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SVEN GAVELIN, INGMAR LUNDSTRÖM,
AND STIG NORSTRÖM

SVECOFENNIAN STRATIGRAPHY ON UTÖ, STOCKHOLM ARCHIPELAGO

CORRELATIONS WITH FINLAND AND SWEDEN

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ISBN 91-7158-091-3

Kartan på s. 8 är godkänd från sekretessynpunkt för spridning.
Statens lantmäteriverk 1976-02-25.

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ABSTRACT

The north-eastern part of Utö island has been remapped, with special consideration being given to stratigraphic and tectonic problems. A geological map of the Utö rocks was published by Holmquist (1910). On this map, one can discern three main rock units. The central part of the island is characterized by "hälleflintas" with beds of limestone and skarn. Along the south-eastern and north-western shores, the rocks are mapped as "mica-schist". Mainly between these two units, a rock termed "quartz-stained leptite" or "quartz-porphyry and tuff" is found. The present investigation has shown that the "mica-schists" in the south-east represent metamorphosed normal epiclastic sediments. Graded bedding and cross-bedding are very common. A detailed recording of these structures has proved that the metasedimentary group here underlies the hälleflinta-leptite group. The lower part of the south-eastern metasedimentary unit is composed of metagraywacke with abundant graded bedding. These rocks grade upwards into metasubgraywackes with abundant cross-bedding and intraformational conglomerates.

The "mica-schists" on the small islands north-west of Utö proper also seem to represent epiclastic metasediments. However, graded bedding is here extremely rare. Cross-bedding has never been observed. The epiclastic metasediments to the south-east therefore differ to some extent from those to the north-west.

The north-western belt also contains beautifully banded tuffs of dacitic to andesitic composition. These rocks are clearly exposed north-west of Utö church.

From the differences between the two belts of metasediments and from scattered observations of graded bedding to the north-west, it is concluded that the north-western metasediments overlie the hälleflinta-leptite group.

At several localities, the quartz porphyry ("quartz-stained leptite") was found to contain xenoliths of various metasediments. On the map one can also see that the quartz porphyry is not absolutely concordant with the boundaries between contrasting rock beds. For these reasons it is suggested that the quartz porhyry is intrusive, probably of a hypabyssal nature.

The map shows that the hälleflinta-leptite group and the quartz porhyry unit form an almost isoclinal fold. Holmquist interpreted this fold as a syncline with a very steep fold axis. This would mean that the metasediments to the north-west and south-east should have the same stratigraphic position. The interpretation presented here is that the fold seen on the map is a large drag fold, the north-western part of which having been cut off by a fault. The fault is assumed to run between Utö proper and the small islands to the north-west.

The new interpretation of the stratigraphy of Utö has been compared with stratigraphic schemes from other parts of the Stockholm archipelago — especially with that of the Lagnö—Svartlöga area (Lundqvist 1962). Many similarities are found. An attempt was also made to correlate the stratigraphy of the Utö area with that of the Svecofennian of central Sweden west of Stockholm and of south-western Finland. The main results of these correlations are summarized in Fig. 22.

A new guide to excursions on Utö is presented in the Appendix.

INTRODUCTION

By

Sven Gavelin

Utö is a large island of the Stockholm archipelago situated 40 km SSE of the centre of Stockholm. The island is geologically particularly interesting because, within a fairly small area, one can study fairly well preserved units of most of the supracrustal rocks which are characteristic of central Sweden, and which represent the middle part of the southern Svecofennian belt in Finland and Sweden. Moreover, the shore outcrops are clean and sometimes "polished", displaying structures on various scales — both sedimentary and tectonic.

The first comprehensive presentation of the geology of this territory was presented in an excursion guide for the XI International Geological Congress 1910. Professor P. J. Holmquist (1910) presented a map on the scale of 1:20 000, accompanied by a petrographic description of the rocks and discussions on stratigraphy and tectonics. More recent works have been presented by N. Sundius (1938, 1947, 1956), Thomas Lundqvist (1962), G. Stålhös (1962, 1969).

In the present paper only the north-eastern part of the island will be considered, from the north-eastern point of the island to about 2 km south-west of Utö church. On Holmquist's map one can discern three main rock units. One includes the central and northern part of the island which is dominated by hälleflintas (or leptites) with abundant intercalations of "crystalline limestone". This rock unit also contains quartz-banded iron ore and sometimes sulfide mineralizations. In all characteristic features the unit corresponds to the wide-spread hälleflinta-leptite group of central Sweden (in part "Bergslagen"), where limestone, skarn, iron and sulfide ores are also characteristic constituents. At Utö these rocks are bordered to the south-east by rocks which were characterized as "mica-schists" by Holmquist on his map. They are referred to as a special kind of "leptites" in the description and can be taken to represent the second main unit on Holmquist's map. Not all Holmquist's "mica-schists" are true metamorphic argillaceous rocks — a large part of them are in fact coarser quarz-rich and feldspathic rocks, which in their present association with the mica schists must represent arenaceous meta-sediments. Conglomerates also occur locally. Cross-bedding was observed by Holmquist at several localities.

Rocks somewhat similar to the representatives of this rock sequence are found north-west of the hälleflinta-leptite belt — on the skerries north-west of the main island of Utö and north and north-west of Utö church. Towards the north-west these rocks become more intensely sheared and drag folded, and an increasing amount of pegmatitic schlieren makes it reasonable to characterize them as veined gneisses. The gneisses also contain more individualized coarse pegmatites, sometimes as discordant veins or dikes, sometimes as irregular bodies or lenses.

The gneiss development can be followed towards the mainland and is probably a direct continuation of the vast gneiss areas ("Sörmland gneisses") south of

Stockholm, which are assumed to represent high-grade metamorphosed sediments of the graywacke suite.

The third unit on Holmquist's map is a continuous bed of "quartz-porphyry" — characterized as "quartz-stained leptite".

Holmquist's map shows that the hälleflinta-leptite-limestone-iron ore unit and the quartz porphyries form an almost isoclinal fold. Holmquist interpreted this fold as a syncline — an interpretation which was probably, at least partly, founded on the facing[1] of cross-bedding in the south-eastern metasediments. Thus, the latter must underlie the hälleflinta-leptite unit. This would imply that the north-western and south-eastern metasediments would stratigraphically correspond to each other and represent different limbs of the large fold. However, it seems very probable that a fault exits in the north-west between Utö proper and the small islands Tallholmen, Persholmen, and Ängsholmen. The structural pattern is therefore not as simple as one would believe after a superficial glance at the map.

During my first excusions on the island I got the impression that the hälleflinta-leptite group corresponded to the leptite group of the Bergslagen and that the metasediments could be lithologically compared with the metasedimentary rocks of the Bergslagen region — cf. for example Grythyttan (Sundius 1923), Smedjebacken (Hjelmqvist 1938), and Sörmland (Magnusson et al. 1960). In all these examples iron ores and coarse crystalline limestones are practically absent in the metasedimentary areas. The epiclastic sediments were always found to overlie the true leptites. If this is the case on Utö, then Holmquist's stratigraphic sequence ought to be reversed and the isoclinal fold would represent an anticline. However, studies of primary sedimentary structures in the outcrops of the south-eastern shore have revealed a facing towards north-west; therefore the metasediments must underlie the hälleflinta-leptite unit. Consequently, if the north-western and south-eastern metasediments stratigraphically correspond, Holmquist's interpretation would be correct. I also accepted this Holmquist's interpretation in my first publications on Utö (Gavelin 1958 and 1960).

However, Thomas Lundqvist (1962) pointed out a possible alternative explanation of the main stratigraphic features of Utö. Lundqvist's investigation concerned the supracrustal rocks on some islands situated 70—80 km north of Utö. Lundqvist made some comparisons between the two areas, especially with respect to rock types and stratigraphy. During joint excursions on the Utö area, we both became aware that the metasediments in the north-west (Persholmen) and those in the south-east (arcund L. Sillvik and Rävstavik) differ in some respects with regard to lithological development (see also pp. 16—19). Lundqvist (1962, p. 90) therefore suggested that at Utö there may be a monoclinal stratigraphic sequence from bottom beds in the south-east to top beds in the north-west. This would

1 The expression "facing" has been defined by Shrock (1948, pp. 17—18) as follows: *"Face,* or *facing* refers to the original upper surface of a layer".

mean that the large bend of the beds, as seen on the map, represents part of a drag fold, the north-western limb of which has been contorted and displaced by faults.

By extending our studies of the north-western limb we found a new kind of rock development north of Utö church. These rocks are characterized by a conspicuous banding with alternating light and dark beds. The dark beds contain feldspar phenocrysts in varying amounts and sizes.

Since the general stratigraphic sequence at Utö is very important for a correlation between different lithological units within the Svecofennian rocks — from Bergslagen to central Finland — it seemed necessary to perform some complementary investigations of the Utö area. For that reason two students remapped and performed petrographic investigations of the metasediments, recording all kinds of structures — tectonic as well as primary. Ingmar Lundström (during 1962) mainly dealt with the south-eastern metasedimentary belt, but also studied outcrops on the northern part of the north-west shore, where contacts between the north-western metasediments and the leptites are exposed. Finally the structures close to the very crest of the fold were recorded.

The north-western belt of metasediments was studied by Stig Norström (during 1966). His investigation covered the islands just north-west of the Utö island proper, the areas north-west, north, and north-east of Utö church.

Our map (Fig. 1) is a simplified presentation of Holmquist's map, with some minor corrections necessitated by the new field data. The map is intended to give a general survey of the main geological features, to show positions of some structural observations, and also to indicate suitable excursion localities.

A number of chemical analyses were made of new material and complementary microscopic studies were performed.

PRESENTATION OF NEW DATA

By

Sven Gavelin, Ingmar Lundström, and Stig Norström

SURVEY OF ROCKS AND STRUCTURES

THE HÄLLEFLINTA-LEPTITE GROUP

On Holmquist's map the hälleflinta-leptite group occupies the central part of north-eastern Utö. (For a definition of "group" and other lithostratigraphic concepts, see International Subcommission on Stratigraphic Classification 1972.) Holmquist distinguished three units. The innermost part is characterized by a large number of limestone beds, separated by beds of light to dark gray hälleflinta or leptite. The hälleflinta-leptite rocks are sometimes massive, sometimes distinctly stratified. Around this division occur skarn-rich leptites, and further outwards from the centre bedded leptites with thin layers of skarn and limestone.

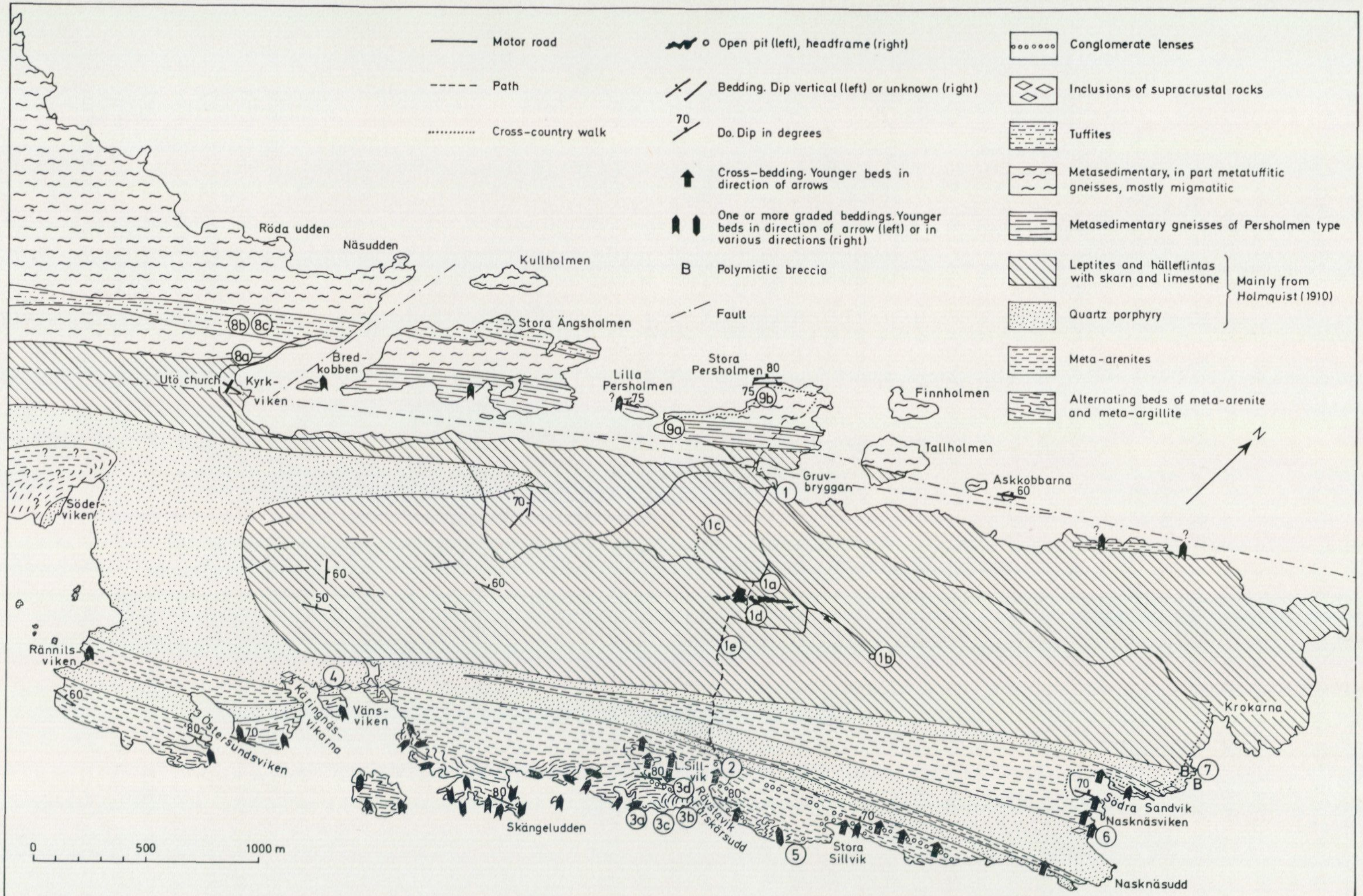

Fig. 1. Generalized geological map of the north-eastern part of Utö.

Fig. 2. Polymictic breccia, 300 m SSE of Krokarna. Excursion locality 7.

The two last mentioned types may be taken to represent a transitional zone towards the metamorphic epiclastic sediments.

In our study we generally paid little attention to these rocks, with the exception of the border zone towards the north-western sedimentary belt. Their mineralogy and petrology have been discribed by Holmquist. The north-western border zone towards the sediments will be discussed in association with the description of these sediments.

On the shore about 400 m SSE of the old farmhouse at Krokarna, a peculiar and special type of rock occurs. It consists of a kind of "breccia", where angular or slightly rounded fragments of hälleflintas, sometimes fine-bedded, possibly also meta-arenites, and limestone appear in a meta-arenaceous or leptitic groundmass (Fig. 2). The "breccia" is bordered towards the south-east by a 100 m thick bed of quartz porphyry, which in its turn is bordered by bedded meta-arenites. North-west of the "breccia" fine-bedded hälleflintas occur.

Holmquist observed this "breccia" and interpreted it as some kind of tectonic breccia, comparable with breccias situated to the east of Krokarna, see Holmquist (1910, Figs. 44—45). This interpretation is certainly erroneous, since the two types of breccia are fundamentally different. In the breccia to the east of Krokarna the hard hälleflinta beds have been broken up, and the limestone with lower competence has flowed between the hälleflinta blocks. In the "breccia"

SSE of Krokarna, on the other hand, limestone occurs as fragments and the acid fragments represent quite varying rock types.

It is difficult to make out how this rock development was formed. The fact that limestone fragments are common would justify its classification as part of the hälleflinta-leptite group. South-east of the porphyry meta-arenites occur, indicating that the "breccia" must belong to the lower part of the hälleflinta-leptite group. It could represent a volcanic breccia or agglomerate. However, the very polymict composition of rock fragments and the fairly abundant occurrence of limestone pieces gives it a different appearence from leptite agglomerates known from Bergslagen. It could also represent a breccia associated with epiclastic sedimentation. Formations of similar appearence are not uncommon in many sedimentary units as basement formations, frequently forming transitions upwards to true conglomerates with worn and rounded boulders from the basement (cf. pp. 33—34). If the "breccia" should represent an epiclastic sediment, it could be taken to indicate a local unconformity.

THE SOUTH-EASTERN METASEDIMENT GROUP

The metasediments on the south-eastern coast of northern Utö very much resemble recent sediments of the graywacke type (Gavelin 1958, 1960, Stålhös 1962). However, two contrasting developments can be discerned in the area. Thus, alternating beds of meta-arenite and meta-argillite predominate between Fårskärsudd and Östersundsvikarna, while pure meta-arenites constitute nearly all the remainder of the metasediments. Minor exceptions to this areal distribution occur, however (see map Fig. 1).

The meta-argillite bedded formation which is particularly characteristic in the Fårskärsudd-Östersundsvikarna area, is characterized by beds of mica schists frequently carrying andalusite, cordierite, anthophyllite, and occasionally almandite (Figs. 3—5). The predominant mica is biotite, sometimes chloritized. Muscovite is generally present but in varying amounts. Oligoclase may be present in small amounts but is generally sericitized. Cordierite and andalusite may be observed in the same thin section but mica schist also occurs with only one of these minerals. Sillimanite is completely absent. The cordierite is sometimes fresh, sometimes strongly pinitized. On the north-western part of Fårskärsudd mica schists occur with abundant almandite, some cordierite but no andalusite. This is the only locality known to us where almandite occurs abundantly. The predominance of either andalusite, cordierite, or almandite is apparently a consequence of variations in the proportions between aluminium, magnesium, and iron in the original sediments.

The meta-argillitic beds regularly alternate with layers of subgraywacke type, where quartz, oligoclase, and biotite are the chief constituents. Stålhös (1962, pp. 63—69) has presented modal compositions for three rock types from this area.

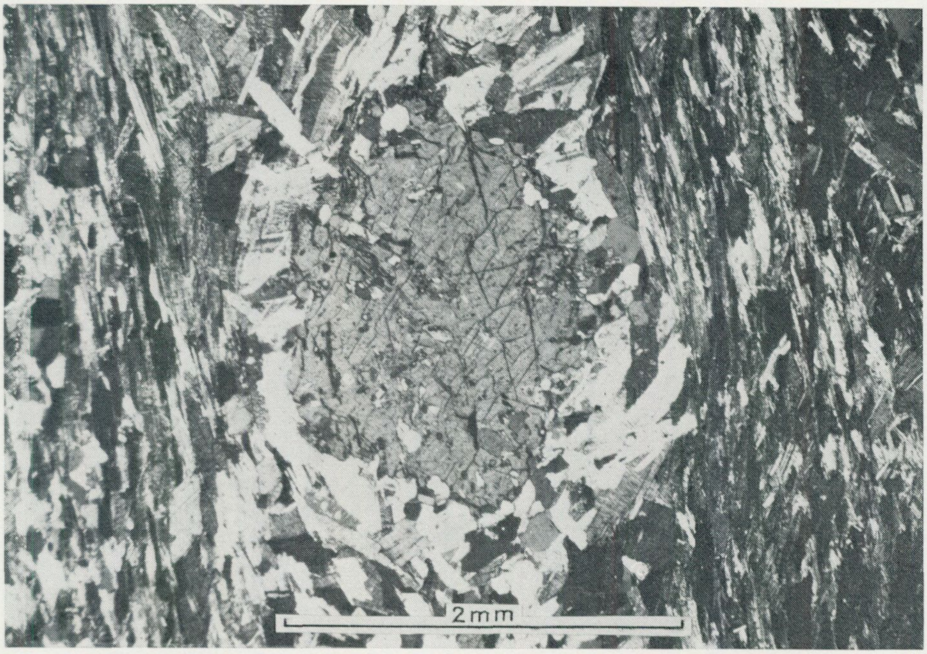

Fig. 3. Andalusite porphyroblast in meta-argillite bed. x nic. Fårskärsudd, excursion locality 3a.

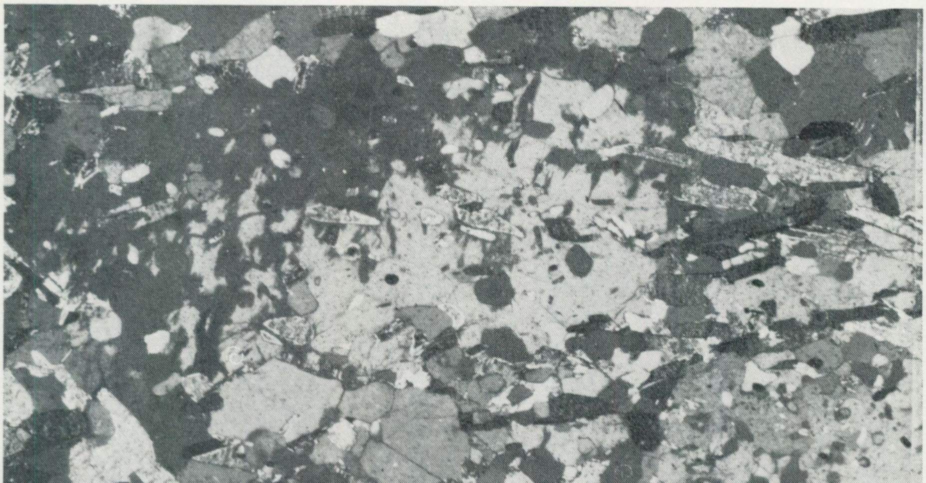

Fig. 4. Cordierite porphyroblast in meta-argillite bed. x nic. Fårskärsudd, excursion locality 3b.

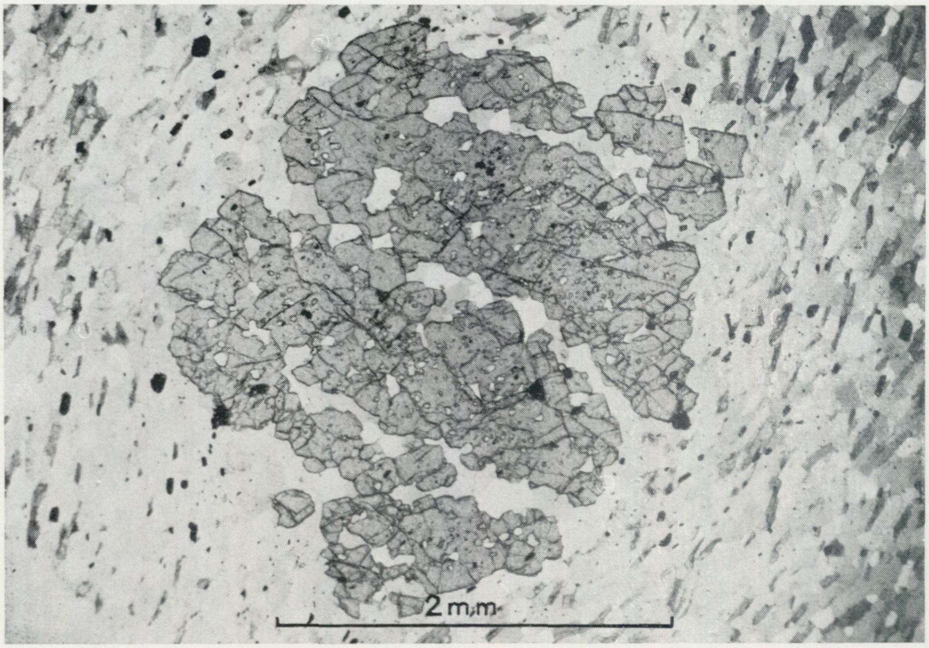

Fig. 5. Almandite porphyroblast in siliceous mica schist. 1 nic. Fårskärsudd, excursion locality 3d.

Fig. 6. Graded bedding at the shore of Rävstavik. Photo Th. Lundqvist.

Fig. 7. Graded bedding. Fårskärsudd, excursion locality 3a.

The chemical compositions of some of the rocks are given in Table 1. Analyses nos. 1—6 represent new analyses, while nos. 14—19 are analyses presented by Holmquist (1910) and Stålhös (1962, p. 34).

Although the rocks are thoroughly recrystallized, graded bedding is frequently conspicuous (Figs. 6 and 7). The thickness of the individual graded beds may vary considerably, (Fig. 7).

The clearly bedded rocks have frequently been affected by shear movements leading to drag folds on a minor scale. The fold axes are generally steep or vertical. The drag folding involves that the facing directions may change very quickly (Fig. 8). The more competent meta-arenitic beds are sometimes disrupted and may even form pseudo-conglomerates. The difference in competence between argillaceous and arenaceous beds is also indicated by the formation of

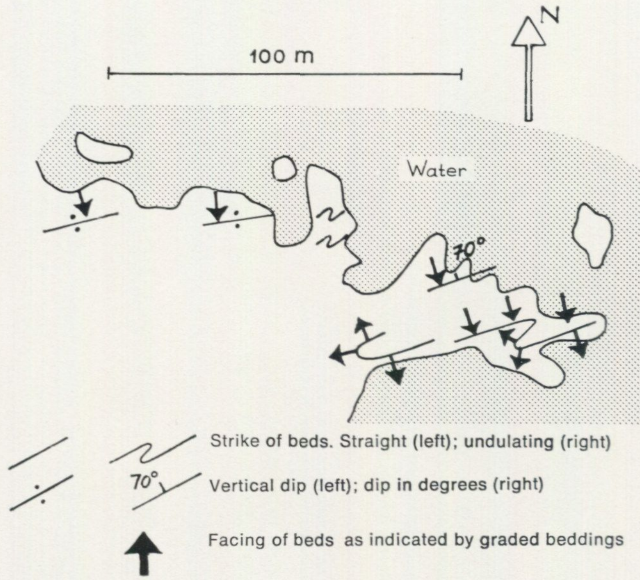

Fig. 8. Deformation style of meta-argillite bedded sediments. Skängeludden on the south-eastern coast.

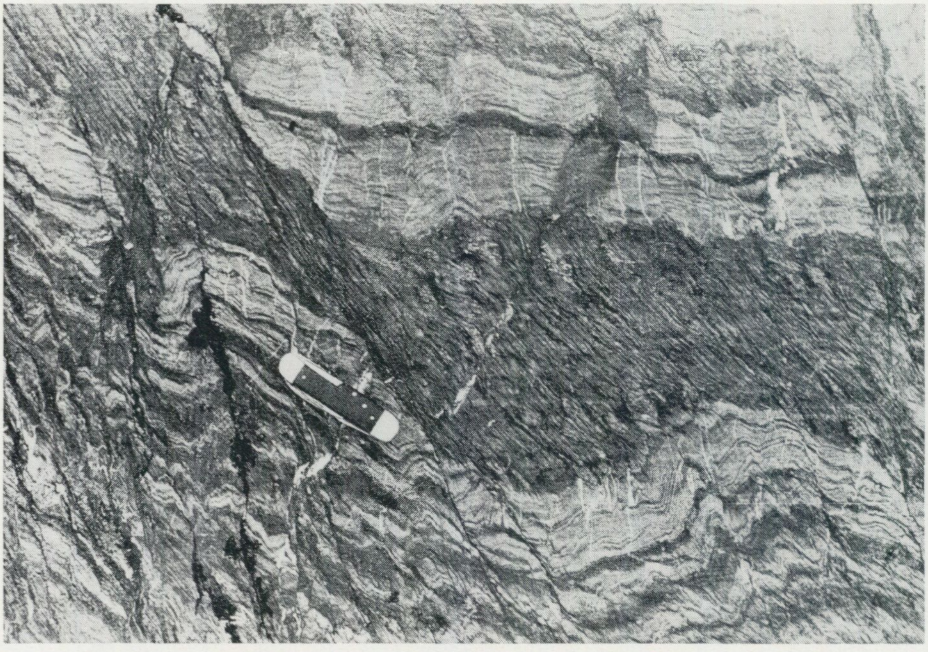

Fig. 9. Deformed metasediments with discordant schistosity. Fårskärsudd, excursion locality 3b. Photo Th. Lundqvist.

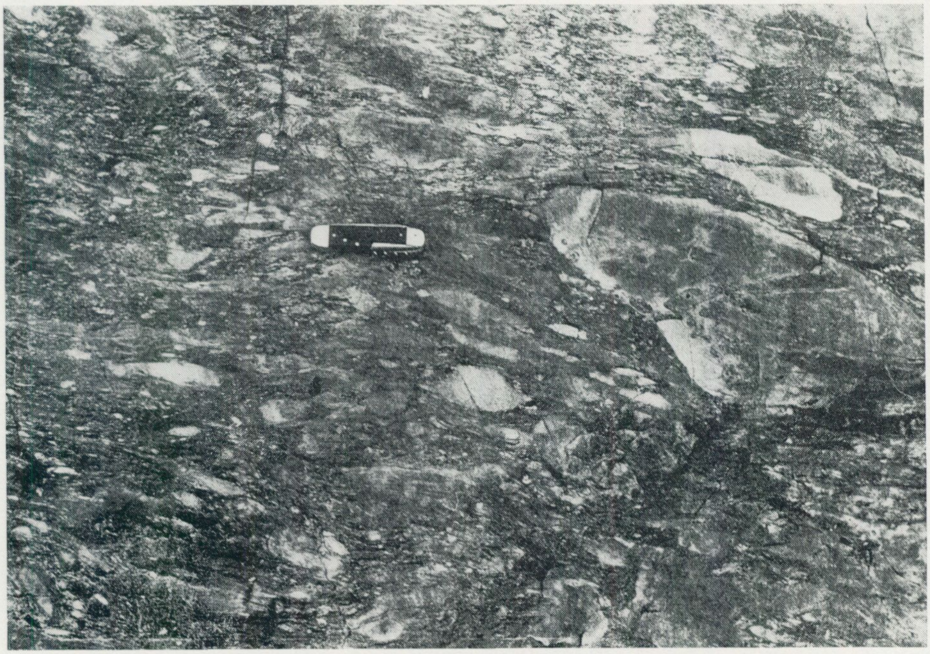

Fig. 10. Conglomerate NW of St. Sillvik. Photo Th. Lundqvist.

a marked schistosity in the argillaceous beds. This schistosity seems to be parallel to the axial planes of the minor drag folds. Thus schistosity is frequently discordant to bedding (Fig. 9).

The facing directions as determined from the graded bedding is indicated on the map (Fig. 1). Each facing symbol may represent several separate field observations. In areas of no or only moderate folding (for example Käringnäset) facing is exclusively towards the north-west. In other areas the folding is so intense that top-bottom determinations of the whole sequence are very uncertain (Figs. 1 and 8).

The meta-arenitic formation occurs in its most characteristic form at L. Sillvik, St. Sillvik, and Södra Sandvik. Argillaceous beds may occur but not as abundantly as in the meta-argillite bedded formation. Thus, at Södra Sandvik, in the upper part of the meta-arenitic formation, there exists a 40 m thick meta-argillitic belt with abundant andalusite.

The clearly meta-arenitic types sometimes pass over into conglomerates with rounded or angular pebbles of various meta-arenites (Fig. 10). The conglomerates sometimes appear as lenses with a very restricted lateral extension. Sometimes, however, they form continuous beds which can be traced over long distances. Both the composition of the pebble material and the appearance of the conglomerate bodies indicate that they represent intraformational and quite local formations. Cross-bedding may appear also in the coarser arenitic types (Fig. 11). Even the conglomeratic meta-arenites may display cross-bedding (Fig. 12). At one locality a structure reminiscent of ripple marks has been observed in this sequence.

No minor drag folds were found in the meta-arenitic division. Since the cross-bedding almost exclusively indicates facing towards the north-west (Fig. 1), it is reasonable to assume that these metasediments conformably underlie the meta-volcanic rocks (leptites and hälleflintas) to the north-west.

The two contrasting sedimentary developments indicate somewhat different sedimentary environments (Pettijohn 1957, p. 285). The meta-argillite-bedded formation greatly resembles graywackes, while the meta-arenitic formation is most similar to subgraywackes deposited in shallow water near the wave base. A shallow water deposition is also indicated for the meta-arenites at Södra Sandvik where meta-argillite fragments are found in the meta-arenite (Fig. 13). These fragments indicate that argillitic sediments were temporarily above water level, where they could dry out and disintegrate into fragments. The graywacke-subgraywacke character of these sediments can also be seen from the rock chemistry (see Table 1).

THE NORTH-WESTERN METASEDIMENT GROUP

The epiclastic metasediment formation. The classical locality for excusions to the north-western metasedimentary Utö rocks is St. Persholmen. On its south-western point a sequence of metasediments occurs where bedding is still well preserved. Fairly thin beds of darker and lighter metasediments alternate (Fig. 14). No grading has been observed at this locality, however. Towards the north-western shore of this little island these metasediments become gradually more sheared, the competent meta-arenite beds being broken up and pegmatitic veinlets more abundant. Individual large pegmatite bodies or veins also occur. On the north-western shore the rocks can be characterized as veined gneisses.

The belt of metasedimentary rocks with preserved bedding can be followed towards the south-west on the islands of L. Persholmen, St. Ängsholmen, and Bredkobben, and towards the north-east on Tallholmen and Askkobbarna. On Bredkobben two fairly distinct examples of graded bedding were found, indicating facing towards the north-west. The same direction is also indicated on the south-western part of St. Ängsholmen. On the north-western shore of Utö, about 1 km ENE of Tallholmen, exist thin intercalations of meta-arenites in the leptite sequence. Here Lundström found two indications of grading, also facing towards the north-west.

The mineral composition of the Persholmen metasediments is simple. Quartz, oligoclase, microcline, biotite, and/or chlorite + muscovite are the chief constituents. See also Stålhös (1962, p. 64) where modal compositions of three types of meta-arenite from St. Persholmen are presented. In an arenaceous bed from

Fig. 11. Cross-bedding. Nasknäsviken, excursion locality 6.

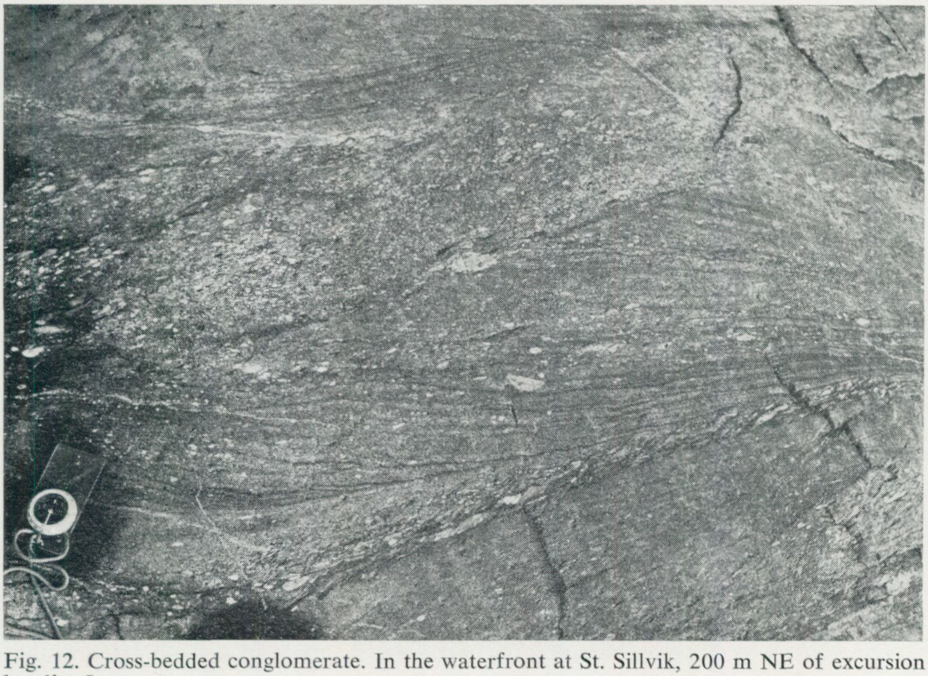

Fig. 12. Cross-bedded conglomerate. In the waterfront at St. Sillvik, 200 m NE of excursion locality 5.

Fig. 13. Meta-argillite fragments in meta-arenite. In the waterfront on the peninsula between S. Sandvik and Nasknäsviken.

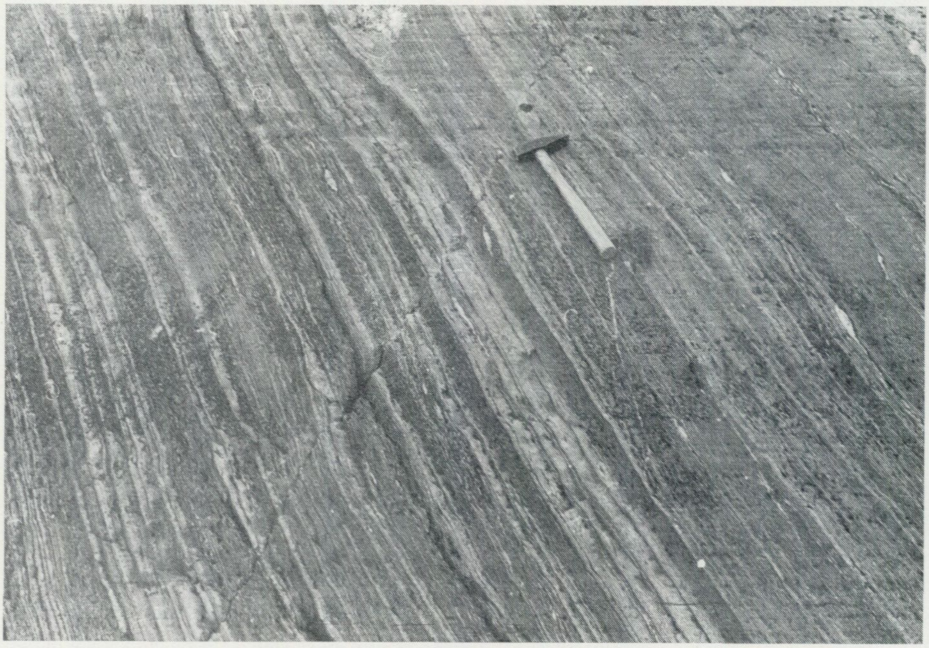

Fig. 14. Bedded meta-arenites. St. Persholmen, excursion locality 9a.

St. Persholmen cordierite has been observed. The chemical composition of these rocks is exemplified by analyses nos. 7 and 8, Table 1, representing two contrasting beds from L. Persholmen.

If the Persholmen metasediments are compared with those from the south-eastern shore, it is obvious that they differ from the outer zone in the south-east, here classified as graywackes with abundant graded bedding. The division into dark (originally argillaceous) and light (originally arenaceous) beds is much more pronounced in the outer south-east zone. Metamorphic minerals indicating the primary clay composition, such as andalusite, cordierite, and sometimes almandite, are abundant in the south-east but rare or absent in the north-west. From field studies only, it could be stated that the Persholmen metasediments to some extent resemble the transitional zone in the south-east between the distinctly graded and often argillaceous metasediments, and the overlying more arenaceous zone, where cross-bedding and conglomerates are common. In this transitional zone, however, andalusite and cordierite are fairly abundant in the micaceous beds. No indications of cross-bedding or conglomerates have been observed in the Persholmen rocks.

The metasediments (Fig. 14) pass over very abruptly into veined gneisses towards the north and north-west. This sudden transition can hardly be explained by a regional change of the P-T-conditions during metamorphism. Gavelin (1960) pointed out that kinematic metamorphism may contribute not only to selective bodily transport of rock components of contrasting physical properties but also to chemical migration of material leading to pegmatitization and granitization. The structural patterns in the section at St. Persholmen from south to north give the impression that the gneisses represent zones where intense shearing movements took place, and such movements were perhaps the ultimate cause of the gneiss developments.

The area around Kyrkviken on Utö proper (south, south-west to west of Utö church) contains several features of great interest. Outcrops 200 m south of the church and close to the church represent gray, dense hälleflintas, frequently with a conspicuous stratification. At the inner, north-western part of the bay Kyrkviken, a bed of limestone occurs in light gray skarn-bearing hälleflinta (analysis no. 12, Table 1).

In thin section this rock displays a granoblastic texture — quartz and clear, twinned plagioclase being the chief constituents. The proportions between these two minerals may vary considerably over short distances. In addition a colourless hornblende occurs more or less abundantly. Some microcline, epidote, and garnet have also been observed. Sphene occurs in fairly large amounts.

WNW from the shore of the bay various types of hälleflintas occur, with an amygdaloidal type being of particular interest since it apparently represents a true volcanic rock (analysis no. 13, Table 1). Quartz, more or less sericitized plagioclase, and to some extent microcline are the chief constituents. Biotite

Fig. 15. Plagioclase-porphyritic metatuffite. 300 m NW of Utö church, excursion locality 8c.

also occurs, in part chloritized. Rounded clusters of coarser plagioclase, generally with a large flake of biotite in the centre seem to represent amygdules.

The hälleflinta-like rocks contain intercalations which seem to correspond with the micaceous meta-arenites of Persholmen. However, these metasediments are often strongly sheared and contain pegmatitic veins to such an extent that they might be characterized as veined gneisses. The section from the shore to 150 m in a north-westerly direction shows that the boundary between the limestone-bearing hälleflinta-leptite group and the metasediments of the Persholmen type is characterized by a transitional zone.

The pyroclastic metasediment formation. About 150 m towards the northwest from the innermost part of Kyrkviken occurs a belt — 120—150 m wide — which has escaped more intense shearing. Here occur clearly bedded rocks, termed tuffites on the map, not previously recognized from the Utö area. To a certain extent they resemble the outer zone of the south-eastern sedimentary group, as their most characteristic feature is a regular alternation between contrasting light and dark beds. Here, however, the dark beds are generally characterized by phenocrysts of plagioclase in a black groundmass (Figs. 15 and 16).

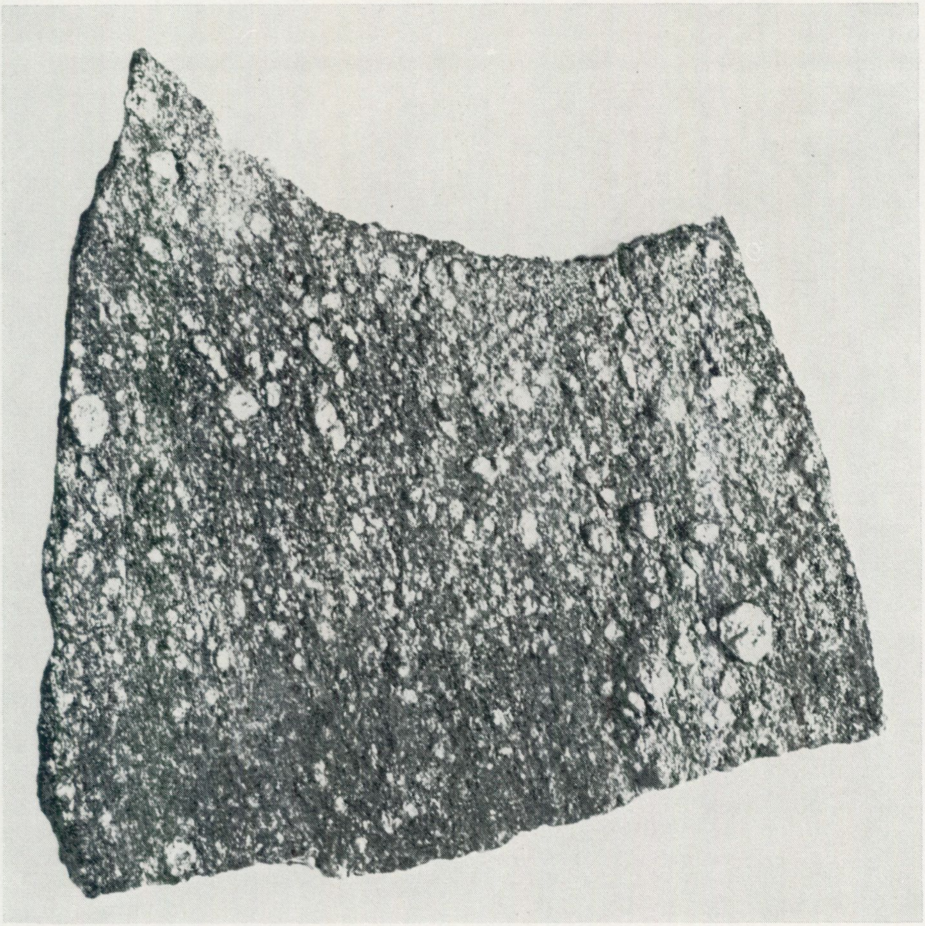

Fig. 16. The same rock as in Fig. 15, but from excursion locality 8b.

These plagioclase phenocrysts vary considerably in size and are very irregularly distributed. Even in hand specimen they appear to be true phenocrysts, an impression which is confirmed by microscope examination (Fig. 17). If this is correct, the bedded rocks in question must represent bedded tuffs, probably of andesitic to dacitic composition.

The dark beds consist of quartz, abundant plagioclase (andesine-labradorite), biotite, and a slightly greenish hornblende. The plagioclase is generally more or less sericitized; the biotite may be almost completely chloritized. The chemical composition of these beds is demonstrated by analyses nos. 10 and 11, Table 1. The analyzed specimens were taken about 100 m apart but represent approximately similar stratigraphic positions. The two analyses are almost identical.

The light beds are more quartz-rich, contain much less biotite (or chlorite)

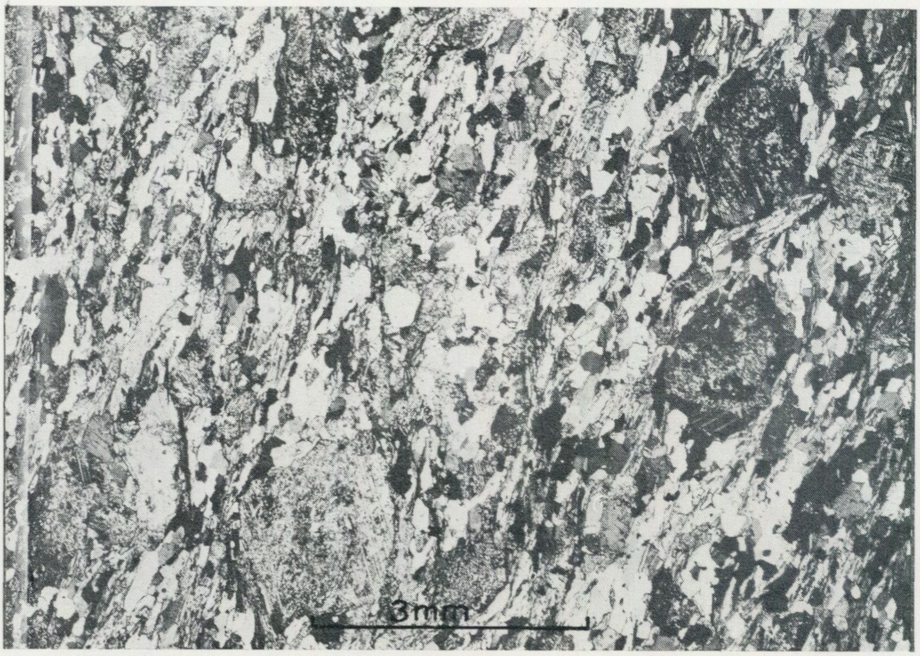

Fig. 17. Plagioclase phenocrysts in tuffite. x nic.

and no hornblende. On the other hand, microcline is sometimes present in appreciable amounts. The chemical composition is given by analysis no. 9, Table 1.

The dark beds have a very characteristic and specific appearance. Towards the north-west the bedded rocks have become strongly sheared and have in part been transformed to veined gneiss. However, even on the north-western shore of the island — for example at "Röda udden" — recognizable remnants of the dark bands with plagioclase phenocrysts have been found, indicating that this probably volcanic rock sequence has a considerable thickness.

The better preserved banded rocks have been followed towards the north-east on the north-western part of St. Ängsholmen, and towards the south-west about 2 km, where they contain narrow beds of limestone and also beds of hälleflinta-like appearance. The transitional zone from the typical hälleflinta-leptite rocks seems therefore to be somewhat broader here. Small intercalations of limestone and skarn, together with leptitic forms, are also found associated with mica schists and meta-arenites on the south-eastern shore of St. Ängsholmen, at Tallholmen and Askkobbarna. However, such calcareous layers are restricted to the border zone towards the hälleflinta-leptite group proper. The transitional features within this part of the area have also been somewhat disturbed by a fault running immediately north-west of the northern Utö mainland.

Fig. 18. Xenolith-bearing quartz porphyry. North of Käringnäsvikarna, excursion locality 4.

THE QUARTZ PORPHYRY GROUP

The quartz porphyry is a fine-grained porphyritic rock, the phenocrysts being quartz and plagioclase. On Holmquists's map this rock type is seen to occur mainly along the boundary between the hälleflinta-leptite group and the south-eastern metasediment group. Generally it seems to run concordantly or semiconcordantly with the main bedding in the area, but it sometimes branches out and then cuts the bedding at a very acute angle (see Fig. 1).

Holmquist interpreted the quartz porphyries as metavolcanites and included them in his hälleflinta-leptite unit, while Sundius (1947, p. 17, and 1956, pp. 666—667) believed them to represent primorogenic intrusions connected with the older Svecofennian granites.

Contacts between quartz porphyry and leptites or metasediments are exposed at several localities. Usually there is no evidence of chilled margins, but at some localities a decreasing grain-size of the quartz phorphyry towards the contacts has been recorded.

In the quartz porphyry xenoliths of various fine-grained metasediments or perhaps also hälleflinta are frequently found (Fig. 18). About 70 m to the north from the locality of Fig. 18, the quartz porphyry was found to contain an angular xenolith — some centimetres across — of a fine-bedded, fine-grained metasediment or hälleflinta. This outcrop, however, is situated below water level, and therefore samples or even photographs could not be obtained. Within the section from Nasknäsudd to just north of Södra Sandvik xenoliths occur both in the upper and lower parts of the quartz porphyry belts. All these observations seem to indicate an intrusive nature for this rock. Whether the intrusion took place at the onset of the volcanic activity, or whether it is definitely later than all the supracrustal rocks (as postulated by Sundius), cannot be determined with certainty from our observations (see also pp. 33—34).

Most of the quartz porphyries discussed above are very uniform and massive over wide areas. Between Stora Sillvik and Nasknäsudd there also occur rocks of a quartz porphyric appearance but these seem to be integral parts in a bedded sequence of the meta-arenitic formation. They alternate with dense beds of the type frequently met with in this formation. They might represent coarser epiclastic metasediments — perhaps some kind of arkoses. However, if the other quartz porphyries would represent subvolcanic intrusions (see p. 33), it would of course be possible that they might represent an admixture of tuffitic material, indicating the first stages of volcanic activity. The high degree of metamorphism and recrystallization makes it impossible to decide with certainty which of these two possibilities is the most probable one.

DISCUSSION OF ANALYTICAL DATA

13 new full analyses of the rocks discussed in this paper are presented in Table 1. We have also included the previous analyses published by Holmquist (6 analyses) and Stålhös (2 analyses). Our material was chosen mainly to determine the characteristic chemical properties of the metasedimentary rock units (and their closely bordering hälleflintas). The discussion is based mainly on the results of the new analyses.

The new "full analyses" have been completed by 6 new determinations of only CaO, Na_2O, and K_2O in samples from the hälleflinta-leptite group. The results of these analyses are presented in Table 2.

Fig. 19 is a compilation of those Niggli symbols which are of interest for the following discussions. They have been combined in certain groups in order to refer the samples analyzed to their positions in the field (see explanation to Fig. 19).

A conspicuous bedding is recorded both in the south-eastern and north-western metasedimentary groups, where clearly contrasting light and dark beds alternate. The analyses nos. 1—4, 18—19 and perhaps 16—17 represent pairs of adjoining dark and light beds from the south-east. In the north-west the same holds true for nos. 9—10, and, to a certain extent, nos. 7—8. However, nos. 16—17 are according to Holmquist's description from a locality where the division into dark and light layers is very insignificant. The *si* values also differ only slightly from one bed to the other. The more acid bed has surprisingly high values

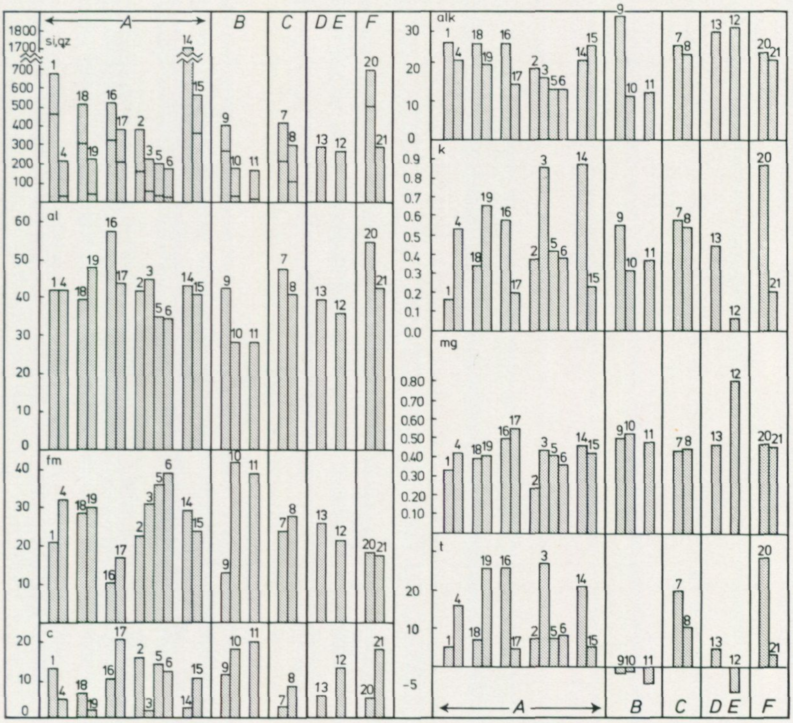

Fig. 19. Niggli values of different rock groups.
A = Metasediments on the south-eastern coast.
B = Tuffites on the north-western coast.
C = Metasediments on the north-western coast.
D = Amygdaloidal hälleflinta north-west of Utö church.
E = Skarn-bearing leptite.
F = Porphyries from the south-eastern coast.
The numbers correspond to those of Table 1.

of *al, k,* and especially of *t,* which would indicate that this beds is more clayey than the dark bed. The fact that we do not know the exact position in the field of Holmquist's material, neither the appearance of the rocks in hand specimens, means that we cannot use this pair as an example of a metasediment with clearly contrasting beds.

Analysis no. 2 represents an arenaceous mica schist from the border zone between the graywacke division with graded bedding and the cross-bedded and partly conglomeratic subgraywacke division. No. 3 is a light mica schist rich in andalusite and situated close to nos. 1—4, no. 5 is a particularly cordierite-rich mica schist from Fårskärsudd, and no. 6 is an almandite-rich mica schist about 60 m NW of no. 5 (see the map, Fig. 1). Analyses nos. 14 and 15 are from Holmquist (1910). No. 14 seems to represent a highly quartzitic meta-arenite, and no. 15 would belong to the graywacke division.

TABLE 1. Chemical analyses of Utö rocks. For localities, see p. 28.

	1	2	3	4	5	6	7	8	9	10	11
Weight-%											
SiO_2	82.1	70.0	58.7	58.2	59.8	55.5	72.7	66.8	72.4	57.4	56.0
TiO_2	0.30	0.5	0.6	0.80	0.99	1.18	0.24	0.4	0.17	0.85	0.90
Al_2O_3	8.8	15.0	20.1	19.4	17.5	19.0	14.0	15.7	13.1	15.4	15.9
Fe_2O_3	0.4	0.6	3.1	1.2	0.9	1.5	0.6	0.7	0.1	0.9	1.5
FeO	1.5	3.1	3.5	4.9	6.6	8.0	2.2	3.4	1.3	6.6	6.8
MnO	0.04	0.06	0.07	0.07	0.10	0.19	0.09	0.13	0.01	0.15	0.15
CaO	1.2	3.1	0.4	1.2	3.9	3.8	0.4	1.7	1.9	5.3	6.2
MgO	0.7	1.1	2.8	2.5	3.0	3.1	1.2	1.9	0.8	4.7	4.0
Na_2O	2.7	2.5	0.6	2.7	2.3	2.7	1.8	2.3	2.6	2.6	2.6
K_2O	0.9	2.4	5.9	4.9	2.7	2.7	4.0	4.4	5.3	1.9	2.5
$H_2O > 105$	0.4	1.2	3.3	3.1	1.5	2.3	1.9	2.2	1.0	2.9	2.5
$H_2O < 105$		+			+	+					
P_2O_5											
CO_2									0.33	0.77	
S											
BaO	0.05	0.07	0.13	0.15	0.07	0.06	0.10	0.09	0.10	0.03	0.03
Sum	99.09	99.63	99.20	99.12	99.36	100.03	99.23	99.72	99.11	99.50	99.10
Cation-%											
Si	79.7	67.3	57.8	56.4	57.5	53.3	70.9	64.3	69.2	55.3	54.3
Ti	0.2	0.4	0.4	0.6	0.7	0.9	0.2	0.3	0.1	0.6	0.7
Al	10.1	17.0	23.3	22.1	19.8	21.5	16.1	17.8	14.8	17.5	18.2
Fe^{3+}	0.3	0.4	2.3	0.9	0.7	1.1	0.4	0.5	0.1	0.7	1.1
Fe^{2+}	1.2	2.5	2.9	4.0	5.3	6.4	1.8	2.7	1.0	5.3	5.5
Mn	0.03	0.04	0.05	0.05	0.1	0.2	0.1	0.1	0.00	0.1	0.1
Mg	1.0	1.6	4.1	3.6	4.3	4.4	1.7	2.7	1.1	6.8	5.8
Ca	1.2	3.2	0.4	1.2	4.0	3.9	0.4	1.8	1.9	5.5	6.4
Na	5.1	4.7	1.1	5.1	4.3	5.0	3.4	4.3	4.8	4.9	4.9
K	1.1	2.9	7.4	6.1	3.3	3.3	5.0	5.4	6.5	2.3	3.1
P											
C									0.4	1.0	
Ba	0.01	0.02	0.05	0.05	0.02	0.02	0.03	0.03	0.03	0.01	0.01
Sum	99.9	100.0	100.0	100.1	100.0	100.0	100.0	99.9	99.9	100.0	100.1
Niggli values											
al	42.1	42.3	45.3	41.9	35.3	34.7	48.0	41.2	42.7	28.5	28.3
fm	21.4	22.7	36.3	32.2	36.8	39.1	24.2	28.1	13.1	41.9	39.0
c	10.6	16.0	1.8	4.9	14.4	12.7	2.7	8.3	11.5	17.9	20.2
alk	25.9	18.9	16.6	21.0	13.5	13.5	25.0	22.4	32.7	11.7	12.5
si	666.7	335.3	224.4	213.1	204.6	172.2	423.4	297.5	400.9	180.3	169.4
k	0.2	0.4	0.9	0.5	0.4	0.4	0.6	0.6	0.6	0.3	0.4
mg	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5
t	5.6	7.4	26.8	15.9	7.4	8.6	20.3	10.5	–1.4	–1.1	–4.3

	12	13	14	15	16	17	18	19	20	21	22
Weight-%											
SiO_2	68.30	66.7	91.67	79.20	76.92	73.99	78.0	59.4	81.02	68.32	62.73
TiO_2	0.41	0.38	0.15	0.34	0.15	0.13	0.37	0.64	0.13	0.37	0.26
Al_2O_3	15.3	15.7	4.18	9.93	14.52	14.47	10.3	21.4	10.90	16.95	14.80
Fe_2O_3	0.1	0.5	0.31	0.18	0.31	0.43	0.40	0.78	0.42	0.37	
FeO	1.0	3.3	0.72	2.04	0.65	1.71	2.73	4.71	0.96	2.27	3.25
MnO	0.03	0.04	0.01	0.05		0.05	0.03	0.05		0.12	0.30
CaO	3.0	1.3	0.15	1.43	1.32	3.84	0.9	0.5	0.32	3.93	4.39
MgO	3.0	1.9	0.50	0.94	0.53	0.99	1.2	2.2	0.68	1.32	3.57
Na_2O	7.1	3.7	0.14	2.83	1.36	2.86	2.6	1.8	0.38	3.98	0.43
K_2O	0.9	4.7	1.58	1.23	3.02	1.15	2.2	5.5	3.65	1.62	3.76
$H_2O > 105$	0.8	1.2	0.43	0.50	1.27	0.51	1.3	2.9	1.37	0.52	1.76
$H_2O < 105$							0.3	0.30			
P_2O_5			0.04	0.13	0.03	0.04	0.09	0.10	0.03	0.16	0.09
CO_2											
S			0.01	0.02		tr				0.01	
BaO	0.02	0.08	0.02	tr	0.08	tr			0.06	0.01	0.04
Sum	99.96	99.50	99.91	100.18[1]	100.16	100.17	100.42	99.95	99.92	99.95	99.79[2]
Cation-%											
Si	62.0	62.9	90.9	76.8	74.2	70.1	75.2	57.1	79.5	63.8	
Ti	0.3	0.3	0.1	0.2	0.1	0.1	0.3	0.5	0.1	0.3	
Al	16.4	17.4	4.9	11.3	16.5	16.2	11.7	24.2	12.6	18.7	
Fe^{3+}	0.1	0.4	0.2	0.1	0.2	0.3	0.3	0.6	0.3	0.3	
Fe^{2+}	0.8	2.6	0.6	1.7	0.5	1.4	2.2	3.8	0.8	1.8	
Mn	0.02	0.03	0.00	0.04		0.04	0.02	0.04		0.1	
Mg	4.1	2.7	0.7	1.4	0.8	1.4	1.7	3.2	1.0	1.8	
Ca	2.9	1.3	0.2	1.5	1.4	3.9	0.9	0.5	0.3	3.9	
Na	12.5	6.8	0.3	5.3	2.5	5.3	4.9	3.4	0.7	7.2	
K	1.0	5.7	2.0	1.5	3.7	1.4	2.7	6.7	4.6	1.9	
P			0.03	0.1	0.02	0.03	0.07	0.08	0.02	0.1	
C											
Ba	0.00	0.02	0.00		0.03				0.02	0.0	
Sum	100.1	100.1	99.9	99.9	99.9	100.2	100.0	100.1	99.9	99.9	
Niggli values											
al	35.9	39.8	46.0	41.1	57.7	44.0	39.5	48.0	55.3	42.9	
fm	21.5	25.8	29.6	23.2	10.6	16.8	28.6	29.9	18.4	18.2	
c	12.8	6.1	3.1	10.8	9.8	21.2	6.3	2.0	3.2	18.0	
alk	29.7	28.3	21.3	24.9	21.9	18.0	25.6	20.0	23.2	20.9	
si	272.1	286.7	705.7	558.6	519.5	380.7	508.0	226.3	697.2	292.3	
k	0.1	0.5	0.9	0.2	0.6	0.2	0.4	0.7	0.9	0.2	
mg	0.8	0.5	0.5	0.4	0.5	0.5	0.4	0.4	0.5	0.5	
t	–6.6	5.3	21.6	5.5	26.0	4.8	7.7	26.0	28.9	3.9	

[1] Including 1.36 % C

[2] Including 1.46 % C and 2.95 % FeS_2

Sample localities of Table 1

1. Meta-arenitic part of a graded bed. 200 m SW of Fårskärsudd. Cf. No. 4.
2. Banded mica-schist. Innermost part of L. Sillvik.
3. Andalusite-bearing mica-schist. 200 m SW of Fårskärsudd.
4. Meta-argillitic part of a graded bed. 200 m SW of Fårskärsudd. Cf. No. 1.
5. Cordierite-bearing mica-schist. Fårskärsudd.
6. Garnet-bearing mica-schist. Fårskärsudd.
7. Biotite-rich, thin-bedded metasediment. L. Persholmen.
8. Meta-arenitic bed in metasediment. L. Persholmen.
9. Light-coloured bed in tuffite. 300 m NW of Utö church.
10. Dark-coloured bed in tuffite. 300 m NW of Utö church.
11. Dark-coloured tuffite. 200 m WNW of Utö church.
12. Light, skarn- and lime-bearing leptite. W of Kyrkviken.
13. Amygdaloidal hälleflinta. 120 m NW of Utö church.
14. "Light gray, quartzitic leptite". N of L. Sillvik. (Holmquist 1910, No. 15.)
15. "Dark leptite". E of Restavik. (Holmquist 1910, No. 14.)
16. "Leptite". The light part of the same bed as No. 17. Innermost part of L. Sillvik. (Holmquist 1910, No. 7.)
17. "Leptite". The dark part of the same bed as in No. 16. Innermost part of L. Sillvik. (Holmquist 1910, No. 8.)
18. "Dark fine-grained meta-arenite". Between St. and L. Sillvik. (Stålhös 1969, p. 57, No. 1.)
19. "Fine-grained, phyllitic mica-schist". Between St. and L. Sillvik. (Stålhös 1969, p. 35, No. 2.)
20. "Quartz-stained leptite". Near L. Sillvik. (Holmquist 1910, No. 9.)
21. "Schistose porphyry". 300 m W of L. Sillvik. (Holmquist 1910, No. 11.)
22. "Black hälleflinta". The Spens mine. (Holmquist 1910, No. 6.)

The tuffites of the north-western metasedimentary belt are represented by nos. 9—11 — the unit with clearly contrasting layers northwest of Kyrkviken. Nos. 7 and 8 represent the Persholmen development of metasediments. Nos. 12 and 13 are from rocks characterized as hälleflinta and represent the transitional zone towards the hälleflinta-leptite unit proper.

The analyses nos. 20 and 21 from Holmquist (1910) would, according to the text, represent quartz porphyries. However, extremely high *al, k* and *t* values makes it very doubtful if the sample taken for no. 20 was really a quartz porphyry. No. 21, on the other hand, seems to fit very well with a quartz porphyry if its chemical and mineralogical composition is considered.

The pairs of contrasting beds from the south-eastern metasediment group, nos. 1—4 and 18—19, have some significant features in common. In both cases *c* and *alk* are higher in the light bed than in the dark one. On the other hand, *k* is higher in the dark bed. Of particular interest is the fact that the *t* values are distinctly higher in the dark beds. All these features clearly indicate that the dark layers contain abundant original clay material. It is noteworthy that the light layers also display an excess of alumina, which could indicate that they too contain some clay material.

The other analyses from the south-eastern metasediment group display fairly varying Niggli values, though an excess of alumina is common to all. No. 3 is a mica schist close to no. 4. In this case, however, muscovite is the clearly dominating mica, which may account for the high *k* value. The cordierite-rich and almandite-rich schists, nos. 5 and 6 respectively, are characterized by somewhat lower *al* values and somewhat higher *fm* values than the others, which would be expected from their mineral compositions.

The pair nos. 9—10 differs significantly from the banded forms in the south-east: *fm* is conspicuously high in the dark layer, *c* is higher in the dark layer, *alk* is, however, lower. The *k* value is higher in the light layer, a trend opposite to the relationsship in the south-east. The most striking difference comes out in the *t* values, however. All the three analyses display a slight deficiency in alumina.

All these data clearly indicate a magmatic genesis. The light layer could represent a rhyolitic composition, the dark layers an andesitic. The whole sequence would then represent tuffs of approximately dacitic composition. However, a slight mixing-in of epiclastic sedimentary material might have taken place during the sedimentation.

The two analyses representing the ”Persholmen type" of the north-western metasediment group, nos. 7 and 8, do not show any significant differences as compared with the south-eastern metasediments. The high *t* values are particularly interesting since metamorphic minerals such as andalusite and cordierite are rare or absent. It seems very probable, however, that these rocks are metamorphic epiclastic sediments. They seem to represent a different sedimentary facies from those in the south-east (no cross-bedding, no conglomerates).

The analyses of border hälleflintas in the north-west, nos. 12 and 13, display some conspicuous variations, but fit very well with chemical compositions of many leptites in central Sweden. The negative *t* value in no. 12 can be explained by the fact that the rock contains both skarn minerals and calcite.

Stålhös (1969, p. 60) has presented a very clear diagram in order to characterize various rock suites from the southern Svecofennian belt, using for parameters the Niggli values of *si* and $t+fm$. The same type of diagram was used by Simonen (1953, Fig. 15). In Fig. 20 we have plotted all the analyses presented in Table 1. The area indicated by broken lines is taken from Simonen (1953) and Stålhös (1969). It is interesting to note that the three analyses of the Kyrkviken tuffitic metasediments (nos. 9—11) fall within this area, as do the border hälleflintas (nos. 12 and 13) and the most reliable analysis of quartz porphyry (no. 21). All other analyses fall within areas characterized by argillites and arenites.

The analyses presented in Table 2 were taken to demonstrate the variations of alkalies and calcium within the hälleflintas and leptites on Utö. In the Bergslagen area of central Sweden, contrasting Na and K leptites are frequently known to have significant stratigraphic positions. The results from Table 2 and the analyses nos. 12 and 13 from Table 1 are summarized in Fig. 21. The variations are surprisingly large. The quotient Na/K varies quite irregularly. Analyses C and D are from specimens only 1 dm apart, and the analyses E and F are also from specimens taken at close proximity.

The number of analyses is definitely too small to give a significant picture of

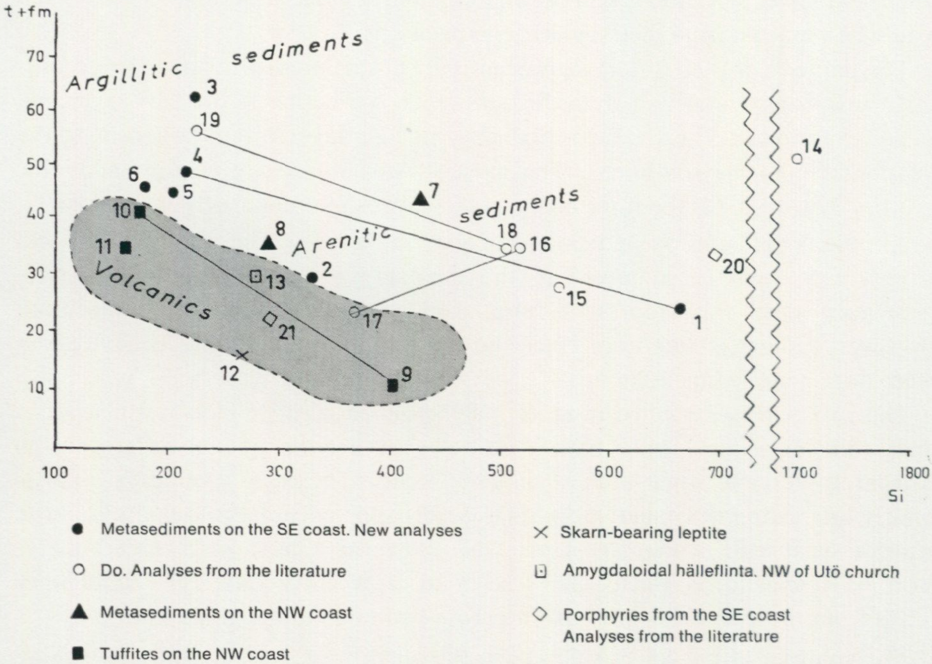

Fig. 20. Niggli *t+fm* and *si* values of Utö rocks. Lines connect analyses from light and dark parts of the same bed.

TABLE 2. Partial analyses of leptites and hälleflintas from Utö (weight-%)

	A	B	C	D	E	F
CaO	3.5	0.2	0.3	1.5	16.1	2.8
Na_2O	1.8	1.7	1.7	2.5	3.5	5.9
K_2O	10.9	6.6	10.7	4.0	0.3	0.2
Cation proportions, recalculated to 100 %						
Ca	17.7	2.0	1.7	14.0	70.7	20.5
Na	16.5	27.6	19.2	42.0	27.8	77.9
K	65.8	70.4	79.1	44.0	1.5	1.6
Sum	100.0	100.0	100.0	100.0	100.0	100.0

A. Grey leptite. 300 m NW of Rävstavik.
B. Reddish grey leptitic hälleflinta. 500 m NW of Rävstavik.
C. Light grey leptitic hälleflinta. 100 m N of the Silver mine.
D. Dark hälleflinta. 1 dm from sample C.
E. Light grey, skarn-bearing leptite. Road-cut 800 m SW of the wind-mill. Omitted in Fig. 21.
F. Greyish white hälleflinta. 25 m N of sample E.

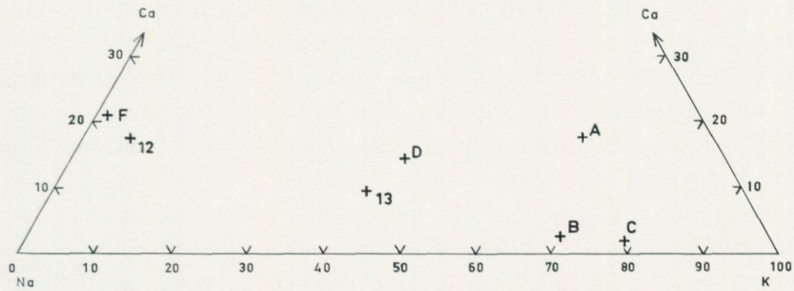

Fig. 21. Ca, Na and K proportions of leptites. Atomic proportions. A—E, F from Table 2; 12 and 13 from Table 1.

the alkali proportions within the hälleflintas and leptites of Utö, but they clearly show that the quotient Na/K may vary considerably over short distances — apparently even between adjoining beds. This quotient can therefore not be used here in any kind of stratigraphic considerations.

SUMMARY

SURVEY OF THE MAIN STRATIGRAPHIC AND TECTONIC FEATURES

The rocks of the Utö area can be divided into four major groups, viz. the south-eastern metasediment group, the hälleflinta-leptite group, the north-western metasedimentary group, and the quartz porphyry group (Fig. 1). The lowest group consists of pure, originally epiclastic sediments on the south-eastern coast. The recorded primary sedimentary structures clearly show that this unit underlies the hälleflinta-leptite group with its limestones, skarn, and iron ore. This meta-sedimentary group has been subdivided into two formations. The lower one is characterized by frequent graded bedding and is defined as mainly graywackes; the upper one is often characterized by cross-bedding and conglomerates with only occasionally graded bedding and is defined as mainly subgraywackes. This indicates a certain change from deep to shallow-water sedimentation. Lateral changes of sedimentary facies also occur, however. The thickness of the sub-graywacke division varies considerably, and within its south-western part cong-lomerates and cross-bedding seem to be absent or only occasional. However, this impression may also be due to poorer exposures in the south-west.

The stratigraphic position of the "quartz porphyries" is not certain. There are many indications that this rock has an intrusive character, and for this reason Sundius claimed that the quartz porphyries ought to be associated genetically with the older granites. Alternatively the quartz porphyries may be hypabyssal intrusions — sills or sheets — representing the first pulses of magmatic activity after the sedimentation of the subgraywackes and before the formation of the hälleflinta-leptite group proper. As the hälleflintas and leptites have been interpreted as acid volcanics, mainly tuffs, sometimes with scattered intercalations of epiclastic sediments, such an interpretation would seem reasonable. The breccia described on p. 9 (see also Fig. 2) might then represent a local erosional break in the volcanic-sedimentary evolution. The fact that limestone is found fairly abundantly as fragments shows that limestone had already been precipitated in appreciable amounts when the breccia was formed.

One of the main purposes of our investigation was to determine the stratigraphic position of the north-western metasediment group. It has been shown that the epiclastic sediments differ in some respects between the south-east and the north-west, that there was a characteristic volcanic activity in the north-west, which has no counterpart in the south-east, and that the metasediments face towards the north-west. All these facts clearly indicate that the Utö area is characterized by a continuous sequence of supracrustal rocks, the uppermost beds being the dacitic tuffs in the north-west. If the gneiss areas further towards the north-west (the Sörmland gneisses etc.) are also considered, it is evident that the dacitic volcanic activity was followed by a new graywacke sedimentation and probably also by basic magmatism.

The dominating tectonic feature within the Utö area is the large isoclinal fold, apparently a part of a large drag fold. The northwestern part of this fold is cut by a fault running NE-SW through Kyrkviken and between St. Ängsholmen and Utö. At Tallholmen this fault zone is exposed and appears as an intensely sheared zone (mica schists with pyrite), in part breccia with angular fragments of pegmatite, showing that the fault is of post-pegmatite age.

From the map (Fig. 1) it is clear that a north-south or north-westerly fault also occurs between Bredholmen, St. Ängsholmen, Kullholmen on one side and the western shore of Kyrkviken—Näsudden on the other. The contact relationships between leptite and metasediments as seen on the map indicate that these movements had both a vertical and a horizontal component.

Bedding within the map area strikes mainly north-east, with steep dips towards the north-west. The axis of the major fold plunges steeply towards the south-west.

The relatively incompetent micaceous rocks in the south-east have often been contorted and folded on a minor scale. The axes of these folds are vertical or plunge steeply towards the south-west and it seems therefore very probable that they are minor folds of the same generation as the major fold.

COMPARISONS WITH OTHER PORTIONS OF THE STOCKHOLM ARCHIPELAGO

Our investigation has covered only a very narrow section through the rock units discussed. Of course it would be desirable to extend the present investigation over the islands towards the south-west and north-east from Utö. Sundius (1938) published a map on which the large islands north-east of Utö were included (Ornö, Nämdö, Runmarö). On this map he has characterized one rock type as a "banded series of diorite-porphyrite, augengneiss, aplite, etc." From the descriptions of Sundius, and also from field studies on northern Runmarö by S. Gavelin, one gets the impression that these rocks represent bedded sediments — pyroclastic as well as epiclastic. This position is also taken by Stålhös (1969), when he discusses the Ornö area. In fact the photos presented by Stålhös (1969, p. 92, Fig. 12) and Sundius (1938, pp. 52—53, Figs. 13—16) demonstrate rocks which look very similar to those north-west of Kyrkviken (Figs. 15 and 16 in this paper). Sundius (1947) discussed a rock type called "femic leptite", which occurs south-east of Runmarö and Nämndö. Its position in relation to the leptite rocks seems to correspond with the south-eastern sediment group of Utö, but most probably Sundius has also included rocks which, in the present paper, have been referred to as skarn-banded and somewhat calcareous hälleflintas. A thorough discussion of Sundius' "femic leptites" and their probable occurrence at Utö has been presented by Stålhös (1962, pp. 63—69).

The most instructive example for stratigraphic comparisons within the Stockholm archipelago is the area described by Th. Lundqvist (1962), situated 30—60 km north-east of Stockholm (the Ljusterö-Svartlöga area). In his summary Lundqvist made some attempts to correlate his stratigraphy with that of Utö. Since the stratigraphy of Utö was not clearly determined at the time of his publication he made many reservations, but most of his suggestions have been confirmed by the present investigation.

The oldest rocks within Lundqvist's area were called "oldest leptites" but were believed to represent metamorphic graywackes. They could therefore be compared with the south-eastern metasediment group at Utö. The uppermost division in Lundqvist's stratigraphy is the limestone-bearing leptites, which can be compared with the hälleflinta-leptite group at Utö with its limestones and iron ore. In Lundqvist's area these leptites are delimited towards the north by vast granite areas and consequently the uppermost units from Utö-Sörmland are not exposed there.

However, the transition from the lowermost sediments (graywackes and subgraywackes) to the hälleflinta-leptite group contains many features of great interest. In Lundqvist's area the metagraywackes ("oldest leptites") are overlain by dacitic rocks — in part sedimentary tuffs or tuffites, in part massive dacites. These rocks are overlain by polymict conglomerates and more fine-grained metasediments. Lundqvist stated that many similarities exist between the "quartz-stained porphyries" on Holmquist's map of Utö and some of his acid dacites, which might represent lava flows or very shallow intrusions. It is questionable as to whether Lundqvist's metadacites on Svartlöga can be defined as typical dacites (69.4 and 72.2 % SiO_2 in two analyses). Holmquists's analysis of quartz porphyry from Utö (no. 21, Table 1) and the average of the three analyses of dacite (not secondarily altered) from Lundqvist's area (Tables 3, 5 and 6 in Lundqvist's paper) are very similar (for example 68.3 % SiO_2, Utö, and 68.7 % SiO_2, Lagnö-Svartlöga). The bedded tuffites north-west of Kyrkviken have a somewhat divergent chemical composition, and they come closer to an ideal dacitic composition (62—64.5 % SiO_2, the variations are due to the proportions of dark to light rock beds).

If the comparisons between the Lagnö-Svartlöga area and Utö are valid so far, it is interesting to note that the breccia on north-eastern Utö (cf. p. 9) lies in exactly the same stratigraphic position as Lundqvist's polymict conglomerates.

The attempt performed in this chapter to summarize our knowledge of the geology of the whole Stockholm archipelago clearly shows that a new systematic revision of the entire area is desirable. Most certainly one would then find many examples of primary sedimentary structures which could contribute to a better understanding of the main stratigraphic and tectonic features.

CORRELATIONS OF THE SVECOFENNIAN STRATIGRAPHY FROM THE UTÖ AREA TOWARDS THE WEST AND EAST

By

Sven Gavelin

The Svecofennian belt in central Sweden and south-western Finland contains two stratigraphic ”key areas”. The eastern one is the famous Tampere area described in detail by Simonen (1953), the western one is the Grythytte field described by Sundius (1923). In both areas there occur low-metamorphic argillites, sometimes graphite-bearing. Many attempts have been made to correlate similar rocks between Grythyttan and Tampere, and the lithological similarities between the meta-argillites in the two areas have frequently been taken as arguments for correlations. Simonen's new stratigraphic scheme differs markedly from that of Grythyttan. The most conspicuous difference is that the meta-argillites overlie the leptite group at Grythyttan, while they form the lowest unit in the Tampere district, underlying the rocks which would have corresponded to the leptites in Sweden.

In Sweden a series of metamorphic sedimentary rocks is situated about 80 km north-east of the central Grythytte field and has been denominated as the ”Larsbo Series” by Hjelmqvist (1938). The metasediments vary in composition but can be characterized as a graywacke suite. The upper portions of the series contain metavolcanics of dacitic or andesitic compositions. The Larsbo metasediments are also assumed to overlie the leptites.

The vast gneiss areas around and south of Stockholm are believed to have been formed from approximately the same kind of sediments as those of the Larsbo series. From descriptions and analyses presented by Stålhös (1962 and 1969) it seems evident, however, that at least several portions of the Sörmland gneisses are more argillaceous than the rocks of the Larsbo Series east of Smedjebacken. The Sörmland gneisses seem to be continuous with the gneisses of the Utö area.

In south-eastern Finland there occurs a belt of supracrustal rocks extending mainly east—west. These rocks are generally high-metamorphic — frequently they occur as gneisses — but certain stratigraphic successions have been recorded at several localities. Simonen (1953, p. 41) has summarized the information available at that time and found that many rock units could be taken to correspond to the rock units in the Tampere area: mica schist (graded meta-argillites) — leptitic schists containing calcareous horizons — polymict conglomerates — amphibolites (metabasalts).

In a later publication, Simonen (1960) has included results from Härme, Neuvonen, Salli, and Edelman and could verify the general trend of the stratigraphic evolution as given in 1953. Salli (1966) has published a more detailed paper on a part of the area, but with the same general stratigraphic trend as published by Simonen 1953 and 1960. Edelman (1960) made an attempt to correlate the stratigraphic columns from south-western Finland to central Sweden. He also made an attempt to compile the results from south-western Finland and recognized the following main divisions (from the top): 1. Upper mica gneiss formation, 2. Basic zone, 3. Leptite formation. 4. Lower mica schists formation. It is evident that this main division fits fairly well with the Utö—Sörmland succession.

M. Laitala (1973) has presented a new description of the Pellinge area, situated about 60 km east of Helsinki. Laitala's three main stratigraphic units seem to offer some analogies with Simonen's stratigraphy from the Tampere area. Laitala's lowermost units are interpreted as metamorphic graywackes and arkoses, frequently with graded bedding and cross-bedding. So far they seem to be very similar to the lowermost metasediments on Utö.

Simonen (1960) has proposed a three-fold stratigraphic division of the Svecofennian supracrustal rocks: Lower, Middle, and Upper Svecofennian. This division was mainly founded on Simonen's experience from the Tampere region.

On the other hand, the Utö area also exhibits a possible three-fold division, but of a slightly different kind than Simonen's. There are two very clear breaks in the geological evolution: the fairly sudden transition from the south-eastern metasediment group (with very subordinate calcareous beds and no iron ores) to the hälleflinta-leptite group with abundant limestones and iron ores. This sequence in turn changes abruptly upwards to the north-western metasediment group. Simonen includes the leptitic rocks in Sweden and Finland in his lowermost division. Starting from Sweden I would also propose a three-fold division but would define the Upper Svecofennian supracrustals as represented by the Grythytte, Larsbo, and Sörmland sediments, whereas the Middle Svecofennian supracrustals would be the leptite group with its limestones (or skarns) and iron ores, and the Lower Svecofennian supracrustals would be the lower Utö metasediments.

The Middle Svecofennian supracrustal sequence of central Sweden is believed to consist mainly of metamorphic rhyolitic or quartz-keratophyric rocks. Dacitic and andesitic volcanics are subordinate. In the south-western Svecofennian belt of Finland the leptitic rocks have been interpreted as meta-arkoses. Simonen also believes most of the leptitic rocks in the Tampere district to represent meta-arenites, but he states that fine-grained rock types also occur which could be interpreted as acid tuffs or tuffites. It seems most reasonable to correlate the ”leptites” in Sweden and Finland. This implies that the volcanic leptite facies of the Grythyttan—Larsbo areas wedges out and almost disappears towards the east. This tendency is also indicated by the small thickness of the leptites at Utö as compared with the Grythyttan—Larsbo districts. This wedging out of the true leptite facies of Sweden could account for the rarity of large-scale iron ores on the Finnish side of the Svecofennides. Laitakari (1952, Fig. 1) considered only three iron ores within the Svecofennian belt worth mentioning: Vikiniemi (20 km SW of Orijärvi), Ojamo (ESE of Orijärvi), and Jussarö (in the southern archipelago). They are all fairly small and represent very subordinate iron ore mineralizations as compared with those of the central Swedish Svecofennides.

In an attempt to correlate the stratigraphic successions from south-western Finland and central Sweden one must remember that the volcanic portion of the Swedish leptites may have been exaggerated in earlier publications. Both Gorbatschev (1969) and Wikman (1972) state, that epiclastic metasediments — in part arkoses — occur within those units which have been mapped as ”leptites” in the Örebro region. Geijer (1967) discussed the environmental conditions during the leptite period and stated that basins must have existed where normal epiclastic sediments could form. The Larsbo metasediments were also characterized as ”leptites” prior to Hjelmqvist’s investigation.

The detailed correlation of the upper Svecofennian supracrustal sequence is not clear, but the most characteristic features are common over large distances. The vast paragneisses of east central Sweden contain abundant amphibolites, which may correspond to some of the basic volcanics in Finland. However, the intensity of basic volcanism in the Upper Svecofennian supracrustal sequence as defined by me, must have varied between different parts of the Finnish-Swedish belt. Both in the Tampere area and in the Pellinge regions, the uppermost part of the stratigraphic columns are represented by thick sequences of basic volcanic rocks.

The Lower Svecofennian supracrustal sequence can be followed from Finland to Utö on the Swedish side, but further towards the west this stratigraphic unit has not been recognized with certainty.

The distribution and facies developments of the Upper Svecofennian supracrustal sequence in central Sweden have been presented in the compilation of the central Swedish iron ores by Geijer and Magnusson (1944, Tavl. 1 and 2). As far as the metasediments of the Grythyttan—Saxå—Stollberg—Hällsjö—Ställdalen—Guldsmedshyttan areas are concerned there seems to be little doubt about their stratigraphic positions as related to the leptite rocks — the lithological evolution is very similar in all cases. In Geijer-Magnusson, Tavl. 2, a small belt of schists of "Grythytte type" is indicated about 10 km north-east of Örebro. This area has been remapped and the results discussed by Gorbatschev (1969) — the eastern part of the belt (called the Glanshammar area), and Wikman (1972) — the western part of the same belt (called the Rinkaby area). Both authors found the same lithological succession: leptite with limestone — banded "leptite" — black (graphitic) schists — mica schists. This sequence fits very well with that of the Grythyttan area. The banded "leptite" of the Glanshammar—Rinkaby area would then correspond to the graywacke unit of Grythyttan. Both Gorbatschev and Wikman believe the banded leptites to represent both metavolcanics and epiclastic metasediments.

These new contributions to the geology of the Svecofennian zone in central Sweden fill a gap in our knowledge of the stratigraphy and facies changes. However, concerning the Glanshammar—Rinkaby zone, Gorbatschev and Wikman disagree as to the main stratigraphic sequence: Gorbatschev believes the argillaceous metasediments to underlie the "leptites" (quartz-feldspar rocks) with limestone beds, while Wikman takes the opposite position. Wikmans interpretation would agree well with the stratigraphy of the Grythyttan—Saxå areas. The graywackes of Grythyttan—Saxå would then correspond to the laminated or banded "leptite" of the Glanshammar—Rinkaby sequence. It is noteworthy that Sundius recorded clearly volcanic ash structures in intercalations in the graywackes of Grythyttan. In my opinion the stratigraphic position of the graphitic meta-argillites in the different areas is worth particular attention. Such rocks are missing in the Lower Svecofennian supracrustal sequence of Utö and southwestern Finland. However, graphitic meta-argillites seem to be absent also in the Upper Svecofennian supracrustal belts between Grythyttan and the Glanshammar—Rinkaby zone.

Wikman points out that Gorbatschev's interpretation of the stratigraphy, at least in part, is founded on the occurrence of cross-bedding and graded bedding, showing facing directions, but that such observations are sparse and that isoclinal folding on a small scale may obscure their validity for regional stratigraphic interpretations. Gorbatschev also emphasizes that his interpretation is "tentative" (Gorbatschev, pp. 488 and 530). He also makes the very important remark (Gorbatschev, p. 530) that if the meta-argillites should overlie the leptites, a lower division of epiclastic metasediments must exist, which in part are developed as polymict conglomerates. One of these conglomeratic beds has a very wide lateral distribution. Could these meta-rudites and some meta-arenites represent the Lower Svecofennian supracrustals of Utö — here probably alternating with meta-volcanics of the leptite type? In such a case the "main conglomerate" of Gorbatschev could represent the western shore line of the basin where the Lower Svecofennian sediments were deposited.

A	B	C
The Grythyttan — Saxå areas	*The Larsbo area*	*The Glanshammar — Rinkaby area*
Upper Svecofennian supracrustal sequence		
Gray meta-argillites Graphitic meta-argillites Graywacke Spilites 1000—1500 m thick	Graywackes, subordinate conglomerates, intermediate and basic volcanics in the upper strata Probably very thick	Mica schist, meta-arenite Graphitic schist/slate Laminated or bedded "leptite" (pyroclastic and epiclastic metasediments)
Middle Svecofennian supracrustal sequence		
The hälleflinta-leptite group with limestone, skarn and sedimentary iron ore 3 500—5 000 m thick	The hälleflinta-leptite group with limestone, skarn and sedimentary iron ore Probably very thick	Leptites with limestone
Lower Svecofennian supracrustal sequence		
Not observed	Not observed	Conglomerates, alternating pyroclastic and epiclastic metasediments, in part forming a transitional zone to the leptites with limestone above

Fig. 22. Survey of stratigraphic rock units from the Svecofennian belt through central Sweden and south-western Finland. The presentations in the various columns are founded on: A, Sundius (1923), Magnusson (1925); B, Hjelmqvist (1938); C, Gorbatschev (1969), Wikman (1972); D, Magnusson et al. (1960) and the present paper; E, Simonen (1953) and Edelman (1960) see also references in these papers; F, Simonen (1953). (Column C is tentative since interpretations of the stratigraphy in the two publications are controversary, see discussion on pp. 37—38.)

The new results from the Glanshammar—Rinkaby area must be considered with reservation. I have followed Wikmans interpretation, also believed possible by Gorbatschev, as it seems to offer a very plausible explanation of the evolution from the Grythyttan field in the west to Finland in the east.

Fig. 22 is an attempt to summarize and compare the stratigraphic sequences from some well-examined areas of the Svecofennian belt through south-western Finland and central Sweden. Very obvious differences between the western parts in Sweden and the eastern parts in Finland seem to exist.

The figures given for thickness of the various units at Grythyttan are of course very uncertain. The lower metasediments at Utö are bordered towards the south-east by granites (according to Holmquist's map). The distance between the boundaries towards granite on one side and the hälleflinta-leptite unit on the other amounts to 1 600 m (if the quartz porphyry is excluded). Because of the frequent repetitions by drag-folding, this figure is certainly too high for the

D	E	F
The Utö and gneiss area south of Stockholm	*South-western Finland*	*The Tampere area*
Upper Svecofennian supracrustal sequence		
Paragneisses, formed from mainly argillaceous graywacke sediments with abundant amphibolites (on the mainland), metasubgraywackes and dacitic metatuffites (Utö) Very thick	Upper mica schists or gneisses with amphibolites Basic volcanics Probably very thick	Basic volcanics More than 1 000 m thick Conglomerates and associated beds of sedimentary rocks 700 – 800 m thick Basic and intermediate volcanics 800 – 1 500 m thick Totally more than 3 000 m in thickness
Middle Svecofennian supracrustal sequence		
The hälleflinta-leptite group with limestone, skarn and sedimentary iron ore (Utö) Approximately 500 m thick	Leptites (mainly arkoses with limestone)	Quartz-feldspar rocks (arkoses, graywackes and pyroclastics) 1 500 – 2 000 m thick
Lower Svecofennian supracrustal sequence		
Metamorphic graywackes and subgraywackes (Utö) More than 1200 – 1600 m thick	Lower mica gneiss	Varved sediments (graywacke argillites, sometimes graphitic) More than 3 000 m thick

thickness of the unfolded sequence, which could be estimated at 1 200—1 500 m. This must represent a minimum value since no lower boundary is visible.

The thickness of the hälleflinta-leptite group has been estimated at about 500 m from Holmquist's map.

The available portions of the north-western metasediments would represent about 300 m for the Persholmen subgraywackes and more than 1 000 m for the dacitic metatuffites, possibly with intercalations of epiclastic metasediments. Since these tuffites must have been overlain by very heavy masses of various graywacke sediments, the total thickness of the uppermost unit must be very large.

In the Grythyttan and Saxå areas the hälleflinta-leptite units ought to be very thick; 3 500—5 000 m seem to be a reasonable minimum value. For the upper division of metasediments at Grythyttan Sundius estimated the thickness at about 1 000 m. From the maps it seems probable that this value can be increased to a certain extent.

No definite figures are quoted in Fig. 22 for the Glanshammar—Rinkaby area.

Gorbatschev's compilation (Gorbatschev 1969, Fig. 4), however, gives a general impression: The Upper Svecofennian supracrustal sequence would exceed 1 500—2 000 m. The thickness of the Middle Svecofennian supracrustals is difficult to estimate, depending on whether the leptites on both sides of the "main conglomerate" correspond stratigraphically or whether the diagram represents a continuous evolutionary sequence. The thickness of the "leptite" group, however, lies between that of the Grythyttan—Saxå areas and that of Utö. The exposed portions of the Lower Svecofennian supracrustals (the epiclastic metasediments) seem to be fairly thin and probably interchange with rocks of the "leptite" type.

The geological evolution of the Svecofennian area of south-eastern Finland and central Sweden appears as follows: In the east the evolution started by geosynclinal sedimentation, at least in the Tampere area. South of Tampere we find more shallow water facies (Pellinge), and the same holds true for Utö, Lagnö and Svartlöga. Further towards the west (from Utö) these sediments probably wedge out. The interpretation chosen for the stratigraphy of the Glanshammar—Rinkaby area could imply that the geosyncline or basin where the Lower Svecofennian sediments were deposited was bordered towards the west by the lower Glanshammar—Rinkaby metasediments.

It is reasonable to assume that the lower portions of the Grythyttan—Saxåfältet leptites were formed contemporaneously with the oldest sediments in the east. This would mean that sedimentation in the east corresponds to acid volcanism in the west. During further evolution the acid volcanism dies out towards the east and is replaced by arkosic sedimentation. Limestone was precipitated during that time both in the eastern and western parts of the Svecofennian belt.

This combined volcanic-sedimentary activity was then succeded by repeated sedimentation and intense intermediate and basic volcanism. Conglomerates of considerable thickness were formed especially in the eastern parts of the Svecofennian belt. The basic volcanism was particularly extensive in the eastern and north-eastern Svecofennides of Finland.

The general picture as presented above must of course be considered somewhat hypothetical and still insufficiently proved, but it may serve as a basis for further discussions and planning of additional field research.[1]

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[1] After having completed this manuscript I received a publication by G. Stålhös (1975), "Description to the map of solid rocks, Nyköping NO", SGU Af 115, where a stratigraphic sequence is presented which in the main is very similar to that of the Utö area. In his Table 8, p. 82, Stålhös has summarized the main stratigraphic features: A middle sequence of leptites and limestones which is here fairly thin and probably wedges out towards the east. Above and below this sequence (= Middle Svecofennian in my presentation, Fig. 22) there occur metasediments which means that both "Upper" and "Lower Svecofennian" in my stratigraphic proposal ought to be present in the area mapped by Stålhös.

The metasediments as described by Stålhös are high-metamorphic and appear as veined gneisses. From Stålhös' presentation it now seems probable to me that the veined paragneisses south and south-east of Stockholm (mainland in column D, Fig. 22, in this paper) may represent both the "Upper' and "Lower" metasediments as defined by me.

REFERENCES

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

EDELMAN, N., 1960: The Gullkrona region. – Bull. Comm. Géol. Finl. 187, 1–87.

GAVELIN, S., 1958: Guide till exkursion C1, VII Nordiska geologmötet.

– 1960: On the relations between kinetometamorphism and metasomatism in granitization. – GFF 82, 230–269.

– and LUNDEGÅRDH, P. H., 1960: Development of gneisses and granites in southern Sweden. – Guide to excursions nos. A 28 and C 23. XXI International Geological Congress.

GEIJER, P., 1967: The Precambrian quartzite in the Norberg District, Central Sweden, and its iron-sand bed. – SGU C 619.

– and MAGNUSSON, N. H., 1944: De mellansvenska järnmalmernas geologi. – SGU Ca 35.

GORBATSCHEV, R., 1969: A study of Svecofennian supracrustal rocks in Central Sweden. – GFF 91, 479–535.

HJELMQVIST, S., 1938: Über Sedimentgesteine in der Leptitformation Mittelschwedens. – SGU C 413.

HOLMQUIST, P. J., 1910: The Archaean geology of the coast-regions of Stockholm. – GFF 32, 789–911.

INTERNATIONAL SUBCOMMISSION ON STRATIGRAPHIC CLASSIFICATION, 1972: Summary of an International Guide to Stratigraphic Classification, Terminology and Usage. – (ISSC Report 7b, editor: H. D. Hedberg, Lethaia 5, 297–323.

LAITAKARI, AARNE, 1952: Ancient rocks in Finland and deposits of ores and other useful minerals, and industries based on them. – Reprinted from Suomi, a general handbook on the geography of Finland, Helsinki.

LAITALA, M., 1973: On the Precambrian bedrock and its structure in the Pellinge region, South Finland. – Geol. Surv. Finl. Bull. 264.

LUNDQVIST, TH., 1962: Det Svekofenniska suprakrustalstråket mellan Ljusterö och Rödlöga i Stockholms norra skärgård. – SGU C 585.

MAGNUSSON, N. H., 1925: Persbergs malmtrakt. Berggrunden inom de centrala delarna av Filipstads Bergslag. Persbergs malmtrakts malmfyndigheter. Beskrivning över mineralfyndigheter. – Kungl. Kommerskollegium 2.

– THORSLUND, P., BROTZEN, F., ASKLUND, B. and KULLING, O., 1960: Description to accompany the map of the pre-quaternary rocks of Sweden. – SGU Ba 16.

PETTIJOHN, F. J., 1957: Sedimentary Rocks. Harper & Row.

PILAVA-PODGURSKI, N., 1955: Nya undersökningar vid Utö järnmalmsfält. – SGU C 541.

SALLI, I., 1966: The Structure and Stratigraphy of the Ylivieska-Himanka Schist Area, Finland. – Bull. Comm. Géol. Finl. 211.

SHROCK, R. R., 1948: Sequence in layered rocks. – New York, Toronto, London.

SIMONEN, A., 1953: Stratigraphy and sedimentation of the Svecofennidic, early archean supracrustal rocks in south-western Finland. – Bull. Comm. Géol. Finl. 160.

– 1960: Pre-Cambrian Stratigraphy of Finland, 1960 – Intern. Geol. Congress. Report of the Twenty-First Session Norden Part IX, pp. 141–153.

STÅLHÖS, G., 1962: Nya synpunkter på Sörmlandsgnejsernas geologi med särskild hänsyn till Stockholmstrakten. – SGU C 587.

– 1969: Beskrivning till Stockholmtraktens berggrund. – SGU Ba 24.

SUNDIUS, N., 1923: Grythyttefältets geologi. – SGU C 312.

– 1938: Berggrunden inom sydöstra delen av Stockholms skärgård. – SGU C 419.

– 1947: Femisk leptit och slirgnejs. – SGU C 488.

– 1956: De geologiska förhållandena inom Utö-området. – GFF 78, 666–669.

WIKMAN, H., 1972: Beskrivning till berggrundsgeologiska kartbladet Örebro NV – Rinkaby – Väringenområdet, s. 28–114. – SGU Af 102.

APPENDIX

GUIDE TO EXCURSIONS ON UTÖ

On Holmquist's map (1910, Pl. 38), which represents the central part of the mapped area in this investigation, a number of suitable excursion localities (Nos. I—IX) have been presented. In the guide to the excursions A28 and C23 connected with the International Geological Congress 1960 (S. Gavelin and P. H. Lundegårdh, 1960, pp. 15—16) several excursion localities were presented and discussed. During our field work a number of new interesting localities have been recorded and additional information obtained for some of the older ones. The positions of localities recommended in this appendix are marked on the map, (Fig. 1). For future excursions it is advisable, however, to combine our guide with those of Holmquist (1910) and Gavelin-Lundegårdh (1960).

However, it should be mentioned that some of the previous objects are not now accessible. Thus, for example, are the bigger open pits of the old iron mines now surrounded by a fence. The specimens of the lithium pegmatite which were previously available in small lumps close to "Gruvbryggan" ("the Mine bridge") are now scarcely to be found any more.

A. Walk from "Gruvbryggan" (loc. no. 1) to Lilla Sillvik (loc. no. 2 = Holmquist no. III).

One first crosses the limestone-bedded hälleflinta-leptite group.

Point 1 a: A stone wall to the left of the road where various types of quartz- and skarn-banded iron ores can be studied. More recently a description of the ores and wall rocks has been presented by N. Pilava-Podgurski (1966), an investigation mainly founded on material from new drill holes.

Point 1b: More low-metamorphic ore, consisting mainly of very beatiful jasper-banded hematite ore, was encountered during an underground prospecting campaign in the north-eastern part of the ore field. Specimens of the jasper-banded ore could at least in 1974 be studied in lumps around the shaft. (It is advisable to visit this locality on the way back from point 2.)

Point 1c: Some small road cuttings with fine-bedded hälleflinta, sometimes with skarn layers. From the main road one has to follow the fence towards the south-east.

Point 1d: When crossing the ore layer one can recognize the pattern of drag-folding along vertical axes (linear structures at the walls of the open pits and the winding outlines of the pits).

Point 1e: Small flat outcrops in the road, where one can observe the first stages of skarn formation, i. e. amphibole needles occurring in a white calcareous groundmass.

On the path further towards the south-east one passes conspicuously layered hälleflintas with skarn followed by quartz porphyry. The most typical exposures of this rock are found on the ridge of the hill descending towards the shore of L. Sillvik.

Point 2: Cross-bedding and conglomerates in the meta-arenites of subgraywacke type. Layered metasediments with discordant schistosity also occur.

B. Walk along the south-eastern shore of Rävstavik to Fårskärsudd.

Point 3a: Graded bedding (Figs. 6 and 7). Large andalusite porphyroblasts in the originally argillaceous beds.

Point 3b: Folded graded metasediments with abundant cordierite in the meta-argillite beds, which also frequently display a discordant schistosity (Fig. 9).

Point 3c: Heterogeneous deformation: High-competent meta-arenite beds are here broken up and occur as fragments in the meta-argillites (cf. Gavelin—Lundegårdh 1960, Fig. 4).

Point 3d: Siliceous mica schist with abundant almandite. If one wishes to extend the excursion towards the north-west the following localites can be recommended.

Point 5: Graded metasediments, beautifully folded. About 200 m towards the north-east, on the northern shore of St. Sillvik, conglomeratic beds with cross-bedding (Fig. 12) are found.

Point 6: Beautiful cross-bedding, in part conglomeratic (Fig. 11).

Point 7: The breccia as exemplified by Fig. 2.

C. South-east of L. Sillvik.

Point 4: The best example of quartz porphyry with xenoliths is found here (Fig. 18). This locality can be reached by walking along the shore from Rävstavik or by following the road towards Käringnäset and walking towards the shore.

D. Excursion on the north-western, epiclastic metasediments.

Point 9a: St. Persholmen is reached by a little bridge.

At the south-eastern point of the island occur bedded meta-arenites (Fig. 14), in part also meta-argillites.

Point 9b: Walking to the north-western point of the island one passes the transition from these metasediments into veined gneisses on the north-eastern part of the island. From here one may alternatively extend the excursion by following the shore towards the north-east and once more cross the transitional zone from gneiss to better preserved metasediments.

E. Excursion to the pyroclastic metasediment north-west of Utö church.

Point 8a: Limestone and light-gray hälleflinta. Similar fine-layered hälleflintas can also be studied around the church.

Walking from *point 8a* to *point 8b* one first crosses amygdaloidal hälleflinta, followed by gneisses, probably formed from metasediments similar to those at Persholmen.

Points 8b and 8c: Conspicuously bedded rocks occur here. The dark beds generally contain abundant phenocrysts of plagioclase (Figs. 15 and 16). A short distance towards the north-west the transformation of these metatuffites into veined gneisses can be studied.

PRISKLASS D

Distribueras genom
LiberKartor
162 89 VÄLLINGBY

Växjö 1976 C Davidsons Boktryckeri AB
Printed in Sweden

ISBN 91-7158-091-3