GEOLOGIE EN MIJNBOUW VOLUME 50 (3), p. 425-428 1971

# THE EFFECTS OF SELECTIVE EROSION BY OVERLAND FLOW ON THE ICE-PUSHED RIDGES OF UELSEN (County Bentheim, Germany)

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## ABSTRACT

The surface of the ice-pushed ridges of Uelsen is marked by parallel ridges of Pleistocene material rich in gravel, and intervening depressions in gravel-free Pleistocene and Tertiary deposits. This relief results from selective erosion by runoff in a humid temperate or a nivation climate. Later periglacial conditions with solifluction and wind action disrupted the drainage system and suppressed the relief. Present geomorphic processes tend to diminish the effects of the periglacial environment.

The ice-pushed ridges of Uelsen are composed of Pleistocene gravels and predominantly coarse sands alternating with Tertiary fine-grained white sands and glauconitic loams and clays. The juxtaposition of gravelly and non-gravelly materials had a profound influence on present-day relief. Conspicuous ridges running parallel to the geological structure alternate with elongated depressions. The ridges may be as much as 15 m high, with slope angles up to 15° (fig. 1). Their position is determined by outcrops of materials rich in gravel (fig. 2), although gravel occupies no more than a narrow strip on the top of some ridges. The depressions are invariably formed in gravel-free sands and loams. They are part of a valley system that is largely dry unless underlain by Tertiary loams and clays.

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It is generally agreed that the present relief of these and other ice-pushed ridges is due to differential erosion of the various deposits (Richter, Schneider und Wager, 1951; de Jong, 1952; van der Hammen, 1961; Grahle, 1960; van den Akker en Knibbe, 1963), but the actual mode of formation is not known. Many erosive processes have been active from the time the glaciers covered the area. They include glacial scouring (Richter, Schneider und Wager, 1951) and erosion by ice meltwaters during the Saalian (de Jong, 1952); the action of snow meltwaters, solifluction and wind in the Weichselian periglacial environment (de Jong, 1952; van der Hammen, 1961); and erosion by runoff during the Eemian interglacial and later interstadials (van der Hammen, 1961), and during the Holocene.

Some of these processes are not sufficiently selective to account for the formation of the gravel ridges. For example, glacial scouring and erosion by ice meltwater, characteristically produce deposits incorporating much gravel. From these and other considerations Richter et al. (1951) concluded that the surface features of the ice-pushed ridges were not formed before the glaciers left the Uelsen area.

An important role is commonly attributed to solifluction, but it is clear that the gravel ridges existed and were in fact much more pronounced before the establishment of the Weichselian periglacial environment, which promoted the solifluction. Solifluction waste found on the flanks of many ridges is typically

Fig. 1
Transverse section of a gravel ridge near Uelsen.

unsorted; it always contains gravel derived from ridge crests, which evidently were lowered by this process (fig. 3). The lower slopes and depressions were subsequently mantled by coversands, and occasional thin layers of gravel in the coversands demonstrate the continued lowering of the ridges during this stage. Material fed into the valleys sometimes deranged the drainage. These are common processes of the evolution of landscapes under periglacial conditions (D a v i e s, 1969). By lowering the ridges and filling the valleys, solifluction and wind flattened a preexisting relief formed by other processes.

The actual processes responsible for the formation of the gravel ridges are not known, but the close relationship between topography and grain-size suggests that only mechanisms relying on the action of running water need to be considered (J u n g e r i u s, 1965). The process that is most dependent on grain-size is erosion by overland flow. Coarse-grained soils have a high infiltration capacity and reduce the volume of overland flow so much that no coarse grains can be carried away.

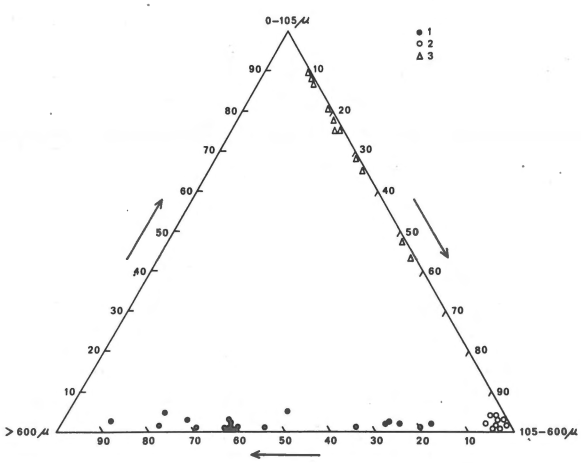


Fig. 2
Texture of gravelly, coarse-sandy deposits occurring on ridges (1); gravel-free, fine-sandy deposits occurring in depressions (2); loamy and clayey deposits occurring in depressions (3). Larger than 600 micron refers to sand and gravel.

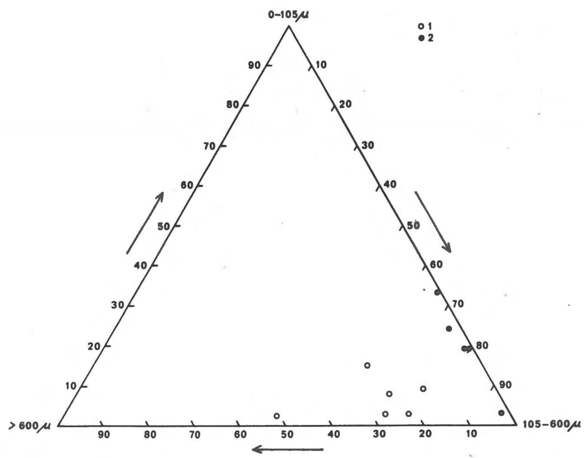


Fig. 3
Texture of solifluction waste (1) and colluvial deposits (2).

It is not certain whether the conditions for selective soil erosion should be sought in a temperate humid or in a nivation climate. The vegetation cover to be expected under interglacial conditions would have favoured selective erosion by protecting the soils against the effects of intense rains. In this connection it is interesting to note that present-day colluvium in lower-slope positions is also largely free of gravel (fig. 3). Moreover, fluvial processes now operative in the areas underlain by fine-grained Tertiary materials tend to reintegrate the depressions into the existing drainage system. On the other hand, it has been demonstrated that meltwater derived from snow preferentially transports grains smaller than 1 mm (Anderson and Bisal, 1969). Snow fall was abundant in early Weichselian times (Grahle, 1960), but less so later when the sea level dropped (van der Hammen and Maarleveld, 1952). In a nivation system, sediment transport is caused by snow movement, or by snow-melt runoff, rather than by mass movement as in the periglacial system (Davies, 1969).

Selective erosion of soils cannot alone account for the formation of the gravel ridges. Streams were necessary to carry the eroded materials away, be it only intermittently. Therefore, precipitation must have been great enough to raise the groundwater level or exceed the infiltration capacity of the surface materials in the depressions. This surface water had little difficulty in cutting into the easily eroded sands and clays, thereby substantially contributing to the formation of the depressions.

As it is not known where the eroded materials were finally laid down, they cannot be used for dating the period of erosion. The lowlands surrounding the ice-pushed ridges of Uelsen are partly covered by fluvial "Talsande", which are largely of Weichselian age (Grahle, 1960). If these sands are related to the formation of the gravel ridges, selective erosion by snow meltwater appears to be the more important process.

## ACKNOWLEDGEMENTS

The authors are greatly indebted to Dr. C. Bloomfield, Rothamsted Experimental Station, Harpenden, U.K. for correcting the English text. The financial assistance provided by the Netherlands Organization for the Advancement of Pure Research (ZWO), is gratefully acknowledged.

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