

# THE GLACIAL ANTICYCLONE AND THE EUROPEAN CONTINENTAL GLACIER.

WILLIAM HERBERT HOBBS.

**ABSTRACT.** Until 1929 when a University of Michigan expedition was based on the great Søndre Strømfjord in Greenland, the geological work of a continental glacier over its periglacial land area had never been studied. It was then discovered that during a short warm season the geological work is accomplished by thaw water and floating ice-blocks. Glacio-fluvial deposits with ice-borne boulders left stranded upon them develop at the front of the ice.

For the rest of the year the geological work is accomplished wholly by fierce outward-blowing storm winds, which lay down loess deposits and associated sand hills extra-marginal to the outwash. Simultaneously ventifacts are produced by sand blasts from the stranded boulders. For the first time, therefore, a satisfactory explanation has been found for the loess deposits and the ventifacts which are associated with all Pleistocene continental glaciers. The paper treats of the latest European continental glacier with due consideration of these geological processes.

**S**TUDY of the Greenland continental glacier has shown that the fixed glacial anticyclone over Greenland extends far out over the periglacial area, and where there is outwash from the glacier front the wind of the anticyclone is for the greater part of the year the dominant agent of geological work, including all the processes of transportation, erosion and deposition.<sup>1</sup>

During the summer months on the western flank of the glacier, its upper surface is melted by warm rains within its intramarginal zone, and the thaw-water descends through crevasses to issue beneath the glacier front. This brings englacial rock debris from the lower ice layers to build up an outwash plain of gravel, sand and mud, according to the well-known fashion learned long ago from the study of the alpine glaciers. But not only is the outwash from a continental glacier on a much grander scale, but ice-blocks large and small become detached from the glacier front through undermining, and with their burden of boulders and smaller rock debris these ice-blocks are carried far out over the plain within the braided stream

<sup>1</sup> Hobbs, William H.: 1931, Loess, pebble bands and boulders from glacial outwash of the Greenland Continental glacier, *Jour. Geol.*, Vol. xxxix, pp. 381-385; 1931, The origin of the loess associated with Continental glaciation based on studies in Greenland, *Compt. rend. Congrès intern. Géog.*, Vol. ii, pp. 1-4; 1942, Wind—the dominant transportation agent within extra-marginal zones to continental glaciers, *Jour. Geol.*, Vol. 1, no. 5, pp. 556-559.

channels. On those summer days with copious rain the plain becomes so flooded as to form a lake, and ice-blocks then emerge from the braided channels to become dispersed over a large part of the glacio-fluvial area. With the melting of these blocks, boulders with much smaller rock material are spread over the plain. Gravel, sand, silt, and in back-water areas clay as well, contribute to build up the outwash area.

At the close of each summer season melting of the glacier ceases, the outwash plain dries out, and the wind then takes over completely from the thaw-water the processes of transportation, erosion and deposition. With wind velocities often much in excess of 100 miles per hour, the surface material of the plain up to pebbles of about an inch in diameter is lifted and carried out to great distances from the glacier front.

The fine silt lifted as dust is carried beyond the limits of the outwash plain and only comes to rest where, beyond the flooded areas, grasses are able to take root. Thus is built up extra-marginal to the outwash a loess deposit which rises on a steep slope at the margin of the outwash area, and thins out at greater distances (Fig. 1).

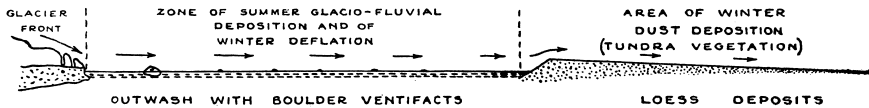


Fig. 1. Schematic diagram to show the conditions within the periglacial area to a continental glacier wherever there is outwash.

The sand which is carried in the air builds up hills or ridges within eddied areas, while pebbles up to an inch in diameter move outward by saltation and may become included within the loess deposit.

Pebbles too large to be thus moved by the wind are left behind to form during the winter season over the outwash a surface armor of pebbles—a pebble or desert pavement.

During the next succeeding summer this pebble armor to the outwash is either redistributed together with newly deposited outwash, or is covered over by the fresh deposit as the plain is further built up. On flooded summer days the stranded boulders of the last summer season are, by the newly drifted ice blocks or the swirling currents which surround them, pushed about, rotated or overturned, so that at the close of

each summer they are left with a new face exposed to the driving sand during the succeeding winter. They are thus after successive seasons reduced to a ribbed ellipsoidal form or to one with many facets (*Windkanter*), according as they are heterogeneous or essentially homogeneous. These ventifacts become "leading fossils" of the outwash areas and are seldom or never left one-sided.

In a monograph now in process of publication in the *Proceedings of the American Philosophical Society*,<sup>2</sup> it has been shown how the distribution of ventifacts and of the loess of the upper Mississippi valley illustrates the processes above described for the latest Pleistocene continental glacier (Wisconsin) in North America. The map of the deposits of the latest continental glacier (*Wurm*) of Europe reveals a quite similar relationship (Fig. 2).

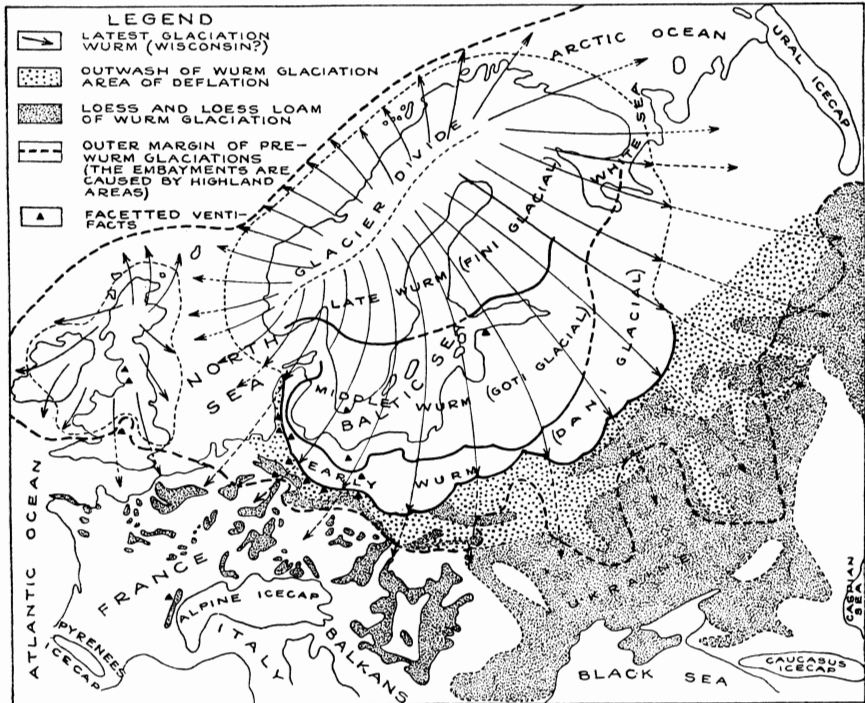


Fig. 2. Glacial map of Europe based on Richter's map<sup>3</sup> after Bubnoff.

<sup>2</sup> The Glacial Anticyclone and the Continental Glacier of North America.

<sup>3</sup> Richter, Konrad: 1937, *Die Eiszeit in Norddeutschland*, Borntraege, Berlin, Map of figure 22 on p. 49.

Outside the outermost moraine of the *Wurm* glaciation there is a rather broad area of outwash, and extra-marginal to this broader areas of loess and loess-loam, the latter largely within the steppe areas of the eastern portion, and particularly the Ukraine of the U.S.S.R. The directions of the winds of the glacial anticyclone (the glacial border is non-lobate) are supplied by the glacial striae and by the long, narrow lakes with essentially the same orientation. There is, however, a moderate clockwise deviation of the winds from these directions due to earth rotation.

Though ventifacts have not as yet been especially sought out, a number of localities for them have been recorded by glacialists and some of these (all *Windkanter*) have been entered upon the map. The deposits of loess are thickest nearest the outwash border, and a typical section after Grahmann<sup>4</sup> is reproduced in Fig. 3.

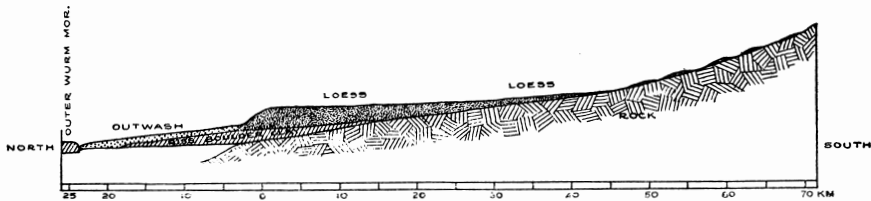


Fig. 3. North-south section from Riese to Aue in Saxony to show the glacial deposits outside the outer moraine of the *Wurm* glaciation in Europe (after R. Grahmann).

In an important work Soergel<sup>5</sup> has treated of these relationships, but without considering the agency of the glacial anticyclone.

<sup>4</sup> Scheidig, Alfred: 1934, *Der Loess und seine geotechnischen Eigenschaften*, Steinkopff, Dresden and Leipzig, Fig. 45, p. 46.

<sup>5</sup> Soergel, Wolfgang: 1919, *Loesse, Eiszeiten und paleolithische Kulturen, Eine Gliederung und Altersbestimmung der Loesse*, Fischer, Jena, pp. 177, 14 text figures.