Glacial Stadials and Interstadials of the Late Precambrian Smalfjord Tillite on Laksefjordvidda, Finnmark, North Norway

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Three glacial conglomerates and two intervening sandstones in the Smalfjord Formation on Laksefjordvidda were deposited during three glacial episodes and two interstadials, respectively. Most of the sequence is preserved in a preglacial palaeovalley. The lowermost conglomerate is interpreted as an indurated ground moraine, and the middle and upper ones are partly ground moraines, partly deposits formed under water. The interstadial sandstones consist of sand and silt carried by wind or rivers into quiet lakes or marine basins situated in the palaeovalley. The Smalfjord Tillite at Tanafjord is correlated with that of the third glacial episode of Laksefjordvidda, while the Bigganjargga Tillite at Varangerfjord is considered to have been formed contemporaneously with the lower or middle glacial conglomerate on Laksefjordvidda.

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Introduction

Laksefjordvidda is the name of the upland south of Laksefjord in Finnmark (Fig. 1). The western part of the area lies at altitudes mostly between 400 and 600 m, whereas the eastern part is somewhat lower, mainly between 200 and 400 m above sea level. The western area is underlain by sandstones belonging to the Tanafjord Group ('Older dolomite-bearing sandstone series' (Føyn 1937)); these constitute part of the Gaissa Nappe (Rosendahl 1945). Edwards et al. (1973) correlated the sequence exposed at Stallogaissa and to the north with the upper part of the Tanafjord Group (Siedlecka & Siedlecki 1971), identifying the Dakkovarre, Gamasfjell, Vagge and Hanglečærro Formations. In 1977 the present authors identified two additional formations of the Tanafjord Group, the Grønnes and Stangenes Formations east of Ullogaissa (Plate 1).

In the eastern part of Laksefjordvidda the predominating rocks are massive, fine-grained sandstones of light greenish–grey colour. Occurrences of tillite were earlier interpreted as remnants of the 'Lower tillite' (Smalfjord Tillite) resting on an erosional surface of these sandstones, which were considered to belong to the 'Older dolomite-bearing sandstone series' (Føyn 1967). In 1975, however, the present authors discovered that glacial conglomerates occur not only on top of the fine-grained sandstones but also in the middle of the sequence and at the base. The mapping of this more or less glacial complex continued in 1976 and 1977.

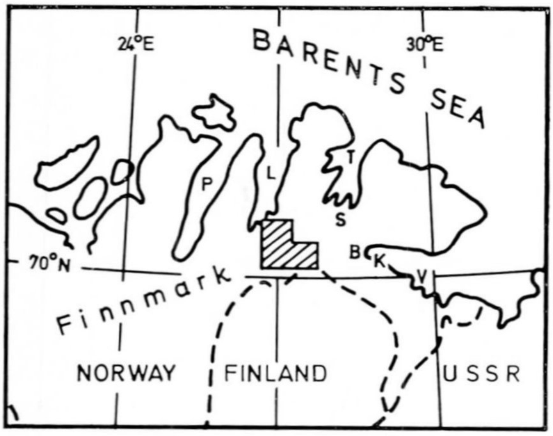

Fig. 1. Key map showing location of the map area (Plate 1), P – Porsangerfjord, L – Laksefjord, T – Tanafjord, S – Smalfjord, V – Varangerfjord, B – Bigganjargga, K – Kvalnes.

The two formations above the Smalfjord Formation, the interglacial Nyborg Formation and the glacial Mortensnes Formation ('the Upper tillite'), are only briefly commented upon in this paper. The Late Vendian Stappogiedde Formation and the Lower Cambrian Breivik Formation (Føyn 1967, Banks 1970, Banks et al. 1971, Føyn & Glaessner 1979) crop out in the northern part of the map area, but these are not considered here.

During the field-work we used aearial photos at the scale of 1:20 000 and topographical maps of 1:50 000. The map, Plate 1, has been drawn using the 1:100 000 topographical map sheets X3 Lebesby, X4 Laksefjordvidda and Y4 Polmak as a base.

Stratigraphy

The tillite-bearing sandstone sequence of Laksefjordvidda rests on an erosional surface truncating several formations of the Tanafjord Group and is overlain by the Nyborg Formation. To avoid confusion with the terms 'Lower tillite' (Smalfjord Formation) and 'Upper tillite' (Mortensnes Formation) we shall use the informal names 'Lower', 'Middle' and 'Upper Krokvatn Diamictite' (Flint et al. 1960a, b) for the three glacial conglomerate units older than the Nyborg Formation. The intervening sandstones are called the Lower and Upper Krokvatn Sandstones (Krokvatn is a lake situated centrally in the Laksefjordvidda area). Thus the Smalfjord Formation on Laksefjordvidda contains the following units:

Unit e)	Upper Krokvatn Diamictite.	Thickness:	up to ca. 100 m
Unit d)	Upper Krokvatn Sandstone.	»	:	up to 200 m
Unit c)	Middle Krokvatn Diamictite.	»	:	up to 25 m
Unit b)	Lower Krokvatn Sandstone.	»	:	up to ca. 70 m
Unit a)	Lower Krokvatn Diamictite.	»	:	up to 25 m

The entire thickness of the Lower Krokvatn Sandstone unit is exposed in a steep mountain slope about 1.5 km south of Vaddasbakte. The continuity and areal extent of the Middle Diamictite is not clear; quite possibly it may wedge out locally.

A good section through the upper part of the Smalfjord Formation occurs east of Uccaskaidde, where the river Adamselv cuts through the two upper diamictites and intervening sandstone. The section was measured over a distance of about 300 m. The beds dip towards the east, increasing from about 25° in the west to about 65° over the greater part of the section. The easternmost 90 m is represented by rocks without visible layering (blockless and unstratified tillite), but the situation directly to the north indicates a rather steep dip for the eastern boundary of this unit. Converted into stratigraphical thicknesses the Adamselv section displays the following sequence (from top to bottom):

78 m	Green or grey diamictite, structureless with few or no macroscopic clasts.
8 m	Stratified mudstones, grey or reddish; some of the beds are rich in clasts, mainly of dolomite.
22 m	Dark grey diamictite without macroclasts.
5 m	Light grey sandstone.
22 m	Dark grey to black sandstone.
37 m	Light greenish-grey sandstone.
30 m	Grey sandstone.
18 m	Debris of grey sandstone.
4 m	Light grey sandstone.
4 m	Debris material.
15 m	Diamictite, clast-bearing (minimum thickness).

The total thickness of the sequence observed at this locality is thus 243 m, consisting of at least 15 m of diamictite, then about 120 m of sandstones of varying appearance, and an uppermost diamictite of ca. 108 m thickness. The substratum of the sequence is not seeen in the river cut, nor is the boundary with the overlying Nyborg Formation. The stratigraphy observed in this section holds good over a distance of about 5 km to the east and southeast. Besides the diamictites the dark grey to black sandstone is a good marker unit within this particular area, but it has not been observed outside this 5 km-wide zone.

Palaeomorphology

The 'Krokvatn sandstones' cover the eastern part of Laksefjordvidda between the lake Store Måsevatnet in the north and the river Dævketæmjokka and the mountain Menavarre in the southeast, an area measuring approximately 30 km × 15 km. Our observations have shown that the sediments of the Smalfjord Formation were deposited in a trough or a valley eroded into the Tanafjord Group. Prior to the erosion the strata of the Tanafjord Group were tilted towards the northwest, since the Krokvatn beds successively truncate

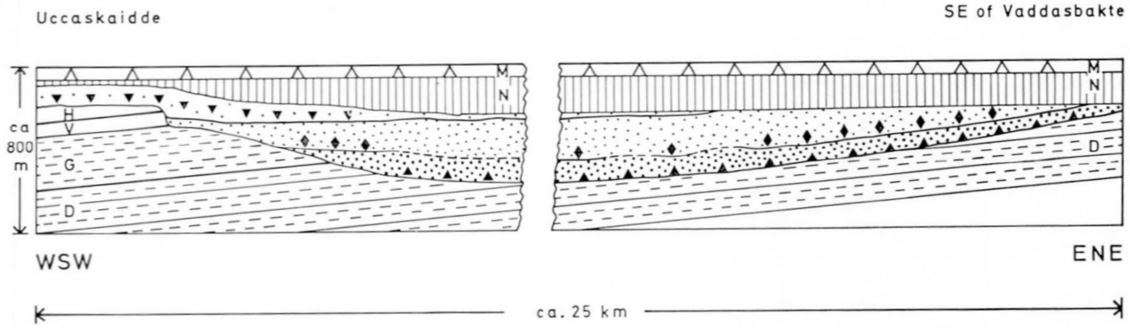

Fig. 2. Schematic section across the northern part of the 'Krokvatn basin' on Laksefjordvidda, showing the probable sedimentary situation at the end of the Vendian glaciation. Symbols and general ornament as in Plate 1. M – Mortensnes Formation, N – Nyborg Formation, H – Hanglečærro Formation, V – Vagge Formation, G – Gamasfjell Formation, D – Dakkovarre Formation.

the Grønnes, Stangenes, Dakkovarre, Gamasfjell, Vagge and Hanglečærro Formations. In the Tanafjord area, there are 935 m of strata between the Grønnes and Vagge Formations (Siedlecka & Siedlecki 1971). The corresponding sequence on Laksefjordvidda has a similar thickness (except for the Stangenes Formation which is considerably reduced). Thus, at least 800 m of sediments above the Grønnes Formation were eroded prior to and during formation of the trough.

The cross-section (Fig. 2) from about Uccaskaidde to southeast of Vaddasbakte shows how the palaeovalley was filled by members of the Smalfjord Formation. To the west successively higher units of the Krokvatn sequence border on progressively younger formations of the Tanafjord Group.

Sandstones outside the 'Krokvatn palaeovalley' at Ruksisbakčokak south of Uccaskaidde and at Čikkojokka in the southeastern corner of the map (Plate 1), correspond stratigraphically to he Upper Krokvatn Sandstone unit. The geology around Ruksisbakčokak was described by Edwards et al. (1973) who established the existence of a scarp in the palaeomorphology formed prior to the deposition of the Upper Diamictite. The scarp faces southwards and is made up of the Vagge shales and thin-bedded sandstones with a cap of Hanglečærro quartzite.

As shown on the section, Fig. 2, the present authors found that the hill Uccaskaidde was also bounded to the east by a scarp prior to the third glaciation. The scarp face may have been more or less similar to the present-day scarp on the southern and eastern side of Uccaskaidde (Fig. 3). The hill may have acted as an obstacle to the third ice movement and thus assisted in producing the remarkably thick deposits there. After the retreat of the ice Uccaskaidde may have been an area of dry land. A feature in favour of this assumption is the marked thinning of the overlying Nyborg Formation from east to west (Fig. 2), from around 200 m to only 25 m over a distance of one kilometre. Over this distance the dolomitic intercalation, which is a common feature of the lowermost beds of the Nyborg Formation, is especially marked,

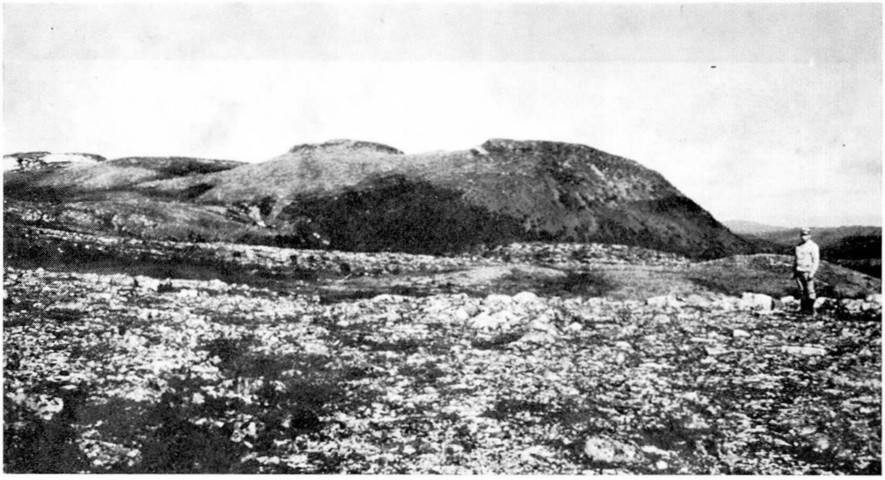

Fig. 3. The southeastern corner of Uccaskaidde, looking north. In the foreground, Gamasfjell quartzite; in the scarp Vagge shale and sandstone with a cap of Hanglečærro quartzite. Above and to the left, Upper Diamictite (Light-coloured, dolomitic).

the thickness of dolomite units exceeding 10 m. The period of favourable conditions for the precipitation of the post-glacial dolomite may have been extended during the gradual transgression of the sea up the seaward-sloping moraine surface.

Along the river Čikkojokka layered sandstones occur above a tillite (Føyn 1937, 1967). The sandstones are in part conglomeratic, and cross-bedding and ripple marks have been observed. This sandstone sequence, about 50 m thick, is overlain by the vividly red, dolomitic shales charactertistic of the lowermost beds of the Nyborg Formation. This stratigraphy indicates that the tillite in the Čikkojokka river cut corresponds to the Middle Diamictite unit, while the Upper Diamictite is lacking. Since outcrops of Precambrian gneiss were observed very close to that of the tillite, the Middle Diamictite must represent the basal tillite in this area.

Holtedahl (1918, 1931) pointed out that the peneplain south of the Caledonian front in Finnmark is replaced towards the east at Varangerfjord by relatively high relief topography of the crystalline basement. Føyn (1967) located the change to occur at Skalvvevarre (S 328 on Plate 1). The section, Fig. 4, shows our interpretation of the morphological and depositional situation towards the end of Vendian time along the present-day sedimentary border.

Lithology and origin

THE LOWER AND UPPER KROKVATN SANDSTONES

The dominant rock-type of both these units (b and d) is a very massive and homogeneous sandstone of light greenish-grey colour. We estimate this lithology to constitute at least 90% of the sediments between the diamictite units. A characteristic and striking feature is the almost complete lack of

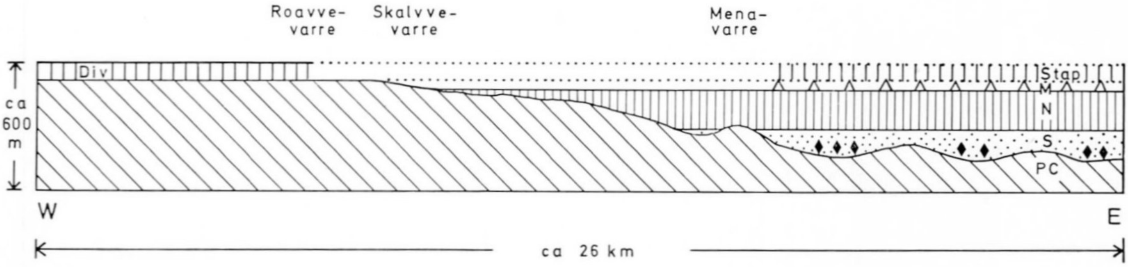

Fig. 4. Schematic section along the southern border of the sedimentary rock outcrop SE of Laksefjordvidda, showing the probable sedimentary situation towards the end of the Vendian. Div – Dividal Group, with conglomerate at base; Stap – Stappogiedde Formation; M – Mortensnes Formation; N – Nyborg Formation; S – Smalfjord Formation (Upper Krokvatn Sandstone with Middle Diamictite at base); PC – Precambrian crystalline basement. The Dividal Group rests on a peneplain, and the Nyborg and Smalfjord Formations on an uneven surface of the crystalline basement.

sedimentary structures. In places, planes are seen which are thought to represent bedding surfaces, the beds being from one to several metres thick. In most places, however, we were not able to distinguish between possible bedding planes and joints. No fine lamination, graded bedding or cross-bedding seem to exist. At one locality (about 700 m south of the south end of lake 209 in the central part of the map area) we observed ripple marks; these are irregular with wavelengths of about 20 cm.

The sandstone is pure and well cemented and has a glassy appearance different from sandstones of the Tanafjord Group. The median grain size is that of very fine sand (Fig. 5); 70% of the material is 'very fine sand and very coarse silt' (Wentworth's scale). However, grains of sizes of up to one mm occur, and no sorting is seen within individual thin-sections. The majority of the mineral grains are angular. Grains (quartz and feldspar) with diametres greater than 0.1 mm, however, are often subrounded and grains above 0.2 mm are usually rounded. Characteristically large, subrounded or rounded grains are dispersed completely at random among the large number of smaller, angular grains, (Fig. 6C). The distinction between the texture of this sandstone and that of the quartzites of the Tanafjord Group is clear (Fig. 6A and B).

The chief mineral of the sandstone is quartz. The content of feldspar is about 20%; plagioclase is somewhat more common than microcline. Accessory minerals are tourmaline, zircon or sphene and amphibolite or biotite. Crystals of pyrite (often altered to iron oxides), calcite and sericite seem to be authigenic. The sericite occurs as a fibrous mass filling the spaces between the other minerals grains. This sericite forms the main constituent of the cement of the rock, even though quartz overgrowths are also present.

At two localities, 7 km apart, in the central part of the Krokvatn palaeovalley area, scattered clasts occur in the sandstone. The clasts consist of granitic rocks and gneiss, they are up to hand size and are 'floating' in the sandstone, forming a layer. The stratigraphical position of these occurrences are uncertain, although they most likely belong to the Upper Sandstone unit.

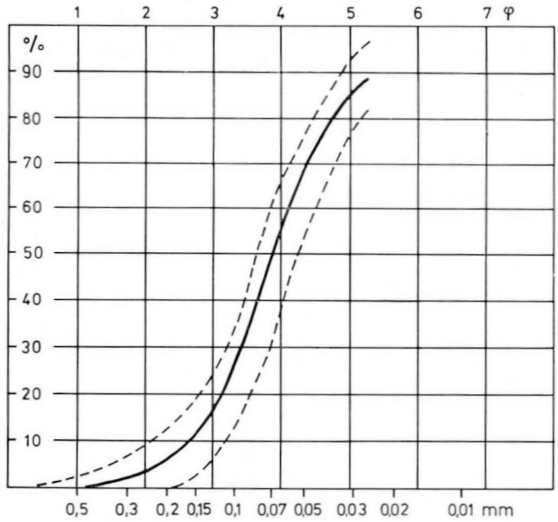

Fig. 5. Grain size distribution in interstadial sandstone, Smalfjord Formation, Laksefjordvidda. Unbroken line: Average grain-size curve based on 855 point counts from seven thin-sections (four from the Lower and tree from the Upper Sandstone unit. Md = 0.07 (or $Md\varphi = 3.85$),

$$\sigma\varphi = \frac{\varphi 16 - \varphi 84}{2} = 0.95.$$

Dotted lines; envelopes of the seven curves.

In the areas of the otherwise uniform, massive sandstones, there occur at various localities units of a darker grey siltstone. These form stratigraphical horizons of 15 to 30 m thickness which can be traced along strike for some hundred of metres. The siltstones are less competent than the sandstones and were more readily affected by Caledonian deformation. Although this may be the reason why they cannot be traced over any great distance, primary swelling and wedging out of individual units is also possible. This lithology occurs above the water-tunnel at the junction of the field road and the river Gaissavuolesjokka. The rock contains the same minerals as the massive sandstone, and the grains larger than 0.025 mm show a similar distribution. The content of matrix (i.e. grains of quartz and feldspar smaller than 0.025 mm and sericite), however, is relatively greater, about 35%, the distinguishable grains appearing to 'float' in the matrix.

The sandstones immediately above the Lower Diamictite and also those just below and above the middle one differ from the common, homogeneous sandstone in having a reddish coloration. Intercalated red siltstones and mudstones, in part laminated, are also present (Fig. 8). A thin-section (Fig. 7A) of one of the rather massive siltstones displays angular grains of quartz and feldspar with diametres mainly between 0.03 and 0.05 mm. The quartz/feldspar ratio is around 4:1.

Concerning the origin of the sands forming the Lower and Upper Krokvatn Sandstones – about 70 and 200 m of mainly massive, fine-grained sandstones almost devoid of sedimentary structures – we must try to envisage how these were transported and deposited into the Krokvatn palaeovalley. The roundness of the larger grains may be a result of earlier sedimentary cycles. Even though a supply of material from gneiss areas must be presumed, a considerable amount of the sand may have been derived from older sandstones.

It seems unlikely that an ice sheet or floes could have been responsible for the transport of material consisting of grains exclusively below 1 mm dia-

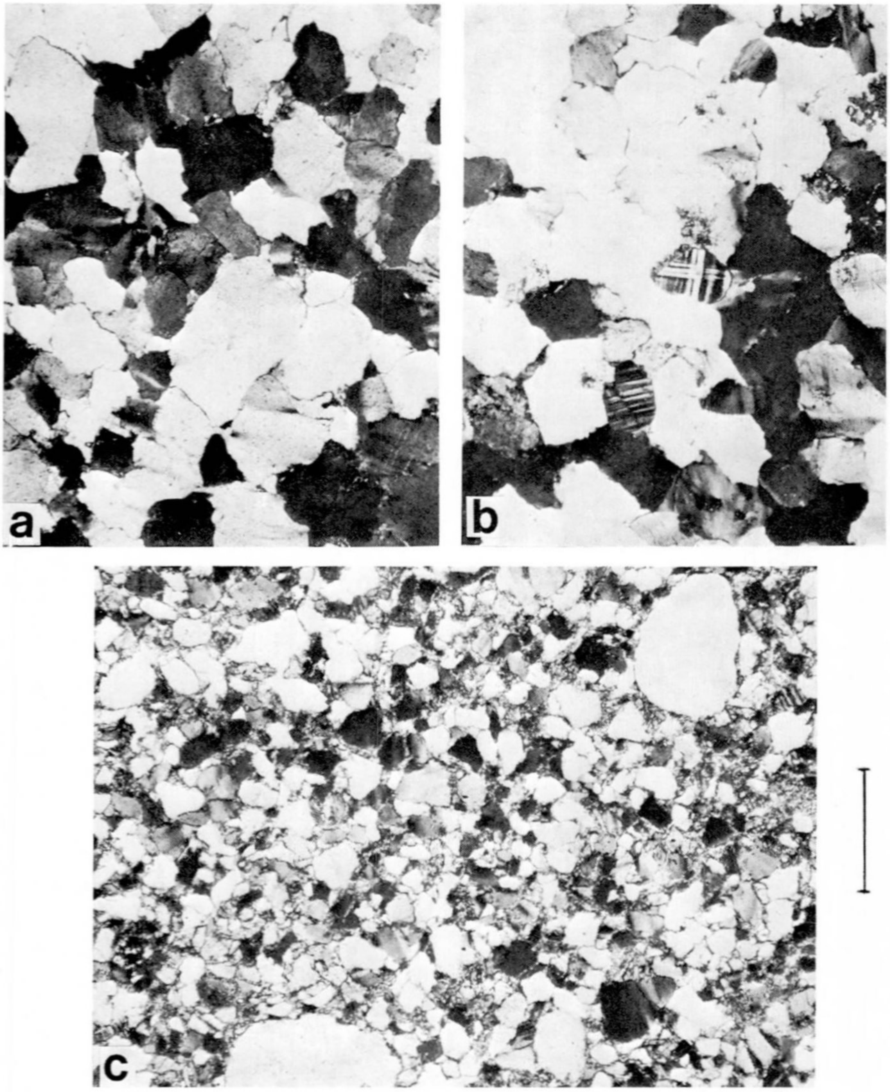

Fig. 6A. Quartzite, Gamasfjell Formation. SE of Uccaskaidde. Specimen X4–188. Crossed nicols.
B. Feldspathic quartzite, Dakkovarre Formation. 5 km SE of Vaddasbakte. Specimen X4–146. Crossed nicols.
C. Lower Krokvatn Sandstone, Smalfjord Formation. 4 km S of Vaddasbakte. Specimen X4–148. Crossed nicols.
Bar-scale = 0.5 mm. Photos L. P. Nilsson, NGU.

meter. The glaciers must presumably have withdrawn during the interstadials. Floes may, however, have transported and dropped the scattered clasts occurring in the sandstone (p. 36).

A red siltstone (Fig. 7A) occurring just above the Middle Diamictite seems to resemble closely rocks that M. B. Edwards (1976, 1979) interpreted as loessite or indurated loess. His loessites occur on top of the Sveanor Tillite (Spitsbergen) and on top of the Smalfjord Tillite at a locallity at Tanafjord.

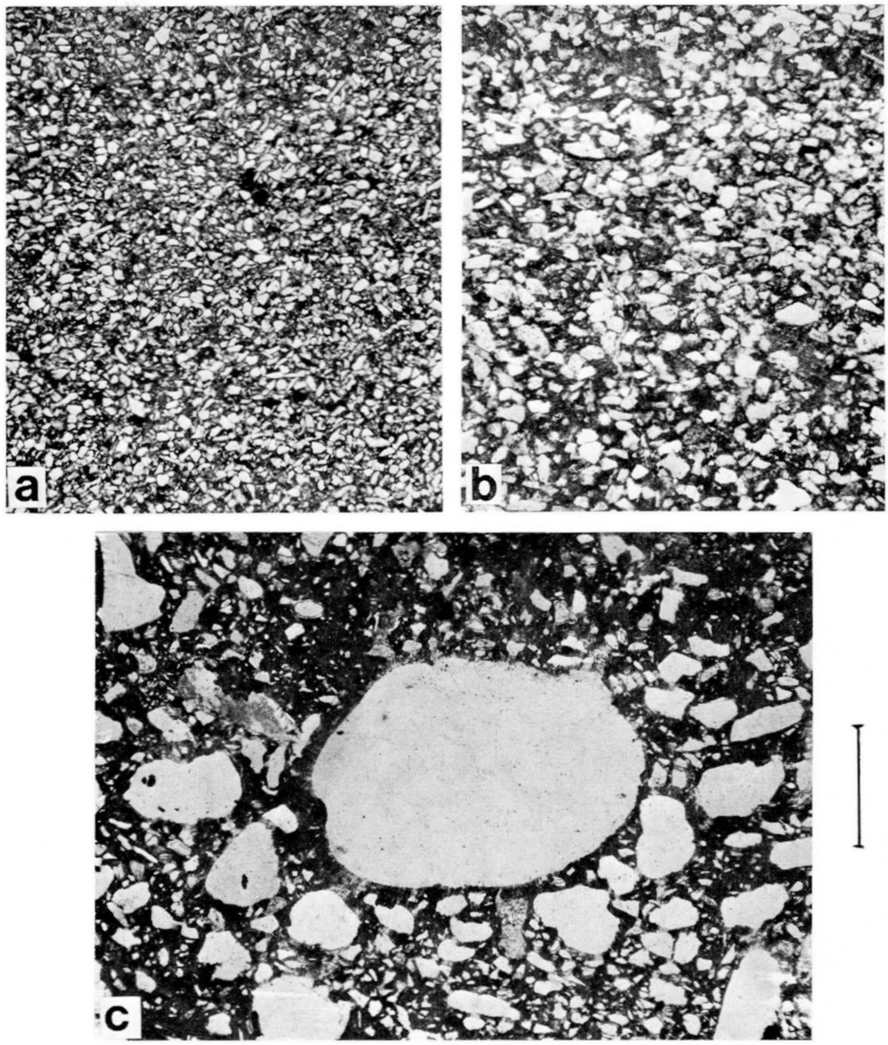

Fig. 7A. Red siltstone, a few metres above the Middle Krokvatn Diamictite, Smalfjord Formation. Along the road (track) between Krokvatn and Gaissavuolesjokka. Specimen X4–130. Plane polarized light.
B. Grey siltstone, equivalent to the Upper Krokvatn Diamictite, Smalfjord Formation. Between '353' and '275' N of Dævketæmjokka. Specimen Y4–19. Plane polarized light.
C. Matrix of the Middle Krokvatn Diamictite, Smalfjord Formation. Along the road (track) between Krokvatn and Gaissavuolesjokka. Specimen X4–90. Plane polarized light.
Bar-scale = 0.5 mm. Photos L. P. Nilsson, NGU.

Accordingly, at least a part of the Krokvatn deposits may be wind-transported material. Most of the Krokvatn Sandstones, however, consist of grains larger than the upper limit of loess. As wind is also capable of carrying larger grains over relative short distances, the possibility exists that the sandstones were formed by sand blown into a lake or marine basin. Another explanation is likely, however. In general, massive, structureless sandstones may be formed by rapid deposition from suspension. Thus, a possible interpretation is that

Fig. 8. The Middle Krokvatn Diamictite and laminated basal beds of the Upper Krokvatn Sandstone, Smalfjord Formation. Looking along the axis of an anticline plunging gently towards the south. About 3 km E of Krokvatn.

sand and silt were carried by rivers into a quiet lake or marine basin situated in the Krokvatn palaeovalley. The scarcity of the finest material suggests low salinity, the clay particles having been transported still in suspension further towards the sea. As the bulk of the sandstones within the two units are lithologically identical, the geological and hydrological environments must have been similar during the two interstadials.

THE LOWER DIAMICTITE

The Lower Diamictite (unit a) occurs on the river bank of Gaissavuolesjokka northeast of Stallogaissa and outcrops are common south and southeast of Vaddasbakte. In both areas it rests directly on the Dakkovarre Formation. The thicknesses observed are from 15 m to 25 m. At one locality east of the lake ca. 3 km SSW of Vaddasbakte, a 2 m-thick layer of sandstone is present within the unit, but everywhere else it is massive. The matrix is usually sandy; besides angular mineral fragments it also contains subrounded and rounded grains of quartz and feldspar. The colour is mostly grey, in part red. The clasts consist of sandstones, granitic rocks and gneisses, up to 40 cm in size. Some of the clasts are faceted. The diamictite is interpreted as a basal tillite (indurated ground moraine).

The clasts of sandstone appear to have originated from the Tanafjord Group. Nothing definite can be said about the source of the clasts of granitic rocks and gneisses, although they have most likely been derived from the crystalline basement in the southeast and transported by the glacier along the palaeovalley. A characteristic porphyritic quartz–diorite occurring directly to the south of Laksefjordvidda has not been found as clasts in the Lower Diamictite, nor has the garnet granulite of the area southwest of Laksefjordvidda.

THE MIDDLE DIAMICTITE

The Middle Diamictite (unit c) closely resembles unit a, and the two units can be distinguished only on stratigraphic criteria. The unit rests on reddish or red sandstones, siltstones or mudstones. In places, similar stratified sediments occur within the lowermost part of this unit and have also been observed on top. At one locality faint lamination and dropstone structures were observed in the otherwise massive diamictite.

Exposures of the Middle Diamictite are abundant in the northeastern part of the Krokvatn area; in the western and central part more or less isolated occurrences are found, and we also interpret some occurrences in the southeasternmost part of the map area (Plate 1) as equivalents of this unit. Unit c is red or grey, and the thickness is estimated to be from 15 m to 25 m. The matrix generally seems to be less sandy as compared with that of the Lower Diamictite. Clasts up to 50 cm across have been observed in the central area. Noteworthy are some granitic rocks of bright red colour. In the tillite south of Menavarre a block measuring 1.5 m across was observed, consisting of the local basement rock, the characteristic porphyritic quartz–diarite.

The diamictite lowermost in the Adamselv section described above (p. 33) has a lithology which is very similar to that of the Lower Diamictite: a rather sandy matrix and the presence of faceted clasts. However, for stratigraphical reasons it must represent the middle unit, even though the material appears to have been deposited under conditions more typical for the lower unit. In general, the Middle Diamictite seems to have been deposited from a glacier which in some parts of the area or for some of the time was floating; elsewhere, or at other times, it appears to have been grounded.

The diamictite south of Menavarre contains material derived from the immediate vicinity or from an area directly to the south of it. Bodies of bright red granite occurring in the basement southeast of the Čikkojokka area are probably the sources of the granite clasts mentoned above. Thus, the ice movements would seem to have been directed towards the northwest.

THE UPPER DIAMICTITE

The Upper Diamictite (unit e) displays a variety of lithologies: buff tillite with dolomite matrix and rich in dolomite clasts; sandstones and purple laminated siltstones; massive grey tillite with many, few or no clasts; dark grey or blue-grey siltstones with or without a fine lamination and with few or no clasts. These various facies are found especially in the northwestern part of the map area, at Uccaskaidde, where the thickness of unit e is estimated to be approximately 100 m. The high content of dolomite clasts here may indicate a rather local, perhaps western source for this material; in this regard, the Porsanger Dolomite occurs only about 8 km west of the western border of the map area. The complexity of the Upper Diamictite at Uccaskaidde implies that it represents more than one glacial advance and retreat.

Eastwards from Uccaskaidde and the Adamselv river-section, the thickness of the Upper Diamictite decreases notably. Below the basal beds of the Nyborg

Formation in most parts of the map area, there is a dark grey siltstone, generally without lamination and varying in thickness from a few metres to about 20 m (Fig. 7B). No clasts were found except at Dollajavrre. The dark grey siltstone is distinctive from the underlying light greenish-grey quartzite of the Upper Krokvatn Sandstone. As we were able to observe a gradual transition from clast-bearing diamictite into the dark grey siltstone, this latter lithology is interpreted as being an equivalent of the highest part of the Upper Diamictite, deposited during the late stages of this period of glaciation.

In the northeastern corner of the map area (Plate 1, Fig. 2) the Nyborg Formation rests unconformably on the Smalfjord Formation, the Upper Sandstone and Middle Diamictite units being absent. In all probability they were deposited but then removed by erosion, either glacial during the third episode or post-glacial.

Comparison with the Smalfjord Formation at Varangerfjord and Tanafjord

The type area of the Smalfjord Formation (Bjørlykke et al. 1967) is situated west of Smalfjord at the head of Tanafjord (Fig. 1), where massive tillites are dominant with subordinate laminated sandstones and mudstones (Føyn 1937, Reading & Walker 1966, Edwards 1972, Edwards & Føyn 1979). Around the inner part of Varangerfjord the Formation displays a different development; stratified sandstones and conglomerates dominate, with local occurrences of unsorted glacial conglomerates, including the well-known Bigganjargga Tillite (Reusch 1891, Holtedahl 1918, Bjørlykke 1967, Edwards 1972, 1975). The development on Laksefjordvidda represents a third type, the bulk of the deposits being massive, almost structureless sandstones containing three horizons of glacial conglomerates.

There are certain similarities between the depositional conditions of the Smalfjord Formation on Laksefjordvidda and those at the inner part of Varangerfjord. The sediments at Varangerfjord appear to have been deposited in a NW–SE-trending through (Bjørlykke 1967). Edwards (1972) records two glacial episodes, perhaps even a third one. In the first episode he includes the formation of the tillites at Kvalnes and at Bigganjargga (Fig. 1). The stratified sandstones with intercalations of conglomeratic horizons differ from the massive, fine-grained sandstones of the Krokvatn trough, but they resemble the sandstones occurring outside the trough. The Bigganjargga Tillite and one of the two lower diamictites of Laksefjordvidda, particularly the lowermost one, are most likely contemporaneous.

In the Tanafjord area the Smalfjord Formation, according to Edwards (1972, Edwards & Føyn 1979), consists of five units, each representing an advance and subsequent retreat of the glacier. Sandstone occurs, but it is an uncommon facies. Edwards correlates the three lowermost units (A, B,C) with the tillite of Uccaskaidde, i.e. the Upper Krokvatn Diamictite on Laksefjordvidda. Unit B is the unit which is particularly rich in dolomite clasts and has a dolomite matrix. Equivalents of the sandstones and of the two lower diamictites of the Krokvatn trough have not been observed in the Tanafjord area. This indicates, in our view, that these lower sediments of the Smalfjord Formation were deposited — or survived the third glacial episode — only in pre-existing troughs or valleys (i.e. on Laksefjordvidda, in the Čikkojokka area and at Varangerfjord). The widespread Smalfjord Tillite occurring outside the troughs corresponds to the third glacial episode of Laksefjordvidda.

In this paper we associate the term *interstadial* with the sediments occurring between the three diamictites of the Smalfjord Formation of Laksefjordvidda, in contrast to the *interglacial* character of the Nyborg Formation between the Smalfjord and the Mortensnes Formation. During the deposition of the sand in the Krokvatn palaeovalley the glaciers must have withdrawn completely, but we don't know whether the oscillations were of regional significance. The interglacial Nyborg Formation, on the contrary, is of greater regional extent in eastern Finnmark.

The glacial units of the Smalfjord Formation recognized by Edwards at Tanafjord and Uccaskaidde indicate continued climatic oscillations, possibly of a similar significance to those which led to the disposition of the diamictites and intermediate sandstones on Laksefjordvidda.

Summary

On Laksefjordvidda the sediments of the Smalfjord Formation consist of three diamictite units with intervening fine-grained sandstones, reflecting three glacial episodes and two interstadials. The bulk of the sediments was deposited in a subglacial depression (palaeovalley) of NNW–SSE trend. The interstadial sandstones make up the greater part of the total thickness of the formation. The sandstones are feldspathic, very fine-grained, massive and homogeneous. A characteristic feature is the almost complete lack of sedimentary structures. The most probable interpretation of the origin of these sandstones is that sand and silt were carried by rivers into quiet lakes or marine basins situated in the palaeovalley, and deposited there by rapid precipitation from a suspension in waters with low salinity. Alternatively, wind could have been the transport agent, at least for a part of the sediments. Siltstones occurring on top of the Middle Diamictite may be interpreted as loessite or indurated loess.

The Lower Diamictite, situated at the base of the formation, is interpreted as an indurated ground moraine. The Middle Diamictite was most likely formed by deposition from a glacier which in some parts of the area or for some of the time was floating; elsewhere, or at other times, it was grounded. The clast contents indicate at southeastern source of the material constituting the Middle Diamictite; also for the Lower Diamictite the movement of the ice is considered to have been from the southeast along the palaeovalley. The greatest thickness of the Upper Diamictite occurs at the hill Uccaskaidde outside the palaeovalley, where the diamictite is resting on different formations of the Tanafjord Group. This unit displays a variety of lithologies, including buff tillite rich in dolomite

clasts. This content of dolomite may indicate a fairly local, western source for the tillite material deposited at Uccaskaidde. In the central and eastern parts of the palaeovalley area only the highest part of the Upper Diamictite is present, occurring as a dark siltstone mostly without lamination.

The Bigganjargga Tillite, situated in a palaeovalley at the head of Varangerfjord, is most likely a chronostratigraphical equivalent of one of the two lower diamictites of Laksefjordvidda, in all probability the lowermost one. The widespread Smalfjord Tillite occurring outside the troughs, e.g. at Smalfjord, corresponds to the third glacial episode of Laksefjordvidda.

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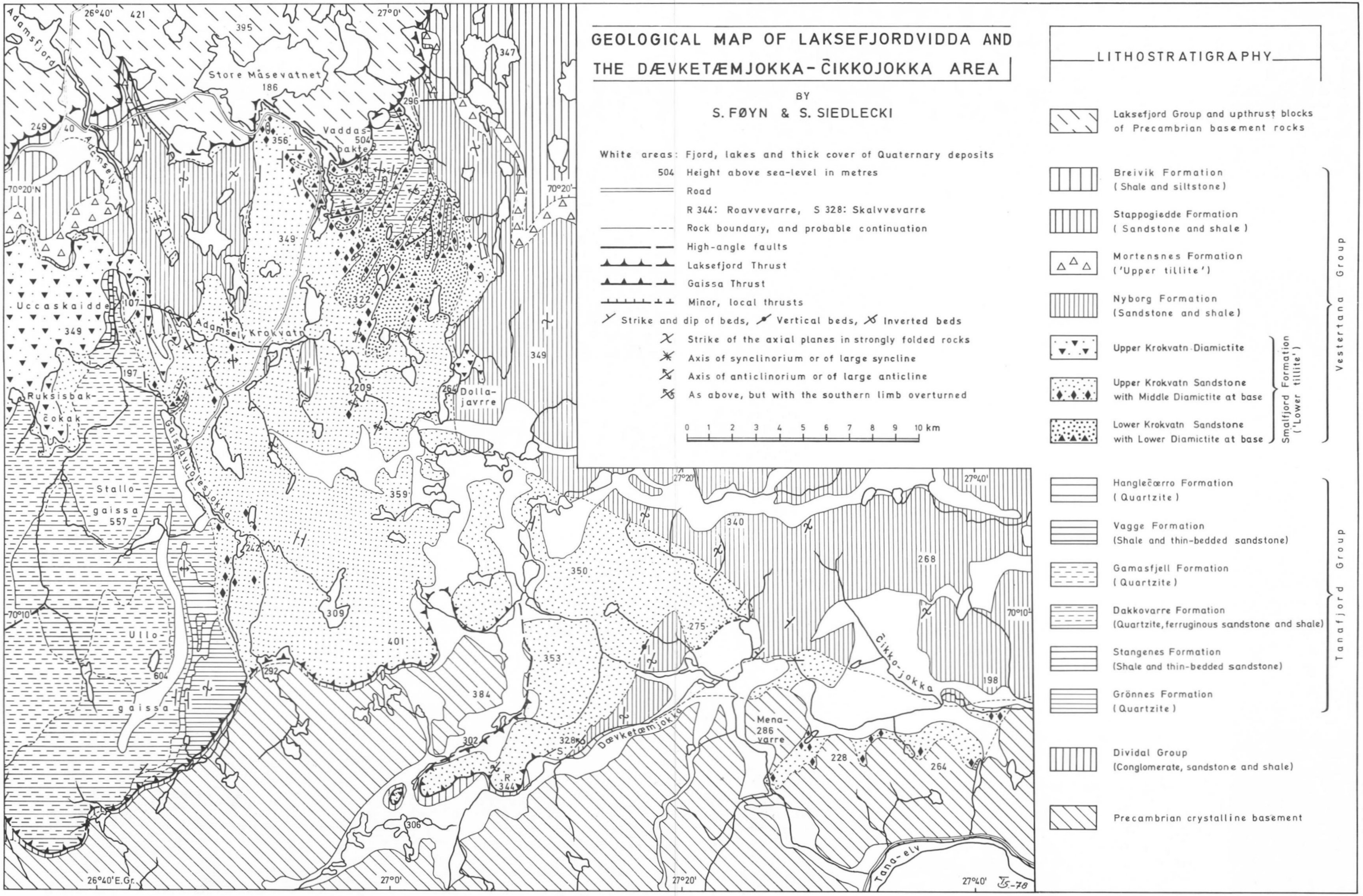
GEOLOGICAL MAP OF LAKSEFJORDVIDDA AND THE DÆVKETÆMJOKKA-ČIKKOJOKKA AREA
BY
S. FØYN & S. SIEDLECKI
White areas: Fjord, lakes and thick cover of Quaternary deposits
504 Height above sea-level in metres
Road
R 344: Roavvevarre, S 328: Skalvvevarre
Rock boundary, and probable continuation
High-angle faults
Laksefjord Thrust
Gaissa Thrust
Minor, local thrusts
Strike and dip of beds, Vertical beds, Inverted beds
Strike of the axial planes in strongly folded rocks
Axis of synclinorium or of large syncline
Axis of anticlinorium or of large anticline
As above, but with the southern limb overturned
0 1 2 3 4 5 6 7 8 9 10 km
LITHOSTRATIGRAPHY
Laksefjord Group and upthrust blocks of Precambrian basement rocks
Breivik Formation (Shale and siltstone)
Stappogiedde Formation (Sandstone and shale)
Mortensnes Formation ('Upper tillite')
Nyborg Formation (Sandstone and shale)
Upper Krokvatn Diamictite
Upper Krokvatn Sandstone with Middle Diamictite at base
Lower Krokvatn Sandstone with Lower Diamictite at base
Smalfjord Formation ('Lower tillite')
Vestertana Group
Hanglečærro Formation (Quartzite)
Vagge Formation (Shale and thin-bedded sandstone)
Gamasfjell Formation (Quartzite)
Dakkovarre Formation (Quartzite, ferruginous sandstone and shale)
Stangenes Formation (Shale and thin-bedded sandstone)
Grönnes Formation (Quartzite)
Tanafjord Group
Dividal Group (Conglomerate, sandstone and shale)
Precambrian crystalline basement
Adamsfjord
Store Måsevatnet
186
Vaddas-504-bakte
Adamselv
Uccaskaidde
Adamselv Krokvatn
Ruksisbak-čokak
Stallo-gaissa 557
Ullo-gaissa
Gaissavuolesjokka
Dolla-javrre
Čikko-jokka
Dævketæmjokka
Mena-286-varre
Tana-elv
26°40'
27°0'
27°20'
27°40'
26°40'E.Gr.
70°20'N
70°20'
70°10'
70°10'
TS-78