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Soil characteristics of the Motte of Werken (West Flanders - Belgium)

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1. Introduction

The archaeological excavation of the Motte of Werken (Vanthournout 1991) shows that the artificial hill, 6 m high and about 50 m in diameter, is made up of tens of layers (fig. 1). Each of these strata can be distinguished on the basis of the color, the texture (particle size distribution), the size and the proportion of the various components deposited in successive layers by man. In such a complex stratigraphy, frequently met in urban excavations, one of the main questions is to know which of the stratigraphic contacts represents a «living floor». Another question is to detect if any particular construction technique has been applied in raising the soil surface. This paper relates the first results of the pedological prospections and analyses performed in order to assist the archaeologist in these aspects of his investigation.

2. Materials and Methods

The prospections were made at a moment that about one quarter of the motte was excavated nearly down to the underlying undisturbed soil. The area of the Carolingian house(s) situated in the central-lower part of the hill was not yet completely removed and has only been observed for some particular features (§ 4.2.). Also the area of the wooden and stone towers is not included in these comments; the upper part of the wooden tower(s) was under excavation at the moment of redaction of this paper and the area of the stone tower has been completely disturbed during an earlier excavation in 1861 (Slembrouck and T'Jonck 1955).

In the first phase a field macromorphological study of the vertical sections was made. The observations were focused towards those characteristics which permit to detect among the numerous strata the successive construction and stabilization phases of the motte. All observations were made on moist sections and all the colors reported here are for crushed moist samples and according to the Munsell Soil Color Charts (1954). The soil horizon symbols are following the A/B/C nomenclature system of the Belgian Soil Survey (Hubert 1961). This part of the study did permit to formulate a first important series of hypotheses and is the main subject of this contribution.

In the second phase carbon, nitrogen and phosphorous contents of 20 preliminary soil samples were determined. A few of these data will be commented in the following chapters.

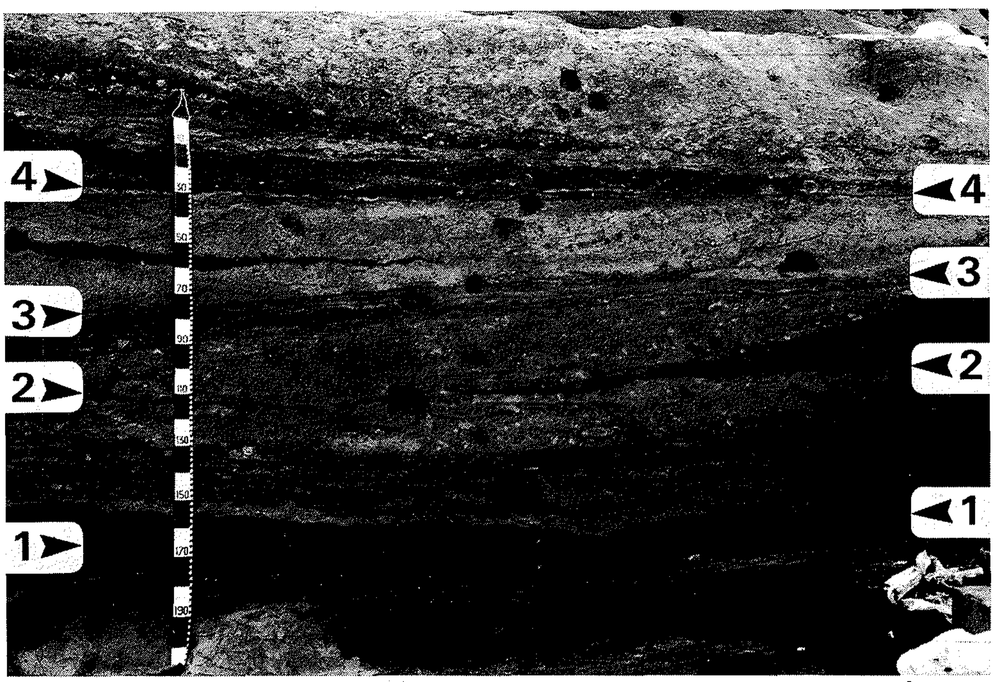

Fig. 1: The complex stratigraphy of the motte. Some layers or horizons in the construction are more important than others. In this section 4 important stability phases could be detected among the approximately 17 lithostratigraphic layers.
1: the plow layer of Soil 2,
2. the farm-yard surface of Soil 3,
3. the farm-yard surface of Soil 4,
4: the farm-yard surface of Soil 5.

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In the third phase 73 undisturbed and oriented samples were collected for the micromorphological study under the petrographic microscope. The samples were air dried, further dried at 105°C, and then impregnated under vacuum with plastic. The thin sections, 30 micrometers in thickness, were 2 x 3 cm large. Some of these sections from samples taken at the level of former surface horizons and living floors will be discussed in this paper.

3. The successive Construction and Stability Phases of the Motte according to the pedological Data

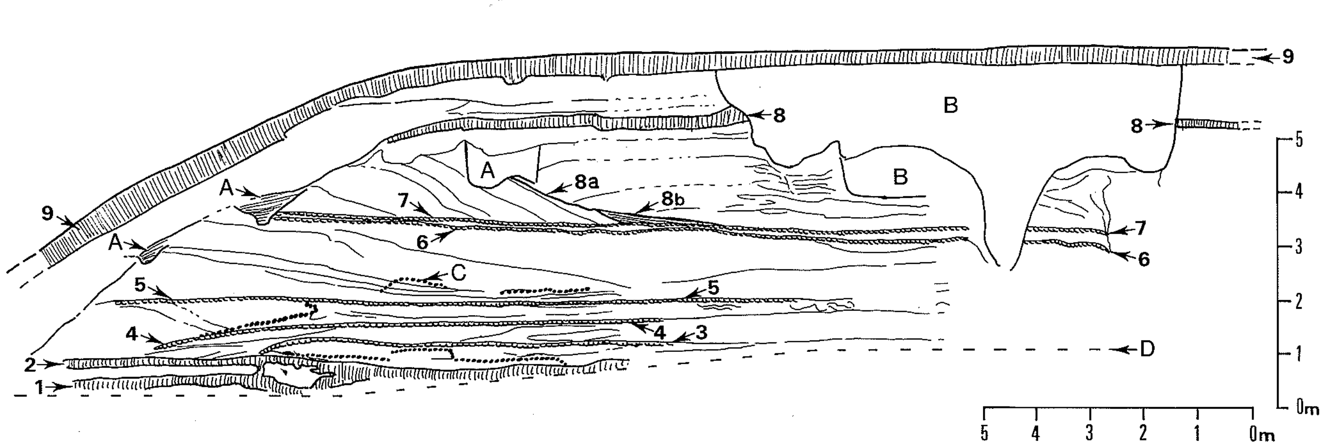
Based on the pedological prospection in that part of the motte situated outside of the houses and the towers, 10 main phases of stability and 9 phases of construction are detected (fig. 2 and 3). These phases are commented here in chronological order, starting with the oldest living floor.

3.1. The Original Soil (Soil 1)

1:

Up to now only a 3 m section through the «original soil» (Soil 1) buried under the motte, could be observed (fig. 2 and 3) The profile (fig. 4) is mainly composed of a 15 - 25 cm thick, homogeneous, very dark grayish brown (10YR 3/2) moderately humiferous very fine sandy surface A horizon and a homogeneous light yellowish brown (1Y 6/4) fine sandy subsurface C horizon; at about 50 - 150 cm depth stands the present-day fluctuating groundwater table whose level is higher in the central part of the Motte (§ 4.1.). The absence of a B horizon could be either due to a strong erosion or to a permanent water table which was previously higher in the profile than today. The size of the section does not permit to decide whether one or both processes has been active. The rather sharp transition between the A and C horizons seems to point to at least some erosion.

Fig. 2: Main stability phases (with soils) and lithostratigraphic boundaries in the vertical section through the non-habitat area of the motte. The house(s) and tower(s) were situated to the right side of this section.
The 9 living floors,
1: the plow layer of Soil 1,
2: the plow layer of Soil 2,
3: the farm-yard soil surface of Soil 3,
4: the farm-yard soil surface of Soil 4,
5: the farm-yard soil surface of Soil 5,
6: the farm-yard soil surface of Soil 6,
7: the farm-yard soil surface of Soil 7,
8a: surface of the outer wall during construction phase 7,
8b: surface of the stratified sediments deposited at the footslope of 8a,
8: the plow layer of Soil 8,
9: the present-day humiferous surface horizon of a meadow soil,
A: traces of trenches,
B: disturbance by 19th century excavation,
C hydromorphic iron-manganese accumulation-bands,
D: lower limit of the excavation.



2:

The dark colour, the strong homogeneity and the thickness of the A horizon, the sharpness of its boundary with the C horizon and the presence from the A towards the underlying C horizon of rather numerous worm galleries and some mole galleries, all filled-up with greyish earth from the A horizon, bring us to the hypothesis that this A horizon is an old plow layer of a crop land parcel (Ap horizon). Indeed, if it was a grassland we would not expect such a sharp transition and the worm and mole galleries would be more numerous.

3.2. First Phase of Surface Raising, Soil 2

1:

In the first phase of soil surface raising a 30-40 cm thick layer of fine sand was added. The characteristics of this phase could be studied over a length of 7 m.

2:

The soil profile (Soil 2) (fig. 4) has also a very homogeneous, moderately humiferous surface boundary. This horizon is however a little thinner (10-15 cm) than the Ap horizon of Soil 1. The soil material between the two A horizons seems to have been similar to the non-humiferous light yellowish brown C horizon of Soil 1, but the bioturbation by earthworms and moles from the overlying A horizon into this layer is so strong that little is left of the original material and the colour is composed of numerous light to dark greyish bands and streaks of filled-up faunal galleries.

3:

The homogeneity of the A horizon, its lower abrupt smooth boundary and the intensive activity of worms and moles makes us conclude that Soil 2 corresponds to a parcel which was occasionally plowed and where the soil was relatively rich in nitrogen. Indeed, high amounts of easily available nitrogen

Fig. 3: The successive construction and stability phases of the motte (cfr fig 2).

1-9 (without circle): the stability phases of the motte and the 9 soil types (see fig. 2).

1-8 (with circle): the construction phases,

- *1: first surface raising,*
- *2: second surface raising, earth dumped from inside to outside, material from nearby,*
- *3: third surface raising, from inside to outside, material from nearby,*
- *4: fourth surface raising, with preliminar outer wall (see fig. 2), material from nearby,*
- *5: fifth surface raising, with preliminary outer wall, material from some distance,*
- *6: sixth, limited surface raising,*
- *7: seventh surface raising, with preliminar outer wall (7a), colluvial sediments at the footslope of the outer wall (7b) and final fill (7c) to construct the platform,*
- *8: eighth surface raising,*

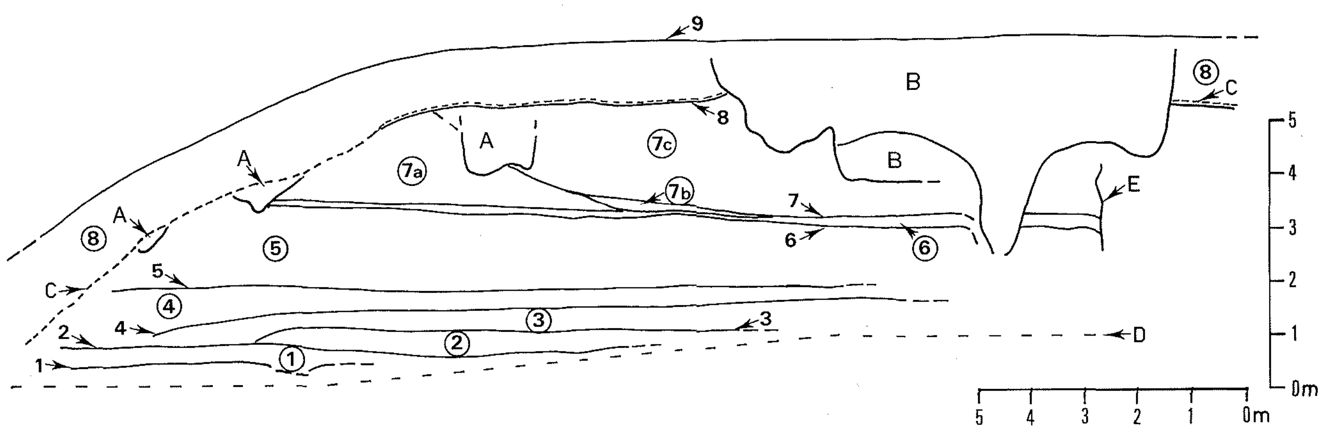
A: trenches,

B: disturbance by 19th century excavation,

C: lower limit of the layer strongly homogenized by bioturbation (see fig. 11),

D: lower limit of the excavation,

E: trace of the outer wall of one of the towers.



favour the presence of earthworms, particularly the deep burrowing and large *Lumbricus terrestris* (Langohr 1986). Once there is an important population of these earthworms, moles will also be very active as worms are their favourite food. The density of mole galleries indicates that their presence was tolerated by the farmer(s). This seems to exclude horticulture, and to some extent also cropland and brings us to the hypothesis that Soil 2 belongs to a parcel which was occasionally plowed and which remained for relatively long periods with meadows and grazing animals.

4:

The original material of Soil 2 is so similar to the material of Soil 1 that we can presume that the earth used to raise the soil surface has been excavated from the immediate vicinity, possibly by digging a ditch for drainage and/or defense. It seems furthermore that one has tried to maintain the same stratigraphic position of the horizons: the humus-rich material has been deposited on top of the humus-poor C horizon material. This corresponds to an excavation and deposition in three steps:

1. excavation and separate storage of the humus-rich surface horizon;
2. excavation and deposition on the surface to be raised of the humus-poor C horizon material and
3. deposition on the top of the previously transported C material of the temporarily stored A horizon material.

3.3. Second Phase of Surface Raising, Soil 3

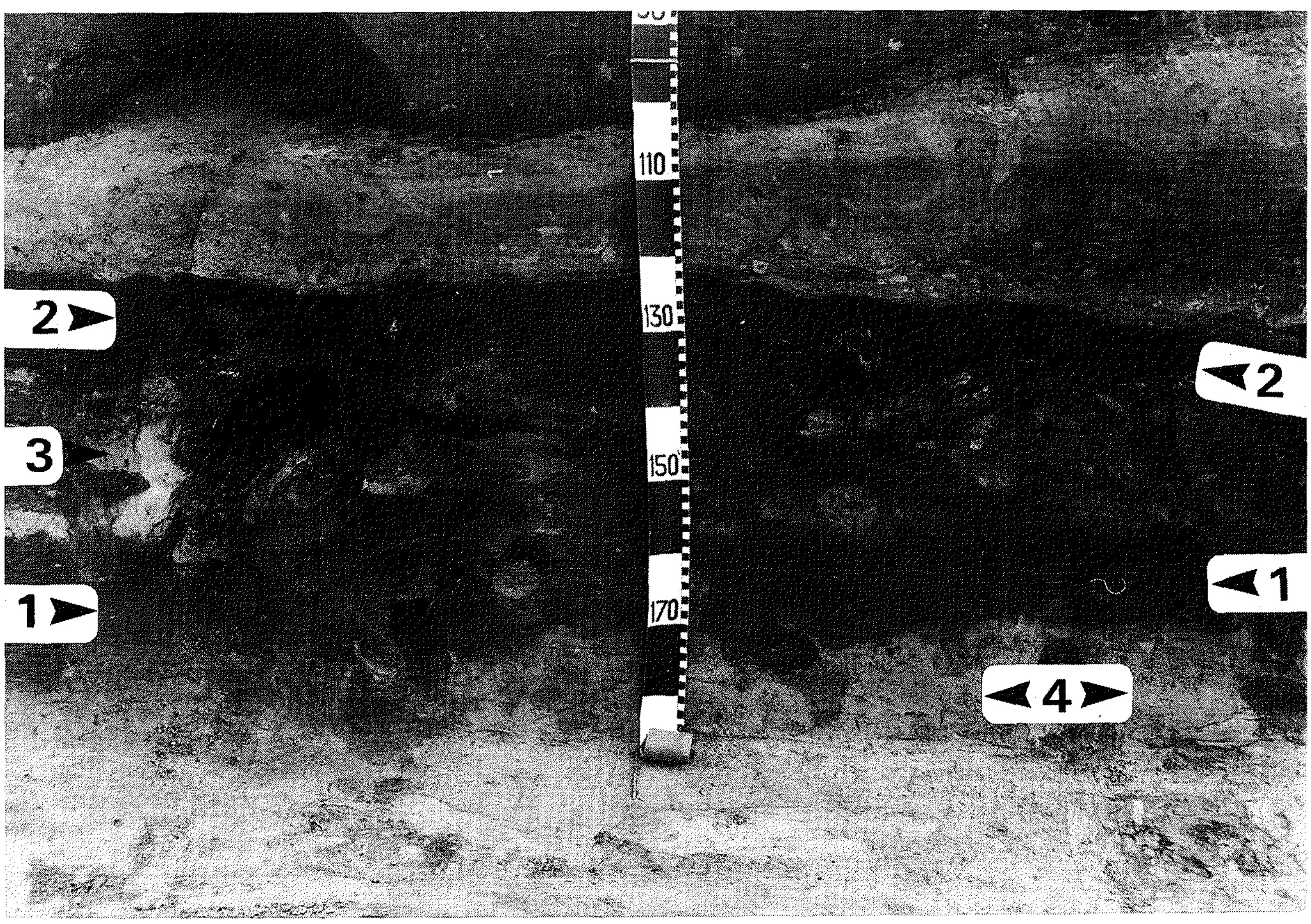
1:

The second phase of surface raising and the third floor (fig. 2, 3, 12 and 13) have been studied from their outer limit (left side of figure 2) up to the area of the habitat (middle-right part of figure 2).

2:

The earth brought to raise the soil surface with 30-40 cm is very similar in colour and texture to the C horizon material of Soil 1. Locally there are some small fragments which resemble to the Ap horizon of Soil 1.

Fig. 4:
1: plow layer of Soil 1, with some mole galleries,
2: plow layer of Soil 2.
The surface of Soil 2 raised by 30 cm of earth. The lower part of this fill shows locally (3) that it was originally composed of light coloured material similar to the soil material below the plow layer of Soil 1 (4); numerous biogalleries, mainly of moles however have resulted in a much darker color of this layer.



3:

The habitation surface (Soil 3) is very low in dark humus compounds and the decision to interpret this stratigraphic boundary as an important stability phase in the motte construction is not based on the colour but on three other characteristics (cfr. fig. 5):

1. the very sharp, continuous and smooth upper limit,
2. the high degree of compaction of the upper 3-10 cm of the soil and
3. traces of tramping, apparently of small cattle (sheep, pigs?).

No traces of ice segregation, typical in moist, dense, fine sandy soils which are exposed to frost, could be observed. There are only a few traces of small worm galleries and mole galleries are completely absent. Neither are there evidences of anthropogenic homogenization such as plowing and/or digging with a spade.

4:

All the characteristics mentioned so far for Soil 3 make us conclude that this corresponds probably to a farm-yard parcel where animals roam around permanently, or where cattle is kept every night. Indeed, the very frequent pressure applied this way on the moist soil can explain the development of a traffic pan and the concomittant obliteration of the lenticular structure which develops in compact soils which freeze. Another possibility would be that this area corresponds to a stable, but the absence of archaeological traces of posts or other features associated to walls seems to exclude this hypothesis.

The study of soil thin sections through the upper centimeters of this floor brings a new argument for the farm-yard hypothesis. Indeed, besides the particular dense packing of the fine sand particles, it is observed that large part of the pores are filled with a substance which is light yellowish, slightly transparent in normal light and dark and without birefringence under crossed polarisers. These are characteristics for nearly colourless amorphous organic material which percolated from the living floor surface into the soil and accumulated in the dense traffic pan layer.

Fig. 5: Farm-yard surface of Soil 4. Six clear tramping traces of small cattle (sheep, pigs ?). The upper limit of the soil is very sharp. Up to 10 cm below this upper limit the soil is extremely compact and shows vague involutions. The soil is poor in dark-colored organic substances, except for the tramping pockets.

3.4. Third Phase of Surface Raising, Soil 4

1:
The third phase of surface raising and its floor (Soil 4) are very similar to what has been described for the underlying phase two and its Soil 3 (fig. 1, 2, 5, 12); the soil surface was raised once more with 30-40 cm by dumping earth very similar to the C horizon material of Soil 1, the living floor is also a characteristic very dense, 5-10 cm thick traffic pan with traces of small cattle tramping (fig. 5) and amorphous light yellowish organic matter infilling of the pores. The main difference with phase 2 is that the raised surface extends 2-3 m more outwards (fig. 2).

2:
Based on the discussion of Soil 3 we conclude that the living floor of soil 4 was most probably also a farm-yard parcel.

3.5. Fourth Phase of Surface Raising, Soil 5

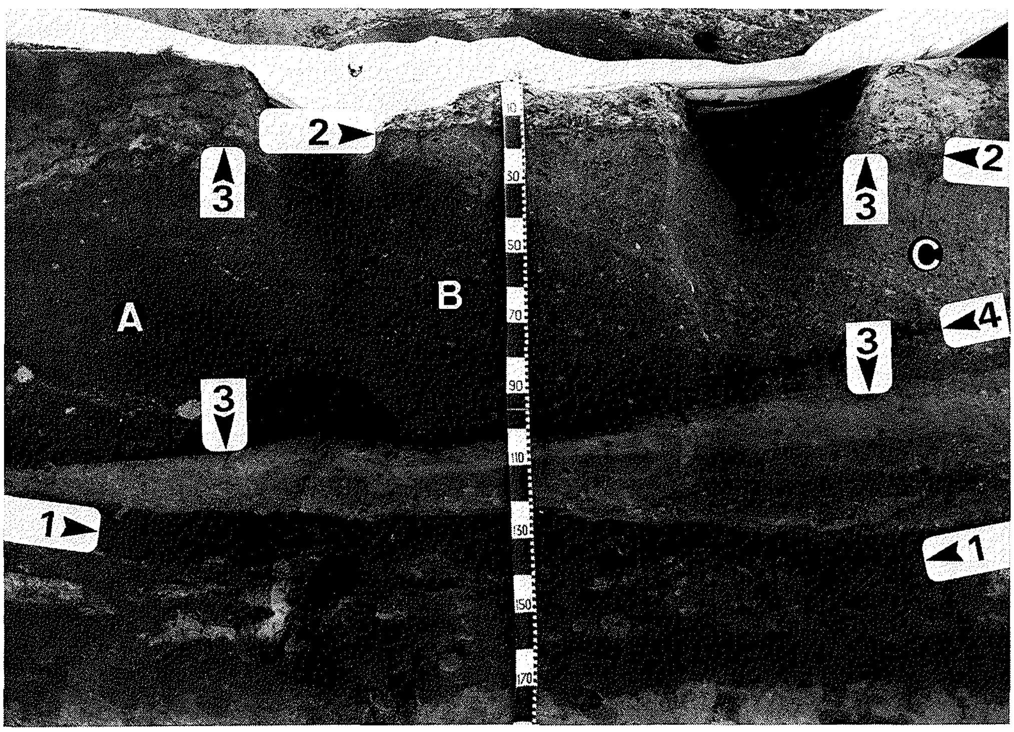
1:
The fourth phase of soil surface raising brings again the floor some 30-40 cm higher. The total surface of the flat living floor has been increased markedly by dumping a layer up to 90 cm thick in the outer 3-4 m of the motte. It seems that in this period the flat living area of the motte has been largest (fig. 2). The outer slope gradient of the motte became also steeper than ever before. However, today it is impossible to measure exactly this outer slope gradient as all original soil characteristics have disappeared because of the intensive bioturbation processes of the final motte surface (see § 3.9./2:).

The earth which was brought is, just as for the three previous phases, very similar to components of Soil 1 and we conclude also that this phase is most probably associated with the digging of a large and probably deep ditch around, or nearby the motte.

2:
The method of surface raising, however, was markedly different. There is a clear sequence (fig. 6 and 7), with earth very similar to the Ap horizon material dumped first as a wall on the outer part of the area to be raised, and then gradually earth composed of a mixture of fragments mostly smaller than 1 cm from Ap and C horizons but with a gradual increase of the former and progressing towards the central part of the motte.

3:
Here the habitation surface (Soil 5) is also similar to Soil 3 and Soil 4 and we conclude once more that this was most probably a farm-yard parcel.

Fig. 6: Outer part of the fourth phase of surface raising,
1: plow layer of Soil 2,
2: farm-yard surface of Soil 5,
3: total thickness of the fourth phase of surface raising,
A, B, C: successive layers with gradually a lighter colour (see fig. 7),
4: hydromorphic iron-manganese crust.



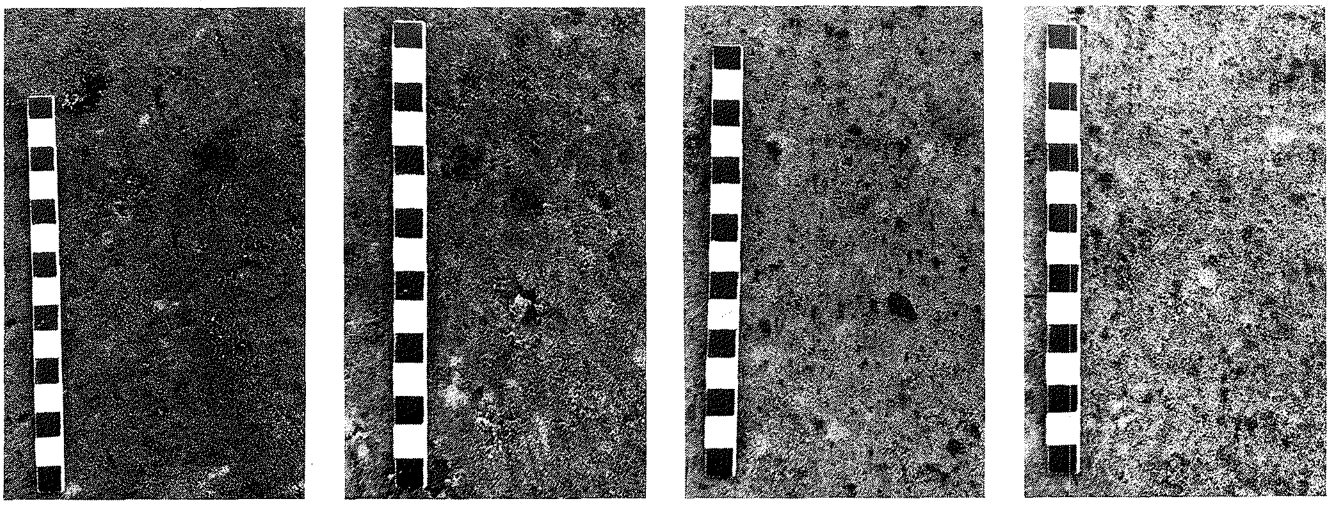


Fig. 7: Close-up, from left to right, of the successively lighter colored earth dumped during the fourth phase of surface raising (cfr. fig. 6). The proportion of dark-colored fragments of original surface soil gradually decreases from the left (earth dumped first) to the right (earth dumped last).

3.6. Fifth Phase of Surface Raising, Soil 6

1:

In the fifth construction phase (fig. 2, 3, 8) the hill was raised with about 1.4 m, this is as much as in total during the four previous events.

2:

The method of earth dumping was comparable to the technique followed in phase four: first a deposit of earth at the outer slope of the hill, creating an 80-100 cm high earth wall and then surface raising and levelling by dumping successive layers of earth on top and along the inner slope of this wall. Four kinds of soil material have been deposited this way.

1. The first material is a very dark grayish brown to dark brown (10YR 3/2.5) humiferous loamy fine sand. The material is finely crushed with very few earth fragments larger than 1 cm and is the main component of the preliminary earth wall.
2. The second layer, only 10-20 cm thick, is for more than half composed of a yellowish brown (10YR 5/4) fine sand. The remaining fraction includes for the rest small fragments of the previous and next horizons.
3. The third layer is 40-60 cm thick, comprising soil clods with different colors and textures. The extremes are strong brown (7.5YR 5/8) fine sandy loamy and light olive gray (5Y 6/2) fine sandy fragments, but all intermediates can be observed. The size of these clods is smaller than 3 cm in the outer 2-3 m of the hill and they become larger, with fragments up to 10 cm in diameter further inwards the motte. Many of these fragments seem to have been partly compressed during the process of dumping.
4. The fourth layer levelled completely the motte surface. It is absent in the outer 3 m of the fill (area of the preliminary earth wall) but covers the whole 1.4 m thickness towards the central part of the motte. This layer is composed of light yellowish brown to light olive brown (1Y 5.5/4) fine sand, loamy fine sand and a few more clayey clods. The fragments are mainly smaller than 2-3 cm, but locally some partly compressed clods up to 5 cm can be observed.

3:

The 4 successive layers described here correspond to the 4 main pedogenetic horizons of an «Scc» type of soil of the Belgian Soil Survey legend (Hubert 1961), i.e. a loamy sandy («S..»), moderately well drained («.c.») soil with a strongly fragmented textural B horizon («..c»). The first dark layer corresponds to the humus-rich Ap or plow layer; the second lighter coloured layer corresponds to the iron- and clay-eluvial E horizon, which also is relatively thin in the undisturbed soil; the third heterogeneous layer matches exactly with the Btg or «strongly fragmented textural B» horizon of such a Scc profile, the soil material is richer in clay and in iron than in the over- and underlying horizons, but it contains also a series of very light coloured iron- and clay-depleted tongues and pockets of E horizon; the fourth and last horizon corresponds to the nearly undisturbed light coloured parent material or C horizon of such a soil. The more clayey clods correspond to an admixture of Tertiary clayey material which is in this region the substratum under the Pleistocene coversands in which the Scc soil profile developed.

4:

As in the fourth phase, it seems that also here the outer slope of the motte was rather steep (probably 25°, or even more) but because of the bioturbation related to the present-day surface soil (see § 3.9./2:) it is impossible to detect exactly the pattern of the old soil surface.

5:

According to the Soil Map of Belgium (T'Jonck and Hubert 1961) the motte of Werken is situated at the lower and outer limit of the sandy «upland soils», just before the contact with the wet and more clayey polder soils. The Scc type of soil is very widespread on the upland, but at a distance of 50-100 m at least from the motte. Thus we can conclude that in the fifth phase of the motte construction, the soil material has not any more been collected by digging deep and large trenches around or in the vicinity of the hill, but by making a large, and at least 3 m deep excavation somewhere on the better drained upland area. This quarry could correspond to an area indicated on the soil map as «loamy sand soils with no particular horizon development» and situated on the upland area some 300-500 m to the east of the motte, a subject still under investigation.

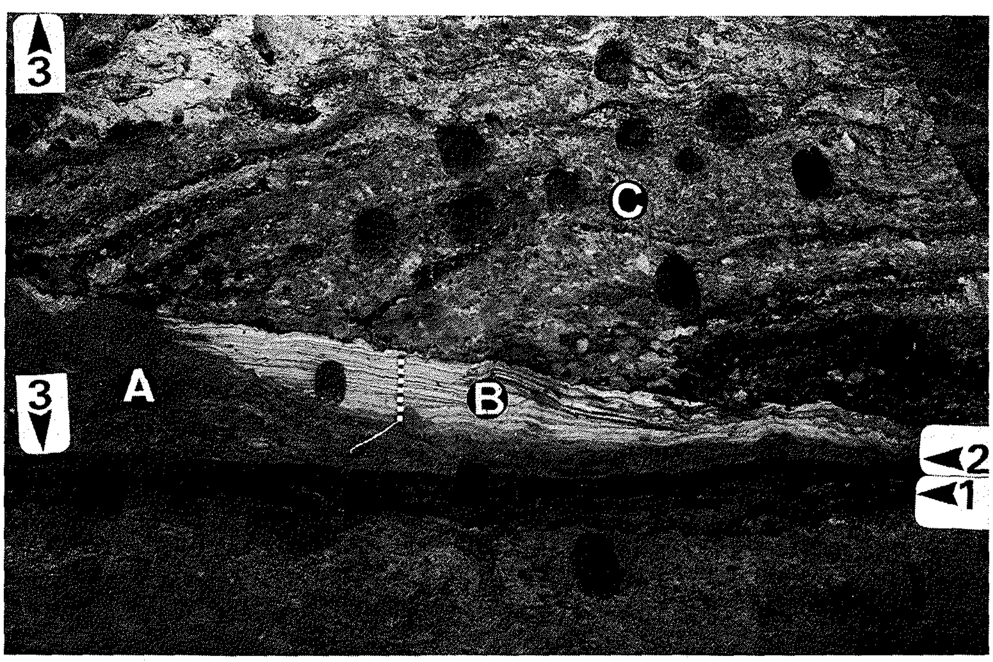
6:
The floor of Soil 6 (fig. 8) is interpreted as one more farm-yard surface. It is a 5-12 cm thick moderately humiferous, very compact horizon with very few traces of small earthworm activity (galleries less than 3 mm in diameter) and only few clear traces of tramping, possibly of small cattle. This farm-yard soil is slightly richer in dark humus compounds than the farm-yard soils 3, 4 and 5 but it is not sure if this is because the soil has undergone a longer stability phase. The surface of this floor is very smooth, except towards the central part of the motte where it has an irregular wavy topography (see further the comments about Soil 7, § 3.7./4:).

3.7. Sixth Phase of Surface Raising, Soil 7

1:
The sixth phase of surface raising (fig. 2, 3, 8) has a very limited extent and magnitude. It corresponds to a maximum of 15-20 cm of earth brought on top of Soil 6, mainly in the central half part of the motte.

2:
The earth deposited here is similar to the fourth layer described for the underlying fifth phase of surface raising (§ 3.6./2: 4.) and so corresponds to the C horizon material of a Scc soil (3.6./3:).

Fig. 8:
1: farm-yard surface of Soil 6,
2: farm-yard surface of Soil 7,
3: the seventh surface raising, made in three phases,
A: the outer earth wall composed of finely crushed and compacted soil fragments,
B: finely stratified colluvial deposits on the footslope of the outer earth wall, sediments which have been deposited by sheet wash on the bare soil surface of 4a,
C: coarse stratified earth dumped without crushing the soil fragments which filled up the space between the outer earth wall (4a) and the tower situated some 8 m further to the right.
There are no traces of plant roots or burrowing animals at the contacts between A, B and C. The dark spots through the section correspond to sampling areas.



3:
The habitation surface (Soil 7) is identical to the underlying one (§ 3.6./6:) and thus seems once more to correspond to a farm-yard area.

4:
Considering the limited extent and magnitude of surface raising it is evident that this phase had a different purpose in the motte construction versus all the previous ones. Two particular characteristics may help to elaborate a hypothesis about the reason for this phase:
1. the floor of Soil 6 has a surface which is gradually lower when passing from the outer half towards the central part of the motte;
2. the area where the earth dumping is more than 10 cm thick (the central part of the motte) shows floors of Soil 6 and 7 which have an irregular wavy topography.

From these data we conclude that the sixth phase of local surface raising corresponds to a readjustment of the original horizontal topography of the floor of Soil 6. Most probably there had been some subsidence in this part of the motte resulting to a concentration of surface runoff water creating rather muddy conditions and soil surface disturbance by puddling by man and/or cattle. The restoration seems to have been only partly successful, possibly because of further weak subsidence of the soil in this central part of the motte.

5:
There can be several causes for this subsidence in the central part of the motte:
1. during the fifth phase of earth dumping the soil has not been compressed sufficiently in this area;
2. in this area there are layers below the fifth dumped layer of the Carolingean houses that are very rich in organic matter and which may subside;
3. the rainwater from the roof of the tower(s) or house(s) did drain into this area resulting to a more strongly contrasting moisture regime of the soil and frequent water saturation, conditions where dumped earth will settle more rapidly than in areas where the soil remains drier,
4. the basement of the tower, situated just beside the central area of the motte, did in one way or another move slightly.

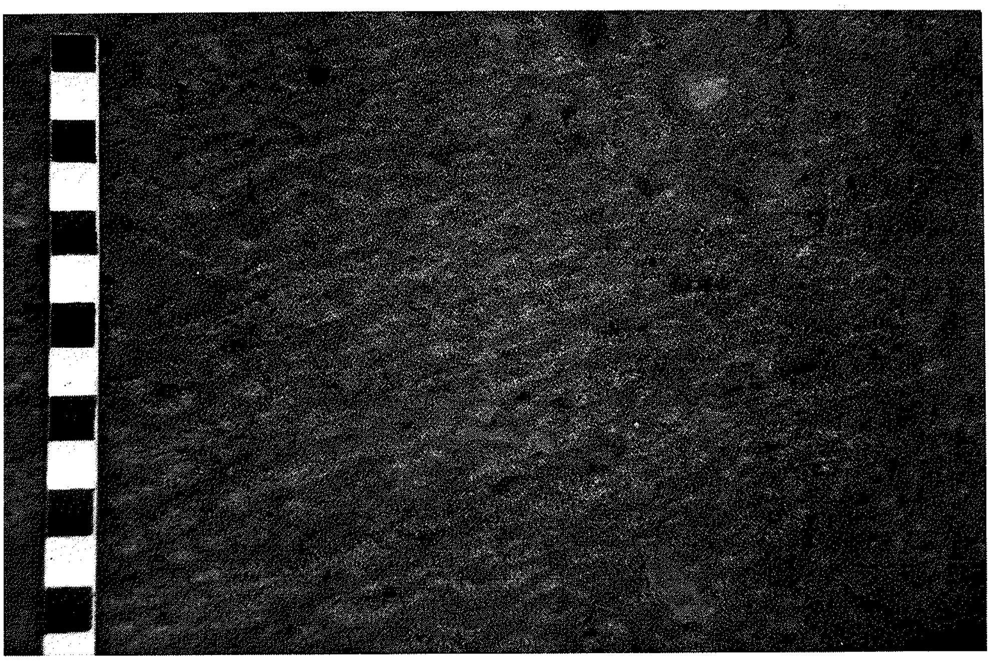
3.8. Seventh Phase of Surface Raising, Soil 8

1:
The seventh phase of surface raising (fig. 2, 3, 8), with an increase of 2 metres in altitude was by far the most important one.

2:
The earth brought during this period was of the same type as the one of phase five (§ 3.6./2: and 3:). Also here we observe fragments of the 4 main horizons of a «Scc» soil profile.

3:
The technique for the motte construction, however, changed once more. Three successive phases can be distinguished here (fig. 2, 3, 8).

Fig. 9: Detail of the dark colored, a few millimetres thick clay accumulation fibres in the finely crushed and compacted earth of the outer wall of construction phase 7a.



1. An earth wall was again raised first at the outer part of the previous living floor. The wall was about 2 m high and about 6 m large at its base. As in phase five it started first by dumping earth on the outer slope of the motte until a small, 60-80 cm high wall was left; after that a series (at least 5 can be recognised) of successive layers have been dumped on top of this preliminar wall and on its inner slope. The colour of these layers is dominantly yellowish brown (10YR 5/4) but here it is also possible to detect layers which are more rich in material coming from the plow layer (Ap), the clay- and iron-eluvial horizon (E), the clay- and iron illuvial horizon (B2t) and the C horizon material of a Scc soil (§ 3.6./3:).
   Important to note is that all the earth of this wall was finely crushed (fig. 8, 9) and few fragments are larger than 1 cm in diameter. This must have been done intentionally, probably in order to obtain a soil which was sufficiently dense in order to avoid slumping of the hill slopes in rainy periods and possibly also in a later period to be able to fix strongly a palisade at the outer part of the new raised floor.

2. On the footslope of the inner part of the earth wall described in previous paragraph exists a deposit of finely stratified material (fig. 8) which was washed down by sheet erosion from the bare slope of the wall. The sediment has a light brownish gray (2.5YR 5.5/2) color and a fine sandy texture on the footslope, where it has a maximum thickness of 20 cm. Further away from the earthwall and up to the traces of the wooden tower, the deposit extends as a 1-3 cm thick black to very dark gray (10YR 2.5/1) clayey layer. Where the erosion sediment is thickest, we can count at least 20 successive layers (fig. 10), each composed of a 5-15 mm thick deposit of lighter coloured fine and very fine sand and covered by a 1-2 mm thin somewhat darker coloured silty layer. Each of these layers seems to correspond to a rain shower and this makes us conclude that the outer earth wall has remained bare for at least a few weeks, if not months. The period of time has, however, not been long enough for a vegetative cover to establish, a feature which to our experience would take some 6 to 10 months, depending when the earth wall was constructed, just before the winter, or after the winter. The period of erosion and sedimentation, of which we see the traces here, could correspond to the time that was needed to work on the foundations and/or the basement of the tower (cfr. Vanthournout 1991).

   The intensity of this sheet erosion is one argument more for the hypothesis that the finely crushed earth of this wall has been continuously packed down, otherwise we would not expect a very strong water flow over freshly dumped earth with a 30 % slope.

3. In the third phase the definitive motte surface was reached by filling up the space between the outer earth wall and the wooden tower. The dumped earth is here again composed of material coming from a Scc type of soil (§ 3.6./3: and 3.8./3: 1.).
   It seems that the earth was dumped first in the area half way between the footslope of the outer earth wall and the wooden tower. As a result we observe a convex stratification and again mainly plow layer material in the lower part and up-

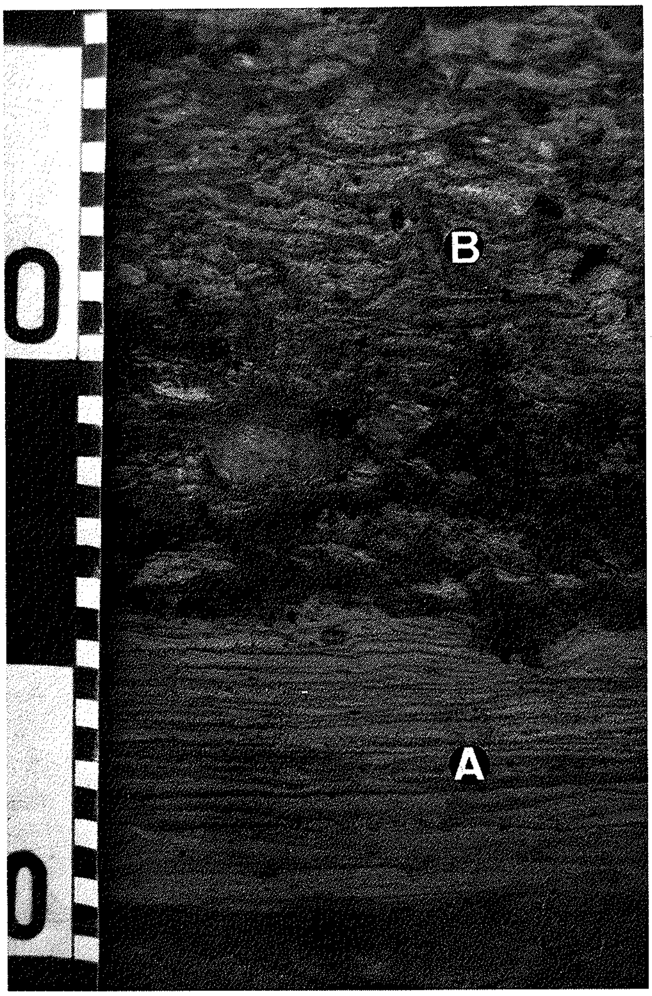


Fig. 10: The difference between clay-accumulation fibres and stratification.

A: detail of 3B in figure 8, a series of about 20 thin, nearly parallel stratifications as result of sheet wash erosion on a bare slope and deposition on the footslope; the very thin darker laminae correspond to the end of a rainfall, with deposition of finer and more humus-rich sediments,

B: darker coloured clay-accumulation fibres in the fill of construction phase 7c; the thickness of the fibres is more variable and because of some involutions, the bands are not so nicely parallel; these features cross locally the litho-stratigraphic units.

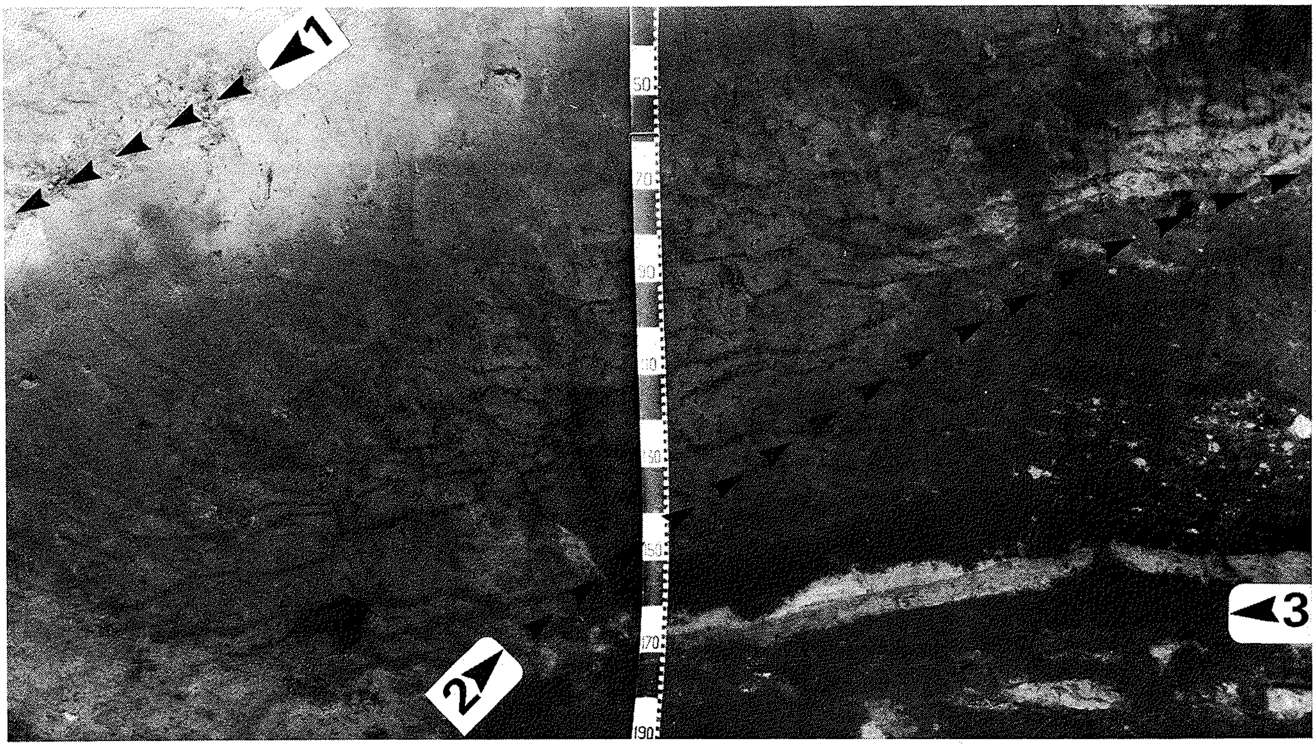
wards a sequence with dominance of E horizon, B2t horizon and C horizon material successively (fig. 8). This time the earth has not been crushed and clods of original soil up to 15 cm diameter can be observed (fig. 8). It is, however, most likely that the soil material was systematically packed down during the process of dumping. Otherwise we would expect traces of «ripening» or sediment settling, such as vertical wedge-shaped cracks and a subsidence of the living floor of this phase in the central part of the motte. Careful examinations of the vertical and horizontal sections through this layer, which represents several tens of cubic meters of dumped material, did not permit to detect any of these settling characteristics.

4:
The soil (Soil 8) of this phase has at least some characteristics in common with Soil 1 (§ 3.1./2:) and Soil 2 (§ 3.2./2:). The soil has a rather uniform thickness (12-16 cm), has a uniform very dark brown to very dark grayish brown (10YR 2.5/2) colour and has a smooth and abrupt lower boundary locally interrupted by some small (less than 3 mm in diameter) worm galleries filled up with dark greyish earth from the surface horizon. The soil contains a little percentage of charcoal fragments, up to 1 cm long and some small brick and baked earth fragments. This living floor is not compacted as in Soils 3, 4, 5, 6 and 7 and the presence of only a few biogalleries makes us conclude that this was probably the plow layer of a kitchen-garden. Today the process of plowing doesn't permit us to detect whether or not there was originally another type of living floor, such as a farm-yard.

5:
A new soil characteristic, present at various degrees of intensity throughout the whole 2 m thick sediment deposited during the seventh phase of motte construction, are somewhar darker coloured clay accumulation fibres (fig. 9 and 10). They are mostly only a few millimetres thick (fibres), but may reach a thickness of 2-3 cm (bands), occur at intervals of a few millimetres up to a few centimetres and are roughly parallel to the surface of Soil 8. The most important set of fibres occur in the finely crushed material of the original outer earth wall (§ 3.8./3:).

6:
It is well known in pedology that the clay dispersion and migration processes are particularly active at pH conditions between 5 and 6.5. As the earth of the Scc type of soil, which was brought here to raise the motte surface (§ 3.7./4:), is a rather acid soil (pH below 5.0) we can conclude most probably that the plow layer of Soil 8 was regularly enriched with lime or calcium carbonate, or the pH of the

Fig. 11: The present-day surface soil of the motte.
1: surface of the motte,
2: 130 cm thick layer in which all archaeological traces vanished as result of several centuries of strong bioturbation by worms and moles on a meadow-covered motte surface; clay-humus accumulation-bands more or less parallel oriented to the present-day surface of the hill are observable in the lower half part of the layer,
3: plow layer of Soil 1,



soil was raised by dumping ash regularly as a fertilizer. Latter hypothesis would be one argument more for considering Soil 8 as part of a kitchen-garden.

3.9. Eighth Phase of Surface Raising, Soil 9

1:

The eighth and last phase of motte construction (fig. 2, 3, 11) raised the surface with another 110-120 cm. Because of the pedogenetic processes of bioturbation, structuration, clay-humus eluviation and clay-humus accumulation it is today very difficult to detect the exact technique of motte raising applied in this phase and the nature of the earth which was dumped down (fig. 11). More detailed field and laboratory investigations will have to be carried out to come to more precise conclusions. For the moment we can only state that the earth had a loamy sandy texture and that at least some of it was composed of fragments from a Scc type of soil, as described for the fifth (§ 3.6./3:) and seventh (§ 3.8./2:) construction phase.

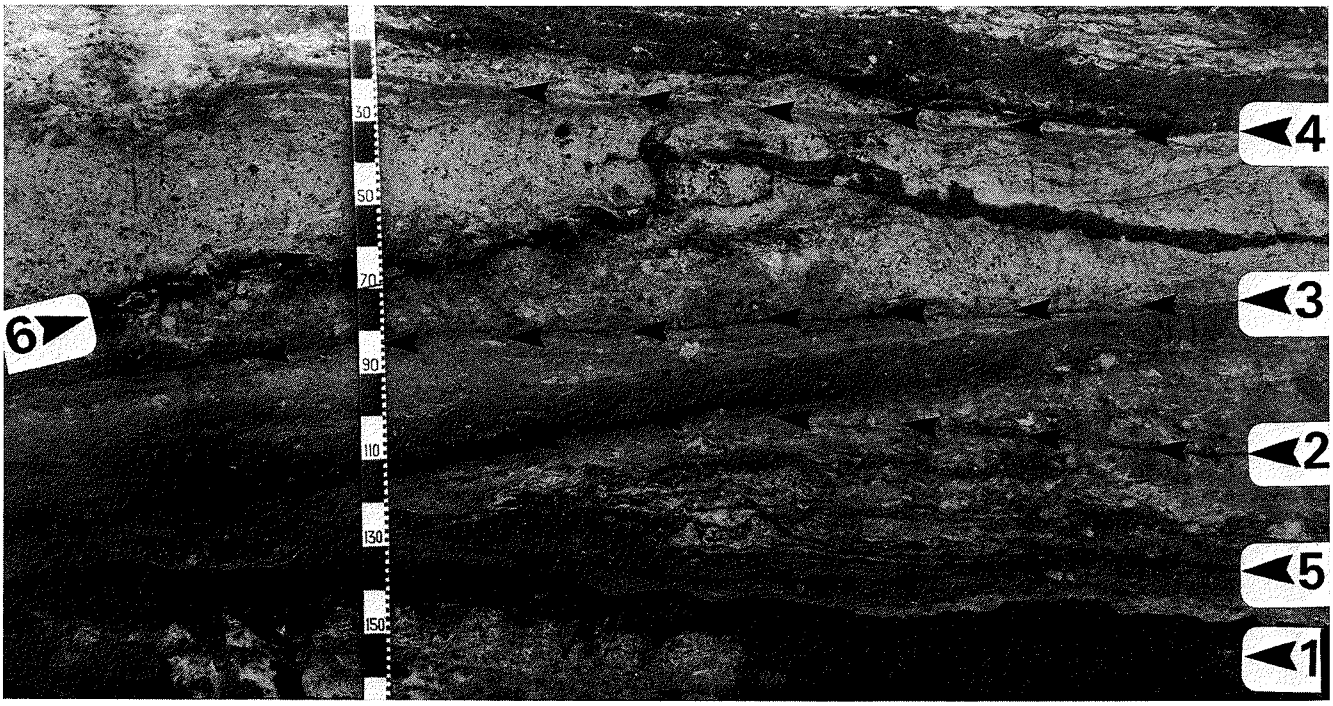
2:

The soil (Soil 9) of this phase (fig. 11), which covers the whole surface of the present-day motte, has a 50 cm thick very dark grayish brown (10YR 3/2) homogeneous surface horizon. The lower boundary of this horizon is very irregular because of the abundant vertical, subvertical and oblique faunal galleries which cross this boundary and of which most are filled with dark grayish material from the surface horizon. Many of these galleries are made by *Lumbricus terrestris*, the largest earthworm in this region (galleries up to 8 mm in diameter). The larger galleries, with a diameter up to 5 cm correspond to moles. Between 50 and 80 cm depth about 50 % of the soil volume is composed of these filled-up faunal galleries, some of which extend further down to about 100-120 cm depth.

This deep and intensive bioturbation by earthworms and moles is characteristic of 1) an A1 horizon 2) a meadow with 3) a high input of manure from grazing animals, 4) a long period (at least several centuries) of pedogenesis and 5) no erosion. The absence of erosion since many centuries is confirmed by the nearly constant thickness of the soil horizons all over the motte, including the flat upper surface, the convex shoulder and the straight slope positions.

The deeper horizon of Soil 9 is a rather uniform yellowish brown (10YR 5/4) horizon in which we can observe only locally some undisturbed fragments of the original dumped earth.

Fig. 12: Hydromorphic iron-manganese accumulations.
1: plow layer of Soil 2,
2: farm-yard surface of Soil 3,
3: farm-yard surface of Soil 4,
4: farm-yard surface of Soil 5,
5: thin iron-manganese accumulation fibre in soil 3; the soil above this fibre is in stronger reduction conditions (more water-saturated) than below this layer,
6: thick iron-manganese crust in the fill of the fourth surface raising phase; here the more strongly reduced zone is situated below the crust.



3:
Soil 9 presents two facies in function of the relief position. On the flat upper surface of the motte, the soil has the characteristics described in previous paragraph. On the slope positions it has in addition from 60-70 m depth a series of clay-humus accumulation bands (fig. 11). These dark grayish brown (10YR 4/2) bands are up to 2-3 cm thick, are roughly parallel to the present-day surface and occur at distances between a few centimetres and 15 cm. In the positions lower than the mid-slope these bands occur also in the material underlying the earth deposited during this eighth phase of motte construction and on the footslope position they may reach up to 150 cm depth. That these accumulation bands are thicker than the clay-humus fibres described in Soil 8 (§ 3.8./5:) may be attributed to the longer period of pedogenesis of Soil 9. Also here we can assume that the original earth dumped in so as to raise the motte surface, was rather acid (cfr § 3.8./6:) and consequently not a very favorable environment for colloid dispersion and migration. Also here we can suppose that the pH of the surface soil has been raised in order to obtain a better crop (meadow) growth. The absence of charcoal and burned earth fragments bring us to the hypothesis that most probably this soil has been limed (addition of calcium carbonate)

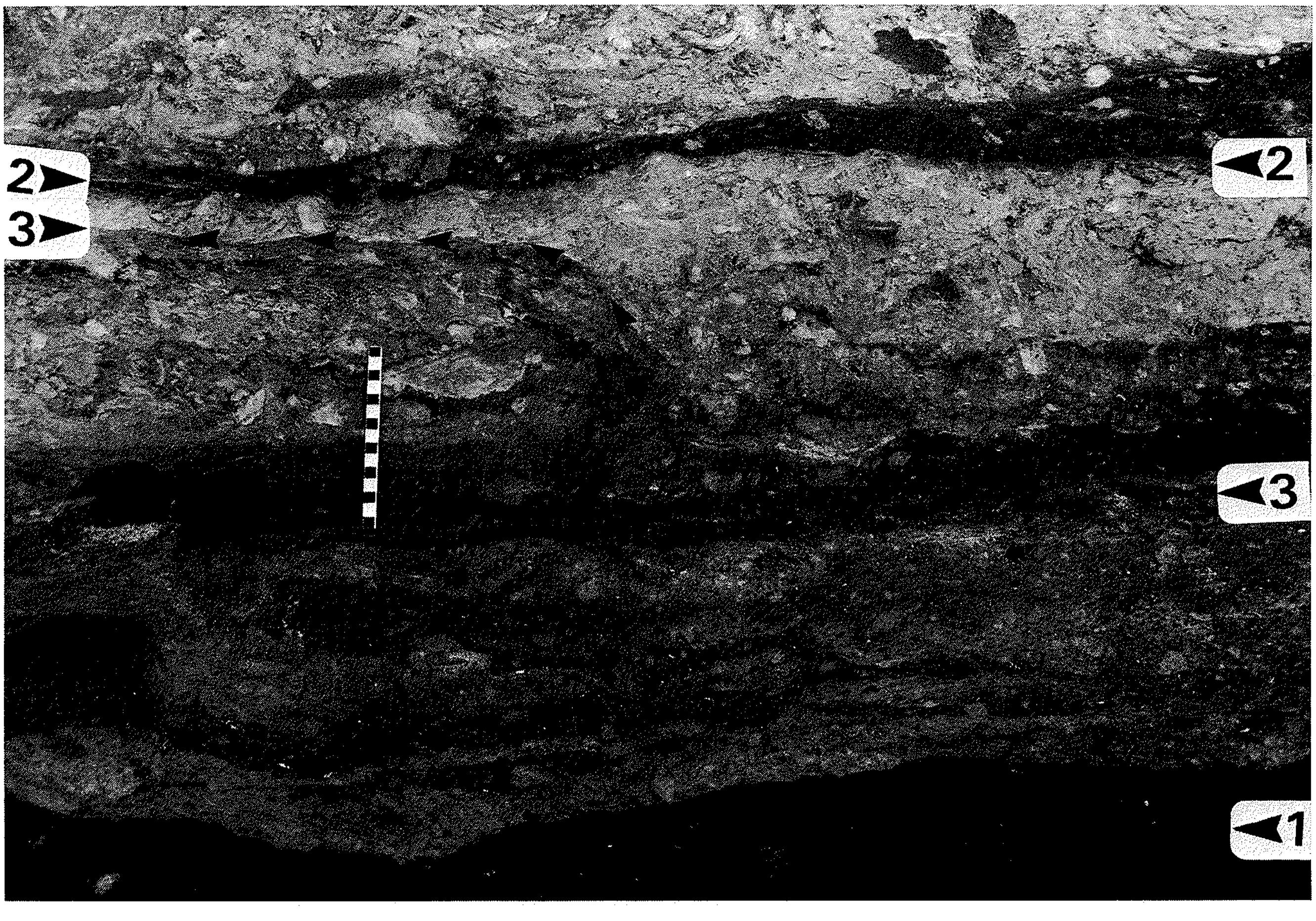
4. Other Soil Characteristics

The field prospections did permit to detect two soil characteristics which have not been mentioned in chapter 3.

4.1. Permanent Water Saturation

At the level of the motte the permanent water table would normally be present at about 1.5 m depth. This is where we observe the present-day water table, but only at the outer part of the motte. Towards the central part of the hill the permanent water table rises up to nearly 2 metres higher into the motte. This slope in the water table is not smooth, it has several pockets extruding outwards, probably related to the different permeability of the numerous layers of dumped earth and compressed habitation surfaces that occur in these lower 2 m

Fig. 13: Hydromorphic iron-manganese accumulations.
1: plow layer of Soil 2,
2: farm-yard surface of Soil 3,
3: very thin (less than 3 mm), hard iron-manganese crust; the soil above the crust is in stronger reduction conditions (more water-saturated) than below the crust. The color difference between zone A and B is a consequence of the difference in reduction conditions, the material was originally the same.



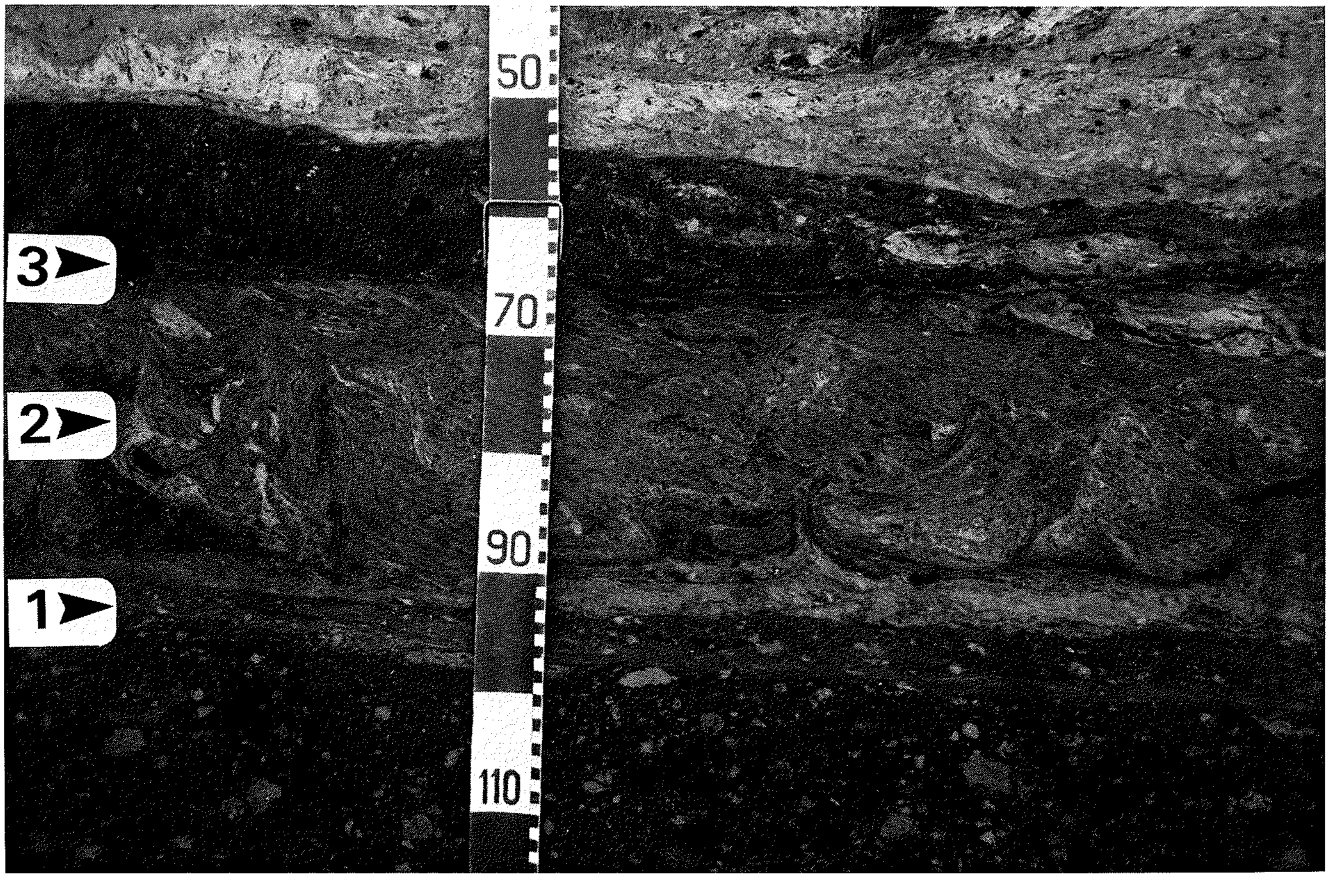
of the hill. The outer limit of the permanent reduction zone is locally enriched in iron and manganese that was dissolved in the reduction zone, migrated towards the water table limit under hydrostatic pressure, and precipitated (fig. 12 and 13) upon contact with a more oxygen rich soil. Locally these precipitations form a continuous and hard crust (fig. 12 and 13) which finally locked up the permanent water. As a consequence of this crust the degree of permanent water saturation increased still more in the central part of the motte.

The presence of this water saturated dome is normal in a hill of the size of the motte of Werken and which has in addition a relatively shallow natural water table in the soil. It is not yet sure to what degree the presence of the successive towers, and their later collapse which created more permeable pockets in the fill, has played a role in the magnitude of this feature. The construction technique observed in the fifth and seventh phase of motte raising, with an initial outer wall of finely crushed, and probably strongly compressed earth, and later filling up of the inner part of the hill with coarser material, may also play a role in the accumulation and final stagnation of percolating water in the central part of the hill. Due to this permanent water-saturated pocket, wood and other putrescible and water-soluble artefacts are much better preserved in this central part of the hill.

4.2. Traces of Puddling

As indicated in chapter 2, the comments made in this paper concern mainly that part of the motte situated outside the habitats (houses, towers). Initial observations of that exposed part of the Carolingean habitat area already permitted us to detect at least one particular attribute which we didn't observe elsewhere. Indeed, some floors in this part of the motte show strong convolutions which resemble some cryoturbation pockets. However, cryoturbation seems to be excluded here because of the textural homogeneity of the material and because of the absence of traces of ice segregation. The size of these involutions and the sharp lower boundary (fig. 14) makes us think about puddling of cattle on a more or less water saturated loose soil layer dumped into a compact subsurface horizon with low permeability.

Fig. 14: Example of a puddled layer.
1: dense, slightly compact paleosurface,
2: layer completely disturbed by puddling, probably caused by horses or cows on a water-saturated loose fill,
3: new stabilization surface.



5. Conclusions

The close collaboration between pedology and archaeology brings new insights in the construction of the motte and also in some of the aspects of its function. In the area outside of the habitat area, nine important stability phases and 8 construction phases of the hill could be detected. Along these successive phases at least 4 different construction methods have been applied. In the first 4 phases the earth came probably from the immediate vicinity of the motte, afterwards it was taken from over a distance of at least several hundreds of metres.

The stability phases are characterized by particular soil types. Also here a sequence is observed. The first two soils seem to be plow layers, in combination with some periods of grazing; the next 5 soils resemble much to farm-yard surfaces, the eighth soil is interpreted as most probably a kitchen-garden and the ninth soil, which is the present-day soil surface, has a characteristic morphology of a very stable meadow with grazing cattle. From these data we can conclude that the surface of the motte platform had at least over large part of the occupation period a function related to agriculture and livestock protection. Some particular characteristics related to pedogenetic processes of clay-humus migration and accumulation, and of oxido-reduction are also detected. Latter characteristic is related to a water-saturated pocket present in the lower-middle part of the hill. Considering the relative weak development of Soils 3 up to 8, we can conclude that the raising of the motte surface was performed in a relatively short period, i.e. less than a few centuries, possibly in 1-2 centuries.

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