

SHORT COMMUNICATIONS

ICE-PUSHED RIDGES IN THE EASTERN PART OF THE NETHERLANDS RIVER AREA

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Surveys by Maarleveld (1949, 1953), Crommelin (1940) and Ter Wee (1962) of ice-pushed ridges and glacial deposits demonstrate that during the Saalian Glaciation the distribution of the inland ice cover in The Netherlands was subject to fluctuations.

After having reached a maximum extent, the inland ice cover diminished by melting, whereupon the ice – but this time over a smaller area – advanced once more. During the expansion of the inland ice cover, when glacial tongues pushed forward, ice-pushed ridges were formed. Numerous measurements of pushed deposits in these ridges enabled Maarleveld and Crommelin (1949) to distinguish from the strike-line pattern various pushing phases during which the ridges were formed.

Maarleveld (1953) arrived at the conclusion that in the Central Netherlands ice-pushed ridges were formed during three pushing phases. Maarleveld (1953) referred to them as pushing phases *a*, *b* and *c*. After his study of glacial deposits in the northern provinces, Ter Wee (1962) established another two pushing phases, viz. phases *d* and *e*. After pushing phase *e* no further inland ice cover occurred in the Netherlands. During the maximum ice cover a mighty glacial tongue, which advanced via the Gelderse IJssel area in a southerly direction through the German Rhine valley up to Düsseldorf, through lateral pressure, caused the formation of the East-Veluwe ridge in pushing phase *a* (Maarleveld, 1953). In Germany a long series of ridges was formed along the west flank by lateral glacial pressure. Thome (1959) on the other hand assumed that this series of ice-pushed ridges was formed by frontal glacial pressure. According to Thome (1959) the advance of the inland ice in pushing phase *a* took place in a westerly direction. Maarleveld and Ter Wee assume a glacial movement in a southerly direction.

South of the Veluwe a wide ice lobe split off from the above-mentioned glacial tongue and moved forward in a westerly direction. From this ice lobe two glacial tongues penetrated still further. One of these glacial tongues, referred to by Thome (1959) as the Valburger lobe, penetrated into what is now known as the Betuwe, while the second tongue, the Kranenburger lobe, moved on in a south-westerly direction. The Valburger and Kranenburger glacial tongues

dug themselves deeply into the subsoil, causing subsoil material to be pushed up laterally and frontally around the tongues. During pushing phase *a* the Valburger glacial tongue laterally formed the ice-pushed ridge of Arnhem. According to Maarleveld and Thome sediments were frontally pushed up by the Valburger tongue, likewise forming a ridge, which ran from the Arnhem ridge and joined up with the Nijmegen ridge.

The Nijmegen-Groesbeek, Kleef and Montferland ridges were formed by lateral and frontal pressure around the Kranenburger glacial tongue.

After the glacial front had receded subsequent to the pushing phase, there were two glacial basins (of the Valburger and Kranenburger glacial tongues) in the eastern part of the present river area, enclosed by an elongated, winding ice-pushed ridge extending from Montferland via Kleef, Nijmegen, Heelsum to Arnhem (Thome, Maarleveld, 1953, 1959). The original connection between the Montferland ridge and the Kleef ridge was demonstrated by Van De Meene (1974).

No indications of the Nijmegen-Arnhem part of the elongated ridge are found in the present landscape.

In order to demonstrate the presence of the ice-pushed ridge in the Betuwe area, as suggested by Maarleveld and Thome, the author undertook a survey some time ago, which has now almost been completed. The results of the coredrilling operations reveal the presence of sands, rich in gravel below the Holocene and late Pleistocene Kreftenheye deposits, of which the total thickness is from 8 to 9 metres. The high quartz content from 60 to 65 per cent of the gravels in the fraction 5-20 mm, and the low content of grey components constitute an indication that these sands with high gravel content belong to a middle Pleistocene deposit (The pebble analysis was done by Mr. J. van der Staay).

In a number of boreholes thick, compact clay layers were encountered at a depth of roughly 0.00 to 1.00 metres below N.A.P. (New Amsterdam Datum Level). The thickness of these clay layers varies from 7 to – in some places – more than 17 metres. A pollen-analytical investigation of the clay formation in a borehole at Ressen proved this clay to be of Waalian age. (Zagwijn and De Jong, internal report).

The high position of these clay formations and the great

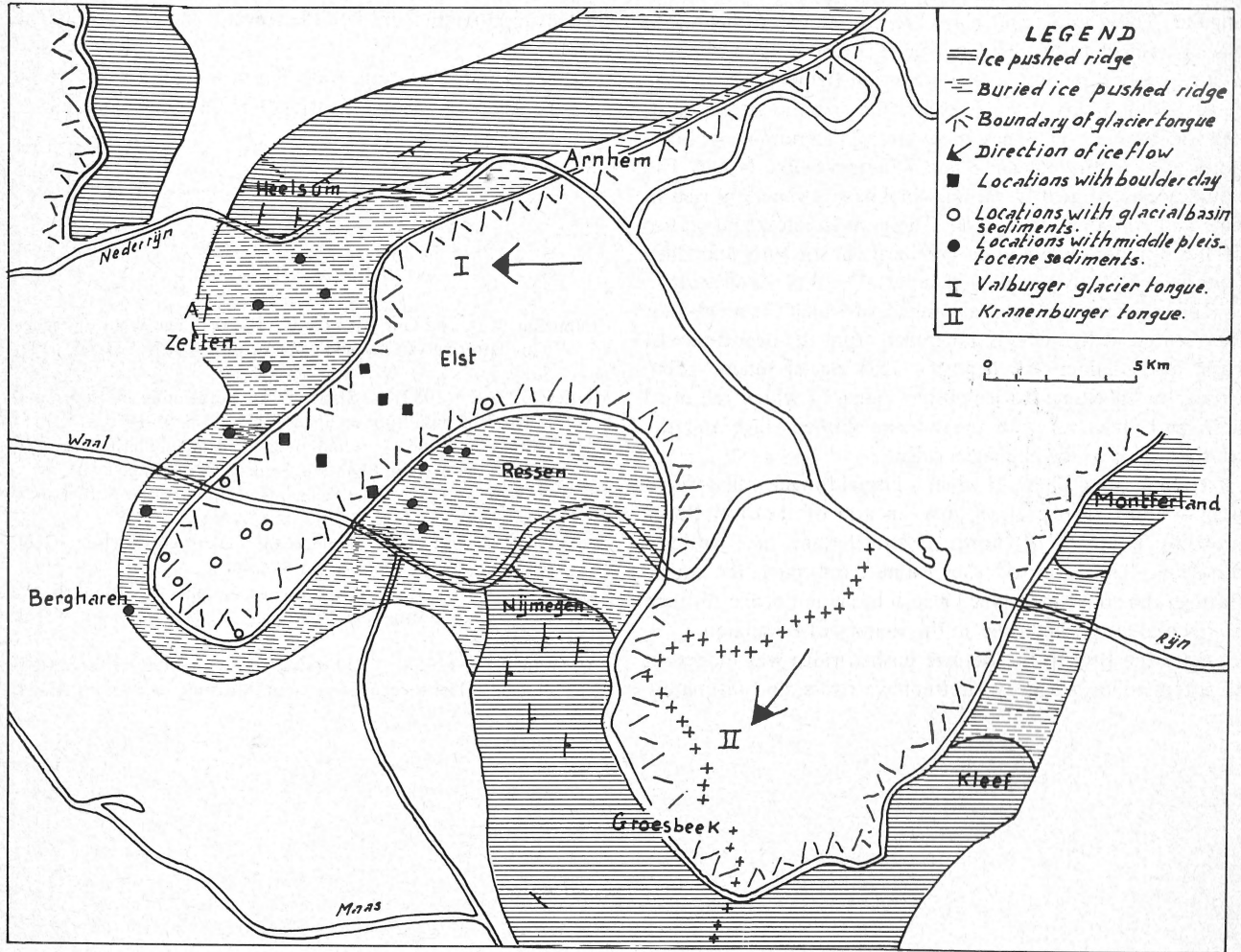


Fig. 1 Map of ice pushed ridges and glacier tongues in the eastern part of the river area.

thickness of the clays would indicate a disturbance of the original position, which may be due to glacial pushing.

In order to determine a possible inclination of the clay layer, the depth of the clay surface in the subsoil was accurately established by means of drilling operations over a limited area. Differences in depth of the clay surface show a dip in easterly direction. In addition, a dip-and-strike survey was carried out. (See figure 1, location A).

In a location south-east of location A, a repetition of deposits was encountered, i.e. sands and gravels with a quartz content in excess of 60 per cent. alternate at increasing depth with a deposit having a quartz content of less than 50 per cent., overlying in turn gravel-rich sands with quartz contents of more than 60 per cent. This alternation of quartz contents over a small vertical distance was not observed in an undisturbed sedimentation; this repetition of layers also indicates that the natural position has been disturbed which is in favour of the presence of a pushed ridge.

Based upon drilling operations during which samples of the clay were obtained, it proved effectively possible to delimit the location of the pushed ridge in the subsoil. (Referred to as the Betuwe ice-pushed ridge).

In order to demonstrate a possible continuation of this Betuwe ice-pushed ridge in a southerly direction, a few more boreholes were drilled between Elst and Nijmegen. The data obtained from these boreholes reveal that in the area between Elst and Nijmegen the Holocene and the late Pleistocene Kreftenheye deposits lie on top of fine- to moderately coarse-grained, silt-containing sands. The thickness of the Holocene and late Pleistocene formation is roughly between 15 and 16 metres and thus appreciably greater than that of the Holocene and late Pleistocene deposits overlying the Betuwe pushed-ridge deposits.

In places, stratified clays occur in the fine- to moderately coarse-grained, silt-containing sands. Coarse-sand layers are sometimes also encountered, the sand grains being highly

angular. These sands and clays are considered to belong to glacial basin deposits. The extension of these basin deposits in a westerly direction is represented in figure 1. During the survey, which served to establish the extent of the basin deposits, boulder clay was encountered in a number of boreholes at a depth between 6 and 7 metres below N.A.P. The boulder clay of greatly varying thickness is generally rich in lime and contains little gravel. The gravels below and on top of the boulder clay contain northern constituents and flint. (Internal sediment-petrological report 475, J.G. Zandstra).

The existence of a glacial tongue, of which the location is represented in figure 1, is concluded from the occurrence of basin and boulder-clay deposits. This glacial tongue is enclosed by an elongated ice-pushed ridge, of which the northern part links up with the Betuwe pushed ridge and the southern part of the Nijmegen ridge.

After pushing phase *b*, when a glacial tongue still covered part of the Gelderse IJssel area, an arm of the river Rhine probably branched off north of Montferland in a westerly direction. This arm of the Rhine continued its course through the above-mentioned glacial basin and broke through the frontal ice-pushed ridge in the vicinity of Bergharen.

After the Brørup the Betuwe pushed ridge was incised in an intermediate stage by Kreftenheye rivers, and ultimately

cleared up altogether by late Pleistocene and early Holocene rivers.

This preliminary publication forms part of a study to be published shortly. Many aspects will be discussed in detail.

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