Drumlins in southern Sweden

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In order to obtain a comprehensive view of all kinds of drumlin moraines, a very large number of such ridges has been studied and compared in four large drumlin areas in the broken South Swedish Highland and in four small drumlin areas with another type of terrain outside the Highland. After short descriptions of each district (topography and elevation, location and types of drumlin moraines), the main characteristics of these ridges are described and analysed. On the basis of all these data and other investigations of the till distribution and ice physics, the formation of the drumlin moraines is discussed from different aspects.

Three modes of initiation of this process may have occurred — (A) accumulation (mostly of till, but also of meltwater sediments) by pressure melting proximally of obstacles, and by slumping and squeezing distally of them, (B) accumulation from stagnant ice melting out at different obstacles, (C) accumulation in basal cavities originated proximally and/or distally of obstacles or only due to differential ice flow. In all cases, the obstacles may have been of different types — rocks, rock hills, plateaux, till sheets, boulder heaps or previous glacial forms of different material. This initial accumulation may have been concluded after the formation of comparatively small moraines — according to A and B above stoss- and lee-side moraines and according to C fluted moraines. The latter have originally a ridge-form, the former usually not, but they too may often have developed into small pre-hills or pre-ridges.

An origination of such pre-ridges has probably been one of the most important factor of a continued evolution into real drumlin moraines. This may have caused so great contrasts in most ice physics on and around the actual places, that zones of different ice activity have rapidly developed, i.e. zones of, mostly, accumulation on the pre-ridges, zones of, mostly, transport beside them. But other factors must also have been fulfilled for a continuation of the drumlin process, e.g. material continuously at hand, enough time and no great changes in ice motion.

The drumlin formation has, in principle, been due to an interaction between three main factors — the topography, the material and the ice — but these must have been complex. If one, two or more of these factors of first or second order have not been totally fulfilled, the drumlin process has changed character, been less important or not at all appeared.

Finally, the age of the drumlin evolution is discussed. Even if some ridges may have been founded during the advance of the last ice cap, most of their characteristics seem to indicate a formation during the ice disappearance, but probably not in the outer zone of real deglaciation but inside it in an inner zone of maximum glacial activity, i.e. in a zone with neither too thin nor too thick an ice.

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Contents

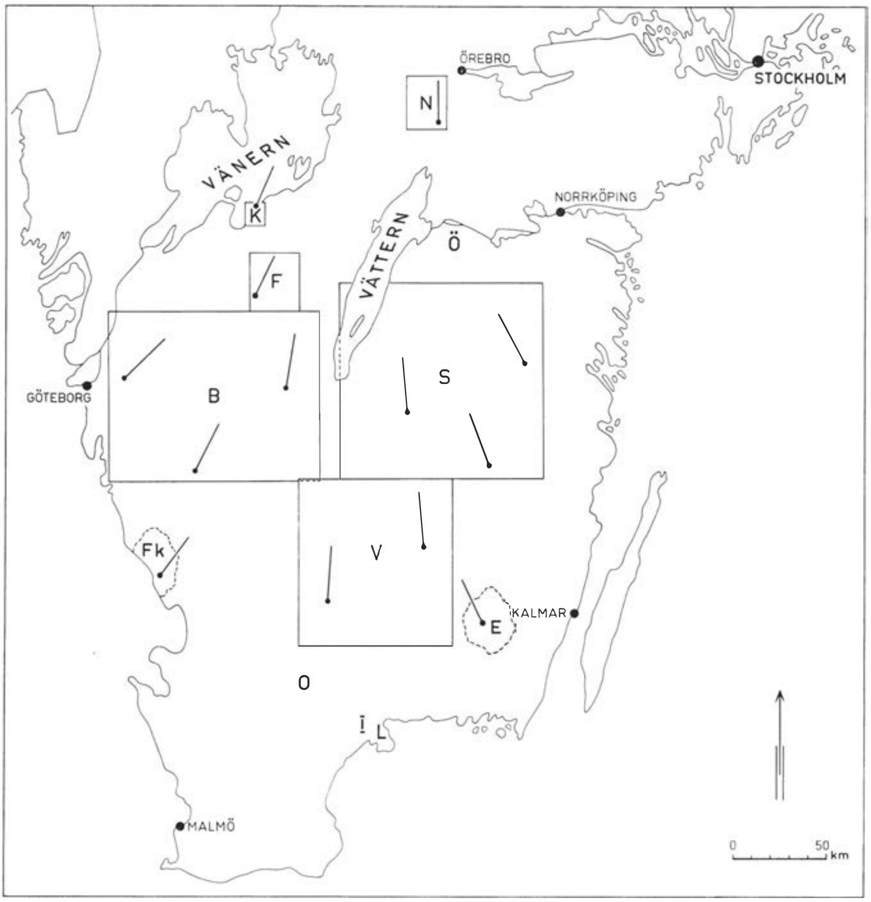


Fig. 1. The drumlin areas studied and mentioned. (1) Described in detail and with maps and tables. On the South Swedish Highland — B = the Borås area (Fig. 8, Table 1), S = the Sommen-Solgen area (Fig. 9, Table 2), V = the Värend area (Fig. 10, Table 3); outside the South Swedish Highland — F = the Falbygden area (Fig. 11, Table 4), K = the Kinnekulle area (Fig. 13, Table 5), N = the Närke area (Fig. 14, Table 6). (2) Described only briefly and without maps and tables. On the South Swedish Highland — E = the Emmaboda area; outside the Highland FK = the Falkenberg area. (3) Mentioned en passant, all outside the South Swedish Highland — L = on the Lister peninsula, I = around Lake Ivösjön, O = in the Osby district, Ö = on the Östergötland plain. The arrows show the main direction of ice movement according to most of the normative glacial striae in each area (cf. geol. maps and National Atlas of Sweden).

Introduction

Drumlins are well-known ridges in all glaciated regions. Their streamlined shape and often conspicuous position in the terrain have induced many geologists to make detailed descriptions (cf. ref.). Thus, their formation was discussed at an early stage, and various basic theories and sundry variants thereof have been propounded. But these differences in interpretation are not surprising, for many characteristics of the drumlins indicate accumulation, others seem to prove erosion, and some may express both a depositional and an erosional evolution.

These divergences in the understanding of these moraines may indicate that they could have a multiplex origin. Indeed many problems are still debatable. One of them is why such ridges exist at all, another is their occurrence both regularly and at random, and yet another is the wide variations in type, shape and internal composition. These and many other features of the drumlins seem to indicate that special conditions must have prevailed for such an activity of the bottom ice, but perhaps also that not all drumlins have developed exactly in the same manner (cf. Hill 1971, Virkkala 1974). In all probability these factors were of crucial importance at the beginning of the drumlin process, a fact which is indicated in many drumlin studies but is seldom explicitly stated (cf. Hill 1971). Hence, the basic question is why and how these moraines started to form, not only how the continued evolution to streamlined ridges occurred. Even if the first problem is the main subject of this paper, the second is worthy of discussion. This is appropriately dealt with in connection with the descriptions of the drumlin characteristics.

Thus, the drumlins vary in many respects. This means that features which may illustrate the principal development, can be slightly apparent or be lacking in many ridges. A search for the primary cause(s) of the drumlin formation must therefore involve study and comparison of many such moraines. Among these, the ones which seem to be incomplete, are the most interesting as they may display some characteristics of the original evolution. But it is equally important to relate these glacial elements to the surrounding milieu as their occurrence and formation must have been connected with the development around them (cf. Hill 1971). Varying topographical conditions, for instance, may have been a decisive factor for differentiations in the ice activity in general and thereby for the drumlin process, too (Gillberg 1964, 1970). Therefore, the drumlins studied may lie in different terrain some characteristics of which should be known, e.g. the distribution, types etc. of the other basal till.

Starting from these assumptions, I have closely investigated three large drumlin areas on the South Swedish Highland and outside them three small districts with an entirely different topography (Fig. 1). Two other small drumlin areas — one on the South Swedish Highland and one on the plain of Halland — have been explored en passant. For even if the drumlins there are interesting in many respects, they are highly similar in each district.

Some of the drumlin characteristics — orientation and position in the terrain, shape, type and dimensions — were easy to study. The material composition, on the other hand, were difficult to penetrate in detail. For deep vertical sections are few and, besides, are never of suitable extent (in parallel with and/or transverse to the ridge axis and right to the bottom of the ridges).

This investigation tries to solve some problems of the evolution of the drumlins in principle. Thus, the report must be, in the main, a discussion of principal features, typical of many ridges. The six drumlin areas more closely investigated were mapped to provide information on different conditions (Figs. 8—11, 13, 14). These maps show broad features of the topography and all the drumlins studied. Ridges displaying representative features, or those which for these and other reasons are mentioned in the text, are briefly described in the tables 1—6 and marked on the maps. But as too many drumlins are included for a continuous numbering, each one of the maps has its own series of numbers. Drumlins with the same number are distinguished from each other by the initial letter of the drumlin district — for instance B12 = drumlin no. 12 in the Borås area.

The terms ascent and descent or ascending and descending terrain are in the following pages used in relation to the direction of the ice movement.

Finally, I will emphasize that nearly all papers discussing the drumlins and their formation are of importance for their understanding and should have been cited. Yet some limitation of references is justified. Therefore the papers quoted are mostly those which in principle deal with the same problems as mine.

The complex of drumlin moraines

A drumlin is a specific type of moraine. Nevertheless it is only a part of a complex of similarly shaped ridges or ridge-like till deposits, of the same origin in principle and with some common features but each one of them with certain characteristics of its own (Ebers 1931, 1937, Gillberg 1955, Kupsch 1966, Flint 1971, Glückert 1973, Aario et al. 1974). Two main types of such moraines are distinguished by Chamberlin (1894) — drumlins and crag moraines. For various reasons, a more detailed classification appears necessary. Notwithstanding it should still consist of a limited number of types with few distinct characteristics. During this investigation, the following have emerged as typical and individual forms. They are classified according to two or three features — position in the terrain, external shape and in one cause material composition.

(1) *Drumlins.* — Ideally they are well delimited, elliptical, streamlined ridges, usually with steeper proximal and gradually sloping distal sides. Partly owing to this shape, the crests are displaced proximally, and the breadth is often greatest in this zone (Fig. 2). If foundation rocks exist, they are completely covered by till and probably normally situated under the crests. As these ridges

Fig. 2. Small real drumlin of ideal shape: proximal side short and the steepest part, low proximal crest, then continuously downward-sloping to the indistinct distal end. Ice movement from the right. Bolum, E. side of Lake Hornborgasjön, Falbygden area (Fig. 11); the small ridge NNE. of Broddetorp (F1).

tend to be of different extent, it is possible to distinguish three types of second order — mammillary hills, lenticular hills and elongated ridges (Chamberlin 1894). These terms can be used for the following main type as well.

(2) *Drumlinoids.* — Not all drumlins are so distinctly shaped as one or more features may differ from those described. In the areas studied this is the norm. But most of these divergences are superficial variations of the usual shape. There is no reason for using another term for such moraines but it may be a matter of subjective judgement, depending on how great differences in shape are to be permitted in a strict nomenclature.

On the contrary, two other characteristics of some drumlins seem to be so special that another designation of these moraines is advisable — possibly the term drumlinoid, a word which hitherto has been used with a vary different meaning. Here it is limited to ridges with the following features: (*A*) the foundation rocks — often glacially eroded and polished (Fig. 3) — project and are often the crest(s), or the foundation rocks are exposed on one or both the long sides; in both cases, however, there is no boundary between the proximal and distal sides, i.e. uniform moraines. (*B*) material other than basal till occurs in large quantities (Fig. 29).

(3) *Crag moraines.* — These correspond to precrags and crag-and-tails according to Chamberlin 1894, stoss- and lee-side moraines according to Björnsson 1953, precrag and postcrag ridges according to the author 1970. They are streamlined ridges or ridge-like till concentrations against rocks and heights of different extent (Fig. 4). Both types usually become narrower and descend towards the proximal and distal ends, i.e. the crests are situated at the rocks (crags). Sometimes both types are developed at the same rock or height but also in these cases each ridge is a moraine of its own with the crag as a definite barrier in between.

In the areas studied, the postcrag ridges are, on average, more elongated but sometimes less regular than the precrags, both in general form and superficially. Furthermore, they usually follow on from

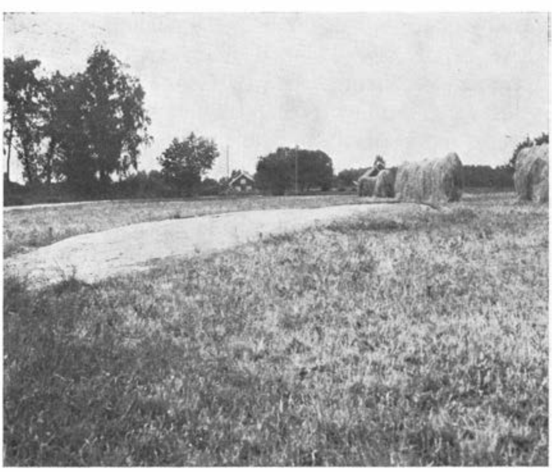


Fig. 3. Drumlinoid with the foundation rock projecting in the distal part, glacially polished; nearly plane surface around. Ice movement towards the reader. Kalvshaga ridge, W. side of N. cove of Lake Åsnen, S. of drumlin group V78, Värend area (Fig. 10).

Fig. 4. Precrag moraine — low, shield-shaped, undulated and not distinctly delimited towards the surrounding terrain, i.e. in all respects not typical ridge-form; comparatively large segments of different gradient. Ice movement from the reader. Baggetorp ridge (S84), Sommen area (Fig. 9).

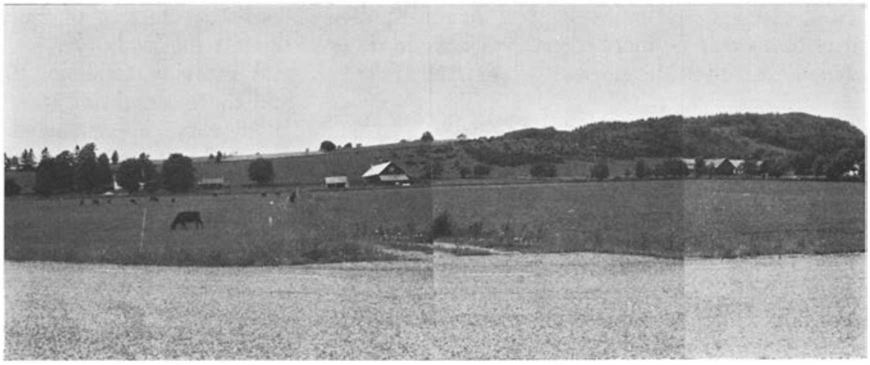


Fig. 5. Postcrag moraine — in direct continuation of the crag (right) from which it slopes in distal direction, first somewhat steeper, then more gradually; well levelled long side with medium-sized gradient; cultivation as far as the till is of suitable thickness for that. Ice movement from the right. Gisseberg ridge (F15), Falbygden area (Fig. 11).

the crags, i.e. there is no distinct limit between them and the latter (Fig. 5). The precrag ridges are generally lower than the crags, i.e. are more or less distinctly delimited from them — more separated if the crags are more exposed (Fig. 6), less so if the crags are covered by till, levelled in places (Fig. 7). But there are several exceptions to these main features.

Thus, the rocks, too, can be almost completely covered by basal till (to a thickness of one or two m). And as they often project here and there and the till can be levelled, such complexes seem to be large drumlinoids of type A. But as the rocks form the greater part of them and are delimiting elements, and as the till is predominant only proximally and/or distally, the correct designation must be precrag and/or postcrag moraines. The main question is how thick the basal till on the foundation rocks is to be for this classification. For the discussion here, this problem is irrelevant.

On the other hand, some ridges which lie proximally and/or distally of rocks or heights — crag moraines by their position — are better

Fig. 6. Precrag moraine with distinct limitation to the crag (left) from which is gradually slopes in proximal direction. Ice movement from the right. Proximal, easternmost ridge on the Linderås plateau (S4), Sommen area (Fig. 9). In the foreground, the lower part of the marginal drumlinoid on NW. side of drumlin group S6; many large surface boulders.

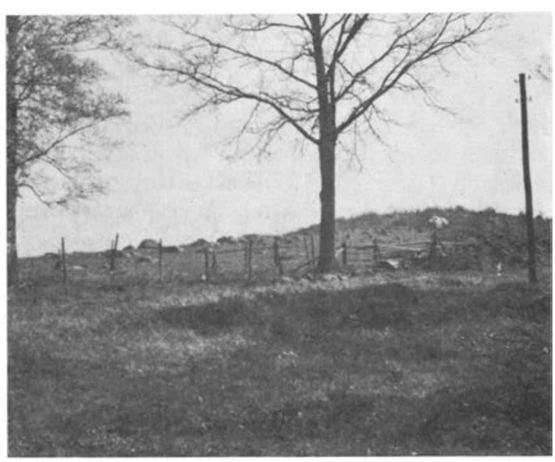


Fig. 7. Precrag moraine with less distinct limitation to the crag (right) which also is covered by till, mostly levelled (rounded shape); many large surface boulders. Ice movement from the left. Upper part of the Svenskbygd ridge (V5), Värend area (Fig. 10).

described as drumlinoids or real drumlins. The latter terms may be more correct when these ridges have short slopes developed towards the rocks.

(4) *Lid moraines.* — All till deposits against rocks are not ridges or ridge-like. They have, instead, a less differentiated form. They have therefore often been interpreted as parts of the ground moraine.

The most conspicuous of these concentrations of basal till are associated with plateaux of different extent, usually on the proximal sides or on the long sides which because of the form and position of the heights have come to lie oriented against the ice movement. The sloping surfaces which are sometimes irregular, even have projecting rocks, or are sometimes more levelled, often merge into the plateau tops and the surrounding lower ground without distinct limits. Locally, the till continues up over the heights; if the latter are not too large, it may cover most part of them. In such cases, great drumlinoids of type A seem to occur. But all characteristics of such complexes indicate that the heights determine their shape. Longitudinal undulations may occur, and the most proximal and/or distal parts are sometimes elongated. In places, the latter have developed into drumlinoids or real drumlins. These may also exist as isolated tops; on the plateaux which are more completely covered by till, they are often situated on their margins.

The last two features in particular indicate that these large till concentrations are older than or simultaneous with the drumlin ridges (cf. Hoppe 1957). Moreover, the position and the more or less levelled form point to a similar origin. They are a special type of crag moraines which have not developed ridge form, either because of having lain at an angle to the ice movement, or because of the magnitude of the heights and/or too little material at hand. Owing to their less differentiated shape, they ought to be distinguished from the real crag ridges. I called them stoss-side moraines previously (Gillberg 1955) but as they occur also distally and can extend over entire plateaux, this term cannot be retained. As such a plateau slope is often called a lid in Swedish (pronunciation *lēd*), this word can be used as a prefix, i.e. lid moraines (cf. Högbom 1905, Fig. 16 in Gillberg 1955, J. Lundqvist 1969a). If the location is clear, the terms proximal, distal, long side or plateau lid moraines are advisable.

(5) *Stoss- and lee-side moraines.* — There also exist undifferentiated crag moraines of small dimensions, usually at comparatively small rocks. All of them cannot belong to the drumlin complex, but must date from the deglaciation, namely those consisting mostly of basal till but deposited at or near the ice border — locally as a kind of rock end moraine (Björsjö 1949, Gillberg 1961) — and those containing mostly ablation till. Yet even if all these are excluded as well as some indeterminable ones, small undifferentiated crag moraines exist, which due to their position and material composition must be assigned to the drumlin complex. In some areas, they seem to be common, e.g. where only a few real drumlin ridges occur. And they are important as in many cases they could be the first foundations of drumlin ridges, and as by reason of their small dimensions some of them can be studied as regards the internal composition (Hillefors 1968, 1974). These moraines should be distinguished from the real crag ridges. As their origin cannot always be determined, the neutral terms stoss- and lee-side moraines can be confined to them, i.e. only indicating the position.

Summary. — Thus, the moraines which are more or less levelled, subglacially formed by moving ice and consist at least superficially of basal till, seem to include the following main types: (1) Whole ridges — drumlins and drumlinoids, (2) Half ridges — precrag and postcrag moraines, (3) Without ridge form — stoss- and lee-side moraines, the large ones on plateau slopes possibly called lid moraines.

All these types can exist independently of each other, each being complete in itself. But many stoss- and lee-side moraines may be embryonic crag ridges (Hillefors 1974), and many of the latter may be incomplete drumlinoids or drumlins (Ebers 1931, 1937, Gillberg 1955). The last two types must be regarded as completed ridges but under special conditions they, too, could have been further changed.

But as this reasoning and the descriptions suggest, some drumlin forms can be misinterpreted or may be difficult to classify, e.g. drumlinoids contra crag moraines, great drumlinoids contra small plateau lid moraines, great crag moraines contra small proximal and distal lid moraines, even drumlinoids contra real drumlins. In reality, it applies to all related types of these moraines and certainly indicates processes of evolution (Ebers 1931, 1937, Rich 1935, Gillberg, 1955, 1970, Flint 1971, Glückert 1973, Hillefors 1974, Virkkala 1974). For this reason, I have not differentiated the types of drumlin ridges on the maps (Figs. 8—11, 13, 14) and sometimes included another denomination in the tables — in parenthesis after the given classification, e.g. drumlinoid (precrag).

Only one special symbol is introduced on the maps — Northwards- and Southwards-oriented

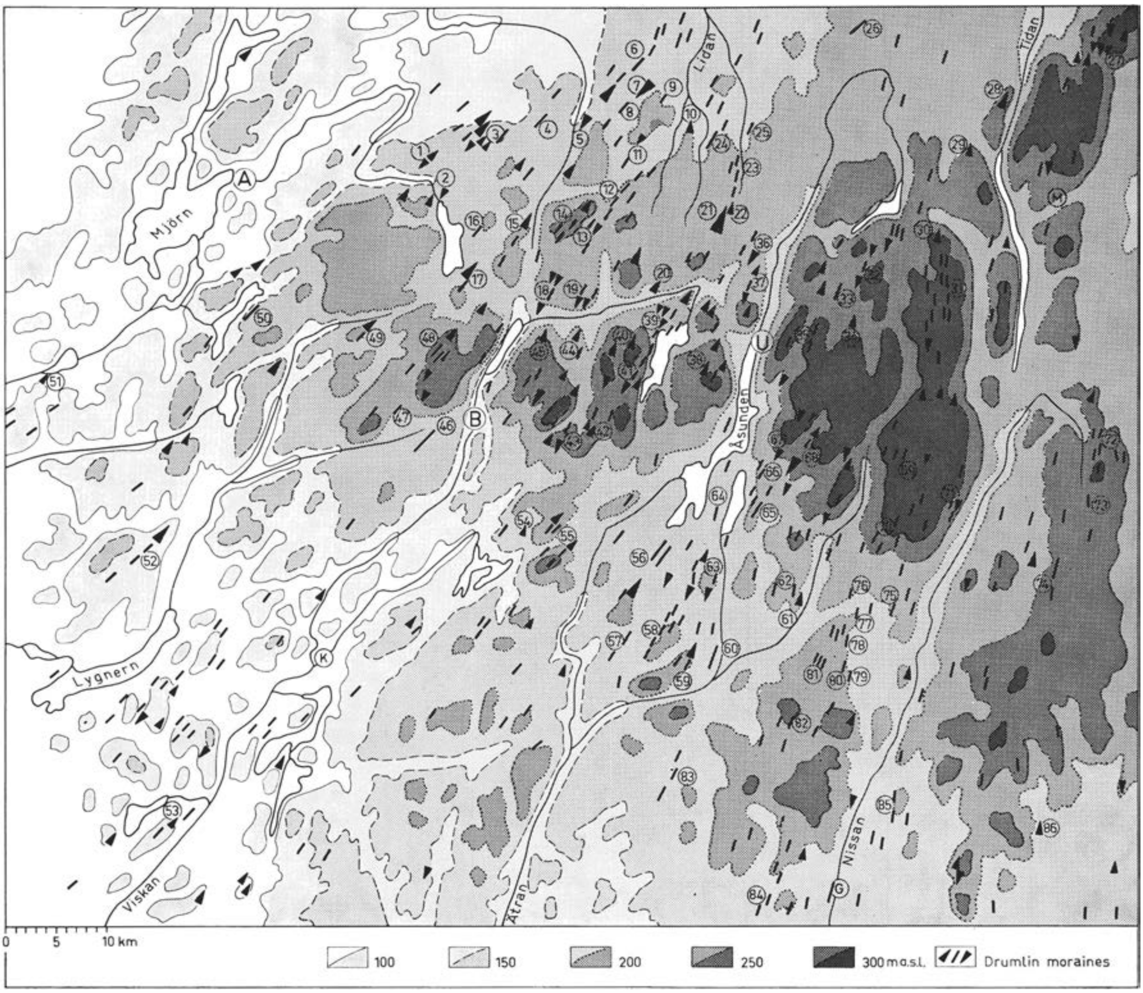


Fig. 8. The Borås area. The isohypses are drawn from the topographical maps — as a rule directly from the now ones but in some parts with the help of existing altitude marks on the older types of such maps. Modifications are made owing to the small scale. For this reason, a minimum length of the signs for the drumlin ridges had also to be decided, i.e. several drumlins are smaller than the signs show. All longer moraines, on the other hand, have their approximate length indicated by different long signs. As all parts of the area have not been studied in equal detail, some few moraines may be missing from the map. Some top and side ridges are also omitted, as they lie too near their major ridges and therefore often coincide with them on the map. Abbreviations: towns — A = Alingsås, B = Borås, U = Ulricehamn; villages — M = Mullsjö, K = Kinna, G = Gislaved.

wedges — namely for ridges with their crests placed in their proximal or distal halves and with markedly sloping short sides from them.

The drumlin areas

Areas on the South Swedish Highland

Most of the drumlin moraines studied lie on the low (highest points 350—375 m above sea level), but locally broken, South Swedish Highland where the predominating valley systems run between NE.—SW. and NW.—SE. Three large districts of such ridges may be distinguished (Fig. 1). Their limitation is somewhat arbitrary but it is natural as the number of these moraines markedly decreases towards the borders of each area. In the rest of the real highland, drumlin ridges frequently occur in a small district W. and N. of Emmaboda (Knutsson 1971). In the descending terrain towards the Baltic in E.—SE. and the provinces of Halland, Skåne and Blekinge in SW.—SE. such moraines are few. Different types of hummocky ablation moraine predominate there. Immediately outside the real highland, drumlin ridges again appear around L. Ivösjön and on the Lister peninsula (mostly large crag moraines) and in great number in the Osby district in N. Skåne (usually small and often irregular, real drumlins but also some large drumlinoids; Persson 1966).

(1) The drumlin area of S. Västergötland — the Borås area (Fig. 8, Table 1; Gillberg 1955) — can be divided into a northern ascent (S. of the Falbygden plain) with some few, narrow and shallow valleys; a central culmination zone of high plateaux between, usually, deep and narrow valleys; and a southern descent, towards the coastal plain of Halland in SW., breaking up into gradually narrower and lower heights between continuously broader and deeper valleys. Northwards and southwards, accordingly, the area merges into the surrounding plains. Although the plateaux are lower in W., it is there distinctly delimited towards the valleys of L. Mjörn and R. Göta älv. In NE., the long plateau of Hökensås forms a N.—S. barrier towards the depression of L. Vättern (just off the map). In SE. high spurs of this plateau form an ascending transition zone eastwards up to the central highland. The bedrock is gneiss throughout, with dioritic variants locally. The northernmost drumlin ridges lie immediately S. of the Cambro-Silurian area of Falbygden.

Most drumlin moraines are in the central part of the N. ascent, in the culmination zone and in the broken highland and descent E.—SE. of L. Åsunden. In other parts of the area, they are few or non-existent, e.g. on the low plateaux in NW.—W., on the N. ascent between the Lidan and Tidan rivers, in the even highland E. of R. Nissan and in the descending terrain in S.—SW. In the latter district, there is a small group of drumlin moraines on the plateaux between the valleys of L. Lygnern and R. Viskan.

The drumlin ridges are normally close together in succession and/or parallel to each other, but such groups are often gathered in long radial series or double series in the direction of the general ice movement, e.g. 6/7—48/47, 9—18, 25—42/43, 67/68—57/59, 70—82. These series usually begin and/or end abruptly, i.e. there are no ridges just N. or S. of them; furthermore, they can abruptly change position, i.e. a distal group of moraines are displaced to the sides of the proximal ones.

Drumlinoids of type A are predominant but their foundation rocks are normally not conspicuous. Thus most of these drumlinoids are nearly real drumlins, a fact which is also apparent by their levelled shape on the whole. Some of these ridges lie isolated and are comparatively high with steep sides. Such a type is not common, however, and except some few in the northern and central parts (8, 25, 46, 50) most of them lie on the descending plateaux between the Ätran and Nissan rivers in SE. (e.g. 76, 77, 79, 83, 85). Real drumlins, which are mostly low and narrow but often long, occur sporadically, and generally in more unobstructed terrain, e.g. on the N. ascent (6, 11, 24), on plateau summits (part of 23, 31) and as tops on, or side ridges of great drumlinoids and lid moraines (34, 37, 38, 44, 48, 60, 62, 63, 70).

Crag moraines are not common, probably due to topographical conditions (comparatively uniform plateaux?). Nearly all lie on the N. ascent and in the culmination zone, and there are approximately as many precrags (e.g. 3, 10, 13, 22, 39, 41, 42, 43, 68) as postcrags (e.g. 3, 13, 18, 19, 22, 27, 32, 35, 39). Lid moraines, mostly proximal and on plateaux, tend to occur where the N. ascent joins the culmination zone and inside it; on the S. descent they are few (Tab. 1). Stoss- and lee-side moraines appear particularly where typical drumlin ridges are rare, e.g. on the N. ascent between R. Lidan and R. Tidan and on the SE. highland E. of R. Nissan. They are also found on the S. descent between the Ätran and Nissan rivers — a comparatively open terrain with many rock hills — but there many of them have an embryonic ridge form (Table 1, nos. 81, 83).

Many of these moraines have a more or less reverse drumlin form, i.e. their crests lie in their distal halves and the proximal sides are sloping, the distal ones steeper (Fig. 17). This fact is partly visible on the map — the wedges to N. — but only ridges with this form strongly developed are shown (cf. p. 148). For in reality about 2/3 of all drumlin ridges here must be assigned to this group. On the other hand, nearly all moraines with their crests in the proximal halves and with sloping distal sides (= ideal drumlin form) are shown on the map — the wedges to S. They are nearly always on descents of separate plateaux or in the descending parts of the whole area.

(2) The topography of the drumlin area of S. Östergötland and N. Småland — the Sommen-Solgen area (Fig. 9, Table 2; Björnsson 1953, Agrell 1974) — resembles that of the former district but with reverse elevations in W. and E. From the Östergötland plain (partly Cambro-Silurian rocks) the terrain gradually ascends southwards and reaches its highest points in S.—SW. It also slopes upwards from E. towards this culmi-

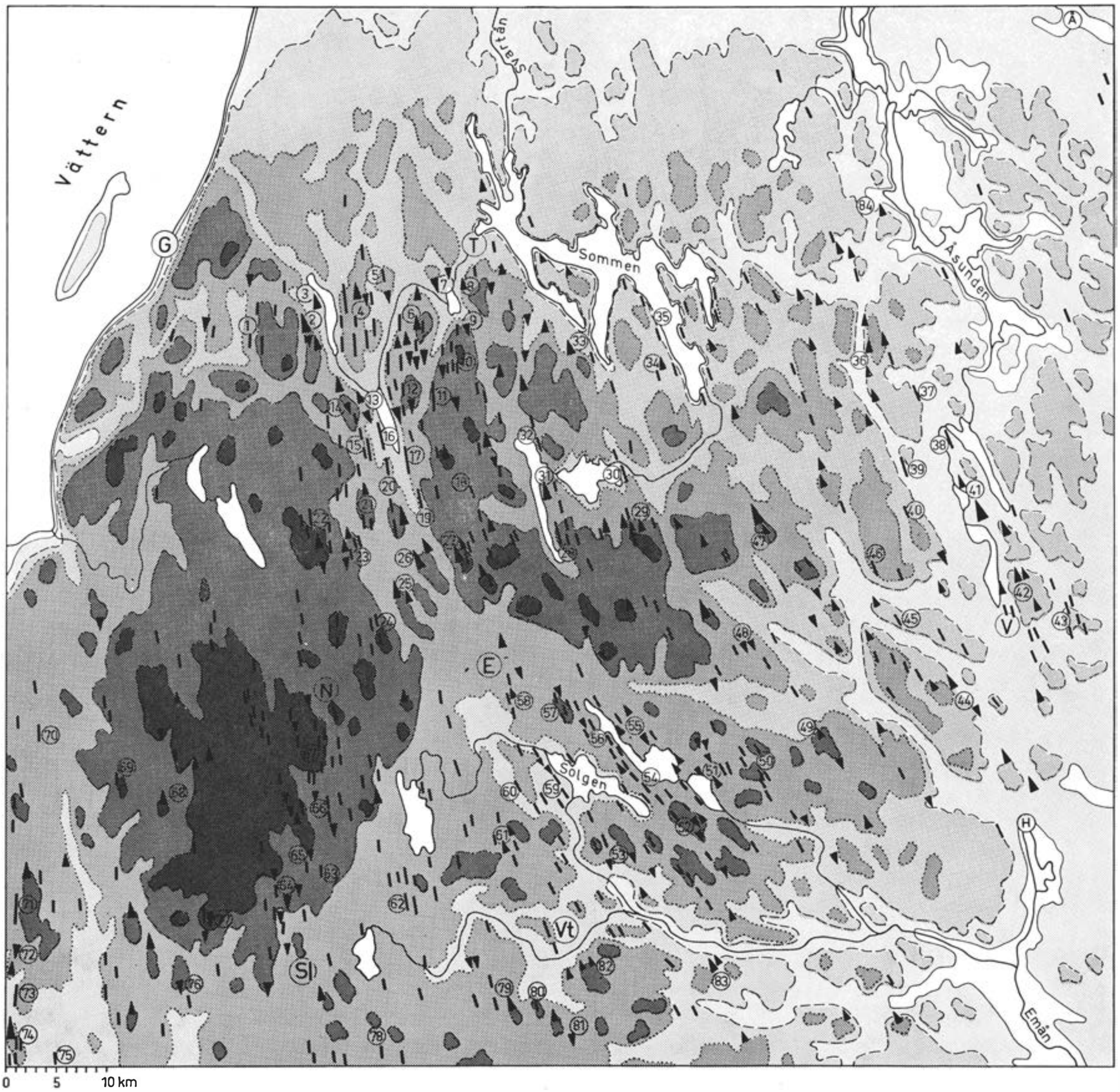


Fig. 9. The Sommen-Solgen area. The same text as for the Borås area also applies here; legend of the signs, too. Abbreviations: towns — G = Gränna, T = Tranås, E = Eksjö, N = Nässjö, S = Sävsjö, Vt = Vetlanda, V = Vimmerby; villages — Å = Åtvidaberg, H = Hultsfred.

nation zone — as plateaux of increasing height. Since this district lies N. of the central highland, its culmination zone is much broader and the S. descent from it first begins in the next drumlin area (Fig. 10). The greatest topographical differences from the former district occur in the central and eastern parts. Due to the occurrence of a great number of fissure zones in the bedrock, running obliquely or perpendicular to the N.—S. main valleys systems, the Sommen area is here greatly dissected in a mosaic of plateaux and rock basins. Apart from the Östergötland plain (cf. above), the bedrock consists of granites and porphyries, the latter being replaced locally in S. by diabases and Pre-Cambrian sedimentary rocks.

There are three parts without or with only a few drumlin moraines — on the low ascent in N.—NE., on the high plateaux E. of L. Vättern and on the descending plateaux in SE. The rest of the area contains a great number of such ridges, concentrated to four parts — on the plateaux around L. Ralången SW. of Tranås, on the low plateaux around Vimmerby, on the low and level plateaux around L. Solgen and in the culmination zone S. of Nässjö. Between these regions, there are small gaps, where such ridges are few, e.g. around Eksjö and in the ascending terrain S.—SE. of L. Sommen.

Such long distinct series of drumlin moraines, discernible in the Borås area, are scarcely apparent here — although there may be some short ones around Vimmerby (38—43), L. Solgen (57—52) and S. of Nässjö (67—64). Instead, somewhat isolated groups of such ridges predominate, usually with two or more lying in succession and/or parallel to each other.

Drumlinoids of type A are prevailing but their foundation rocks are usually conspicuous. High and isolated such ridges with steep sides are found especially in the highland around L. Solgen and S. of Nässjö (e.g. 56, 58, 59, 61, 62, 63, 76, 77, 79). The occurrence and types of real drumlins partly differ from these features in the Borås area — more numerous long and low ones (18, 60, 66, 70, 73, 75, 78), fewer as plateau summits (some of 22, 24, 43, 67) but many as top or side ridges of great drumlinoids and lid moraines (e.g. 4, 11, 15, 20, 27, 28, 31, 34, 55, 61). As in the Borås area, many of these drumlin moraines display crests in their distal halves (= reverse drumlin form), wedges to N. (Fig. 9).

A fairly large number of crag ridges are found — about 20 precrags (Figs. 4, 6) and 20 postcrags. They occur throughout but with greater concentration to the middle part, i.e. in the most broken terrain. Lid moraines are few and are mostly of the proximal type. Nearly all of them lie in the transition zone between the N. ascent and the central, broken terrain (Table 2). Stoss- and lee-side moraines are found especially on the N. ascent in NE., between L. Sommen and L. Åsunden, and in SE., i.e. in districts with few real drumlin moraines (cf. the Borås area).

(3) The drumlin area of S. Småland — the Värend area (Fig. 10, Table 3; Rydström 1971) — consists in N. of broad plateaux (highest in NE.) which are the S. spurs of the culmination zone of the former area. The S. part is lower, comparatively uniform, with small differences in height, and it continuously slopes southwards, i.e. it is the S. descent of the central highland. Except in NE., the valleys which are shallow but often broad with many lake basins, tend to slope southwards. The bedrock consists of granites and porphyries, in the W. part also of schistose gneiss.

The drumlin moraines are mostly situated in the N. part with high and level plateaux, on the disrupted central descent and on the lower and uniform descent in SE. — there being a great concentration around L. Helgasjön. Nevertheless they are few on the high plateaux in NE., in the even terrain in NW., and especially on the open descent towards L. Möckeln in SW. Long, radial series of such ridges are scarcely developed; a number of short ones may be distinguished (38/40—33/34, 75—76, 79/80—88). The outstanding feature is small groups of drumlin moraines in succession or parallel to each other — the latter position being particularly common. In the northern and central parts these groups lie near each other, while in SW. and SE. they are more isolated.

Drumlinoids of type A predominate, the N. parts displaying more of Sommen type, i.e. with distinct foundation rocks (Fig. 3), and in the central and southern parts more of Borås type, i.e. with the foundation rocks almost completely covered by till. Some drumlinoids of type B are found, e.g. 36, 41, 71 (Fig. 29; Strandmark 1956, Knutsson 1959, Rydström 1971). Steep and high, isolated drumlinoids are somewhat more frequent but often smaller than in the two former areas; they occur throughout but with some concentration to the central district (e.g. 23, 32, 44, 66, 74, 80, 82, 85, 86). Real drumlins are comparatively common, especially in the open and even terrain in the central and SE. districts. Several are of the long and low type (e.g. 3, 22, 23, 24, 26, 27, 28, 38, 57, 63, 69, 75, 78, 83), while some are tops or side ridges of other large moraines (e.g. 14, 29, 35, 47, 48, 53, 56, 61, 62, 71, 79, 80); nevertheless they are seldom found on plateau summits.

Crag ridges — even precrags (Fig. 7) and postcrags at the same rock hill (e.g. 5, 16, 45, 64) — are few, being roughly equal in number to those in the Borås area. Lid moraines are rare (Table 3). Both these types occur exclusively in connection with the plateaux in N. or at the beginning of the S. descent. This shows that they are more topographically controlled than the other types of drumlin ridges, i.e. they are less often found in even and open terrain with small rocks. Stoss- and lee-side moraines are rare, which is surprising as the low descent in S. — at least from the topographical point of view — ought to have been suitable for an origination of such forms.

As evident on the map (Fig. 10), drumlin ridges with their crests in the proximal halves (= ideal drumlin form) are more frequent, especially in the central and S. parts. Indeed they are in fact more usual, as only the most typical of them are included while most ridges of the other type (reverse drumlin form) are entered. But the dif-

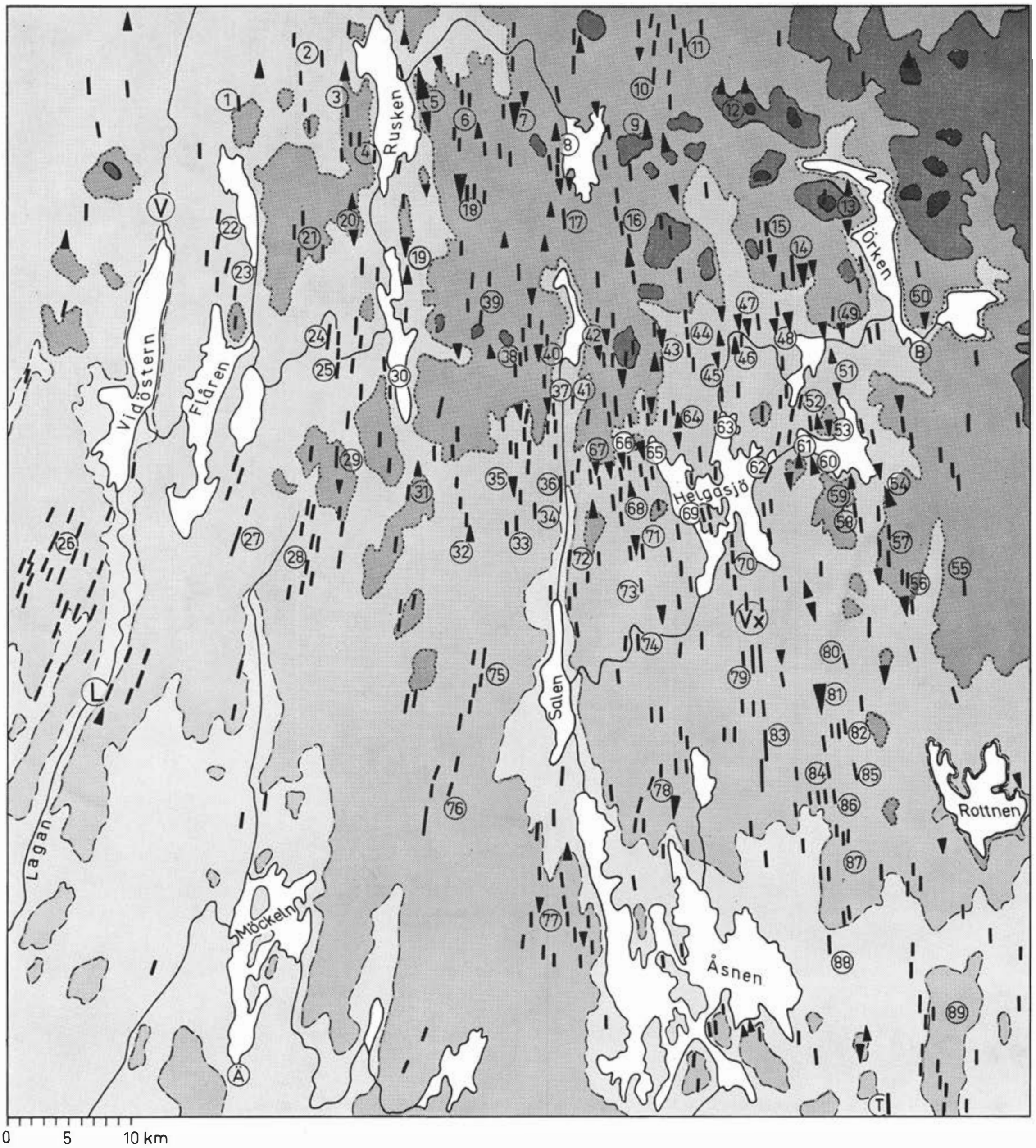


Fig. 10. The Värend area. The same text as for the Borås area also applies here; legend of the signs, too. Abbreviations: towns — V = Värnamo, L = Ljungby, Vx = Växjö; villages — B = Braås, Ä = Älmhult.

ferences in number between these two types are smaller than in the other areas. Many drumlinoids and real drumlins do not display markedly divergent short sides but both the latter are often short and steep or gradually sloping.

In the N. parts there are small rock hills, which are partially or completely covered by thin till, often levelled; locally this till is thicker proximally or distally and can be elongated into small crag ridges (e.g. 4, 6, 10, 21, 39). The former hills are obviously not any drumlin moraines. But due to the occurrence of the latter small ridges together

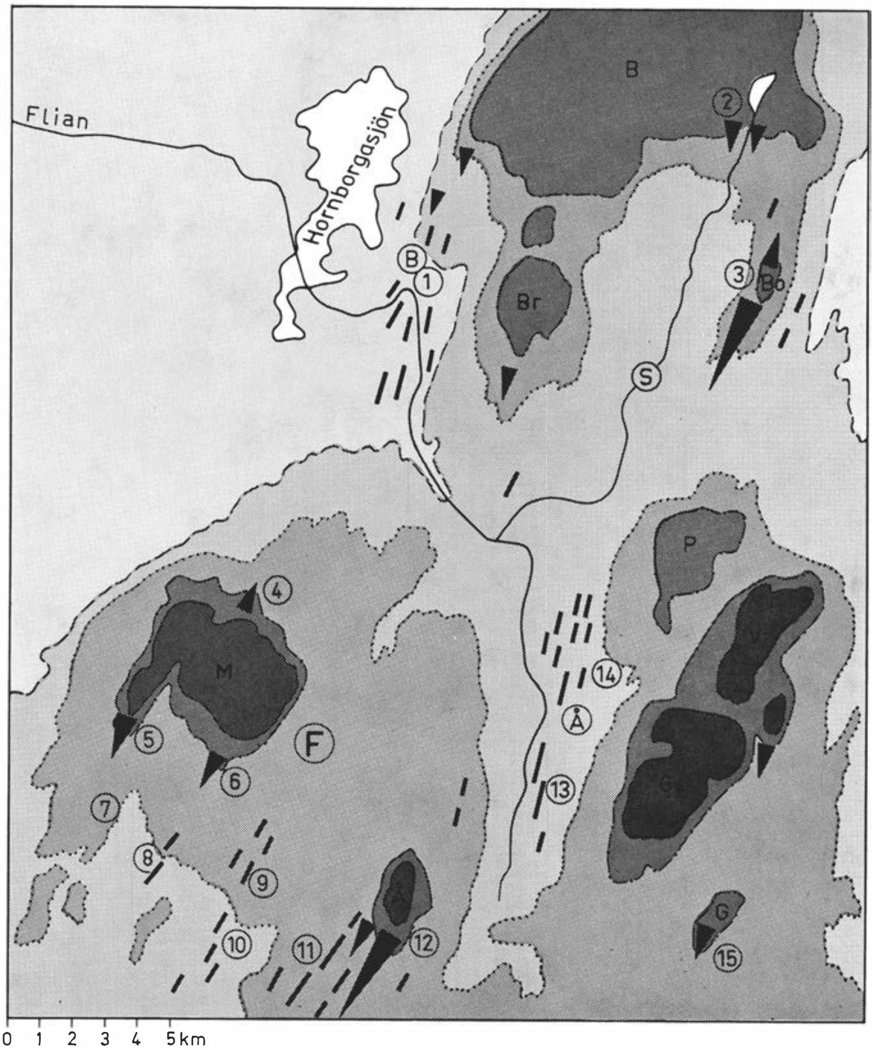


Fig. 11. The Falbygden area. The same text as for the Borås area also applies here; legend of the signs, too. Abbreviations: town — F = Falköping; villages — B = Broddetorp, S = Stenstorp, Å = Åsle; plateaux — B = Billingen, Br = Brunnhemsberget, Bo = Borgundaberget, P = Plantaberget, V = Varvsberget, Ge = Gerumsberget, G = Gisseberget, Å = Ålleberg, M = Mösseberg.

with them, it may be important to mention them (Table 3). Certainly, all these types may be embryonic crag ridges or drumlinoids, i.e. they show something of the drumlin evolution.

(4) The Emmaboda area (without map and table; Knutsson 1971). This drumlin district is situated immediately SE. of the Värend area (Fig. 1). Topographically, it is divided into low plateau (150—170 m above sea level) which are even or gently slope southwestwards and rise about 15—20 m above the surrounding, shallow and narrow valleys, or lake basins.

The drumlin moraines (somewhat over 100 in number) are concentrated to one group W. and one group N.—NE. of Emmaboda (on the latter see Fig. 1 in Knutsson 1971). They normally have medium dimensions but a few are over 1 km long and about 30 m high. Also some short and low ones exist. Most of them are SSE. sloping postcrag ridges (Fig. 22), or comparatively plane drumlinoids with the foundation rocks in their middle parts. But some may be characterized as irregular, somewhat elongated hills rather than distinct ridges, perhaps indicating a drumlin formation in progress. This is also suggested by the fact that stoss- and lee-side moraines often occur.

The drumlin moraines are usually isolated or parallel to each other but rarely in succession, and in such cases they are not often more than two. Another typical feature is that many of the drumlin ridges form summits of small plateaux or great drumlinoids. And a third characteristic is that tney normally project as tops of basal till above lower-lying hummocky ablation moraine, or in the valleys also glacifluvium (Knutsson 1971).

Areas outside the South Swedish Highland

Some small drumlin areas are found on the lowlands which surround the South Swedish Highland in SW.—NW. (Fig. 1). They are well delimited, as the surrounding terrain usually lacks such ridges. Topographically, they are in main even plains without distinct valleys but with different elevation. Yet all of them contain projecting rocks, and some large plateaux occur which have more or less determined the position of the drumlin moraines.

(1) The Falbygden area (Fig. 11, Table 4) may be divided topographically into three parts — the Pre-Cambrian peneplain in NW., a gently ascending plain of mostly Cambro-Silurian rocks (except in the Åsle valley) merging in the south with the N. ascent of the Borås area, and all round it isolated plateaux of Cambro-Silurian rocks with top diabase.

The number of drumlin moraines is not great but many of them are of particular interest. Four comparatively uniform groups are distinguishable — around Broddetorp (1), N. and S. of Åsle (13, 14), in connection with Ålleberg (11) and W. of this height (9, 10). In all these places the moraines are well developed ridges, mostly real drumlins, only a few being drumlinoids of type A. They lie both in succession and parallel to each other, and the former in particular have often fused. The dimensions tend to be intermediate in length and breath but often small in height.

The remaining drumlin moraines are large, isolated crag ridges (cf. Munthe 1906, Munthe et al. 1928). Most of them are long and high, downward-sloping postcrags (2, 3, 5, 6, 12, 15), although there is a short and broad precrag at Borgundaberget (3) and a broad, proximal lid moraine with three projecting lobes (embryonic ridges?) at Mösseberg (4). At Billingen, Mösseberg and Varvsberget, the postcrag moraines lie at the corners of these large heights; at Borgundaberget, Ålleberg and Gisseberget (Fig. 5) they project in toto from these small plateaux.

Fig. 12. Radial ridge of irregular shape (e.g. curved distal side, steeply sloping) and consisting of comparatively loose till, rich in boulders. Ice movement towards the reader. Bolum, E. side of Lake Hornborgasjön, Falbygden area (Fig. 11); the ridge lies N. of the ridge in Fig. 2.

There are in this area several other, small and isolated ridges, which because of their orientation and certain other features could belong to the drumlin complex, e.g. along the E. side of L. Hornborgasjön and at Stenstorp (Munthe et al. 1928). Some characteristics — irregular surfaces and sides and loose till rich in boulders (Fig. 12) — seem to indicate, however, that they are not normal drumlin moraines. Many of them ought rather to be classified as radial moraines from the deglacation (sensu Granlund 1943). Apart from these properties, this assumption is suggested by the fact that they lie together with or near other deglaciation forms, partly belonging to the Middle-Swedish moraine complex. Because of this uncertainty of classification these ridges are not included in the map — except one as an example (7).

(2) The Kinnekulle area (Fig. 13, Table 5; Gillberg 1969, 1970) is confined to this isolated height. It rises as a monadnock between the basin of L. Vänern and the Västergötland plain. From bottom up to about 190 m, different width terraces of Cambrian-Ordovician rocks are developed, then Ordovician-Silurian shales, covered by diabase, form a narrow peak. The bedrock surrounding the height is gneiss.

In no other district studied, does so great a

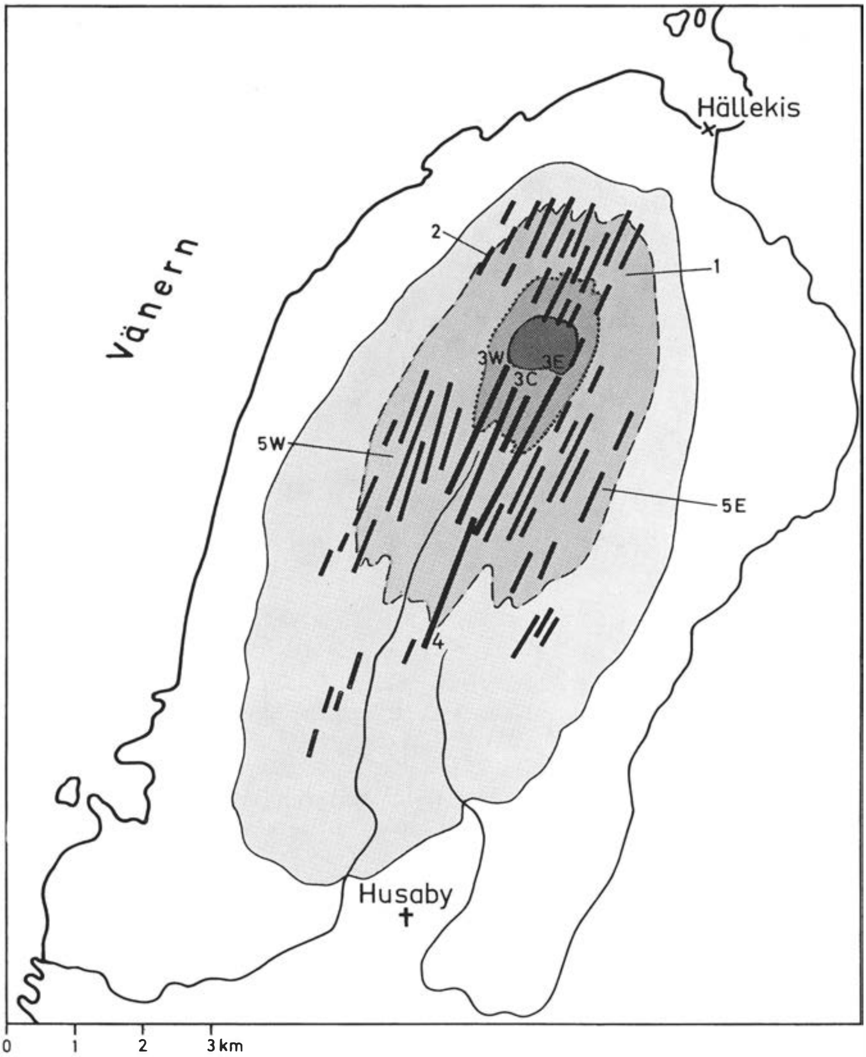


Fig. 13. The Kinnekulle area. The same text as for the Borås area also applies here; legend of the signs, too.

number of drumlin moraines occur in such a small area. Proximally, there are 18 precrag ridges which combine to form a gently rounded, large precrag. Distally from the peak, there are three large, downward-sloping, somewhat irregular postcrags, the central one of which is partly double. Immediately S. of them, in the continuation of the depression W. of the E. postcrag, the isolated ridge "Stenåsen" is found. Both in shape and material composition it is different from the other drumlin moraines, but this very fact makes it particularly important to understand some principles of the drumlin formation. Finally, there are 31 real drumlins on the long sides of the peak.

Being situated on different slopes of Mt. Kinnekulle, all these moraines are topographically controlled in position but also small differentiations of the rocks have probably been of importance to their location. Furthermore, most of their characteristics seem to indicate that they are not completed; and some features seem to be more explicable if the accumulation has at least started in subglacial cavities (Gillberg 1970).

(3) The Närke area (Fig. 14, Table 6; Sahlström 1910, Fromm 1972) which lies on the S. part of the Närke plain, is limited to W. by the plateau of Kilsbergen and to S. by the W.—E.

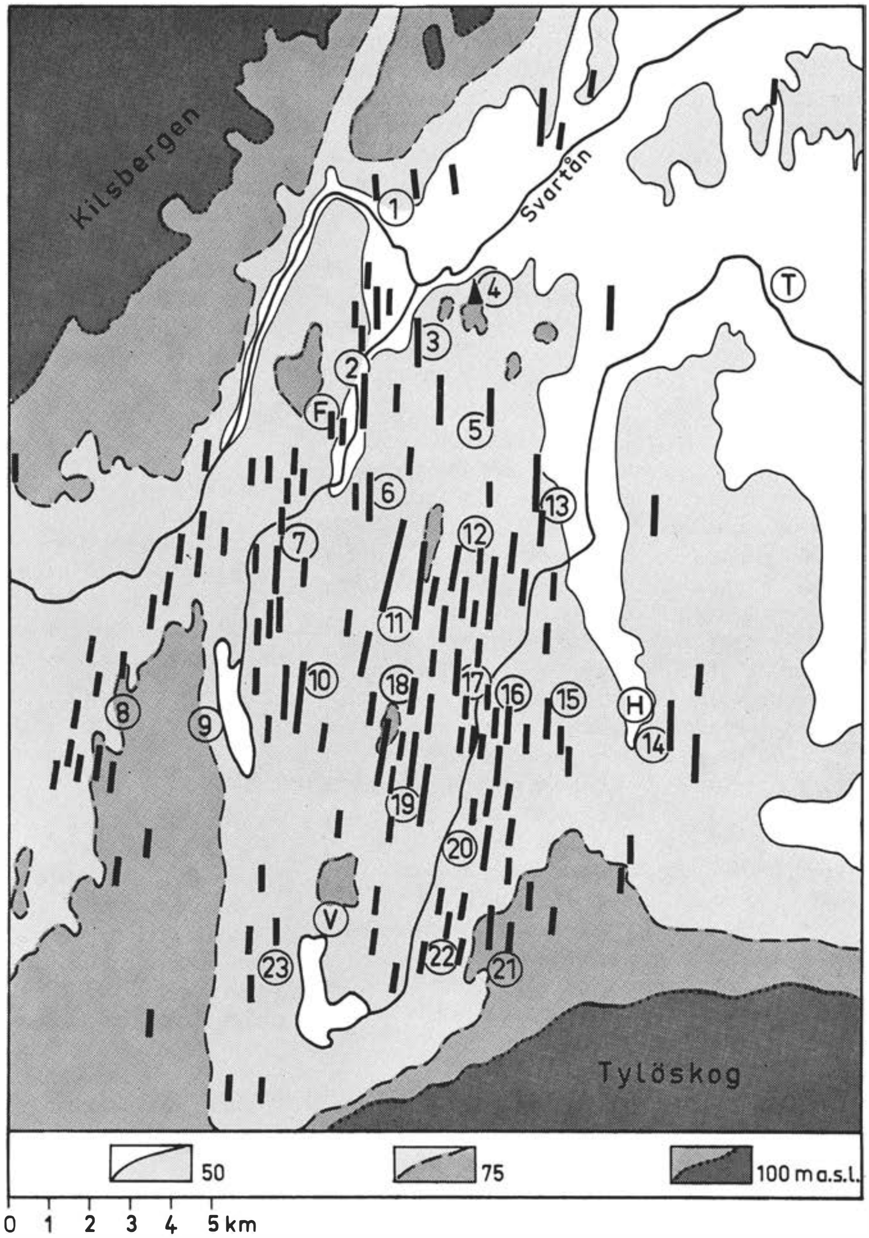


Fig. 14. The Närke area. The same text as for the Borås area also applies here; legend of the signs, too. As the plain is too flat, however, the isohypses are drawn with an equidistance of 25 m, instead of 50 m on the other maps. Abbreviations: villages — F = Fjugesta, T = Täby, H = Hardemo, V = Viby.

oriented, low plateau of Tylöskog (highest points 75—100 m above the plain). Towards E. it slopes downwards to L. Hjälmaren (22 m above sea level). The drumlin ridges occur, accordingly, in a triangle the topography of two sides of which must have acted as a barrier to the bottom ice. The bedrock is mostly of Cambro-Silurian age but different types of Archeaen rocks are found all around, and locally inside, the drumlin area.

The drumlin moraines are mostly concentrated to the middle part of the plain. Two long eskers form distinct limits of this district — in E. the

Hardemo esker just past Hardemo and dead north in the shallow valley of R. Täljeån (Täby), and in W. the Viby-Edsberg esker from Viby dead north to Fjugesta. Outside this area, the drumlin ridges are fewer; there are some individuals in E. and N. and three groups in W. Distinct, radial series of such moraines are rarely present. Moreover, separate groups are often difficult to distinguish, especially in the middle of the area, but this is fortuitous. In reality, the drumlin ridges are definitely concentrated in uniform groups, although often connected with each other by some isolated ridges. In contrast to the other drumlin areas, these moraines lie parallel to each other rather than in succession.

Crag ridges are few (1, 4) and lid moraines are lacking, certainly because of the topographical conditions, i.e. an even plain with only small rocks. Drumlinoids of type A do not seem to occur but two ridges (11) may be characterized as drumlinoids of type B as they include glacifluvial material (cf. p. 162). All other moraines are real drumlins, and many of them may lack foundation rocks (Sahlström 1910, Fromm 1972). Drumlins of typical shape are few and are usually more isolated, or form the predominant ridge of a small group (Fig. 16). Instead, most drumlins have features which give them a less "distinct" shape, e.g. plane surfaces, irregular long sides, short and steep proximal sides, similar distal sides or very gradually sloping ones, more than one crest, and several of them in groups more or less fused. On average, the levelling does not yet seem to have been the prevailing process. Except some isolated and steep ridges, many drumlins are long, narrow and often low. Many of these features seem to indicate a ridge formation in progress.

(4) The Falkenberg area (no map and table). In the middle of the coastal plain of Halland (Fig. 1), there are a small number of drumlin moraines, nearly all of which are associated with small heights (isolated parts of the SW. spurs of the South Swedish Highland). They are, accordingly, crag ridges — mostly precrags but locally with small continuations on the postcrag sides, or sometimes lying on one long side of a height (e.g. at Steninge). Their dimensions vary, and both small (80—100 m long, 5—15 m high) and large ridges occur (2—3 km long, 20—40 m high). The most typical of the latter is to be found at Skrea, near Falkenberg. In contrast to the other drumlin areas, some of these moraines are comparatively short, both in actual size and in relation to breadth and height. But this is certainly fortuitous. Late- and Post-Glacial sediments occur all round and often cover the most proximal parts of these ridges.

The occurrence of drumlin moraines here is notable, as they seem to be more or less nonexistent in the N. part of the coastal plain which has the same topography, even with the end of river valley. A similar difference between these two areas is also apparent as regards the deglaciation forms — mostly large end moraines, a few out-wash deltas in N., the reverse being true of the S., i.e. in the drumlin district. Taken together these facts seem to indicate certain difference(s) in the ice activity in these two areas during both glaciation and deglaciation.

Main characteristics of the drumlin moraines

All glacial elements have features which are of importance for an understanding of their formation. In the case of the drumlin ridges, three main characteristics seem worthy of discussion — the position in the terrain, the superficial features and the material composition.

Position in the terrain

As the maps show (Figs. 8—11, 13, 14), the drumlin ridges are found in varying grand topography (cf. Ebers 1926, 1937, J. Lundqvist 1970) — mostly in ascending terrain in the Borås and Sommen areas, on descents in the Värend and Emmaboda districts, and on plains outside the South Swedish Highland. (Although many geologists have often emphasized a special topography for such forms, all drumlin articles show that such a varying location applies in all regions). A closer examination shows, however, that these moraines commonly lie on, or are connected to, plateaux of differing extent. This is particularly true in the highland; but owing to the inclusion of but few isohypses, the maps do not always show that. Nevertheless this position is equally obvious in the lowland districts; and by reason of the isolation of existing heights, it is more clearly visible on the maps.

On the whole, the drumlin moraines seem to occur anywhere on the plateaux but their distribution is not so random. The following principles of their location may be distinguished. (*A*) Such moraines are more usual on the proximal than the distal sides of the heights (Ebers 1926, 1937, Fairchild 1929, Armstrong & Tipper 1948, Björnsson 1953, Gillberg 1955, 1970, Glückert 1973, Agrell 1974). This is particularly apparent in ascending grand topography, somewhat less obvious in descending terrain. Nevertheless a proximal location predominates higher up on the plateaux. (*B*) In the last position, such moraines normally decrease in number, and on the highest plateaux they are few or lacking (Armstrong & Tipper 1948, Hoppe 1951). Furthermore, existing ridges are usually small. Both these features often apply to isolated heights at lower level. (*C*) On large plateaux, such moraines are preferably situated at the corners, both proximally and distally but locally more often in the latter position (Gillberg 1970). (*D*) Such ridges are seldom found at the bottom of great and deep valleys, especially in dissected terrain (often apparent in other descriptions but seldom pointed out; cf. Rich 1935, J. Lundqvist 1969a). This fact is clearly evident where two parallel depressions border each other. If drumlin moraines occur there — and they often do — they are found on the heights in between, e.g. SW. of L. Sommen and NE. of L. Solgen in the Sommen area (Fig. 9). There are exceptions, namely in shallow and broad valleys in an otherwise uniform terrain, e.g. in the S. part of the Värend area (Fig. 10). (*E*) Irrespective of this general occurrence on the plateaux (*A—D* above), the drumlin ridges are preferably situated where the gradient of the ground changes (increases or decreases), but not too abruptly, i.e. seldom beside precipices (cf. J. Lundqvist 1970). They are often located at or near the base of the heights, proximally and/or distally but more seldom on their long sides. On the latter, they occur higher up and often on the margins of the summit surfaces, i.e. where those begin to slope downwards (many examples in each table).

Thus, plateaux of different extent have at many places determined the location of the drumlin ridges. Yet small rocks and rock hills have been of similar importance (Högbom 1905, Slater 1929, Björnsson 1953, Gillberg 1955, Reed et al. 1962, Vernon 1966, Hill 1971, Knutsson 1971, Johansson 1972, Glückert 1973, Minell 1973, Agrell 1974). All crag ridges and most drumlinoids have developed at or around such obstacles (Figs. 3—7). Morover many real drumlins may have such foundations. According to the layout of the surrounding terrain, all these moraines on the South Swedish Highland are probably constructed in this way. In the places where this mode has been confirmed (by well-borings or in deep sections; Björnsson 1953), these rocks usually seem to be small, even in high ridges. Accordingly, a relation between the dimensions of the foundations and the type of drumlin ridges in principle seems to be present: small rocks — real drumlins; large rocks, small rock hills — drumlinoids and small crag ridges; large rock hills, heights of different extent — large drumlinoids and crag moraines of all dimensions; plateaux — many ridges of all types, and lid moraines. Such a correlation is feasible, for the greater the obstacles were, the more material and the longer time must have been necessary for a total covering of them. Therefore in many places this process has not been completed, i.e. crag moraines appear instead of drumlinoids and both these forms instead of real drumlins (cf. Chamberlin 1894, Ebers 1931).

The types of obstacle seem to vary both in number and position in different grand topography. In flatter terrain, they are often lower and smaller and occur in greater isolation; in dissected terrain, they are usually higher and broader and lie nearer to each other. This fact together with the data discussed suggests that different grand topography should display different types of drumlin ridges, i.e. real drumlins and small to medium-sized drumlinoids in a more even terrain, large drumlinoids, crag ridges and lid moraines in a more broken landscape. Indeed this is true in principle. The former predominate on the Falbygden and Närke plains and in the more uniform parts of the Borås and S. Värend areas; the latter are prevalent in the broken Sommen district, the central and SW. parts of the Borås area and the N. part of the Värend region (Tables 1—4, 6). This condition may be very pronounced in places. Only crag ridges occur on the ascent and descent of Kinnekulle, and only real drumlins are found on the rock terraces on its side (Table 5; Gillberg 1970). An obvious exception is the Halland plain, where only crag ridges are found. Yet this may be due to the fact that the projecting heights are very distince there, and also due to this area's vicinity to the ice border during the last glaciation.

But there are further indications that different drumlin types occur in different grand topography. On the N. ascents of the South Swedish Highland (the Borås and Sommen areas) precrag ridges and drumlinoids with the rock foundations in the centre or more distally predominate (Figs. 8, 9, Tables 1, 2); on the descents of them (the Värend and Emmaboda areas) postcrag ridges and drumlinoids with the rock foundations in the centre or more proximally are more usual (Fig. 10, Table 3, p. 146). On the plains in SW.—NW., such a differentiation is reversed or not at all obvious. On the gently descending Halland plain there are mostly precrags, while on the gently ascending plains of Falbygden and Närke real drumlins or postcrags predominate (Figs. 11, 14, Tables 4, 6, p. 146).

As most of the drumlin moraines studied are connected to topographical obstacles of different type and extent, their positions are more or less topographically controlled; so probably their formation (cf. Högbom 1905, Fairchild 1929, Björnsson 1953, Gillberg 1955, 1970, Aronow 1959, Reed et al. 1962). But there exist areas which are characterized by the same obstructing topography, but which lack such ridges (cf. Aronow 1959, Glückert 1973), e.g. some other parts of the South Swedish Highland. Indeed some areas with comparatively unobstructed terrain (descents and plains) have similar moraines, e.g. areas such as are described here. Furthermore, not all projecting rocks or heights have drumlin ridges, even in districts otherwise possessing a great number of them, e.g. in all the areas studied. Nor have all drumlin moraines such foundations, e.g. on Kinnekulle, or on the Närke and Falbygden plains. In some cases, accordingly, topographical differentiations seem to have played only a minor role or none at all for the location of the drumlin ridges (cf. Hill 1971). The conclusion must therefore be that some further factor(s) may have been of an equally decisive importance for their formation (Högbom 1905, Fairchild 1929, Björnsson 1953, Gillberg 1955, 1970, Aronow 1959, Reed et al. 1962, Hill 1971).

In all the drumlin areas studied — and in other glaciated regions, too — the drumlin moraines are usually adjacent, two or more in radial succession, often double series (Figs. 8—11, 13, 14, Tables 1—6). As to their general position, they are clearly connected with each other, therefore probably formed together. One or two of these ridges are usually larger than the others with some of the smaller ones nearby. Thus, the sequences of drumlin moraines are often divided into groups composed of one or two major ridges and one or more minor ridges. The position of them in relation to each other varies but seems to be the same in many places. On more even ground, the smaller ridges in such groups usually lie proximally of the greater ones, e.g. B6, 12, 24, 65, S32, 41, 54, 65, V11, 25, 27, 32, 58, 64, 70, 75, 76, F8, 9, 11, N7, 10. On plateaux, the larger ridges are found on the ascents or descents, while the smaller moraines lie beyond and/or on their tops, e.g. B14, 15, 19, 32, 36, 38, 52, 55, 57, 62, 83, 85, S14, 22, 43, 47, 52, 57, 58, V16, 29, 37, 42, 47, 60, 65, 67, F12, and on most lid moraines. The summit ridges are locally lacking, however.

In this connection another fact is also evident. The separate moraines in direct succession are nearly always displaced to the side of each other (Figs. 8—11, 13, 14, Tables 1—6; Alden 1905, Gillberg 1970). This difference in position is also obvious between whole groups of ridges (particularly in the Borås area, Fig. 8). Thus, as regards their exact position the moraines in sequence are partly independent of each other. The size of connections between the different ridges can be further emphasized. Each ridge in succession may be a ridge of its own; or, some of them, especially those in groups, can be more or less fused, i.e. the gaps between them are more or less filled by till, e.g. B6, 12, 58, 59, S6, 20, 29, 43, 54, 74, V15, 22, 26, 28, 38, 42, 43, 52, 58, 69, 76, 83, F11, 14, K5, N13 (Tables 1—6). This fact often appears from descriptions and maps of other drumlin areas but it is seldom indicated (cf. Alden 1905, Fairchild 1929, Schmidle 1932, Gillberg 1970).

Another placing of the drumlin ridges is also found. They frequently lie with two or more in parallel — both in free position, in succession and connected to plateaux (Figs. 8—11, 13, 14, Tables 1—6). Sometimes they are independent of each other, sometimes they are members of uniform groups — locally they are fused, e.g. B48, 56, S6, 20, 54, 58, 74, V18, 28, 35, 43, 68, 69, 79, 82, F14, K5, N2, 8, 16, 21 (cf. Alden 1905, Hollingworth 1931, Schmidle 1932, Gillberg 1970, Glückert 1971, 1973, Aario et al. 1974). A difference in dimensions often exists in these cases. One or two are larger (major ridges), while one or more are smaller (minor ridges). Normally the latter lie on the, topographically, more free sides of the former, e.g. B3, 18, 19, 70, S15, 27, 55, 83, V18, 28, 35, 43, 53, 56, 71, 79, 86, K5, N6, 12. Locally, two (three) parallel ridges may be equal in size, including large ones, e.g. B5, 56, S48, 62, V47, 79, 82, N10. In these cases, they all lie in open terrain. Yet this is not surprising, as a parallel location as a whole seems to be more common in such topography (S. part of the Värend area and on the plains) than in more broken terrain (the Borås and Sommen areas).

In addition a combination of these two placings of the drumlin ridges may occur, namely groups of two parallel moraines and a third one between them proximally or distally, e.g. proximally one B59, S50, V23, 26, 42, 48, 49, 66, F14, N8; distally one S22, V42, 47, 65, 69, K3—4, N16, 22 (Figs. 8—11, 13, 14, Tables 1—6). The dimensions of the individual ridges in such groups are often equal but if any difference exists, the single ridges are smaller than the two parallel ones. This type of placing tends to occur in more even terrain or on gently sloping plateaux. In the latter cases, the parallel moraines lie on their slopes, the single ridges lie higher up on or outside them.

These three recurrent positions of the drumlin moraines are such an organized characteristic that they must be due to special conditions during the formation, especially its beginning. As regards the reason, it may here be pointed out that the topography alone scarcely can have been this determining factor, in any case not directly. For there are several ridges which are apparently not at all controlled by it (cf. p. 142).

As the drumlin moraines are built up subglacially by moving ice, they (= their long axes) should extend in the direction of the ice movement (confirmed in all drumlin areas). They can therefore, together with the striae, be used to determine it (Figs. 1, 8—11, 13, 14).

An analysis from this aspect gives the following information. In the central South Swedish Highland, the main ice movement had a N.—S. direction. Along the fringes, i.e. in the Borås and Sommen areas, it has diverged to NE.—SW. and NW.—SE. (Figs. 8, 9; Gillberg 1955, 1964, Agrell 1974). This must have been a topographical effect, as the highland slopes downwards to lower terrain around L. Vänern — the valley of R. Göta älv in W. and around the Baltic in E. These two large depressions, i.e. comparatively unobstructed terrain, may have functioned as the main tracks of the ice cap. They were probably transport zones around the highland projecting between them. This is indicated partly by the fact that drumlin ridges are few found in the surroundings of these depressions (cf. J. Lundqvist 1970). The highland, i.e. more obstructive terrain, may have been a lee area with slower ice motion, and so have been more dominated by accumulation, e.g. of a great number of drumlin moraines (Figs. 8—11, 13, 14). But they seem to have been by no means a uniform deposition area but were certainly divided into zones of different ice activity (confirmed by differences in the till distribution, Gillberg 1964; cf. p. 164). The depression of L. Vättern and its continuation far to S. was presumably a transport zone of great importance. Moreover, only a few drumlin ridges are found in the countryside nearby (Figs. 8—10).

Examples of somewhat different orientation of the drumlin moraines and the striae are also to be found. In the Närke area the latter mostly indicate an ice movement towards SSE. (Fig. 1). The drumlin ridges are in the S.—SW. part often oriented towards S.—SSW. (Fig. 14). This is certainly a topographical effect as a shallow and narrow depression separates the plateaux of Kilsbergen and Tylöskog in SW., i.e. the ice there could move more freely than dead south over Tylöskog.

What is more in the Halland area, the drumlin ridges and the striae often indicate different ice movements (there are several striae with an orientation other than marked on the map, Fig. 1). Nevertheless this may be due to this district having lain near the border zone of the ice cap, i.e. in a place where divergences in the ice activity may have been of frequent occurrences. The internal variations in orientation of the drumlin ridges may be a topographical effect, i.e. the isolated heights on the low Halland plain may have caused a differently directed till accumulation locally (cf. Gillberg 1964, 1967).

Separate drumlin ridges with divergent orientation in relation to others nearby are also found in the South Swedish Highland, i.e. in an area where the ice movements are markedly influenced by the topography. On some plateaux, small summit ridges (e.g. B23, 31, 69, S67; Figs. 8, 9, Tables 1, 2) display an orientation different from that of the lower-lying moraines. The position of the latter is obviously topographically controlled, i.e. they show a topographically directed ice movement. On the plateaux, however, the existing obstacles were so small that the ice was not influenced by them and so moved more or less without hindrance (cf. Hollingworth 1931).

Other drumlin ridges are examples of the reverse, i.e. they are still more topographically oriented than their neighbours (cf. in many other drumlin regions). Either they lie on the margins of other such moraines or of large plateaux, e.g. B12, 41, 51, 63, S13, 36, V60, 62, 78 (Figs. 8—10); or they are located on rocky walls between two valleys or lake basins, i.e. their orientation is determined by the former, e.g. B64, S54 (Figs. 8, 9); or they lie around a great lake basin with irregular limitation and therefore surrounded by irregularly placed plateaux, e.g. many ridges around L. Helgasjö in the Värend area (Fig. 10); or they are situated on isolated heights, surrounded by higher plateaux which have been more decisive for the ice motion, e.g. S7, 25, 26 (Fig. 9); or they are members of a large group of moraines which have probably influenced each other's position, e.g. B41, 72, S12, V11, K5—W (Figs. 8—10, 13); or they lie in a shallow depression which has a somewhat different orientation from the main direction of ice movement on the surrounding plain, e.g. F13, 14 (Fig. 11); or they lie on rock terraces between a high peak and a lower-lying plain, i.e. where the ice motion may sometimes have changed depending on which surrounding topography was most decisive for it, e.g. K5 (Fig. 13).

All these examples of different orientation of separate ridges in various positions seem to establish a fact which has earlier been stated in connection with a discussion of the till distribution (Gillberg 1964, 1967). The bottom ice has strictly followed the underlying terrain and so been divided into a network of divergent, "secondary" ice movements (cf. G. Lundqvist 1935, Holmes 1937, Gillberg 1964). Also the accumulation may therefore have changed direction for short distances, even intermittently have altered in one and the same locality.

Superficial features

The levelled, more or less streamlined form has always been regarded as one of the most pronounced characteristics of the drumlin ridges. Rightly so, but this is only an expression describing the general shape without respects to the minor features. Irregularities of different kinds, sometimes insignificant, locally distinct, are found in many places.

Many drumlin moraines are not truly elliptical with an even outline but tend to have curving long sides, i.e. have a less regular lower boundary to the surrounding ground (cf. Fig. 12). Such a shape is typical of many low, real drumlins but also of crag moraines, especially postcrags (Gillberg 1970), i.e. in both cases certainly ridges in formation; furthermore locally of moraines with steep long sides. Accordingly, this form seems to be usual in ridges on which the levelling process has not yet been dominant.

When seen from a distance, most drumlin moraines seem to be uniform and nearly totally levelled. A closer study shows, however, that superficially they can be divided into large and small segments, usually delimited from each other by small knobs, short steps or shallow hollows, but sometimes only distinguishable by changed gradient (Figs. 4, 15). Thus, the surfaces often display undulations of different size and orientation. Most of the segments are comparatively levelled (Figs. 2, 3, 16, 18, 22, 24, 27). This is especially the case on the proximal slopes, on the top surfaces proximally and centrally, and on the upper parts of the long sides or throughout the latter when they have a low to medium gradient. There seems to be a relation in principle in this connection — the better the levelling, the greater and more uniform the different segments; a perfectly levelled proximal slope, for instance, can form a unit from bottom to top. More irregular surfaces (Figs. 12, 15, 25), i.e. many segments which may or may not be uneven, are mostly found distally, on steep long sides and on ridges with thin till. (In the latter case, the underlying rock surfaces still determine the superficial shape).

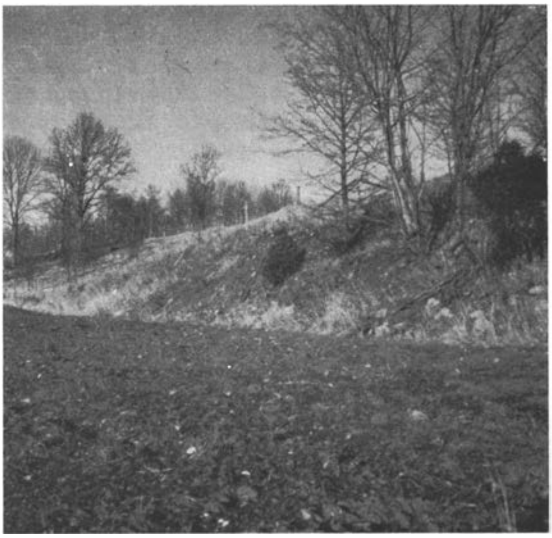


Fig. 15. Low and narrow real drumlin, the W. long side of which is steeper in the foreground (towards the proximal crest), flatter in the background (towards the central surface, comparatively plane but lying lower than the crest), i.e. it is an example of a ridge side divided into separate segments, distinguishable by clear differences in gradient. Ice movement from the right. Central ridge in Helgesta group (N19), Närke area (Fig. 14).

More than one crest can occur and be located in any position (cf. Alden 1905, Ebers 1926, Hoppe 1951); and it/they can be small, independent ridges (cf. Fairchild 1929).

(Examples of moraines with obvious divergences superficially — proximally even, distally irregular: B24, 32, 28, 61, 82, S19, 38, 41, 65, 68, V18, 20, 24, 27, 33, N19; proximally irregular, distally even: B76, S35, 40, 69, V14, 35, 71, 76, N10, 13; comparatively irregular throughout: B71, 72, 73, S56, V2, 11, 18, 55, N7, 8).

Each one of these superficial irregularities is perhaps a less important drumlin feature. But all together their occurrences must prove that the drumlin moraines are primarily forms of accumulation. Moreover, the great variations in their characteristics, orientation and size seem to indicate that this process has not occurred uniformly throughout the ridges, nor has it always been simultaneous. The surfaces are normally even, however. This must be evidence of a levelling (moulding) activity which apparently has become more pronounced with increased height and breadth of the ridges (but not too great). Yet the fact that the original accumulation features are still obvious may indicate that this levelling, except on plane parts and proximally, occurred mainly by filling with new or redeposited material rather than as a result of real erosion (removing). As the proximal sides are usually more levelled than the distal ones, this process proceeded in the direction of the ice movement, i.e. partly similar to, partly divergent from the accumulation. Such a combination of two so different activities which were certainly co-ordinated at times but have replaced each other on occasions, definitely proves that the drumlin formation has continued subglacially by a (comparatively slowly?) moving ice — to create a form of least resistance (in principle as stated by most drumlin geologists).

All divergences from a uniform and levelled shape appear on all types of drumlin moraines, whatever their dimensions. But they are more common on crag ridges than on drumlinoids, on the latter than on real drumlins and especially on small ridges but also on many of the largest ones. On the whole, accordingly, the differences in their occurrence seem to be an expression of different stage of completion of the ridges, i.e. more irregularities = a drumlin accumulation in progress, or if it is concluded, a levelling not yet completed.

Thus, the short sides, i.e. proximally and distally of the crests, are sometimes differently, sometimes similarly shaped superficially. As for the length and the gradient, they are usually asymmetric. If the proximal side is short and steep (10—20°), the distal is long-gliding and gently sloping (2—10°), and the crest lies more proximally = ideal drumlin form, the normal type described (Figs. 2, 16, 21); typical examples — B5, 9, 18, 43, 83, S64, 71, 73, V7, 14, 15, 18, 19, 27, 33, 40, 42, 43, 53, 54, 67, 75, 78, 81, 85, F1, K5, N7, 16, 17, 20. If the proximal side is long and gradually ascending, the distal is short and steep, and the crest lies more distally = reverse drumlin form (seldom described; cf. Aario et al. 1974); typical examples (Figs. 17, 20, 21) — B20, 21, 49, 52, 63, 83, S28, 31, 41, 47, 68, 83, V19, 32, 43, 54, 80. But there are many moraines with both the proximal and distal sides having a more or less similar slope, often with a medium gradient; the crests are in these cases nearly always centrally placed (also seldom described; cf. Hollingworth 1931); typical examples (Fig. 18, 21) — B4, 8, 46, 56, 74, 77, 79, S1, 6, 16, 22, 35, 37, 46, 54, 63, 76, 77, V25, 30, 38, 83, 84, 87, K5, N5, 6, 22.

The short sides can also end with a short and steep precipice (20—30°). Such a form is de-

Fig. 17. Real drumlin with reverse drumlin form: long, upward-sloping proximal side (somewhat steeper in the lowest part), low distal crest and short, steep distal side. Ice movement from the left. The ridge lies distally SW. of "Stenåsen" (K4), Kinnekulle area (Fig. 13).

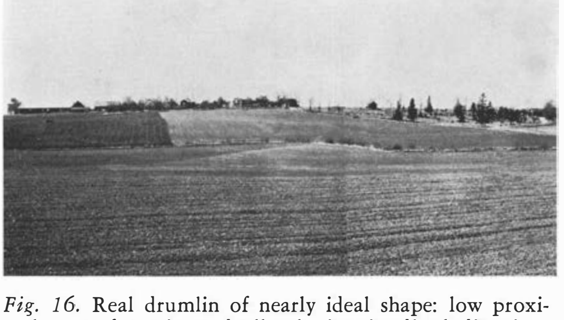


Fig. 16. Real drumlin of nearly ideal shape: low proximal crest, from it gradually sloping in distal direction; the proximal side is longer and more gently sloping than often is the case but obviously it is the steepest part; well levelled long side with comparatively flat gradient. Ice movement from the right. Alavi ridge (N20), Närke area (Fig. 14).

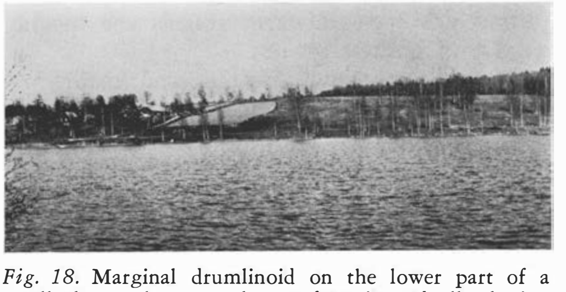


Fig. 18. Marginal drumlinoid on the lower part of a small plateau; low central crest, from it gradually sloping in both proximal and distal direction; comparatively steep long side. Ice movement from the left. Kalvsved ridge (S32), Sommen area (Fig. 9).

Fig. 19. Real drumlin with the proximal side divided into a short and steeper bottom part ("precipice") then a long, more gently upward-sloping part towards the low crest (just outside the photo). Ice movement from the right. S. ridge in Hovmene group (F14), Falbygden area (Fig. 11).

finitely more common proximally than distally and it is especially typical of plane ridges, e.g. B3, 11, 24, 52, 64, 75, 80, S18, 60, 66, 70, 73, 75, 78, V17, 22, 23, 25, 26, 36, 63, F10, K1, N2 18. It is also found on high moraines, and in these cases, the proximal sides are often divided into two parts — a short precipice and above this a longer, more gentle slope up to the crest (Fig. 19). In a few places, such precipices may be located higher up on the ridges, i.e. up to the tops the sloping proximal sides are divided into three parts, with gentle, steep and gentle gradient.

Only one marked difference in the proximal and distal form occurs on occasion. The distal side may have so gentle a slope that the end of the actual moraines is difficult to distinguish (cf. Fig. 2), e.g. B9, S37, V27, 78, K5 (Gillberg 1970). The proximal sides never have so diffuse a transition to the surrounding ground.

The variations in the shape of the short sides may be due to several causes. Indeed, the proximal parts which were oriented towards the moving ice, are of greatest interest.

Stoss-side moraines, precrags and many low drumlinoids and drumlins may by reason of their form and dimensions be evolutionary ridges. Most of them have long-gliding rather than steep proximal sides (Figs. 4, 20, 21). Thus, a more gentle slope of the latter may be an original feature. This is highly probable, as the lower the gradient of the deposited material has been, i.e. a suitable transcending angle, the less the resistance to the moving ice (Schäfer 1933, cf. Högbom 1905, Björnsson 1953, Vernon 1966).

Precrag ridges tend to be gradually ascending, postcrag ridges gradually descending but they differ in gradient because of the height of the crags (Figs. 4—7). Many drumlinoids (type A) with gradually upward-sloping proximal sides and distal summits may therefore be evolutionary precrags, and many drumlinoids with proximal crests and gradually descending distal sides may be evolutionary postcrags. Also many real drumlins with these different forms probably belong to these evolutionary types. In these cases, the location of the foundation rocks may have determined the continued accumulation and the final shape of the ridges.

The form of the proximal sides — hardly of the distal ones — seems also to be related to topographical conditions. In ascending terrain, the drumlin moraines, on average, proximally are more sloping (cf. if crag ridges exist there, precrags predominate; Figs. 8—10, 21, Tables 1—3); in descending terrain, they usually have steeper proximal sides (cf. if there are crag ridges, postcrags predominate; Figs. 8—10, 21, Tables 1—3). But also the presence or absence of adjacent obstacles seems to have played a similar role in this connection, although this is not invariably apparent. Moraines with a more open background, i.e. no obstacles in the proximility, have on average steeper proximal sides than those with a more confined background (rock hills or other drumlin ridges proximally). In the latter places, the proximal sides are usually more sloping — a form especially typical of moraines lying immediately in distal succession, e.g. B2, 83, S51, 72, V19, 43, 54, F13, 14, N7, 16. In principle, the cause of these charac-

Fig. 20. Real drumlin with gently upward-sloping proximal side. Ice movement from the left. The long, central ridge in Knista group (N2), Närke area (Fig. 14).

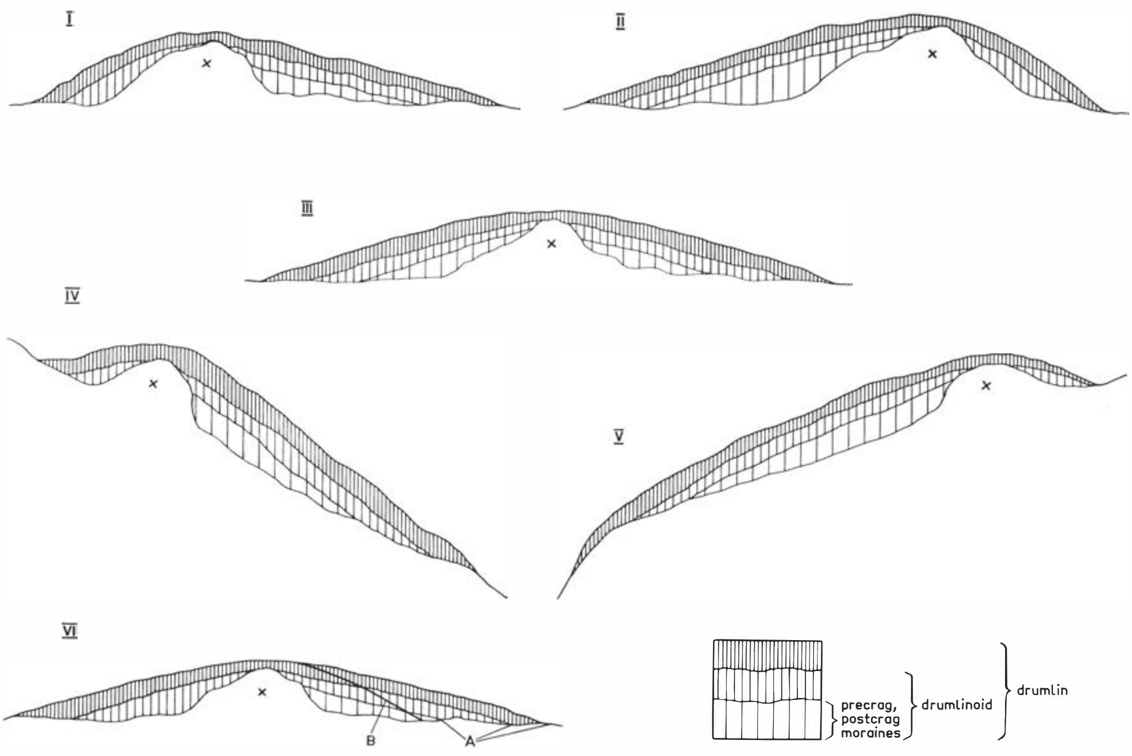


Fig. 21. Principal sketch showing different types and different shapes of drumlin moraines due to different positions of the obstacles (rocks, till sheets, boulder heaps, etc.) or due to the location in differently sloping terrain. Ice movement from the right. The crosses = obstacles of different kind, not always existing, however. Each figure part will also show possible evolutionary series of drumlin moraines, i.e. crag moraines — drumlinoids — real drumlins but self-evidently the addition of new material (= enlargement in length and height) do not need to have always occurred uniformly and simultaneously along the whole ridges. All types are found in the different areas; for examples, see the text. (I) with distal obstacle, long-sloping proximal side, distal crest and steep distal side = reverse drumlin form; (II) with proximal obstacle, steep proximal side and proximal crest, long-sloping distal side = ideal drumlin form; (III) with central obstacle, central crest and approximately simularly shaped proximal and distal sides; (IV) in ascending terrain = precrag moraine, drumlinoid and real drumlin with reverse drumlin form; (V) in descending terrain = postcrag moraine, drumlinoid and real drumlin with ideal drumlin form; (VI) possible evolution of a ridge with ideal form due to secondary erosion proximally; sometimes transport of material from there to the long sides and to the distal side. (A) original accumulation surfaces; (B) secondary erosion surface.

teristics should be the same: ascents and proximal obstacles = decreased ice motion and more intensive proximal accumulation, and gradually upward-sloping surfaces of the actual deposits; descents and no proximal obstacles = less impeded ice motion and no till accumulation proximally or, if such did occur, steeper proximal sides of existing ridges.

But there are drumlin moraines with steep proximal sides but the form of which cannot be explained, either as a result of the location of the foundation rocks or due to the placing of the ridges in the terrain. In these cases, a greater steepness proximally must have another cause. On small moraines, it may be an original characteristic, forming a kind of contact side towards the moving ice, and perhaps this may be possible also on some large ridges. But as most of the latter should have developed continuously (cf. p. 153), such a proximal form may be a secondary feature, probably as a result of a gradual sharpening, or real erosion by the ice (Fig. 21). If so, this could in places have caused a shortening of these slopes, often a transition of material from there to the distal sides, sometimes also a change in the location of the crests from the middle to a more proximal position. A real erosion would be suggested by the fact that these sides are always more uniformly levelled than other parts of the drumlin ridges. As greater steepness proximally is more usual on ridges with a less confined background, i.e. more free ice motion (cf. above), this may also be a criterion that erosion was at least possible there. But it seems difficult to prove that this process did in fact occur. Perhaps the short, proximal precipices which sometimes exist, show the first signs of erosion. Furthermore, differences in the orientation (and the dip) of the till grains may provide evidence thereof (cf. p. 161).

The shape of the short sides never seems to be related to the dimensions of the drumlin moraines. Small, intermediate and large ridges can be of any type, proximally and distally. There is impossible to decide, however, whether the material composition was of importance in this connection. For even if many granulometrically different types of till exist in the ridges studied, they are, on average, too similar to be used as proof. On the other hand, there seems to be an obvious difference in levelling of ridges with divergent till types. On Kinnekulle, the drumlin moraines with predominantly medium-sized, parly clayey till with few boulders (K1, 5) are more levelled and uniformly shaped than those with coarse till with many boulders (K3, 4; Gillberg 1970). This is very plausible, especially if the material deposited has been soggy. Under such conditions, a finer, partly adhesive, till would have been more mouldable by the ice.

As mentioned before, many drumlin moraines have sloping short sides but are nevertheless not marked on the maps. This omisson should be explained now. I am of the opinion, that the gradient of the short sides should be estimated or measured in relation to the underlying ground, i.e. if the latter slopes, its gradient must be deducted from that of the drumlin surfaces. If this is done, many ridges which lie in ascending or descending terrain and are more or less sloping proximally and/or distally, in reality have low gradient on their short sides (except locally on the lowest parts), and their crests are hardly apparent, if at all. Indeed, it is the real form, independent of other conditions, which shall be described and discussed.

If this is added to the fact that many drumlin ridges, especially small and low ones, are comparatively plane, the following conclusion seems to apply. A ridge form with low gradient of both the short sides and the top surface seems to be a typical drumlin characteristic and is probably an original feature (Fig. 22). Both greater steepness proximally (and/or distally) and distinct crests developed may, accordingly, in most places be features of continued evolution (cf. W. B. Wright 1912), either due to the occurrence, placing of the foundation rocks (cf. p. 146) and partly due to an irregular growth in height (cf. p. 151); or, if they are not dependent on these factors, they might be secondary features (cf. above).

Many of the superficial irregularities are most pronounced on the long sides. One of them — short steps or shallow hollows — is worthy of further attention. Ground water or wells often

Fig. 22. Well levelled, low postcrag moraine (the crag inside the forest to the left) which lies on gently sloping ground, is equally high throughout and has nearly the same gradient as the underlying ground, i.e. if the latter fact is eliminated, the top surface of the ridge is nearly plane. Ice movement from the left. Trällebo ridge, Emmaboda area.

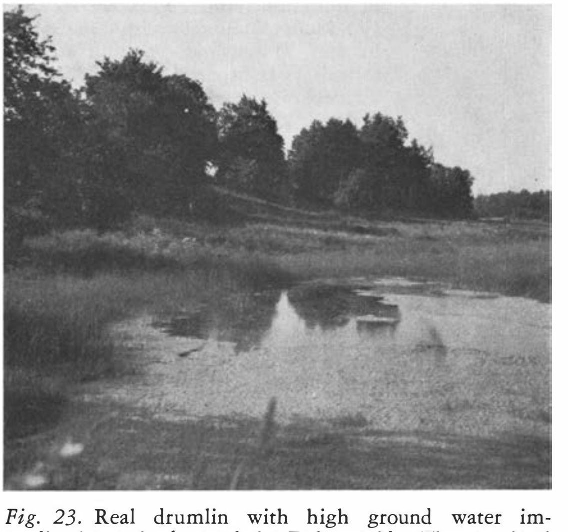


Fig. 23. Real drumlin with high ground water immediately at the base of the E. long side. The proximal W. ridge in Via group (N12) Närke area (Fig. 14).

appear there, as well as inside marginal top ridges and at the bottom of full ridges (Fig. 23), e.g. B4, S23, 39, 62, 77, V14, 81, 86, N12 (Knutsson 1971). This fact may depend on some material differences round about, e.g. the existence of granulometrically different till, or of beds of meltwater sediments, and/or the position of the bedrock. Such divergences from a more uniform basal till could indicate changed accumulation of some kind, perhaps even that small top drumlins on large drumlinoids or lid moraines may be independent upper ridges (cf. p. 151).

Regarding the length and gradient, the long sides show the same wide variations as the short sides, i.e. on one moraine they are similarly shaped, on another they are asymmetric. But in contrast to the short sides, their form often seems to be related to one dimension. Broad ridges tend to have longer and more gently sloping long sides (5—15°) (cf. W. B. Wright 1912, Glückert 1971), furthermore the latter are usually well levelled, may be uniform throughout in all directions, and their limitation to the surrounding ground may be indistinct (Fig. 24). If such ridges are not too high, they have a shield-shaped form, e.g. some ridges in the centre of the Värend area. On narrow moraines, the long sides are usually steeper (15—25°) (Armstrong & Tipper 1948) and are more delimited from their surroundings (Figs. 15, 25). These, too, may be comparatively levelled but they may show great irregularities locally. As the last characteristic is also typical of many short and low ridges, and of many crag moraines, this shape of the long sides may be normal for drumlin ridges which are not fully completed (cf. p. 153).

Fig. 25. Great drumlinoid with comparatively steep E. long side, undulated, somewhat flatter towards the bottom (cf. Fig. 24) and with a shallow hollow in the background. Ice movement obliquely towards the reader. N. ridge at Dalstorp, between B70—B62, Borås area (Fig. 8).

In many cases the modifications of the long sides also seem to be dependent on the placing of the ridges and on the shape of the neighboring terrain. Many moraines which have one long side surrounded by more open terrain (a valley or lake basin or no immediate obstacles) and one

Fig. 24. Real drumlin with well levelled W. long side; very flat gradient, somewhat increasing towards the nearly plane top surface. Ice movement towards the reader. The great central ridge in Välanda group (N7), Närke area (Fig. 14).

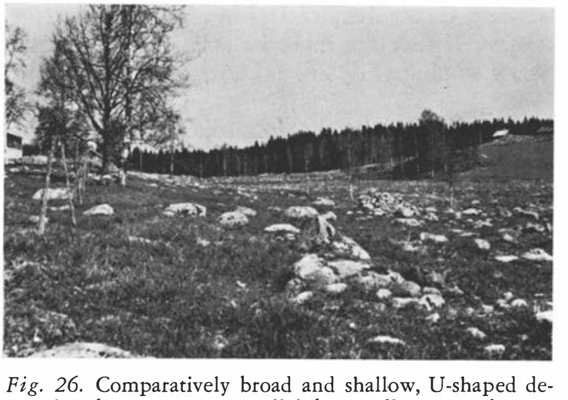


Fig. 26. Comparatively broad and shallow, U-shaped depression between two parallel but well separated postcrag moraines; partly filled with till with many large surface boulders; meltwater eroded during the deglaciation. The long side to the left gradually sloping, the long side to the right certainly somewhat steeper just on the photo but on average with the same medium-sized gradient. Ice movement towards the reader. Two of the postcrag ridges in the drumlin group S6, Sommen area (Fig. 9).

Fig. 27. Long, intermediate broad and intermediate low, real drumlin; well levelled throughout (as often in other places partly due to cultivation); nearly plane top surface with only a very low central crest. Walls of large boulders removed from the drumlin surface. Ice movement from the left. Njölhult ridge (S37), Sommen area (Fig. 9).

long side which is more confined (plateau slope, rock hills or other drumlin ridges beside), have asymmetric long sides. Towards the open terrain, the latter are longer, more gently sloping and nearly always levelled (Fig. 24); towards the confining terrain they are steeper, sometimes levelled but more often irregular (Fig. 25). Typical examples are: ridges on plateau slopes, B7, 12, 17, 41, S18, 32, 46, V30, 72, 84, N3; more isolated ridges, B23, 42, 66, 77, 78, S38, V24, 36, 38, F8, N5, 12, 13, 19. The fact that the distance to adjacent obstacles has played an important role is clearly shown on parallel moraines. When they lie near each other, their inward long sides are steeper; if they are more isolated, these are more gently sloping (Fig. 26) (cf. Armstrong & Tipper 1948).

No obstacles in the immediate vicinity seem to have involved that in many cases accumulation has developed also sideways, i.e. a broadening of the actual moraines or of one of their long sides; this process was normally followed by levelling. If obstacles existed near the sides, a continued accumulation there was more difficult or even impossible, i.e. no broadening of these moraines or of one of their long sides took place; levelling has occurred locally.

The crests are usually placed more proximally (Figs. 2, 16, 21) or more distally (Figs. 17, 21) but in many cases they lie centrally (Figs. 18, 21). The top surfaces can also be comparatively plane (Figs. 3, 27), a characteristic of many long and low, real drumlins, usually in open terrain (Sahlström 1910, Fairchild 1929, Fromm 1972 and others). For examples of all types, see p. 145 and Tables 1—6.

The crests are often no more than culminations of the ridges but there are sometimes more than one (cf. Alden 1905, Ebers 1926, Hoppe 1951). Locally, however, they project as real summits, one or more in number and differently placed (cf. Fairchild 1929). On many lid moraines and drumlinoids, these are the foundation rocks, sometimes mostly exposed, sometimes covered by thin till, e.g. B8, 14, 16, 25, S16, 67, V12, 86, 88, and at all crag moraines. In other places, these summits are hills, sometimes more irregular, sometimes more levelled and even with embryonic ridge-form, e.g. B24, 28, 30, 32, 40, 42, 57, 62, 64, 68, 78, S38, 47, 49, 53, V12, 16, 17, 27, 32, 37, 40, 53, 58, 71, 79, 81, 83, F7, K3—C, 4, N11, 14. Locally, they are small drumlin ridges, sometimes distinctly independent of the underlying moraines, sometimes gradually merging with them, e.g. B4, 15, 18, 19, 21, 28, 34, 35, 36, 38, 44, 45, 60, 70, S3, 11, 15, 20, 31, V14, 18, 31, 34, 47, 50, 51, 53, 59, 60, 61, 62, 75, 78, 80, and some in the Emmaboda area. In many cases these top ridges have developed at or around foundation rocks. Thus, if the latter are exposed, they are small crag moraines or drumlinoids; or they are small, real drumlins, if the rocks are totally covered by till, or if they are wholly composed of such material.

The occurrence of such top hills and ridges does not seem to be related to the location and shape of the underlying moraines. But it is clearly dependent on the dimensions of the latter. For these elements are only found on large drumlinoids and lid moraines which because of all characteristics seem to be well developed. But their position may be anywhere — proximally, centrally or distally. In most cases, this placing is determined by the location of the foundation rocks.

Nor do the types of till seem to have influenced the formation of these top hills and ridges. The latter are certainly not found in the Närke, Kinnekulle and Falbygden areas, i.e. where Cambro-Silurian rocks most often predominate in the drumlin till. But this till is granulometrically similar to that of the drumlin ridges on the South Swedish Highland (cf. p. 157). The lack of top hills and ridges in the lowland districts may therefore be due to the normally small dimensions of the underlying moraines, or due to the usual lack of foundation rocks there.

These top hills and ridges, especially those with much till, are most important in that they may illustrate something of the drumlin evolution in general; and they may have developed differently. The final accumulation may have continued in only one or two places (= these summits) but not round about (cf. W. B. Wright 1912). This mode of formation can include two variants, however. Either, after piling up to these top ridges, the accumulation did not continue beside them; or, after the underlying great moraines were completed, the top ridges formed by a renewed accumulation, i.e. there was an interval in the formation of the actual complexes. The second main alternative may be that these top hills and ridges developed by real erosion (cf. Alden 1905), i.e. removing of material around them, certainly because the underlying moraines became too large and offered too great resistance to the ice.

The last method, i.e. remaining summits, seems to be very plausible but there are arguments against it. In some places, the isolated tops are undifferentiated hills; if real erosion had occurred, they would have been more or less levelled. Furthermore, many high moraines have such top ridges in their centre, i.e. both the proximal and distal sides are lower. At least where these tops consist entirely of till, it is difficult to understand how they can have been preserved in this position. This applies still more to moraines with more than one summit ridge, either regularly or randomly placed. The first alternative seems to be most probable because of the shape of the last two types of moraines. Moreover, there are but few arguments against it. For if the accumulation was irregular both in place and in size, its completion or cessation could also be irregular; or, it may have resumed after an interval and been concentrated to only one or two places, i.e. the recent top ridges. Especially where the limitations of the latter are independent of the underlying moraines which in their turn are uniform, such a variant of the evolution of a large drumlin complex may not be excluded (Gillberg 1970).

On some large drumlin moraines the top hills or ridges lie in succession or parallel to each other or on the fringes, i.e. in positions typical of all drumlin ridges (cf. Alden 1905). This may be a random location, i.e. the lie of the foundation rocks is so and/or the accumulation and levelling have been concentrated so. But locallly such long and broad moraines with top ridges regularly placed could have developed in another way. Two or more, separate, small moraines — in succession or in parallel — may have fused as a result of till accumulation between them. Such an evolution is suggested by the fact that a coalescence of independent ridges in such positions has begun in some places, e.g. in succession B6, 39, 58, 59, 65, 74, S4, 6, 28, 29, 43, 54, V15, 22, 26, 28, 38, 43, 58, 69, 76, 83, F11, 13, 14, N3, 13; parallel ones B3, 48, 56, 70, S20, 27, 56, 74, V1, 18, 35, 38, 43, 56, 71, 79, 86, F14, K1, 5, N2, 5, 6, 8, 16, 21 (Tables 1—6). The degree of fusion is different, as is evident from the shape and position of the actual ridges and from the thickness of the till in between.

It is hardly possible to prove how these summit ridges in each place did develop. Differences in material composition and in orientation and dip of boulders and stones between these elements and the underlying moraines or the till fillings could exist locally. But such divergences may occur with any kind of evolution.

The exact size of each drumlin moraine seems to be of only descriptive interest. Furthermore, the limitation of some ridges is so indistinct that the exact values of one (or two) dimensions are difficult to define, e.g. length of those with continously sloping distal sides, width of those with one long side continuing down a plateau slope, and height of crag ridges with the crag covered by till.

As the characteristics of the sides and the crests often are dependent on the height and placing of the foundation rocks and the location of the ridges, the differing dimensions of the latter may be related to the same factors. Furthermore, it is of interest to see whether typical combinations of size exist, and whether such ridges are specially formed or placed. A discussion of these conditions calls for approximate values of the different dimensions, although it may suffice to describe them in general terms. The following groups seem to be suitable in this respect.

Length — < 100 m = short; 100 m—500 m—1,5 km = intermediate, or more precized, intermediate short and intermediate long; > 1,5 km = long.

Width — < 75 m = narrow; 75 m—200 m—500 m = intermediate narrow and intermediate broad; > 500 m = broad.

Height — < 15 m = low; 15 m—30 m—45 m = intermediate low and intermediate high; > 45 m = high.

Stoss- and lee-side moraines are usually small in all three dimensions, although sometimes intermediate narrow; this seems to suggest that increased length, and especially increased height, involved a more distinct limitation to the sides, i.e. the beginnings of ridge-form. Among the crag moraines, the postcrags are usually longer than the precrags but most of all those studied belong to the intermediate category in both length and width. The height is normally of intermediate size at the crags (even higher) but then often steeply decreases downwards, i.e. many crag ridges are low in their proximal or distal parts. Small such moraines, i.e. having at least two dimensions below the minimum values above (usually width and height) are few, e.g. B1, 13, 18, 21, 39, S2, 4, 27, 44, 56, 77, V8, 29. Nor are any of the crag ridges large in all three dimensions. A few are long but only intermediate in width and height (locally high at the crags), e.g. S25, 26, 27, 42, 64, V5, 45, 54, F3, 13, K3. They always lie at isolated heights of moderate size, never at large plateaux. Thus, the drumlin accumulation was more concentrated at the former and probably continued over a long time; but for various reasons it was smaller in extent at the latter and perhaps of shorter duration. Finally, a special type of postcrags may be mentioned, not because of their differing size but their variation in shape so that a superficial glance gives a wrong idea of their dimensions. They may be described as broad at the crags then rapidly narrowing and steeply sloping towards the end, i.e. they seem to be short, e.g. B18, 22, 35, S7, 51, 52, 72, 81, V16, 64, 65, F2. But this is an optical illusion caused by the steepness of the slope. Often the length of these ridges, sometimes the width, are intermediate.

The dimensions of the drumlinoids and real drumlins vary more widely, and many combinations of their sizes are found. Only those which are of special interest will be briefly described.

Short, narrow and low moraines are few, only some on the lowlands, e.g. some of F10, 11, 12, K5, N2, 7, 8, 12, 20; cf. Fig. 2. Instead, the ridges which — in relation to other — should be designated small, are intermediate short, narrow or intermediate narrow and low. Such moraines are found in all the areas studied and in all locations but on the South Swedish Highland they tend to occur as summit ridges (on plateaux or other moraines), or as minor ridges in small groups, both in succession or parallel to the major ridges, e.g. B3, 6, 14, 18, 23, 24, 31, 34, 37, 38, 39, 48, 55, 60, 69, 70, 71, 72, 78, 81, S3, 4, 10, 11, 12, 14, 15, 22, 23, 28, 29, 31, 43, 50, 57, 58, 59, 61, 67, V2, 8, 11, 14, 16, 18, 25, 26, 27, 28, 29, 31, 33, 35, 37, 42, 44, 46, 47, 51, 53, 56, 58, 62, 64, 67, 68, 70, 71, 75, 76, 78, 79, 89, F3, 8, 9, 10, K5, N5, 6, 7, 8, 12, 17, 19, 20. The moraines with the following sizes are a special type — intermediate long or long, narrow (or intermediate narrow) and low. They usually lie in open terrain and on gently sloping ground; nearly all of them are real drumlins, often with plane surfaces, e.g. B11, 17, 24, 52, 56, 58, 74, 75, 80, 82, S18, 37, 60, 66, 70, 73, 75, 78, 83, V3, 7, 22, 23, 24, 57, 63, 69, 76, 78, 83, F11, K4, 5, N12, 18. Some drumlins and drumlinoids which are intermediate in length, seem to be higher than they are, e.g. B8, 25, 39, 58, 76, 77, 79, S56, 58, 61, 63, 76, 79, V23, 66, 74, 82, F9, N17, 21, 22. This results from a combination of three or four facts: the crests are very marked (often rocks), they are of intermediate width, their position is isolated and the sides are comparatively steep. Really large ridges, i.e. with all dimensions above the uppermost limits or the height somewhat smaller, are rare, e.g. B21, 46, 50, 60, S11, 16, 17, 30, 31, 38, 41, 62, 77, V14, 18, 36, 80, 81. They only occur on the South Swedish Highland, being comparatively isolated on plateaux or on gently sloping ground.

This short description shows, that the drumlin moraines vary widely in size, both in general and in each district, and that the latter partly differ from each other in this respect (cf. Ebers 1926, 1937, Fairchild 1929, Chorley 1959, Reed et al. 1962, Gillberg 1970, Glückert 1971, 1973, Hill 1971). Intermediate ridges predominate throughout but are usually intermediate great on the South Swedish Highland, intermediate small in the lowland districts. Ridges with a least two dimensions below the minimum values are common, and form a large group of summit and side ridges. Really large moraines are few.

The dimensions of the drumlin ridges seem to be influenced to some extent by their location, possibly also by the type of terrain. This is particularly true of the extreme ridges, i.e. the smallest and the largest, and those designated as long and low. Most of them are found on even or gently sloping ground and often in more open terrain.

The shape of the drumlin moraines never seems to have played any role in this connection, however. For ridges with ideal or reverse form or those with symmetric or asymmetric short and/or long sides may belong to either category and may have any combination of dimensions. Nor does the type of till appear to make any difference in this respect, although the supply of material must.

The drumlin moraines have long been characterized in terms of the relation between length and width, 2:1, 3:1 etc. This may be an acceptable mode of expression but it is not always significant. For if these sizes are fixed at 2:1, the extent of a ridge can be very different — 100:50 m or 1,4 km:700 m, and 4:1 may be 400:100 m or 2 km: 500 m. And such a difference may sometimes be important.

The proportions of most of the moraines studied (about 70 %) are of 3:1 and 4:1 (2,7—4,3). As this seems to be the norm in all drumlin areas (Fairchild 1929, Gillberg 1955, Chorley 1959, Reed et al. 1962, Glückert 1971, 1973) and as the most perfect ridges are of this type, this may express a definite form, irrespective of the exact dimensions. Moraines of other sizes are fewer. Most of them are of the combination 2:1; some typical examples are B6, 8, 77, 79, 83, S28, 61, V45, 62, 85, N6. Those with 5:1 (6:1) are the least common, e.g. B11, 46, 56, 68, 74, 75, S29, 71, 77, V7, 14, 22, 23, 56, 79, 83 K3, 4, N11, 12, 13 (nearly all mentioned).

There seems, in principle, to be a connection between the height and the width of the ridges, i.e. the higher—the broader. A reverse relation (the broader—the higher) does not always hold good for many "broad" moraines are only intermediate in height. And any combination of length and height may occur. A definite relation between the last and the two other dimensions is therefore impossible to establish (Hollingworth 1931, Gillberg 1955). This may be explained in many cases by the presence, location and height of the foundation rocks and their influence on drumlin growth.

There is a strong probability that the drumlin ridges were built up during a continuous accretion of drift. For such large moraines which are found today, can hardly have been completed immediately. The different dimensions — perhaps in some cases, the shape, too — could therefore represent stages in development (cf. W. B. Wrigth 1912, Vernon 1966). In simple terms this means: short, narrow and low from the beginning, then increasing in all direction to a final stage — long, broad and high. But as most ridges have intermediate dimensions or belong in part to the last category, it is difficult to decide whether their evolution did follow this pattern. There are exceptions from it, however, and they are important as they may provide data on the growth, at least of these ridges.

Some long moraines are low and comparatively narrow. In comparison with many other ridges, their length seems to be at its "maximum" but their width and height are not complete. Crag moraines are often long but are in proportion often narrow and proximally and distally low. As many of them may be evolutionary ridges, their height, especially, may be increased — as may their width — by a continued enlargement. High but narrow moraines are also found. These seem to have grown greatly in height but less in width, sometimes also in length. Large moraines with summit ridges exist, i.e. presumably with "complete" height on the tops but not around them. Finally, the short sides are often well levelled and comparatively uniform, while the long sides are steep and irregular. This could be regarded as evidence of a greater completion in length than in width. This may also be indicated by another fact. On some, often comparatively broad moraines, one or both the long sides have a flatter gradient in the lower parts, somewhat steeper towards the top surfaces (Figs. 24, 25). This may show the beginning of a supply of material to the long sides, i.e. a broadening of the actual ridges has started but is not completed in height.

There is some doubt as to the advisability of explaining the growth of the drumlin ridges according to sporadic examples and extreme features. Yet it is the only alternative as most moraines seem to be more or less complete and therefore show few signs of their evolution. Some conclusions may be drawn, however. (*A*) The first accumulation often seems to have occurred over a long distance, either in the shape of long, uniform ridges, or divided into two or more ridges in succession, in places partly fused. (*B*) The continued growth often seems to have mostly appeared in height, sometimes throughout but usually more irregular. As a result, the ridges may have increased in width, too, particularly where the height is at its greatest. (*C*) Very broad moraines may have developed by a fusion of two or more parallel ridges. (*D*) Independent, long (-high) precrag and postcrag moarines are present locally at the same rock or rock hill. If they should have developed into drumlinoids, their width was the last dimension to be completed. As is partly evident on Kinnekulle (Gillberg 1970), this accumulation on the long sides of the crag seems to have begun first when the till deposits are proximally so much enlarged in width that they protrude outside the crag. Their prolongation then directly resulted in a deposition on the long sides, i.e. a broadening of the whole complex.

Thus, the development into complete drumlin moraines often seems to have occurred in the sequence of first length, then height and width but usually the latter dimension last.

A natural question in this connection concerns the maximum possible size of a drumlin ridge. This cannot be answered beyond doubt, as we do not know how the evolution of the recent moraines would have occurred during a continued ice activity. All we can say is that these ridges vary widely in dimensions, that large ones exist, and that many of them seem to be more or less complete. Thus, the question is irrelevant. But other facts may be of importance for this problem. (*A*) Normally the ridges gradually become more levelled and real erosion may appear, at least proximally. (*B*) The length is generally in proportion to width, 3:1 (4:1), especially in the case of probably complete ridges. (*C*) Also small moraines can have an ideal form.

This discussion seems to lead to the conclusion that some kind of equilibrium between syngenetic accumulation and levelling (and local erosion) finally appeared (Högbom 1905, Fairchild 1929, Hollingworth 1931, Ebers 1937, Björnsson 1953, Gillberg 1955, 1970, Chorley 1959, Johansson 1972); or in other words: after reaching a certain size, the ridges have ceased to develop, i.e. no new material has been deposited or, if it has, it has rapidly been carried away or, if it has remained in place, earlier accumulated material has been removed. But as more or less completed ridges differ in size, this equilibrium must have been reached in different ways, at different places and on different occasions. It must therefore be related to different factors, each one decisive in itself but especially so when combined with the others.

One of these factors is evident from the foregoing discussion. This is the topography, both its general type and the existence, size and position of obstacles, i.e. in every way the location of the ridges. One example of this influence may be given. Moraines in more open terrain seem more often than others to be complete as do small ones, i.e. the obstacles not only decided the beginning of evolution, they also retarded the final equilibrium.

The material

As the drumlin ridges were built up subglacially by a moving ice, the main material must be basal till. All descriptions verify this as do the open sections in the areas studied. But the latter are too few and usually too shallow to give any comprehensive information about the drumlin till. The latter is dense, compact and in some places cementation has begun; large boulders are few except on the top surfaces, and small sand lenses and foliation have been observed locally, i.e. all the characteristics of normal basal till (Fig. 28).

Fig. 28. Section through a short real drumlin S. of Hästveda, N. Skåne. Dense, compact basal till throughout; indistinct foliation in places; boulders mostly towards the top. Ice movement obliquely from the left.

Four sections are interesting, although for different reasons — three in the areas investigated, one in their immediate vicinity. (1) The deep section in a precrag on Kinnekulle has already been described in detail (Gillberg 1969); but two features may be reiterated as they may have some bearing on the drumlin problems. Taken as a whole this precrag has at least two tills, each being 4—5 m thick, and there are indications that they are separated from each other by a real interval in the accumulation. The lower till is of so heterogenous a lithological composition in the distal end of the precrag that it must result from redeposition of material from the proximal part. (2) In the Hackvad drumlin (N18), a section about 3 m deep was exposed and studied in 1958 (it is now destroyed). It showed a specific "stratification" — the predominant shale material was deposited in conformity with the drumlin top and down its long sides (cf. Sahlström 1910, Fairchild 1929, Granlund 1943, Minell 1973). It

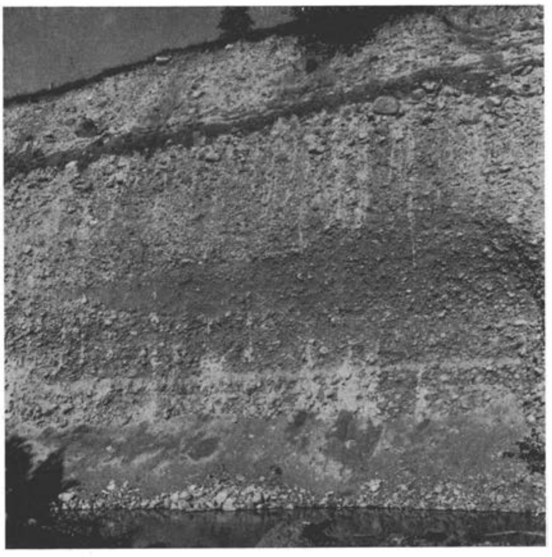


Fig. 29. Section through a great drumlinoid (precrag) at Torps bruk (V41), Värend area (Fig. 10). About 3,7 m compact, sandy basal till lying over about 15 m stratified material — mostly stones, gravel and coarse sand, comparatively well sorted and rounded, partly well bedded but partly not. In places, soil creeping of silt from the till at the contact between the two drifts. Ice movement from the left.

resembled "layers on layers", presumably indicating a successive addition of material. (3) In the high drumlinoid of Torps bruk in the Värend area (V41, Fig. 10), 3.5—4 m thick, sandy basal till covers near 15 m thick stratified debris (Knutsson 1959, Rydström 1971). The latter consists of stones, gravel and coarse sand, mostly rounded and well sorted, usually also well bedded (Fig. 29). (4) In a short drumlin, S. of Hästveda in N. Skåne, the roughly 7 m deep section shows a uniform basal till with indistinct foliation in places and a few boulders, nearly all towards the top (Fig. 28). But towards the bottom of the proximal end, some other features were found. Sand and gravel exist, deformed, folded and following the upward slope of the drumlin surface but clearly being part of the till (Fig. 30). These suggest deposition by moving ice, pressing forwards and upwards on the already accumulated till.

Granulometric analyses of drumlin till are seldom reported (Johansson 1972), only the main type of it being sometimes specified (clay till — Alden 1918, Fairchild 1929; sandy till — Granlund 1943, Björnsson 1953, H. E. Wright 1957, Glückert 1971, 1973, Aario et al. 1974). However, the exact grain size composition may be worthy of note. As the drumlin moraines are special, glacial elements, it is not inconceivable that they are composed of a specific type of basal till. Indeed, this has on occasions been remarked, has even been regarded as necessary (Alden 1918, Fairchild 1929, Granlund 1943, Björnsson 1953, Smalley & Unwin 1968). For all these reasons, I have taken samples from several ridges in the different areas — if possible from open sections, otherwise from road cuttings or by digging (Tables 1—6). The diagrams — in lognormal scale (Gillberg 1969, 1970) — show the mean composition of all these samples and the most extreme of them in each district (Fig. 31).

Different tills can also vary lithologically. Such divergences should be taken into consideration, e.g. to see where the actual tills originate = the transport distance (Gillberg 1964, 1967, 1969). For such studies, the gravel (2 cm—2 mm) which is in fact more representative than stones and boulders (J. Lundqvist 1952, Gillberg 1964, 1969, 1970), will give sufficient information. Nevertheless all fractions should properly to be analysed in order to arrive at a correct view in this connection. For gravel studies of the drumlin till, the bedrock must be different and distinguishable around and proximally of these moraines. Only in the N. parts of the Borås and Sommen areas

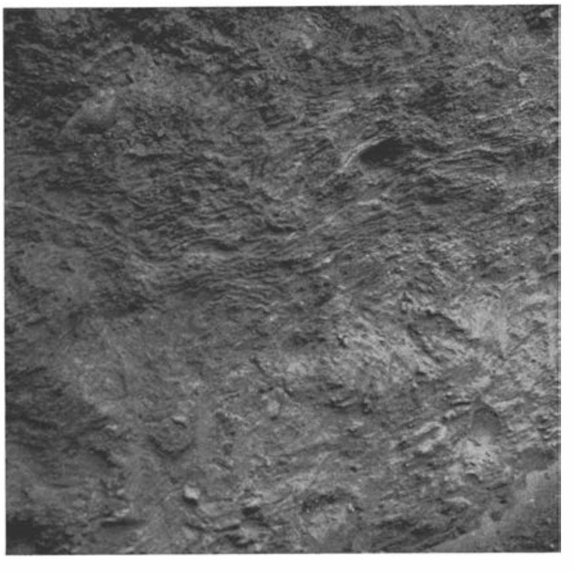
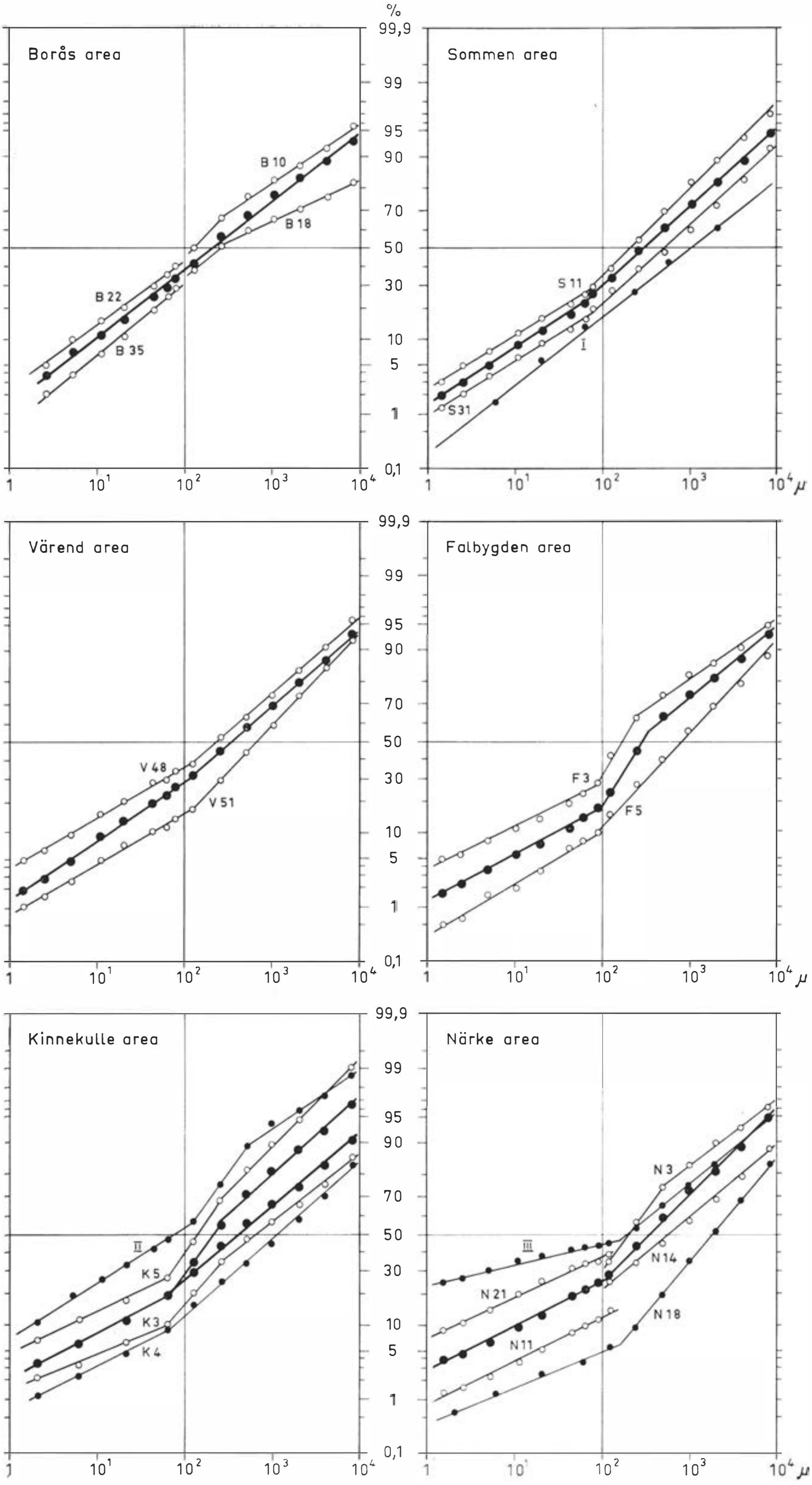


Fig. 30. Section (about 1,7 m) through the same drumlin as on Fig. 28, lowest proximal part. Typical basal till only towards the bottom; above it, many layers of gravel, sand and fine sand, deformed and folded by the over-riding ice; towards the top (and higher up) in principle the same till as at the bottom but here more gravelly and with many stones, and not so compact. Ice movement from the left.


Borås area
B 10
B 18
B 22
B 35
Sommen area
S 11
S 31
I
Värend area
V 48
V 51
Falbygden area
F 3
F 5
Kinnekulle area
II
K 5
K 3
K 4
Närke area
III
N 3
N 14
N 21
N 11
N 18
%
99,9
99
95
90
70
50
30
10
5
1
0,1
1
10^1
10^2
10^3
10^4
μ

and partly in the Närke, Kinnekulle and Falbygden districts are these conditions fulfilled, i.e. where Cambro-Silurian rocks occur in suitable positions in relation to the Archaean bedrock. As the results of these investigations were discussed previously (Gillberg 1964, 1967, 1969), only the relevant facts will be reiterated in different connections here.

The granulometry of the drumlin till varies comparatively little in the Borås area, somewhat more in the Sommen and Värend districts, still more in the Närke and Falbygden areas and very much on Kinnekulle (Fig. 31). This fact illustrates the bedrock around the ridges, and thus their lithology — till of gneiss in the first area, till of granites and porphyries in the two following areas, till of Cambro-Silurian rocks with gneiss and granit in the Närke and Falbygden areas, and till of gneiss, diabase and Cambro-Silurian rocks in varying quantities on Kinnekulle. The relation between different fractions is comparatively similar in each district, however. If greater differences in this respect occur, they are found in the coarse material, especially in Närke and on Kinnekulle.

The mean composition lines are of three main types — being uniform or having one or two discontinuities (Fig. 31). The latter are sometimes very pronounced, as in mixed till in the Närke, Kinnekulle and Falbygden areas, sometimes more indistinct, as in more homogenous till in the three other areas. Moreover, separate samples, not illustrated, usually show the same types of lines in each district. There are divergences, however: uniform lines — three in the Sommen area; lines with flat lower, and steep upper, parts (one discontinuity) — four in the Borås and one in the Falbygden districts; lines with steep lower, and flat upper, parts (one discontinuity) — one in the Borås, one in the Sommen and four in the Värend areas; lines with two discontinuities — six in the Borås, two in the Sommen and two in the Närke areas.

Thus, the tills analysed granulometrically show wide variations — from predominant coarse till to high frequencies of medium-sized material, on Kinnekulle even silty-clayey till. What is more, all types of composition lines exist. This can be supplemented by all the data on varying drumlin tills in other areas, especially those composed chiefly of clay (Alden 1918, Fairchild 1929), or those containing a great number of boulders throughout (Munthe et al. 1928). The answer to the problem of the material composition must therefore be: the drumlin moraines may be built up of any kind of basal till, they may even consist of two or more different types (Gravenor 1953, Virkkala 1961, Gillberg 1970, Hill 1971). Nevertheless this is to be expected, as different rocks, which exceedingly determine the grain size composition, are represented in the drumlin tills. The possibility may not be excluded, however, that till of special composition could, more easily than other types, have been concentrated locally in such ridges (cf. ref. p. 155).

But this problem can be defined more restrictedly. The drumlin till may have a grain size composition other than that of the surrounding basal till. In order to determine this point, I have analysed the latter type of till in the areas studied. But this investigation is made very different in the separate districts. A large number of samples were taken in the Borås (38) and Kinnekulle (30) areas — in the former only from the northern and central parts but not always in the immediate vicinity of the drumlin ridges; in the latter district certainly throughout but mostly beside these moraines. In the other areas, only about ten samples were taken in each of them, irrespective of the location of the drumlin ridges. Some important facts emerged despite these differences in sampling.

On the South Swedish Highland, the drumlin till and the normal basal till tend to be of the same granulometric types, and even the values of different fractions may correspond. And the mean composition lines of both types of till approach coincidence (therefore those of the

Fig. 31. Grain size composition of drumlin tills in the six areas studied in detail — lognormal scale (cf. Gillberg 1969, 1970). The thick lines with large filled circles show the mean composition of such tills analysed in each district (15 in the Borås area, 15 Sommen, 15 Värend, 8 Falbygden, 8 Närke, 49 Kinnekulle; Tables 1—6). (In the last diagram two such lines exist in the coarse fractions as two, partly different, tills are found in different drumlin ridges, W., E. and N. of Kinnekulle peak; Gillberg 1970). The thin lines with small open circles show the exact composition of extreme drumlin tills in each district; sometimes (Sommen, Värend, Falbygden, Kinnekulle areas) such extremes are from only one drumlin throughout all fractions, sometimes (Borås, Närke areas) the extremes are from two ridges, one in the finer, one in the coarser fractions. Five other tills are included for comparison (thin lines with small filled circles): K4 — coarse till from the drumlin "Stenåsen" (mean of four samples), N18 — coarse till from the drumlin at Hackvad, I — coarse till from drumlin S40 (analysis in Björnsson 1953), II — mean composition of till II in profile 6 in the great till section on the NW. slope of Kinnekulle, K2 (Gillberg 1969), III — a clayey till near drumlin N19.

normal basal till not being inserted in the diagrams). These facts are not surprising as the bedrock is similar in each area. The normal basal till seems to be more extreme in places, i.e. it shows greater divergences in the finest and the coarsest fractions. This may be due to the accumulation having occurred at different positions in the terrain; the deposition of the drumlin till almost invariably appeared in a similar milieu.

On Kinnekulle, the predominant drumlin till is also of the same type as the normal basal till in the vicinity (Gillberg 1970). Nevertheless, an obvious exception is present. The till of the three postcrag moraines is noticeably coarser. The lithological composition shows the reason. This till originates chiefly in the top area so that it is transported a short distance and has undergone but little crushing. Furthermore, this distal drumlin area was almost completely shielded by the high peak so that little material has been carried inwards from the sides. The isolated ridge "Stenåsen", distally of the postcrags, also displays a coarse, local till from the top. A part of this is even coarser, being almost a boulder till of mostly diabase. This is an interesting point, as it is bottom material of this ridge, which seems to be incomplete, judging by the general shape (Gillberg 1970).

In the Falbygden and Närke areas, differences in grain size composition between the drumlin till and the normal basal till in its vicinity often occur. Nearly all samples from the drumlin ridges contain comparatively coarse, or even very coarse till (Fig. 31), which is locally rich in boulders. This fact has been established by Sahlström (1910) and Munthe (1928). As for the large postcrags at some of the Falbygden plateaux, such coarse material composition is comparatively natural. This till mostly originates from these heights. But it is not so coarse and local as on Kinnekulle. This is probably because the Falbygden moraines did not lie in so pronounced a lee-position as the equivalent ridges on Kinnekulle, i.e. material has also been carried inwards from the sides. As for many of the small drumlin moraines on the Närke and Falbygden plains, such a coarse till is more surprising. These ridges are chiefly found on Cambro-Silurian rocks. Thus, they would be expected to contain much material of this kind, and may display a finer grain size composition. The first assumption is correct (cf. below) but not the second. The normal basal till in the vicinity is often finer, and even real clay till exists (e.g. line III, Fig. 31). Locally such till is found on the drumlin surfaces, e.g. U21. The fact that it differs from the underlying till may well be evidence of a continuous accumulation (plastering-on); in any case the uppermost till must have been deposited somewhat later.

Thus, the drumlin till may sometimes resemble the normal basal till in the vicinity (Ebers 1926, Virkkala 1961, Glückert 1973, Aario et al. 1974). But it may have another granulometric composition. In all the known cases here, it is coarser than the surrounding basal till. This presumably indicates a short transport distance and a comparatively rapid accumulation. But the most important fact in this connection is that the coarse drumlin till is bottom material of small moraines or occurs in crag ridges. According to their dimensions and/or often irregular shape, both these types may be incomplete.

Another problem is open to discussion. Different kinds of topography often seem to have determined the type of drumlin ridges (cf. p. 141). Thus, the question is whether the latter feature may also depend on the grain size composition of the till. This would seem to be possible in theory. For if a till has freely accumulated, this could have resulted in a more rapid and completed enlargement of the actual moraines, i.e. real drumlins rather than drumlinoids and crag ridges.

Such a tendency is not apparent in the areas studied. On Kinnekulle, exactly the same till is present in the real drumlins and the precrags. On the Närke and Falbygden plains, coarse till predominates in the real drumlins; it is sometimes coarser than that found in the drumlinoids and crag moraines on the South Swedish Highland. And in the latter districts, there is little correlation between the drumlin till and the type of ridge.

Apart from the facts already established of the drumlin lithology, the following are important. In the Närke and Falbygden areas, the local Cambro-Silurian rocks seem to predominate (60—80 %) in most drumlin moraines (Sahlström 1910, Munthe et al. 1928). In some small ridges, a single rock material (sandstone or shale) may even be the only type, sometimes in form of whole sheets (Sahlström 1910, Fromm 1972). This must suggest an immediate accumulation (cf. the coarseness). On Kinnekulle, the mixed till (in the precrags and the drumlins beside the peak) is always predominated by gneiss (40—80 % of the gravel), while the different Cambro-Silurian material varies widely in it (Gillberg 1969, 1970). Indeed, in some ridges, one of the latter rocks is present in great quantities. In N. part of the Borås area, Cambro-Silurian rock fragments from Falbygden are particularly frequent in a central zone between the Tidan and Nossan valleys (Gillberg

1964). Thus they also occur in most of the present drumlin moraines — in varying quantities but nearly always of the same mean percentage as in the surrounding basal till (locally up to 45 %). The Ca frequency of the finer fractions is usually somewhat lower in the drumlin till, however. From the Cambro-Silurian area of Östergötland, the fragments of such rocks have been carried southwards on a broad front over the S. part of the plain (Gillberg 1964). In the ascending terrain to the S., this material is found mostly in the great Sommen and Åsunden valleys (cf. Agrell 1974) but very little, if any, on the plateaux between them. Since the drumlin moraines tend to be located on the latter, their tills generally contain only Archaean material.

Accordingly, also the lithology of the drumlin tills — and still more than the granulometry (cf. above) — indicates a local origin of it, often extremely local (stated in many drumlin regions).

As in other drumlin areas, loose and coarse ablation till is found only sporadically on or in direct connection with the drumlin ridges. This fact is especially apparent where such till covers wide expanses in the form of hummocky moraine, e.g. S.—SE. of the Värend district. Drumlin ridges are not common there but where such occur, e.g. in the Emmaboda area, they and the hummocky moraines lie clearly separated from each other. The former are situated on the plateaux, often as summits, while the latter lie on the lower sides of them or in the shallow valleys (Knutsson 1971; cf. G. Lundqvist 1940, 1951). Between these two types of moraine, a narrow zone with ablation till which does not form hills, may appear in places.

The presence or absence of ablation till on the drumlin ridges provide valuable information. If such material is absent, i.e. typical basal till forms the drumlin surfaces, this must indicate that the accumulation of the latter debris by moving ice (= drumlin process) has continued until almost the very end of the presence of ice at the actual places (W. B. Wright 1912, Hoppe 1951, 1957). Very little drift has so remained to become ablation till. If, on the other hand, the latter material is more common on the drumlin ridges, it must indicate that in the main the drumlin formation was concluded before the deglaciation begun there and nearby.

However, ablation till sometimes exists, locally as embryonic hummocks, on the (proximal and) distal ends of some drumlin moraines or immediately distally of them. This material would probably in places have become drumlin till, i.e. a distal accumulation on these drumlin ridges was in progress, but the levelling was not, when the ice motion more or less ceased. The debris which has existed for a continued enlargement distally, has then become ablation till, locally in form of irregular hills.

Boulders are not common in normal basal till, so they are rare in drumlin till (verified in nearly all sections; Figs. 28, 30). There are exceptions, which are all found in low ridges — some on the Närke and Falbygden plains (Sahlström 1910, Munthe et al. 1928) and "Stenåsen" on Kinnekulle (Gillberg 1970). On the other hand, boulders often appear in great numbers on the surfaces of many drumlin moraines on the South Swedish Highland (Figs. 6, 7, 26; Björnsson 1953, Gillberg 1955, Knutsson 1971; cf. Glückert 1971, Aario et al. 1974). In reality, they have occurred on most of these ridges, for great stone walls always exist around the arable fields there (Fig. 27). Judging by their large numbers and the grain size, they are of local origin. This is certainly true of places where the presence of different rocks allows of clear determinations. In N. parts of the Borås and Sommen areas, these top boulders are of local gneiss and granite, while the ones further down in the drumlin till, to some extent, may be more far-traveled. Where boulders occur distally of large heights, they mostly derive from these source areas (Gillberg 1970).

According to their superficial position, the top boulders belong to the last accumulated material. Presumably most of them should have been deposited in the ablation till. But as they are pressed down into the substratum (Knutsson 1971), they must be regarded as members of the drumlin till. This fact, as well as their preferred longitudinal orientation, are clear signs of ice motion, i.e. the drumlin process continued until the very end of the presence of active ice there (cf. above). As these top boulders form a kind of surface layers, such an appearance may also be a criterion of an addition of the drumlin material as successive coatings.

A question which arises in this connection, seems to be why do not boulders, with some exceptions, occur more often in the lower drumlin till — despite the fact that it is mainly of local origin in other fractions. This may be explained by some form of differentiation in transport and accumulation by the ice. The finer material probably had a tendency to stick fast in the debris deposited; the large fragments were transported one by one and therefore tended to freeze more easily into the moving ice and so be carried away for further crushing (Gillberg 1964). Thus, the boulders on the surface would not have remained in place if the drumlin process had continued, or they would not have accumulated there at all. If real boulder "layers" occur in lower parts of drumlin till (Johansson 1972), it may therefore point to temporary, concluded accumulation, but certainly a rapid covering with new material as protection. Occurrences of real boulder till in some drumlin ridges may, on the other hand, indicate a rapid, concentrated accumulation, probably locally in another manner than by plastering-on (cf. p. 170).

The orientation of stones and boulders has often been cited as a typical feature of different sediments and of their different forms. Therefore, studies of it have been performed in drumlin moraines in many areas. All of them produce the same result — a principal orientation of the grains parallel with the long-axes of these ridges (G. Lundqvist 1948, Hoppe 1951, Björnsson 1953, Gillberg 1955, 1970, H. E. Wright 1957, Hill 1971, Johansson 1972, Glückert 1973, Minell 1973). This result confirms that the material generally moved in semi-viscous gliding along the subglacial transport and accumulation on the underlying ground (Glen et al. 1957). A parallel orientation is not strictly exact, however. Many boulders have an oblique position; an average of 75 % of them are found within a range of about 10—25° from the drumlin trend (cf. Hill 1971). But for several reasons, they are normally assigned to the main orientation. Divergences of about 45° or more, however, may be evidence of vital differences but even they may be fortuitous. Indeed, both a small and a large deviation in the boulder orientation in the drumlin ridges may be explicable without special conditions. Many features of these elements show that the accumulation did not occur uniformly throughout, that redeposition probably took place, and that levelling or real erosion contributed as a shaping process. If in addition, the material in accumulation was soggy, and the surface of the substratum was irregular and had different gradient in different places, the supply of new debris may usually have been forced into different direction. Thus, a boulder orientation which diverges from the mean orientation of the drumlin ridges need not be remarkable and may even be a normal feature. In itself, it may not be a definite proof of any special evolution.

This problem was discussed because a more oblique pebble orientation in drumlin till has been proposed as a criterion of a deposition from the sides inwards to subglacial cavities (Hoppe 1951). Such a development may have occurred locally (cf. p. 170). Yet it probably presupposes a rapid accumulation of much material in order to preserve this position of the grains. As a result of a more continuous addition of debris, the normal ice motion over and parallel with the cavities may have predominated and oriented all material "parallel" with the ridges in formation, i.e. a reorientation of the debris deposited may have appeared (cf. Gravenor & Meneley 1958, MacClintock & Dreimanis 1964, Boulton 1971, Hill 1971). Cavity fillings with an original boulder orientation preserved may therefore be found only locally, and only towards the bottom of the drumlin ridges.

Regarding the analysis of boulder orientation in the areas studied, some restrictions existed a priori. The open sections are not of such an extent that a sufficient number of grains can be measured for a detailed statistical treatment. Only the tendency of their orientation may be obtained. The surface boulders occur in sufficient number but presumably the possible influencing factors applied especially to them. To arrive at an accurate view of this problem, furthermore, it is not enough to analyse the boulders on different ridges as units. These studies should be made on equivalent parts of the ridges, i.e. for comparisons of the proximal sides, the distal sides etc. If this is done, some other restrictions existed. The top surfaces and the long sides must often be excluded; the former because their boulders were removed for cultivation of the drumlin ridges, the latter partly for the same reason, partly because secondary changes in the boulder orientation probably occurred in some cases by solifluction (G. Lundqvist 1949, Gillberg 1970, Hill 1971).

Nevertheless the superficial boulders may in places be interesting from this aspect. On 77 of 78 drumlin ridges studied (in all districts), about 70—80 % of these boulders have the normal orientation with the drumlin trend, within a deviation of 10—20° from either side (cf. Fig. 32). The only exception is "Stenåsen" on Kinnekulle. There the irregular, but by no means exceptionally extreme, boulder orientation is in a low bottom ridge on which an addition of new till seems to have begun (Gillberg 1970).

A closer study to discern whether any differences exist between different sides of the drumlin moraines has been made in the northern and central parts of the Sommen area. 28 ridges are analysed for this purpose (70—90 boulders on each part studied). The divergences between them are so small, however, that mean diagrams for the different sides of all the ridges suffice to show the tendency which seems to exist (Fig. 32). (The predominant orientation is taken as reference line, i.e. without regard to each drumlin trend and

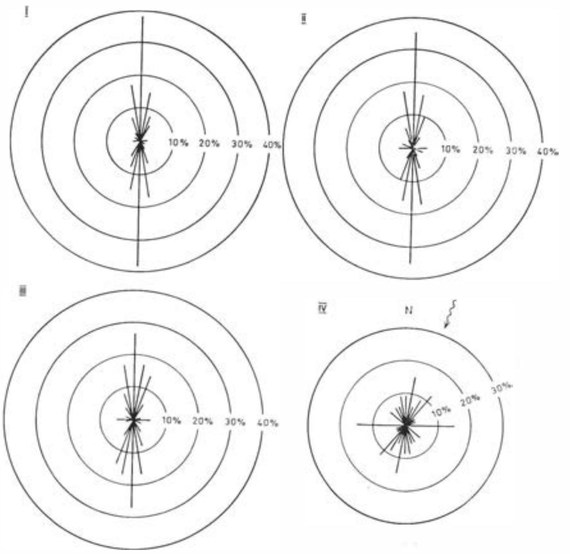


Fig. 32. The orientation of superficial boulders. (I) mean orientation on the proximal sides of ten drumlin ridges, (II) mean orientation on comparatively plane top surfaces of nine drumlin ridges, (III) mean orientation on the distal sides of nine drumlin ridges. In all these cases, the exact orientation of the actual moraines is disregarded, instead, the maximum values on all ridges are taken as reference percentage (cf. the text). (IV) the exact orientation of 102 boulders on the bottom part of the drumlin "Stenåsen" on Kinnekulle (Gillberg 1970); the arrow shows the drumlin trend.

without showing any point of the compass). The proximal parts and the top surfaces show an equivalent boulder orientation; the distal sides diverge but little from them but the differences is there nevertheless (cf. Minell 1973). The boulders with exact position with the ridge trend are fewer, the number lying within a deviation of 10—30° is greater, and the number of more oblique and transversally lying boulders is much greater. These divergences may indicate that the distal sides retain more original features of accumulation (cf. more irregularities there); the proximal sides, which are usually more levelled, are more influenced by the moving ice.

On the northernmost, shield-shaped precrag at S36 (Fig. 9), a curious feature may be mentioned. On four places on its upper part, four to six large boulders lie in succession and strictly oriented with the ridge trend; there are small boulders on each side which are oriented inwards them with a deviation of 15—25°. As the ridge surface does not seem to be influenced by human activities, nor is there any reason to mistake solifluction, this "structure" must be original. But what is the cause of it? — the existence of different stream zones in the ice or what?

Analyses of the dip of stones and boulders in the drumlin till would perhaps be of significance (H. E. Wright 1957, Hill 1971, Johansson 1972) but for different reasons have not been made. Surface boulders are in many places sufficiently numerous, and certainly their orientation provides some information but their dip seems mostly to follow the gradient of the drumlin surfaces (at a glance). Moreover dip analyses should preferably be made inside the drumlin till — to see if any differences from this respect exist between different "layers". For if this is the case, they could give evidence of the kind of accumulation (successive plastering-on or immediately). But the sections are here too few and too shallow and the amount of suitable material is often too small to allow of reliable results. Whatever material is analysed, however, the dip of it should be measured in relation to the underlying ground, or locally to the drumlin surface (cf. the gradient of the short sides, p. 148).

Stratified drift in connection with drumlin moraines may lie under, inside or just beside the drumlin till (Alden 1918, Ebers 1926, 1931, Slater 1929, Hollingworth 1931, Gravenor 1953, Knutsson 1971, Rydström 19717, Hillefors 1974 and others).

If it occurs as bottom material, it was probably deposited during a previous glaciation or glaciation phase. It has then during a renewed glacial activity functioned as foundations for the drumlin ridges (cf. projecting rocks). Thus in these cases, there was an interval in time (interglacial or interstadial) between the accumulation of the two kinds of debris. But of course, there is a probability that the drumlin process directly succeeded the deposition of the glacifluvium — during the advance of the ice or during a stagnation and oscillation in deglaciation time.

Stratified drift in this position has been found in some drumlin ridges in the centre of the Värend area, e.g. V36, 41, 73 (Fig. 29, Table 3; Strandmark 1956, Knutsson 1959, Rydström 1971). It is covered by basal till, at least 3 m thick, locally up to 10 m. The accumulation of the latter material is obviously the result of ice in motion, for the recent ridges are in most features typical drumlin moraines. If there were no gravel pits to expose the type of bottom debris, these ridges would scarcely have been noticed as any special type of drumlins. However, this complicated material composition raises one question, namely should these ridges be classified as drumlinoids of type B or as eskers with covering till. Personally, I see no reason for the latter designation as according to all superficial characteristics they are drumlins. For if the different bottom configuration is to determine the classification, ridges with rock foundations do not belong to the drumlin complex either.

Some other drumlin moraines may have glacifluvial bottom material. A search of them would be justified but possible occurrences of such debris can scarcely be of importance for the drumlin problems. For if such material exists, it only shows that it, instead of rocks, acted as foundations for the drumlin formation, and that, if it forms bottom eskers, these certainly developed totally or partially in cavities but that the covering till was deposited only as coatings on them. The most interesting fact would be, whether a real interval did or did not occur between the accumulation of these two kinds of debris (cf. Hillefors 1974a).

Secondly, meltwater material can appear as integral layers in the drumlin till. Some finds of such debris have been made but it is only of small extent, e.g. sand lenses. Such occurrences have sometimes been regarded as a criterion of the appearance of drumlin formation in basal cavities (Hoppe 1951). This may be true but even if they are of great extent such deposits can hardly be used as more than a secondary argument for this theory. Intermittent meltwater activity was certainly not uncommon at the bottom of the ice, as the temperature there may often have fluctuated near 0° C, especially by great friction against the substratum. Layers of pure sand, even inclined bedded, in normal basal till appear as proof. They often lie so close to the latter material as to exclude accumulation in real cavities; rather they are criterion of a successive deposition of all the actual debris (cf. G. Lundqvist 1951). But some pockets in connection with irregularities in the underlying material or near large boulders and projecting rocks may have been present, and they could have been filled by various debris. Of course, some integral, glacifluvial layers may be redeposited material, probably transported in frozen state and/or as small sheets and over a short distance, e.g. from proximal to distal side (Möller 1960). Otherwise they would have been disturbed or transformed to till.

Finally, if glacifluvial material appears on or near the sides of drumlin moraines, it must derive from the concluding deglaciation. And if so, this — like ablation till in equivalent location (cf. p. 159) — shows that the drumlin formation was completed before this time (cf. Alden 1905). Such debris is rare in most of the areas studied. Only in the Sommen and Värend districts, small esker hills are sporadically found in such contexts, more often distally than proximally, and in only one locality between two ridges (V22). This placing of the glacifluvium is certainly due to the development of tunnels or crevasses during the deglaciation in connection with already present ridges.

Elsewhere, existing eskers etc. are found separated from the drumlin moraines, certainly because the meltwater was normally located in the lower parts of the terrain rather than on the plateaux, i.e. mostly the places of the drumlin ridges. The Emmaboda district is a typical example (cf. p. 137; Knutsson 1971). But such a separation of these two kinds of glacial elements is also obvious in a similar milieu, e.g. on the Närke plain where the eskers lie in the large gaps between different groups of drumlin moraines (cf. p. 140).

In the last area there exists glacifluvial material on the W. sides of two drumlins, N11 (Sahlström 1910). These are of interest, for if this debris (coarse and slightly sorted) were removed, certainly radial but irregular ridges would remain, i.e. by no means real drumlins in form. Accordingly, it seems that this glacifluvium is a part of these moraines and despite somewhat divergent placing rather belongs to the first type above. If the drumlin formation had continued, it would presumably have been covered by typical basal till.

The more debris is included in the ice, the more difficult is its flow and accumulation often occurs (Russel 1895, Högbom 1905, Fairchild 1929, G. Lundqvist 1940, Gillberg 1964). Thus, much material — apparently the more the better but certainly also a continuous supply of it — seems to have been an essential factor for formation of drumlin moraines, or at least for their number and their dimensions (cf. Björnsson 1953).

The last two conditions seem in part to be indicated in the areas investigated. In nearly all drumlin districts, the ridges decrease in number and finally peter out in the direction of the ice movement (Figs. 8—11, 13, 14). If such moraines again appear more distally, this drumlin area is separated from the proximal one by a zone of varying breadth, and with only few ridges or none at all, e.g. Sommen contra Värend district. The paucity of moraines in these zones may be due to much material having been deposited proximally. Only after a distance in distal direction was the ice loaded enough for a new drumlin formation. Small quantities of debris may therefore be one cause of the absence of such ridges in some places. Moreover the fact that these moraines in groups are normally of different dimensions — major and minor ridges — may depend on the amount and supply of material and of different concentrations thereof. It is impossible to decide from the actual characteristics, however, whether or not the type of drumlin moraines, as well as the shape of their sides and crests, are also due to these factors.

Of course, much material is a relative definition. In some areas, generally distributed, sometimes thick basal till is found but few or no drumlin ridges (cf. Gravenor 1953); in other districts the proportion between material and number and dimensions of these forms is rather the opposite (cf. J. Lundqvist 1970). Thus, other factors than the amount and continuous supply of debris must have governed whether a drumlin formation started or not. One of them has already been discussed — the topography as a whole and all different kind of obstacles.

Summary

The following characteristics of the drumlin moraines seem to of greatest importance for an explanation of their formation.

Mostly topographically controlled in position — either on plateaux or both there and on plains usually connected to small obstacles, i.e. mostly located where the gradient of the ground changes; seldom situated in lowest parts of deep valleys; more often proximally placed or of proximal type (e.g. precrags) in ascending terrain, more usually distally placed or of distal type (e.g. postcrags) in descending terrain; usually lying together, in succession or parallel to each other and often in groups; in the former position normally displaced to the side of each other; in groups often one or two ridges greater than the others.

Often with great variations in shape — irregularities especially found on crag moraines and on small ridges of all types, and more usually distally and on the long sides; original, proximal form often gradually ascending, greater steepness there possibly due to real erosion; levelling a normal process which proceeded in distal direction; sometimes a fusion of ridges in succession or parallel to each other; enlargement probably in sequence of length, height and breadth; small ridges can have an ideal form.

Concentrations of basal drift — of whichever grain size composition and usually of the same type as the similar till around; if different from the latter, here always coarser; in principle of local origin, often noticeably (in small ridges and distally of heights); boulder orientation with the long axes of the ridges but superficially with some differences proximally and distally; a more divergent placing in this only found in a small bottom ridge; meltwater material locally exists in different position to the drumlin till.

Till accumulation and drumlin formation

The drumlin moraines are radial ridges subglacially formed. Thus they represent one expression of the activity of the moving bottom ice. The course of the latter is therefore of importance for the understanding of the drumlin process. But naturally, the drumlin ridges may in turn provide information on the ice activity in general (Aario 1976).

Major topography

The fact that the drumlin moraines extend in the direction of the ice movement, and occur in radial succession, seems to indicate the existence of special accumulation zones (cf. Alden 1911, W. B. Wright 1912, Fairchild 1929, Ebers 1937). One explanation of that may be that the material has been irregularly incorporated and transported in the ice, which resulted in local concentrations of till. Yet such a material state could certainly have lasted for only a short distance. Lithological studies of till seems to indicate a comparatively rapid distribution to the sides of the newly gathered debris (G. Lundqvist 1935, 1940, 1951, J. Lundqvist 1952, Gillberg 1964, 1967, 1970). If till concentrations due to irregular material transport nevertheless appeared, they would have occurred soon after the incorporation of a specific material, i.e. this till must be of local origin. In fact this is often true, also in drumlin moraines (cf. p. 159).

Indications of real accumulation zones do seem to exist, however. My own studies of the till lithology in some areas show a division into zones of different ice activity (Gillberg 1964, 1967, 1970). A short summary of these investigations is thus called for. The distribution of varying rock debris by the ice was not only a result of differences in material resistence but was also dependent on the type of topography. It clearly varies in ascending and descending terrain. In the former the crushing process was slower (= flatter distribution lines of the gravel), while in the latter it occurred more rapidly (= steeper distribution lines of the gravel). Moreover, the actual rock debris was transported shorter a distance on ascents, the reverse being true on descents and plains; and this in principle concerns both the coarse and the fine material.

Taken together these facts seem to indicate: accumulation rather than transport in the former terrain, more incorporation and transport than accumulation in the latter. In a broken highland — irrespective of the mean gradient and without changed type of distribution lines — the great valleys show in principle the same development as do the descents and plains i.e. transport for the most part. As they differ in depth and breadth and their bottom can slope either upwards or downwards, they can vary in this connection, however. Except towards the summit, the great plateaux usually show the same evolution as do the ascents, i.e. accumulation as a rule. But as the actual indicator material in these studies often is far-traveled, many of them appear as lee areas, i.e. their basal till is mainly of local origin. Also small topographical differentiations seem to have resulted in the development of similar activity zones, although narrow (e.g. on Kinnekulle; Gillberg 1970) or less distinct (e.g. in Uppland; Gillberg 1967). It is evident, too, that the more complicated the terrain, i.e. the more broken it is with frequent changes in gradient (e.g. the South Swedish Highland), the more different the zones in number and breadth (Gillberg 1964 contra 1967). But the broad zones usually include both ascents and descents or valleys, although one type of topography predominates. This certainly indicates that each major zone may have been divided into various small zones, i.e. small transport zones in large accumulation zones and vice versa. This should apply to all areas. Nevertheless it is difficult to distinguish these differentiations as such discernment presupposes great regularity in the accumulation of the till and no disturbing effects (cf. p. 165).

The question now is whether these activity zones bear any relation to the placing of the drumlin moraines. In the Borås and Sommen districts, i.e. plateau landscape with large valleys, most of these ridges lie in ascending terrain (Figs. 8, 9) and mainly in the most obvious accumulation zones, while only a few are situated in or around the deep valleys, i.e. the typical transport zones (Gillberg 1964). On the other hand, some other accumulation zones have few of these moraines. On Kinnekulle all these ridges lie in the real accumulation zone, both on the ascent and descent from the peak and on the more level ground beside it (Gillberg 1970). In Närke they lie on a gently ascending plain with indistinct activity zones — on average a transport area — but not on the plateau S. of it with sharply defined zones (Gillberg 1967). On the Uppland plain, i.e. in principle an area of mostly transport but with some narrow accumulation zones established, there are hardly any typical drumlin ridges.

In the other drumlin districts where no distribution analyses have been made and different activity zones are unknown, these ridges tend to lie on descents (the Värend and Emmaboda areas) or on plains (the Falbygden and Falkenberg areas). Thus they appear in a topography which should be characterized by transport mostly but which can have been divided into zones of second order and of different types (cf. above). In all probability, the occurrence of such moraines there are indirect indications thereof.

From these and other facts the following concepts of the ice motion and the ice activity may be deduced. With increased quantity of material the bottom ice loses plasticity and its capacity to flow is diminished (Russel 1895, Högbom 1905, Fairchild 1929, G. Lundqvist 1940) — but the greater the obstruction the less the motion, too. As in other external processes, such a reduced motion would result in accumulation, due in principle to overload of material for the actual motion, or perhaps more correctly, overload in relation to the surrounding, more freely moving, ice (ice rich in debris contra ice poor in debris; cf. J. Lundqvist 1969). In other words this means that the variations in the ice physics, in the quantities of bottom material and in the bottom topography locally and finally combine in a suitable manner for deposition (cf. Boulton 1975). In that the ice motion per se, i.e. without an increased amount of debris, must have been slower on ascents and plateaux due to increased obstruction, accumulation is more likely on such terrain (cf. above and many drumlin ridges in such a landscape; cf. Fairchild 1929). Incorporation and transport of new material must have been activities of second order. Thus the accumulation was here topographically controlled in major. Locally it was also material controlled, as the quantity of debris must always have been a decisive factor for a reduction of the ice motion. On descents, plains, some plateau tops and in valleys, the obstruction has been smaller, so that the ice could move more easily. The predominating activities in such terrain would be transport and incorporation of new material. The latter process may sometimes have resulted in too high a concentration of debris, which may have caused a reduced ice motion and so accumulation. Consequently the latter activity was here largely controlled by the material and appeared less regularly than on ascents (cf. fewer drumlin ridges there and more irregularly placed). But this accumulation has certainly been more concentrated in places with greater obstruction, i.e. on the sides of surrounding slopes and on projecting obstacles (cf. existing drumlin ridges usually situated there). As regards position, accordingly, the accumulation in this terrain was controlled to some extent by the topography.

Thus, the accumulation of basal till resulted from an interaction between two main factors, the material — especially its quantity but perhaps locally the type of it — and the topography — especially its gradient but also the general shape. Or in other words: variations in the material transported by the ice, and in the ground under the ice, have caused radical changes in the ice motion, especially the basal flow, and so the ice activity has often changed (Fairchild 1929, Hill 1971; in principle also suggested by other geologists, e.g. Högbom 1905, G. Lundqvist 1940, Björnsson 1953, Vernon 1966, Smalley & Unwin 1968, J. Lundqvist 1969, 1970, Hillefors 1974).

However, irrespective of the cause of the start of deposition, its continuation must finally have resulted in so decreased a quantity of material that the process came to an end. Sooner or later it could have been replaced by incorporation of new debris and a transport thereof. This in its turn may, after a distance, have caused new accumulation. In the direction of the ice movement, accordingly, the ice activity may have occurred in repeated succession of incorporation — transport — accumulation but certainly with no distinct limits in between (cf. Russel 1895). This may have been the case in all kinds of terrain, and that irrespective of an origination of different activity zones transversely to it (cf. p. 164). (This does not mean a motion in longitudinal waves, however — as discussed by Flückiger 1934 and von Engeln 1938 — but it must, in main, have been dependent on variations in topography and material supply). A small indication of such repeated conditions may be that both proximally and distally of great drumlin areas such ridges are nearly always few or lacking (Figs. 8—10). This fact is partly evident also inside such an area, i.e. sequences of few-many-few drumlin ridges often occur in the direction of the ice movement (Figs. 8—11, 13, 14). Both these features are typical in many other drumlin regions, even if this is seldom pointed out (cf. Fairchild 1929).

Proofs of such a strict evolution are few, certainly because the conditions for it were seldom sufficiently uniform. Normally, instead, several factors may have appeared which caused wide variations — now visible in an irregular till distribution, for instance. The following seem to be the most probable. (*A*) In many areas, e.g. the South Swedish Highland, the topography varies so rapidly that the flow and activity of the ice may have changed from place to place. There its minor features must have been more decisive for the glacial development (cf. p. 166). (*B*) The accumulation has also been dependent on the quantity of material in the ice. If for any reason the latter has been small, the former process may have not occurred, even where it should have appeared. (*C*) The accumulation may have started before the ice was overloaded but also continued after the quantity of debris in the ice was greatly reduced. It may have been accelerated by the presence of a great amount of fine material and/or by a soggy state of the bottom debris, i.e. easier adhesion to to the material deposited and probably frozen. (*D*) If any other of the factors which determine the ice motion has changed — which may have occurred even at the same locality during the same glaciation (Gillberg 1964) — a place or an area which was first characterized by predominating accumulation, may later become for the most part a place or an area of incorporation. Thus, material accumulated may have been again picked up and redeposited distally (cf. Russel 1895). Such a process was probably more usual in ascending terrain, where slight topographical differentiations may, because of the slow motion, have caused repeated variations in the ice activity, or in transition zones between large plateaux and large depressions, where the bottom ice motion may have often changed, being determined either by the former or the latter topography (Gillberg 1964, 1970).

This discussion has given only a few facts for understanding drumlin initiation and formation. Their occurrence in all grand topography is explained, as in spite of the type of the latter, zones of different ice activity apparently have existed. In reality the drumlin placings tend to verify the previous studies of the till distribution (Gillberg 1964, 1967, 1970), i.e. the very existence of great zones dominated by different ice activity. But to some extent it indirectly indicates a further division into such zones, especially in areas (descents and plains) where the lithological studies have shown indistinct ice activities, or where no studies have been made and nothing is known about these conditions.

The occurrence of accumulation and transport zones during the fabric time of basal till may possibly explain another fact, which is really irrelevant to this paper. The divergences in the appearance of ablation till and the forms it takes may ultimately depend on these conditions. Or in other words: in the primary accumulation zones most of the material in the ice must have been deposited during the "glacial" phase, i.e. little of it has remained for an accumulation during the "deglacial" phase; in the transport zones the conditions were reversed. Therefore the ablation till and many forms of it (e.g. end moraines and hummocky moraines) mostly lie on descents, more even plains and in valleys, less often on ascents and plateaux (cf. G. Lundqvist 1940, 1951, Knutsson 1971). Yet there are always exceptions in both types of topography, i.e. where activity zones of second order have developed during the "glacial" phase.

Minor topography

Both in more or in less obstructed terrain, i.e. ascents and plateaux contra descents and plains (valleys), the drumlin moraines are mainly connected with rocks and heights of different extent (Figs. 3—7, 21, 22; cf. p. 141). In all probability this minor topography was most decisive for the formation of such ridges, certainly also for their placing in succession and parallel to each other (cf. Högbom 1905, Björnsson 1953, Gillberg 1955, Vernon 1966, Hill 1971, Knutsson 1971, Johansson 1972, Glückert 1973, Minell 1973, Hillefors 1974). Thus, there have been the convexities of the ground which have been most important in this connection (J. Lundqvist 1969a, 1970).

All obstacles must have caused changes in the physics of the ice (cf. theories thereof, e.g. Nye 1952, 1959, Weertman 1964, Lliboutry 1968). They must have functioned as barriers which the bottom ice must overcome by going either over or around them as best it could (Schäfer 1933). The shape and dimensions of these obstacles must have been of great importance thereby (Glückert 1973). Their steepness may also have been a decisive factor, not only per se but also in relation to the surrounding ground, i.e. the size of the angles between the latter and the obstacles. The different conditions in these very transition zones, i.e. in the concavities to the convex ground, may ultimately have determined the form taken by the glacial activity. (The temperature gradient must be greater over the convexities; and as the melting of bottom ice must be smaller thereby, also the deposition of debris must be smaller there; thus the reverse being true over the concavities; Nobles & Weertman 1971). As the evolution must always have been dependent on the ice and on variations therein, even at a distance (cf. theories cit. above), the course of events at one obstacle may differ from another, despite similarity in location and shape — or sometimes due to differences in these features (cf. Lliboutry 1968).

At small rock hills or at rock hills with small to moderate angle to the surrounding ground (maximum height and breadth cannot be defined but large plateaux are not included), the obstruction may have been so slight that the ice could overcome most of it without accumulation (Schäfer 1933). Such an evolution may be one cause of the absence of drumlin ridges. The same is also true of middle and upper parts of plateaux, especially if accumulation has occurred on their lower, proximal slopes (cf. the number of such moraines always decreases towards the tops). In three parts of the barriers (three concavities), the conditions may have greatly diverged, however. In the proximal angle to the background, the ice motion would be reduced because of increased gradient of the substratum (= increased friction, pressure and counter-pressure), distally of the crest have increased due to reverse conditions, and in the most distal angle of the rock have been somewhat reduced again as a result of normally increased gradient of the following ground. The two latter places may often have lain near other or even have coincided, however.

In the first, locally also in the third, place, the ice must have been in upwards, compressive motion (Nye 1952, Hillefors 1974); and it may have been so obstructed that accumulation resulted by pressure melting (Vernon 1966, Boulton 1970, 1971, Hillefors 1974). This was certainly more probable in the proximal concavity, as the obstruction would be more abrupt there. Nevertheless it can have not appeared, if the ice contained small quantities of debris. Consequently an accumulation in the most distal angle must sometimes have been dependent on what happened proximally, i.e. if deposition occurred in the latter place, it was less probable in the former, or vice versa. Of course, it may have appeared on both sides, especially at small and low rocks (= small obstruction, sufficient material for a double accumulation). In the second place, i.e. immediately behind the obstacle, all the conditions may have been divergent but sometimes resulted in accumulation. Friction and pressure have decreased, and the ice moved more freely downwards and merged into extensive flow (Nye 1952, Vernon 1966, Hillefors 1974). If the obstacle slopes continuously from the top, presumably no accumulation has occurred. But if it has been more or less concave, this can have led to an origination of a basal cavity in the ice in which material slumped from the rock crest or the glacial sole and/or sometimes squeezed from the sides (Hoppe 1951, Dahl 1967, Boulton 1970, 1971, Johansson 1972, Hillefors 1974).

Indeed, another factor may have determined this initial development. As the ice activity in general has been different on ascents and descents or plains (cf. p. 164), it may have resulted in the beginning of accumulation on different sides at separate obstacles. In the South Swedish Highland, such a relation does seem to exist, i.e. more pre-crags and proximally upward-sloping drumlins and drumlinoids in ascending terrain (the Borås and Sommen areas), more postcrags and distally downward-sloping drumlins and drumlinoids in descending terrain (the Värend and Emmaboda areas; Figs. 8—10, Tables 1—3). In the former districts, the ice motion has in itself been so obstructed that the barriers have often immediately forced an accumulation; in the latter areas the ice has tended to move more freely, i.e. it has often been able to partly overcome the obstacles so that the accumulation has been more distally concentrated.

This initial deposition might have continued until the filling debris has formed a sloping surface of least resistance to the ice motion, proximally towards and/or distally from the obstacles. While a complete covering of the latter with till has not proved necessary thereby, they may have projected without preventing the passage of the ice. After this filling, the accumulation may have ceased, as the obstruction to the ice motion has mostly been neutralized, i.e. no more material was needed, or would have even increased the resistance again.

Such more or less completed till concentrations towards and away from rocks and rock hills normally have an undifferentiated shape (Boulton 1970, 1971, Hillefors 1974). Nevertheless they are an independent type of moraine both as to their origin and as to their position — stoss- and lee-side moraines. But some of them are elongated, i.e. show the beginnings of ridge-form. This surely indicates that these, but probably many others, are or could be embryos of real drumlin moraines. Another fact which perhaps suggests this theory is that such stoss- and lee-side moraines are fewer where real drumlin ridges occur in great numbers, and they are more frequent, where the latter are few (cf. p. 130). The latter districts are often characterized by less distinctive topography (e.g. more even parts of the South Swedish Highland), i.e. areas where typical accumulation and transport zones were probably less developed during the fabric time of basal till.

In many places, accordingly, the till accumulation at different obstacles seems to have continued, despite the fact that it was not essential for an easier passage of the ice. The consistent question is why did this occur and why has real ridge-form of these deposits developed. This is the second problem of the drumlin formation.

First of all, the ice must, more or less constantly, have been loaded or overloaded with debris, so that the conditions were for a long time favourable for deposition. Furthermore, the initial filling material ought rapidly to have acquired a gradient of least resistance to the ice motion (cf. above). Owing to these facts, erosion has been, if not totally prevented, at least reduced to a minimum (= levelling). For if this activity was intermittently in progress or predominated, a continuous lodgement of till may have been difficult if not impossible. Perhaps this occurred locally and material deposited, even as small drumlin ridges, has been carried away (= another cause of the absence of such moraines?).

One factor which can have controlled the evolution into ridges may have been the shape, and especially the dimensions, of the obstructing rocks and rock hills (Glückert 1973). A greater height of the latter would have involved an increased height of the deposits — to reach the most favourable transcending angle — but also an increased length of them — to preserve a surface suitable for passage of the ice. A broadening of them to the sides of the obstacles may not have been necessary, as it would hardly make the overgliding motion easier. But an accumulation concentrated mainly to length-height or height-length may soon have resulted in the origination of a pre-hill or a pre-ridge. Indeed, this would have intensified the contrasts in motion there and on the surrounding ground, especially if it was lower-lying. In other words this means that a formation of a pre-ridge can have favoured or even have involved the origination of local zones of different ice motion and so different ice activity, i.e. at each obstacle one zone with slower and more obstructed motion, and so mostly deposition, and on each side of it one zone of more unobstructed and rapid motion and so mainly transport (cf. Shaw 1975, Shaw & Freschauf 1973, Aario 1976; cf. Fig. 33). As a result, such pre-ridges may not only have been preserved but may have developed into crag moraines and/or complete drumlin moraines by a continued accumulation. Such an evolution should, on the whole, have been the easier the more rapid the formation of pre-ridges.

A dividing into differential zones during the drumlin process has earlier been suggested by Ebers (1931). Also Armstrong & Tipper (1948) and Gravenor & Meneley (1958) have discussed a similar development (cf. Kupsch 1955) but they supposed that the transport zones have rather been erosion zones and were most decisive for the ridge formation. Any clear signs of erosion beside the drumlin moraines have not been found in the areas studied, however; the process of deposition seems in all places to have been the dominant activity in this connection (as suggested by most drumlin geologists).

On the other hand, Shaw (1975) and Aario (1976) have discussed an evolution in part similar to mine (cf. Shaw & Freschaf 1973). If secondary flow in spirals towards the ridges which both these authors propose, really can have occurred in the ice must still be an open question, but such a flow (including accumulation) could perhaps more rapidly and more easily than another type have resulted in an enlargement of typical drumlin moraines. Whichever kind of motion existed, however, initial pre-ridges seem, in my opinion, to have been a necessary condition for the final drumlin formation.

A fact which may partly indicate such a development discussed, is that comparatively many drumlin moraines are long, narrow and low (Tables 1—6; cf. p. 152). In principle, they can be pre-ridges which have not enlarged in height and breadth, either because accumulation ceased, or there was no time for a continuation of it, or too little material was available. As the ice was still moving, however, they have usually been levelled and tend to have "typical" drumlin form. There are also ridges which are irregularly shaped, more often distally than proximally, most usually on the long sides but even overall (cf. p. 144). Many of them, particularly if they are of small dimensions, may be pre-drumlins which have neither enlarged nor been more than partially levelled if at all. Moreover, other radial ridges occur which because of their irregular shape and also divergent material composition have not been classified as drumlin moraines (not marked on the maps, but some mentioned in the next). At least some of these could be such pre-ridges (cf. p. 174).

Another fact which may be in accordance with a formation of different activity zones is that differences in pressure of the ice must have rapidly developed between zones of different motion etc. From many reasons, those of the latter which had a lower and more horizontal pressure, would have become the places of deposition (Alden 1911, Fairchild 1929, Slater 1929, Gillberg 1955, Gravenor & Meneley 1958, J. Lundqvist 1970, Evenson 1971, Glückert 1971); and the longer the time of preservation of these conditions the more favourable for a formation of full ridges. Differences in pressure may have developed, however, not only in the direction of the main ice flow but also between the proximal and distal parts of the obstacles (Vernon 1966, Evenson 1971, Hillefors 1974).

Accordingly, a prolongation of the deposits would have gone more smoothly distally, as the ice motion was freer there and as these sides had lower ice pressure both in relation to the proximal parts and to the transport zones beside, i.e. a supply of material could there have occurred both over the obstacles and from the transport zones (cf. Gravenor & Meneley 1958). An increase in height would be more common proximally because of accumulation towards a barrier by ice moving upwards and a supply of material only from the background. Provided that no disturbing factors appeared, this would have led to ridges with ideal drumlin form (Vernon 1966), and the postcrags would be longer and more frequent than the precrags. Furthermore, somewhat greater divergences in the boulder orientation distally (more obliquely) may not be surprising, as the material there may partly have come from the transport zones beside (cf. p. 161).

Many of the drumlin moraines have other shapes, and in many cases the length was the first dimension to be completed (cf. p. 154). The former characteristics may be explained by changes in ice activity resulting from differences in the gradient of the terrain or in the type of grand topography (cf. p. 146), or by the placing of the foundation rocks, often in relation to other obstacles (cf. p. 146), or by differences in material supply (cf. above). The occurrence of transport zones beside the real accumulation zones may explain why the ridges widened at a comparatively late stage. Furthermore, by reason of their isolation, the long sides of them have been more irregular or more levelled, or parallel moraines have formed. Both the dimensions and the shape of the drumlin ridges may also be explained by only changes in direction and continuation of the ice motion, i.e. without influence of other inconvenient conditions; if undisturbed = greater and more elongated moraines, if disturbed = smaller and more irregular moraines (W. B. Wright 1912, Vernon 1966).

Another feature is also explicable by such a division into activity zones, namely why succeeding ridges are displaced in relation to each other. The formation of a zone of concentrated accumulation often resulted in a lack of debris in straight rows of it (instead, a new transport zone developed?). But distally (and/or proximally?) of the original transport zone(s) a new accumulation zone would have been possible (the best example is "Stenåsen" on Kinnekulle; Gillberg 1970). Thus, in spite of the location of the separate moraines, there was probably a slight difference in time of formation of the different ridges. But which moraine has become largest can hardly have depend on this factor but on the topographical conditions and the material supply, both at the actual place and immediately proximally thereof. From all these facts it appears that the different activity zones may have had an obvious influence on each other, even on the origination of new ones, i.e. the appearance of only one such zone (of accumulation or of transport) may have resulted in another (or other) of reverse type etc. — and so finally a whole drumlin field.

The great crag ridges and drumlinoids, sometimes two or more together, all of which lie in connection with or on the slopes of large plateaux, may partly have started their development in another manner. This may apply even if many of them were founded on minor obstacles.

If the obstructing barriers were too large and/or formed too great proximal angles to the background, and/or the ice motion has for any reason been too much reduced there, the proximal bottom ice could not pass over them directly. Instead, it has probably been more or less attracted to the less impeded ice motion on the sides of these obstacles, i.e. diverging bottom ice "streams" have developed (shown by variations in till lithology; Gillberg 1964, 1967, 1970). On moderately broad heights, all proximal ice may have moved sideways. Sometimes, however, part of it may have remained as proximal lee ice between the barrier and the diverting ice, perhaps throughout the glaciation, and almost or totally motionless (Ahlmann 1938, G. Lundqvist 1940, Gillberg 1964). And the broader and the steeper the plateaux, the more often such lee ices may have developed and may have functioned as bottom-filling "material" for the over-gliding ice. Changes in the direction of the ice movement may locally have carried them away, and they need not always have formed again. But they may also have melted out in situ (by pressure melting by the over-gliding ice?) and left its debris in place, locally in form of small pre-hills (Boulton 1970, 1971).

Distally of a large height, the lateral bottom ice "streams", being unobstructed because of the cessation of counter-pressure and partly friction of the barrier, may have converged inwards (also confirmed by the till lithology; Gillberg 1964, 1967, 1970). Indeed, the occurrence and the rapidity of this event must have been dependent on the extent and shape of the obstacles, but also on the configuration of the surrounding terrain. If this converging motion has started already on the long sides of the heights, the bottom ice may have joined immediately at the distal side of the latter. But the more distally this have appeared, the greater has been the chance of an origination of distal lee ice, probably greater than proximally as a stationary barrier existed against the moving ice (Ahlmann 1938, G. Lundqvist 1940, Gillberg 1964). As a result, such lee ices may have been more constantly left behind. On the other hand, they may partially, intermittently and/or completely have been caught up in the motion of the over-gliding ice (Gillberg 1970). Any formation of distal deposits from them can hardly have occurred, as they may have contained little debris originally.

Both proximal and distal lee ices may have developed locally before the growing up of an ice cap, namely from advanced outposts of snow-firn in the lee of steep plateaux. But whenever they formed, their existence may in many places have prevented an accumulation during the fabric time of basal till, i.e. be another cause of the absence of drumlin ridges (Hillefors 1974).

When such diverging and/or converging bottom ice "streams" have appeared, great contrasts in pressure and motion must have existed along one or more transition zones, between the mainly unimpeded ice on the sides of the plateaux and the more or less obstructed, slower moving or motionless ice in their lee. They would be most pronounced where the gradient of the ground has changed, near projecting rocks and at the corners of the barriers, where the friction and counter-pressure on the ice arose comparatively abruptly (proximally) or more or less ceased (distally; Gillberg 1970).

In these very transition zones, the conditions for accumulation (sometimes from stagnant ice, cf. above) would have been highly favourable. And more than in the former case, this process may have continued more smoothly, as the material deposited would have preserved, or even increased, the contrasts in motion etc. inwards and outwards. Thus, even if the start of this evolution seems to have been somewhat different from that of the former alternative, the enlargement of the original debris may have occurred for the same reasons and in the same way as at small rocks, i.e. local accumulation zones developed. Indeed, it may have led more easily to origination of preridges or real ridges as these zones would primarily be more or less elongated.

Owing to all these conditions, the large crag moraines and drumlinoids which may have enlarged in this way, are usually higher and longer than those at small obstacles. Furthermore, they occur as often distally as proximally, certainly because sufficient quantities of material for accumulation in the former position may have been added by erosion of the plateaux (Gillberg 1970). Another feature, different from those of small moraines, is that the proximal ridges usually are more elongated. The reason for this is probably that the prolongation of the original deposits resulted in more proximally diverging ice motion, i.e. the ice from the background was at a much earlier stage — or continuously earlier — involved in the unobstructed motion to the sides. Erosion of the proximal slopes of these ridges has therefore seldom occurred but a sharpening of their outer parts has sometimes appeared (Gillberg 1970).

The evolution of these ridges has certainly been somewhat different due to the breadth of the barriers, too, i.e. dependent on how many accumulation zones were present. Naturally, one zone led to one unifom, proximal and/or distal moraine. Indeed, even if two accumulation zones have formed, a filling between them (thus, no lee ice) can have given the same result in places. But especially on broad plateaux, two or more deposition zones can have developed individually into two or more, separate moraines. In these cases, lee ices may have played a decisive role locally, either because they originally existed and so contributed to the formation of more than one accumulation zone, or if they have developed later between the incipient ridges, because they prevented a fusion of them.

Drumlins without rock cores

However, there are drumlins without rock foundations; in the areas studied certainly many of the small ones in the Närke, Kinnekulle and Falbygden districts (Sahlström 1910, Munthe et al. 1928, Gillberg 1970, Fromm 1972). According to some geologists, cores or sheets of till, even boulders, could have functioned as initial obstacles around which the continued lodgement has taken place (Högbom 1905, Fairchild 1929, Slater 1929, Armstrong & Tipper 1948, Gravenor 1953, Reed et al. 1962, Vernon 1966, Hill 1971). Yet if this formation is valid, they may have been deposited soon after their incorporation in the ice as material in such a state could scarcely have been coherent for a particularly long distance. As a rule therefore, these till nuclei may have had a comparatively coarse composition, or even contained many boulders. Deposits from a previous glaciation or deglaciation may also have functioned as initial obstacles for recent drumlin moraines, especially if they were in the form of ridges, e.g. in the Värend area (Table 3; cf. p. 161). Drumlins of this type have been found in other regions, too (e.g. Hill 1971, Hillefors 1974a). Indeed, it may be possible that also some (many?) of the largest ridges in the areas studied are built up in this manner.

In spite of this kind of foundations, the continued evolution may have proceeded in the same way as discussed above, i.e. different activity zones have developed, and drumlin formation occurred in some of them.

Bottom cavities in the ice

In many localities where the bottom ice has changed motion, often rapidly, changes in its other properties may have occurred due to great contrasts in surrounding terrain. This may in some cases have resulted in a breaking up of (temporary) bottom cavities (Hoppe 1952). Indeed, as the forwards motion still continued, a "collapse" of ice inwards and downwards would soon occur. But if the cavities were open for a longer time, differences in pressure and temperature gradient may have developed in and around them (cf. p. 166) so that deposition inwards began by slumping and squeezing — soon becoming pre-hills or preridges. At different obstacles, this process may have been more rapid, if the over-gliding ice was in pressure melting because of increased obstruction (proximally), less rapid, i.e. the cavities open for a longer time, if the over-gliding ice moved towards a zone of less obstruction (distally). In the former case, the possible pre-hills or pre-ridges should become smaller or not at all appear; in the latter be more distinct. However that may be, then the evolution presumably continued as discussed above, i.e. different activity zones developed at and around these projecting deposits (despite the cavities were still open or closed) and real drumlin moraines formed by a successive addition of material (cf. Gravenor & Meneley 1958).

Tensions or other changed physics of the ice which may have caused bottom cavities, would have easiest appeared where diverging and/or converging ice motion has occurred, i.e. proximally and distally of large plateaux (Gillberg 1970). Projecting obstacles (rocks, till sheets, even large boulders) may also have favoured such a process, as the existing concavities towards and from them may have directly become bottom cavities in the ice (cf. Hoppe 1951, Boulton 1971, Hillefors 1974). Since in principle the ice motion differed in different terrain (cf. p. 164), these events may have been more usual proximally in ascending topography but distally in descending terrain. Indeed, they may also have appeared solely as a result of changes in the gradient of the ground, or of the presence of great topographical differentiations (e.g. in transition zones between a valley or plain and a large plateaux; Gillberg 1970) — or even of overload of material, especially of coarse composition. In places, accordingly, drumlin ridges may occur which have no foundations at all.

Great differences in terrain may indicate, that specific types of grand topography would have been more predisposed than other for a formation of bottom cavities, and so possibly of drumlin moraines. This is feasible: (*a*) in broken terrain with wide variations in position and extent of plateaux and valleys (e.g. the South Swedish Highland), (*b*) where an enclosed terrain widens, i.e. valleys open out or a broken highland merges into a plain (e.g. in Halland) or becomes more uniform (e.g. the Värend area), (*c*) where a more open and uniform terrain becomes enclosed or more broken up (e.g. N. parts of the Borås and Sommen areas) or a plain is distally blockaded by plateaux (e.g. in Närke). In all these cases, a definite ice quantity has first moved in a defined milieu, and then in another of quite different type and extent. Indeed, these very changes in topography could have led to great modifications in ice motion etc. All these types of terrain have a great number om drumlin moraines.

But where the ice has moved in comparatively similar milieu, the conditions for tensions — and bottom cavities — were presumably limited or non-existent, e.g. on great plains without surrounding plateau landscape (e.g. Uppland, partly Södermanland), on the top surfaces of high plateaux (throughout the South Swedish Highland) or in large valleys. In the last milieu in particular, the ice was definitely delimited under high vertical pressure, i.e. it cannot have spread out to the sides and its motion was more or less unchanged. In all these terrain, especially the large valleys, the drumlin moraines are few or absent. Of course, the occurrence of minor topographical irregularities and/or local overload of material in the ice may have resulted in the appearance of isolated cavities and so drumlin ridges in such terrain as well.

Where the conditions for an origination of bottom cavities were favourable, the chance of them being numerous may have been great. In many cases, the primary cause was surely the occurrence of many obstacles of all kinds. But it can have been an after-consequence, even twice over, i.e. the breaking up of one cavity has led to new tensions round about so that new cavities resulted there, perhaps especially if a pre-ridge rapidly formed in the first place. In principle the whole of this evolution may have appeared fortuitously. The recent drumlin moraines should therefore be located anywhere. In fact they sometimes are, but as a rule they lie in succession, displaced and/or parallel to each other or i groups (Figs. 8—11, 13, 14). Indeed, this fact may be partly explained by the consistent formation of new cavities, discussed above.

As regards a drumlin formation in this manner, a crucial question is natural, if the existence of bottom cavities is a real fact or not. Indeed, this seems to be the case; such hollows (often filled with water) have been observed in recent glaciers, usually in comparatively thin ice — 30—40 m (Haefeli & Brentani 1955, Fischer 1963, Kamb & LaChapelle 1964, Theakstone 1966, Peterson & McKenzie 1968, Drake & Ford 1970) but in all probability also at a depth of more than 200 m (Savage & Paterson 1963). In any case, an origination of bottom cavities and a beginning filling of them with debris might, easier than other manners of drumlin initiation, have led to a formation of pre-hills or pre-ridges; and so also different activity zones would easily have developed.

Summary

Thus, three modes of initiation of the drumlin formation have been discussed: (*A*) accumulation by pressure melting proximally of obstacles, and accumulation by slumpig and squeezing distally of them; in both cases especially in concavities of terrain, (*B*) accumulation from stagnant ice, melting out at different obstacles (particularly large ones); most probably proximally of them, (*C*) accumulation in basal cavities (slumping and squeezing), originated proximally and/or distally of obstacles, or only due to differential ice flow because of other topographical differentiations, possibly also due to differences in amount of material.

In the two former cases, the deposits may have been completed without ridge-form, i.e. stoss- and lee-side moraines, but pre-hills or pre-ridges were often formed; furthermore, foundations of any kind (rocks, plateaux, till sheets, previous glacial material or forms) may, in principle, have been necessary for such accumulations. In the third case, pre-hills or pre-ridges may always have developed; foundations certainly favoured this process but may not always have been necessary.

Stoss- and lee-side moraines are described, the position, shape and material composition of which conform to evolution A (Hillefors 1974). But above all, such forms are observed at recent glaciers, to some extent during formation (Boulton 1970, 1971). The last fact also partly applies to B above (Boulton 1970, 1971). There are direct and indirect proofs of evolution C, as fluted moraines, both those which have melted out and those found under the glaciers seem to be founded in this manner — although several possibilities of their exact development are discussed (de Quervain & Schnitter 1920, Dyson 1952, Hoppe & Schytt 1953, Gravenor & Meneley 1958, Schytt 1959, Baranowski 1970, Boulton 1971, Shaw & Freschauf 1973, Shaw 1975). Many facts therefore point to an including of the latter elements as a special type in the drumlin compex (cf. p. 174) — perhaps together with a form called "drumlinized ground" (cf. Fairchild 1929). In reality these two types of ridges could be similar in most features.

The question naturally arises whether any of the drumlin characteristics more or less indicate the type of initiation. As regards the position in the terrain, the location of the recent drumlin ridges can satisfactorily be explained by all three processes. The only exception is possible when many such moraines occur together proximally and/or distally of a large plateau (e.g. on Kinnekulle) or in a small, topographically uniform area (e.g. the Närke plain). Their existence may be more in accordance with evolution C than A and B.

As regards the material composition, only the bottom parts of the drumlin ridges may give evidence of the initiation. The remaining material, i.e. most of it in the recent ridges, presumably indicates little of this process but mostly of the more or less continuous supply of new debris and special features thereof. The last evolution may have pursued its own course, irrespective of the type of initiation. Unfortunately, however, the bottom material of the drumlin moraines are seldom available for a detailed study — in the areas studied only in some few ridges (cf. p. 158) — but nevertheless it is to be discussed. One exception is, when it in some large ridges is built up of debris from previous glacial phases (Hill 1971, Hillefors 1974a). In these cases, the question is only why and how the continued evolution to streamlined moraines has occurred, i.e. the second phase of the drumlin formation.

In all the three modes of iniation, the bottom material may certainly be debris incorporated in the ice comparatively near the actual places. Irrespective of how the former processes began, they may have diverged from the normal basal activity in that they were both sudden and swift. Yet material just picked up may have originated from previous glacial or interglacial/interstadial debris (Dahl 1967), or from till (and meltwater sediments) deposited by the actual ice but again incorporated by it (redeposition), or from the bedrock. This bottom material may therefore vary widely, especially granulometrically.

According to some geologists, who have studied stoss- and lee-side moraines previously and recently formed (Boulton 1970, 1971, Hillefors 1974), the material proximally deposited by pressure melting seems mostly to be typical basal till, often with foliation and a boulder orientation which follows the direction of ice flow comparatively strictly; the distal material may be less regular in all features and also contain meltwater debris, possibly partly carried over from the proximal side (Möller 1960, Hillefors 1974). In fluted moraines apparently only till is present most often of medium-sized to fine composition, but sometimes with a certain separation granulometrically — somewhat coarser towards the bottom (Hoppe & Schytt 1953); if an enlargement of them continued in the same manner (basal cavities), meltwater material may also be found (Hoppe 1951). If the initiation debris was till sheets or till nuclei, it would be coarse or very coarse (p. 170).

Accordingly, the composition of the bottom material does not appear to give any decisive information of the initiation of the drumlin ridges; nor does it seem possible that the type per se has determined the type of the beginning formation. On the other hand, variations in the material composition could have been of importance for the following enlargement to real ridges (Fairchild 1929, Granlund 1943, Smalley & Unwin 1968, J. Lundqvist 1969), even if no features seem to indicate this in the areas studied. The critical factor may always have been the amount of debris, often in relation to that in the surrounding terrain. One fact seems to be probable, however. The material deposited ought rapidly to have been frozen — but possibly still semi-plastic, i.e. in part formable by the over-gliding ice (cf. Mac Clintock & Dreimanis 1964, Evenson 1971, Boulton et al. 1974); intermittently it may have partly melted, and frost processes may sometimes have appeared and locally been of importance in that they contributed to a formation of pre-hills or pre-ridges (cf. Baranowski 1969, 1970). The glacial sole and its debris might have been in a soggy state, even water-saturated, at least during the accumulation (Nobles & Weertman 1971). Indeed, these two conditions, i.e. the material deposited being frozen but in part "plastic" and the material in deposition being soggy ("viscous") ought to have continued during the following evolution — to preserve and enlarge the ridges in formation (in any way probable characteristics of fluted moraines; Hoppe & Schytt 1953, Baranowski 1970). Rapid injections of frozen till could have occurred in places, however, especially in cavities or zones of low pressure (Evenson 1971).

As regards the superficial features, they can hardly show anything of the initial process(es). They only give evidence of the different course of the enlargement of the ridges and of the state of equilibrium between accumulation and levelling (cf. p. 154). The only possible exceptions may be the low, narrow and plane ridges. These features could perhaps indicate a formation in basal cavities, as they are typical characteristics of fluted moraines.

Probably all three types of initiation of the drumlin formation occurred, perhaps in some cases in combination, especially A and C, possibly B and C, less often A and B. Yet one problem still remains, i.e. how the second phase appeared — the enlargement to typical drumlin moraines. As regards the first part of it, i.e. the enlargement, all features which could indicate it — at least in the areas studied — seem to establish a successive, but intermittently rapid, addition of debris (if not always in form of plastering-on; cf. above). As regards the second question, i.e. a ridge formation, the theory here presented could be a possible explanation: after different kinds of initial accumulation, pre-hills or pre-ridges have sometimes formed; so great contrasts in basal motion and activity of the ice were not only realized but also gradually increased at and around these elements; different activity zones have thus developed — accumulation zones at the pre-ridges, transport zones around them (Fig. 33).

The drumlin moraines have belonged to the zones of decrased ice motion, decreased pressure and decreased erosion; and as long as they have preserved a suitable transcending ground for the ice, they have been forms of least resistance to it (Högbom 1905, Alden 1911, Fairchild 1929, Schäfer 1933, Björnsson 1953, Gillberg 1955, 1970, Vernon 1966). Their formation has always been due to an interaction between different conditions in the topography, the material and the ice (Högbom 1905, Fairchild 1929, Björnsson 1953, Gillberg 1955, Aronow 1959, Reed et al. 1962, Glückert 1971, 1973). As for the till distribution in general these three factors must be complex, i.e. each one is divided into factors of second order, certainly of different importance in different places and during different time (Gillberg 1964). If one, two or more of them have have not been partially or totally fulfilled, the drumlin formation has, in any way, changed its character, or been less important, or even not at all appeared (cf. Glückert 1973). Indeed, much of this process is still not exactly determinable; thus, it is impossible to express it with a simple formula, scarcely even with a diagram.

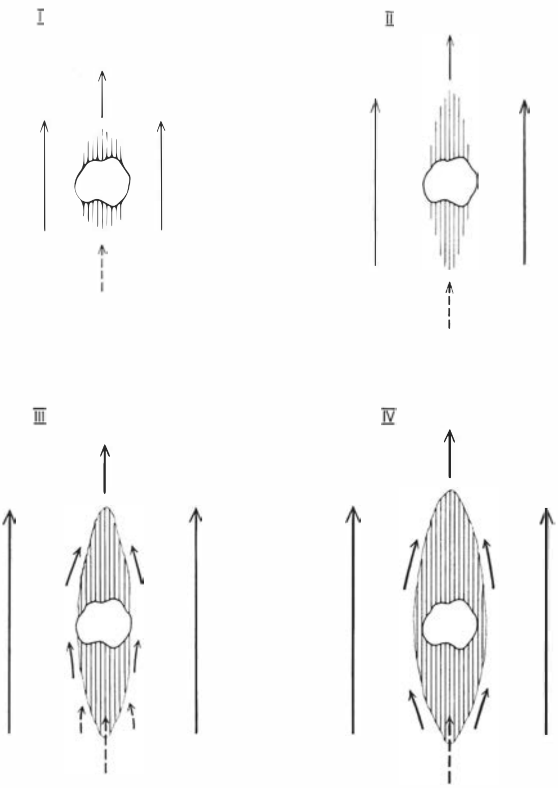


Fig. 33. Principal sketch showing the possible drumlin formation discussed in detail in the text. Arrows with continuous lines = predominant unobstructed ice motion and higher vertical pressure; arrows with dashed lines = predominant obstructed ice motion and lower vertical pressure. (I) undifferentiated stoss- and/or lee-side moraines developed at small rocks; only small differentiations in ice motion etc. (II) pre-ridge formed, proximally and/or distally of an obstacle or totaly without any obstacle; locally the length already completed; beginning contrasts in ice motion etc. on and beside the pre-ridge = beginning of different activity zones. Such pre-ridges are certainly found in many places (cf. the text) but are usually regarded as small crag moraines, drumlinoids, or even real drumlins if rock obstacles are not visible. (III) typical crag moraine(s), drumlinoid or real drumlin developed at and around an obstacle, or real drumlin without any obstacle; length and height normally completed; clearly differentiated ice motion etc. on and beside the ridge(s), i.e. accumulation zone on the ridge, transport zone beside it. (IV) completed drumlinoid with obstacle or real drumlin with or without obstacle developed; also the breadth has increased. The differentiations in ice motion etc. are at their maximum but the accumulation is of more secondary importance, instead, the levelling process predominates (locally also real erosion).

All pre-ridges may have been irregularly shaped. First a continued lodgement of new till, followed by levelling of the overgliding ice, may have resulted in the real drumlin characteristics. Therefore, if pre-ridges still retain in their initial habitus, many of them should often lack many typical drumlin features, and sometimes not be regarded as real drumlin moraines (in normally defined meaning). Especially if the initial till was coarse and in other respects similar to ablation till, some of them should perhaps be called "radial moraines" — sensu Granlund (1943), i.e. radial ridges formed during the deglaciation only in crevasses. The question is what would have happened to this type of moraine, if the ice had remained in motion or had grown up again. Some of them would perhaps have been destroyed but others could probably have given rise to an origination of local accumulation zones, in which an enlargement to streamlined drumlin ridges had occurred. In other words, accordingly, some of these "radial moraines" in Västerbotten and other regions may be a specific type of pre-drumlins. If this is right, they belong to the drumlin complex despite their irregular shape, divergent material composition and differently initial formation; so they may form a further group in this complex. The latter should therefore include the following members: whole drumlin ridges, half drumlin ridges, drumlin moraines without ridge-form, fluted moraines and other similar, radial ridges.

The age of the drumlin formation

No direct proofs of the age of the drumlin formation exist but nevertheless this problem is worthy of discussion.

In places, comparatively thick basal till (e.g. on Kinnekulle) or thick glacifluvium (e.g. in the Värend area) from a previous glaciation phase form foundations of large drumlin moraines. This composition gives a relative age of this bottom material, in some cases even more precized — > 40000 B.P. on Kinnekulle (Gillberg 1970) and about 30000 (or 24000) B.P. in the vicinity of Göteborg (Hillefors 1974a). It also establishes another fact, namely the relative age of the covering tills — younger than this bottom material. Moreover, as this drumlin till is similar to it in the surrounding terrain — somewhat different in lithology etc. but similarly influenced by weathering, vegetation, soil types etc. — it, and thus the drumlin process, must be from the same time, i.e. the concluding phase(s) of the last glaciation (in all regions, a self-evident assumption).

There is another fact of great importance for this discussion. Irrespective of the beginnings of the drumlin process and the immediate evolution of it, its continuation to streamlined ridges, i.e. in reality a differentiation in separate activity zones, must indicate a plastic and moving ice, throughout topographically controlled, with its basal layers at or near the melting point and probably comparatively thin — at least if basal cavities are to arise (Fairchild 1929). Furthermore, if the suggestion that the Würm ice cap — except in the outer parts in S. and W. — was mostly in a frozen and rigid state during its largest extent (Schytt 1974), these properties of the ice, as mentioned above, must exclude a drumlin formation during the last main glacial phase.

Three possibilities for the age of this process remain: (*A*) totally during the last advance of the ice, (*B*) beginning in this phase but mostly concentrated in, and concluded, during the time of the disappearance of the ice, (*C*) totally during the latter phase. (Disappearance does not mean real deglaciation at each place, however; cf. below).

The first alternative may be the least probable as it presupposes hardly any influence of the moving ice after the advance, and certainly no renewed basal accumulation. The second possi,-bility, which included an interval of slight, or no, ice activity, nevertheless seems to possible. The occurrences of top ridges (more or less independent) on other drumlin moraines could point to such a development, as could the very existence of so many large ridges, i.e. those whose formation may have covered a long time. There are hardly any direct evidence of this, and even if great sections were open, clear differences in the till composition and till features would seldom occur between the lower and the upper parts of these ridges. The tills from the time of advance and the time of disappearance would, on average, be similar in most respects (it was in reality the same ice cap). Indeed, some occurrences of boulder pavements in an otherwise comparatively boulder-free till (erosion? — Johansson 1972) or a recurrent difference in the lithology throughout a drumlin ridge would perhaps indicate changes in the ice conditions nearto and far from the actual places (Gillberg 1970). Thus, it may not be excluded that some ridges may have been founded at the time of advance, especially their bottom parts, but that the evolution to real ridges first occurred during the phase of disappearance. A drumlin process in basal cavities seems difficult to understand with such an interval, however, as it presumably involved a true continuity.

The third alternative is the most plausible, especially because it must have denoted a conti-

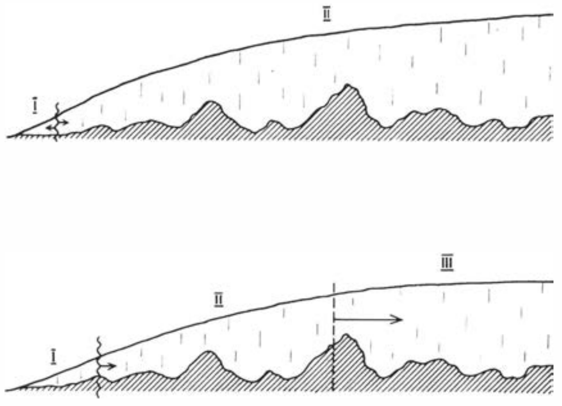


Fig. 34. Principal sketch showing the possible division of the ice cap into zones of different states and activities. Ice movement from the right. Upper figure part — at the time of the largest extent and thickness of the ice. (I) outermost zone; locally in activity and with formation of end moraines or other terminal elements. The inner limit to zone II is at times nearer the ice margin, sometimes farther inside (the small arrows will show this changed position). (II) main part of the ice; in frozen and rigid state; in average no obvious activity. Lower figure part — at the time of disappearance of the ice which is more or less in continuous thinning and retreat. (I) outermost zone; in deglaciation and therefore partly is divided into separate lobes, partly has more uniform margins, partly is breaking up and leaving dead ice behind; formation of end moraines, hummocky ablation moraines and different forms of glacifluvial material. (II) inner zone; in renewed activity and backwards increasing in extent, partly independently, partly simultaneously with the retreat of the deglaciation zone (the long arrow will show this); zone of drumlin formation. (III) innermost zone; originally in frozen state but successively becoming active again, i.e. being part of zone II. During the advance of the ice cap, zone III and II move towards the margin.

nuous evolution throughout — whatever type appeared. This is normally supposed by most drumlin geologists; and where the ice movement has been differently directed during the advance and during the phase of disappearance, it is an established fact (J. Lundqvist 1970).

If it is true that only the outermost parts of the ice cap have been in motion and active but the rest of it has been in a frozen state (cf. above), this must indicate that — when the ice began to disappear — an outer zone of real deglaciation developed, with the thinning of the ice successively retrogressing concurrently with the marginal retreat. But behind it a presumably continuously more extensive, inner zone formed, with the ice in renewed motion and activity. The drumlin formation ought to have occurred in this last zone, as the conditions for all kinds of initiation of such ridges and an origination of different activity zones would have been fulfilled there (Fig. 34). Such a location has often been suggested but usually from quite different reasons (Fairchild 1929, Björnsson 1953, Gravenor 1953, H. E. Wright 1957, Smalley & Unwin 1968, Johansson 1972, Aario et al. 1974). Owing to the existence of different type of topography, different plateaux having been ice-free in different time inside the thinning ice, and the ice border having locally been lobated etc., the drumlins must have developed at different times during the disappearing phase (Fairchild 1929), and also have been differently placed in relation to the deglaciation zone. A close connection of a drumlin zone with an exact location of the ice margin (at special end moraine complex, for instance) may therefore seldom have appeared, especially in time; in any case no indications thereof exist in the areas studied. Indeed, isolated exceptions seem to exist, e.g. in Dalsland (Gillberg 1961) and on the Östergötland plain in Sweden, and probably in N. Germany and in the Alps. Completed stoss- and lee-side moraines may locally have developed comparatively near the ice border (Boulton 1970, 1971, Hillefors 1974), or even form parts of marginal complexes (Björsjö 1949, Gillberg 1961).

In accordance with the above theories of the time and location of the drumlin process, and with hitherto known course of the deglaciation in S. Sweden, the relative age of the drumlin areas (in relation to each other) should be (the oldest first) — the Falkenberg area (lies nearest the last ice margin), the drumlins on the highest plateaux of the South Swedish Highland, the drumlins situated lower down on the latter, the Falbygden and Kinnekulle areas, and latest the Närke area.

Among the above-mentioned factors decisive to a drumlin formation, i.e. in reality to an origination of different activity zones, the thickness of the ice must have been one of the most important (as many other factors are dependent on it). According to Boulton et al. 1974, the minimum ice thickness which will inhibit shearing influence on the upper parts of the deposited till is 27 m (disregarding possible differences in permeability of the material in and under the ice and in water pressure). Any indications of shearing processes in the drumlin till are not obvious in the sections in the areas investigated; and even if these studies cannot have been made sufficiently closely, these results may indicate that the drumlin formation took place under at least 30 m thick an ice. An indirect proof of this may be that only fluted moraines and some stoss- and lee-side moraines have been found immediately in connection with the ice margin but never any real drumlin ridges. A consistent conclusion may therefore be that suitable conditions for a formation of such moraines are not fulfilled in the outermost parts of the ice. On the other hand, this may not be the case under too thick an ice either, for basal cavities may there have appeared more seldom, the pressure may have been too concentrated to allow decisive differences in it (especially in parallel zones), suitable differences in temperature gradient may not have appeared, and the ice may, in all places, not have followed the terrain. A maximum thickness of the ice cannot be given,. however, and can hardly be approximated (50—300 m ??). But in all probability, such an inner zone of the disappearing ice discussed ought to have been of suitable thickness in all respects.

If the drumlin formation has occurred inside this inner zone of the ice, the last question may be whether it developed during phases of stagnation of the ice margin (deglaciation stadials) or during phases of retreat of the ice margin (deglaciation interstadials). The answer is presumably during both, or rather during all of them in the time of disappearance, as the existence of so many and such large drumlins hardly suggest a short formation time. But a correlation to any special phases for a special drumlin area or drumlin location is not feasible, and has certainly not existed. The main phases of the drumlin process ought to have been the stadials, however, as these ought to have been characterized by more activity, or even reactivity, of the ice than may the phases of retreat. Perhaps therefore, the drumlins, in spite of special shape, composition, location (and possible bottom parts of older sediments), are rather proofs of colder phases. In any case, they are not deglaciation elements — apart from the radial moraines sensu Granlund, i.e. if they belong to the drumlin complex.

Table 1. The Borås area.

Abbreviations in this and the following tables:
DR = drumlin(s), DID = drumlinoid(s), PREC = precrag ridge(s), POSTC = postcrag ridge(s), LID = lid moraine(s), TS = till sample

1	Ljur	Plateau LID with five small, irregular PREC and POSTC; the former shorter and steeper, the latter longer and more out-gliding (area in progress?).
2	Åsen Årred	Distal LID with two protruding ridge-like lobes; on a distal plateau, a top DID with long, upward-sloping proximal side.
3	Asklanda	Three parallel ridges, partly fused distally; the southern of them divided into a short and high POSTC and an incomplete and irregular PREC; the two other ridges are long, comparatively plane PREC (DID) with short proximal sides; this group also includes a small, distal top DID and a low and narrow PREC, SE. of the first moraine; immediately to W., a marginal DID with central crest.
4	Grude	High DID with two marginal, low top ridges (high ground water inside); comparatively plane surface, short and steep proximal and distal sides.
5	Hov	Two parallel, high DID with steep proximal slopes, long and downward-gliding distal sides and a deep depression in between; TS (top of E. ridge, foundation digging 3,5 m).
6	Mjäldrunga Skölvene	Six moraines in succession, two and two partly fused and of them the distal one always greatest; low and intermediate broad DR except the southernmost, a large DID (PREC); the four distal ridges lie on the margin of a low ascent, therefore they have a more SE. orientation; the two N. ridges and three other immediately to E. lie on an even plain, their orientation therefore only determined by the ice movement.
7	Plate	Long marginal DID, proximally divided into two ridges; distally the W. of them in its turn divided into a short E. and a long and low W. lobe; the W. long side steeper, more levelled.
8	Vimle	High DID with central rock top and steep proximal and distal sides.
9	Eriksberg	Low POSTC, distally out-gliding without distinct limits to the surrounding ground.
10	Broddarp	Low and irregular PREC; TS (distal side, gravel pit 1,4 m).
11	Örum	Long, low and narrow DR with plane surface, short and steep proximal and distal sides.
12	Österod Kåtorp	Five marginal DR and DID in succession; the three northern partly fused; the southernmost ridge lies higher up on the plateau, in isolated position and therefore with comparatively similar long sides; the four other ridges have steeper W. (outer) long sides.

13 Bogared	Ridge divided into one small proximal PREC and two small distal POSTC (in progress to one uniform ridge?); immediately to SE., a short and high POSTC.
14 Mollungen Långared	Proximal LID with top DID; distally of it, a long DID, proximally divided into two ridges with distal top rocks; to W., a small side DR; TS (E. side of proximal DID, digging 1,5 m).
15 Älgarås	Proximal LID with top DID; distally of it, another top DID.
16 Tämta	Undulated DID with central rock top; TS (distal side, digging 1,6 m).
17 Vänga	Low DID proximally on a small plateau; E. long side short and irregular with rocks; continues proximally in a long, lower-lying DR, somewhat displaced to NW.
18 Komlösa Fristad	Proximally two small POSTC; centrally a large DID with a small top ridge and a small, isolated side DR to W. (not marked); distally a small POSTC (not marked) and a large DID with downward-sloping distal side; TS (proximally of central DID, side of rivulet 1,9 m).
19 Tärby	Distal LID with large proximal top DID (with proximal and distal rock tops) and a small POSTC to E.
20 Härna	Great DID, distally situated on a small plateau but with upward-sloping proximal side, short and broad distal side and proximal and distal crests.
21 Älmestad	Long and high DID, very broad distally and centrally and there with two tops (nearly a small PREC and a small POSTC); the proximal part continuously narrowing and downward-sloping towards the end; immediately to S., a small rock area with till deposits on lee-sides and between some rocks (in progress to real ridges?).
22 Möne	DID divided into a long, upward-sloping PREC and a short, steep POSTC (not marked); TS (central part of PREC, road cutting 1,4 m).
23 Öjelunda	Four low DID (DR) on even plateau ascent; their orientation only determined by the ice movement (the ridges around are more topographically placed).
24 Öra	Long, narrow and low DR with short, steep proximal slope; proximal and central part well levelled and gently ascending towards the projecting, more undulating distal part (rock?); two small, isolated DR proximally (one marked).
25 Döve	High DID with proximal rock top (POSTC); more levelled E. long side (free), more undulated W. long side (towards small rocks).
26 Vårkumla	Long and low DR with short, steep proximal and distal slopes; comparatively plane surface with six small tops, differently placed (two of them, rocks); both long sides simularly shaped; thus, in main, typical drumlin features but the ridge orientation is markedly divergent — NE.—SW. (adjacent ridges lie nearly N.—S.).
27 Knipan	Five (three on the map) POSTC, partly fused near the rock hill; proximally on the same plateau, three isolated, high DID with central crests but differently sloping short sides.
28 Dintestorp	Proximal LID with proximal top DID and distal top hill.
29 Rullesås	Proximal LID without distinct top hills or top ridges.
30 Starhester	Proximal LID with undifferentiated top hummocks.
31 Tåhult Gravsjö	Plateau with twelve small DR and DID; the former lower and more levelled, the latter higher and more irregular; all nearly N.—S. oriented (=-direction of general ice movement); adjacent ridges more topographically placed.
32 Kättestorp Långsered	Proximally a low, irregular DID; distally a long POSTC with higher and more undulating proximal part, lower-lying and more levelled distal part, gradually out-gliding.
33 Lund	Small plateau LID with undulated proximal and distal sides, the latter ridge-like (in progress to real POSTC?).
34 Sjöryd	Proximal LID with small top DR (not marked).
35 Duvered	Plateau LID with proximal, well-formed, top DID; distally a high top DID (most rock) and to W. a short POSTC; TS (distal side of proximal DID, road cutting 2,8 m).
38 Övre Vång	Long side LID with great, distal top DID.
39 Ek	Broad, proximal LID; small top DR; short and narrow, distal LID and to W. an isolated, low DID, lower-lying.
38 Remma	Proximal LID with small top DR; to S. followed by a long plateau DID, proximally more levelled, distally more irregular and with proximal and distal crests; immediately to SE. a similar LID with a long DID distally.
39 S. Ving	Plateau LID with long proximal DID (PREC); a small top DID; on W.—SW. side, two marginal POSTC partly fused, one lower-lying isolated POSTC and most distally a low DR (transition ridge to group 41); on SE. side, one high marginal DID (POSTC) and one high, lower-lying, isolated DID; TS (E. side of proximal DID, gravel pit 2,3 m).
40 Horsared Stavared	Broad, proximal LID, partly divided into two parts, each one with beginning top DR.

41 Vatunga	Two DR and two DID in succession on E. plateau margin; the proximal ridges have short W. long sides but long, downward-sloping E. long sides (towards a lake); the distal ridges lie higher up on the plateau and are more SW. oriented, partly due to a high rock hill with a large PREC to E.; TS (E. side of most distal ridge, digging 1,7 m).
42 Skälvarås	Great PREC with distal top hill, levelled E. long side and more irregular W. long side; to E. a lower-lying side DR (not marked).
43 Kråkhult Senåsa	Plateau LID with proximal DID (steep proximal side, more out-gliding distal slope), distal PREC to W. (with top hill) and distal DID to E. (POSTC); TS (W. side of proximal ridge, road cutting 1,7 m).
44 Rångedala	Proximal LID with top DID; distal top DID also on SE. part of the same plateau.
45 Bondarp	Proximal LID with top DID; TS (proximal slope, road cutting 2,6 m).
46 Viared	High, long DID with all sides steep and comparatively plane surface; TS (distal slope, digging 1,7 m).
47 Bäckabo	Undulated DID on E. plateau margin; steep, irregular E. long side, short and more levelled W. long side.
48 Bredared	Proximal LID with a great, proximal top DID and three, parallel, distal top DR, partly fused; to W. of them, a small, isolated, low side DR (not marked); TS (top of proximal DID, foundation digging 2,8 m).
49 Hedared	Proximally upward-sloping, large DID followed by a small, distal top DR; TS (W. side of proximal DID, gravel pit 1,9 m).
50 Ödenäs	High DID with all sides steep (on rock ridge between two lakes?)
51 Gullringsbo	Small proximal LID with orientation entirely determined by the topography; adjacent ridges are more SW. oriented (= the main ice movement).
52 Ubbhult	Small proximal LID passing over into a great, comparatively plane, proximal DID (with steep distal side); distally of it, a small, irregular DID partly fused with a long top DID; most distally, another, long and low, top DID.
53 Horred	Large DID on W. margin of Viskan valley; of type B as glacifluvial material towards the bottom; on a distal plateau, one small proximal DID and one large, distal top DID.
54 Hökhult	High, undulated DID; TS (proximal side, gravel pit 2,8 m).
55 Lockryd Gränd	Ridges on both sides of lake Lysjön, their orientation entirely determined by this valley; S. of the lake, a great proximal DID followed by two small plateau DID in succession; N. of the lake, a marked, proximal LID and two parallel, distal top DID.
56 Länghem	Two long, parallel DID (DR), fused in the middle; comparatively plane surfaces, the small crests reversely placed, prolonged distally.
57 Brotorp	Small plateau LID with large, proximal DID (with proximal and distal crests) and a small, distal DID (PREC).
58 Boda Brunnsbo	On W. margin of a small plateau; proximally two, irregular DID; distally three low and plane DR, partly fused; higher up on the plateau, two high, isolated DID.
59 Ödegärde	Three large DID in a triangle; the proximal one fused with both the distal ones.
60 Limmared	Long, high DID on E. plateau margin (long side LID); proximal and distal top DR; W. long side lower, more levelled, E. long side steeper, more irregular (especially distally).
61 Gisslarp	Marginal DID with central crest; distally (especially to E.) some small hummocks (incomplete addition of till?).
62 Gryttered	Small plateau LID with long, proximal top DR and distal top hill.
63 Rösered	Plateau LID with proximal, upward-sloping DR, three marginal DR and two distal, downward-sloping lobes (DID); the W. ridges partly oriented by the topography.
64 Finnekumla	Broad and long DID with proximal and distal top hills and plane surface; orientation parallel with L. Åsunden.
65 Toarp	Short proximal DID with incomplete till addition to E; long distal DID divided into a longer and higher proximal part, a shorter and lower distal part.
66 Berga	Great DID with steep proximal side, levelled W. long side and undulated E. long side with some hills.
67 Boarp	Distal LID divided into two POSTC; proximally the E. of them, distally the W. of them highest and more levelled.
68 Påbo Rånnaväg	Proximally a comparatively high PREC; centrally an irregular DID with central top hill; distally a large DID with the W. part prolonged in proximal direction, the E. part prolonged distally; W. long side more levelled, E. long side more irregular.
69 Ramnö	Four small plateau DID; their orientation only determined by the ice movement (adjacent ridges more topographically controlled).
70 Ölsremma	Low plateau LID with short proximal and long distal DID; two small, lower-lying side DR; immediately to N. (Algrena) a large DID with higher E., lower W. part (two parallel ridges fused or very irregular growth in height?).

71 Karsbo	Three proximal (two marked) and one distal DID, all with steep sides and comparatively irregular; the two proximal ones to E. partly fused; immediately to S., a very irregular ridge (in progress? — not marked).
72 Jordhult	Seven small, irregular, low plateau DR and DID with somewhat different orientation.
73 Ekornnahult	DID, very irregular throughout (in progress?).
74 Bondstorp	Long, low and plane, marginal DID, partly fused with a short and plane distal DR.
75 Lövåsen	Long, low and plane DR with two small, low DR to E.—NE.
76 Ljungsarp	Comparatively steep DID, proximally more irregular, distally more levelled and prolonged.
77 Askåker	Steep DID with central crest; W. long side more levelled.
78 Spolabo	Long DID with lower top hill proximally. higher top distally; levelled W. long side, more irregular limitation to E.; immediately to W., three low DR in a triangle.
79 Fiås	High DID with all sides steep and central crest.
80 Remmabo	Long, low and plane DR, broadest centrally.
81 Moghult	Three parallel, low DR. distally connected to a small rock hill; S. from here, some small undifferentiated hills (ridges in progress?).
82 Mossebo	Long and low DID with proximal crest, plane surface and distal top hill; more levelled proximal part, more irregular distal part; also at Larsbo (to W.) a similar DID but undulated throughout.
83 Hylte Älvshult	Isolated, steep DID proximally; then a small proximal LID passing over into a plateau DID with high, proximal crest, out-gliding distal side; most distally a new plateau DID with upward-sloping proximal part, distal crest and short, steep distal side; S.—SW. from here, some small hills (incomplete mammillary hills? — not marked).
84 Gölebo Askebo	Two DID with comparatively plane surfaces, long proximal parts, short and higher distal parts (rocks?).
85 Svalås	Isolated, large DID with all sides steep; small, lower-lying distal DID.
86 Mjogaryd	Marginal DID with more levelled W. long side.

Table 2. The Sommen area.

1 Björkenäs	Two parallel, marginal DID; the W. one with central crest and sloping proximal and distal parts; the E. one with small, proximal and distal tops, and comparatively plane surface in between.
2 Sötåsa	Marginal PREC on narrow height; small, isolated POSTC distally.
3 Näs	Proximal LID with small top DID (PREC).
4 Linderås	Low plateau (LID) with three W., marginal DR, two proximal, large PREC with a small POSTC in between, and four distal DR; the W. and distal ridges are comparatively broad and plane, the crag ridges are higher and narrower; except on the latter, usually small crests, differently placed; TS (distal side of NW. ridge, digging 1,6 m).
5 Öberga	Downward-sloping POSTC with proximal top DID.
6 Garpenberg Frinnaryd	Plateau with proximal LID; centrally two W., marginal DID (the N. of them with middle crest, the S. of them with distal crest) and four top DID (PREC) at two small. top heights; distally one large, W. marginal DID (with central crest) and four DID (POSTC). near each other and with narrow U-depressions in between; the three W. ridges in succession, partly fused as well as the central and distal ridges in succession; TS (distal side of distal, marginal DID, road cutting 2,0 m).
7 Ebbarp Katarp	Two POSTC, somewhat differently oriented.
8 Björnklo	Proximal LID (long side LID) with beginning small top hills; TS (E. side of proximal part, gravel pit 1,7 m).
9 Hyltan	Small plateau with top DID and E. marginal POSTC.
10 Sundhult	On W. plateau margin; two N. parallel ridges, the W. of them a large DID. the E. of them a small DR; four S. parallel ridges, no 1 and 3 of which (from W.) are great DID, nos. 2 and 4 are small DR; meltwater-eroded depressions between all ridges.
11 Notåsa	Long side LID (or large DID as comparatively free, proximal and distal slopes) with small top DR; TS (W. long side, road cutting 2,3 m).
12 Öringe	On distal part of plateau no. 6; two large DID on W. margin, two small DR inside them, and towards a small top height, one proximal and one distal, great DID; somewhat differently placed (topographical effect or due to having influenced each other).
13 Härjestad	PREC and POSTC on E. plateau margin, comparatively broad and steep, topographically oriented.

14 Tabbarp	Long, levelled PREC and small, irregular POSTC, followed by a small, isolated, distal DR, displaced.
15 Vittaryd	Large plateau DID (LID) with a small top DR and a small side DR to W.; proximally of the latter. a small DID, displaced; all in succession of no. 14; TS (between the top and side DR, digging 1,7 m).
16 Ralingsås	Very distinct, high DID with two rock tops and all sides comparatively steep.
17 Marbäck	Long side LID (or great DID as free, distal slope); no top hills or top ridges.
18 Assjö	Low and plane DR with levelled W. long side, more undulated E. long side; TS (distal side, gravel pit 1,8 m).
19 Mariefors	Great marginal DID with lower E. long side and more irregular, distal part.
20 Aneby Hareryd	Isolated. high DID with plane surface and distal side somewhat more sloping than the proximal part; on the following S. plateau, a proximal LID with top DR and two distal, parallel DID, both partly marginal and fused; TS (central part of proximal DID, foundation digging 2,1 m).
21 Skärsjö Tofta	Proximal LID and two distal, marginal DR (the W. of them, rather a POSTC with beginning proximal addition of till).
22 Lönholmen	High DID with central crest and all sides steep; distally of it, a small group of top ridges (mostly DR) with differently sloping short sides.
23 Lidhult	Proximal LID; distally to W. of it, a short, broad PREC and a long, downward-sloping POSTC, partly fused; beside the rock top. a small side DR to E.; on E. plateau margin, two parallel DID (high ground water in between); TS (E. side of POSTC, road cutting 1,7 m).
24 Slätthult	Small plateau (LID) with two proximal and one distal top DR, partly marginal.
25 N. Solberga	Two large PREC (the W. one rather DID) on a small, isolated height; topographically oriented; TS (proximal side of W. PREC, gravel pit 1,9 m).
26 Knutstorp	Two high DID (PREC) on a small, isolated height; topographically oriented.
27 Råskog	Two large PREC (DID), partly fused; the E. of them with a distal. small top POSTC and a lower-lying side DR; TS (proximal part of W. PREC, gravel pit 2,0 m).
28 Tunnarp	Long side LID composed of two low. comparatively long, proximal DR and one central. low DR in a triangle; to E. in succession, a large proximal DID, a small central and a small distal DR.
29 Helgesfall	Small height with a long, proximally upward-sloping W. DID, centrally two DID in succession, fused (the proximal one is lower, comparatively plane and with steep proximal side, the distal one is higher and steeply upward-sloping towards the distal top) and to E., a long, proximally upward-sloping DID; distally of this complex. some small top ridges (one inserted). and on the E. side of it, a narrow, lower-lying DID with small, proximal and distal top hills.
30 Forsnäs	High, comparatively plane DID with all sides steep; proximally of it, a small, isolated DR; TS (proximal side of large DID, gravel pit 2,4 m).
31 Lägernäs	Great DID with upward-sloping proximal side and distal top DR; TS (distal part, road cutting 1.9 m).
32 Kalvsved	Marginal DID with central crest, levelled and steep W. long side, short and more undulated E. long side; a small, isolated proximal DR.
33 Höglycke	Great DID (proximal LID) with a distal top PREC; TS (W. side, digging 1,7 m).
34 Beseryd	Comparatively high, steeply sloping PREC with a low, side DR to E.
35 Marek Sjöhult	Four DID on W. margin of lake Sommen; comparatively low, plane and more irregular proximally; nos. 2 and 4 (from N.) greater than the other.
36 Äskebäck Fröåsa	Four marginal PREC (the northernmost rather a proximal LID).
37 Njölhult	Long, narrow and comparatively plane DR with long, upward-sloping proximal part and long, out-gliding distal side.
38 Flaka	Great DID (PREC) with steep proximal side, comparatively plane central part and irregular, higher projecting distal part (rock); W. long side more undulated.
39 Örsåsa	Great DID (PREC) with steep proximal and distal sides and comparatively irregular long sides (the E. of them with high ground water at bottom).
40 Slättefall	Narrow and plane DID with irregular proximal side; on the small height to S., a beginning, proximal LID.
41 Ål	Small proximal PREC; great distal DID with upward-sloping proximal side, comparatively plane surface and undulated distal part.
42 Sjundhult	Two great, proximal PREC (the W. one highest) and a distal top DID; on the E. side of lake Krön, some beginning ridges (one of them is a comparatively distinct PREC).
43 Långbrössle	Small plateau with two proximal DID, one small, central top DR and two marginal, distal DID (the E. of them, partly fused with the top ridge).

44 Kongskulla Åkemåla	Small plateau with short, proximal and distal LID; on it, there are also some small PREC and POSTC (not marked), the former mostly lie on the top, the latter are more marginally placed.
45 Målen	Low and irregular, distal top DID on a small, undulated plateau; beginning proximal LID.
46 S. Kvill	Marginal DID with central crest and long W. long side, short and steep E. long side.
47 Fundshult	Long proximal DID (DR) with lower, comparatively plane proximal part and higher and shorter, distal part; on the same height, also a short, distal top DID (PREC).
48 Haddås	Two parallel, isolated POSTC; the W. of them with proximal, irregular addition of till.
49 Lid	Broad, proximal LID with top hill; on the same plateau, also a small, distal POSTC.
50 Hultna Kråkshult	Seven short, isolated top DID; the four distal ones form a group and are more irregular.
51 Bellö	On W. plateau slope towards lake St Bellen; two proximal, more irregular POSTC, each one followed by a great, distal DID with upward-sloping proximal side and on average more levelled; higher up on the plateau, there are two small POSTC to N. and two small PREC to SE. (only one marked), all more topographically oriented.
52 Svallarp	Small plateau with two proximal, more irregular DID, one distal PREC to E. and one distal POSTC to W.; the two E. of these ridges are marginal, the two W. of them are top ridges; immediately to S., a short POSTC.
53 St. Röslida	Two distal LID; the E. of them is smaller, rather a beginning POSTC, the W. of them is greater with a small top hill.
54 Edshult	On the low plateau between lakes Solgen and Mycklaflon; nine ridges in succession and parallel to each other (top DR and E. marginal DID); all fused and topographically oriented; the two proximal ridges smallest, the three central ones broadest and longest, comparatively plane, and the four distal ones highest and higher situated.
55 Olofstorp	Long PREC and long POSTC at the same plateau, each one followed by a small side DR, lower-lying.
56 Östraby Värhult	Proximally, one long and high E. DID with all sides steep; to W. of it, one small POSTC and three small irregular ridges (DR in progress?; only one marked); distally, one isolated DID with two parallel tops.
57 Boaryd	Small plateau with one great, proximal DID and three small, distal top DID (partly marginal); immediately NW. of the height, a small, isolated POSTC; TS (proximal side of great DID, road cutting 1,9 m).
58 Bonderyd	Proximally, one isolated, high DID; centrally, one small DR to W. and one great DID to E., fused; distally, one small DID.
59 Mellby	Five short, irregular DID in succession and with all sides steep; distally to W., three similar DID; here also some stoss- and lee-side moraines (area in progress?).
60 Äspenäs	Long, low and plane DR; about 5 km to W., a similar DR at Katteryd.
61 Hallamåla Hult	Two high DID (PREC) with two small proximal DR and two small distal DID; all displaced.
62 Buggeryd	Two high, parallel DID with all sides steep and comparatively plane surfaces; rivulet in between.
63 Ulvstorp	High, isolated DID with all sides steep and double crests.
64 Drageryd Hjälmseryd	Distally of a small height; to E. one long, broad POSTC; to W. one long, gently sloping DID following by a short POSTC with one small DR on each side.
65 Säveda	Small proximal POSTC; great distal DID with levelled proximal part, more irregular distal part.
66 Grimstorp	Long, low and plane, proximal DR, followed by a small, distal DR which is the proximal part of a small LID with well developed distal side.
67 Spexhult Skieryd	On a low plateau, about 13 top DR and DID, the latter more irregular; their orientation entirely determined by the ice movement (adjacent ridges more topographically controlled); most ridges are comparatively small, only the one at Skieryd is higher, more distinct with central rock top (or PREC and POSTC against this rock); TS (E. side of the latter ridge, digging 1,5 m).
68 Fagerhult	Comparatively long, high DID with long-sloping, levelled proximal part, shorter and more irregular, distal part.
69 Rommenås	PREC with steep and short, irregular proximal side (in progress?) and comparatively plane, central and distal part (towards the rock).
70 Fägrida	Long, low and plane DR.
71 Hult	Long marginal DID (long side LID) with steep proximal side, long out-gliding, distal part.
72 Gummarp	Short and narrow POSTC in distal slope, followed by a short but broader PREC in proximal slope.

73 Tofteryd	Long, low and plane DR (partly marginal), distally out-gliding in the surrounding ground.
74 Hagshult	Small plateau with great proximal DID (with distal top), centrally two parallel DID and distally one small DID; all fused; to W. of the latter, one isolated, comparatively high DID.
75 Jönshult	Low and plane DR with somewhat concave E. long side.
76 Horveryd	High, isolated DID with central crest, distally situated of a steep POSTC.
77 Vakås	To W. a high DID with comparatively plane surface and all sides steep; to E. a long-sloping, irregular POSTC; high ground water in between; distally, a small POSTC.
78 Solkaryd	Long, low and plane DR; at Fröset to E., a similar DR but higher.
79 Myresjö	To W., three high, isolated DID with all sides steep; to E., a high, short proximal LID (PREC).
80 Gunnarshult	Irregular top DID on a small height with thin till but in beginning levelling (in progress to a great DID?).
81 Restorp	Broad and steeply sloping POSTC with beginning addition of till proximally.
82 Gettinge	Two high PREC at the corners of a small height; between them a small esker.
83 Repperda	Low, long-sloping DID with short distal side (rock); to E. of it, a small PREC.
84 Baggetorp	Low and shield-shaped PREC. undulated and with not distinct ridge-form; clearly divided into different segments with different gradient.

Table 3. The Värend area.

1 Fryele	Marginal DID, divided into a lower, plane W. part with short W. long side, and a higher, distally gently sloping E. part with both long sides steep (fusion of two parallel ridges, or enlargement in progress, either the lower or the higher part?).
2 Hisinge	Three small, irregular DID (boulder-rich); here also some other small ridges (not marked), still more irregular and rich in boulders (radial moraines in sensu Granlund or hummocky ablation moraines — drumlins in progress?).
3 Moboda	Comparatively steeply upward-sloping proximal LID with distal part passing over into the plateau; long and low distal plateau DR.
4 Brunnstorp	Four comparatively high, isolated rock hills with thin till, more or less levelled (certainly not any drumlin moraines but mentioned as examples of such a type — beginning crag ridges?).
5 Svensbygd	Comparatively steeply upward-sloping PREC; central rock area, mostly covered by till; long POSTC, undulated and downward-sloping in some steps.
6 Släthult Skärshult	Five small DID (or two sloping PREC, three short, steep POSTC); also here some other hills may be beginning such moraines, cf. no 4 (not marked).
7 Hjälmseryd	Low and narrow, distally long-sloping DID; TS (middle part, road cutting 2,0 m).
8 Grönskulle	Proximal DID (PREC). connected to a short and high rock hill with thin till; S. of the latter, two small, parallel DID, the E. of which is followed by a low DR; distally two small POSTC.
9 Lövshult	Narrow, steeply upward-sloping PREC (DID) with distal, irregular addition of till; at Älmefall S. from here, a small height with irregular, proximal till deposits (PREC in beginning?) (not marked).
10 Holma	Rock hill with comparatively levelled, thin till; cf. no. 4.
11 Eskilstorp	Eleven low DR-DID in comparatively even terrain; two are longer, with plane surfaces and well levelled; the other are short, somewhat more irregular; some are differently oriented.
12 Huluboda	Two short and broad, proximal LID; with top hill (E.) or top rock (W.).
13 Kyrkotorp	Large plateau LID with proximal and distal, steep slopes; the latter divided into two lobes; small top DR (not marked).
14 Bråna Källreda	On distal part of a small plateau; to W., one isolated, short DID; in the middle, two long DID, the W. one with proximal and distal crests, the E. one with proximal top and steeply downward-sloping distal part; to E., one DID with irregular proximal part and short, steep distal slope; rivulets between all ridges.
15 Buskatorp Gisshult	On E. margin of a small plateau; two and two parallel, irregular DID; the W. ones isolated, the E. ones (in succession) partly fused and continuing in a distal, downward-sloping DID.
16 Velhult Rösås	On W. plateau margin; proximally, three small DR; centrally, a short and steep POSTC (lower than the rock hill) followed by an irregular, more sloping PREC (also lower than its rock hill): on distal side of the latter, a small DID passing over into another small plateau; all ridges in succession and displaced.
17 Lammhult	Long and narrow DID with proximal and distal crests, and steep, proximal and distal slopes; to W., a short, steep PREC; TS (E. side of DID, digging 1,7 m).

18 Karshult	Long, high DID with comparatively steep proximal side, more sloping distal part, central top DID and distal top rock; to E., a small, distal PREC, partly fused with the large DID; immediately eastwards there are some small, irregular DR-DID (two marked).
19 Flathalla Lyåsa	Distally situated and distally sloping DID on a narrow rock hill (or small plateau LID); immediately S. of it, a high, steeply upward-sloping DID, proximally situated on another small height.
20 Sötåsa	Comparatively irregular POSTC with hummocky ablation till most distally; immediately to S., a low and plane, isolated DR, displaced.
21 Högamålen Björnhult	Three high DID (most rocks, cf. no. 4); some other, similar ridges exist in the vicinity (not marked).
22 Hindsekind	Two long, low and plane DR in succession, partly fused (partly with glacifluvial debris); distally to SW., another similar but more undulated DR.
23 Voxtorp	Two comparatively high DID, partly situated on the proximal slope of a small height; proximally between them, a long, low and plane DR, somewhat differently oriented.
24 Långshult	Narrow, long, plane, distally prolonged DR; proximally more levelled, distally undulated; W. long side more irregular.
25 Långstorp	DID with central crest and steep proximal and distal sides; proximally of it, two short, low and plane DR, fused.
26 Ekornarp Guddarp	Group of about 22 DR-DID on comparatively even plain; the five central ones best developed, low and plane (but with low, middle crests) and with short and steep, proximal and distal slopes; those in succession partly fused; the other ridges are shorter and somewhat higher (therefore more distinct) and lie nearly always isolated.
27 Hörda	Long, low and plane DR with undulated distal part, out-gliding in the surrounding plain, and more levelled, somewhat higher, proximal part; short, proximal DR of similar shape.
28 Torp Hyalt	Group of small, low and comparatively plane DR in succession and in parallel; the two proximal ones fused; the three central ones in succession also fused and with two isolated side DR to E.; the distal ridge somewhat higher than the other mentioned.
29 Upplid	Small plateau LID (large DID) with low top ridge; distally of it, a short POSTC.
30 Sjuhult	Two marginal great DID with central crests; the W. long sides are shorter and more irregular; the proximal DID is more undulated on average.
31 Mistelås	Short, broad and steep proximal LID with small, proximal top DR (not inserted); marginal top ridge more distally.
32 Hakafors	High DID with steep long sides; higher distal part (rock), long-sloping proximal side; immediately proximally, one low DR, and still more proximally, two small, incomplete DR.
33 Sköldstad	Small plateau LID with proximal and distal, protruding lobes (to W.); small central DR; and long, marginal, comparatively plane DID (DR) to E. — with steep proximal side, more long-gliding distal part, partly displaced (originally two ridges?).
34 Uråsa	Broad DID with two marginal top ridges and plane surface in between (the W. one is somewhat higher, shorter).
35 Elofstorp	Long, low POSTC with beginning addition of till proximally of the rock; small side DR on each long side, both fused with the large ridge; distally to E., a short, isolated DID with central crest.
36 Grännaforsa	Long, high and plane DID (of type B as glacifluvial material exists under 10 m till); out-gliding proximal and distal sides; steeper E. long side; TS (proximal slope, digging 2,0 m).
37 Bokelid Vegby	High proximal DID; central DID with proximal top (rock?) projecting above the plane, distal part; the latter is divided into two lobes, the W. of which has short and steep distal slope, the E. of which has more out-gliding distal side; two small, isolated DR most distally.
38 Vångsnäs	Two comparatively low and plane DR on W. margin of lake Fiolen, in succession, fused but displaced; inside and parallel to the distal ridge, there is a new DR of similar type, followed in succession by another DR, also fused but displaced; the latter gradually passes over into a small distal LID; the two central ridges largest.
39 Kopparås Hässleberg	Four short, comparatively high DID (most rocks, cf. no. 4); some other, similar "ridges" exist in the vicinity.
40 Vitteryd	DID with high, rounded proximal part (rock) and plane, gradually out-gliding distal part, lower situated.
41 Torpsbruk	Hig and steep DID (PREC) (of type B as 4 m till over 15 m coarse glacifluvium); TS (top side of DID, gravel pit 2,1 m).
42 Bredhult Brantåsa	Plateau LID with two isolated, proximal DID; centrally one great DID, partly fused with the E. of the former ridges; distally in succession, two parallel DID (forming a large LID); to W. of them a high, isolated POSTC; SE. of this group, there is a small height with three small top DID and one great, steeply sloping, distal DID; TS (E. side of central DID, digging 1,4 m).

43 Berg Ernatorp	Group of two proximal DID (the W. one broader and distally sloping, the E. one greater but narrower) and two distal DID (the W. one greater); reverse sloping of the great ridges; all fused.
44 Bergsjön	Four small DID in succession; the proximal and distal ones are greatest.
45 Holkastorp	High PREC and POSTC at the same height (or small plateau LID with well developed proximal and distal slopes).
46 Nykulla	Great PREC with top DID.
47 Tolg	Two large DID, the W. one with two proximal top DR and narrowing distal slope, the E. one with one top DID and broad, distal slope; distally a small DR between the former ridges.
48 Munkatorp	Small proximal DR in triangle with two, distally sloping DID; TS (E. side of W. ridge, road cutting 1,6 m).
49 Hultåsen	Broad distal LID (or DID as short proximal slope); proximal top DID in between.
50 Sjösås	Large plateau LID with proximal, plane top DR and broad, distal LID between two lakes.
51 Varetorp	Small plateau LID with comparatively distinct, narrow proximal and broader, shorter distal slopes; small proximal top DR (not marked); TS (proximal side of LID, digging 1,4 m).
52 Norraby Söraby	Four great DID (DR) around S. part of lake Övrasjö; both ridges on each side of the lake are partly fused, but displaced; the W. ridges are higher, the E. are broader; TS (proximal side of SW. ridge, road cutting 1,7 m and distal side of SE. ridge, digging 1,5 m).
53 Löpanäs	Two large, parallel DID; the E. one rather a small LID with proximal top ridge and steep, distal slope; the W. one is a real DID with distal top hill and steep and short, proximal and distal sides; to W., two small, low side DR (one inserted).
54 Björnamo	Long, upward-sloping DID (PREC); on a small proximal height, there is a long, downward-sloping DID with a small top DR.
55 Attsjö	Low and broad DID with irregular surface and two small marginal "ridges" (in progress to one great DR?).
56 Kårestad	Long DID on distal plateau-slope (with proximal and distal rock tops), partly fused with a small, lower-lying E. side DR and with a great proximal DID with an isolated side DR to E.; TS (distal side of distal DID, digging 1,4 m).
57 Almestad	Two long, low and plane DR, partly parallel, and a small distal DID in between; still more distally, a marginal DID with downward-sloping distal side.
58 Tveta	Low proximal DR; centrally a high DID; distally a small DID with distal top hill; all fused but displaced.
59 Kråkenäs	Proximal LID with W. central and E. marginal top DID.
60 Gasslanda	Long proximal LID with a small top DR; distally of it, there are three low DR, nearly connected to the projectong rock top of the height (not marked); all ridges topographically oriented.
61 Nyborg	Proximal DID with two low, marginal top DR (not marked); from the same height, also a distal DID, displaced to W.
62 Stojby	Broad, shield-shaped marginal DID with proximal and distal, low top DR; E. long side short, W. long side long but both well levelled; TS (distal side, digging 1.6 m).
63 Åbyfors	Long, low and plane DR (distinct esker S. of it, low esker N. of it).
64 Hult	Long-sloping PREC and short, steep POSTC at the same height; two small, isolated proximal DID, displaced to W.; TS (proximal side of PREC, gravel pit 1.7 m).
65 Ör	Narrowing and steeply sloping POSTC; distally of it, three isolated, low DR in a triangle.
66 Sunnanåkra	Three, comparatively isolated DID on low, distal plain, forming a triangle; the proximal ridge is highest, the distal ridge to W. is shortest, the distal ridge to E. is broadest and longest.
67 Horda	Distal LID divided into two, steeply sloping DID (POSTC); the W. of them is divided into three lobes and distally followed by two isolated, low DR; TS (distal side of E. DID, road cutting 1,7 m).
68 Härlöv	Group of one proximal DID to E., two low and plane, proximal DID to W., fused, and one great, distal DID on flat ascent; TS (distal side of inner W. ridge, deep ditch 2,3 m).
69 Helgö	Three, comparatively low and plane DR in a triangle; all fused.
70 N. Växjö	Four small DID in succession, displaced; nos. 2 and 4 are highest (from N.).
71 Tixatorp	High and long DID with two small side DR distally; all fused; the proximal side irregular and prolonged.
72 Lekaryd	Marginal DID with steep W. long side (of type B as glacifluvial material found towards the bottom).
73 Långstorp	Two small, parallel DR, fused; irregular addition of till distally of both (in progress to one large ridge?).
74 Härensås	High DID with all sides steep; small similar ridge to W.

75 Vare Färanäs	Five plane DR in succession, somewhat displaced; mostly short proximal sides, more long-sloping distal sides; nos. 1 and 4 (from N.) longest and highest, the first of them with a short side DR to W., no. 4 with proximal and distal top "ridges"; TS (E. side of most distal ridge, digging 1,6 m).
76 Moshult Hullingsved	Three low DR in succession; nos. 1 and 2 (from N.) partly fused, no. 3 longest, with proximal and distal crests and proximally more irregular; to E., some small, irregular ridges (two marked).
77 Hunna Torsås Horgemo	Small height with well developed proximal LID, irregular distal LID, and several DID of different shape and dimensions; of the latter, the marginal ones are largest, the top ridges are smallest; one ridge (S. of proximal LID) is distally divided into two lobes.
78 Odenslanda Valeryd	Low plateau with small, low and undulated DID; the three N. ridges are broader with proximal crests; the distal DID to SE. with marginal top ridge to W. and distal slope, out-gliding in the plateau slope; the W. ridges partly differently oriented.
79 Telestad	Two long DID with short, steep proximal sides and more sloping distal parts, partly fused; E. ridge with proximal top hill, W. ridge with distal crest; small side DR to E. of E. DID (not marked); isolated, high DID to W.
80 Hemmesjö	High, comparatively plane DID with central, low top DR; upward-sloping proximal side, short and steep distal side; the large DID is oriented towards SE., the top DR is oriented towards S.
81 Tegnaby	Large DID with proximal higher part (rock?), lower distal part, prolonged and divided into two ridges with a rivulet in between.
82 Tofta	Three parallel DID, partly fused; the E. and W. ones are narrower and somewhat distally sloping, the central one is broader and with plane surface; immediately to W., a small, plane DR, lower-lying.
83 Tävelås	Two long and plane ridges, fused and displaced; the SW. of them is a low DR with small proximal crest; the NE. ridge is a higher DID with central top hill (rock); both have out-gliding short sides to the surrounding ground.
84 Torsjö	Low marginal DR with central crest; both the proximal and distal parts are comparatively plane and the short sides short, steep; the distal part more prolonged.
85 Hörda	High DID with steep long sides, proximal crest and distal side more out-gliding.
86 Ö. Torsås Ingelstad	To E. a high DID with proximal and distal rock tops; rivulet to W. of it and then three parallel DID, partly fused; the E. of them is highest, the central one has prolonged proximal part and the W. ridge is lowest.
87 Säljeryd Orraryd Östad	Eight DR-DID on comparatively even ground; the three proximal ones are low and broad with beginning top ridges; the two distal ones are more irregular.
88 Väckelsång	DID with central rock top; the proximal part is longer, has plane surface and short, steep proximal slope; the distal part is shorter and is more steeply sloping (or long PREC and short POSTC).
89 Högahult Kroksjöbo	Low plateau with low and short DID (some POSTC); the ridges mostly lie on the W. side (towards the ice movement); on the E. side hummocky moraines are partly found (cf. the Emmaboda area).

Table 4. The Falbygden area.

1 Broddetorp	On the W. margin of Billingen, approximately at the limit between Cambrian sandstone and alum shale; N. of the church, two POSTC and two DR, all irregular, indistinct; to the south, seven DR, levelled and usually with steep an short proximal sides; the two ridges beside river Flian most distinct due to river erosion of the depression in between; TS (long side of S. ridge at Flian, digging 1,5 m).
2 Rådene N.	Two POSTC on each side of the outlet of L. Simsjön, comparatively steeply sloping, irregular; TS (distal part of W. ridge, digging 1,6 m); on both sides of them, some protruding till concentrations, probably beginning similar ridges.
3 Borgundaberget	Short and broad PREC, mostly at W. corner of the height; long, steeply out-gliding POSTC with steep long sides, in distal part divided into three lobes (most distally almost complete ridges); immediately to E., a small, lower-lying side DR (not inserted); E. of this plateau, there are some small and irregular ridges which may be characterized as radial moraines rather than real DR (two inserted); TS (top of proximal part of POSTC, road cutting 1,6 m, and long side of distal part of it, digging 1,5 m).
4 Jättene	Broad and steep, proximal LID, divided into three lobes (beginnings of real ridges?).

5 Ravelstorp	Great POSTC at W. corner of Mösseberg; centrally and distally divided into two ridges; the W. of them highest and proximally more distinct, distally more irregular; the E. of them flatter and distally more distinct; TS (middle part of W. ridge, road cutting 1,7 m).
6 Skyberg	Comparatively irregular POSTC at E. corner of Mösseberg; between it and the former ridge, small protruding lobes (beginning ridges?).
7 Odenskullen	A high radial moraine rather than a real DR but in parts with beginning drumlin form — high, more irregular, proximal part (rock?), levelled, more out-gliding, distal part; this ridge is included as an example of a probable drumlin in progress.
8 Näset	DR with upward-gliding proximal side, distal crest and short and steep distal side; levelled W. long side, more irregular E. long side; small and irregular proximal DR.
9 Tomten	Distinct DID, proximally divided into two short and steep lobes (the E. with rock), undulating top surface, steep distal slope; TS (proximal side, gravel pit 1,9 m); low DR proximally W., mammillary hill proximally E.
10 Långholmen	Three small, low and plane DR in succession, displaced.
11 Flaka	Two long, low and arched DR with somewhat steeper distal slopes; the distal one centrally divided into a higher middle "ridge" and two small side "ridges", the E. of which is fused with the large, proximal DR; a short and low DR, proximally of the latter (outside Ålleberg).
12 Ålleberg	At the W. corner of the height, a short POSTC, distally partly double; centrally and at E. corner of it, a long and high POSTC, steeply sloping proximally and in the middle, planer distally but with two low crests; levelled W. long side, undulating E. long side with some hills from the deglaciation; distally to W., two low, isolated, side DR.
13 L. Hallan	Two long and low DR; the S. displaced to E. and with distal crest, the N. displaced to W. and with proximal crest; out-gliding short sides towards each other.
14 Hovmene	Nine DR in group; the five S. ones higher, the four N. ones lower but with steeper proximal sides; the long S. one apparently composed of two ridges in succssion but almost totally fused; the two centrally W. displaced but somewhat fused; of the four N. ones, two and two in succession fused but also two and two in parallel fused; TS (distal side of southernmost ridge, road cutting 1,6 m).
15 Gisseberget	Broad, steeply sloping POSTC; TS (distal side, digging 1,5 m).

Table 5. The Kinnekulle area.

1 N. of the peak	18 PREC of small to intermediate dimensions; the N. and lower of them distally merge into the till slope, the uppermost are directly connected to the peak; the depressions between the former, comparatively deep and typically U-shaped, those between the latter ridges are shallower and narrower, but nearly all were used by meltwater during the deglaciation; the proximal sides, especially of the lower ridges, comparatively short and steep; mixed till throughout.
2	The large till section described by the author in 1969.
3 S. of the peak	Three large POSTC; the W. and E. of them directly connected to the peak, the former more rounded, the latter more irregular but both comparatively high, narrow and steeply downward-sloping, partly in steps; the central ridge with a transverse depression towards the peak is proximally very high and partly double, distally it is only one long, low and narrow ridge; shale-diabase till with many boulders.
4 Stenåsen	Isolated ridge in continuation of the depression between the central and eastern POSTC; distally, comparatively plane, "whole" ridge; proximally, markedly lower (bottom ridge) but with 5—6 tops of boulder heaps; somewhat more irregular boulder orientation in this bottom ridge; coarse diabase-shale till but nearly all boulders of diabase.
5 W. and E. of the peak	Isolated side DR on the even limestone terraces on both sides of the peak; mostly low, narrow but locally comparatively long; sometimes fused proximally; the inner ridges more typical DR, often with ideal form; the outer ridges always lower, locally only longitudinal undulations of till; a few with somewhat different orientation; mostly mixed till but locally with greater quantities of sandstone (or limestone).

Table 6. The Närke area.

1 Hidinge	Two POSTC, irregular on the whole but with comparatively plane surfaces and steep distal slopes.
2 Knista	Group of six DR; one great proximal ridge with proximal crest and surrounded by four small side DR, the two N. of which fused with the great DR, the two S. free from it but fused

	together; distally one long DR, divided into a proximal "peaked" part, a more irregular central part and a comparatively plane distal part (two ridges fused?), the proximal short side more gradually ascending, the distal short side steeper and shorter.
3 Magria	Marginal DR (DID), distally divided into two "ridges", the E. of them partly passing over into a more distal DR; steep W. long side, low E. long side; TS (proximal long side, road cutting 1,7 m).
4 Granhammar	Short and broad PREC with steep proximal side.
5 Ingelstorp	DR with central crest, steep and undulated E. long side, more levelled W. long side with lower side DR; TS (central summit, road cutting 1,4 m).
6 Riseberga	High, levelled DR (DID) with steep proximal side, steep but somewhat out-gliding distal side; E. long side steep, W. long side with undulating, lower-lying side DR; some low, longitudinal undulations proximally (beginnings of new ridges?); TS (proximal part of W. side DR, road cutting 1,5 m).
7 Välanda	Group of eight DR; proximally four, isolated mammillary hills, displaced; centrally one long DR with proximal crest and distally out-gliding between two DR with central crests; to W. of them, one low and narrow, isolated, side DR; TS (proximal part of central ridge, digging 1,5 m); immediately to S. (Logsjö) a small DR, irregular and with two proximal crests (in progress?).
8 Västkärr	Group of four proximal DR, irregularly placed and five distal DR, in parallel and the three SW. ones partly fused; the E. ridges are lower, narrower and more levelled, the W. are somewhat higher and less regular.
9 Tångeråsa Trystorp	Some longitudinal undulations on E. margin of a low plateau — "drumlinized" till or real pre-ridges (not inserted).
10 Gräfsta	Two parallel DR, proximally less regular (especially the eastern), centrally and distally well developed ridges (especially the western).
11 Kvisserud	Two long, parallel DID (type B as coarse, nearly unsorted, glacifluvial material exists on the W. long sides); the E. ridge proximally connected to a small height; the western with proximal and distal tops, somewhat displaced (two original ridges fused?); TS (proximal side of W. ridge, gravel pit 2,3 m).
12 Via Hervesta	Group of two large DR with seven small DR between and beside (not all inserted); the latter ridges always displaced, well levelled and with plane surfaces and comparatively similarly shaped long sides; the E. great ridge is long, low, narrow and plane, the western is higher, broader and more undulating; both have proximal crests and steeper W. long sides; TS (E. long side of W. great ridge, digging 1,5 m).
13 Näsby	Long DR, divided into a N. and S. part, somewhat displaced; the northern is more irregular on the whole and has steeper, undulating E. long side, more levelled W. long side with a small, lower-lying "ridge"; the southern part is a well-formed DR with plane surface and both long sides well levelled (probably two ridges fused; the northern somewhat younger?).
14 Hardemo	DR with higher proximal part (rock?), lower and longer distal part, more irregular; all sides comparatively steep; TS (W. long side, digging 1,5 m).
15 Öja mosse	Long and narrow ridge with comparatively plane surface, esker-like but till up to at least a depth of 1,5 m; to SE. (Glippsta) two low "ridges" with all sides out-gliding (longitudinal undulations rather than real DR).
16 Öja	Group of two large DR proximally; the western with proximal crest and fused with a small side DR; the eastern being higher but more plane; distally a new DR beginning between the two former.
17 Bärsta Vilsta	Two parallel, isolated DR of intermediate dimensions and very similar in all features; proximal crests, steep proximal sides, more out-gliding distal parts, W. long sides more irregular, E. long sides more levelled; some small mammillary hills distally.
18 Hackvad	Two parallel DR; the western very low and narrow and with plane surface; the eastern somewhat higher, more undulating and with steeper long sides; TS (distal part of E. ridge, gravel pit 2,0 m).
19 Helgesta Värnsta	Three large DR with comparatively different shape; the W. one is highest, has steep W. long side, more undulating E. long side and both proximal and distal crests; the central ridge is the most irregular and has partly two proximal crests; the E. DR has a well-formed proximal part, a more undulating and longer distal part, somewhat displaced (two ridges?); between the W. and central ridges there are three low and narrow DR in succession.
20 Alavi	Long DR of nearly ideal form, surrounded by five small, isolated DR (two proximally, three to E.).
21 Gullberga	Two parallel DR, partly fused distally; steeper W. long sides; W. ridge higher; TS (proximal side of W. ridge, road cutting 1,7 m).
22 Hageberg Vallby	Five, comparatively high mammillary hills, isolated, displaced; the three proximal ones in a triangle.
23 Körlingsberg	Three broad, arched but low DR on comparatively even ground.

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