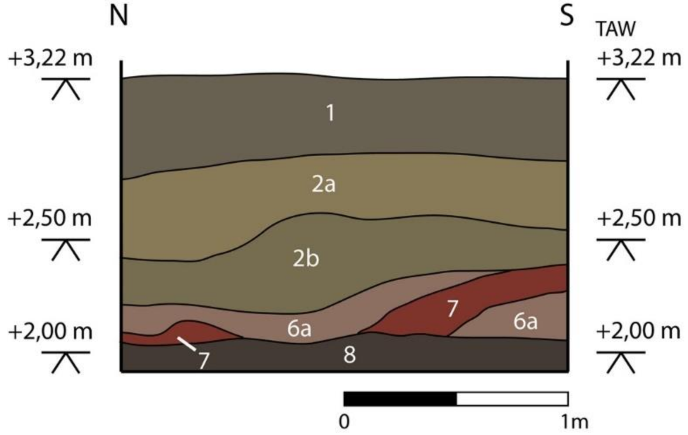
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
6a	Light reddish brown clay with a crumbly structure, many rust spots and peat and ash chunks	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
7b	Clay with lots of 'zelas' fragments	Roman occupation layer
8	Dark greyish peat	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand

Profile LFZ 77/14 D-A



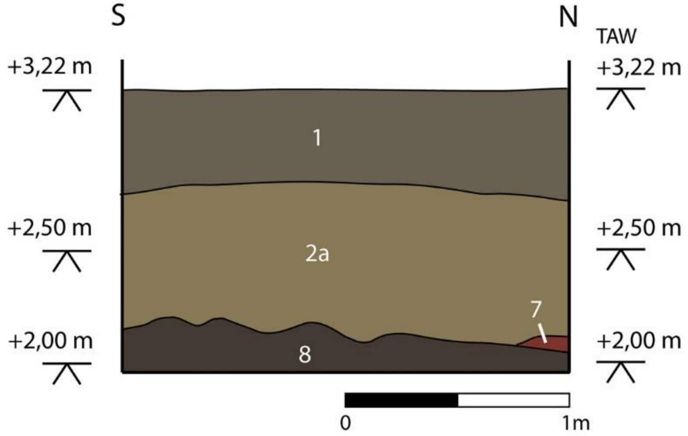
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
6a	Light reddish brown clay with a crumbly structure, many rust spots and peat and ash chunks	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
8	Dark greyish peat	
9	Light brownish yellow, slightly humus sand with a fine texture	Pleistocene sand

Profile LFZ 77/14 A-B



Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
2b	Dark olive grey (5 Y 4,5/2,5), sticky clay with a medium granular texture and few roots. Local phosphate enrichment, small lime concretions and rust spots discernible	
6a	Light reddish brown clay with a crumbly structure, many rust spots and peat and ash chunks	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
8	Dark greyish peat	

Profile LFZ 77/14 C-D



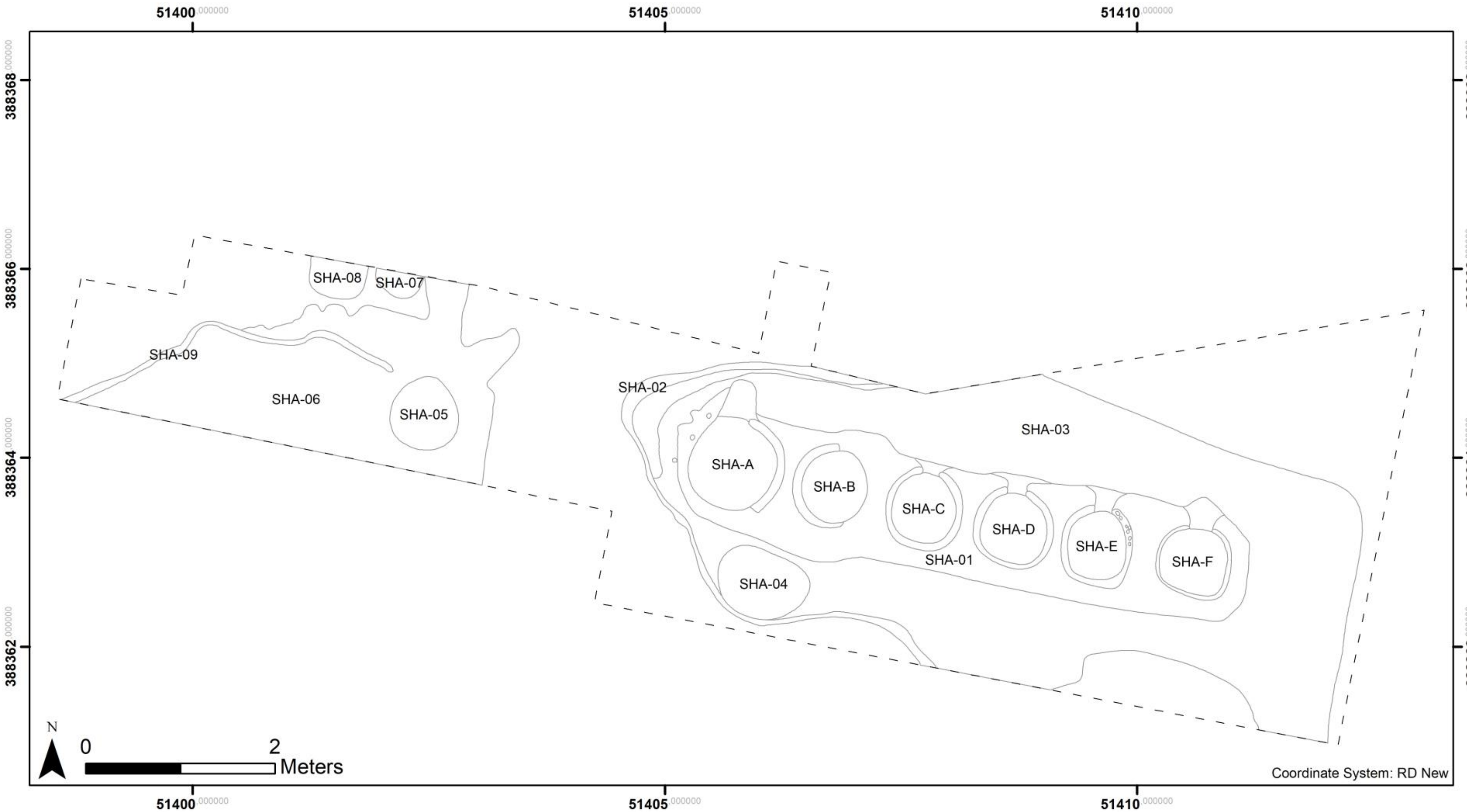
Layer	Description	Interpretation
1	Dark brownish grey (2,5 Y 4/1,5), slightly sticky clay with a granular texture, a high humus content and lots of roots	Plough soil
2a	Light olive brown (3,5 Y 5/2,5), slightly sticky, plastic clay with a coarse granular texture and roots are common	
7	Reddish brown, crumbly clay mixed with sand, peat chunks, 'zelas', briquetage and charcoal fragments	Roman occupation layer
8	Dark greyish peat	

‘s-Heer Abtskerke

Feature	Interpretation	Dating	Description
SHA-A	Hearth	ROM	Hearth A was one of six heating structures (the westernmost hearth) cut into a raised clay bank (SHA-01) and consisted of a circular structure with a north facing entrance connected to a small stoke-hole/flue. The recorded stoke-hole measured 0,4 m in length and 0,35 m in width. In its surviving form, the hearth itself had a diameter of 1 m and a maximum preserved height of 0,3 m. On the eastern side of the hearth some sort of hearth lining was recorded measuring 0,1 m in width. Both the north-south (section C-D) and east-west (section A-B) profile of the hearth were recorded. In these profiles, the hearth had a flat/light concave bottom and steep sides and a layered hearth filling (ash and clay?) which might suggest multiple firing sequences or repeated use.
SHA-B	Hearth	ROM	Hearth B was one of six heating structures cut into a raised clay bank (SHA-01). In its surviving form, the circular hearth had a diameter of 0,8 m and a maximum preserved height of 0,3 m. On the western side of the hearth some sort of hearth lining was recorded measuring 0,1 m in width. Both the north-south (section E-F) and east-west (section A-B) profile of the hearth were recorded. In these profiles, the hearth had a flat/light concave bottom and steep sides with fragments of green glazed slags. The profiles also show a layered hearth filling (ash and clay?) which might suggest multiple firing sequences or repeated use.
SHA-C	Hearth	ROM	Hearth C was one of six heating structures cut into a raised clay bank (SHA-01) and consisted of a circular structure with a north facing entrance connected to a small stoke-hole/flue. The recorded stoke-hole measured 0,1 m in length and 0,25 m in width. In its surviving form, the hearth itself had a diameter of 0,8 m and a maximum preserved height of 0,3 m. Some sort of hearth lining was recorded measuring 0,1 m in width and the north facing entrance was approximately 0,2 m across. The east-west (section A-B) profile of the hearth was recorded in which the hearth had a flat/light concave bottom and steep sides with fragments of green glazed slags. The profile also shows a layered hearth filling (ash and clay?) which suggest multiple firing sequences or repeated use.
SHA-D	Hearth	ROM	Hearth D was one of six heating structures cut into a raised clay bank (SHA-01) and consisted of a circular structure with a north facing entrance connected to a small stoke-hole/flue. The recorded stoke-hole measured 0,2 m in length and 0,2 m in width. In its surviving form, the hearth itself had a diameter of 0,8 m and a maximum preserved height of 0,3 m. Some sort of hearth lining was recorded measuring 0,1 m in width and the north facing entrance was approximately 0,2 m across. The east-west (section A-B) profile of the hearth was recorded in which the hearth had a

			flat/light concave bottom and steep sides with fragments of green glazed slags. The profile also shows a layered hearth filling (ash and clay?) which suggest multiple firing sequences or repeated use.
SHA-E	Hearth	ROM	Hearth E was one of six heating structures cut into a raised clay bank (SHA-01) and consisted of a circular structure with a north facing entrance connected to a small stoke-hole/flue. The recorded stoke-hole measured 0,25 m in length and 0,2 m in width. In its surviving form, the hearth itself had a diameter of 0,75 m and a maximum preserved height of 0,3 m. Some sort of hearth lining was recorded measuring 0,1 m in width and the north facing entrance was approximately 0,2 m across. In the hearth lining fragments of green glazed 'slags' were recorded. The east-west (section A-B) profile of the hearth was recorded in which the hearth had a flat/light concave bottom and steep sides with fragments of green glazed slags. The profile also shows a layered hearth filling (ash and clay?) which suggest multiple firing sequences or repeated use.
SHA-F	Hearth	ROM	Hearth E was one of six heating structures cut into a raised clay bank (SHA-01) and consisted of a circular structure with a north facing entrance connected to a small stoke-hole/flue. The recorded stoke-hole measured 0,35 m in length and 0,25 m in width. In its surviving form, the hearth itself had a diameter of 0,75 m and a maximum preserved height of 0,3 m. Some sort of hearth lining was recorded measuring 0,05 m in width and the north facing entrance was approximately 0,25 m across. The east-west (section A-B) profile of the hearth was recorded in which the hearth had a flat/light concave bottom and steep sides with fragments of green glazed slags. The profile also shows a layered hearth filling (ash and clay?) which suggest multiple firing sequences or repeated use.
SHA-01	Clay bank	ROM	Feature SHA-01 consisted of a sub-rectangular shaped clay bank with a northwest-southeast orientation. On first glance, the western end seems to be disconnected from the main clay bank by debris layer SHA-03. Even though this is not 100% clear in the plans and cross-sections, it is more likely that that debris layer SHA-03 laid on top of the clay bank forming one continuous feature. In this supposed form, the recorded clay bank measured 6,7 m in length, 1,3 m in width and approximately between 0,35 and 0,4 m in depth. This clay bank was artificially raised on top of the underlying peat and was used to create the heating structures
SHA-02	Clay	ROM	Feature SHA-02 is a 0,15 m wide clay band recorded on the western and southwestern of the clay bank and debris layer.
SHA-03	Debris layer	ROM	Layer SHA-03, amorphous in plan, was recorded in the eastern part of the excavation trench and surrounded the clay bank (SHA-01). It consisted of a 0,3-0,4 m thick deposit of whitish calcareous ash, charcoal fragments, green glazed slags and pottery fragments. In profile, this debris layer consists of a succession of multiple small layers which might

			represent episodes of cleaning out the heating structures or dumping episodes. However, the exact nature, consistency, colour etc of these small layers was not described in detail.
SHA-04	Unknown function	ROM	Feature SHA-04, semi-circular in plan, was recorded south of the clay bank (SHA-01) and hearth A and B (SHA-A and SHA-B). In its surviving form, the feature was 0,75 m long and 1 m wide. The plans contain no information about its depth or its filling, making an interpretation impossible
SHA-05	Unknown function	ROM	Circular shaped feature SHA-05 was situated to the west of the clay bank (SHA-01) with a diameter of 0,7 m. In profile (section A-B), this feature seems to be a bit larger with a width of 1,2 m and a depth of 0,2 m. The feature has a flat bottom, a gentle sloping sides and a layered fill. The exact nature of the different layers could not be determined on the plans and therefore its function remains unknown.
SHA-06	Debris layer	ROM	Layer SHA-03, amorphous in plan, was recorded in the western part of the excavation trench. It consisted of a 0,3-0,4 m thick deposit of whitish calcareous ash, charcoal fragments, green glazed slags and pottery fragments and might represents dumping episodes of production waste.
SHA-07	Refuse dump	ROM	Refuse dump SHA-07, semi-circular in plan, was situated in the north western part of the excavation trench and extended beyond the limit of excavation. In its surviving form, the feature was 0,25 m long and 0,5 m wide. The profile and depth were not recorded but the feature contained a large concentration of pottery fragments
SHA-08	Refuse dump	ROM	Refuse dump SHA-08, semi-circular in plan, was situated in the north western part of the excavation trench and extended beyond the limit of excavation. In its surviving form, the feature was 0,4 m long and 0,6 m wide. The profile and depth were not recorded but the feature contained a large concentration of pottery fragments
SHA-09	Ash concentration	ROM	Feature SHA-09, west of debris layer SHA-06, was a 0,1 m wide band of debris consisting of zelas, pottery, chalk, slags etc. However, compared to layer SHA-06, it contained a higher concentrations of whitish ash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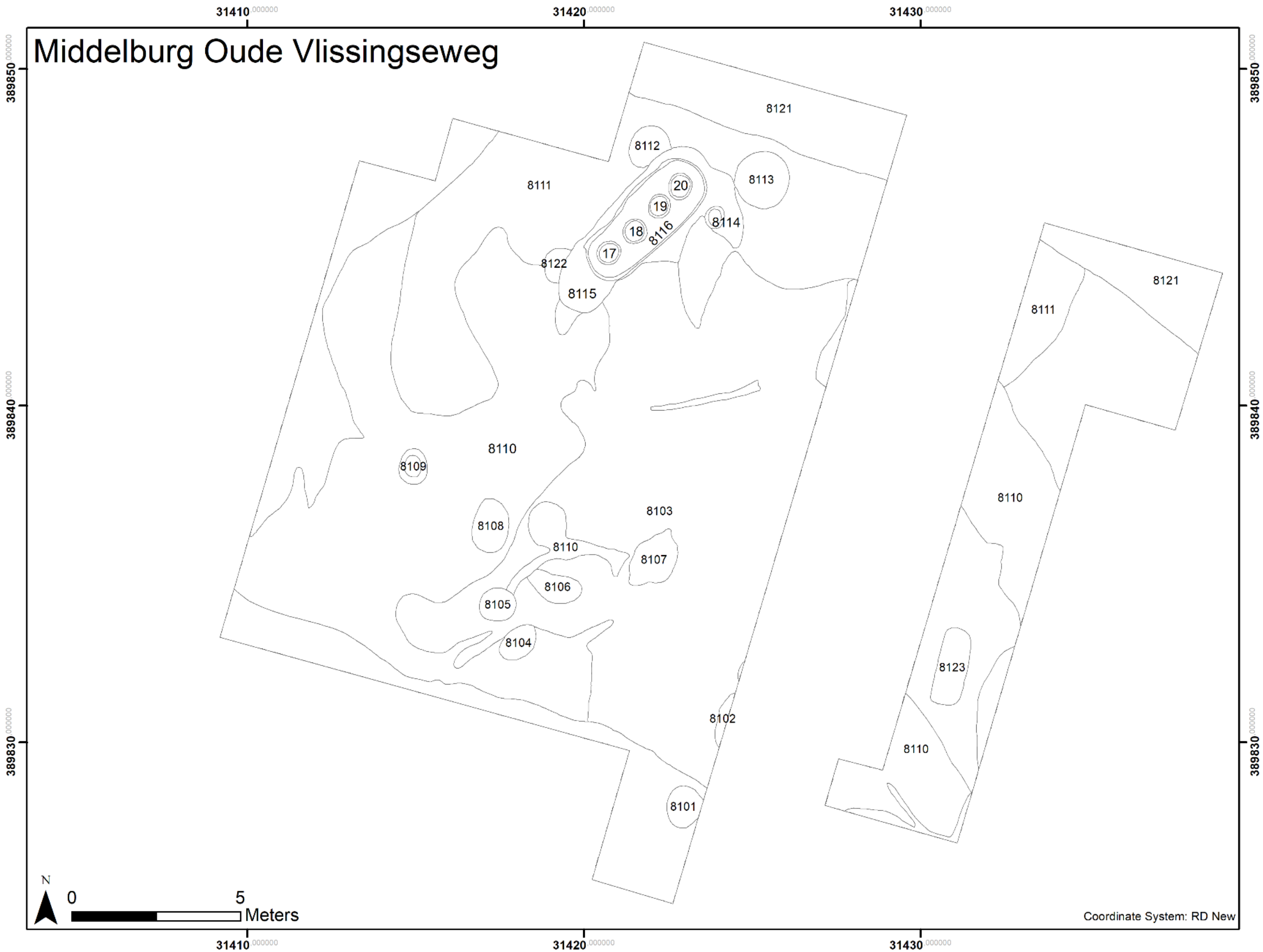
Middelburg Oude Vlissingseweg

Feature	Interpretation	Dating	Description
8101	Pit	MOD	Pit 8101, circular in plan, was situated in the southeast corner of excavation trench 1 and measured 1,25 m in length and 1 m in width. A small part of the profile was recorded in section A-B. This pit was one of 4 similar pits (8112, 8113 and 8122) spread out across the excavation and might have been some sort of robbing attempt. The features are cut immediately into the Roman layers after the topsoil and clay was removed. In the original drawings, these pits are described as pits dug by a third party while the excavation was in progress.
8102	Refuse dump	ROM	Semi-oval refuse dump 8102 was situated at the eastern limit of excavation trench 1 and the eastern end of the feature extended beyond the limit of excavation. It is surviving form, the feature was 1,6 m long, 0,30 m wide and 0,5 m deep with steep sides and a flat bottom. The exact nature of the fill or the recovered finds was not recorded.
8103	Debris layer	ROM	Debris layer 8103, amorphous in plan, covered the eastern half of trench 1 and extended beyond the limits of excavation. The same layer was also recorded in trench 2, east of trench 1. The layer comprised an 0,4-07 m thick deposit of whitish ash, 'chalk' slags, green glazed slags, charcoal and pottery fragments which was sealed by a post Roman clay deposit.
8104	Refuse dump	ROM	Refuse dump 8104, situated in the southern part of excavation trench 1, was oval in plan, measuring 1,15 m in length and 1 m in width. The feature's depth was not recorded. It consisted of a mixture of shells, primarily mussels and cockles.
8105	Refuse dump	ROM	Circular refuse dump 8105, situated north west of dump 8104, had a diameter of 1,05 m. The depth was not recorded but the fill primarily consisted of mussels and cockles shells.
8106	Refuse dump	ROM	Refuse dump 8106, amorphous in plan, measured approximately 1,6 m in length and 1,1 m in width. The exact depth was not recorded, but the feature primarily consists of a large concentration of mussels and cockles shells.
8107	Refuse dump	ROM	Refuse dump 8107, amorphous in plan, measured approximately 1,95 m in length and 1,2 m in width. The exact depth was not recorded, but the feature primarily consists of a large concentration of mussels and cockles shells.
8108	Refuse dump	ROM	Oval shaped refuse dump 8108, 1,6 m long and 1,1 m wide, was situated north of refuse dump 8105 and 8106. The exact depth was not recorded, but the feature primarily consists of a large concentration of mussels and cockles shells.

8109	Hearth?	ROM	Hearth 8109 was situated east of the clay bank (8116) and hearth battery (8117-8120). In its surviving form, the circular hearth had a diameter of 0,9 m including some sort of hearth lining approximately 0,15 m thick. No stoke-hole or flue was recorded. The hearth seems to be constructed on top of the working floor (8111) and is surrounded by debris layer 8110.
8110	Debris layer	ROM	Debris layer 8110, amorphous in plan, covered the western half of trench 1. The northern part of the debris layer lay on top of a clay working floor/surface (8111) while the southern part lay directly on top of the peat. The same layer was also found in trench 2, east of trench 1. The layer itself consists of a 0,2-0,5 m thick deposit of ash, charcoal, slags and pottery. Most likely, this layer is very similar to debris layer 8103, but contained less whitish ash and/or a higher concentration of charcoal.
8111	Working floor/surface	ROM	Layer 8111, amorphous in plan, covered the northern half of trench 1 and might have extended beyond the limits of excavation. The layer also extended southwards, but there the working floor was covered by debris layer 8110, 8103 and 8115. The layer consisted of a 0,2-0,3 m thick deposit of clay artificially placed on top of the peat forming a more stable work environment.
8112	Pit	MOD	Pit 8112, semi-circular in plan, was situated near the northern limit of excavation trench 1 and measured 1,3 m in length and 1 m in width. This pit was one of 4 similar pits (8101,8113 and 8122) spread out across the excavation and might have been some sort of robbing attempt. The features are cut immediately into the Roman layers after the topsoil and clay was removed. In the original drawings, these pits are described as pits dug by a third party while the excavation was in progress.
8113	Pit	MOD	Pit 8113, circular in plan, was situated near the northern limit of excavation trench 1 and had a diameter of 1,65 m This pit was one of 4 similar pits (8101, 8112 and 8122) spread out across the excavation and might have been some sort of robbing attempt. The features are cut immediately into the Roman layers after the topsoil and clay was removed. In the original drawings, these pits are described as pits dug by a third party while the excavation was in progress.
8114	Hearth?	ROM	Hearth 8114 was situated east of the clay bank (8116) and hearth battery (8117-8120). In its surviving form, the circular hearth had a diameter of 0,6 m including some sort of hearth lining approximately 0,1 m thick. No stoke-hole or flue was recorded. The hearth seems to be constructed on top of the working floor (8111) and is surrounded by debris layer 8115.
8115	Debris layer	ROM	Debris layer 8815, amorphous in plan, surrounds clay bank 8116 and the hearth battery (8117-8120) and lay on top of a clay working floor/surface (8111). The layer comprised a 0,3 m thick deposit of ash, charcoal and clay.

			Compared to debris layer 8103 and 8110, this layer was much darker due to the high concentration of charcoal or char.
8116	Clay bank	ROM	Feature 8816 consisted of a sub-rectangular shaped clay bank with a southwest-northeast orientation. In its surviving form, the feature measured 4,35 m in length, 1,75 m in width and ca. 0,7 m in depth. This clay bank was artificially constructed on top of the underlying peat and was most likely part of a larger working floor/surface (8111). In this clay bank, surrounded by debris layer 8115, 4 hearths were constructed.
8117	Hearth	ROM	Hearth 8117 was one of four circular heating structures (the southwestern most hearth) constructed into a clay bank (8116). Van den Berg interpreted this clay bank as one large fireplace of 6 by 2 m (actual measurements on the plans suggests a clay bank of approximately 4,35 by 1,75 m). However, the excavation drawings clearly depict 4 circular features that might be interpreted as separate heating structures. In its surviving form, the hearth itself had a diameter of 0,75 m including some sort of hearth lining approximately 0,1 m thick. No stoke-hole or flue was recorded with certainty, but some marks on the drawings might indicate the presence of a stoke-hole on the south-eastern side of the structures. Profile E-F was cut through the clay bank and the heating structures but, unfortunately, the hearths were not recognised or not recorded properly. The area was filled with a mixture of whitish ash, charcoal, slags and (burned) clay.
8118	Hearth	ROM	Hearth 8118 was one of four circular heating structures constructed into a clay bank (8116). Van den Berg interpreted this clay bank as one large fireplace of 6 by 2 m (actual measurements on the plans suggests a clay bank of approximately 4,35 by 1,75 m) However, the excavation drawings clearly depict 4 circular features that might be interpreted as separate heating structures. In its surviving form, the hearth itself had a diameter of 0,75 m including some sort of hearth lining approximately 0,1 m thick. No stoke-hole or flue was recorded with certainty, but some marks on the drawings might indicate the presence of a stoke-hole on the south-eastern side of the structures. Profile E-F was cut through the clay bank and the heating structures but, unfortunately, the hearths were not recognised or not recorded properly. The area was filled with a mixture of whitish ash, charcoal, slags and (burned) clay.
8119	Hearth	ROM	Hearth 8119 was one of four circular heating structures constructed into a clay bank (8116). In its surviving form, the hearth itself had a diameter of 0,75 m including some sort of hearth lining approximately 0,1 m thick. No stoke-hole or flue was recorded with certainty, but some marks on the drawings might indicate the presence of a stoke-hole on the south-eastern side of the structures. Profile E-F was cut through the clay bank and the heating

			structures but, unfortunately, the hearths were not recognised or not recorded properly. The area was filled with a mixture of whitish ash, charcoal, slags and (burned) clay.
8120	Hearth	ROM	Hearth 8120 was one of four circular heating structures (the north-eastern most hearth) constructed into a clay bank (8116). In its surviving form, the hearth itself had a diameter of 0,75 m including some sort of hearth lining approximately 0,1 m thick. No stoke-hole or flue was recorded with certainty, but some marks on the drawings might indicate the presence of a stoke-hole on the south-eastern side of the structures. Profile E-F was cut through the clay bank and the heating structures but, unfortunately, the hearths were not recognised or not recorded properly. The area was filled with a mixture of whitish ash, charcoal, slags and (burned) clay.
8121	Peat extraction pit?	POST-ME	Feature 8121 was situated at the north eastern end of the excavation and extended beyond the limit of excavation. The feature might be interpreted as a post medieval peat extraction pit or a more modern disturbance.
8122	Pit	MOD	Pit 8122, semi-circular in plan, was recorded west of debris layer 8815 and measured 1,6 m in length, 0,55 m in width and 0,5 m in depth. In profile (section C-D), the pit had almost vertical sides and did not cut the underlying peat. This pit was one of 4 similar pits (8101, 8112 and 8113) spread out across the excavation and might have been some sort of robbing attempt. The features are cut immediately into the Roman layers after the topsoil and clay was removed. In the original drawings, these pits are described as pits dug by a third party while the excavation was in progress.
8123	Refuse dump/water reservoir	ROM	Rectangular shaped refuse dump 8123 was situated in the eastern part of the excavation (excavation trench 2) and measured 2,3 m in length, 1 m in width. It comprised a deposit of very fine white ash with 'chalk remains' (whitish slags). The feature was partly cut in the underlying peat. The exact function is unknown and it might have been some sort of refuse pit.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Appendix 3: datasets chapter 8

This appendix refers to the supplementary information to chapter x. This contains the sample list and the raw data of the SEM-EDS measurements and the XRD results.

Chapter 8 has been integrally published in the Journal of Archaeological Science.

> Dekoninck, M., Goemaere, E., Dewaele, S., De Grave, J., Leduc, T., Vandenberghe, D., De Clercq, W. *Geochemical and mineralogical characterisation of vitrified waste material discovered in large quantities on Roman salt production sites along the southern North Sea coast*, Journal of Archaeological Science 146, 105665

The raw data has been published and can be consulted as appendix of the JAS article, see https://doi.org/10.1016/j.jas.2022.105665

English summary

Salt archaeology has become increasingly popular in the last decades, and researchers worldwide strive to understand how salt was extracted, distributed and consumed by past communities. This dissertation contributes to this still-expanding international field of research by studying the salt production process's technical and social organisation in a remote northern part of the Roman Empire: the *civitas Menapiorum* (part of the modern-day southern North Sea coast). From the nineteenth century onwards, epigraphic evidence led historians and archaeologists to assume a thriving salt trade in this area. Gradually, more archaeological data emerged in the coastal area pointing towards important salt production activities in the Menapian *civitas*. Yet, these Roman salt-making activities have only received fragmented attention.

This dissertation addresses this problem and, more specifically, focuses on two topics: (1) the technical reconstruction of the salt production activities and (2) the identification of the social actors involved in organising said activities. This was achieved by thoroughly assessing all salt production-related evidence discovered during prospections or excavations in the Menapian coastal plain.

By analysing the archaeological sites and the material culture found on them, it became apparent that the way salt was produced drastically changed in the study area towards the end of the second century CE. Two chronologically distinct phases (first – early second century and late second – early third century) exist in which the production process clearly differed by the technological choices made by the salt producers. These choices significantly impact but also reflect the socio-cultural and economic sphere in which the activities took place.

In the first phase (first – early second century CE), salt production boomed in the northern part of the *civitas Menapiorum,* and the production process was firmly rooted in the local Iron Age traditions. This phase is characterised by the use of briquetage material that gradually increased in size and the occurrence of isolated, individual hearths to evaporate the brine. At these sites, small-scale salt production was probably organised on a more 'domestic' level in which the entire (extended) family worked together to complete the variety of tasks necessary to produce salt. Other actors involved in the social organisation are the *salinatores*. Although the precise role of these *salinatores* is still controversial, we propose that they were 'tax farmers' specifically tasked to collect some of the produced salt in kind as part of the overarching *civitas* tax. Whatever their role, the *salinatores*-inscriptions also pointed towards an important relation between Menapian salt and the Roman military. This relationship was probably a major incentive to the local population to further develop the 'salt industry' in the area.

After the tumultuous political-economical mid-second century, the way salt was produced drastically changed in the Menapian *civitas*. In this second phase (late second – early third century CE), new sites appeared that are characterised by a hearth battery of multiple adjacent heating structures and a transition towards metal evaporation pans. These innovations required a

considerable investment but significantly enhanced the site's efficiency and productivity. This considerable upscale in salt production activities also signals a transition towards a more complex production system. Consequently, these new late second-century production sites might be considered a ‘workshop industry’ where skilled labourers worked together on a ‘full-time’ basis to produce salt. These innovations were implemented by private businessmen or *negotiatores* with the necessary capital to invest in salt production sites. Their incentive could have derived from a need to increase the local productivity to fulfil their contractual obligations with the Roman army. Yet, the introduction of this new way of producing salt did not lead to a breakdown of the briquetage technique. The old and the new production process coexisted well into the third century CE. However, this ‘golden age’ lasted not long, and the Menapian salt production collapsed by the end of the third century.

All in all, this dissertation contributed to our understanding of the technical and social organisation of the salt production process and showed that salt formed the motor of the Menapian coastal economy.

Keywords: salt; salt production; *chaîne opératoire*, briquetage, social organisation, technological change, salt merchants, archaeology, archaeometry, North Sea, coastal wetlands, civitas Menapiorum, Belgium, Zeeland, Northern Gaul, Roman

Nederlandstalige samenvatting

Onderzoekers wereldwijd hebben zich de laatste decennia toegelegd op het onderzoek naar de productie, distributie en consumptie van zout in het verleden. Ook deze doctoraatsstudie wil bijdragen aan dit continue groeiende onderzoeksveld. Hiertoe wordt de technische en sociale organisatie van het zoutproductieproces bestudeerd in een noordelijke uithoek van het Romeinse Rijk: de *civitas Menapiorum*. Archeologen en historici vermoedden al in de 19de eeuw op basis van epigrafisch bronnenmateriaal dat er in de Romeinse periode een bloeiende zouthandel aanwezig was in dit gebied, gelegen aan de huidige zuidelijke kust van de Noordzee. De daaropvolgende decennia werd meer en meer archeologische data in het kustgebied verzameld die eveneens wees op een belangrijke productieactiviteit. Tot nog toe kregen deze sporen van Romeinse zoutwinning echter weinig aandacht, en slechts weinig onderzoeken werden uitgewerkt of gepubliceerd.

Deze gefragmenteerde *status quaestonis* vormde het uitgangspunt van deze studie, waarin twee probleemstellingen centraal staan: (1) de technische reconstructie van het zoutproductieproces en (2) de identificatie van de sociale actoren betrokken bij de organisatie van de productie. Een gedetailleerde studie van alle sites (opgravingen en prospectievondsten) gerelateerd aan zoutproductie in de Menapische kustvlakte vormde de basis om deze onderzoeksvragen te beantwoorden.

Uitgebreide analyses van de archeologische sporen en de materiële cultuur tonen aan dat de manier waarop zout werd geproduceerd in het studiegebied drastisch veranderde op het einde van de tweede eeuw o.t. Het verschil in productieproces in deze twee fasen (eerste – vroege tweede eeuw en late tweede – vroege derde eeuw) is te verklaren door de technologische keuzes van de zoutproducenten. Deze keuzes hebben een effect op, maar weerspiegelen ook de sociaal-culturele en economische sfeer waarin de productieactiviteiten worden uitgevoerd.

In de eerste fase (eerste – begin tweede eeuw) nam de zoutproductie een hoge vlucht in het noordelijke deel van de *civitas Menapiorum* en was het productieproces nog stevig nog verankerd in de plaatselijke ijzertijdtradities. Deze fase wordt gekenmerkt door het gebruik van steeds groter wordende recipiënten en pijlers in briquetage aardewerk. Bovendien komen enkel individuele geïsoleerde haarden voor om de pekel te verdampen. Op deze sites was zoutproductie wellicht kleinschalig en georganiseerd op een 'huiselijk' niveau. De hele (uitgebreide) familie werkte samen om de verschillende taken in het productieproces uit te voeren. In deze fase zijn ook de *salinatores* als sociale actor betrokken bij de zoutproductie. Hoewel hun precieze rol nog ter discussie staat, suggereren wij dat ze 'belastinginners' waren die een deel van het geproduceerde zout in nature inden als onderdeel van de overkoepelende *civitas*-belasting. Wat hun functie ook was, de *salinatores*-inscripties wijzen ook op een belangrijke relatie tussen Menapisch zout en het Romeinse leger. Deze relatie was voor de plaatselijke bevolking wellicht een belangrijke stimulans om de 'zoutindustrie' in het gebied verder te ontwikkelen.

Na het tumultueuze politiek-economische midden van de tweede eeuw veranderde de manier waarop zout werd geproduceerd drastisch. In deze tweede fase (eind tweede – begin derde eeuw) verschenen nieuwe sites, gekenmerkt door een haardbatterij met meerdere naast elkaar liggende verhittingsstructuren en door een overgang naar het gebruik van metalen verdampingspannen. Deze innovaties vergden een forse investering, maar verhoogden de efficiëntie en de productiviteit van de sites aanzienlijk. Deze sterke schaalvergroting duidt ook op een omschakeling naar een complexer productiesysteem. Dit productiesysteem wordt omschreven als een '*workshop industry*' waarbij bekwame vaklui 'voltijds' werkten om zout te produceren. Hoogstwaarschijnlijk werden deze vernieuwingen doorgevoerd door particuliere ondernemers, ook wel *negotiatores* genoemd. Deze *negotiatores* bezaten het nodige kapitaal om te investeren in de zoutproductiesites. Hun belangrijkste drijfveer was wellicht het opvoeren van de plaatselijke productiviteit om hun contractuele verplichtingen met o.a. het Romeinse leger na te kunnen komen.

Toch leidde de introductie van deze nieuwe productiemethode niet tot het buiten gebruiken raken van de briquetagetechniek. Zowel de oude als de nieuwe productietechnieken bleven tot ver in de derde eeuw naast elkaar bestaan. Deze bloeiende industrie was echter geen lang leven beschoren en tegen het eind van de derde eeuw verdween de zoutproductie volledig in het studiegebied.

Samenvattend, dit onderzoek draagt bij aan ons begrip van de technische en sociale organisatie van het zoutproductieproces in de Menapische kustvlakte. Bovendien toont het aan dat zoutproductie en - handel een drijvende kracht was van de lokale kusteconomie.

Kernwoorden: zout, zoutproductie, *chaîne opératoire*, briquetage, sociale organisatie, technologische verandering, zouthandelaren, archeologie, archeometrie, Noordzee, kustlandschap, *civitas Menapiorum*, België, Zeeland, Noord-Gallië, Romeins