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Dwelling on peat; fissures as a recurrent feature of prehistoric structures built on peat in the Western Netherlands

This article presents a discussion of a recurrent phenomenon in settlements on peat in the Western Netherlands which has received little attention so far: the presence of fissures through the peat along the longitudinal and usually central axis of prehistoric dwellings. These fissures show a characteristic asymmetrical shape and a fill which consists of often well preserved anthropogenic floor layers and occupation debris. The data stem from several habitation sites, all located on meso- to oligotrophic peat in the Southern area of Midden-Delfland and dated to the Middle Iron Age to the Roman period. Most structures within these sites were badly disturbed by geological processes that took place during the Late Iron Age and possibly during the Roman period.

A review of the literature revealed that such fissures occur regularly in other peat sites in the Western Netherlands, also on sites with no post-depositional disturbance. In this article it is argued that fissuring took place at least partly during and because of habitation. The pressure exerted by the buildings themselves and by the many floorlayers caused compression and cracking of the soft and instable subsurface. As the pressures of the wooden building frames are down- and outwards across the structure, this will result in fissures along its long axis. In Midden-Delfland, these disturbances were aggravated by post-occupational processes. The latter caused subsurface disintegration and erosion of the softer peat layers below the occupied areas, which in turn resulted in the further sagging and breaking up of the habitation remains to various degrees.

1. Introduction

Within the framework of large scale environmental reconstructions in the polders of Midden-Delfland, designated as a ‘green zone’, a number of archaeological sites were and are being excavated prior to destruction. Some sites were known from a survey (Bult 1983); others were discovered while being destroyed during reconstruction works (Abbink 1993; Van den Broeke 1991; this vol.).

Since the start of the project in 1987 six sites with habitation remains dating from the Middle, Late and Roman Iron Age were partially or completely excavated by the Institute of Prehistory of the University of Leiden (except site 16.48[1]) (fig. 1). All sites were located on meso- to oligotrophic peat and at each, except at site 16.10, the remains of two or more farmsteads were recovered.[2] Rebuilding at the same location is thus characteristic for the Iron Age occupation in Midden-Delfland, in contrast with the peat settlements of the Assendelver Polders (Brandt *et al.* 1987) and those in the Southern parts of the Meuse estuary (Van Trierum 1992, 73, 82) from the same period.[3]

Site 16.59 contained the heavily damaged remains of at least two successive building phases from the Iron Age. At *c.* 25 m distance a 1st century AD farmstead (site 16.24) was excavated (Abbink/Frank 1991). Site 16.48 also contained a probably Roman period farmstead built over a Middle Iron Age predecessor (Ter Brugge 1992). Site 15.04 and site 11.07/17 are the largest Middle Iron Age habitation areas excavated so far. At 15.04 the remains of six buildings could be distinguished at several building locations (Abbink 1989); three, possibly four, structures were built successively in a small area at site MD 11.17, while the remains of at least two more buildings were present within a distance of *c.* 50 m, at site MD 11.07 (Koot 1993).

All of these farmsteads were badly damaged. The construction wood and floor layers were preserved only insofar they had collapsed into the peat fissures or had otherwise subsided to a level much lower than that of original habitation. Fissures were present in all of the excavated farmsteads in Midden-Delfland. Those of site MD 15.04, the first large scale excavation in Midden-Delfland, are the basis for the descriptions and ideas in this article as their shape, location and fill proved to be characteristic for most other sites (fig. 2).

Figure 1. Midden-Delfland. Polder names with sites excavated by the IPL (a) and the three redevelopment areas (b). The first two digits of site numbers refer to the individual polders.
Circle: Iron Age sites.
Triangle: Roman period sites

The natural stratigraphy is more or less the same in all sites, (fig. 3). Reed peat developed on a Dunkirk 0 deposit (A2, fig. 3). In most sites the formation of this peat was interrupted by a thin clay deposit (B2, fig. 3). The C14 date of the first peat on this deposit was dated to 2730 BP ± 45 (GrN-16754) and 2970 ± 35 (GrN-16914).[4] The reed peat gradually changed into mesotrophe and/or oligotrophe peat (cushions) during the Early and Middle Iron Age. At the time of the Middle Iron Age settlements the total peat cover (A1+B1, fig. 3) must have been at least 2 m thick. At present the remaining thickness of the upper layer (B1) is usually less then 20 cm in 'undisturbed' circumstances. The decay is due to drainage and subsequent oxidation of the peat since the Medieval period. This also resulted in the decay of all organic remains from the prehistoric occupation under such circumstances.

During the Later Iron Age, flooding took place in most parts of the Meuse estuary, referred to as the Dunkirk I deposits (Van den Broeke, this vol).[5] However in the area discussed here the influence was largely indirect; geological disturbance mainly occurred below the surface in the form of erosion of the weaker (reed) peat layers above the first Dunkirk 0 deposit (A2, fig. 3) (Abbink 1989). The process taking place was one of increased waterlogging of the peat and the formation of lake-like areas in which 'islands' of peat were lifted upwards, but where very little movement of water and material took place.[6] The force of water action was especially reduced below the inhabited areas.

These post-occupational processes had both negative and positive effects on the archaeological remains. They caused damage in most of the excavated sites, but in varying degrees. There is a relation between the degree of disturbance and the density of the occupation itself. In some areas within and around inhabited areas the original peat cover was completely destroyed and redeposited as laminated layers of clay mixed with organic matter, sometimes including redeposited occupation material; this occurred most often at the border of and around the occupied areas. Subsurface erosion was usually less intense below the habitated areas and even less so where habitation

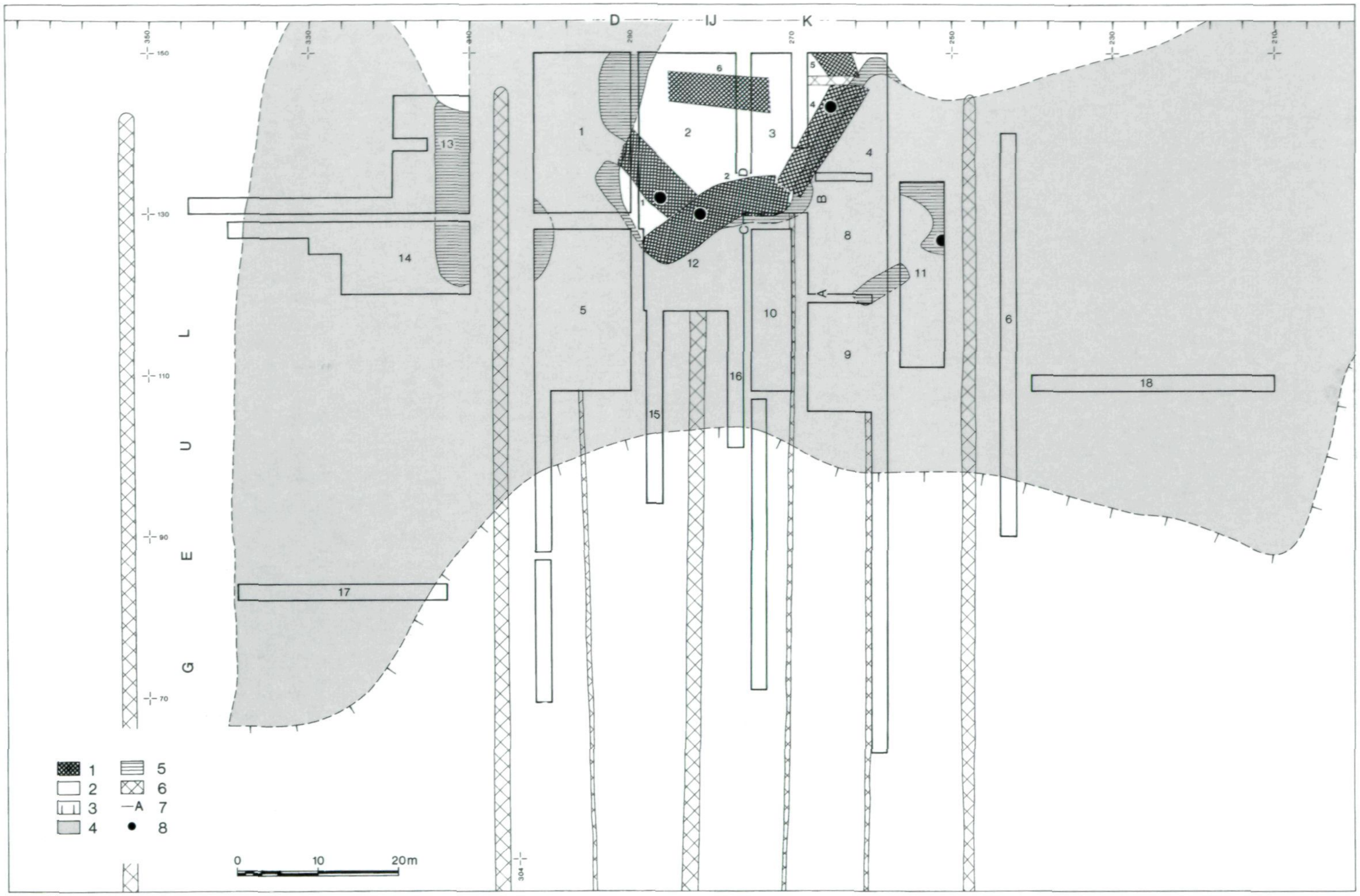

Figure 2. Foppenpolder, site 15.04. Preliminary plan of the excavations with: building remains preserved in fissures in zone 1, possible building remains or activity areas in zone 2 (badly disturbed by postdepositional processes)
1. Buildings 1,2,4,5,6 in zone 1; 2. Zone 1, oligotrophic peat with habitation remains; 3. Zone 2, oxidized peat without habitation remains; 4. Zone 3, disturbed; redeposited peat and clay; 5. Concentration of remains of habitation in zone 3, including a possible house (house 3) in trench 8/11; 6. Modern ditch; 7. Sections; 8. Hearth; Drawing by I. Stoepker, IPL.

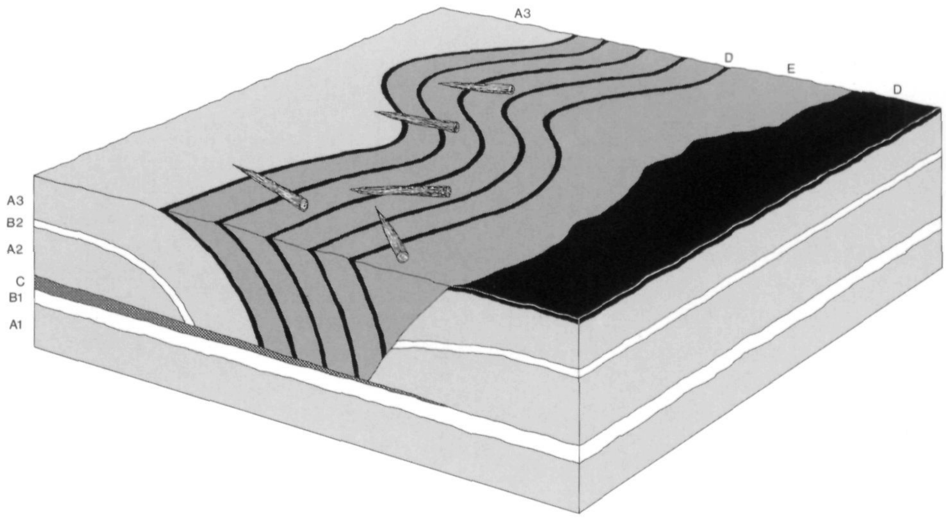

Figure 3. Schematic representation of *fissures* in buildings. On the right the 'undisturbed' stratigraphy in Midden-Delfland at present: the upper peat layer (A3) is oxidized and the organic material of the habitation is decayed. Note the break in the natural peat. On the left the still coherent peat (A2, 3) and floorlayers (D), sunken and tilted towards the deepest part of the fissure (E), filled with debris of floors, wood and other occupational remains. Drawing by H. de Lorm, IPL.
A1, A2, A3. Holland peat; B1. Dunkirk 0, early deposit; B2. Dunkirk 0, later deposit, c. 1200 BC; C. subsurface intrusion and erosion horizon with mixed peat/clay deposit; D. (tilted) floor layers; E. occupation debris in central part of the fissure.

remains were particularly dense. Subsequently less damage was done to the occupation levels.

The same processes however also resulted in the preservation of organic remains, such as wood and floor layers. Part of the prehistoric buildings and their internal features were displaced downwards after the retraction of the water to below the present day watertable, thus saving them from the post-Medieval oxidation and decay. Site 16.10 is the only site where neither flooding nor subsurface intrusion took place. Here little or no organic occupation material survived.

However in the formation of fissures, factors other than these post-depositional disturbances must have been involved as such fissures are also found in sites where no flooding or waterlogging occurred.

2. Construction and use of prehistoric farmsteads in Midden-Delfland

Before turning to the discussion of the fissures, the construction and use of the farmsteads will be discussed briefly. Due to the disturbances mentioned above no reconstruction of a complete farmstead, *i.e.* its total length, width and specific construction could as yet be made. The available evidence indicates however that most of the Iron Age farmsteads were similar to the better preserved examples excavated elsewhere in the region (*e.g.* Van Trierum 1988, 1992; Wind 1973).[7] The wooden structures had at least two, but possibly three longitudinal rows of internal roof supports. The upright posts in the wattled walls probably also had a roof-supporting function.

In Rockanje 8-52 (Van Trierum 1992) and Broekpolder (Wind 1973) there are indications, as at sites MD 15.04, 11.17 and 16.59, that double and/or closely spaced posts were used, both for the internal roof supports as for those within the walls. The majority of the posts were made of roundwood of ash and alder, the bark still attached. The diameters varied but seldom exceeded 12 cm. If they did the tree trunk was cleft into two, four or eight parts (Abbink 1993; Vermeeren int. report; see also Wind 1973). Whether or not extra supporting posts were present outside the walls or if posts were placed along the central axis, as is the case in many farmsteads at Voorne-Putten (Van Trierum 1992), could not yet be established for the farmsteads in Midden-Delfland.

Data from the better preserved dwellings suggest the usual division into a stalling area and dwelling part with a hearth. Frequently renewed floor layers were a recurrent feature within the farmsteads of Midden-Delfland (figs 4, 5), as in all other sites of the region (tab. 1). The standard procedure was as follows:

First, a layer of dung was laid out on the old land surface. The dung was covered by a layer of reed or sedge, usually laid out in a neat criss-cross pattern. In the Roman period farmstead of MD 16.48 a layer of branches was found incorporated within a floor (see also tab. 1). These layers formed the habitation surface, represented by a layer of ash, charcoal mixed with any kind of debris produced by animals and humans, *e.g.* dung, potsherds, butchery- and food remains. Such floors were constructed in both dwelling and stalling area, although the latter may have contained more dung. It is very likely that the floor, especially the manure, was meant to protect the soggy and vulnerable old landsurface.[8] After a while the floor was renewed in the same manner, again including manure. That the renewal of floors took place within the existing structure is shown by figure 5; the bundles of reed were carefully laid out around an upright post. In house 2, MD 15.04, at least five of such floors were still preserved with a minimum total thickness of 70 cm. (fig. 4).

At present we do not know how long a dwelling would have been in use and how often the floors were renewed. The only indirect evidence is provided by dendrochronological dates for four Roman period buildings at Nieuwenhoorn. The time between the different phases varies from 6-23 years (Brinkkemper/Vermeeren 1992; also Van den Broeke this vol).[9]

3.1 FISSURES THROUGH BUILDINGS IN MIDDEN-DELFLAND

The main characteristic of these fissures is their asymmetrical shape and fill in cross-section (figs 3, 4). Figure 3 is a schematic representation of some essential recurrent features:

- One side, the right in figure 3, is steep, formed by a near vertical, clean break through the peat and clay layers (A1, B; A2), but usually not extending further than the Dunkirk 0 clay layer A2. In some places large chunks of peat were on the verge of breaking off the main body on this side. Outside the limits of the fissure the natural layers are still present in their original horizontal position, but the peat is much reduced in thickness because of oxidation and decay, while the floorlayers and building wood have decayed completely.
- The deepest part of the fissure is the U or V shaped area, often situated just in front of the vertical break, containing a soft, structureless mixture of bits of floors and occupational debris.
- The opposite side of the fissure is defined by gently sloping and coherent peat-, clay- and floor-layers, without a break in the (natural) layers outside the fissures. Within the fissure the original stratigraphy of both peat and floor layers are very well preserved, as are the organic materials themselves, even though or rather because they are all tilted down towards the deepest part of the fissure. In some places the floorlayers were tilted as much as 90 degrees!
- All fissures occur along the longitudinal axis. The deepest part is usually located more or less along the central axis (as reconstructed from the position of the wattle walls and the hearths). An exception may be site MD 16.59 where a fissure seems to occur along the long wall.[10] The side with the sloping layers generally extended up to the long wall of the building, which was found collapsed to a horizontal position or even tilted downward. Parts of walls, like the floors, survived more or less intact in most houses, but notably in house 1 and 2, MD 15.04 and house 1, MD 16.59. On the opposite side however the long wall had usually completely decayed as it was situated outside the fissure. There is as yet little evidence about the short ends of buildings in Midden-Delfland, but there are indications that the faults narrowed or stopped towards these sides.

The above, and its representation in figure 3, is an idealtype description of the form and fill of fissures. Much variation was observed in the depth, width and fill of the fissures both between and within farmsteads. In site 15.04 the depth to which floor layers had subsided varied from *c.* 50 cm (house 6) to more than 1 meter (house 1 and 2); the total width also varied but is usually more than 3 m, *i.e.* the fissures extended over more than half the width of the buildings. In general there appears to be a relation between the width and depth; the smaller cracks are also less deep with less disturbance of all features. The thickness of the surviving peat and floor layers varies with the depth of the fissure: in house 2, MD 15.04, the floors measured 70 cm at the point where they were maximally preserved. The maximum recovered thickness of the upper peat layer (B1) was 1.20 m. Both the peat and floors are likely to have been much thicker originally.

Moreover the degree to which the original stratigraphy was disturbed, can vary considerably from one meter to the next within most houses. The length over which the original stratigraphy was preserved was seldom more than 2-3 m. The floors can be badly broken up into small chunks, displaced both horizontally and vertically. The position of the centre of the fissures (E, fig. 3) also varied in relation to both sides.

To sum up, the fissures in the Midden-Delfland buildings are characterized by their asymmetrical shape and fill as well as their whimsical course throughout one building.

Figure 4. Section through tilted floorlayers in the fissure of house 2, site 15.04, Foppenpolder

Figure 5a. Renewed floorlayer put on around a small post, house 2, site 15.04.

Figure 5b. Detail.

3.2 Parallels in the western Netherlands

The discussed features of the Midden-Delfland farmsteads are by no means exceptional. Since the 1950's quite a number of farmsteads located on peat have been excavated in the Western Netherlands, notably in the Assendelver Polders and the Meuse estuary. Table 1 lists the indications for the presence of fissures and/or "pressed down" floor layers within these farmsteads. Although most publications are of a preliminary nature it was possible to deduct many similarities between Midden-Delfland and those sites, sometimes with the help of the original field drawings and photographs. In all of these peat settlements floor layers consisting of dung, reed and/or wood (twigs and branches) were observed.[11] The presence of a fissure through the centre of the farmstead could be definitely established for the Iron Age peat sites at Kethel (IA 11), Hargpolder (IA 10), Broekpolder (IA 13-9), Holierhoekse Polder (IA 24-8), located in the immediate vicinity of the Midden-Delfland sites.

The shape and fill of the fault at site Q in the Assendelver Polders (Therkorn 1987) is very similar to those in Midden-Delfland. Van Trierum (1992) mentioned fissures in several settlements, south of the Meuse. In Spijkenisse 17.35 the fissure is related to the post occupational processes comparable to those in Midden-Delfland. In site 17.34 the fissure was filled in during occupation, *i.e.* before the DI flooding of the site. In site 18.50 (ibid, 72) a layer of dung was present in the centre of the byre, whereas a fissure was observed running along one of the walls.[12] In Nieuwenhoorn (site 09-89, Roman period) a fissure formed along one of the walls during occupation and 'forced the inhabitants to rebuild' (ibid, 88).

Both subsidence and fissures are often more pronounced within the stalling area, but also extend into or occur in the living area, as for example in site 10 (Hargpolder) with a tilted hearth and site 11 (Kerklaan) and Spijkenisse 17.34, see table 1. In the Midden-Delfland farmsteads fissures through both parts are usual.[13]

Altogether the data show that the construction and renewal of floors in living and dwelling areas was a standard procedure within (and sometimes also outside) buildings on peat in the Western Netherlands, whereas the association with fissures is a common phenomenon. There are however several settlements and buildings on peat without such fissures, for example most of the (Roman) Iron Age buildings on peat in the Assendelver Polders, several buildings in the Voorne-Putten sites (Van Trierum 1992) and those in some Roman period settlements in Schiedam (tab. 1).

4. Interpretation and hypotheses

There are thus two basic questions concerning the fissures: a. when and how and b. why do they take place?

4.1 How and when did fissures develop

The first question is whether faulting took place during or after occupation or both. The data provide evidence for both. Although the post habitation processes in the Meuse area, discussed above, were partly responsible for the subsidence of occupation remains, they cannot be the sole cause as fissures also occurred in locations without such influence. Moreover, subsurface erosion cannot explain the specific form and location of fissures within buildings. The following arguments can be put forward to associate fissures with the occupation itself:

- There is ample evidence, specifically in the thickness of floorlayers, that the floors compressed the underlying peat and consequently subsided during occupation. Going in or out of the house and stalling cattle would otherwise have become difficult if not impossible. The compression is no doubt due to the pressure exerted by the weight of the floors, which was increasing with every new floor.
- The shape and fill of the fissures suggest that some form of disintegration, perhaps oxidation?, of the natural peat took place below the occupied surface. It seems likely, that this is associated with the development of a (vertical) fault. These faults may have started out as small more or less V-shaped cracks which slowly but surely deepened as well as widened. The mixed and structureless fill in the centre of the fissures and the 'near' breaks in the peat suggests a continuous process of bits of peat- and perhaps floor layers breaking off. This indicates that cracking took place during occupation and that the inhabitants kept on repairing the cracks by filling them with debris and dung (as was clearly the case at site Q and Spijkenisse 17.34). So far, no direct evidence of such repairs was found in the Midden-Delfland sites.

Site Q is by far the most informative example with clear evidence for actions of the inhabitants in reaction to the widening and deepening of the fault during occupation. Therkorn (1987, *fig.* 6) *mentions the sliding down of floor* layers and snapping of the ground plate between the stalling and working area. Repairs were made during occupation, such as a wooden revetment along the fissure in part of the byre. This revetment however also slided down. The groundplate for the dividing wall was repaired as well and then covered again with new floors (ibid). The fissure at Spijkenisse site 17.34, which as an exception occurred outside the dwelling, was also filled in during occupation. According to Van Trierum it was probably caused by the presence of the creek (pers. comm.). These observations clearly confirm that fissuring took place and became worse during occupation.

Supporting evidence was found in MD 15.04 and 16.10: In MD 16.10 numerous small cracks were found in the remaining natural peat with tilted remains of floors and debris (mainly consisting of sandy clay and much decayed organic material). Tilting and subsidence was more pronounced around the hearth. However, any evidence for repairs was lost due to the bad preservation of floors and peat. The small fault of house 6, MD 15.04 (fig. 6) showed that a U-shaped hollow had formed in the peat below the surface, which was filled with a chunk of broken off and pressed down peat covered by a small section of floor levels.

To summarize, these data suggest three hypotheses about when en how fissures occurred:

Firstly, small cracks were being formed from the beginning of occupation onwards and gradually developed into a large continuous fissure.

Secondly, some form of peat decay took place within the fissures leaving empty spaces into which occupation levels subsided especially along the central axis of the building. Repairs of floorlayers in this area must have been an ongoing process.

Thirdly, the (final) tilting of the peat and floor layers as stratigraphically coherent units at one side of the fault

Table 1. Parallels for fissures in peat sites the Western Netherlands

DESCRIPTION FEATURES:

a. Site name (local designation), location and municipality, OS: Ordnance Survey map, dating, publication
b. Type of floors
c. Evidence of subsidence and/or fissures
d. Evidence for post habitation (subsurface) erosion and/or flooding during the Later Iron Age/Roman period. Dunkirk III deposits will not be mentioned here.

IRON AGE

1a. **Site Q, Assendelver Polders**, 25 W, EIA, Therkorn e.a. 1984
1b. Stalling area: dung, straw, twigs.
Dwelling area: sand, dung, wood shavings, turfs.
1c. Fissure through the stalling area, extending into the partition and dwelling area, filled in during occupation with dung and other materials.
1d. None

2a. **Site 24-8, Holierhoekse Polder**, mun. Vlaardingen, 37 O, EIA, possibly two phases. Havelaar 1970, Wind 1973, van Heeringen 1987
2b. Stalling area: dung, ash, burnt bone
Dwelling area: 'reed', possibly clay on manure
2c. Text and field drawings: Wedge-shaped fissure (50-70 cm deep) through stalling area, filled with dung, possibly also below hearth
2d. A thin layer of clay within the floors of the living area is interpreted as flooding; however this layer almost certainly part of the floor structure as it is absent in the stalling area.

3a. **Site 13-9, Broekpolder**, mun. Vlaardingen, 37 O, M/LIA, possibly two phases, Van Heeringen 1987,Wind 1973
3b. Stalling area: dung, ash, sand
Dwelling area: Reed floors (manure not mentioned)
3c. Text and field drawings: 'Subsidence of dung and debris of more than 1 m. **with disturbance of underlying peat layers'** in stalling area (emphasis added)
3d. None.

4a. **Site 10, Hargpolder**, mun. Schiedam, 37 O, IA, Van Heeringen 1987, Verwers 1965. Limited excavation area, mainly dwelling part.
4b. Dung, reed, (possibly ash and clay around the hearth)
4c. Field drawing and photographs (Archives Schiedam): fissure through dwelling area with partly tilted floors and hearth
4d. Post occupation flooding, clay covering floor layers in fissures. No subsurface erosion.

5a. **Site 11, Kerklaan**, Kethel, mun. Schiedam, IA, 37 O, Van Heeringen 1987, Verwers 1965.
5b. Dung, reed
5c. Field drawings: fissure in most of the excavated area (which includes part of the stalling and living area) filled with floors and manure, with partly collapsed wall,
5d. No data

6a. **Site 17.35, Spijkenisse**, EIA, OS 17, Van Trierum 1993.
6b. Stalling area: dung, reed.
Dwelling area: dung, no later floors surviving
6c. No clear indications. However along both long walls Dunkirk I deposits were present below the structureal remains (wood).
6d. Post occupation (sub)surface erosion and flooding.

7a. **Site 17-34, Spijkenisse**, MIA, OS 17, Van Trierum 1993
7b. Stalling area: dung on layers of reed
Dwelling area: tree trunks covered with twigs and manure. The yard was covered with a thick layer of manure, vegetable material, ash and occupation debris (p61)
7c. Text: Peat fissure from the short wall of the living area towards the creek. The fissure was filled in during occupation with branches, dung and sods (thickness 30 cm) and had formed before subsurface erosion (pers. comm. Van Trierum)
7d. Post occupation (subsurface) erosion.

8a. **Site 10-28, Spijkenisse**, MIA, OS 10, Van Trierum 1993
8b. No data
8c. Fig. 47: peat fissures along the long walls
8d. Post occupation flooding and deposition of clay

9a. **Site 18-50, Spijkenisse**, MIA, OS 18, Van Trierum 1993
9b. A layer of dung through the middle of the stalling area 9c. As the layer of dung is partly lying below the level of the wooden beams of stalls this indicates subsidence in central part of byre.
9d. No data

10a. **Site 09-89, Nieuwenhoorn**, Roman period, OS 9, Van Trierum 1993
10b. The farmsteads were built on a raised platform (partly made of dung), more than 1 m. thick, on an oligotrophic peat cushion.
10c. A fissure along the (Southern) long wall "which forced the inhabitants repeatedly to rebuilding" (p89)
10d. Surface deposition of Dunkirk I clay, no subsurface erosion.

ROMAN PERIOD SITES ON A THIN D1 CLAY DEPOSIT ON PEAT

1a. **Schiedam, Nieuwlandse Polder, site IR 1**, 37 O, Apon 1960: Site IR 1
1b. Floors consisting of twigs, clay and peat sods with a thickness of 60 cm in living area.

2a. **Schiedam, Nieuwlandse Polder, IR 2e,** 37 O, Apon 1960: Site IR 2e
2b. Floors with a thickness of 60 cm.

3a. **Schiedam, Kethel**, Roman IA, Modderman 1973
3b. Field drawings show a subsidence of floors (consisting of small tree trunks, twigs, manure and reed) of at least 40 cm. Outside the dwellings the yard was 'heigthened' towards the creek with twigs, dung, peat and occupation debris, with a total thickness of 1.20 m, also indicating considerable subsidence. There are no indications for fissures and/or tilting of floors.

Figure 6. Section through the small fissure of house 6, site 15.04, Foppenpolder, showing blocks of broken off peat and floors.

(figs 3, 4) partly points to a post occupation origin. This type of subsidence must have been a very gradual and slow process as both floor- and peatlayers were found broken off together as one unit. A post occupation date is also suggested by the presence of chunks of floorlayers and the sometimes chaotic distribution of twigs and structural wood in the fill of the fissures. This phase can be linked with the postdepositional subsurface erosion (see below).

However, it can also be argued that the final 'snapping' of the peat and consequently the sagging of the peat-floorlayers as a coherent unit took place after a period of occupation, but before the postdepositional changes. Taking site Q, Assendelver Polders and MD 16.10 again as an example, this tilting occurs in the same manner in sites without such postdepositional disturbances. The main difference seems to be one of degree rather than kind of subsidence, fissuring and tilting. It is suggested here that the final snapping and the development of one large fissure ultimately led to abandonment of the building.

4.2 WHY DO FISSURES DEVELOP?

The second major question is why cracks did develop in some cases or indeed why not in others. There are three seemingly obvious explanations for the existence of fissures during occupation which are also mentioned in the literature.

Therkorn (1987) suggested that the house was built over an already existing fault in the peat, which the inhabitants filled up with manure and used as a 'natural' dung drain.

Alternatively, the inhabitants themselves dug a gully through the centre of the byre, as a manure drain as suggested by Havelaar (1960) and Wind (1973). Both explanations are unsatisfactory. Considering all examples collected here it seems very unlikely inhabitants of peat areas built their houses by happenstance over a peat fault. If done intentionally, I can think of no reasons, rational or otherwise, for such a choice.[14] The weakness of the subsoil and of the manure itself would lead to continuous damage to the surface and would be a danger to cattle as well as humans. Moreover the fissure at site Q clearly worsened, *i.e.* became wider and deeper during occupation.

Clearly the data from site Q can be interpreted in a different manner in light of the Midden-Delfland evidence. The construction of a primary floor directly on the old landsurface as the first habitation layer in all sites discussed here (tab. 1) suggests that the inhabitants tried to protect and conserve the natural subsoil as much as possible. Reinforcements of these floors at areas most trodden on, such as entrance areas, are also a common feature (see Therkorn 1987; Van Trierum 1992). In house 2, MD 15.04 a large wooden platform measuring *c.* 1 × .80 m was incorporated within the floor in what is interpreted as the entrance area (Abbink 1989). The same arguments can be used to reject the idea of a dung drain. Most importantly, this idea obviously does not explain the presence of fissures within a dwelling area or within the wall, as observed in several farmsteads.

More likely the fissures are caused by a combination of several factors and processes associated with the habitation itself.

The first of the arguments in favour of this hypothesis was discussed above, *i.e.* the floors will cause compression of the natural peatlayers and more so after every renewal. The occupation surface will become dirty and mushy after some period of use. The pressure of the floors may have been aggravated by trampling by cattle and humans. Together these factors could result in small cracks and/or destruction of the floor and the peat. Renewal of the floors solved this problem temporarily and also increased the firmness of the foundations. But at the same time this added more weight contributing to subsoil compression and cracking. The archaeological evidence suggests (sub)surface deterioration took place more quickly in the stalling area than in the dwelling quarters and more so in the central parts of the buildings. Repairs of floors could have been an ongoing process before complete renewal took place.

Secondly the wooden structure itself is likely to play an important role. It not only exerts vertical load, but sideward pressures as well. Depending on the specific roof-attachment techniques this pressure will be outwards or inwards: in three- and four-aisled structures such as published by Van Trierum (with only a few central posts) the roof will have been secured at the wall-posts (so-called 'hanging' roof). The pressure of the roof is then directed outwards (pers. comm. drs. J. Flamman, drs. H. van Londen; see also Huyts 1992).[15] Because of the very non-resilient subsoil the whole structure would therefore tend to sag down- and outwards. This might also result in damage to the peat along the central axis.[16]

To summarize, it is suggested here that the combined weight exerted by the structure, the floors and the inhabitants are the major cause for the occurrence of fissures, which must have started to form in the peat itself. The pressure of the floors is mainly downward, perhaps more so in the most trodden areas, *i.e.* the central aisle(s). The load of the structure itself is also outwards from the centre. This could explain both peat-fissuring and the orientation of faulting as being usually along the central, longitudinal axis of the house. Continued occupation probably worsened the situation and it highly probable that the continuous sagging and cracking of peat-and floorlayers finally resulted in the formation of one large fault, causing floors and peat to tilt towards its main course in the end. This hypothetical process however presupposes the decay (oxidation) of the peatlayers in and around the fissures. However, how and why this decay took place and wether or not compression and cracking were the cause of it, is not explained by these processes and remains difficult to explain (see below).

At the same time the continuous adding of floors also consolidated the farmstead interior and perhaps stabilised the subsurface. This solidity could explain why in Midden-Delfland old building sites were so often selected for the erection of new farmsteads.

Faults occurring along a wall as in Spijkenisse 10-28 and possibly MD 16.59 may indicate a different building construction, with pressures directed inwards.[17]

A third and as yet very hypothetical factor which could have played a role in this process is the possible change in water content and circulation in the peat underneath the occupation layers: the load may have pushed the water in the peat down- and outwards and/or caused dehydration of the upper peat layers weakening their structural coherence, whereas the building and floors would cut off the rainwater. Again, why and how differences in water content and pressure would result in a fissure is as yet not clear.
As Casparie pointed out for the peat tracks in Drenthe, subsidence will cause water from the environment to run off to these tracks, which resulted in a better conservation of peat on these tracks. The peat below the tracks was partly oxidized (Streefkerk/Casparie n.d.). Translated to the Midden-Delfland situation this entails that the floors would be well preserved, whereas the peat below might have been subject to oxidization.

Fourthly, post-depositional factors played a role in creating the final situation as encountered in excavations. There is probably a two-way relation between these processes and the shape and fill of the fissures as present at the time of excavation for the sites in Midden-Delfland (and those on Voorne-Putten, Van Trierum 1992):

a. There is an inverse relation between the (density of) occupation remains and the degree and location of erosion: below the remains of farmsteads erosion occurred mainly in the reed peat layers (A2, fig. 1) above the clay deposit. Hardly any erosion took place in the upper peat layers (B1) or below the Dunkirk 0 deposit (A2), which was obviously resistant to erosion. The compression of the upper peat layer and the compactness of the heavy floor layers diminished or even halted the erosive force of the water (which was very weak in the first place) in and below these layers. This explains why house 6, MD 15.04, surrounded on all sides by other farmsteads was not affected by the subsoil erosion.
   The same observations were previously noted for Medieval dwelling mounds (built on peat-mounds) in the Northern Netherlands:

> "In the peat large numbers of often vertical faults were seen, together with large chunks of peat, displaced sidewards and tilted. Many faults had their point of contact with the ditches, others occurred just along the mounds".... Where mounds and dwellings were present, no lifting took place as "the heavy mounds could not float" (Casparie 1987, 5, 7).

Clearly in most Midden-Delfland farmsteads this 'point of contact' was also just at the occupied surfaces.

b. Subsurface erosion must have aggravated the subsidence of the peat and occupation layers within farmsteads surviving above the erosive zone. After retraction of the water these layers slowly sank down and tilted as coherent levels in some places. However the tilting can only be partially the result of this process, as witnessed by MD site 16.10 and site Q for example. In other parts within a building the floors lost their coherence and were broken up into chunks and pieces. Moreover the washing down of ash and dung to the deepest levels, which was noted often, is probably also a post-depositional feature. Clearly the postdepositional processes alone cannot explain why the subsurface erosion always resulted in 'faults' along longitudinal axis, always more or less the same way and the same place. This must be due to already existing conditions, that is to previously formed differences in subsidence and density of the occupation layers within the farmstead. These conditions determined the specific influence of post depositional processes on the occupational remains.

5. Summary and conclusions

The presence of fissures within structures built on peat is the result of several, closely related 'natural' processes, which are set into motion by the habitation itself. The pressures of the structure and floors together lead to subsidence and cracking of the underlying peat in a specific manner.

The evidence suggests that more subsidence and fissuring took place in the centre of the buildings and possibly more so in the stalling area. The habitation layers are probably thicker in the stalling area because trampling by cattle necessitated more frequent repairs of the floors, while the fissures grew larger and deeper because of the weight of these floors and finally resulted in a large fault with floor- an peatlayers tilting downwards.

In other words, it is probable that repairs of the fissure, the floors and of the structure itself were impossible beyond a certain point of disturbance and that this was the main reason to abandon a building! It is also quite likely that the experience of the inhabitants with dwelling on peat led them to use thinner posts and/or lower quality wood species, because they would last for the maximum possible duration of one habitation phase in one building. Following this line of reasoning, the choice of old building sites makes sense as these provided a much more compacted building platform.

After abandonment, post-depositional erosion reinforced already existing faults and/or the subsidence of floors in most of the sites and dwellings in the Meuse estuary, but it is unlikely they were ever causing them.

The explanations offered here for the obviously very complicated processes involved in dwelling on peat are obviously to a large extent hypothetical and by no means final. There are several unexplained aspects of fissures. For example, I can think of no good reason for the asymmetry in their fill and shape. Nor is it clear why fissures occur in some areas and not in others. Finally it is still uncertain why and when the final and coherent tilting of floors, all at the same angle, occurred. Most likely a number of factors together determine whether faults will occur or not, *e.g.* the specific local composition and thickness of the peat layer, the specific water circulation, the presence and especially thickness of clay layers within the peat, the density of occupation etc.

The reasons for the differences in location of fissures, along the central axis or along one of the long walls, are also unclear. This could be connected with differences in constructional details, mainly the distribution of the weight of the roof, *e.g.* with pressure of the structure directed inwards or outwards (see Huyts 1992). A much more detailed analysis of the Midden-Delfland and other peat settlements than executed so far is needed to gain insight into these differences (see postscript 1995). Also if we are to understand the complicated archaeological remains on peat in the Western Netherlands, experiments with dwelling on peat in all its aspects need to be carried out.

Postscript 1995

Since the submission of this article, an excavation was carried out in the Holierhoekse Polder at site 10.07, directed by drs. C. Koot, of a virtually 'undisturbed' 3-aisled dwelling on peat. The data at this site confirm most of the hypotheses and conclusions presented here. A very clear and deep fissure ran through the centre of the building. A clear vertical break was present within the peat and floorlayers, which both were tilting towards this break, but at different degrees and angles on either side. The postoccupational subsurface erosion was very limited and restricted to one end of the house, while the fissure covered the entire dwelling. Altogether, the evidence suggests a final 'snapping' of the peat after a period of occupation, but before the postdepositional changes took place. This confirms the idea that fissuring ultimately led to abandonment of the building or even to partial collapse when still in use.

notes

1 The project Midden-Delfland is a cooperative undertaking of the Institute in Leiden (mainly Iron Age) and the Institute of Pre- and Protohistory of the University of Amsterdam (mainly Roman period). Site 16.48 was excavated in 1987 by the local amateur society Helinium under supervision of J.P ter Brugge, with assistence from the Institute. The excavations at sites 11.07/11.17 were directed by drs. C. Koot, IPL. All other excavations were directed by the author.

2 The excavation at site 16.10 was limited to trialtrenching. It is quite possible that the remains of more buildings were present in the near vicinity.

3 However rebuilding at the same location took place in the Roman Period at several peat sites south of the Meuse (Van Trierum 1992, 84-91).

4 These dates correspond to other Duinkerke 0 dates in the area, see Van Heeringen 1992.

5 The terms 'Duinkerke 0 and I' are used here because they are widely understood reference terms, although their meaning is increasingly doubtfull. The dating as well as the impact of these transgression phases seem to vary considerably at local and regional levels. See also Van den Broeke, this vol. for a general review of the geological conditions.

6 The subsurface intrusion of water and the related deposition of clay is known as 'klappklei'.

7 The construction of Roman period farmsteads will not be discussed here. In this period a specific, so-called 'A' construction was used in a number of farmsteads in the Meuse estuary (Hallewas 1986).

8 Manure also has a conserving influence because of its chemical composition (pers. comment dr. Brongers) as was clear from both the preservation of old landsurface and of the floor-layers themselves.
The estimated amount of manure incorporated in one floorlayer is *c.* 1.50 to 3.75 m^3, indicating that manure must have been collected and kept apart over a period of time!

9 Estimates given in the literature for the 'lifespan' of posts made of ash and elder are very low: 6-12 years. These stimates are based on modern evaluations with unprotected posts. See Brinkkemper/Vermeeren 1992; Koot/Vermeeren this vol. More experimental research is needed to make any reliable estimate for the longevity of farmsteads built on peat. Further detailed research of the built-up of the floorlayers may provide more information (see Abbink 1993).

10 The surviving stretch of wall of this farmstead showed a construction in which more sturdy upright posts were placed at *c.* 40-50 cm intervals, perhaps indicating extra roof supports comparable to for example Spijkenisse 10-28 (Van Trierum 1992)? There were also indications for a double wall as in site Q, Assendelver Polders (Therkorn *et al.* 1987).

11 To incorporate clay and wood within the floors seems to be mainly a late Iron Age/Roman period habit in the Meuse estuary, as it is in Midden-Delfland (site 16.24 and 16.48, possibly 16.10).

12 Perhaps the Duinkerke I clay deposits along the walls in site 17.35 (Van Trierum 1992, fig. 37) can also be interpreted as an indication for already present cracks.

13 However the farmstead was only partially excavated, not including the central part of the byre.

14 Peat faults are indeed not uncommon and still happen in Midden-Delfland during a very dry summer but they are small vertical cracks with a polygone structure.

15 According to Huyts (1992) the pressure in a 4-aisled construction is exerted inwards. However this depends on the specific roof-construction. With few en asymmetrically placed central posts it is not likely that these posts carried the main weight of the roof. Also the extra posts outside the walls present in most of the farmsteads on Voorne-Putten (Van Trierum 1992) suggest a construction whith an outward direction of the pressures.

16 A seemingly obvious solution to building problems on peat was to use rather thin, but many (paired) posts, together with the use of groundplates, wedges and double posts, for all of which evidence is available. The many posts can be tied together more securely into a stable (super)structure, while small posts will not sink down as easily as large and heavy ones (Abbink 1993).

17 Again the asymmetry is striking; the fissure at site 10-28 occurred along one side only.

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