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Younger Dryas deposits of the Tjonger Valley fill in the NE Netherlands (extended abstract)

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Introduction

Younger Dryas gyttja is wide-spread in the investigated 12km of upstream reach of the Tjonger River Valley and in a major tributary to the north of Haule (Fig. l). The stagnant-water gyttja is similar to gyttja from pingo remnants in the area (Van der Meulen 1988) and consists largely of silt (loess) with some organic components including common remains of *Pediastrum* algae. The gyttja fills a gently undulating coversand relief within the valley. From the earlier Late Glacial only some marginal peats and the upper parts of coversand accumulations (< 2m) are known. Together with Holocene peat these deposits compose the upper part of the up to 10m thick valley fill, which largely consists of Weichselian alluvial sands (Fig. 2; De Groot 1987).

Stratigraphy

In the Tjonger Valley the Younger Dryas sequence comprises in stratigraphical order:

Mini-depressions, locally well-developed with vertical bowl-funnel- and horizontal circular-oval-shaped sections. Largest depths can surpass 2m while widths measure up to 6m. The bowl-shaped depressions are lined with sand—gyttja interlaminations with often some coarse-grained sand layers (0.1–5 cm thick). The fill consists largely of concordantly-bedded sand.

Gyttja (up to 1m thick) with scattered involutions (metre size). Gyttja-coversand interlaminations are largely restricted to the vicinity of a few major coversand accumulations; small coversand ridges are intercalated in a few cases. In narrow valley parts the gyttja is preserved in shallow channel fills. Intercalated gravel strings and coarse sand laminae are local features, which can be 100m wide in cross-section. The coarse incursions mark shallow erosion surfaces. The tree-pollen spectra contain 30–60% *Betula* (highest frequencies at the base), 4–15% *Pinus* and variable percentages of *Salix*. Shrubs are more than incidental contributors; in contrast herbs are scarce except for *Artemisia* (1–5%). *Pediastrum* algae remains are abundant.

Coversand is widely distributed in a few sections (widths up to hundreds of metres, thickness up to 1m). Scattered involutions of decimetre to metre-size are known from this interval in the Tjonger Valley and also in a parallel valley to the south. The coversand deposit veneers the gyttja or can be correlated with a relatively inorganic gyttja top. The latter gyttja type shows the lowest tree pollen numbers overall within the Younger Dryas.

Peat (up to 1m thick) has similar pollen contents as the main part of the gyttja; however, *Pediastrum* remains are lacking. A pollen-dated valley segment (1km long) shows that Younger Dryas peat expanded across the valley starting from a marginal area with older Late Glacial peat. The Younger Dryas peat is covered by 1dm of black Late Preboreal peat extending even beyond the gyttja area. Silty Boreal and Early Atlantic peat grew in an upstream position from the across-valley accumulation of Younger Dryas peat. Besides the first major occurrence of *Alnus* pollen the Early Atlantic peat contains major amounts of *Betula* and *Pinus* pollen, which decrease upwards in the sequence together with decreasing silt content. Atlantic peat with low *Betula* and *Pinus* numbers covers the entire area.

Special features

Red deer (Cervus elaphus) bone accumulations were found in the top of a 2dm-thick Younger Dryas gyttja

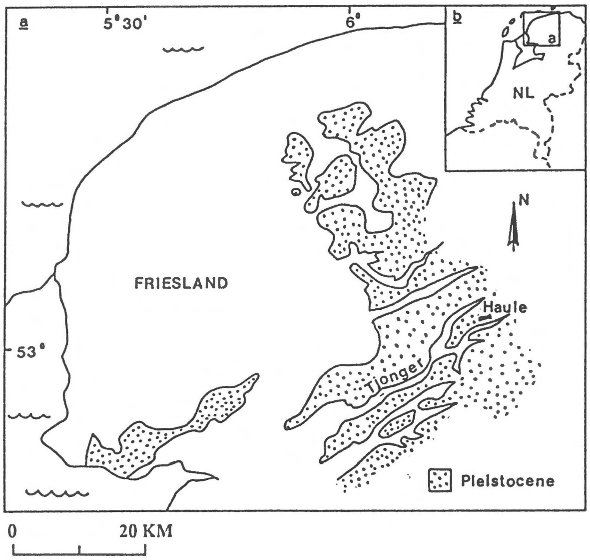

Fig. 1. Map (a) showing the Tjonger Valley as one of the erosion valleys, incised in Pleistocene deposits of SE Friesland (NE Netherlands, inset b). The area to the north and west of the Pleistocene is covered by Holocene peat and clay.

layer at a shallow traverse of the Tjonger Valley near Haule (Van der Meulen 1989; Fig. 1). The gyttja here overlies a low, transverse coversand ridge. Apart from a largely complete skeleton, 5–25 bones were recovered from each of six separate sites positioned 25 to 125m apart in a 500 m wide section. Except for an extra shoulder blade of a deer calf at one locality, the bones represent one single deer per site. Therefore at least seven deer died and were preserved in the area of the traverse.

Lateral intrusion ridges (height × width × length = 1.5 × 15 × 150m) and small *vertical intrusions* (h × w × l = 1 × 2 × 2m maximally) of sand and gyttja occur in the peat cover of a valley segment near Haule. The distribution of the two intrusion types proved to be related to the thickness of the Late Glacial–Early Atlantic organic cover (Fig. 3). The lateral intrusion ridges are situated in valley sections, where thick peat (1—2m) strongly thins at the valley margins (Van der Meulen 1990). A large number of vertical intrusions is found in the relatively thin (0.5–1m) peat overlying a transverse sand ridge. Additionally small-scale loadings ('droptails') of peat in clastic deposits mostly lie in separate areas with thinnest peat cover (up to 0.5m thick).

In a narrow part of the studied valley segment (250 instead of the usual 700m wide) the intrusion ridge size and the number of vertical intrusions decrease. An incipient ridge from this setting shows the basic ridge geometry; a large fold of the sand surface overturned towards the valley margin (Fig. 4). Shear displacement at the top level of very small sand intrusions in gyttja is directed towards the valley margin, just as the overturning of the vertical gyttja intrusion in the peat (Fig. 5).

The gyttja intrusion in Fig. 5 disrupts the Late Preboreal black peat layer. In general, deformation of peat ranging in age from Late Glacial to Early Atlantic has been observed. The vertical intrusions shown to the right in Fig. 3 penetrate 1 m of Boreal and especially Early Atlantic peat.

Summary and interpretation

Younger Dryas gyttja is a wide-spread deposit overlying the sandy Weichselian fill of the Tjonger Valley in the northern Netherlands. Scattered series of mini-depressions mark the base of the gyttja. Locally, extensive coversand or peat accumulations of the Younger Dryas overlie the gyttja. One red deer skeleton and remains of six other individuals were recovered from the gyttja along a shallow valley traverse. Large and intermediate-size involutions deform the upper part of the valley fill, including Early Holocene and Early Atlantic peat.

Aeolian clastic sedimentation dominated during the early part of the Younger Dryas in a valley with extensive shallow lakes in a coversand relief. This aeolian sedimentation maintained transverse dams, and coversand ridges did even migrate into the standing water. Inblown silt (loess) and some organic production, partly by algae, made up the gyttja. Episodic run-off sheetfloods caused local, but wide inflows, which laid down gravel and coarse-grained sand sheets. The interval ended with an increase of eolian sand sedimentation, decreasing tree presence, and a lower lake level. This can possibly be ascribed to a more arid and/or colder climate.

This dominant clastic sedimentation and Younger Dryas lake drainage were succeeded by extensive peat growth in at least part of the valley. These peats expanded far beyond the area earlier occupied by peat growth. Early Holocene and Early Atlantic peat growth only filled depressions in the former Late Glacial peat-

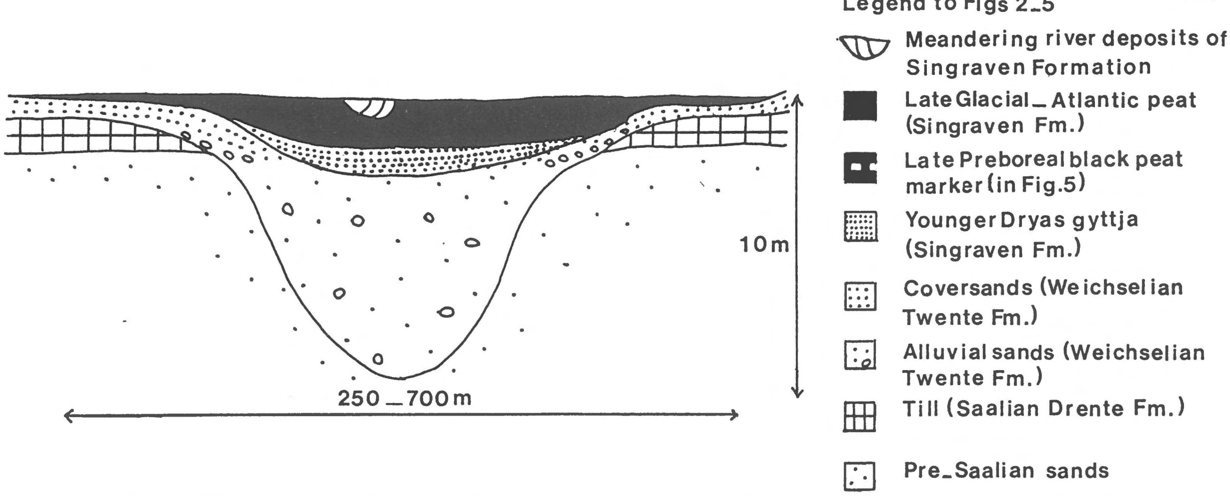

Fig. 2. Schematic cross section of the Tjonger Valley fill. The valley is cut in Saalian till and older sands (Eindhoven Formation). The fill consists largely of Weichselian alluvial sand. Marginal coversands, Younger Dryas gyttja, peat and meandering river deposits make up the upper part.

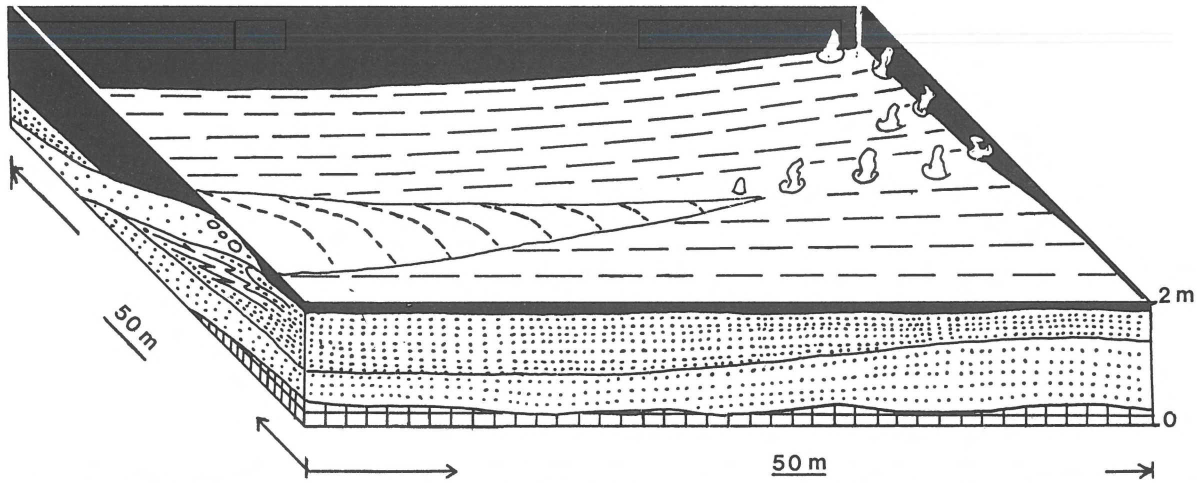

Fig. 3. Schematic block diagram (peat taken off) showing a lateral intrusion ridge passing into an area with vertical intrusions. This transition appears to be related to decreasing peat thickness. The intrusions, derived from Weichselian alluvial sands, broke through Younger Dryas gyttja and also deformed underlying sediments. See Fig. 2. for legend.

land, except for the Late Preboreal (black) peat, which extended even beyond the gyttja area.

At least seven red deer perished on a shallow traverse during their crossing of the valley. The bone dissemination at individual sites is principally determined by the setting with respect to inflow. The least dispersed skeleton clearly lay most favourably. Removed halves of a femur pair, the presence of bone chips and probably also the presence of sets of parallel, fine grooves testify to human activity.

Reconstruction of the permafrost history starts on the assumption that the mini-depression fills represent a melting phase of a permafrost top at the onset of Younger Dryas flooding (Van der Meulen 1989). Similar fills resulted after sand deposition on top of peats and muds with lower density during subrecent flooding in the area of the former Dutch Zuiderzee inland sea (Van Loon & Wiggers 1976). The mini-depressions in the Tjonger Valley developed during loading of scour troughs with basal coarse sand and gyttja. Sagging of these depressed fills required liquefaction of the underlying sands. Melting of a permafrost top of at least 2m thickness would have achieved the necessary density contrast. Permafrost became restored later on in the Younger Dryas, during a dominance of coversand over gyttja sedimentation and possibly even during the peat growth phase.

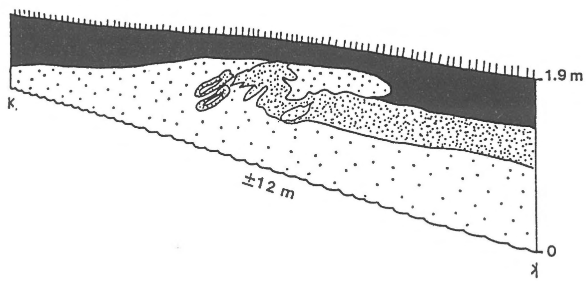

Fig. 4. Tracing of view, taken from a ditch in the Tjonger Valley margin, of strongly deformed and thickened Younger Dryas gyttja (fine stippling) as a result of incipient lateral intrusion by Weichselian sand (coarse stippling). The ditch wall dips 37°. See Fig. 2 for legend.

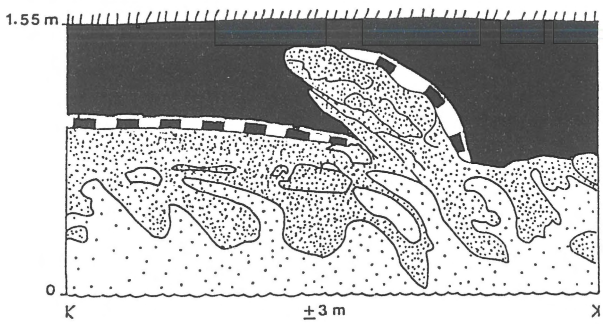

Fig. 5. Tracing of Weichselian sand intrusions (coarse stippling) in Younger Dryas gyttja (fine stippling) and of a gyttja intrusion in peat (in black). The intrusions are sheared towards the Tjonger Valley margin (to the left). The 1 dm-thick Late Preboreal peat layer (black and white blocks) is strongly deformed. The sketched ditch wall dips 37 °.

The intrusion ridges can be explained as products of gravity spreading in the top of the valley fill (Van der Meulen 1990). Liquefied sand became squeezed out as intrusion ridges at the margins of the thickest peat sections, due to a build-up of lateral pressure. Where only thinner peat occurred, vertical pressure release was not inhibited and a multitude of small vertical intrusions developed. Nevertheless, subsidiary deformation (such as shearing and overturning in Fig. 5) can be ascribed to differential lateral stresses. This indicates complete instability in areas with up to 1m thick peat, just as in the case of the thickest peat accumulations. Gravity spreading was not involved in 'droptail' formation underneath the thinnest peat in separate marginal areas. Not only peat thickness determined the amount of gravity spreading. With decreasing valley width from 700 to 250m, sediment displacement became more restricted, probably because of easier dissemination of excess water.

In the northern Netherlands clastic sediment mobilization on the scale described from the organic cover in the Tjonger Valley is only known from cryoturbate settings. A similar origin for the involutions near Haule seems likely. Thus, permafrost of several metres thickness can have been present during the early Younger Dryas flooding of the Tjonger Valley and also during the later parts of the Younger Dryas period. In view of the Early Atlantic age of the youngest peat deformed by involutions, permafrost is suggested to have persisted that long.

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