

Preliminary results of an archaeological survey of the land-sea transition at Doelpolder Noord (prov. of Antwerp, B)

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1. Research context

This paper will present the research context as well as the first results of the FWO funded research project entitled ‘An archaeological survey of the land-sea transition zone at Doelpolder Noord: impact of sea level rises on the palaeolandscape and human occupation from prehistory to the middle ages.’ The project is aimed at developing an archaeological evaluation strategy for the land-sea transition of the Scheldt estuary and its alluvial plain. In addition, the local chronology of the impact of sea level rise will be refined and its consequences on the human occupation history and preserved archaeology of the alluvial plain studied. The main research area is located between the village of Doel (Beveren) and the nearby border with the Netherlands. The land-sea transition is represented here by the Scheldt river estuary, the tidal mudflats, the salt marshes of the ‘Paardenschor’ and ‘Schor van Ouden Doel’ and nature reserve of Doelpolder Noord (Fig. 1).

During the late Pleistocene, the sand-ridge Maldegem-Stekene in north-western Flanders was formed with branches oriented SW-NE, extending across the current trajectory of the Scheldt into the Pleistocene cover sands of Holland. After its formation, this undulating sand ridge landscape was concealed by early Holocene alder carr peat (bassiveen), organic old sea clay (oude zeeklei/Calais klei), mid Holocene oligotrophic peat (Hollandveen) and (Post-)Medieval marine sands and alluvial clays due to increased fluvial and marine influences (Deforce, 2011; Vos & Van Heeringen, 1997).



Fig. 1 - Location of Doelpolder Noord (1), Paardenschor and Schor van Ouden Doel (2) and Scheldt river (3).

During harbour construction works, it was discovered that the microtopography of this pleistocene landscape and its associated archaeological sites were well-preserved in the Scheldt Polders. Salvage excavations have shown that the tops and flanks of micro-sand ridges within this undulating landscape contained numerous archaeological sites ranging from Final Paleolithic to Early Neolithic times (Crombé, 2005). From the Middle Neolithic until the Early Middle Ages, the area was a large peat marsh but hardly any archaeological information has been recorded for this area. However, as proven in the archaeological records from the Netherlands, this peat marsh must have been inhabited from the Roman period onwards (De Clercq, 2009; De Clercq & Van Dierendonck, 2008). The occupation during the Later Middle Ages must have been situated on top of this peat landscape, well-after the peat growth had stopped. From historic documents, it is known that dikes were erected as early as the 13th century, creating the Doelpolder (Klinck *et al.*, 2007). Other parts of the polder were regained from marine influences in the 18th and 19th century. Depending on the time of this embankment, traces of this occupation can still be seen on historic maps or the current digital elevation model (Fig. 2).

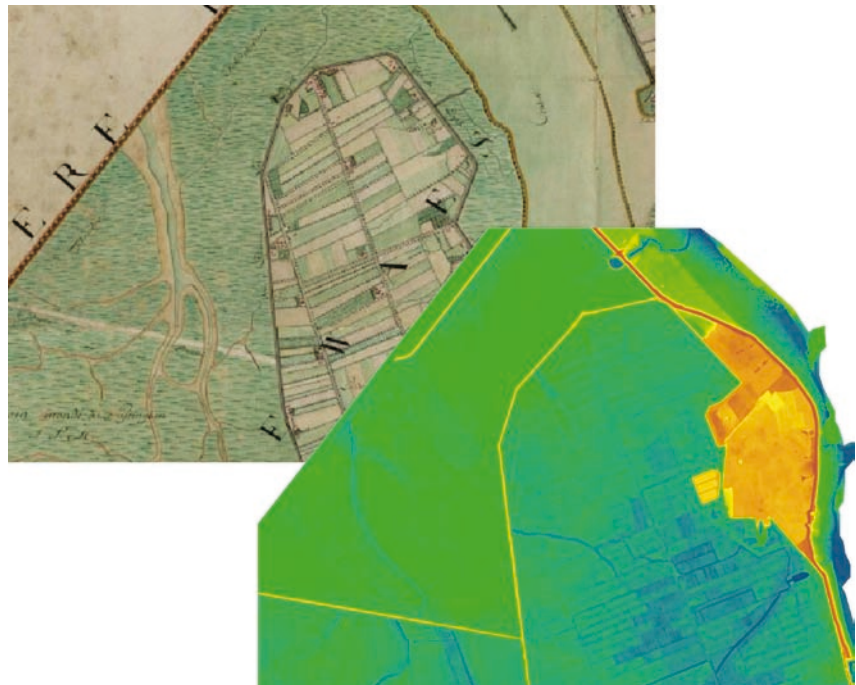


Fig. 2 - Doelpolder Noord on the Ferraris map (1770-1777 AD) and the current digital elevation model (AGIV).

The terrestrial study will focus on a 90 m wide transect through the nature reserve of Doelpolder Noord, which has been evaluated in context of nature compensation works by Archeologische Dienst Waasland (ADW) (Klinck *et al.*, 2007). The transect contains a micro sandridge buried about 2 m deep, flanking a 8 to 9 m deep depression in the Pleistocene sands but mostly consisting of an averagely undulating topography buried 5 to 6 m deep (Fig. 3).

2. Methodology

The evaluation process of the Scheldt Polder landscape for prehistoric sites starts generally with a reconstruction of the Pleistocene topography to guide further archaeological evaluation. First, the currently preserved geological strata are registered trough a palaeo-landscape hand-augering survey in a 30 to 50 m staggered grid, using a 7 cm Dutch auger or 2 to 3 cm gauge auger. These data are used to reconstruct the paleotopography and landscape development, in order to define possible areas where preserved archaeological

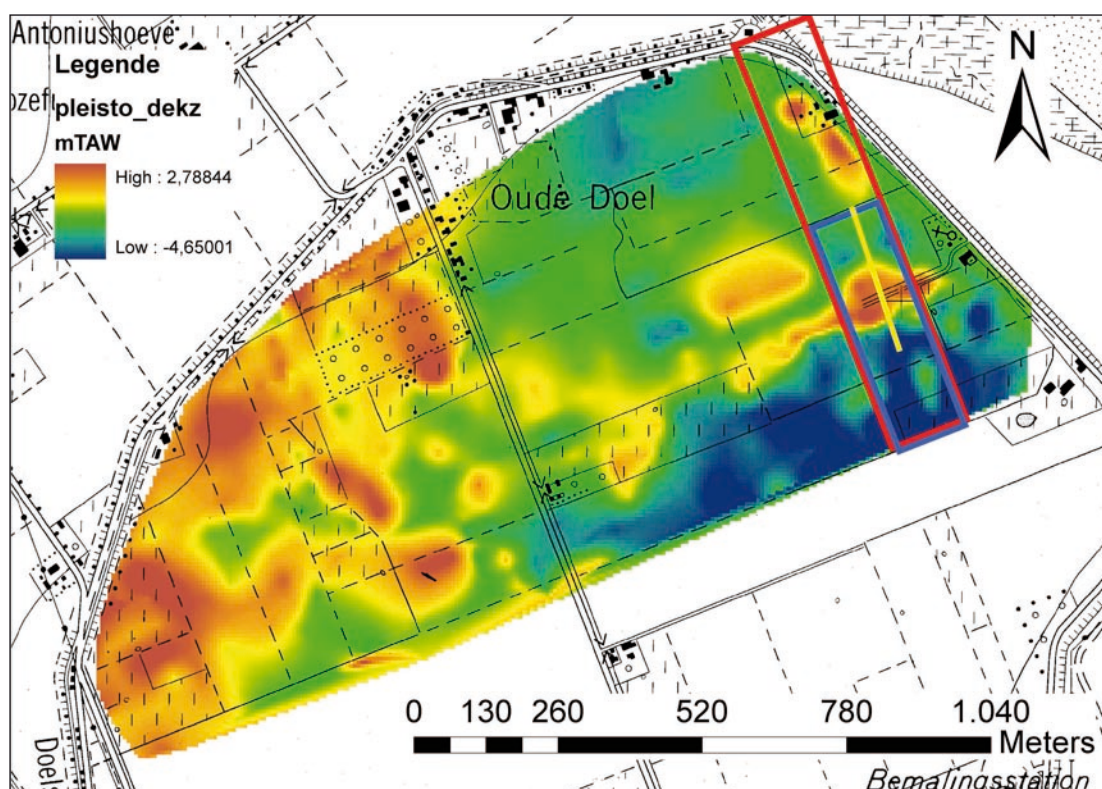


Fig. 3 - Pleistocene paleotopography inferred from handaugering by ADW and annotation of the survey area covered by GEM and ERI (Red); EM31 and 34 (Blue) and Land Seismics (Yellow).

sites can be expected. In a subsequent phase, these soil strata possibly containing flint scatters are sampled using a 10 to 12 cm Dutch auger, depending on the nature and depth of the target and ground water table, in a 10 m staggered grid. The samples are sieved using a 1 mm mesh and checked for archaeological indicators. These data do not allow an archaeological evaluation and if indicators are found, the previous grid is densified to 5 m (De Clercq *et al.* 2011). It is however practically impossible to collect samples manually at great depth. Furthermore, this strategy is slow, not ergonomically sustainable and requires a lot of manpower, while not all recorded information is necessary for reconstructing the palaeotopography. The interpolation between auger points does not allow an accurate delineation of geomorphological features, possibly containing archaeological sites, so the archaeological sampling strategy is challenging and prone to over or under sampling errors.

No evaluation strategy has yet been proposed for proto- and early historic sites, probably located on the peat surface. Depending on the age of the Polder, later (post-) Medieval sites can be detected using the evaluation procedure for uncovered landscape as they are located closer to the surface. As near surface geophysical survey techniques allow the collection of large numbers of data points at greater survey speed, it was assumed that their inclusion in the Scheldt Polder palaeolandscape evaluation would facilitate the process and allow a more detailed evaluation of deeply buried landscapes. Nevertheless, validation through augering would still be necessary.

Geophysical methods are hampered however by the clay-rich top-soil and therefore exclude Ground Penetrating Radar, which is well suited to map palaeolandscape topography on more sandy soils (Chapman *et al.*, 2009). In addition, the complex stratigraphy impedes robust geophysical modeling and Post-Medieval to recent use of the landscape could hide underlying features.

The terrestrial geophysical methods used include electromagnetic induction (EMI), electrical resistance imaging (ERI) and land seismics (Fig. 3). Marine seismic survey was performed on the Scheldt river, intertidal area and inland creeks. The electrical conductivity measured by (EMI) can be related to texture, moisture and electrolyte (salt-) content variations of the measured soil volume (Simpson, 2009). A hand-carried geophex GEM-2 sensor (www.geophex.com) was used in horizontal coplanar coil orientation to collect continuous data on lines more or less 2.5 m apart. Measurement positions were tracked using a handheld GPS. The peak of its exploration depth is 1.5 m but by varying the frequency of the induced electromagnetic field, the sensor is theoretically sensitive to greater depth extends. Electrical resistance imaging data (ERI) (Samouëlian et al. 2005) were collected using an AGI Supersting R8 in an inverse Schlumberger configuration. Measurements were collected along lines located 10m apart and along the sections, electrodes were positioned 2 m apart. The resulting data were processed using Earthimager 2D software.

A less mobile geonics EM31 sensor was used both in horizontal coplanar (HCP) and vertical coplanar coil orientation (VCP) with a respective exploration depth of 3 or 6 m. The geonics EM34 is not mobile and requires two operators but has a greater depth of exploration reaching to 7.5 m in vertical coplanar mode at 10 m coil separation. EM31 data were collected every 2.5 m along lines 5m apart. EM34 data were collected every 5 m along lines 10 m apart. These data were gathered using measuring tapes in a grid tied to reference points located by RTK-GPS. The EM31 and EM34 data are so far only available for the southern half of the study area but it is planned to be expanded further north (McNeil, 1980).

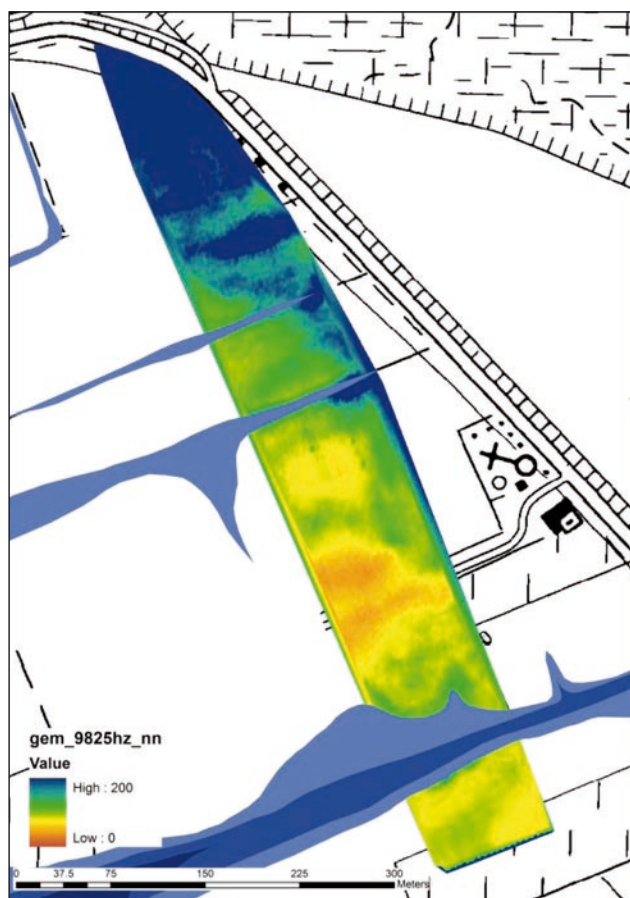


Fig. 4 - GEM conductivity data (mS/m) at 9825Hz induced electromagnetic field.

In general terms, seismic survey is performed measuring the time between the transmission of a seismic wave into the soil or water and the reception of its reflections caused on interfaces of differing acoustic impedance. The first trials with land seismic measurements were carried out using S-waves as these tend to give detailed information in the upper meters of the subbottom. A portable S-wave vibrator source was used with a sweep frequency from 10 to 240 Hz. The geophones, set 1 m apart, were contained in a flexible cable that was dragged over the field. In one day a section of 250 m was collected. The marine seismic measurements were collected using a parametric echosounder (main frequency 8-14 kHz).

The geophysical data will be verified by various augering techniques and electrical cone penetration tests (CPT), measuring tip resistance and sleeve friction of a cone when forced into the ground (Thooft 2007). These can both serve as a calibration and interpretation tool or a survey method on their own if geophysical techniques do not allow the detection of the palaeolandscape.

In order to verify the presence of archaeological sites, the sandridge will be sampled both manually and mechanically with varying sampling diameters.

3. Results of the 2011 fieldwork

The first results indicate that the EMI data allow a detailed delineation of Pleistocene micro-sandridge, archaeologically the most relevant feature, as a low conductivity anomaly. Particularly the GEM data (Fig. 4) reveal a lot of detail showing even a small increase of conductivity centrally trough the top of the micro-sandridge correlating to a small depression. This ridge is surrounded by a band of higher conductivity values, indicating the presence of conductive peat on the flanks of the ridge in the measured soil volume. More to the north, the GEM data also mapped a possible gully with crevasse deposits, which was not mapped in the augering data. The depression in the Pleistocene sands could not be distinguished from the average depths either because the larger volume of peat in the depression was counterbalanced by the larger volume less conductive sandy sediments on top of it or because the conductive sediments filling the depression were not measured within the sensor range at all. It has to be mentioned that the EM31 in VCP has a worse resolution, because the instrument had to be carried 1m from surface, eliminating an important share of the response.

The ERI was less successful at mapping the sandridge (Fig. 5). Above ground water it was detected as a high resistance feature but below ground water no contrast was present. The groundwater table is too conductive to allow currents to travel trough the Pleistocene sands. Due to the object oriented nature of ERI, superficial modern disturbances prohibit detection of deeper features as well.

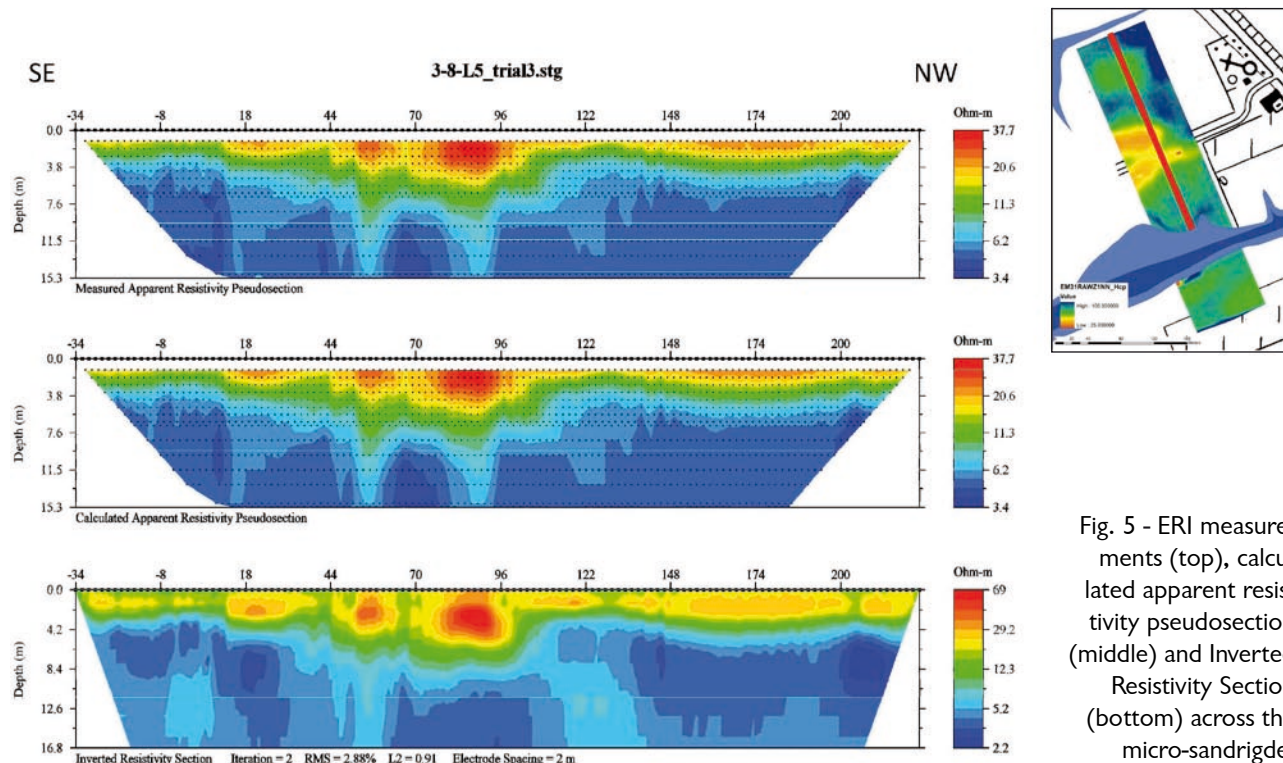


Fig. 5 - ERI measurements (top), calculated apparent resistivity pseudosection (middle) and Inverted Resistivity Section (bottom) across the micro-sandridge.

The first tests with terrestrial shear wave reflection profiling clearly show the top-Pleistocene topography (Fig. 6). However, this method is very slow and can hardly be called cost-effective. Due to the abundant presence of (biogenic) gas in the peaty sediments, the marine seismic data quality was often very poor with a limited seismic penetration (less than 1 m). The seismic profiles in the extreme south-eastern corner and in the intertidal area to the north show the best penetration (Fig. 7). Here, a number of shallow reflectors and ancient tidal gullies can be clearly observed as the latter have eroded the peat layers.

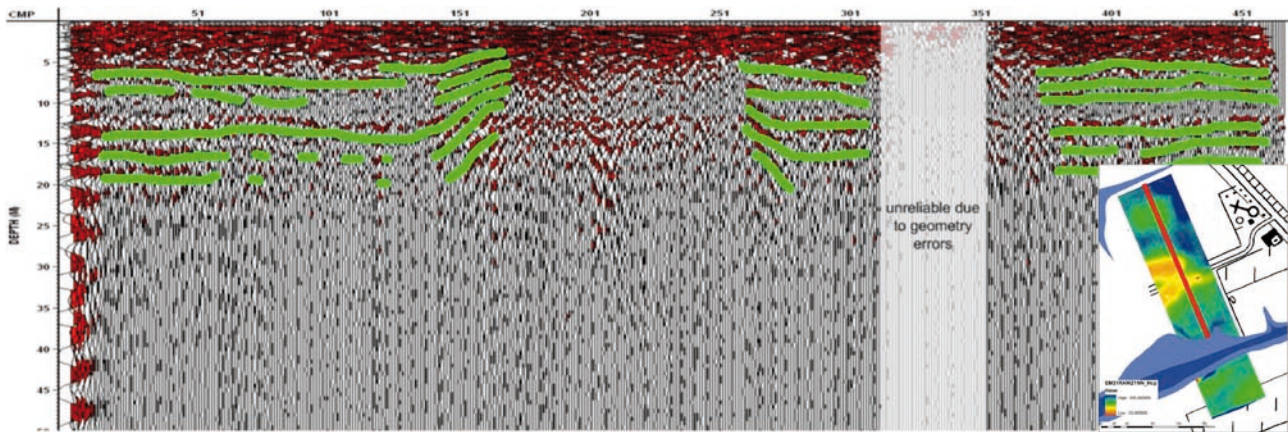
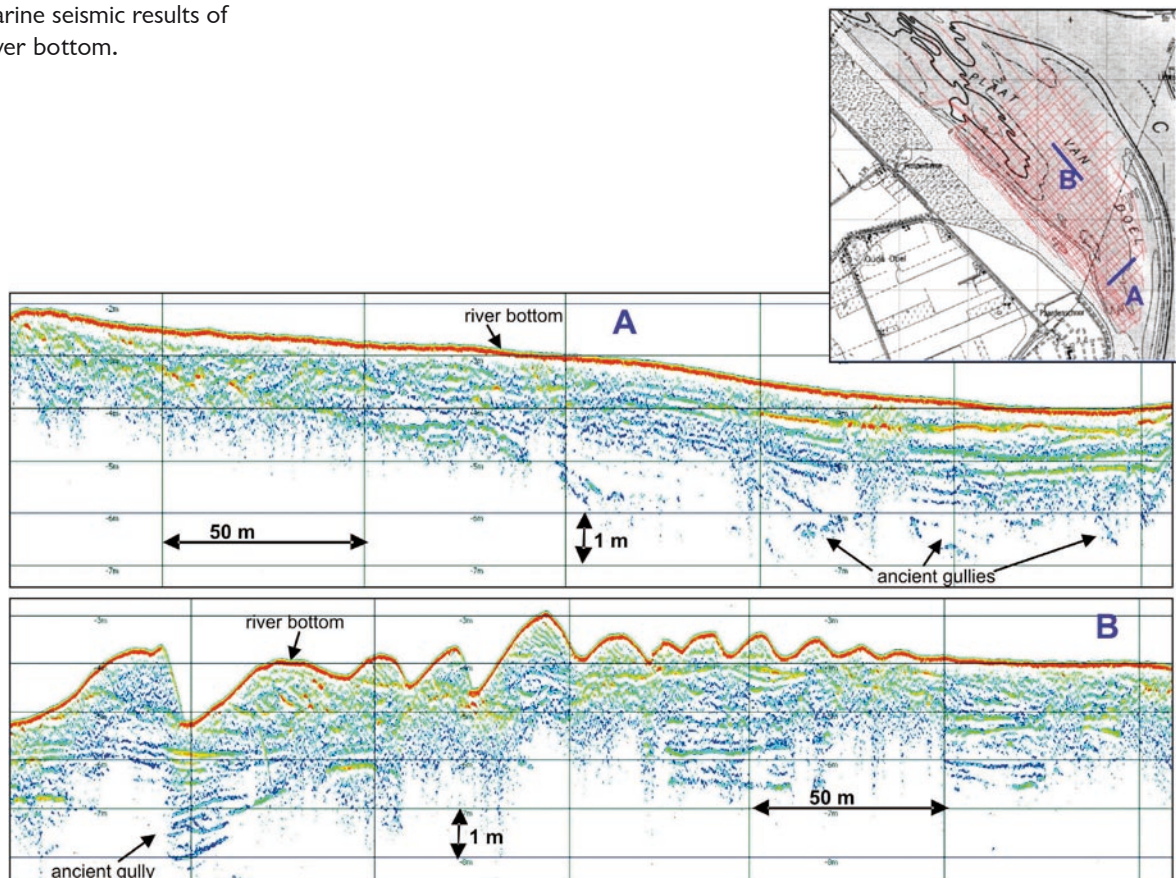


Fig. 6 - Land seismic results of a section across the micro-sandridge.

A series of 40 cone penetration test was collected by SGS-Lippens Geotechniek (Fig. 8). It was found that the peat has a much smaller tip resistance than the under- and overlying sands, thus allowing a straightforward manual classification. The old sea clay deposits in the depression could also be inferred from the data. The existing soil classification charts (Robertson, 1990) do not allow an automated interpretation however, as the peat layer is considered clay to silty clay, possibly due to the compaction of the peat.

Archaeological sampling was performed on the micro-sandridge in a staggered 10 m grid using a manual 10 cm diameter Dutch auger. The sample locations were based on the auger data collected by ADW. Only the top of the ridge could be sampled well up to a depth of 2.5 to 3 m. Samples at greater depths could often not be retrieved from the

Fig. 7 - Marine seismic results of Scheldt river bottom.



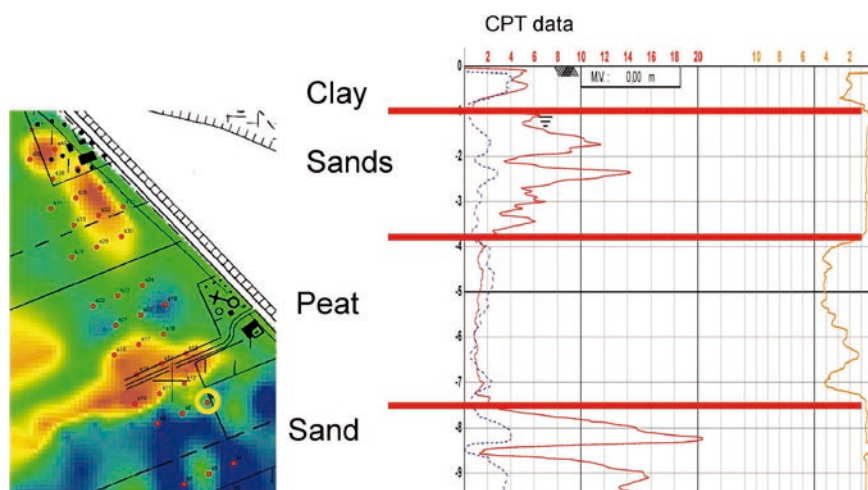


Fig. 8 - CPT plot showing tip resistance (MPa) (red), sleeve friction (MPa) (dashed blue) and friction ratio (%) (yellow).

borehole to liquefied marine sands above the peat. Nevertheless, several samples contained archaeological indicators such as flint chips and burnt bone (Fig. 9).

4. Interim conclusions and prospects for future work

It can be concluded that EMI survey allows a rapid and detailed mapping of the palaeotopographic features, relevant for the archaeological evaluation. Interpretation can be aided by a limited number of augering to identify the anomalies present in the dataset. For a better appreciation of the electromagnetic data, depth modeling could create a more easily interpretable palaeotopography. This requires a number of points where the depth to the modeled layer is known. For this purpose both augering and cone penetration tests could theoretically be used.

ERI is a far slower technique but could possibly reveal more stratigraphic information. The low resistance of the groundwater table and peat impedes the detection of the Pleistocene topography however. Further processing and tests with other configurations will be done however.

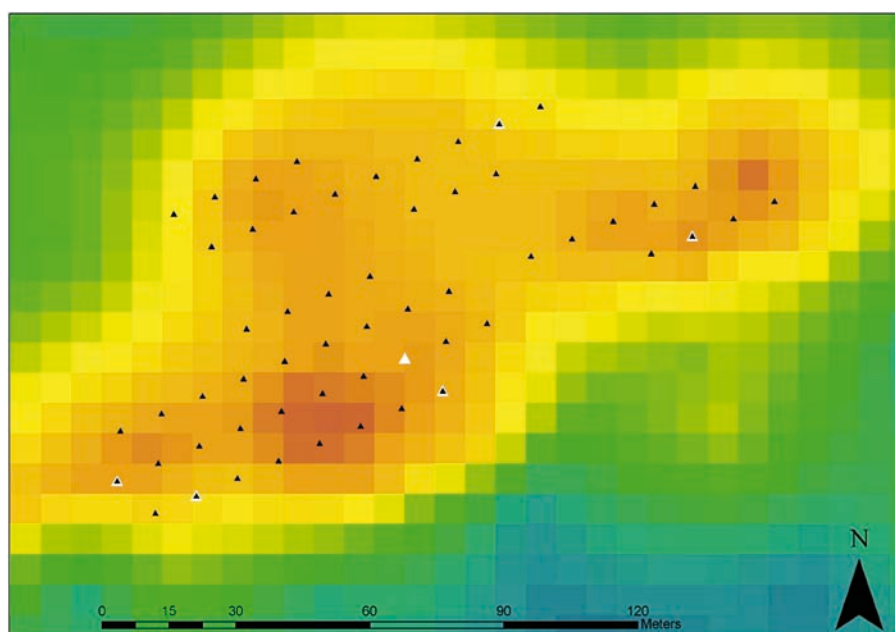


Fig. 9 - Manual augerings with sample recovery with archaeological indicators (white) and negative samples (black).

Land seismics has good results but due to its slow data acquisition speed, further developments have to be made before large scale applications are possible. Marine seismic is well-suited for the detection of palaeogullies but is largely impeded by peat-gas.

The CPTs were successful at detecting both top and basis of the peat and well as the old sea clay in between. Because of their rapid acquisition and relative cheapness, they could serve as an excellent calibration tool for the EMI data or if EMI is impossible, even as a gridded survey technique on their own combined with a limited number of augering. A local soil classification chart is needed however for automated interpretation.

The current archaeological sampling strategy is well suited at limited depths. Mechanical augering has to be performed at greater depths where loose sands above the peat impede sample collection. To restrict the costs of this, an accurate palaeotopographical model is required.

Bibliography

- CHAPMAN H., ADCOCK J. & GATER J., 2009. An approach to mapping buried prehistoric palaeosols of the Atlantic Seaboard in Northwest Europe using GPR, geoarchaeology and GIS and the implications for heritage management. *Journal of Archaeological Science*, 36: 2308-2313.
- CROMBÉ Ph., 2005. *The last hunter-gatherer-fishermen in sandy-Flanders (NW Belgium). The Verrebroek and Doel excavation projects (Vol.1: Palaeo-environment, chronology and features)*. Archaeological Reports Ghent University, Universiteit Gent, Gent.
- DE CLERCQ W. & DIERENDONCK R. M., 2008. *Extrema Galliarum. Zeeland en Noordwest-Vlaanderen in het Imperium Romanum*. *Zeeuws Tijdschrift*, 58 (3-4): 6-34.
- DE CLERCQ W., 2009. *Lokale gemeenschappen in het Imperium Romanum: transformaties in rurale bewoningsstructuur en materiële cultuur in de landschappen van het noordelijk deel van de civitas Menapiorum (provincie Gallia-Belgica, ca. 100 v. Chr. - 400 n. Chr.)*. S.n.
- DE CLERCQ W., BATS M., LALOO P., SERGANT J. & CROMBÉ Ph., 2011. Beware of the known: methodological issues in the detection of low density rural occupation in large-surface archaeological landscape-assessment in Northern-Flanders (Belgium). In: BLANCQUAERT G., MALRAIN F., STÄUBLE H. & VANMOERKERK J. (ed.), *Understanding the Past: a Matter of Surface-Area, Acts of the 13th Session of the EAA Congress, Zadar 2007*. British Archaeological Reports (BAR), International Series 2194: 73-89.
- DEFORCE K., 2011. Middle and late Holocene vegetation and landscape evolution of the Scheldt estuary: a palynological study of a peat deposit from doel (Belgium). *Geologica Belgica*, 14 (3-4): 277-288.
- KLINCK B., MEERSCHAERT L. & VAN ROEYEN J.-P., 2007. *Paleolandschappelijk en archeologisch onderzoek van de te realiseren natuurcompensatiezone "Weidevogelgebied Doelpolder Noord en Kreek" in het kader van het Containergetijdedok-West (Gemeente Beveren)*. Eindrapport. Archeologische Dienst Waasland, 102, Sint-Niklaas.
- MCNEIL J. D., 1980. *Electromagnetic terrain conductivity measurement at low induction numbers*. Technical Note TN-6. GEONICS Limited, Ontario: 15 p.
- ROBERTSON P. K., 1990. Soil classification using the cone penetration test. *Canadian Geotechnical Journal*, 27 (1): 151-158.
- SAMOUËLIAN A., COUSIN I., TABBAGH A., BRUAND A. & RICHARD G., 2005. Electrical resistivity survey in soil science: a review. *Soil and Tillage Research*, 83 (2): 173-193.
- SIMPSON D., 2009. *Geoarchaeological prospection with multi-coil electromagnetic induction sensors*. PhD Thesis, Ghent University, Faculty of Bioscience Engineering, Ghent.
- THOOFT K., 2007. Empirische regels voor de interpretatie van sonderingen en het afleiden van mechanische parameters van grond in Vlaanderen. *Geotechniek*, juli 2007.
- VOS P. C., VAN HEERINGEN R. M., DE WOLF H. & FISCHER M. M., 1997. *Holocene evolution of Zeeland (SW Netherlands)*. Netherlands Institute of Applied Geoscience TNO, s.n.

Abstract

In 2011, an interdisciplinary research project was started at Ghent University investigating the occupation history of the Scheldt polders. A first geophysical and coring campaign was undertaken at Doelpolder Noord to reconstruct the paleotopography of the top of the Pleistocene coversand and the peat covering it. An eolian micro-sandridge in the survey area was sampled to detect possible archaeological sites. This paper presents the first fieldwork results.

Keywords: Alluvial geoarchaeology, Geophysical survey, Augering, Cone Penetration Tests, Scheldt Polders.

Samenvatting

In 2011 werd een interdisciplinair onderzoeksproject naar de bewoningsgeschiedenis van de Scheldepolders opgestart aan de Universiteit Gent. Een eerste geofysische en boorcampagne te Doelpolder Noord is reeds uitgevoerd om de paleotopografie van het Pleistocene dekzand en het afdekkende veen te reconstrueren. Een eolische micro-zandrug werd bemonsterd om mogelijke archeologische sites te detecteren. Deze paper presenteert de eerste onderzoeksresultaten.

Trefwoorden: Alluviale geoarcheologie, Geofysische prospectie, Boringen, Sonderingen, Scheldepolders.

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