1:200 000 was based on the Danish national grid, and so was the topographic series at scale 1:20 000. The former army map edition 1:20 000 with the 1-km national grid was used for plotting the basic tematic data; it provided a sufficiently detailed map for the field work, and the scale reduction from 1:20 000 to 1:200 000 was immediately suitable for EDP due to the mathematical consistency between the two series. Having at disposal an automatic flat-bed plotter (a KINGMATIC) fully equipped with scribing tools, it furthermore became possible to combine the automatic scale reduction of the generalized data with a direct scribing of the colour plates.

For printing the five tematic shades the 3-colour technique was chosen and this influenced greatly the final output of the cartographic processes. For connecting the printing plates with the initial colour plates the flow-diagram shown in fig. 1 was elaborated. This represents a compromise between the wide range of available reproduction materials and -methods and the technical aspects of automatic scribing.

These technical aspects of the automatic scribing and the screencopying as well were also considered when the total number of tematic data was sorted up into 6 specific sections, each corresponding to one of the 6 scribings shown in fig. 1, upper line. Thus the EDP sorting-up procedure — and before this the digitizing procedure was influenced directly by the selected cartographic techniques.

A coordinated planning covering all aspects of a specific cartographic task may save a lot of time and money and add to a better mutual understanding between author and cartographer to the benefit of tematic cartography.

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GENESIS OF LAYERED LATERAL MORAINES
Implications for palaeoclimatology and lichenometry

OLE HUMLUM

Humlum, Ole: Genesis of Layered Lateral Moraines: Implications for Palaeoclimatology and Lichenometry. Geografisk Tidsskrift 77:65–72. København, June 1, 1978.

From the eastern Alps, three localities are described with lateral moraines of a typical layered structure with alternating zones of high and low block content; the origin of the structure is discussed. Attention is drawn to the potential palaeoclimatic significance, and difficulties in connection with lichenometric dating are discussed.

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Lateral moraines are associated with valley glaciers and are formed by the deposition of material along the lateral margins of glaciers below their equilibrium line. Several mechanisms of deposition operates, and, depending *inter alia* on relief, climate and degree of glacial activity, lateral moraines may vary greatly in character from region to region.

The purpose of the present paper is to describe a type of lateral moraines characterized by a layered internal structure and to comment on the genesis of these moraines. Layered lateral moraines are usually large and very conspicuous, and their stratification have undoubtedly been noted at several earlier occasions (see e.g. Galloway 1956 and Vivian 1975, p. 425), but according to the author's knowledge no discussion on the origin of the layered structure *per se* seems to have been published.

Lateral moraines are among the most well-defined landforms in mountains former or recently experiencing valley-glaciation, and lateral moraines are therefore often used in connection with dating of the geomorphological history in these areas. Several dating methods are currently in use (see e.g. Andrews 1975), but during the last decade dating by lichenometry (Beschel 1950), has become increasingly common, as this is a cheap method demanding only a minimum of equipment. However, in lichenometry several botanical and geomorphological pitfalls exist, which, if not recognized, may lead to serious misinterpretations, and in the last section of this paper, a geomorphological appraisal of the suitability of lichenometric dating of layered lateral moraines will be presented.

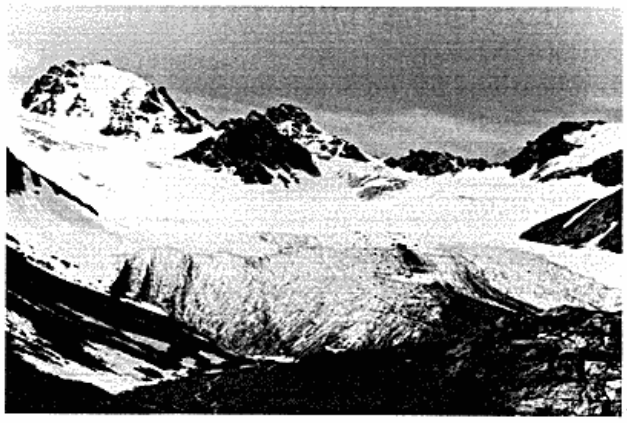

Fig. 1 Jamtal Ferner, viewed from the right 1860-lateral moraine towards SSW (1977). In the left background is seen the top Vordere Jamtal Spitze (3178 m). Note medial moraines on the glacier surface.
Fig. 1. Jamtal Ferner i Silvretta Alperne, Østrig, set mod SSV fra gletscherens højre 1860-sidemoræne. Til venstre i baggrunden ses Vordere Jamtal Spitze (3178 m). Bemærk midtmoræenerne på gletschertungen. August 1977.

Fig. 2. Proximal side of the right lateral moraine at Jamtal Ferner. Note the layered structure visible in the profile, which is about 25 m. high.
Fig. 2. Indersiden af Jamtal Ferners højre sidemoræne. En lagdelt struktur ses i profilet, der er ca. 25 m højt.

OBSERVATIONS ON LAYERED LATERAL MORAINES

The glacier Jamtal Ferner (fig. 1; the word »Ferner« meaning »glacier« in part of the eastern Alps — coming from the old High German word »Firn«) is a valley glacier in the Silvretta Alps in the western part of Austria.

Jamtal Ferner is surrounded by high rock walls and carries material supraglacially in medial moraines. Only a minor amount of material seems to be transported in an inglacial position, and the basal load is confined to a glacier sole not thicker than 0,2-0,4 m. Since c. 1860, this glacier has melted about 1700 m back, leaving a foreland deliminated by distinct lateral- and terminal moraines (see Vorndran, G. 1968 and Vorndran, E. 1969).

The proximal side of the lateral moraines, which are about 50-100 m high, is frequently experiencing small landslides and fresh profiles are permanently maintained in this way. At several places a conspicious layered structure appears in the profiles, consisting of zones with alternating high and low content of large blocks (fig. 2). The layering is subparallel to the crest of the lateral moraine. Visually judged, most of the large blocks in the block-enriched zones appear to be orientated with their a-b-plane parallel to the distal slope of the lateral moraine.

A similar layered structure is seen in the lateral moraines of the glacier Guslarferner in the Ötztaler Alps, also in Austria. The layering is especially distinct in the left lateral moraine (fig. 3), where furthermore abundant large blocks exposed in the proximal slope generally are orientated with their a-b-plane parallel to the distal slope of the moraine. This tendency towards parallelism with the distal slope is especially pronounced for blocks found in the block-enriched zones. The layering is subparallel to the moraine crest, and only few blocks found in block-enriched zones display signs of glacial abrasion (stria, shattermarks etc.). Guslarferner is currently transporting material supraglacially in medial moraines, while inglacial transport and transport at the glacier sole quantitatively seems to be of less importance. Especially the left part of the glacier is supplied with talus from the surrounding high rock walls.

Layered lateral moraines have been observed by the author at several other localities in the Alps; both in Switzerland (Gornergletscher and Oberaletschgletscher) and in Austria (Diemferner, Zulzenauferner and Wildgerlos Kees). The observations made at these localities all are very similar to those presented above, and at this place only one further locality should be described in some detail.

The glacier Waxeggkees (fig. 4) in the southern Zillertaler Alps, Austria, has long been known for its fast reactions on climatic changes (Heuberger 1977). Around 1850 this glacier reached the bottom of the valley Zemmgrund and was at this time confluent with the neighbouring glacier Hornkees. Since then both glaciers have melted substantially back, with only two small readvances terminating around 1902 and 1923 (Heuberger 1977). After 1960, however, Waxeggkees has advanced about 200 m, and is apparantly continuing this advance today.

As was the case at the other localities mentioned earlier in this paper, the glacier Waxeggkees carries material supraglacially in medial moraines, whereas both inglacial transport and transport in the glacier sole seems to be of minor importance only.

The foreland of Waxeggkees is delimitated by large lateral moraines (fig. 4), which displays a very clearly

Fig. 3. Left lateral moraine at Guslarferner. Note the number of large blocks pointing out of the proximal (to the right) side of the moraine. About a third down the proximal side a block-enriched zone can be seen.

Fig. 3. Guslarferners venstre sidemoræne (Ötztaler Alperne, Østrig). Mange store blokke ses at pege skråt udad-opad morænens inderside (til højre). Omtrent en trediedel nede ad indersiden ses et blokrigt bånd.

Fig. 4. Waxeggkees viewed towards SSW (1977). Above the glacier, the top Grosser Möseler (3478) is seen. Note the large lateral moraines, which delimits the area covered by the glacier around 1850. Furthermore, two small moraine systems dating from 1902 and 1923 are seen, halfway down the valley.

Fig. 4. Waxeggkees i Zillertaler Alperne, Østrig, set mod SSV. Over gletscheren ses toppen Grosser Möseler (3478 m). Foran gletscheren ses store sidemoræner, der afgrænser området som var dækket af gletscheren i 1850. Mellem sidemorænerne ses mindre endemoræner fra henholdsvis 1902 og 1923. August 1977.

layered structure (fig. 5). The stratification is made up by zones of alternating great and small content of large blocks. Further, due to the considerable height of the moraines (c. 150 m), it was possible to judge the validity of the impression gained at other localities; the layering being subparallel to the moraine crest, inspected in profiles parallel to the crest.

As can clearly be seen from fig. 5, this first impression only holds for the upper part of the moraines at Waxeggkees, the individual layers progressively dipping steeper and steeper away from the glacier in the lower part of the profile. Moreover, by closer inspection, the upper layers in the profile are seen to meet the crest of the moraine at a small angle, that is, the crest is in the case at Waxeggkees *not* perfectly parallel to the upper layers either.

Many large blocks in the moraines are orientated with their a-b-plane parallel to the distal slope, and, inspected in profiles normal to the moraine crest, the same holds good for the individual layers in the stratified internal structure (fig. 6). Most blocks are either angular or subangular, and only few display signs of glacial abrasion.

ORIGIN OF THE LAYERED STRUCTURE

All glaciers observed with forelands delimitated by layered lateral moraines were characterized by supraglacial transport apparantly dominating quantitatively in comparison with both inglacial transport and transport in the glacier sole.

Furthermore, only a subordinate part of blocks in the block-enriched zones showed clear signs of glacial abrasion, and visually judged, both the a-b-plane of large blocks in the lateral moraines as well as the individual layers tend to be parallel to the distal slope of the moraine ridges.

There is general agreement on the concept that lateral moraines are produced by dumping of material along the lateral margins of valley glaciers, but there is less agreement about the relative importance of material derived from the rock walls above the glacier and material derived from the glacier itself (Price 1973).

Some fundamental inferences about the genesis of the layered structure found in some lateral moraines can be drawn from the characteristics presented above. I would suggest that layered lateral moraines are dominated by material derived from rock walls above the glacier, and that each block-enriched layer developed during a period with frequent rock falls on the glacier surface from rock walls above the equilibrium line (lateral moraines are usually formed only below the equilibrium line). During these periods, the glacier probably transported exceptionally large amounts of supraglacial material, which subsequently was dumped along the glacier margins to form the block-enriched zones today visible in lateral moraines. Each layer in the moraines thus represents an old distal surface inclined away from the glacier at the angle of repose. This interpretation also explains the preferred orientation of the a-b-plane of individual blocks found in layered lateral moraines.

It is somewhat more difficult to explain the origin of the more fine-grained layers. These may well consist of a mixture of material derived partly from rock walls above the glacier, partly from the glacier itself. However,

Fig. 5. The proximal side of the right lateral moraine at Waxeggkees. A layered structure is clearly seen in the section, which is about 100 m high. Note that the layering gradually becomes more steeply inclined in the lowermost part of the profile. Glacier movement from the right.
Fig. 5. Indersiden af højre sidemoræne ved Waxeggkees. En lagdelt struktur ses tydeligt i profilet, der er ca. 100 m højt. Lagdelingen hælder stejlest i profilets nederste del. Gletscherbevægelse fra højre mod venstre.

dumping from the convex glacier surface on to the ice free areas along the margins is expected to be the final depositional event, and I reject the contention of Galloway (1953, p. 732) that the internal fabric of lateral moraines should reflect an inglacial fabric in the glacier tounge.

Accepting the hypothesis outlined above, moraine-building periods must have been periods of large glacier volume, as the glacier surface must have been at least as elevated as the moraine ridges to make the dumping mechanism possible. The proposed development of a layered lateral moraine is outlined in fig. 7. This interpretation brings along two conclusions: A) Layered lateral moraines are gradually being built up the valley slopes, and B) A higher and higher glacier surface is needed to supply further material to the distal slopes of existing lateral moraines.

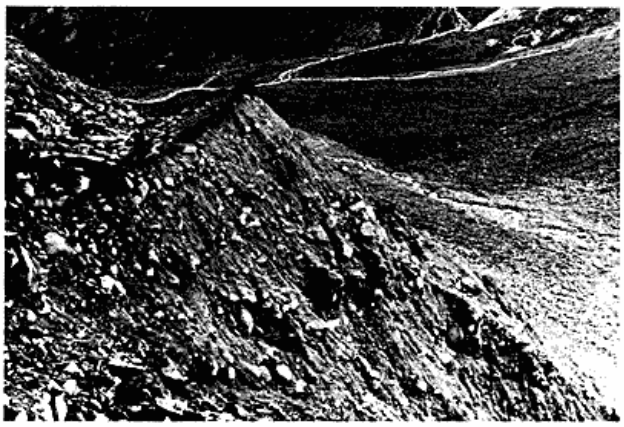

Fig. 6. Transversal section in the left lateral moraine at Waxeggkees. The zone with abundant large blocks dips outward from the glacier foreland, parallel to the distal slope of the moraine. Note the person standing left of the moraine for scale.
Fig. 6. Profil tværs gennem den venstre sidemoræne ved Waxeggkees. E af de blokrige bånd er gennemskåret og det ses, hvordan båndet gælder parallelt med morænens yderside (til venstre). Størrelsesforholdene angives af personen, der står til venstre for morænen.

AGE OF LAYERED MORAINES IN THE EASTERN ALPS

According to the hypothesis explaining each layer in layered lateral moraines as old distal slopes, individual layers must roughly correspond to former glacier surface profiles when inspected in longitudinal profiles as shown in fig. 8. This also implies that a considerable time-span may have passed between deposition of the lowermost layers and the uppermost layers in lateral moraines of this type.

The work of Patzelt and Bortenschlager (1973) has shown that glaciers in the eastern Alps were reduced to their present dimensions as early as 9500 ± 200 years B.P., and that during the Holocene they have never significant extended beyond the limits set by the large moraine systems typical found in front of the recent glaciers. Furthermore, as a general rule, these moraines appear to have been founded in the Early Holocene.

Historical reports tell us that most alpine glaciers reached the crest of their large lateral moraines several times during the period ca. 1600-1860 (the Little Ice Age, fourth phase of Neoglaciation cf. Sugden and John 1976). At least parts of the distal slope of these moraines may therefore be of this young age. On the other hand, according to the work quoted above, the oldest part of these large moraine systems was laid down in connection with glacier advances in the early Holocene, and the internal structure of the moraines may thus in one way or another reflect major geomorphological events during almost the whole of Holocene.

PALEOCLIMATIC IMPLICATIONS

A considerable proportion of the material in layered lateral moraines may have an origin as rock-fallen material according to the hypothesis presented in this paper. Combined with the assumed long period elapsed during development of the present moraine systems, this represents a potential possibility to determine the minimum number of periods during the Holocene characterized by a high rock-fall activity, as several of these periods may have been recorded in layered lateral moraines as block-enriched zones. However, the reader is forewarned that this section presents interpretations of increasingly speculative nature.

Höllermann (1964) emphasizes the importance of frost weathering for the mechanical disintegration of rocks in mountains raising above the local snow line. He further states that the existence of a persisting cover of snow or ice

tend to inhibit the production of talus. The same conclusion is reached by Vorndran (1969), who draws attention to the connection between production of talus and the frequency of temperature changes across 0°C (German: Frostwechsel) measured at the rock surface.

Vorndran states that the height in which the maximum number of 0°-crossings (freeze — thaw shifts) is encountered in air varies with time of the year — much the same as the freezing level does. Two levels — one low (winter) and one high (summer) — experience particularly many 0°C-crossings each year due to this movement, and the mechanical disintegration should accordingly be at maximum at these levels. However, only the summer level is morphological active, because the level which encounters the winter-maximum usually at this time has a protecting blanket of snow, whereas even the highest rock walls looses much of their protecting snow each summer, thus causing the summer-maximum to occur in a level with partly non-protected rock walls.

In order to produce large amounts of talus from rock walls above a glacier, the absolute height of these rock walls must coincide with the level for summer-maximum of 0°C-crossings. Any other situation, either cooler or warmer, will tend to depress the intensity at which the glacier surface is supplied with rock-fallen material.

As mentioned earlier, a necessary condition for lateral dumping to take place along a glacier tongue is that the glacier surface is at least as elevated as the crest of the lateral moraines. This condition may be fulfilled during a glacier advance caused by positive mass balance, while the glacier surface will sink below the crest of adjoining lateral moraines during periods of retreat. That is, dumping of material on lateral moraines will normally occur only when a glacier gains a larger volume, and consequently, the deposition of talus-dominated zones in layered lateral moraines is generally thought to indicate a shift towards climatic conditions more favourable for glaciers — the talus material mainly being produced while the level with summer-maximum of 0°C-crossings coincides with the rock walls above the glacier during the general downward movement of this level. Depending upon the relative and absolute height of rock walls above a glacier, the period with maximum talus production will occur during a long or short period, early or late in a period of general climatic deterioration. It should further be stressed, that only a part of the total number of periods with large talus production will be recorded in layered lateral moraines due to the glacier surface moraine crest constriction mentioned above.

Assuming the moraine-building process to be intermittent, layered lateral moraines may yield a basis for an absolute dating of rock-fall activity during the Holocene, as old soils developed on the moraine during periods of relative warmth later may have been buried beneath younger deposits. Several examples of fossil soils found in

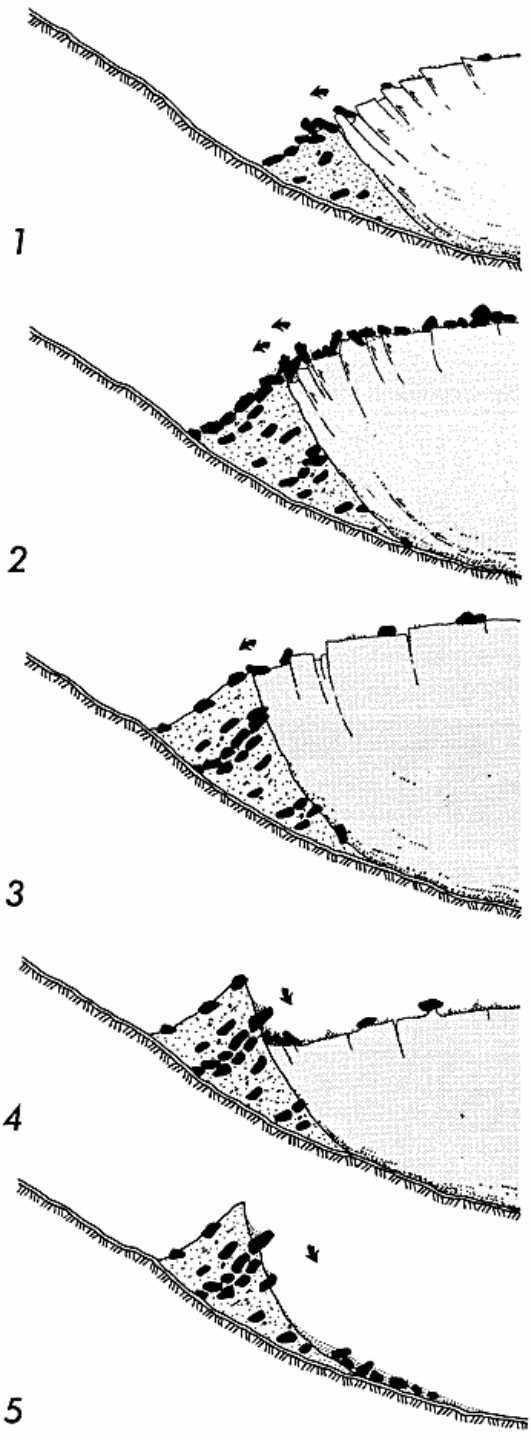

Fig. 7. Inferred development of a layered lateral moraine as seen in transversal section. The glacier advances from 1 to 3 and recedes from 3 to 5. Note how a block-enriched zone is deposited during period 2 by dumping of abundant large blocks from the glacier surface.
Fig. 7. Formodet udvikling af en lagdelt sidemoræne. Snit vinkelret på gletscherens længdeakse. Gletscheren avancerer fra situation 1 til 3, og smelter tilbage fra 3 til 5. Et blokrigt bånd aflejres i situation 2 ved aflæsning af mange store blokke fra gletscherens overside.

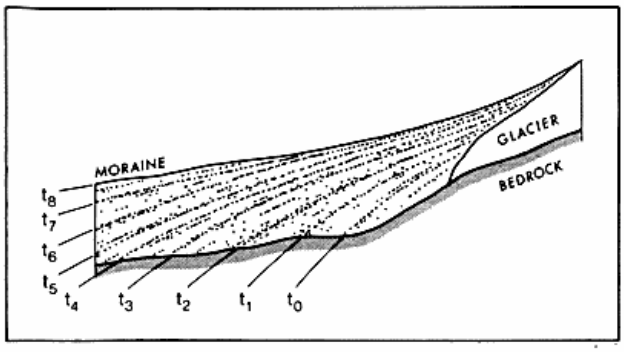

Fig. 8. Idealized representation of the stratification in layered lateral moraines. Longitudinal section. Block-enriched zones of different ages are indicated with progressively younger ages from tO to t8 (recent).
Fig. 8. Idealiseret gengivelse af strukturen i lagdelte sidemoræner. Alderen af de blokrige bånd er angivet med aftagende alder fra t0 til t8 (recent).

Fig. 9. Large block (c.4.5 m long) with right half overgrown with lichens, laying on an active medial moraine on the glacier Längentaler Ferner. Largest circular individual of *R. goegraphicum* was 62 mm in diameter.
Fig. 9. En stor blok (ca. 4,5 m lang), hvis højre halvdel er bevokset med laver, liggende i en midtmoræne på gletscheren Längentaler Ferner, Stubaier Alperne, Østrig. Det største cirkulære individ af Riczocarpon geographicum var 62 mm i diameter.

lateral moraines are given by Heuberger (1966), Patzelt and Bortenschlager (1973) and also by Metz and Nolzen (1973).

LICHENOMETRIC DATING OF LAYERED LATERAL MORAINES

The dating of layered lateral moraines by lichenometry is considered unsafe, unless at least two phenomena related to geomorphological events are recognized.

The first condition which concerns lichenometric dating lies in the deduced dumping of supraglacial material on layered lateral moraines. Originally, it was assumed (Beschel 1961) that blocks transported by glaciers would initially be free of lichens at the time of deposition. This basic assumption was later questioned by Mattews (1973), who found several blocks with lichens on an active medial moraine on the glacier Storbreen, Norway. Also the present author has in a few occasions found supraglacial blocks with living lichens, as shown by figure 9, showing a large block partly lying on the glacier Längentaler Ferner, Stubaier Alps in Austria, overgrown with lichens. This block obviously originated from a high rock wall above the eastern part of the glacier, as the diameter of the largest individual of the crustose lichen *Rhizocarpon geographicum* was 62 mm, which in this area indicates an age in excess of hundred years, thus far exceeding the probable length of the blocks' supraglacial history, the Längentaler Ferner only being c. 1,2 km long.

If blocks with living lichens were to be dumped on a lateral moraine, they could cause an overestimation of the age of the moraine. Because the deposition of supraglacial material is expected to be particularly abundant on layered lateral moraines, the possibility of incorrect dating by use of the largest lichen diameter encountered will be correspondingly large in this case. One way to meet this difficulty should be to isolate »old« lichens by applying size-frequency analyses on lichen populations from adjacent sites as demonstrated by Benedict (1967) and Matthews (1973).

The second problem met by lichenometrical dating of layered lateral moraines once again must be attributed to the assumed importance of deposition by dumping. It has earlier been mentioned, that during the development of layered lateral moraines a higher and higher glacier surface is needed to supply new material to the distal slope of the moraine. That is, with time it becomes increasingly difficult for the glacier to dump further material on the moraine. Therefore, in some cases only the uppermost part of the distal slope displays an age corresponding to the time of the latest glacier advance (fig. 10), or may even display a lichenometric age at the crest far exceeding the age of the latest glacier advance if virtually no dumping took place.

To sum up, the lichenometric dating of layered lateral moraines by use of the largest lichen may lead to serious overestimation of the age of the latest glacier advance in the area under investigation. Therefore, detailed geomorphological mapping of layered lateral moraines plus size-frequency analyses of lichen populations should be carried out as a basis for establishing the chronology of the geomorphological history of an area by means of lichenometry.

SUMMARY AND CONCLUSIONS

1: Layered lateral moraines observed in the Alps are today associated with valley glaciers apparently transporting larger quantities of material supraglacially than inglacially.

2. Block-enriched zones in layered lateral moraines are

Fig. 10. The distal slope of the left lateral moraine at Guslarferner, Ötzaler Alps, Austria. The moraine ridge is 5-15 m high. Only the uppermost part of the distal slope has a lichenometric age corresponding to the latest glacier advance around 1845, whereas the lower part plus the small ridge consisting of large blocks in the foreground has a lichenometric age corresponding to an earlier advance culminating in 1771. The right lateral moraine is seen in the background.
Fig. 10. Ydersiden af den venstre sidemoræne ved Guslarferner, Ötztaler Alperne, Østrig. Set fra denne side er morænen 5-15 m høj. Kun den øverste del af morænens yderside har en lichenometrisk alder svarende til den seneste maximalstand i 1845, mens den resterende del af skråningen samt den mindre vold af store blokke i forgrunden har en lichenometrisk alder svarende til en tidligere maximalstand i 1771. Gletscherens højre sidemoræne ses i baggrunden.

dominated by rock-fallen material originating from rock walls above the glaciers, and layered lateral moraines seems essentially to be deposited by the dumping of supraglacial material.

3. Layered lateral moraines in the eastern Alps (and possible also in other areas of the Alps) appear to have been founded in Early Holocene, and the layering may represent a more or less complete record of climatic variations during the Holocene.

4: Lichenometric dating of layered lateral moraines may yield erroneous results, unless detailed geomorphological mapping of the moraines plus size-frequency analyses of lichen populations are carried out.

RESUME

I artiklen beskrives en særlig type sidemoræne, som er iagttaget ved flere gletchere i Alperne. Denne morænetype er karakteriseret ved sin størrelse (ofte mere end 100 m høj), samt ved en iøjnefaldende lagdelt indre struktur. Som følge af det sidstnævnte karakteristika omtales morænetypen i artiklen som »lagdelte sidemoræner«.

Lagdelingen i lagdelte sidemoræner udgøres af bånd med skiftevis stort og lille indhold af store blokke (Fig. 5). I tværsnit ses båndene at hælde parallelt med morænens yderside, ligesom også hyppigt de enkelte store blokke i blokrige bånd er orienteret på tilsvarende vis. Kun undtagelsesvis viser blokkene tydelige tegn på gletscherpåvirkning (skurestriber, seglformede brud osv.).

De lagdelte sidemoræner træffes i forbindelse med gletschere, der i dag synes at transportere mere materiale supraglacialt end inglacialt. Også materialetransport i gletschernes sål er beskeden. Lagdelte sidemoræner formodes derfor hovedsageligt at være opbygget af materiale, der er transporteret supraglacialt, og som er resultatet af bjergskred fra de omgivende bjergsider. Det nedstyrtede materiale føres ned i gletscherens ablationsområde, hvor det skrider ned fra gletschertungens konvekse flanker, og derved danner volde langs gletscheren under ligevægtslinien. De enkelte bånd i lagdelte sidemoræner kan således opfattes som gamle ydersider, der senere er begravet og nu kikker igennem på sidemorænernes inderside. Specielt menes de blokrige bånd at være aflejret i perioder, hvor bjergskredsaktiviteten har været særlig stor fra bjergsiderne over gletschernes akkumulationsområde.

Tidligere undersøgelser i Østrig har vist, at de store morænesystemer som ses foran de fleste gletschere i Østalperne, allerede grundlagdes kort efter istidens ophør, og at gletscherne i de sidste ca. 9500 år ikke på noget tidspunkt har overskredet disse morænesystemer i nogen væsentlig udstrækning. Dette resultat åbner sammen med den ovennævnte tolkning af lagdelte sidemoræners dannelse mulighed for at detaljerede studier af den indre struktur i lagdelte sidemoræner kan give oplysning om minimumsantallet af klimaperioder i løbet af holocæn, hvor klimaet har forårsaget stor hyppighed af bjergskred. Påvisning af begravede forvitringsoverflader med organisk indhold i lagdelte sidemoræner vil endvidere give potentiel mulighed for absolut datering af perioderne med stor bjergskredshyppighed fra de omgivende fjelde.

I løbet af de seneste 25 år er datering ved hjælp af lichenometri (dvs. aldersbestemmelse på grundlag af størrelsen af bestemte lavarter) blevet mere og mere almindelig i geomorfologiske undersøgelser, og et meget anvendt dateringsobjekt specielt i geomorfologisk-klimatologisk sammenhæng er naturligvis morænesystemer. Derfor er der grund til at påpege, at netop som en følge af den formodede dannelsesmekanisme af lagdelte sidemoræner kan traditionel lichenometrisk datering af denne morænetype give en alder væsentligt højere end den seneste maximalstand for områdets gletschere. Årsagen hertil er dels faren for at laver oprindeligt voksende på en fjeldvæg kan overleve et styrt ned på gletscheren samt den efterfølgende transport frem til aflejringsøjeblikket på en sidemoræne, dels muligheden for at intet eller kun lidt materiale er aflejret på morænen i forbindelse med gletscherens seneste maximalstand. Det sidstnævnte forhold er et resultat af lagdelte sidemoræners tendens til at flytte gradvis sidelæns opad bjergsiderne, hvorfor der kræves en stadig tykkere og tykkere gletschertunge for at sikre fortsat aflejring af nyt materiale på denne morænetype.

ACKNOWLEDGEMENTS

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ET FORSØG PÅ EN KLIMATISK-HYDROLOGISK REGIONSINDDELING AF HOLSTEINSBORG KOMMUNE (SISIMIUT)

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Hasholt, B. & H. Søgaard 1978: Et forsøg på en klimatisk-hydrologisk regionsinddeling af Holsteinsborg kommune (Sisimut). Geografisk Tidsskrift 77: 72-92. København juni 1, 1978.

The Holsteinsborg municipality (Sisimut) has been divided into climatic and hydrological regions. The investigation is of a preliminary character due to the limited possibilities for field work.

The regionalization is based upon selected climatological and hydrological parameters; these were primarily snow cover (precipitation), potential evapotranspiration, run-off, and temperature. Measurements of water quality have been used as indicator of the aridity in the area.

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Indledning

Fredningsudvalget for Grønland ønskede at gennemføre en registrering af naturressourcer og bevaringsværdige områder i Grønland. Forud for en generel registrering valgte man at foretage en forsøgsmæssig undersøgelse af en enkelt kommune, således at erfaringerne herfra evt. kunne danne grundlag for en senere generel kartering. I forbindelse med tilrettelæggelsen af undersøgelsen blev der lagt vægt på, at den skulle baseres på allerede indsamlet materiale i form af litteratur, kortmateriale og flyvebilleder. Der har derfor ikke været midler til rådighed til egentligt feltarbejde. Herværende forsøg på en regionsinddeling er fremkommet som et delresultat af ovennævnte undersøgelse. Den er således primært baseret på tilgængeligt materiale, som ofte er meget sparsomt. De 14 dages feltundersøgelser har derfor fortrinsvis været anvendt til en besigtigelse af området og til et strengt nødvendigt antal målinger for at kunne kontrollere hypoteser og fremkomme med kvantitative udsagn. Forfatterne er fuldt ud klar over de begrænsninger, som de mangelfulde feltundersøgelser indebærer. Når de fundne resultater alligevel fremlægges, er det, fordi de i vid udstrækning synes at bekræfte hinanden og være i god overensstemmelse med fx botaniske undersøgelsers resultater. De anvendte undersøgelsesmetoder har vist sig frugtbare og den fundne regionsinddeling vil kunne danne grundlag for videregående undersøgelser med anvendelse af bedre tekniske hjælpemidler.

Fig. 10. The distal slope of the left lateral moraine at Guslarferner, Ötzaler Alps, Austria. The moraine ridge is 5-15 m high. Only the uppermost part of the distal slope has a lichenometric age corresponding to the latest glacier advance around 1845, whereas the lower part plus the small ridge consisting of large blocks in the foreground has a lichenometric age corresponding to an earlier advance culminating in 1771. The right lateral moraine is seen in the background.
Fig. 10. Ydersiden af den venstre sidemoræne ved Guslarferner, Ötztaler Alperne, Østrig. Set fra denne side er morænen 5-15 m høj. Kun den øverste del af morænens yderside har en lichenometrisk alder svarende til den seneste maximalstand i 1845, mens den resterende del af skråningen samt den mindre vold af store blokke i forgrunden har en lichenometrisk alder svarende til en tidligere maximalstand i 1771. Gletscherens højre sidemoræne ses i baggrunden.

dominated by rock-fallen material originating from rock walls above the glaciers, and layered lateral moraines seems essentially to be deposited by the dumping of supraglacial material.

3. Layered lateral moraines in the eastern Alps (and possible also in other areas of the Alps) appear to have been founded in Early Holocene, and the layering may represent a more or less complete record of climatic variations during the Holocene.

4: Lichenometric dating of layered lateral moraines may yield erroneous results, unless detailed geomorphological mapping of the moraines plus size-frequency analyses of lichen populations are carried out.

RESUME

I artiklen beskrives en særlig type sidemoræne, som er iagttaget ved flere gletchere i Alperne. Denne morænetype er karakteriseret ved sin størrelse (ofte mere end 100 m høj), samt ved en iøjnefaldende lagdelt indre struktur. Som følge af det sidstnævnte karakteristika omtales morænetypen i artiklen som »lagdelte sidemoræner«.

Lagdelingen i lagdelte sidemoræner udgøres af bånd med skiftevis stort og lille indhold af store blokke (Fig. 5). I tværsnit ses båndene at hælde parallelt med morænens yderside, ligesom også hyppigt de enkelte store blokke i blokrige bånd er orienteret på tilsvarende vis. Kun undtagelsesvis viser blokkene tydelige tegn på gletscherpåvirkning (skurestriber, seglformede brud osv.).

De lagdelte sidemoræner træffes i forbindelse med gletschere, der i dag synes at transportere mere materiale supraglacialt end inglacialt. Også materialetransport i gletschernes sål er beskeden. Lagdelte sidemoræner formodes derfor hovedsageligt at være opbygget af materiale, der er transporteret supraglacialt, og som er resultatet af bjergskred fra de omgivende bjergsider. Det nedstyrtede materiale føres ned i gletscherens ablationsområde, hvor det skrider ned fra gletschertungens konvekse flanker, og derved danner volde langs gletscheren under ligevægtslinien. De enkelte bånd i lagdelte sidemoræner kan således opfattes som gamle ydersider, der senere er begravet og nu kikker igennem på sidemorænernes inderside. Specielt menes de blokrige bånd at være aflejret i perioder, hvor bjergskredsaktiviteten har været særlig stor fra bjergsiderne over gletschernes akkumulationsområde.

Tidligere undersøgelser i Østrig har vist, at de store morænesystemer som ses foran de fleste gletschere i Østalperne, allerede grundlagdes kort efter istidens ophør, og at gletscherne i de sidste ca. 9500 år ikke på noget tidspunkt har overskredet disse morænesystemer i nogen væsentlig udstrækning. Dette resultat åbner sammen med den ovennævnte tolkning af lagdelte sidemoræners dannelse mulighed for at detaljerede studier af den indre struktur i lagdelte sidemoræner kan give oplysning om minimumsantallet af klimaperioder i løbet af holocæn, hvor klimaet har forårsaget stor hyppighed af bjergskred. Påvisning af begravede forvitringsoverflader med organisk indhold i lagdelte sidemoræner vil endvidere give potentiel mulighed for absolut datering af perioderne med stor bjergskredshyppighed fra de omgivende fjelde.

I løbet af de seneste 25 år er datering ved hjælp af lichenometri (dvs. aldersbestemmelse på grundlag af størrelsen af bestemte lavarter) blevet mere og mere almindelig i geomorfologiske undersøgelser, og et meget anvendt dateringsobjekt specielt i geomorfologisk-klimatologisk sammenhæng er naturligvis morænesystemer. Derfor er der grund til at påpege, at netop som en følge af den formodede dannelsesmekanisme af lagdelte sidemoræner kan traditionel lichenometrisk datering af denne morænetype give en alder væsentligt højere end den seneste maximalstand for områdets gletschere. Årsagen hertil er dels faren for at laver oprindeligt voksende på en fjeldvæg kan overleve et styrt ned på gletscheren samt den efterfølgende transport frem til aflejringsøjeblikket på en sidemoræne, dels muligheden for at intet eller kun lidt materiale er aflejret på morænen i forbindelse med gletscherens seneste maximalstand. Det sidstnævnte forhold er et resultat af lagdelte sidemoræners tendens til at flytte gradvis sidelæns opad bjergsiderne, hvorfor der kræves en stadig tykkere og tykkere gletschertunge for at sikre fortsat aflejring af nyt materiale på denne morænetype.

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