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GLACIAL DEPOSITS IN THE NETHERLANDS TRANSFORMED UNDER PERIGLACIAL CONDITIONS

A review

In the Netherlands only boulder clay occurs deposited during one glacial period. In the north of the country the boulder clay overlies the marine Mindel—Riss deposit and is in turn covered by marine Riss—Würm layers. This was what suggested the idea that during the Riss-glaciation the Netherlands were only covered with ice-sheet. Thus all the glacial forms such as ground moraine plains, push moraines, eskers, drumlins, out-wash plains, kames and kame-terraces would approximately be of the same age.

It has been argued that the land-ice cap in the Netherlands was preceded by a Riss-interstadial (Brouwer 1948) and it is furthermore known that the Warta-stadial is younger. The land-ice covering may be therefore assumed to have been produced in the part of the Riss known as Drenthe-stadial (for subdivision of the Riss see Lüttig 1958 and Woldstedt 1954). In connection with the extension of the land-ice at least 5 phases or staffels can be distinguished in this stadial (Maarleveld 1953; Wiggers 1955), but nothing is known concerning their duration. The ice-front is only known to have been very mobile.

The deposits of the Drenthe-stadial have been subjected to severe periglacial erosion at the end of Riss and during Würm. In many cases it is possible to acquire a clear notion of the extent of the Würm periglacial erosion by the occurrence of a deposit overlying the Riss—Würm interglacial. The problem of dating the erosion will be here dealt with in short.

In the first place some attention must be paid to the changes in the ground moraine landscape in the northern part of the Netherlands (fig. 1). This flat ground moraine landscape is cut by a number of valleys which are primarily Riss in age (Edelman & Maarleveld 1958). Further-

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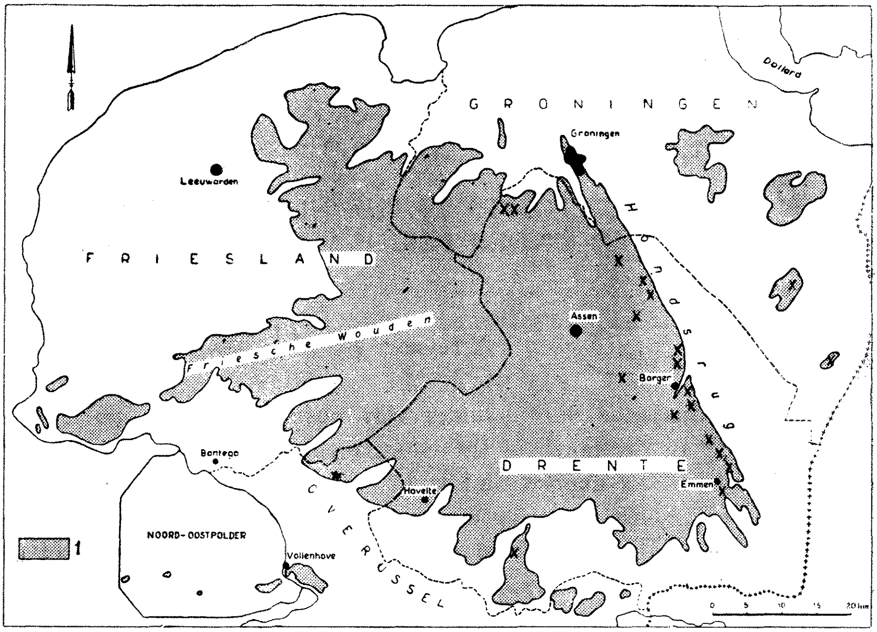

Fig. 1. Ground moraine landscape of the northern part of the Netherlands (published in: Edelman and Maarleveld 1958)

1. subsurface ground moraine

more the area is characterized by the occurrence of many small lakes which are, at least partly, würmian. From the nature of the material underlying the boulder clay the land-ice may be assumed to have passed over a flat landscape on its way southwestward. Therefore the base of the boulder clay is also fairly horizontal.

In many places the boulder clay appears to be strongly eroded and the so-called *boulder sand* may be regarded as a residue. The thickness of the boulder sand layer varies 60—100 cm (Veenenbos 1954). It is a sand deposit containing loam, gravel and stones. It has often been pointed out by the Wageningen School that the boulder sand is Würmian in age. Presumably the Riss boulder clay has been deeply weathered during the warm Riss—Würm interglacial and some local traces dating back to this time are found in the soil profile. It is so-called *red yellow podzolic soil* (written report by Ir. B. van Heuveln) which testifies to warmer climatic conditions than those prevailing to-day. The boulder clay, severely weathered during the warm interglacial, underwent strong erosion of the Würm period under the periglacial conditions and the high percentage of cover sand [1] contained in the boulder sand is regarded as a proof confirming this conception.

Data obtained by deep borings have been published recently which show that locally the boulder sand is overlain by Riss—Würm interglacial deposits while no boulder sand overlies the Riss—Würm interglacial layer (Wensink 1958). The boulder sand in these localities occurs at a depth of more than 8 metres and it is not yet known to what an extent other deposits may have disappeared through erosion. Of great importance however is that the quantity of the boulder sand in the borings in question is rather small viz. 10—26 cm, while the boulder sand found in other places averaged 60 to 100 cm in thickness (Veenenbos 1954). From these borings it appears, however, that the insignificant thickness of the boulder sand is may be at least in a small proportion of Riss age.

As demonstrated by calculation of the stones, the boulder clay contains 25 stones >5 cm in diameter per cubic metre (de Waard 1947). Calculations in boulder sand exposures near Vollenhove and Havelte (fig. 1) showed an average of about 100 stones >5 cm per cubic metre which equals a boulder clay quantity of 4 cubic metres.

Accepting an average thickness of 20 cm for boulder sand of Riss age and an average thickness of 80 cm for the whole boulder sand deposit, there remains a thickness of 60 cm or a quantity of $6/8 \times 4\ m^3 = 3\ m^3$ of boulder clay. These 3 cubic metres of boulder clay have disappeared owing to periglacial erosion during the Würm time. In this connection we think of vigorous downwash by snow meltwaters of the severely weathered Riss boulder clay during the Riss—Würm interglacial.

Recently drumlins were recognized in the north of the Netherlands (fig. 2). The elevations occurring in this terrain contain a nucleus of potters' clay, a very heavy clay, the origin of which has not yet been wholly cleared. The overlying boulder clay is mixed with potters' clay and is consequently heavier textured than normally (table I). In various places the potters' clay crops out. The heavy texture of the material — potters' clay as well as boulder clay — has undoubtedly contributed to the fact that these phenomena of Riss age are still recognizable in spite of Würm periglacial erosion.

Also other glacial deposits such as kames and eskers are not totally destroyed by erosion during the Würm. These terrain elevations consist of sand containing gravel and especially near the surface, some coarse ma-

[1] Cover sand, an eolian deposit, is Würmian in age and the admixture of cover sand in boulder sand is explained by alternate wind blast and solifluction (see p. 49 of this journal).

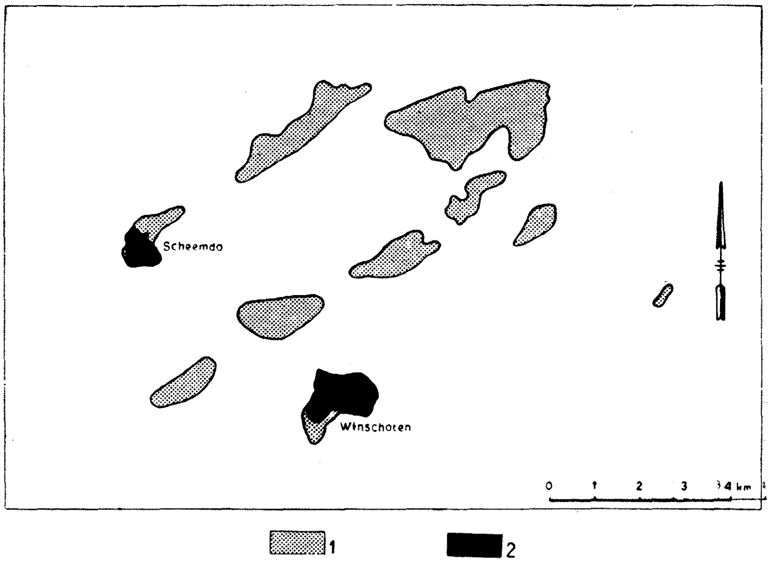

Fig. 2. Drumlins in the vicinity of Winschoten, derived from maps of L. A. H. de Smet (according to Edelman and Maarleveld 1958)

1. drumlins; 2. town

Table I

Grain size distribution of potters' clay and boulder clay

		0—16 μ	16—50 μ	50—105 μ	105—210 μ	210—420 μ	420—850 μ	>850 μ
Potters' clay	Winschoten [1]	98,5	2,0	—	—	—	—	—
Boulder clay	Winschoten [1]	64,0	5,7	14,0	13,0	3,0	0,6	0,1
Boulder clay	Netherlands (170 samples) [2]	23,5	8,5	14,7	29,0	16,8	5,4	2,2

[1] According to verbal information of Ir. de Smet.
[2] According to de Ridder and Wiggers (1956).

terial (Maarleveld 1956). This strongly suggests that this coarse material prevented further erosion. Undoubtedly has the finer textured material been removed by erosion.

The largest glacial phenomena in the Netherlands are the push moraines (fig. 3). A maximum width of over 10 km has been found and widths of 4 km are very common. The elevations are varying. If the post-Riss (boulder clay) fill is thought away than the maximum elevation of the largest push moraine amounts to ca 200 metres (see fig. 5). For smaller push moraines an approximate elevation of 100 metres can be accepted.

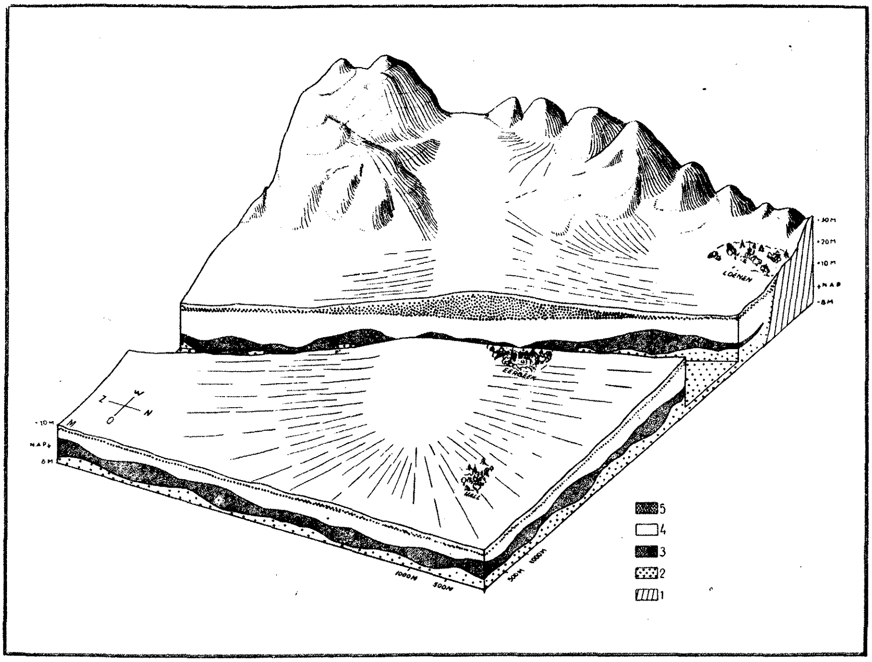

Fig. 4. Block diagram of niveo-fluviatile deposits in the vicinity of Eerbeek, Eastern Veluwe (according to Maarleveld 1949 and published in: Edelman and Maarleveld 1958)

1. pushed layers; 2. valley fill of Riss age; 3. continental Riss—Würm interglacial deposit; 4. sand deposit of Early Würm age; 5. niveo-fluviatile deposit mantled by cover sand

The very wide glacial valleys were filled in the Riss time and to a much lesser extent during the Eemian (fig. 5). Consequently in the largest push moraine at the end of the Riss—Würm interglacial the maximum difference in elevation was reduced to ca 100 metres and in the smaller ones to ca 60 metres. These data are known by the occurrence of easily datable substratum layers (see e. g. Burck 1949).

Although at the beginning of the Würm the relief was less distinct than during the Riss, differences in height were nevertheless sufficiently considerable to cause severe erosion. The question of the extent of periglacial erosion will be discussed below.

Formerly it was assumed that during the Riss the push moraines were much higher than to-day. Now we know that this assumption is not correct. The push moraine consists morphologically of three parts. It has two steep flanks (the steepest of which was in contact with the land-ice) and a fairly level higher part. On this flat part some remnants of a boulder clay cover are found which prove that at that place the push moraine still has about the same height as during the Riss time. The erosion was strongest on the flanks of the push moraine (see also Dylik 1952) thus forming numerous erosional valleys.

However, not all the valleys are of Würm age. At the place of the wide funnel shaped valley of to-day, a valley already existed in the Riss time (Edelman & Maarleveld 1958). Furthermore valley erosion in the same place is certain to have been frequent during the Würm time too. This is proved by the enormous alluvial fans overlying layers of Riss—Würm interglacial age (fig. 4). Apart from solifluction especially the snow meltwaters must have been a strong erosion agent and in the alluvial fans beautifully cross-bedded sands can be seen, the so-called niveo-fluviatile deposits (van der Hammen & Maarleveld 1952).

Especially the fine-sandy deposits of the push moraine were submitted to erosion. As demonstrated by detailed investigations the higher parts of the push moraines consist of gravel- or stone-rich material while the lower parts, in which the valleys are situated, are fine-sandy (Schelling 1953).

The quantities of eroded material are difficult to determine. One gets the impression that a substantial, may be the most substantial, incision into the push moraines of the Netherlands does not date back to the

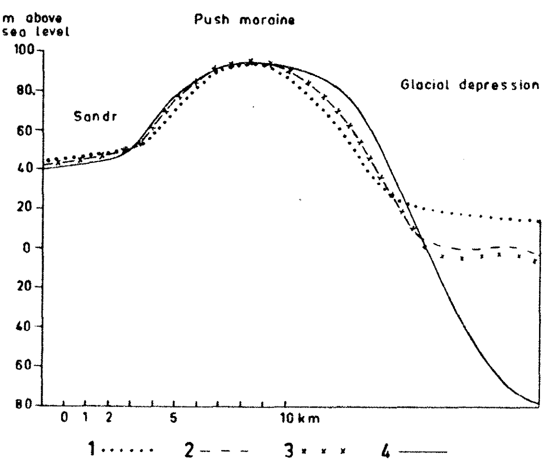

Fig. 5. Changes in the cross-section of a push moraine (Veluwe) from the Riss glaciation up to present-day times

1. present-day surface; 2. surface at the end of the Riss—Würm interglacial; 3. surface at the end of the Riss glaciation; 4. surface of Riss boulder clay

Würm periglacial, but to the Riss glacial and was chiefly caused by erosion due to inland-ice meltwaters. This however does not alter the fact that the glacial form has very considerably changed after the Riss—Würm interglacial (fig. 5). This change took place under periglacial conditions and was predominantly caused by erosion through snow meltwaters.

When reviewing the present-day knowledge on the transformation of the Riss glacial landscape in the Netherlands during the Würm time, the conclusion to an important transformation appears justified. However the changes are of such a nature that in various cases the original form is still recognizable. Furthermore erosion was undoubtedly selective, since deposits containing the heaviest and coarsest material have been, at least partly, preserved.

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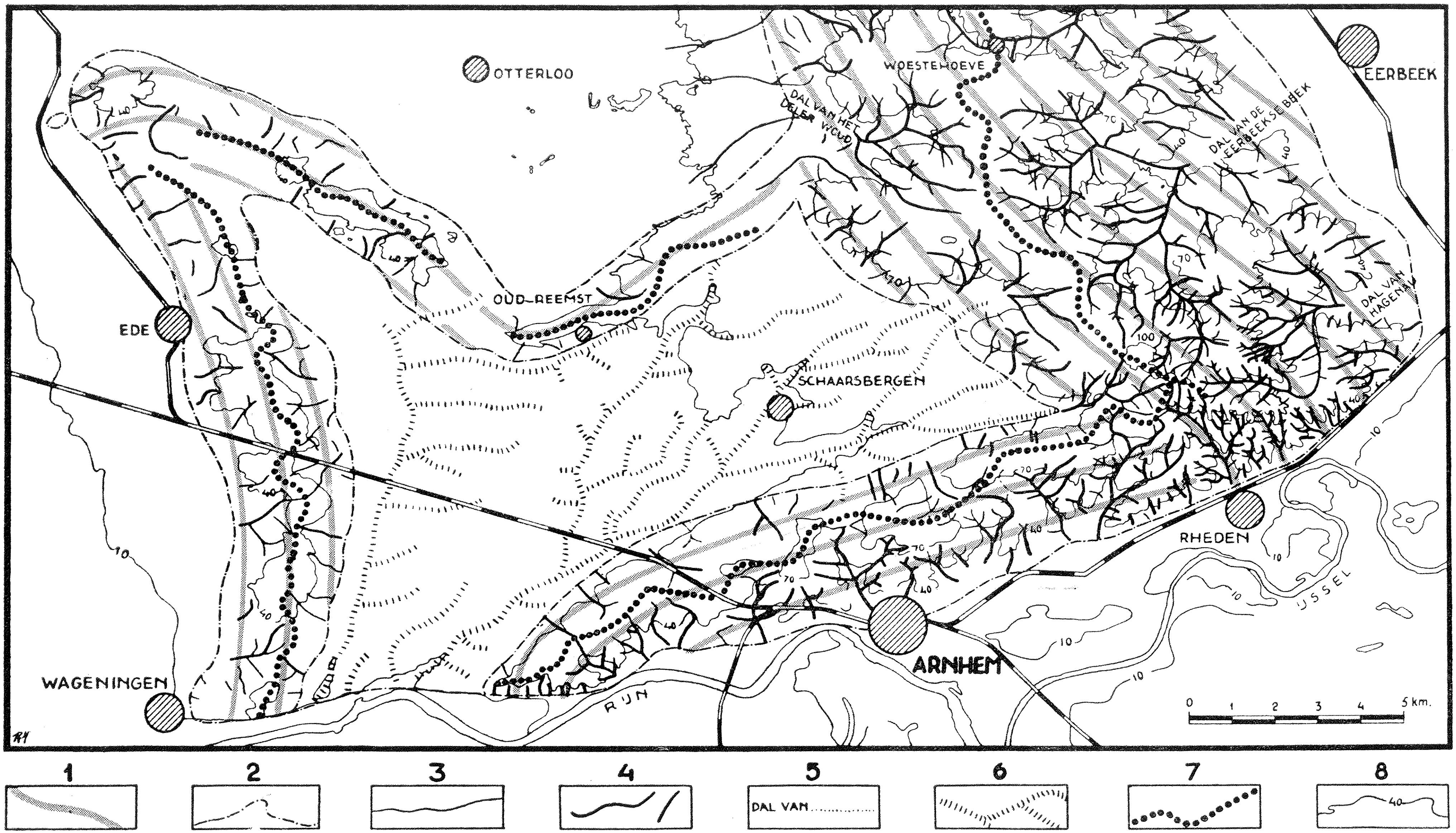

Fig. 3. Map of the push moraines of the Southern Veluwe, partly according to Crommelin and Maarleveld, 1949 (published in: *Natura*, 1950)

1. direction of pushed layers; 2. limit of the push moraine; 3. dry valleys of smooth form; 4. dry valleys of distinct form; 5. funnel-shaped valleys; 6. valleys of outwash plain; 7. watershed; 8. contour line