SVERIGES GEOLOGISKA UNDERSÖKNING

SERIE C NR 805 AVHANDLINGAR OCH UPPSATSER ÅRSBOK 78 NR 3

ANDERS G. LINDÉN

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CONTENTS

ABSTRACT

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In the area north of the Emå valley, west of Vetlanda, a series of moraine ridges has been briefly investigated. The ridges are deposited rather independently right across the morphology of the landscape between 190 and 280 m above sea level. The individual ridges are often asymmetrical in cross section and very similar in size, only their lengths vary. The observations made indicate a basal formation at the edge of a rather thick ice sheet in supra-aquatic environment.

In several of the valleys southwest of Vetlanda, flat glaciofluvial deposits are situated in crest positions and in most cases the valleys descend northwards, proximally to the deposits. The deposits end abruptly in the north and they are overlain by till in their proximal parts, where moraine ridges also occur. The deposits are probably formed marginally and are of the types marginal delta and sandur plain.

The origin of the deposits can be assigned to a period of stagnation in the ice recession, when the ice even advanced over its earlier deposited sediments. The available datings of the deglaciation in the region indicate that the origin of the marginal deposits in the Vetlanda area probably can be related to the Older Dryas Chronozone.

INTRODUCTION

While carrying out inventories of the sand and gravel resources for the local authorities of Vetlanda and Eksjö, different types of ice-marginal deposits were observed. Within these central and northeastern parts of the South Swedish Upland, knowledge of the period of deglaciation is as yet limited. Over the years, several more or less hypothetical ice-marginal zones or lines have been proposed by De Geer (1896), Munthe (1910, 1940), E. Nilsson (1953, 1968), G. Lundqvist (1961), Mörner (1969, 1970, 1979), Berglund (1976, 1979) and Lagerlund *et al.*

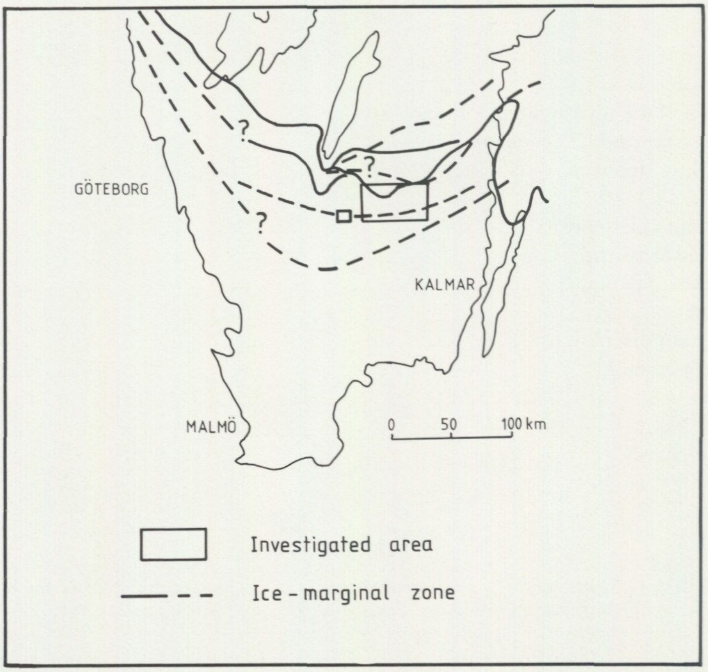


Fig. 1. Ice-marginal zones in the central part of the South Swedish Upland according to proposals from different authors.

(1983). Most of the zones are compiled in Fig. 1. More detailed investigations of landforms, morphology and types of glaciofluvial and moraine deposits have been made by Persson (1970, 1974), Agrell, Friberg & Oppgården (1976), Bjelm (1976) and Gillberg (1976). Agrell *et al.* describe morphological indications of a stagnation in the recession of the last ice sheet. Their investigations made it possible to fix the position of the "Vimmerby line", a zone with ice-marginal deposits, which extends more than 30 km southwestwards from Vimmerby and 100 km in the opposite direction towards the coast in the northeast. A readvance of a short duration within the present investigation areas has been proposed by Lagerlund *et al.* (1983). The frontal conditions are expected to have been cold based along the whole extension of their "D-line".

DESCRIPTION OF THE INVESTIGATED VETLANDA AREA

The area is situated in the central part of the South Swedish Upland. The undulating landscape varies in altitude up to 100 m, but generally less. The marked valley of the Emå river runs through the area in an east–west direction from about 200 m above sea level in the west to about 100 m above sea level in the east. Most of the other main valleys have northwest–southeaster trends. The Precambrian bedrock is heterogeneous and composed of several, very different rock types.

GLACIAL STRIAE AND ICE RECESSION

Observations of glacial striae in the investigated area have been presented in several papers (Hummel 1877, Holst 1885, 1893, Stolpe 1892, Persson 1970, 1972 and Bjelm 1976) and Fig. 2 shows a compilation of most of them. Their orientations indicate very diverging directions of ice movement from N 60°W to N 35°E. Fewer variations are found within the southern, southeastern and eastern parts of the area where the directions are mainly from NNW or N, except in the east where directions from the northwest dominate. Northwesterly directions are also found in the central and northern parts of the area and still more westerly striae N50–60°W are reported from a limited area east of lake Bellen (Stolpe 1885). Even southeast of Vetlanda striae from the NW–W have been observed, e.g. coarse striae from N85°W which cross the regional N30°W-system according to Persson (1970).

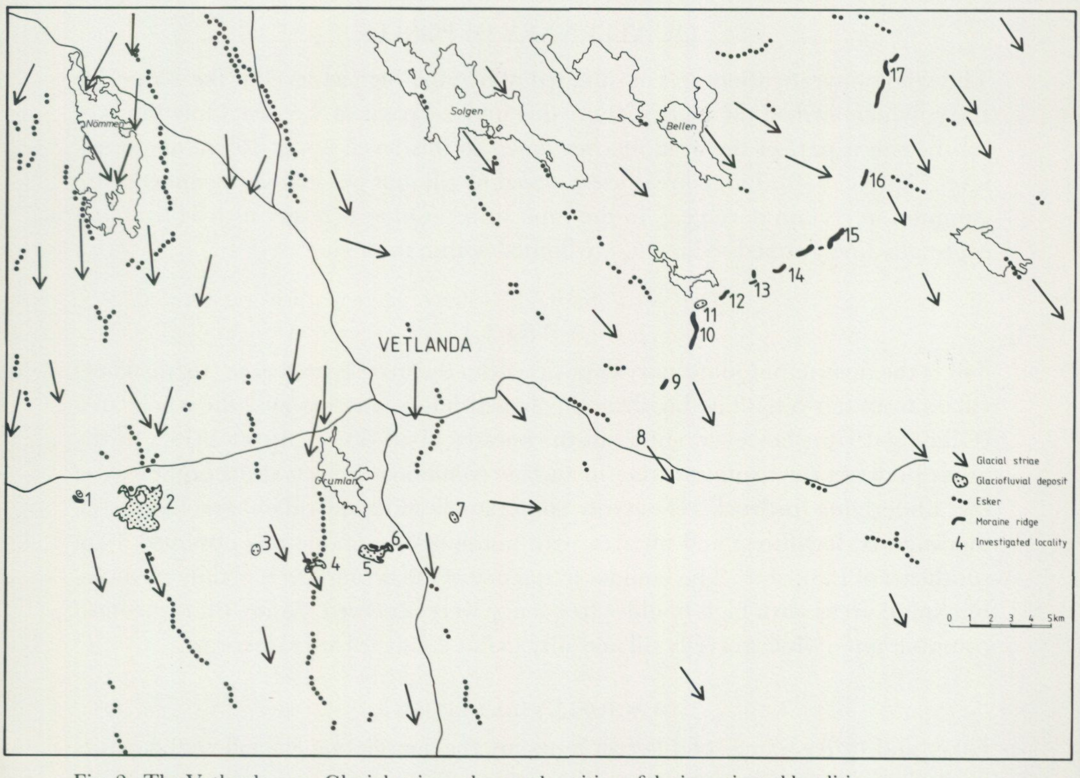


Fig. 2. The Vetlanda area. Glacial striae, eskers and position of the investigated localities.

To the north and northwest of Vetlanda, different directions between northwest and northeast have been found. Around lake Nömmen, the investigations of Persson (1972) revealed the following evolution. A dominating ice movement from northwest is shown by a common system of striae and was followed by movements from north and finally from NNE during a short period. This youngest NNE movement can, according to Bjelm (1976), be explained by local topographic conditions as the youngest regional ice movement in other areas was from the NNW. Before this phase there was a period with a more westerly movement. A system of striae from N50°W crossed by a N–S system situated a little to the north of the present investigated area has been documented by Bjelm (1976).

Drumlin-shaped hills are common in the area (Gillberg 1976) and their orientation, northwest–southeast, is in agreement with the main system of striae.

As the observations of striae are scattered, the knowledge of most of the localities is very limited and because no field studies of striae have been performed by me within the present investigated area it is not possible to give a comprehensive regional presentation of systems of striae, ice movements and age relationships.

QUATERNARY DEPOSITS

The whole investigation area is situated above the highest level of the Baltic Ice Lake, which formed the highest shore line in these parts of Sweden. Only the very southeastern part of the area reaches down to this level, about 105 m above sea level (Agrell 1976). Large areas are covered by till, but glaciofluvial sediments are common in certain parts, e.g. in the Emå valley. Other deposits such as peat and especially fine-grained sediment, are limited within the area.

TILL

Till is the dominant Quaternary deposit within the investigated area. Its thickness varies from 0.5–5 m. The big drumlin-shaped hills occurring over the whole area (Gillberg 1976), however, show till thicknesses of 20–30 m (Bjelm 1976). In the areas between the drumlins, the till surface commonly reflects the morphology of the underlying bedrock. However, some small moraine ridges are found (cf. investigated localities) and an area with hummocky moraine was observed 3 km southeast of Landsbro. The boulder frequency of the till surface is mainly medium, but small areas with high boulder frequency were observed. Sandy till is the most common type, while gravelly till and silty to fine sandy till are rather rare.

GLACIOFLUVIAL DEPOSITS

Esker and valley fillings of different types are the dominating glaciofluvial deposits in the area (cf. Bergsten 1943 and Bjelm 1976). Long continuous eskers are rare in this region because of the broken topography. Their length seldom exceeds 5 km. The eskers are mainly sharp ridges, 20–50 m in width, 2–10 m high and with even or slightly undulating crests (Lindén 1981). They consist of sediments with mainly horizontal bedding. Sometimes the bedding is irregular or diffuse. The granulometric composition of the eskers varies, but very often the material is dominated by stone and gravel. The sediments are often rather poorly sorted. Transitions between glaciofluvial sediments and till occur in the deposits.

The eskers are at many places surrounded by more or less level gravel fields or terraces, which are characteristic feature in the region. Esker nets with parallel and transverse eskers, hummocks and kettles have been found at a number of places. Another type of esker, engorged esker, running downslope at right angles to the contours was found at three localities (Lindén 1981). Along or near the eskers are sometimes found terraces, plateaux, hummocks or ridges which are distinguished as inframarginal deposits, kames and kame fields. The composition of the sediments in these deposits varies but sandy layers seem to dominate.

At several places there are small terraces situated at different levels. These lateral terraces were deposited by meltwater streams between the ice margin and ice-free slopes. Their material content is very variable, e.g. stones and boulders as well as sandy sediments. The surfaces of the terraces are not always level.

Valley fillings with flat or undulating surfaces cover large areas. Their morphology (plateau, terrace, level or undulating field), internal structures, grain-size composition and genesis vary a great deal. Distinct plateaux-shaped level deposits occur at some places (see localities 2 and 5). They consist of sandy and gravelly layers mainly dipping southwards with the characteristic bottomset, foreset and topset bedding of a delta. At the time of their accumulation, there was an ice lake at the ice-margin. In other valleys, the meltwater rivers formed flat outwash plains in supraaquatic positions both marginally and extramarginally (e.g. localities 3, 4 and 8). On their surfaces stream channels of different sizes and directions can be observed. The sediments in these sandur plains are generally coarse-grained, stony or gravelly at the surface. At greater depth they sometimes are sandy. At a few localities, an incomplete plain (terrace) has been formed on only one side of the valley. On its surface stream channels have been observed. In some valleys flat undifferentiated valley trains (cf. Lundqvist 1979) were deposited. Near the surface the sediments are coarse-grained, stony or gravelly, while the composition of the deeper layers is unknown. There probably was a great discharge of meltwater through these valleys during the deglaciation of the area. In many valleys such glaciofluvial drainage caused mainly erosion and, e.g. east of Vetlanda, glaciofluvial erosional features such as bare washed bedrock, thin residual coarse material and erosion valleys are found.

INVESTIGATED LOCALITIES

THE VETLANDA AREA

1. *Fagrahult.* South of the farm Fagrahult which lies approximately 15 km southwest of Vetlanda there is a small gravel pit in a till-covered glaciofluvial deposit (Fig. 3). The locality is situated 240 m above sea level in the central part of a flat valley. The deposit has an even ridge shape and a northwest–southeast orientation. The southern part of the 150 m long deposit is about 5 m high and the cross section is asymmetric with a steeper southern side. The pit in the southeastern part shows between 1 and 2 m of till above sediments dominated by sand and gravel. The mainly gravelly till has medium to high content of stones and medium content of boulders. The contact between the hill and the underlaying sediments is usually distinct. On the northern side of the pit, on the northeastern slope of the ridge-shaped deposit, the upper 0.5 m of a layer of fine sand shows evidence of postdepositional deformation with folding and breccia structures at the irregular contact to the till above. The observations indicate a northerly ice movement when the till cover was deposited.

Only some 50 m further south of this deposit a marked moraine ridge is found (Fig. 3) in the northern part of a bog. Its main orientation is nortwest–southeast but it has a convex shape towards the south. The ridge is 3 to 5 m high, 20 to 30 m broad and about 100 m long. It is asymmetric in cross-section with a steeper southern slope.

2. *Lannaskede.* Northwest of Landsbro, about 12 km southwest of Vetlanda, a large complex deposit extends over a wide area in a flat depression just north of a hilly terrain (Figs. 2 and 3). The southern half of the deposit is very even, and sand- and gravelpits show delta sediments of different grain sizes. The northern half, on the other hand, has a hilly morphology with ridges, mounds and hollows. The deposit, the Lannaskede plateau, has been investigated by Nelson (1910), who describes the plateau-shaped delta, the ravines in its distal part and three proximal feeding eskers with approximately the same coarse-grained sediments as in the proximal parts of the delta. The level of the delta surface is about 230 m above sea level, and according to Nelson the 2.2 square kilometer large delta has a gradient southwards of less than 1:200. The three ice rivers, represented by eskers, discharged their sediment load at the ice margin into an ice lake, which was dammed soutwards in the valley. About 3 km further south in the valley there is a clay pit. The plateau character of the delta with marked slopes and existence of large dead-ice hollows indicates the presence of large dead-ice parts, when the delta was deposited (Persson 1974).

Fossil stream channels were observed on the even surface of the central part of the deposit. The southern half of the delta generally has a 0.5 to 1 m thick surface layer of stony, gravelly topset beds, on top of more than 8 m sandy and gravelly

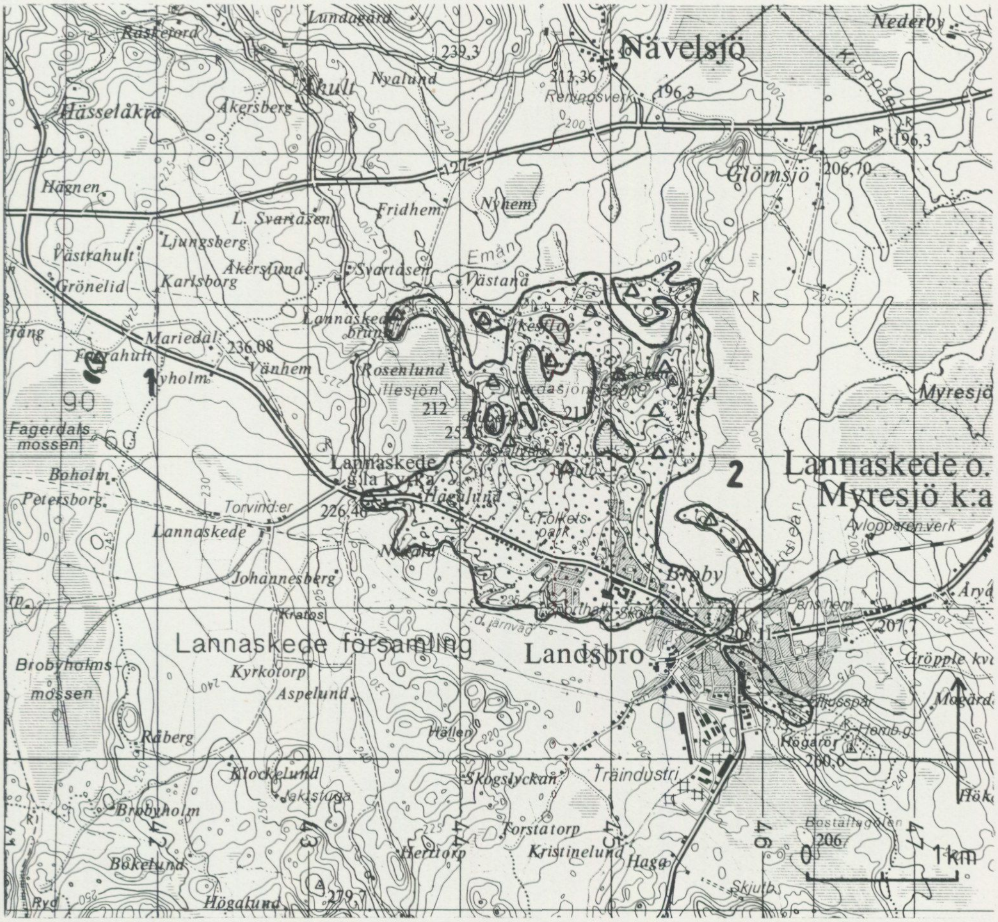
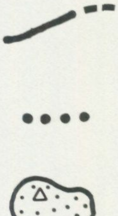


Fig. 3. Localities 1 and 2. Topographic map 6E Nässjö SO.



Ridge, mainly composed of till investigated resp. not investigated

Ridge with mainly glaciofluvial sediments

Glaciofluvial deposit partly covered by till

3 Locality

forset beds and fine-grained bottomset beds. In the periphery, especially in the south and southeast (cf. the ravines in the south) silty and fine sandy bottomset sediments dominate, but a gravelly surface layer is present everywhere. To the southeast the river Linneån flows in a distinct deep channel through the delta, which probably was eroded during the final drainage of the ice-dammed lake.

The northern half of the deposit has a variable morphology with eskers, 30 to 40 m high mounds, sharp ice-contact slopes, kettle holes and other dead-ice hollows. A 1–3 m thick till layer lies on top of almost the whole northern part. The stratigraphy can be studied in the large gravel-pit in the northeastern part, where the till mainly has a sharp contact to the underlying sediment sequence (Figs. 4 and 5). The till is compact and of lodgement type. In places fissility was observed and it was also possible to make rough estimations of fabric. The long-axis orientation was about north–south with a northerly plunge of the clasts. The till has a low to medium content of stones and a low boulder content. The material <20 mm has a composition typical for a sandy till (sample A in Fig. 6). It contains rounded stones and fine-grained material of glaciofluvial origin, sometimes completely mixed up but often as included lenses and smudges. Their composition

Fig. 4. Till-covered, coarse-grained delta sediments in the northeastern part of the Lannaskede plateau. — Photo A.G. Lindén 1981.

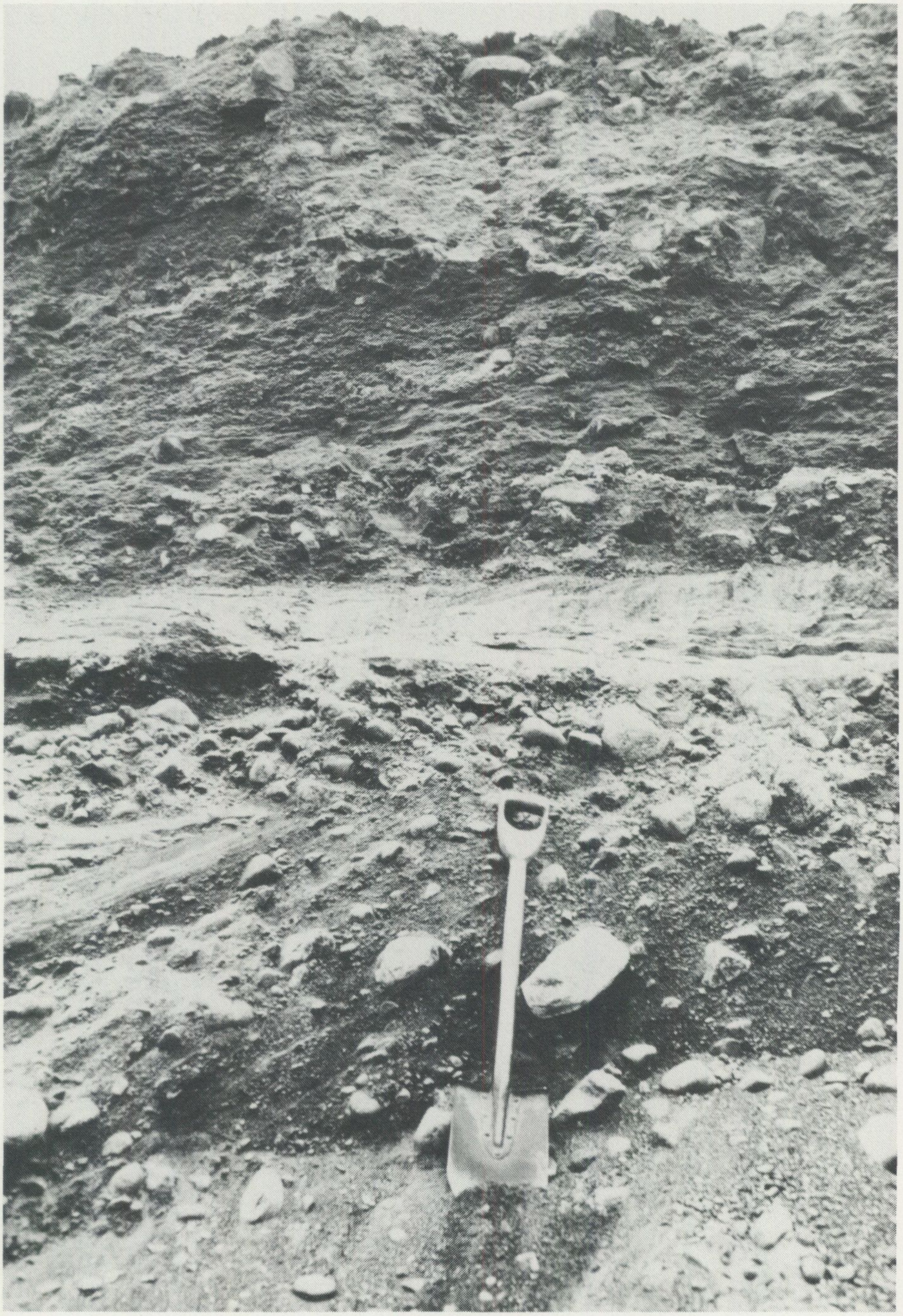


Fig. 5. The till layer at the surface of the Lannaskede plateau. The contact between the till and the glaciofluvial sediments below is sometimes very sharp. — Photo A.G. Lindén 1981.

varies a lot and inclusions of stony gravel as well as clay were observed. In some silty and clayey lenses the lamination is preserved.

Locally, the contact to the sediments below the till is undulating and less sharp because of down squeezings of till, or sometimes fillings of till in former stream channels. The uppermost layer of the sediment sequence consists of topset beds with mainly stony gravel but also fine sand, which to a limit degree show post-depositional deformations (Fig. 5). The layer is 0.5–1 m thick and is underlain by discordantly cut foreset beds. The foreset beds are mainly coarse-grained (stony and gravelly, see Fig. 4), but sandy beds do occur more particularly in the distal direction.

The topography and the sedimentological structures observed make it probable that the Lannaskede plateau can be classified as a marginal delta. The morphology indicates the depositional environment of a disintergrating ice-marginal zone with sub-glacial crevasses and probably also open crevasses. A later reactivation and advance of the ice before the final deglaciation of the area is obvious from the till layer on top of the northern half of the deposit.

3. *Bjädesjöholm.* About 1 km northeast of Bjädesjöholm, a small, flat glaciofluvial deposit is found in the valley of Kullabäcken (Fig. 7). It is situated in the highest parts of the valley and shows a marked break in the north towards the thin valley filling which continues northwards. The deposit has a slight convex crossection, which flattens out southwards and it contains a coarse-grained glaciofluvial sediment. In the small gravel pit in the northern part no stratification was visible. The abrupt and marked slope in the north is an indication of ice-contact and, together with the crest position in the valley, the deposit is interpreted as a sandur plain formed at the icefront.

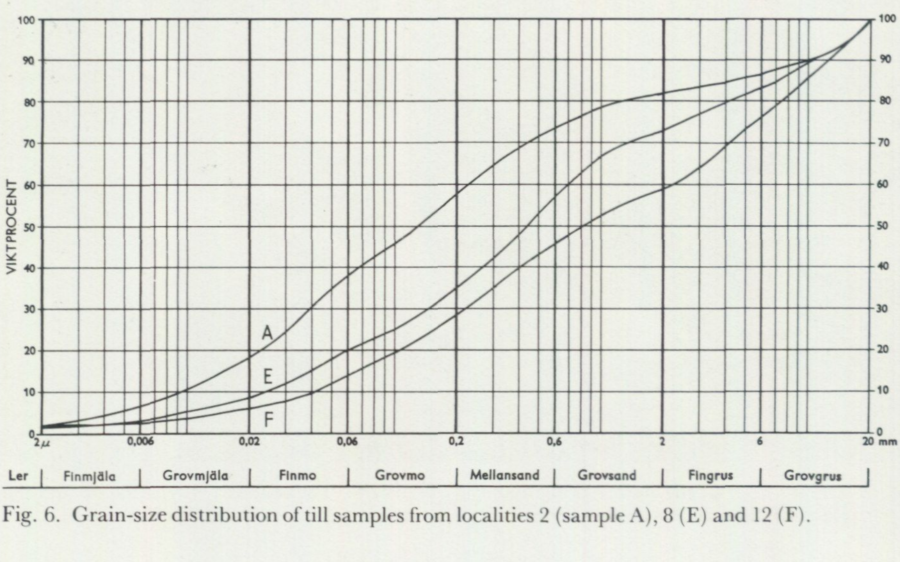


Fig. 6. Grain-size distribution of till samples from localities 2 (sample A), 8 (E) and 12 (F).

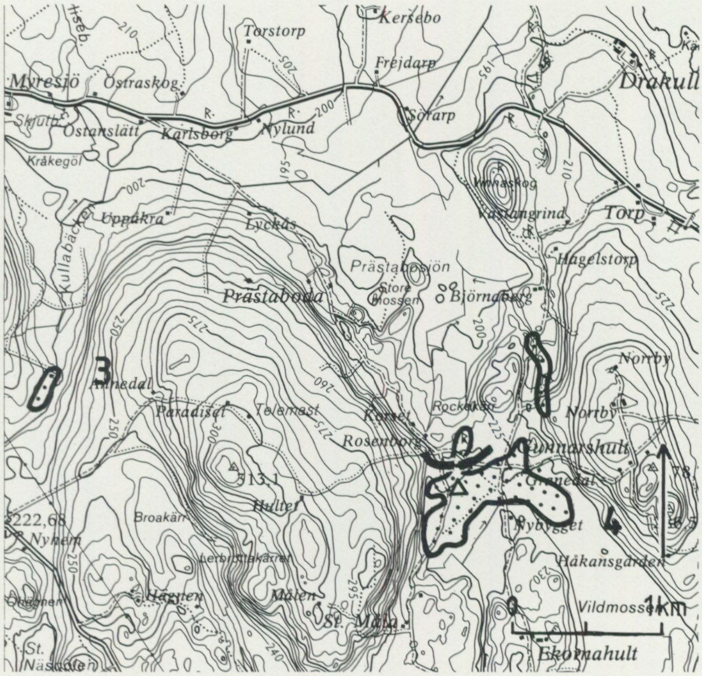


Fig. 7. Localities 3 and 4. Topographic map 6F Vetlanda SV. Legend, see Fig. 3.

4. *Gunnarshult.* In the marked valley west of Gunnarshult approximately 8 km southwest of Vetlanda lies a valley filling with an even morphology (Figs. 2 and 7). It is situated at the crest level of the valley about 225 m above sea level. Northwards the valley rapidly sinks some 30 m in height. Along the northern edge of the deposit there is a distinct course of moraine ridges.

The eastern moraine ridge (Fig. 8) is orientated ENE–WSW. It is about 190 m long, 2 m high and 20 m wide. It is composed of both sandy and gravelly tills with a medium frequency of boulders at the surface. The cross-section is asymmetrical with a steeper slope towards the south. The crest of the ridge varies slightly altitude.

The moraine ridge in the west is largely orientated E–W but its most westerly part turns northwestwards and disappears into the valley side. It is probably built up of sandy till and it has a medium frequency of surficial boulders. The dimensions of the ridge are: length about 200 m, breadth 30 to 50 m and height undulating between 2 and 4 m.

North and northeast of the deposit there are feeding eskers. The esker in the north is only 1–2 m high and 20–30 m broad and it runs through the course of moraine ridges. The esker consists of a coarse-grained stony sediment. Southwards it passes over into the plane valley filling, which has a layer of till at the surface in

Fig. 8. Small road-cut through the eastern moraine ridge of locality 4. — Photo A.G. Lindén 1980.

its northern part. The till layer is 0.5 m thick and decreases in thickness and disappears southwards. It reaches farthest south in the western part of the deposit, which can be explained by the topographical features to the north (Fig. 7).

Fossil stream channels, with changing directions were observed south of the moraine ridges. In a small pit in the central part of the deposit there was a coarse-grained sediment dominated by stones. The thickness is more than 2 m. Coarse-grained sediments (stony gravel) can also be studied in pits in the southwestern part. In the southernmost part of these gravel pits there are even sandy layers present. Traces of embedded dead-ice blocks occur as hollows along the western side.

The flat glaciofluvial deposit was problably formed at the ice margin where the sediments accumulated in a supra-aquatic environment as a sandur plain at the crest level of the valley. The till layer and the moraine ridges north of the sandur plain indicate a reactivation of the ice front, which advanced at least 200 m over the sandur plain. The marked moraine ridges which are orientated at right angles to the youngest known ice movement (see pp. 5–6) can be interpreted as end moraines. The turning of the western ridges towards the north suggests a lobe-formed ice margin in the marked valley.

5. *Simnatorp*. A large complex deposit (Figs. 2 and 9) with glaciofluvial sediments, partly covered by till and with moraine ridges in its proximal part is found in the wide valley at Simnatorp, about 7 km south of Vetlanda. The main part of the deposit consists of a delta formation which extends about 1 km southwards. In the eastern part of the delta there are traces of dead ice (hollows and marked slopes). The valley dips northwards and the deposit is terminated by a marked slope in the north. The surface of the deposit reaches up to about 210 m above sea level which consequently is the minimum altitude of the water level of the ancient ice lake which was dammed in front of the land ice. A corresponding threshold has been found about 7 km to the southeast.

In a large gravel pit in the western part of the deposit, 5–7 m of thick delta sediments are covered by a 0.5 to 1 m till layer. The delta sequence consists mainly of sandy foreset beds dipping southwards, among which locally small bottomset beds of silt occur. A 1 to 3 m thick bed of stony gravel lies under the till layer. In the upper part of the gravelly bed (about 0.5 m) the layering is disturbed and deformed. The contact to the overlying till is somewhat undulating. At places, till wedges penetrate down into the coarse-grained gravel bed. The wedges are about 0.5 m long and dip southwards. Sample B, which was taken in such a wedge, has a normal grain-size distribution for a sandy till (Fig. 10). The till has a medium content of stones and a low boulder content. Its thickness increases northwards and in a gravel pit in the northwestern part of the delta it is 1 to 1.5 m thick. The

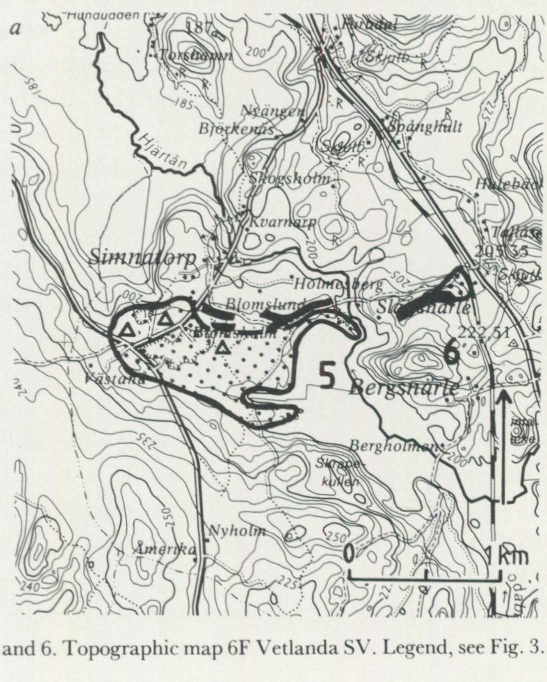


Fig. 9. Localities 5 and 6. Topographic map 6F Vetlanda SV. Legend, see Fig. 3.

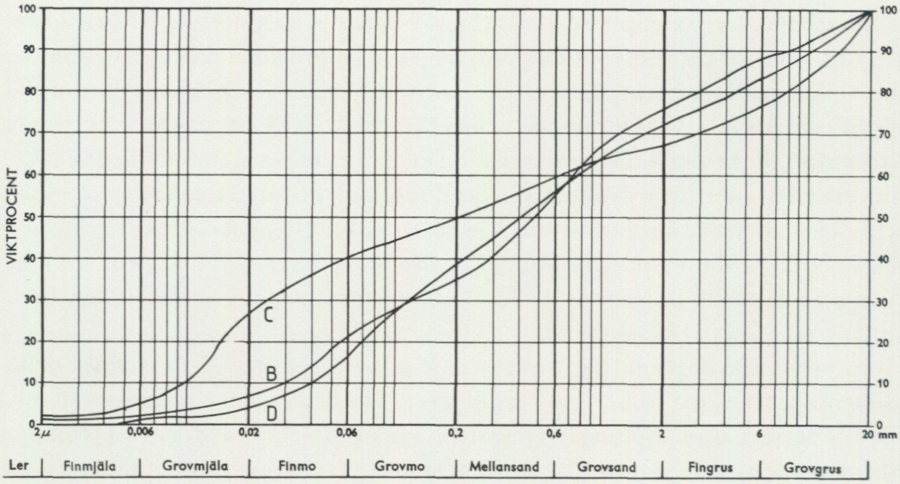


Fig. 10. Grain-size distribution of till samples from locality 5.

till layer contains fragments, lumps and drawn out parts of the underlying sediments, and the delta sediments below show postdepositional tectonic deformation caused by ice movement from the north. In this gravel pit, in the proximal part of the delta, wedge-like forms of till pressed down into the delta topset bed were also observed. The till of the proximal slope is a compact lodgement till with medium boulder frequency at the surface and with a medium stone content. It contains redeposited sediments, which also is obvious from the grain-size distribution curve of sample C in Fig. 10 (about 40 per cent silt and clay and 30 to 35 per cent gravel).

In the coarse-grained gravel layer at the top of the delta sequence, small balls and angular pieces of red-brown clay were found.

In the northern and northeastern part of the deposit, there is a course of moraine ridges (Fig. 9). The height of the ridges is 3–5 m and their breadth varies between 20 and 40 m. At the surface there is a medium boulder frequency, but the number of boulders is generally higher on the northern slopes of the ridges. The northerly slopes are also sometimes steeper than the southern slopes. In the northern part of the delta, two small parallel ridges occur which are about 40 and 100 m long, respectively. At the western end of the long ridge, at Blomslund, a 1.5 m deep section in the ridge shows sandy till (sample D in Fig. 10) with medium stone content and low boulder content. The grain-size distribution of the <20 mm fraction is similar to that of the sample from a till wedge about 500 m further to the southwest (sample B in Fig. 10).

No moraine ridges occur in the northwestern part of the deposit. This may be due to the main topography of the area. To the east, where moraine ridges occur, the morphology of the bedrock is hilly, while it is flat to the west (Fig. 9). In the flat western part the land ice probably moved more freely than in the hilly eastern part. The environment in the west was therefore unfavourable for the formation of ridges. This is also supported by the areal extent of the upper till layer, which reaches further south in the western part than in the eastern part of the delta.

The documented ice advance in the northern part of the delta supports its classification as a marginal delta.

6. *Slättsnärle*. A moraine ridge runs about 450 m eastwards from Hjärtån at Slättsnärle, about 7 km south of Vetlanda (Fig. 9). Its breadth is 50–100 m and it is 8–12 m high. The slope towards the north is strikingly steeper than the southern slope. At the surface, there is a medium boulder frequency with scattered large boulders. In the east, there is a flat, terraced glaciofluvial deposit at the end of the moraine ridge. The sediments are fine-grained (sand and silt) and were probably deposited in an ice lake in a tributary valley to the valley south of Simnatorp.

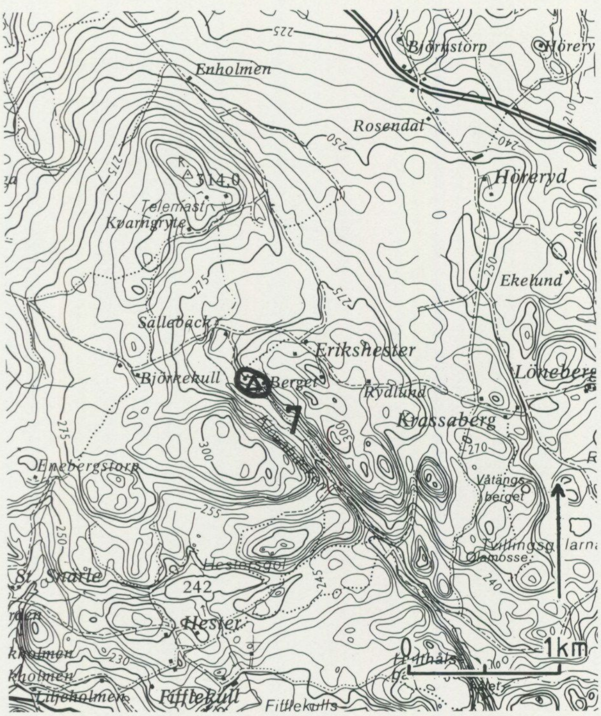


Fig. 11. Locality 7. Topographic map 6F Vetlanda SV. Legend, see Fig. 3.

7. *Erikshester.* 0.5 km southwest of the farm Erikshester, about 6 km southeast of Vetlanda, there is a sub-moraine glaciofluvial terrace deposit on the eastern slope of the narrow Klövabäcken valley (Fig. 11). A gravel pit is situated in the western side of the deposit. The level of the flat terrace surface is about 275 m above sea level, and the contact to the layer of till above is sharp and slightly undulating. The till is compact and its composition is sandy with a medium content of stones and low content of boulders. It contains small lenses of sandy and gravelly sediments. The till layer is about 1.5 m thick. The upper 2 m of the underlying sediment sequence consists mainly of horisontally layered sandy sediments. They are underlain by gravelly sediments (gravel and stony gravel) the thickness of which is unknown.

8. *Bruksgården.* In the wide Emå valley there is a large glaciofluvial valley filling. In a gravel pit 300 m southeast of Bruksgården, 13 km east of Vetlanda, a till layer was observed in the central part of the stratigraphy (Figs. 2, 12 and 13). The top layer is built up of stones and gravel and is 1.5–2 m thick (Fig. 14). This layer has a wide extension in the valley. On its surface there are fossil stream channels, scattered boulders and dead-ice hollows. In the coarse material, there are stony spool bars and thin horisontal layers of sand. The contact to the underlaying layer

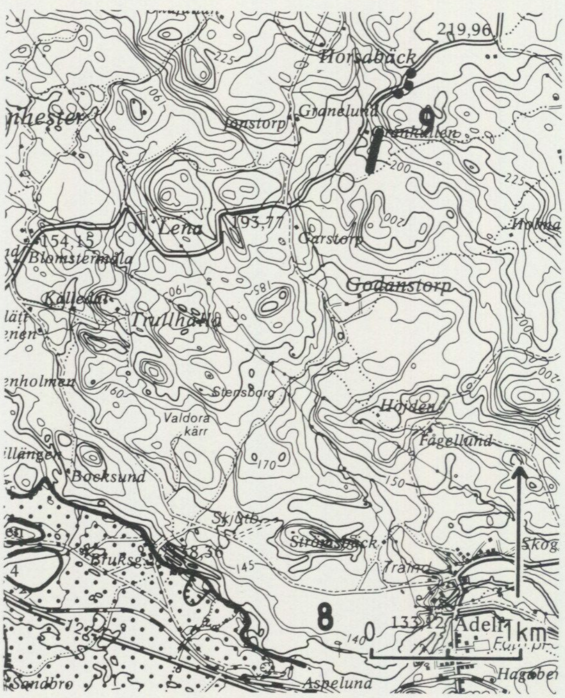


Fig. 12. Localities 8 and 9. Topographic map 6F Vetlanda SV. Legend, see Fig. 3.

Fig. 13. Coarse-grained sandur sediments above and below a till layer at locality 8. — Photo A.G. Lindén 1980.

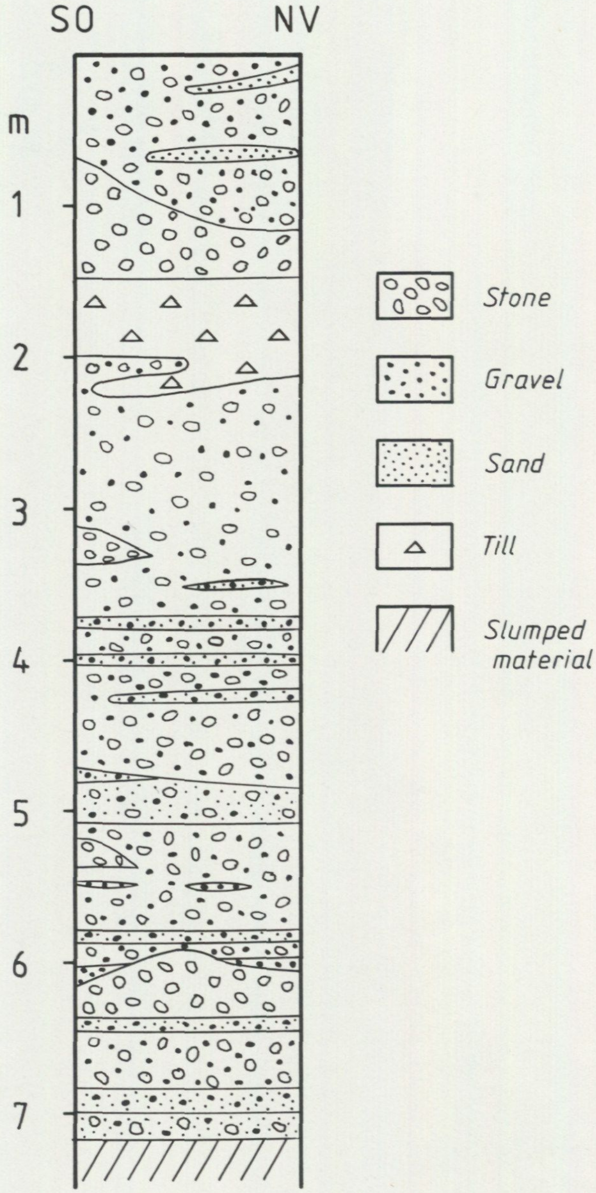


Fig. 14. Stratigraphy at locality 8.

of till is generally sharp. The composition of the till varies, but it is predominantly a sandy till with medium stone content (sample E in Fig. 6). It contains reworked glaciofluvial material especially in the lower part of the layer, where fragments, lenses and smudges are frequent. Till wedges (max. 3 m long) were observed pressed down into the underlying stony and gravelly layer (Figs. 13 and 14). The orientation of the wedges indicates that the direction of ice movement was from west–northwest at this locality. Under the till layer there is a zone of undulating thickness where the primary stratification of the sediment is distroyed. The zone is about 0.5–1 m thick, and the material is dominated by stones and gravel. Coarse-grained glaciofluvial sediments continue down to the bottom of the gravel pit and the 6 to 7 m thick sequence has a horisontal stratification. Thin sandy layers are present. Stony spool bars were observed throughout the whole sequence. There is an increase of the average grain size upwards to the till layer. The coarse-grained sequence has a sharp lower contact to a bed with horisontally layered, silty fine sand. The fine-grained bed is more than 2.5 m thick.

At the studied locality, an advance of the land ice over a sandur plain is indicated by a continuous layer of till on coarse glaciofluvial sediments. During the following deglaciation another wide sandur plain was deposited in the Emå valley.

9. *Grankullen.* At Grankullen, about 14 km east of Vetlanda, a 300 m long moraine ridge runs southwards from the hill east of the house (Fig. 12). Close to the hill, the ridge shape is rather flat but southwards it is sharp. The eastern slope is steeper than the western, and the frequency of boulders on the surface is higher on the eastern slope. The ridge is 40 to 50 m broad and 7 to 8 m high. The surface layer consists of rather coarse-textured till. Along the eastern side of the ridge occur flat valley fillings with a gravelly composition.

Another glaciofluvial deposit lies on the northern slope of the hill along the main road. It is situated at the western mouth of a flat, hanging valley. In the northern part of the deposit there is a ridge which contains boulders and stones. The ridge is 140 m long, about 25 m broad and 2–4 m high and it is orientated at right angles to the direction of the valley. At its southern end the ridge turns westwards and changes into a narrow lateral terrace. A small pit in its southern part consists of about 2 m coarse-grained, poorly sorted gravel upon gravelly till.

In the even valley east of the ridge flat bedrock outcrops occur. They are surrounded by thin valley fillings of coarse gravelly sediments.

10. *Vrånghult.* The main road northwards from Vrånghult follows a more than 1.5 km long course of moraine ridges (Fig. 15). The course winds in a northerly direction along the southern end of a long drumlin-like hill. The middle ridge turns sharply towards the north–northwest and runs up to the crest of the long drumlin at about 280 m above sea level. The drumlin form of the hill is incomplete

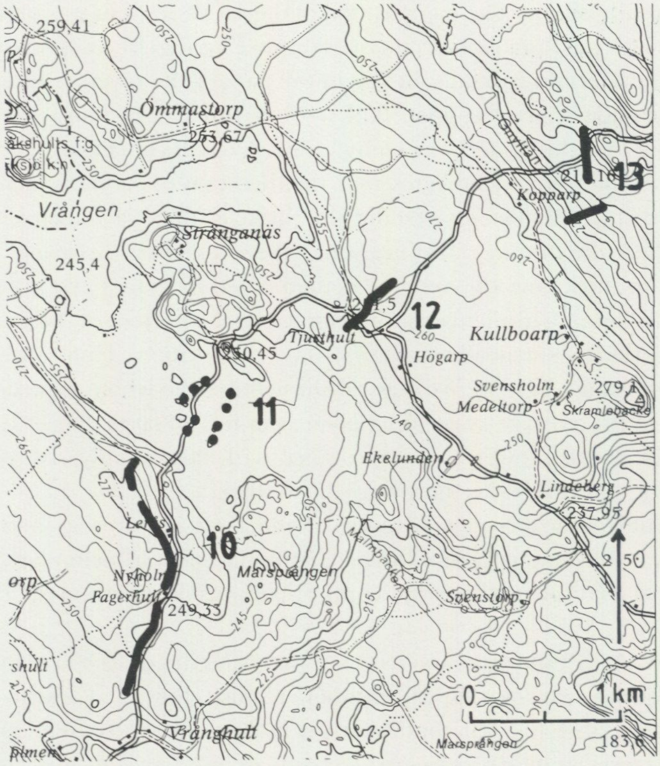


Fig. 15. Localities 10, 11, 12 and 13. Topographic map 6F Vetlanda SV. Legend, see Fig. 3.

and ends abruptly close to or a little south of the moraine ridge. The hill belongs to the pre-crag moraine type according to the classification of Gillberg (1976).

The shape of the moraine ridges is sometimes very sharp. Generally they are asymmetric with a steeper eastern side. The frequency of surficial boulders is often higher on the eastern side. Their height varies between 2 and 5 m and the breadth between 20 and 30 m. According to observations made in small pits along the road the composition of the material in the ridge varies. Some pits show coarse-grained glaciofluvial material, others till.

11. *Stränganäs*. In the relatively broad valley south of Stränganäs, there are four ridge-formed hills which are orientated at about right angles to the direction of the valley (Fig. 15). The northern ridge is the largest and has, to a great extent, been exploited. In the centre of the 300 m long, 70 m broad and 3–6 m high ridge there is a gravel pit. The pit has been reclaimed, but shows layers of gravel, sand and fine sand under 1 m thick till at the surface. The other ridges at the site all seem to

consist mainly of glaciofluvial sediments, and no till was observed on their surfaces. They are all smaller than the northern ridge, the two eastern ridges are 3–5 m high, while the southwestern ridge is very flat and rises only one meter above the surrounding peatland.

12. *Tjusthult.* The farm Tjusthult lies on the western side of a long hill with a drumlin shape, a pre-crag moraine according to Gillberg (1976). A moraine ridge runs downhill close to the farm (Figs. 15 and 16). The clearly defined ridge is 3–8 m high, 40 to 50 m broad and about 600 m long and is orientated northeast–southwest. In the northeast, the ridge flattens out and disappears completely near the crest of the drumlin-like hill.

In the central part of the moraine ridge there is a reclaimed pit. Gravelly till with a high content of stones dominates (sample F in Fig. 6). A small pit 150 m further east on the southeastern slope of the ridge shows stones and gravel.

13. *Kopparp.* About 350 m southeast of the farm Kopparp, on the eastern side of the drumlin-like hill described above, lies a 300 m long and 1–2 m high moraine ridge. (Fig. 15). It consists of sandy till with a medium frequency of boulders at the surface. The ridge has a main orientation about N70°E. On the opposite side of the valley a moraine ridge crosses the main road about 500 m northeast of Kopparp. The ridge is about 350 m long and flattens out and disappears gradually at both ends. The ridge is 20 to 30 m wide and 2–3.5 m high. Its orientation is north–south (about N5°W). In the central part of the ridge the eastern side is steeper than the western.

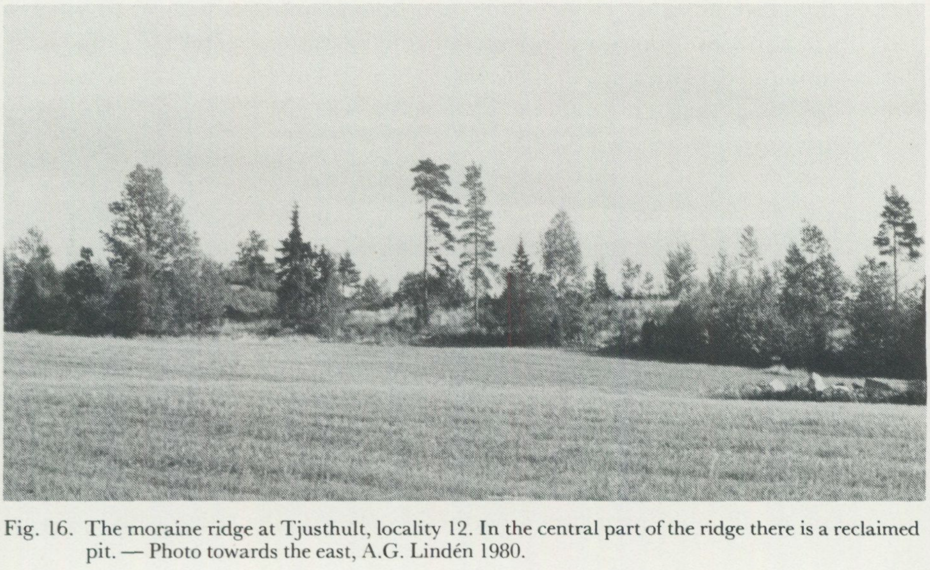


Fig. 16. The moraine ridge at Tjusthult, locality 12. In the central part of the ridge there is a reclaimed pit. — Photo towards the east, A.G. Lindén 1980.

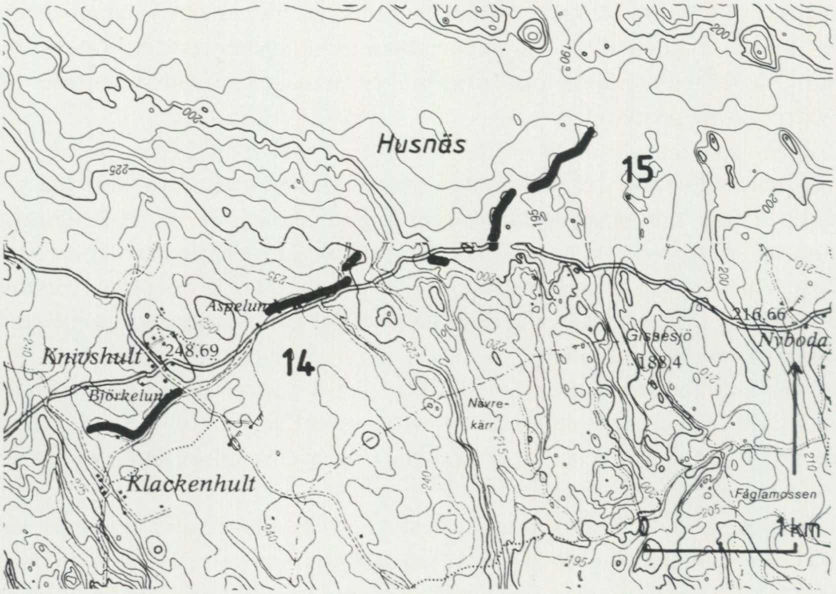


Fig. 17. Localities 14 and 15. Topographic map 6F Vetlanda SO and NO. Legend, see Fig. 3.

14. *Knivshult*. On both the northeastern and the southwestern slopes of the hilly area at Knivshult there are moraine ridges (Figs. 17 and 18). All the ridges usually have steeper slopes to the south than to the north. The ridge in the southwest is continuous and 800 m long, 30–60 m broad and 2–4 m high. Half way along its length the ridge abruptly changes direction from about east–west in its western part to a northeast–southwest orientation in the eastern part. Here the ridge flattens out and disappears near the crest of the hill. The crest level of the moraine ridge is relatively constant at about 245 m above sea level. The boulder frequency of the surface is medium, and the ridge is probably mainly composed of till.

The moraine ridges in the northeast have not been deposited at an constant altitude as the ridge above, but instead they run downhill on the flat slope from about 240 m above sea level down to about 225 m above sea level. In the western part, the ridge shape is less marked than in the central and eastern parts. The western ridge is about 50 m broad, 3–4 m high and 600 m long. On the lowest part of the slope, the course of ridges is diffuse.

A little south of the main road at the foot of the valley side, there is a cutting trough a small moraine ridge. The orientation of the ridge is about E–W and it is about 1.5 m high. The ridge consists of gravelly till with medium stone and boulder content and small lenses with sandy and gravelly sediments. A rough estimation of till fabric indicates a northerly prefered orientation with upglacial dip.

15. *Husnäs.* 1 km east of Husnäs a system of ridges, built up of till and glaciofluvial material, runs in a northeasterly direction out into the middle of the wide valley of Rydån (Fig. 17). The ridges rise 3–7 m (maximum 10 m) above the surroundings and they have varying orientations, widths (30–70 m) and lengths. The slopes towards the southeast are steeper than the slopes towards the northwest.

The surface of the ridges has a medium boulder frequency and the till is normally sandy. The content of stones is low to medium and the content of boulders is low as can be studied in a small gravel pit in the central part of the locality. The till at the surface is about 1.5 m thick and it has a sharp contact to a sequence of gravelly and sandy sediments below. The till has a lodgement character and according to rough ocular estimations of fabric, the clasts of the till seem to have a prefered orientation towards the northwest and an upglacial plunge. The lowest part of the till layer includes small lenses and fragments of sorted sediments. In the upper part of the sediment sequence, there is a layer of stony gravel which shows post-depositional deformation features. The sequence contains the following layers from the top: about 0.5 m stony gravel, 1 m sand with thin layers of silt, 0.3 m stony gravel, 1–2 m sand and fine sand and 0.2 m gravelly sand. The stratification of the sediment sequence has a general inclination towards the northwest and the two sand beds especially become thinner in that direction.

The sediment sequence has a sharp contact to the underlying compact sandy till. The till has a medium stone content and a low content of boulders. Fissility was observed and rough ocular estimations indicate a northern fabric with an upglacial dip of the stones in the till. Even the till layer at the bottom of the pit has lodgement characteristics.

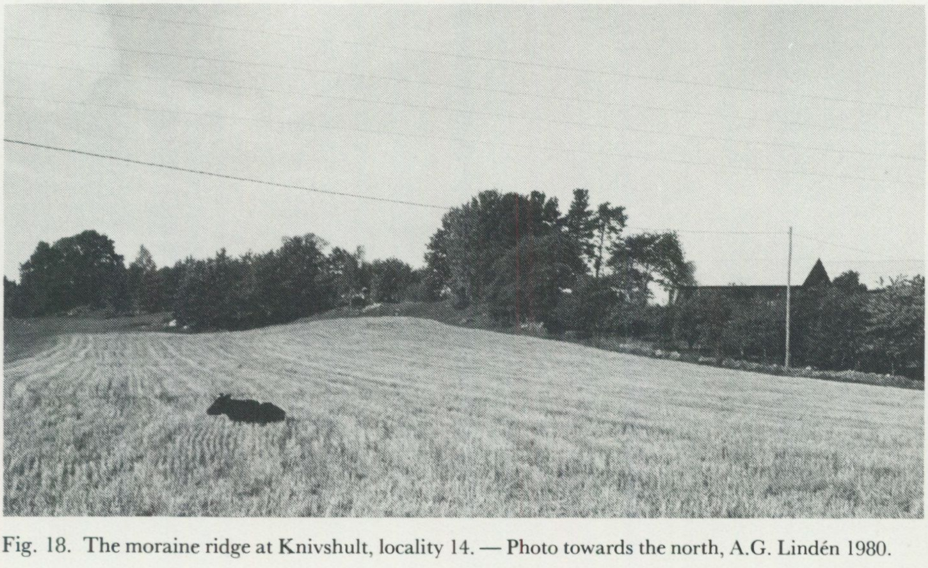


Fig. 18. The moraine ridge at Knivshult, locality 14. — Photo towards the north, A.G. Lindén 1980.

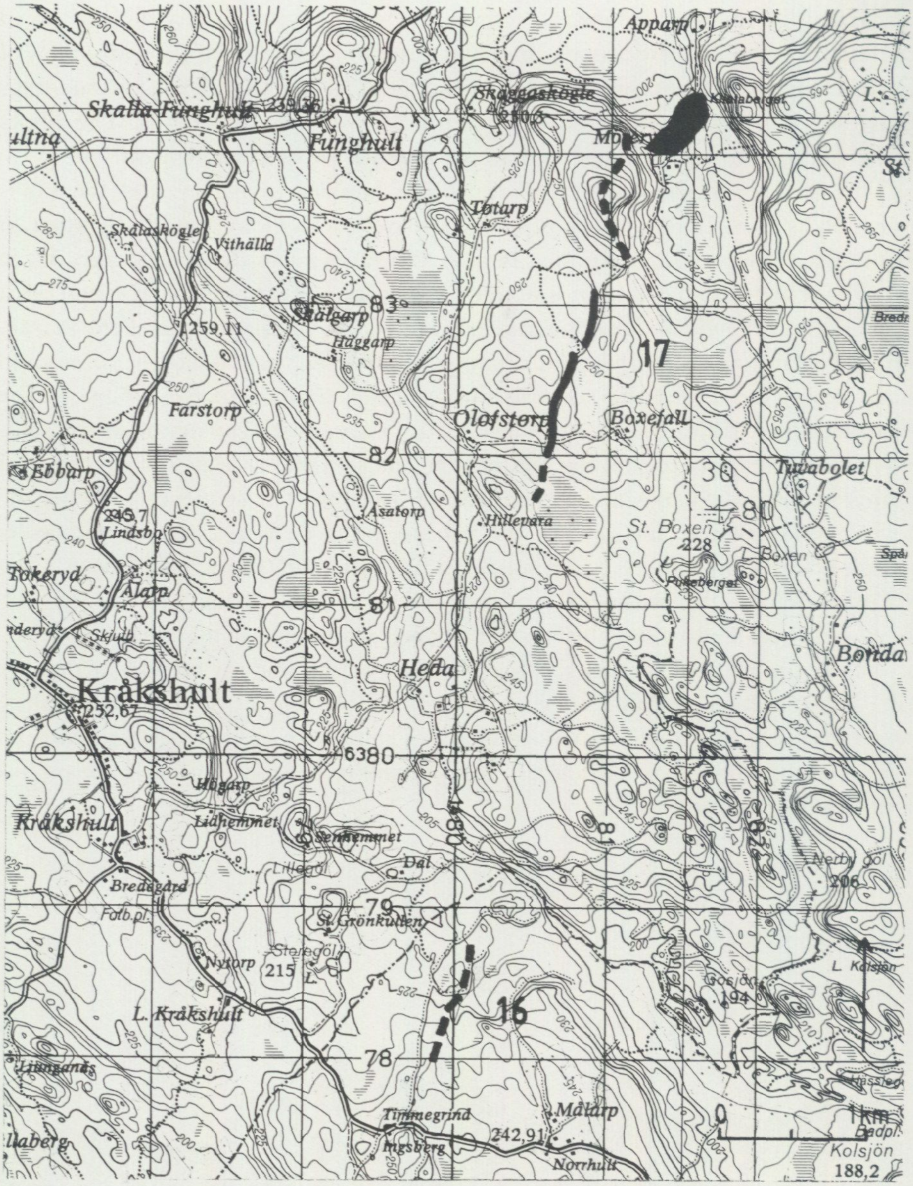


Fig. 19. Localities 16 and 17. Topographic map 6F Vetlanda NO. Legend, see Fig. 3.

Glaciofluvial sand and gravel were also observed in the southern part of the locality, but sandy till probably dominates in the ridge. In the most northeasterly ridge sand also occurs.

16. *Timmegrind*. Northwest of Karlstorp, immediately northeast of Timmegrind, a series of smooth moraine ridges runs down the even slope towards the NNE (Fig. 19). The northern part consists of a 400 m long ridge, 3–4 m high, and with a marked eastern side. The boulder frequency at the surface is a little higher on the eastern than on the flat western slope. The origin of these smooth ridges is unknown.

17. *Möreryd*. 2 km south of Möreryd, the road to Olofstorp crosses an area with rolling hills. Along the road an almost continuous, well-formed moraine ridge runs in the direction of about N15°E (Fig. 19). The ridge is about 1.5 km long and usually 20–25 m broad. Its height varies between 2 and 6 m. The eastern side is most often steeper than the western. About 250 m north of the crossroad in the south lies a small depression in the ridge. It is about 25 × 10 m and 2 m deep and is probably a dead-ice hollow. Its orientation is perpendicular to the ridge.

The till in the ridge has a variable composition. Both sandy and gravelly till with medium stone and boulder content were observed. Across the hill, southwest of Möreryd, runs another moraine ridge of about the same size as the ridge already described.

The village Möreryd is situated on a rather smooth ridge stretching across the valley in a northeast–southwesterly direction. No cutting or gravelpit was observed, but the morphology and the orientation indicate that the ridge probably is a moraine ridge.

VRIGSTAD

Vrigstad is situated immediately south of the highest hills in the central part of the South Swedish Upland (Fig. 1). The undulating hilly landscape in the region has a relief of 20 m to more than 100 m. According to Stolpe (1892), the direction of striation in the area north of Vrigstad is N5–35°W, but 5 km to the southeast the direction is N5°E. In the valley at Vrigstad, there is an extensive glaciofluvial deposit (Fig. 20). A gravel pit in the northeastern part of the deposit shows a complex stratigraphy with sand and gravel beds both at the bottom and at the surface, between which occur layers of fine-grained sediments and a heterogeneous till-like layer. Two sections in the eastern wall of the pit were studied (Fig. 21).

The bottom bed consists of more than 1 m of sand and gravel in horisontal layers. In the northern section, a thick sequence of mainly silty sediments with thin laminae of fine sand overlies the bottom bed. Climbing ripples are present. A

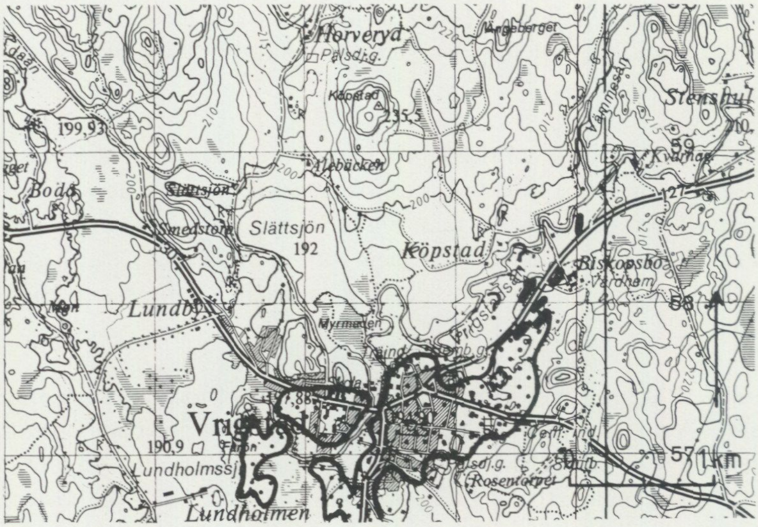


Fig. 20. Locality Vrigstad. Topographic map 6F Nässjö SV. Legend, see Fig. 3.

large boulder was observed, which probably has been pressed down into the fine-grained sediments. At the top of the sequence there is a horizon, about 15 cm thick, with disturbed and folded sediments, mainly fine sand, at the contact to the following layer. This layer is very compact in comparison with all the others in the section. The layer is composed of a poorly sorted, rather coarse-grained till-like sediment (sample G in Fig. 22) and appears to consist of both redeposited glaciofluvial material and till.

The till-like layer is 5–10 cm thick. It is overlain by a 5 cm thick layer of coarse sand followed by about 0.5 m of horisontally layered sand and silt. Climbing ripples occur in this layer. At the surface, the section is completed by about 1 m of sand and gravel in horisontal layers.

About 30 m further to the south, another section of the pit wall was cleared and investigated. The same sand and gravel units were found at the top and at the bottom as in the previously described section, but in the central part of the section there are distinct differences between the two sections. First the till-like layer lies directly on the coarse-grained bottom unit and it has been pressed down through the sequence of silty sediments, which is shown by its undulating and disturbed upper contact. The till-like sediment is also very compact in this section. It is heterogeneous with lenses and thin layers of till material and a high frequency of inclusions of reworked glaciofluvial material (sample H in Fig. 22). At the contact, disturbed layering of the bottom gravel was observed as well as incorporations of gravelly material in the till-like stratum. The thickness of the layer is about 0.6 m but it becomes thinner towards the south. The fine-grained sequence above the

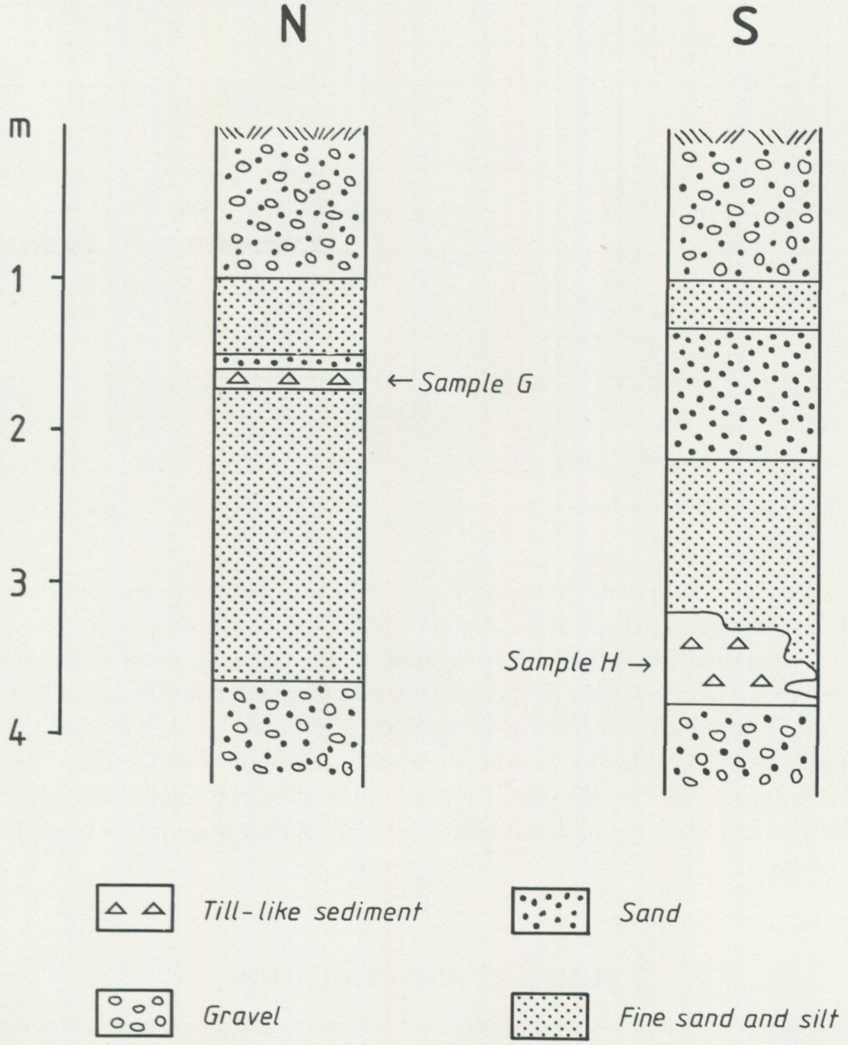


Fig. 21. Stratigraphy in the eastern wall of the gravel pit in the northeastern part of the valley filling at Vrigstad.

"till" consists of fine sand and silt with ripple structures (climbing, asymmetric and also regressive ripples) and it has a sharp boundary towards the almost equally thick layer of horizontally layered sand above. On top of that follows another fine-grained layer of about 0.3 m of sand with ripple structures, which corresponds to the very similar, 0.5 m thick, fine sandy layer under the gravel at the top in the first section.

At Biskopsbo about 1.5 km northeast of Vrigstad a system of moraine ridges has been briefly surveyed (Fig. 20). The ridges are situated in the northeastern part of

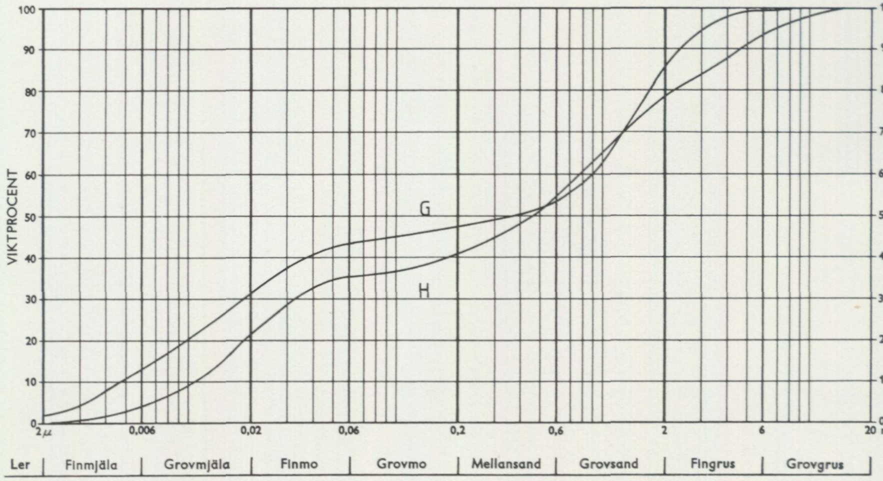


Fig. 22. Grain-size distribution of samples from a layer with till-like sediments.

the large valley filling and on the southeastern side of the flat valley. They have a well-developed ridge shape and a slightly winding course over the fields (Fig. 23). Their orientation varies from N50°E to almost N–S. Often the cross section of the ridges is asymmetric, with a steeper side towards the southeast. The breadth of the individual ridges is 25 to 30 m, height 1–5 m, and length between 50 and 150 m. The southernmost ridge has a diffuse continuation southwards for about 100 m, but disappears close to the gravel pit described above. A small roadcut in the southern ridge shows a probably reworked glaciofluvial material with a till-like composition.

SUMMARY AND DISCUSSION

Apart from the drumlin-shaped hills the moraine do not form distinct landforms within the Vetlanda area. The small moraine ridges which have been observed in the northeastern part of the area, north of the Emå valley, seem to be integral parts of a 20 km long series of ridges with an orientation NNW–SSE (Fig. 24). The series of ridges is deposited rather independently right across the morphology of the landscape between 190 m above sea level and 280 m above sea level. The individual ridges are often asymmetrical in cross section and are normally of about the same size. Only their lengths vary. There are very few cuttings or pits in the ridges, which makes it impossible to give a more thorough description of their composition. Generally they seem to consist of sandy till, but also gravelly till has been observed. At some places it is obvious that the ridge, or a part of it, is more or less built up of glaciofluvial sediments with only a thin cover of till, e.g. localities

Fig. 23. Moraine ridges northeast of Vrigstad. — Photo towards the northeast, A.G. Lindén 1982.

11 and 15. Also, material with a transitional composition between gravelly sandy sediments and till is found. Hollows and similar forms indicating embedded ice blocks were recognized at a few localities. The till fabric has been roughly estimated ocularly at a few localities, and a preferred orientation at about right angles to the ridge is evident with an upglacial plunge of the clast.

The ridges are orientated approximately at right angles to the existing eskers to the north and northwest (Fig. 2). It is assumed that the orientation of the eskers roughly shows the direction of the ice movement. There are also observations of striae supporting a similar direction of ice movement.

The observations, described together with the different topographic positions of the ridges on level uplands, on slopes and in the bottoms of valleys (Fig. 24), indicate a basal formation for the transverse ridges at the ice-margin. They can therefore be classified as end moraines. They have probably been deposited at about the same time along the margin of a rather thick ice (cf. the differences in altitudes), either during a period of stagnation in the ice recession with the ice-front equilibrium or during a readvance of the ice.

In several valleys, flat glaciofluvial deposits form valley fillings. They are sometimes situated in crest positions near a threshold as sandur plains, e.g. the localities 3 and 4, and sometimes as terraces or plateaux across the valley with delta characteristics as the localities 2, 5 and 6. At all the localities, except locality

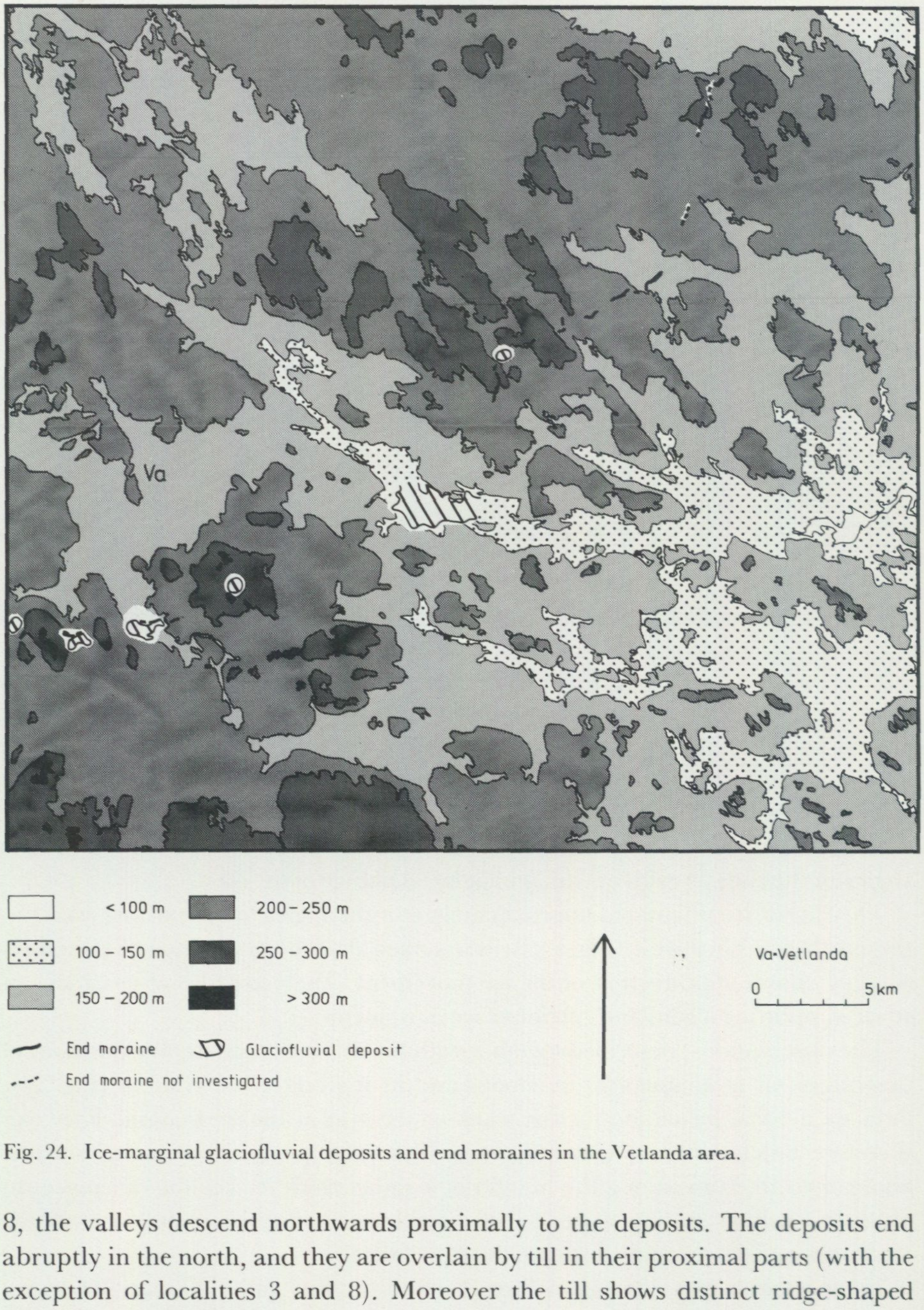


Fig. 24. Ice-marginal glaciofluvial deposits and end moraines in the Vetlanda area.

8, the valleys descend northwards proximally to the deposits. The deposits end abruptly in the north, and they are overlain by till in their proximal parts (with the exception of localities 3 and 8). Moreover the till shows distinct ridge-shaped landforms with about the same height and breadth dimensions as the moraine ridges described above. The E–W orientated ridges in the proximal part of the valley fillings are, however, shorter. South of the ridges there is a thin till layer on the surface of the glaciofluvial deposit. This till grows thinner and disappears 100 to 200 m further south. The thin till layer is exposed in the gravel pits and inclusions of lenses, fragments and smudges of different kinds of sediments (gravel-laminated clay) have been observed. In the contact zone to the underlying glaciofluvial sequence downpressed till, sometimes till wedges, folds, faults and drag structures have been recognized indicating an ice-advance from the north.

With the knowledge of the regional distribution and the variation of types and morphology of glaciofluvial deposits from the areas 30 km northwards and 15 km southwards from the investigated area (Lindén 1981, 1982), it is obvious that the deposits at localities 2, 3, 4, 5 and 8 probably are true marginal deposits, marginal deltas and sandur plains. Their origin can be assigned to a period of stagnation in the ice recession, when the ice even advanced over previously deposited sediments. A period of stagnation probably including readvance is also indicated by the distinct series of end moraines in the eastern and northeastern parts of the Vetlanda area. Their extension right across the topography of the landscape, together with other observations, shows that the ice was active at the time of their formation, and that the period probably had a climatical explanation. However, restricted lower areas with landforms indicating disintegration of stagnant ice have been observed in the region.

The locality at Vrigstad also indicates a stagnant period during the ice recession combined with a restricted advance southwards over previously deposited sediments. At present it is, however, not possible to connect the marginal deposits at Vrigstad with the documented course of marginal deposits around Vetlanda.

To the northeast, marginal deposits in the so-called Vimmerby line have been described by Agrell *et al.* (1976). They represent a stagnation of the receding ice front during either Older Dryas or the beginning of the Younger Dryas Chronozones. The line is supposed to belong to the Taberg readvance described by Nilsson (1953), and to have a WNW orientation. The present author finds it more probable to connect the ice-marginal deposits around Vimmerby with corresponding types of deposits in the Vetlanda area, a correlation not contradicted by the present knowledge of the ice movements of the region. This leads to the assumption that the ice-marginal zone in the Vetlanda area is separated from the Taberg–Levene zone and has an older age. Indirectly this is supported by the number of marginal zones west of the South Swedish Upland (e.g. Berglund 1979, Fredén 1979, 1982 and Johansson 1982). Munthe (1910), Lundqvist (1961) and Nilsson (1968) all indicate the probable existence of an ice-marginal zone which is older than the Taberg–Levene zone and situated a little further south. A corresponding zone a little south of Vetlanda has recently been proposed by Lagerlund *et al.* (1983).

An attempt to date the deglaciation of the area northwest of Lannaskede was made by Bjelm (1976). Both pollen analyses and C^{14} dating were used. Both methods show that the region was ice free at about 12 500 years B.P. during the Bölling Chronozone. A later re-interpretation by Björk (1981), points out the uncertainty of these datings and he proposes instead the presence of a more or less complete Allerød stratigraphy overlain by Younger Dryas sediments. The C^{14} age is probably 600–800 years too old according to Björk. He mentions that the Older Dryas Cronozone has been documented at Växjö. At Åseda, approximately 32 km southeast of Vetlanda, a peat layer below about 6 m of gravel, probably extra-marginal glaciofluvial sediments, has a Younger Dryas age (Robertsson 1974). The reported datings of the deglaciation of the region indicate that the origin of the marginal deposits in the Vetlanda area probably can be related to the Older Dryas Chronozone.

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REFERENCES

GFF = Geologiska Föreningens i Stockholm Förhandlingar
SGU = Sveriges geologiska undersökning

AGRELL, H., 1976: The highest coastline in southeastern Sweden. — Boreas 5. Oslo.

AGRELL, H., FRIBERG, N. & OPPGÅRDEN, R., 1976: The Vimmerby line — an ice-margin zone in north-eastern Småland. — Svensk Geogr. Årsb. 52. Lund.

BERGLUND, B.E., 1976: The deglaciation of southern Sweden. Presentation of a research project and a tentative radiocarbon chronology. — Univ. Lund, Dept. Quat. Geol. Rep. 10. Lund.

— 1979: The deglaciation of southern Sweden 13 500–10 000 B.P. — Boreas 8. Oslo.

BERGSTEN, K. E., 1943: Isälvsfält kring norra Vättern. — Medd. Lunds Univ. Geogr. Inst. Avh. 7. Lund.

BJELM, L., 1976: Deglaciationen av Småländska höglandet, speciellt med avseende på deglaciationsdynamik, ismäktighet och tidsställning. — Univ. Lund, Dept. Quat. Geol. Thesis 2. Lund.

BJÖRK, S., 1981: Synpunkter på en till stora delar fragmentarisk deglaciationskronologi i S. Sverige. — *In:* Den senaste nedisningens förlopp. — Symp. 12–13 jan. 1981. Univ Stockh., Inst. Quat. Geol. Stockholm.

DE GEER, G., 1896: Om Skandinaviens geografiska utveckling efter istiden. — SGU C 161. Stockholm.

FREDÉN, C., 1979: The Quaternary history of the Baltic. The western part. — *In* V. Gudelis & L.-K. Königsson (eds.): The Quaternary history of the Baltic. — Acta Univ. Ups. Symp. Univ. Ups. Annum Quingentesimum Celebrantis 1. Uppsala.

— 1982: An outline of the marine stage of the Väner basin. — *In* E. Olausson (ed.): The Pleistocene/Holocene boundary in south–western Sweden. — SGU C 794. Uppsala.

GILLBERG, G., 1976: Drumlins in southern Sweden. — Bull. Geol. Inst. Univ. Uppsala, N. S. 6: 125–189. Uppsala.

HOLST, N. O., 1885: Beskrivning till kartbladet Hvetlanda. — SGU Ab 8. Stockholm.

— 1893: Beskrivning till kartbladet Lenhofda. — SGU Ab 15. Stockholm.

HUMMEL, D., 1877: Beskrivning till kartbladet Vexiö. — SGU Ab 3. Stockholm.

JOHANSSON, B. T., 1982: Deglaciationen av norra Bohuslän och södra Dalsland. — Göteborgs Univ. Geol. Inst. Publ. A 38. Göteborg.
LAGERLUND, E., KNUTSSON, G., ÅMARK, M., HEBRAND, M., JÖNSSON, L.-O., KARLGREN, B., KRISTIANSSON, J., MÖLLER, P., ROBISON, J. M., SANDEGREN, P., TERNE, T., and WALDEMARSSON, D., 1983: The deglaciation pattern and dynamics in South Sweden, a preliminary report. — LUNDQUA Report 24. Lund.
LINDÉN, A. G., 1981: Grustillgångar i Vetlanda kommun. — Länsstyrelsen i Jönköpings län. Jönköping.
— 1982: Grustillgångar i Eksjö kommun. — Länsstyrelsen i Jönköpings län. Jönköping.
LUNDQVIST, G., 1961: Beskrivning till karta över landisens avsmältning och högsta kustlinjen i Sverige. — SGU Ba 18. Stockholm.
LUNDQVIST, J., 1979: Morphogenetic classification of glaciofluvial deposits. — SGU C 767. Uppsala.
MUNTHE, H., 1910: Studies in the Late-quaternary history of southern Sweden. — GFF 32. Stockholm.
— 1940: Om Nordens, främst Balticums, senkvartära utveckling och stenåldersbebyggelse. — Kungl. Sven. Vet. Handl., Ser III, Bd 19. I. Stockholm.
MÖRNER, N.-A., 1969: The Late Quaternary history of the Kattegatt Sea and the Swedish West Coast. Deglaciation, shorelevel displacement, chronology, isostasy and eustasy. — SGU C 640. Stockholm.
— 1970: The Younger Dryas Stadial. — GFF 92. Stockholm.
— 1979: The deglaciation of southern Sweden: a multi-parameter consideration. — Boreas 8. Oslo.
NELSON, H., 1910: Om randdeltan och randåsar i mellersta och södra Sverige. — SGU C 220. Stockholm.
NILSSON, E., 1953: Om södra Sveriges senkvartära historia. — GFF 64. Stockholm.
— 1968: Södra Sveriges senkvartära historia. — Kungl. Sven. Vet. Akad. Handl., Ser IV Bd 12, I. Stockholm.
PERSSON, T., 1970: Skuror och andra erosionsrännor inom Smålands högland. — Svensk Geogr. Årsb. 45. Lund.
— 1972: Geomorphological studies in the South-Swedish Highlands. — Medd. Lunds Univ. Geogr. Inst. Avh. 66. Lund.
— 1974: Eskers, plateaux, terraces and other glaciofluvial forms in the southern and central parts of the South-Swedish Highlands. — GFF 96. Stockholm.
ROBERTSSON, A.-M., 1974: Pollen analysis of organic material covered by sand and gravel at Åseda, central Småland, southern Sweden. — GFF 96. Stockholm.
STOLPE, M., 1892: Beskrivning till kartbladet Nydala. — SGU Ab 14. Stockholm.

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