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WEICHSELIAN PINGO REMNANTS AND PERMAFROST ON THE DRENTE PLATEAU (THE NETHERLANDS)

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ABSTRACT

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Geomorphological and geological investigations on closed topographic depressions and valley systems on the Drente plateau allow correlations to be made between the location of pingo remnants on the plateau and the Weichselian drainage pattern. In general, the depth of the remnants varies between 2 and 7 m, but locally the geological structure of outcropping sediments is responsible for the development of extremely deep pingo remnants, reaching a maximum of 17 m. This figure gives a tentative estimate of the minimum depth of the permafrost then prevailing.

INTRODUCTION

Current research on pingo remnants in The Netherlands is concerned with the detailed palynological and palaeo-ecological study of the organic infilling of some deep pingo remnants (SOHL, in prep.), and with the investigation of the mode and period of pingo growth in the Drentsche Aa valley system (DE GANS, in prep.). In this paper, one very deep and two very shallow remnants will be discussed on the basis of two detailed cross sections. These reveal evidence about the location of the remnants and about the minimum depth of the permafrost base.

THE DRENTE PLATEAU

The Drente plateau is located in the northern part of The Netherlands (Fig. 1). It has a regional slope of 40 centimetres per kilometre to the northwest. Large areas of the plateau are covered by a sticky to sandy lodgement till which has a varying thickness, and which was formed during the Saalian glaciation (TER WEE, 1966, 1976, 1979). The till belongs to the Drente Formation (Table I) and overlies fine sands of the Eindhoven and Peelo Formations. The Peelo Formation also locally

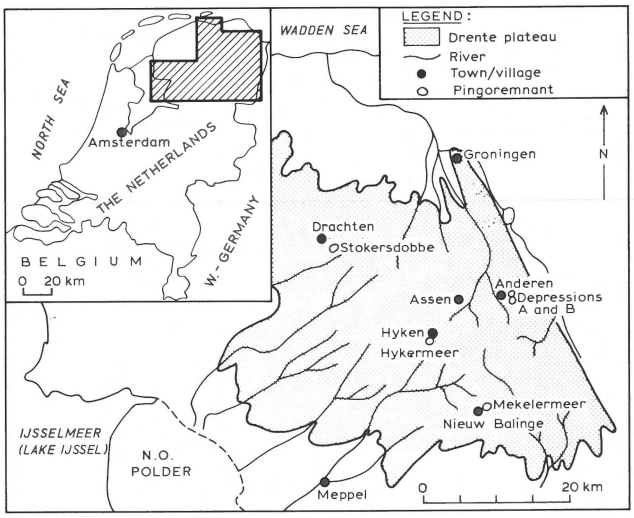

Fig. 1
The Drente plateau and location of the investigated pingo remnants.

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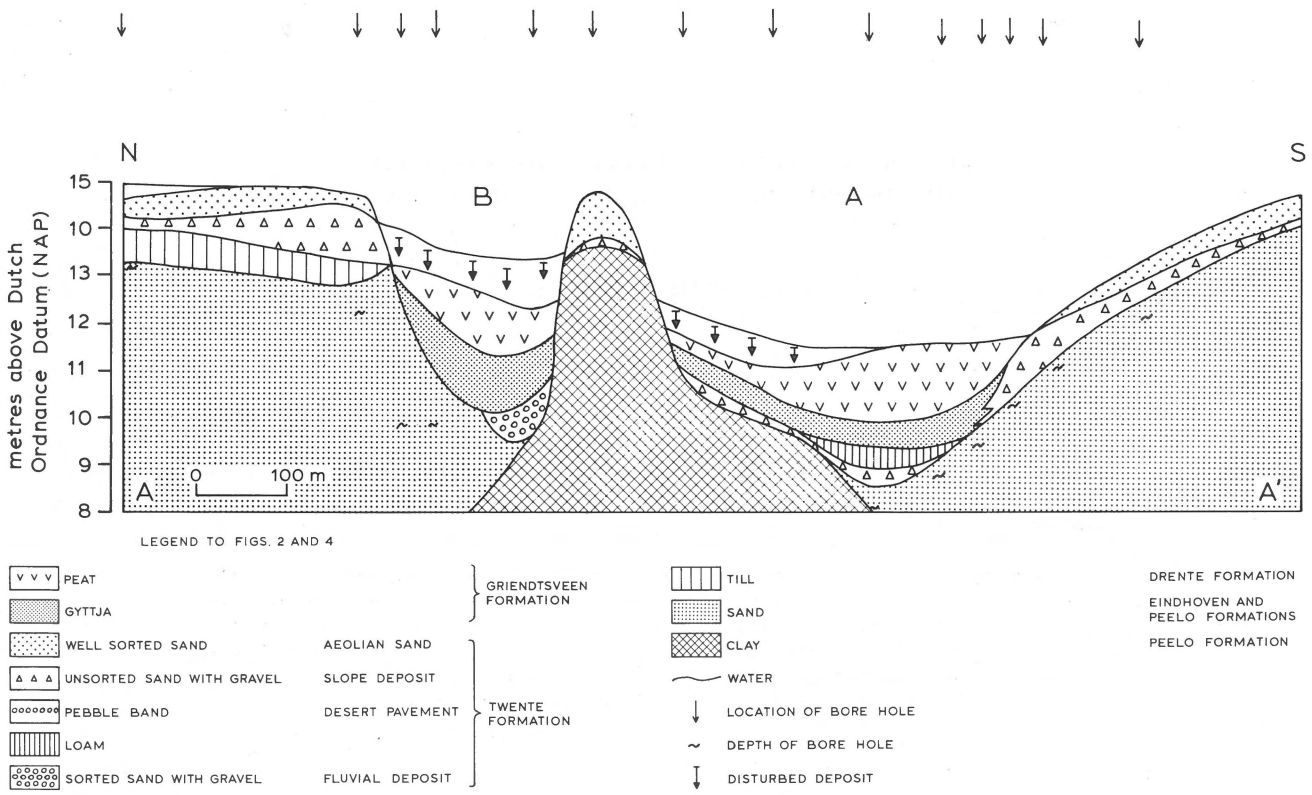

Fig. 2
Cross section 1 – Anderen.

Table I
Generalised stratigraphy and lithology of the Drente plateau.

CHRONOSTRAT.		LITHOSTRATIGR.	LITHOLOGY
HOLOCENE		GRIENDTSVEEN FORMATION	PEAT AND GYTTJA
WEICHSELIAN	LATE GLACIAL		WELL SORTED SAND (AEOLIAN); SAND MIXED WITH GRAVEL (SLOPE DEPOSIT); SORTED SAND WITH GRAVEL (FLUV. DEP)
	PLENI-GLACIAL	TWENTE FORMATION	
	EARLY GLACIAL		
EEMIAN		ASTEN F.	
SAALIAN		DRENTHE F.	TILL
		EINDHOVEN F.	SAND
HOLSTEINIAN		NO DEPOSIT	
ELSTERIAN		PEELO F.	SAND AND CLAY (POTKLEI)

contains clay (potklei) deposits (ZAGWIJN & VAN STAALDUINEN, 1975). After the melting of the Saalian land ice the plateau was dissected by fluvial erosion in the Eemian and Weichselian, giving rise to a dense drainage pattern (DE GANS, 1981). During the later stages of the Pleniglacial the valleys were filled with sorted sand possessing a fining-upwards sequence, and this deposit is interpreted as a fluvial sediment belonging to the Twente Formation (DE GANS, 1980). At the end of the Pleniglacial the fluvial activity decreased and was replaced by slope and aeolian processes. The slope deposits consist of sand mixed with gravel, whereas the overlying aeolian sediments are well sorted and characterised by a grain-size median of 150-210 μm. These aeolian sediments also blanket much of the pre-existing relief. The organic material filling the depressions comprises gyttja, detritus gyttja and peat and is assigned to the Griendtsveen Formation (ZAGWIJN & VAN STAALDUINEN, 1975).

PINGO REMNANTS ON THE PLATEAU

During the coldest part of the Weichselian, which is dated about 20,000 B.P. (compiled by KOLSTRUP, 1980), permafrost existed on the plateau and pingos were formed (PARIS ET AL., 1978). MAARLEVELD & VAN DEN TOORN (1955) were the first to recognise pingo remnants as such on the Frisian part of the plateau on the basis of the Late Glacial age of the oldest

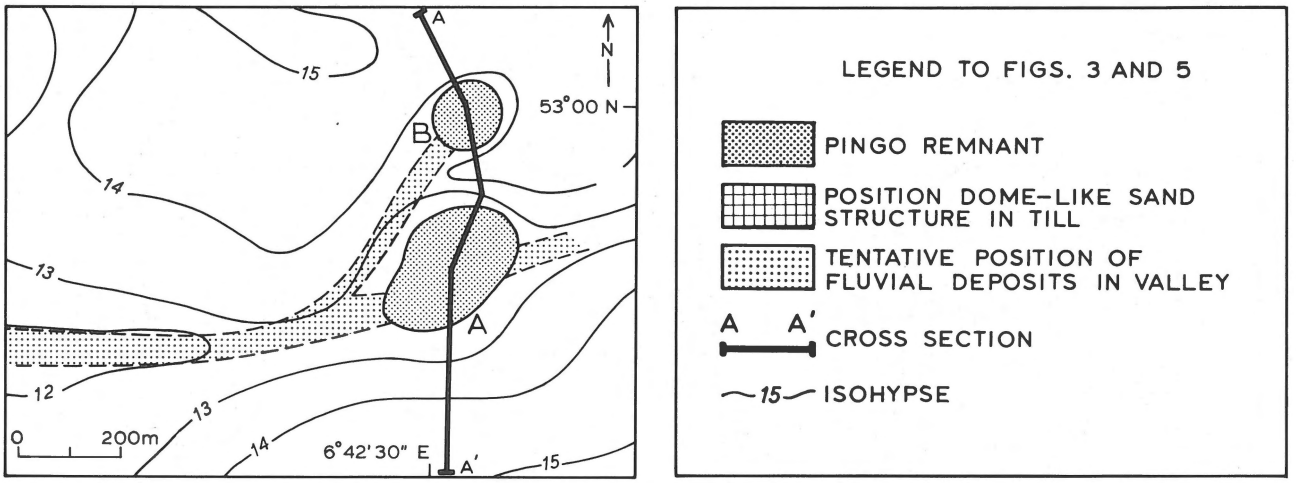

Fig. 3
The Anderen area.

organic infilling and the occurrence of a surrounding rampart which consists of non-aeolian material. DE GANS (1976) suggests that till strata, if present, may show deformation structures due to the growth of the ice cores. The maximum thickness of the infilling material of pingo remnants investigated so far was found in the Stokersdobbe, about 6 km southeast of Drachten (Fig. 1), and amounts to 7 m (PARIS ET AL., 1979). The minimum thickness of the pingos investigated until now is 2 m (DE GANS, 1976) and this thickness may be used as a rule of thumb to discriminate pingo remnants from aeolian depressions on the plateau.

CROSS SECTIONS OF SOME PINGO REMNANTS

From the evidence derived from two cross sections which are thought to be representative of pingo remnants on the plateau, their position and structure will now be discussed. The sections have been constructed from bore-hole data which were obtained by means of hand drilling equipment.

Cross section 1 – Anderen

This section (Fig. 2) is located 1 km east of the village of Anderen (Figs. 1 and 3). Here, two topographic depressions are located in a small valley system. The section shows that they are both filled with gyttja and peat respectively, with a thickness of 2-2.5 m. Depression *A* has a more or less oval plan and a diameter of 300 metres maximally, which is wider than the valley floor in which it is located.

Underlying the organic material, a loam layer and sand mixed with gravel, which is interpreted as a slope deposit belonging to the Twente Formation, are located within the depression. Below the depression no fluvial valley deposits are found. They seem to have been completely removed during the formation of the depression. South of the depression a slope deposit is found which interdigitates with the gyttja in the depression and is interpreted as rampart material which has been redeposited in the depression.

Depression *B* has a circular plan and a diameter of 150 m. Below the organic infilling neither loam nor slope deposit is found in the depression. Instead, a thin remnant of sorted sand with a fining-upwards sequence is found below the depression, indicating its position in a former valley.

North of depression *B*, sand mixed with gravel is located and this is interpreted as a slope deposit forming a rampart. All these deposits belong to the Twente Formation. The till stratum is slightly upturned towards the centre of the depression. In between both depressions an older clay (potklei) deposit is located which at present constitutes the interfluve between the depressions. However, the bottoms of both depressions are rooted in the fine sand of the Peelo Formation.

Cross section 2 – Mekelermeer

This detailed cross section (Fig. 4) is located 1 km northeast of the village of Nieuw Balinge (Fig. 1). It shows a topographic depression 12 m deep with internal slopes up to 7° in gradient. It is partly filled with gyttja and detritus gyttja. It is probable that the infilling of the present-day lake has never reached the stage of peat growth. The depression is surrounded by a thick impermeable till up to 5.5 m. Locally, the underlying fine sand of the Eindhoven or Peelo Formations forms a series of dome-like structures, and as a result of these phenomena the till is in places very thin or even lacking (Figs. 4 and 5), creating a 'geological window'. On top of this till and surrounding the depression a deposit is found which consists of sand, gravel and till fragments. This layer is interpreted as a slope deposit which was built into a rampart around the Mekelermeer before and during the destruction of the former pingo. A pebble band lies above the slope deposit, and this

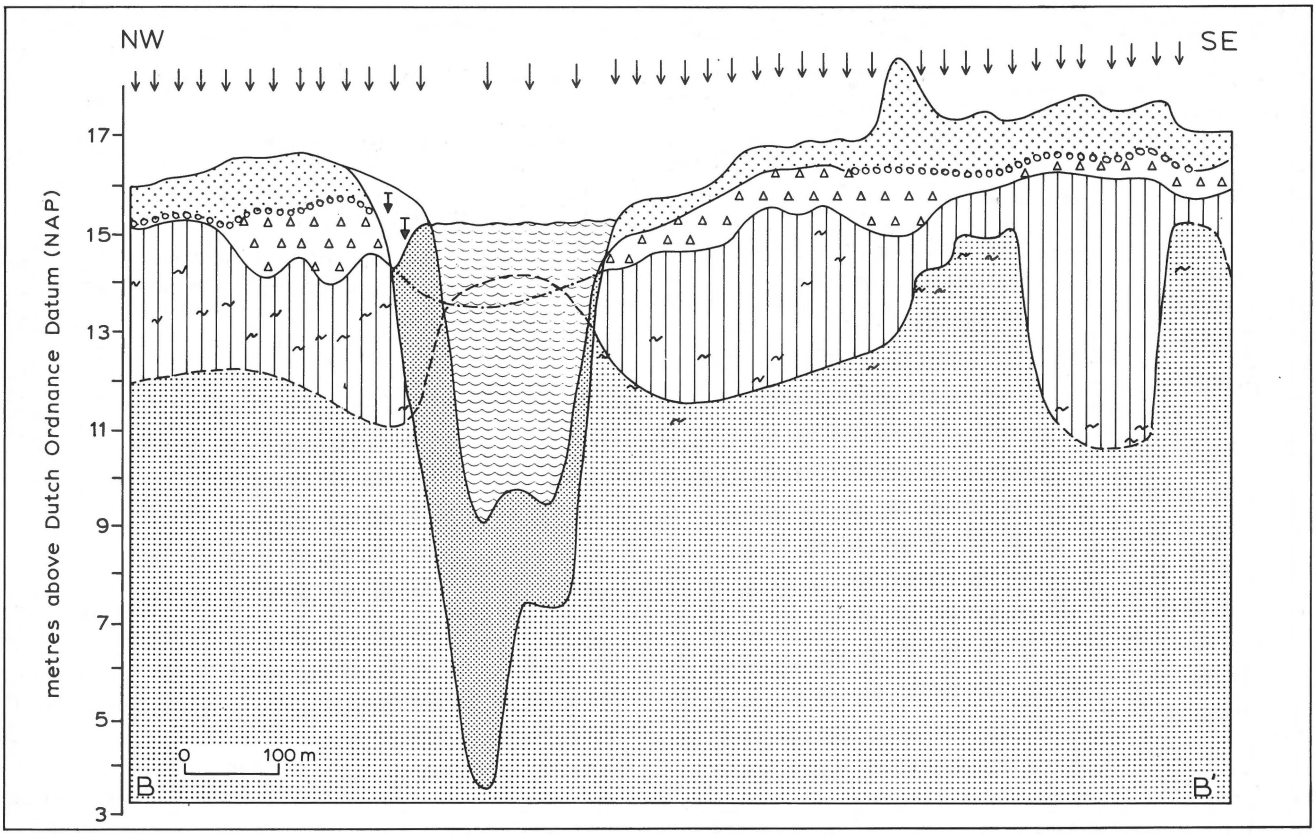

Fig. 4
Cross section 2 – Mekelermeer.

corresponds with the findings of PARIS ET AL. (1979), who correlated the band with the Beuningen gravel bed as described by VAN DER HAMMEN & WYMSTRA (1971) and later by KOLSTRUP (1980).

The relief around the depression is made up of aeolian deposits which blanket the pre-existing relief. The top of the till near the depression is eroded to a depth of 1 m. This erosion surface is thought to be part of a fingertip valley tributary connected with a drainage system west of the depression. The depression is located where this valley cuts through the till into one of the sand dome structures. Part of this structure was, however, destroyed by the creation of the depression, as was the deepest part of the erosion surface in the former valley offshoot.

DISCUSSION

On the basis of the cross sections the three topographic depressions are interpreted as pingo remnants, firstly because the gyttja in the depressions is thought to have a late glacial age which dates their origin in the early Late Glacial or the Pleniglacial (VAN DER HAMMEN, 1951; PARIS ET AL., 1979; CLEVERINGA ET AL., 1977; CLEVERINGA & DE GANS, 1978; SOHL, in prep.) and secondly because they are partly surrounded by a rampart which is composed of non-aeolian material (DE GANS, 1976).

The pingo remnants so far investigated also have two further characteristics in common: the base of each remnant on the plateau is rooted in the sand deposits of the Eindhoven or Peelo Formation; and each remnant is located in the upstream part of shallow but relatively wide valleys. These observations are supported by data of MAARLEVELD & VAN DEN TOORN (1955), NOSSIN (1961), PARIS ET AL. (1979) and DE GANS (in prep.). Large parts of these valleys are covered at present by aeolian sand which obliterates the valley morphology.

The location of the pingo remnants in the valleys suggests that the pingos were formed as open-system types by artesian or hydrologic head under discontinuous permafrost conditions. However, it cannot be entirely excluded that they may have originated as closed-system pingos which could have developed if a talik was located below these parts of the valley, and if such a talik was subsequently enclosed by aggrading permafrost caused either by climatic fluctuations or by changing river regimes (DE GANS, in prep.). The deepest pingo remnant is located upon a 'geological window', where impermeable till surrounds a dome-like structure in the sand of the Peelo or Eindhoven Formation (Fig. 4). The development of this extremely deep remnant was related to the specific hydrologic conditions which were created in the pre-

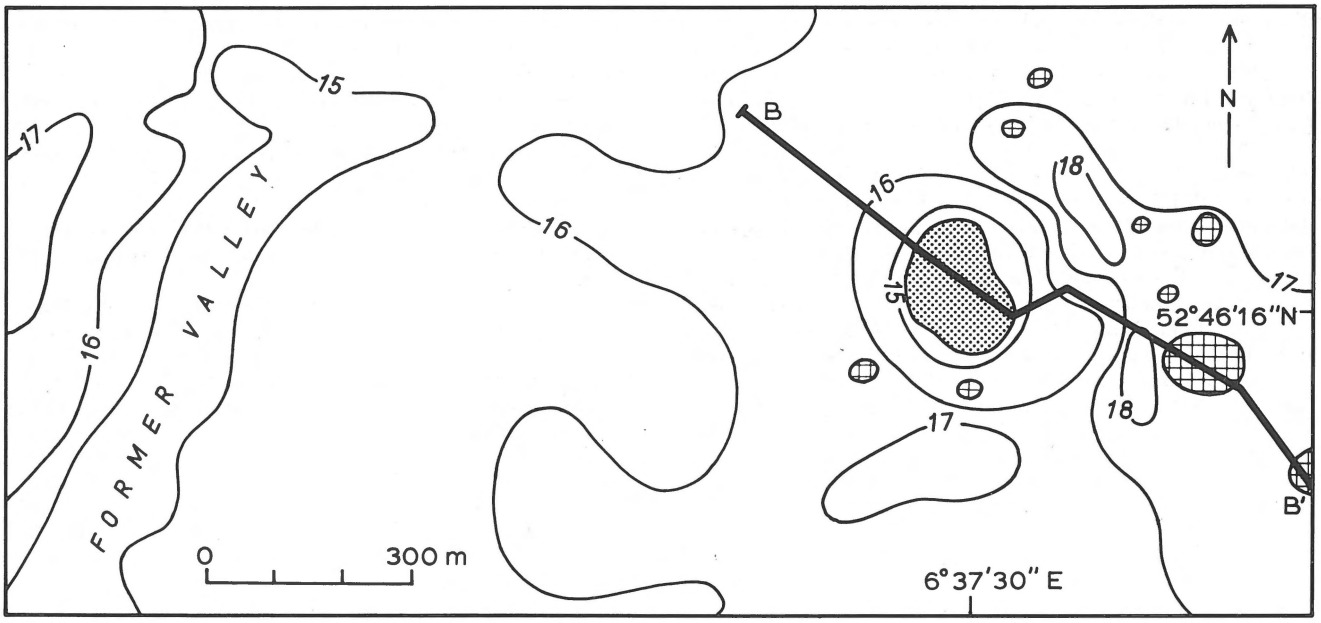

Fig. 5
The Mekelermeer area.

sence of permafrost by the erosion of the superimposed valley offshoot into this sand structure. This also applied to the Hijkermeer, 1 km southwest of the village of Hijken (Fig. 1), which has a depth of 17 m, measured from the water surface (SOHL, in prep.). This is the maximum depth of the pingo remnants so far discovered on the plateau. For the time being, it gives an estimate of the minimum depth of the permafrost base during the growth of the related pingos. The minimum depth of 2 m for the infilling as a criterium to discriminate pingo remnants on the plateau corresponds approximately with the thickness of the active layer during the Pleniglacial (MAARLEVELD, 1976). This conclusion is arrived at because, of necessity, ice-core growth must take place below the active layer to prevent immediate melting.

CONCLUSIONS

The pingo remnants as found on the Drente plateau are located in the upstream part of valleys which were active until the end of the Pleniglacial. As the ramparts surrounding the pingo remnants are relatively small with respect to the size of the depressions (DE GANS, 1976), notably erosion must subsequently have taken place. The minimum depth of 2 m of the infilling material in pingo remnants is correlated with the presumed thickness of the active layer during the growth of the pingos. The deepest pingo remnants are located upon 'geological windows' where sand domes of the Peelo or Eindhoven Formation penetrate the overlying till of the Drente Formation. The maximum depth of 17 m so far found for a pingo remnant (Hijkermeer) gives the minimum depth of the base of permafrost during the growth of this pingo.

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