NÅGRA GLACIALMORFOLOGISKA FORMELEMENT OCH DERAS VITTNEBÖRD OM INLANDSISENS AVSMÄLTNINGSMEKANIK I SVENSK OCH NORSK FJÄLLTERRÄNG. CARL M:SON MANNERFELT. *Geografiska Annaler*, Årg. 17, Haft 1–2, 1945, pp. 1–239

THIS brilliant morphological study of the erosional and depositional forms associated with the decay of the last ice sheet in the central part of the Scandinavian mountain range is a work of outstanding importance to all glaciologists and geomorphologists. It is based on the detailed examination of eight areas in this mountain region, ranging from one of 600 sq. km. in the vicinity of the Oviksfjällen massif down to smaller, carefully chosen areas of about 50 sq. km. Some lie on the north-west and some on the south-east side of the main watershed. They are all west of the main ice divide of the Scandinavian-Baltic ice-sheet of the last glaciation. The author first gives a critical summary of the facts and inferences from earlier glaciological studies of modern glaciers and ice-sheets, expecially those of Alaska and Iceland.

The glacier ice below the snowline is convex upwards and thus favours the concentration of summer melt water towards its margins, with the consequent formation of marginal drainage channels on the adjacent rising, ice-free ground. Above the snowline the glacier surface is concave upwards, and this marginal concentration of melt water is not to be expected. Therefore the prevalence of melt water channels, cut either as direct drainage channels from the ice across ice-free cols* or marginally to ice lobes, is considered an indication of a snowline higher than the ice surface in the vicinity. It appears that this condition existed when the Baltic ice was still a thick mass some tens of kilometres broad.

In the Oviksfjällen massif, east of the main Scandinavian watershed, the surface of the ice was below the snowline when the highest summit (1,370 m.) was first bared. It is probable that this was also the case over the ice divide itself (at about 1,600 m.). At a somewhat earlier stage in the Rondane, which, owing to its more westerly position, probably had a snowline minimum much lower than Oviksfjällen, marginal channels occur at altitudes of nearly 1,600 m. Even now the Rondane has a névé field and would probably have small glaciers except for its comparatively continental climate and low precipitation. This region is the highest examined by the author, and even at this relatively early stage in the deglacierization the ice was "climatically dead." Its further decay was due essentially to the vertical lowering of the whole surface by ablation. Indications of movement such as the disturbance of subglacial deposits formed during the decay have not been observed; it seems probable that the ice was almost stagnant soon after it became climatically dead.

The author gives detailed accounts of the various land forms produced during the downwasting. The closely and regularly spaced parallel sequences of marginal drainage channels are most striking. In some cases upwards of fifty were found on one hillside. Such groups are interpreted as marking the annual recession of the ice margin. While the actual linear extent of the recession depends on the direction and angle of slope of the ground, estimates from various situations give an average figure of 3 to 4 m. for the (annual) vertical thinning of the ice between successive channels.

Data from marginal channels and from lateral sand and gravel terraces indicate a forward slope of the ice of 1 in 30 near its termination. Farther from the ice front the surface slope is much gentler.

Channels, now largely dry, were cut down the hillsides subglacially by melt water plunging beneath the ice. These are called "subglacial chutes" in the English summary. Of special interest

* The author's "col gullies."

among the constructional forms are the narrow ridges, a few metres high, orientated downwards on the hillsides. On excavation these prove to be bedded sand and gravel with a thin covering of unbedded ablation moraine clearly deposited during the final disappearance of the superincumbent ice. The gravel ridges are interpreted as detritus-choked, subglacial stream courses—"subglacially engorged eskers." In some cases they appear from the maps to be in groups concentrated in broad recesses or concavities in the hill slopes. The intervening buttresses or convexities are free from these deposits, but are seamed by marginal channels. In Dörrsjöarna, in Oviksfjällen, the esker ridges are clearly tributary to a subglacial esker belt (partly concealed by ablation moraine and lakelets) which follows the axial belt of the valley. Higher up on the hillside there are subglacial chutes which appear to lead down to the hillside esker ridges. This valley also provides an excellent example of a channelled outwash plain—a fossil "sandur." From another part of this region (Lillfjället) a well-developed lateral terrace has formed in an area with abundant subglacially engorged eskers. Some of the latter terminate upslope at the terrace and so appear to be approximately contemporaneous with it—an interesting case which is suggestive of marked variations in the hydrological conditions within the ice.

The final ice melting in the recesses in the hills generally produced hummocky ablation moraine on the low cols. In the valleys there is a progressive passage from ablation moraine on the intermediate slopes, through hummocky (knob and kettle) moraine with glaciofluvial material to pitted outwash deltas and terraces. Finally these merge into lower level marginal terraces and dead ice-dammed lakes. This sequence is finely displayed in the Dörallselva valley near Döraalsaeter in the Rondane.

Dr. Mannerfelt recognizes a late revival of local ice in some of the cirques in the Rondane and Sylarna areas. In the former he has been able to date this recrudescence as postglacial by means of pollen analysis. In general, however, the cirques have little or no frontal (terminal morainic) deposits; they are considered to date back to at least part of the last glaciation, having been "protected" at its maximum. Even in the high mountain district of Sylarna, the most maritime of the areas studied, the latest striæ demonstrate an uphill movement of the inland ice westward across the mountains. The evidence is wholly consistent with a gradual disappearance of the ice by uniform downwasting, as occurs in the more continental areas to the south and east. The author recognizes, however, that in certain mountain massifs local glaciers existed during and after the downwasting period.

A detailed classification of land forms associated with "dead ice" is given under the headings of "supraglacial," "lateral," "subglacial" and "extramarginal or frontal."

A full summary in English is provided and—an especially helpful point—the descriptions of all the illustrations are accompanied by an English translation.

The work is profusely illustrated by photographs, line drawings and maps. The larger scale maps are stereoscopic and show contour detail plotted from aerial photographs. Among the most effective photographs is that in Fig. 9, an aerial view showing a supraglacial delta. This is clearly recognizable after the disturbance of the surface by the final melting of the ice below and the formation of a typical hummocky ablation moraine topography.

The reviewer is convinced of the validity of the author's main conclusions, especially as he has recently had the advantage of seeing the Rondane area under the guidance of Dr. Kaare Ström and Mr. Tore Sund, whose detailed studies there fully support Dr. Mannerfelt's interpretation. Professor Flint's stagnation interpretation of the decay of the last ice sheet in eastern North America is well founded. It seems desirable to stress the importance of this concept, not only in those areas of Pleistocene glaciation, where decay in situ on a limited scale has been suggested, for example in the Midland Valley of Scotland and in Northumberland, but in others where it has not yet been critically considered.

In this connection it may perhaps be recalled that the late stage in the decay of the last ice-sheet

in Edenside has been interpreted as one of the progressive thinning or downmelting with little or no supply or forward movement from the Lake District valleys. If this view is accepted valley-head corrie-moraines may well represent a renewal of the local glaciers, a hypothesis which is not novel but is one to which it is hoped to give further study. A post-glacial phase of laminated clay formation suggestive of the recrudescence of glaciers appears to lend support to this view. Evidence of this phase has been obtained from core samples taken from the bottom of Lake Windermere by Miss Pennington (now Mrs. Tutin) of the Freshwater Biological Station at Wray Castle.

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CRYOPEDOLOGY: The study of Frozen Ground and Intensive Frost Action with Suggestions on Nomenclature. By KIRK BRYAN. *American Journal of Science*, Vol. 244, 1946, pp. 622–92

THE author sets out to introduce some order into the terminology of the study of frost action and permanently frozen ground. "Cryopedology" is his name for these studies. There is clearly a need for some rationalization, but the new words he introduces, derived largely from Greek and Latin roots, are in many cases rather cumbersome for every-day use. The ideas and phenomena associated with the new terms are very clearly conveyed and the paper renders a useful service in sorting out the various meanings given to the older words and phrases in the past.

Nevertheless it seems a pity to replace such a self-explanatory word as frost-heaving by the term "congeliturbation," although as the author points out there is no way of deriving from such verbal expressions corresponding nouns for the products of their action. Instead of frost-heaved silt the proposal is presumably "congeliturbate silt." Where the action of frost is merely to freeze the water in the rock voids and fissures without building up ice lenses, the splitting open of the rock due to the water-ice expansion is called "congelifraction." A few lines after introducing this word it appears that the author falls into his own trap by using the more familiar term "frost action."

The terminology of the movement of soil downhill as a result of frost-heaving and thawing on slopes is discussed at some length. In considering the terms that have been used in the past to describe the material moved by the above process it is surprising to find the word "warp." According to the *Shorter Oxford English Dictionary* this word as a noun dates from before 1700 and is an alluvial deposit laid down naturally or artificially by water and even to-day it is in common use amongst drainage engineers. The term "solifluction" introduced by Andersson (1906) is frequently used for the migration of weathered material downhill under the action of frost-heaving and thawing. Although Andersson himself may not have understood the mechanics of the process, his type localities are all in cold regions where the phenomenon is important. Bryan wishes to use the word "congeliturbation" in this sense, but there does not seem to be sufficient differentiation in his use of the word. Presumably, for example, an area of level ground subjected to annual frost-heaving and thawing would be called "congeliturbate ground," but in no sense will it be migrating downhill.

The widespread lowering of relief produced by "congeliturbation," which various authors have suggested as the origin of the smooth broad upland surfaces in Tibet, Iceland, and South East Alaska, is appropriately called "cryoplanation."

The active zone above permanently frozen ground, which seasonally freezes and thaws, is termed the "supragelisol"; the word "mollisol" appears to be synonymous. The combined actions of thawing and softening of the mollisol are known as "mollition," but it is often necessary to refer to these two actions individually. Several other words are introduced for the various zones in permanently frozen ground, but to use the author's summarizing phrase, they are "somewhat overpowering in number."