Lithostratigraphy and Correlation of the Archean and Early Proterozoic Rocks of Finnmarksvidda and the Sørvaranger District

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Siedlecka, A., Iversen, E., Krill, A.G., Lieungh, B., Often, M., Sandstad, J.S., Solli, A. 1985: Lithostratigraphy and correlation of the Archean and Early Proterozoic rocks of Finnmarksvidda and the Sørvaranger district. *Nor.geol.unders. Bull. 403,* 7-36.

Archean and Early Proterozoic rocks of Finnmarksvidda and the Sørvaranger District are grouped into lithostratigraphic and lithodemic units and are systematically described. Some correlations are proposed and the foundations for these correlations are discussed. The lithostratigraphic successions of the Kautokeino and Karasjok greenstone belts are correlated with each other and with the older Precambrian rocks exposed in the tectonic windows. From this emerges an outline of geological events which occurred in the Early Precambrian in these terranes.

Contacts between the Archean rock units of the Sørvaranger District are often faulted and therefore stratigraphic relationships between the various gneiss complexes and groups are uncertain. There are, however, indications that the Bjørnevann Group and part of the Jarfjord Gneiss are correlative; the same is true for parts of the Varanger and Kirkenes Gneiss Complexes. There seem to be two, stratigraphically unrelated banded-iron formations, both formerly assigned to the Bjørnevann formation and now described separately as the Bjørnevann and Garsjø Groups. The Early Proterozoic Petsamo Group is subdivided into four formations and stratigraphic relations within the group are discussed.

The complex Archean stratigraphy of the Sørvaranger district does not have equivalents on Finnmarksvidda. The volcano-sedimentary sequences of the Kautokeino and Karasjok greenstone belts may at the present stage of work only roughly be compared with the Petsamo Group.

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Introduction

The initiation of NGU's Finnmark Project in 1980 started a new phase of intensive geological investigation in Finnmark. Bedrock mapping at a scale of 1:50 000 is an important part of the project and has, so far, been concentrated on Finnmarksvidda (Plate 1). Although the work is by no means complete, we consider it useful to present our preliminary results and interpretations. At the same time, there seems to be a need for a unified lithostratigraphic terminology and better founded classification of the Precambrian of Finnmark and of Finnmarksvidda in particular. In this paper we present our subdivision of the Precambrian rocks into main regional-geological units and introduce a lithostratigraphic classification. The lithostratigraphy is partly a revision of terms and units described earlier (Holmsen et al. 1957, Wennervirta 1969, Skålvoll 1964, 1971, 1978, Gustavson & Skålvoll 1977, Meriläinen 1976, and others) and is partly based on new published and unpublished results of the Finnmark Project (Henriksen 1983, Solli 1983, Sandstad 1983, Solli & Sandstad 1984, Often 1984, 1985, Olesen & Solli 1985, Krill 1984, 1985, Krill et al. 1985, Olsen & Nilsen, 1985).

In order to make this review as complete as possible we have included in this paper stratigraphic data from the westernmost part of Finnmarksvidda, based on Fareth et al. (1977), and from the Alta-Kvænangen-Altenes and Repparfjord-Komagfjord tectonic windows based mainly on papers and reports by Zwaan & Gautier (1980), Fareth (1979), Pharaoh (1980), and Pharaoh et al. (1983).

In the course of this work it became obvious that inclusion of the rock units of the Sørvaranger District in the present review would be advantageous. Contributions from B. Lieungh

and E. Iversen, Prospektering A/S, made this possible. The rock units of the Sørvaranger District are described and their origin and stratigraphy discussed by these two co-authors in a separate chapter (p. 19). Though based partly on earlier work by Bugge (1960, 1975, 1980) and Bugge & Iversen (1981) this chapter contains a considerable amount of new data and ideas basic for a better understanding of the geology of the Sørvaranger District and for future research.

The lithostratigraphy of the Precambrian of Finnmarksvidda presented here was a joint effort by the remainder of the co-authors. The chapter dealing with the lithostratigraphy of the Kautokeino Greenstone Belt (p. 9) was written by J.S. Sandstad and A. Solli, while the lithostratigraphy of the Karasjok Greenstone Belt (p. 13) was the joint responsibility of A.G. Krill, M. Often and A. Siedlecka. The Tanaelv Migmatite, Levajok Granulite and Baisvarri Gneiss Complex were described by A.G. Krill. A. Siedlecka is mainly responsible for compilation of data (text, illustrations and correlation table), discussions, and the final form and content of the paper.

General Geology

Inner Finnmark, including Finnmarksvidda and the Sørvaranger District, is underlain by Archean to Early Proterozoic basement rocks exhibiting a general NNW-SSE structural trend, in particular on Finnmarksvidda. This is in contrast to outer Finnmark which is occupied predominantly by Late Precambrian to Early Paleozoic rocks forming the northernmost part of the NE-trending Scandinavian Caledonides. At the interface between these major units there occur the Late Precambrian to Cambrian autochthonous rocks (the Dividal Group and its equivalents in East Finnmark) which overlie their basement with an angular unconformity and are overthrusted by the Caledonian nappes (Plate 1).

The Archean-Early Proterozoic basement, to which this paper is restricted, consists primarily of supracrustal sequences, often referred to as greenstone belts, and of gneiss complexes (Plate 1). The *Kautokeino Greenstone Belt* in the west is separated from the eastern, *Karasjok Greenstone Belt* by the *Jer'gul Gneiss Complex*. Westernmost Finnmarksvidda has been subdivided by Fareth et al. (1977) into the *Rai'sædno (Gneiss) Complex* and the *Njallajåkka Complex* which is a minor greenstone belt.

A granulite belt is thrusted from the east upon the Karasjok greenstone belt (Plate 1). This *Levajok Granulite Complex* is the northern end of the Lapland granulite belt which extends over 300 km south and east.

The Sørvaranger District is dominated by Archean rocks (granite-gneisses and various supracrustal rocks) assigned to several separate units among which the *Bjørnevann Group* containing banded iron formation has been studied in some detail. A Proterozoic greenstone belt, occurring on Norwegian territory in the Polmak and the Pasvik areas, completes the main features of the stratigraphy of Sørvaranger (Plate 1 and Table 1).

Plutonic and hypabyssal rocks of ultramafic to felsic composition dissect the gneisses and the greenstone belts of Finnmark. These rocks are generally excluded from the following text unless they are of importance for stratigraphic considerations.

In the text which follows we use terms Archean and Proterozoic following the recommendations of the Subcommission on Precambrian stratigraphy (James 1978). The bulk of the rocks described below are of Early Proterozoic or Proterozoic I age, i.e. belong to a 2500–1600 m.y. era (Harland et al. 1982). No fossils have been found in the Precambrian rocks considered in this paper, with the exception of poorly preserved stromatolites occurring in dolomitic parts of the sequences cropping out in the tectonic windows.

Finnmarksvidda, description of rock units

Jer'gul Gneiss Complex

Name: Jer'gul is a small settlement about 35 km west of Karasjok along the main road (no. 92) crossing Finnmarksvidda (map sheet M 711 2033 IV, Iešjåkka). The name Jer'gul (granite-) gneiss complex was introduced by Krill (1984a). Formerly the complex was called the central gneiss dome, older gneiss complex, Pre-Karelian gneissose basement etc.

Type area: The complex occupies central parts of Finnmarksvidda and no particular area may by pointed out as typical. The main rock types are well exposed in roadcuts 5 - 10 km

east of Jer'gul (M711, 2033 IV), in particular in the roadcut 5.5 km east of Jer'gul (M711 2033 IV, UTM 123033), and in northern parts of the area (M711 2034 IV).

Lithology: The Jer'gul Gneiss Complex is a composite unit. Grey, weakly to moderately layered gneisses of tonalitic composition constitute the predominant rock type. Parts are rich in mafic minerals and may represent metamorphosed intermediate to basic intrusives and extrusives. Foliated pink granites/granodiorites represent younger generations of rocks in the complex. Mafic to ultramafic dykes and gabbroic intrusions, in places occurring in swarms, were intruded during the youngest episode(s) of magmatism. Subordinately and locally there occur inliers of amphibolites and schists of volcanic and sedimentary origin. (These may correlate with the Gåldenvarri and Vuomegielas Formations described further in the text).

Boundary: The lower boundary is unknown. The complex constitutes the lowermost rock unit of Finnmarksvidda. The upper boundary is in the northern and eastern areas marked by an angular unconformity between the Jer'gul Gneiss Complex and the Skuvvanvarri, and in part the Masi Formations. The boundary with the Vuomegielas Formation is nowhere exposed but is assumed to be unconformable (see below and in Siedlecka 1985). In the west the gneisses and the adjacent volcano-sedimentary sequences of the Kautokeino Greenstone Belt are commonly intruded by granodiorites. These intrusions, foliated along with the host rocks, are difficult to distinguish from the gneisses which they intrude. Future mapping will probably resolve this problem. For the time being, however, they are included in the Jer'gul Gneiss Complex.

Correlation: The complex may be correlated with the bulk of the Rai'sædno Complex (Table 1).

Age: Archean - Early Proterozoic. The oldest U-Pb date is around 2730 Ma (Meriläinen 1976): Rb-Sr dates may reach c. 3000 Ma. (Olsen & Nilsen, 1985). A Rb-Sr date of 2110 ± 105 Ma has recently been obtained for a granitic rock underlying the unconformity at Skoganvarre (Krill et al. 1985).

Kautokeino Greenstone Belt

Introduction The Kautokeino Greenstone Belt is a c. 50 km wide belt of supracrustal rocks situated between the Rai'sædno and Jer'gul Gneiss Complexes (see Fig. 1). The contact to the Rai'sædno Gneiss Complex is faulted or intruded by younger granitic to dioritic rocks, while the contact to the Jer'gul Gneiss Complex mostly is intruded by granites and granodiorites. To the north, the Caledonian rocks overlie the greenstone belt, but on aeromagnetic maps its continuation to the Alta-Kvænangen Window (Plate 1) is clearly seen. To the south the Kautokeino Greenstone Belt wedges out in the vicinity of the border to Finland, so no direct correlation to any Finnish greenstone belt can be made.

Descriptions of the rocks within the greenstone belt are earlier given by Holmsen et al. (1957), Gustavson & Skålvoll (1972), Skålvoll (1978), and Solli (1983).

The Kautokeino Greenstone Belt is dominated by basic volcanic rocks, but included in the belt are also two thick formations consisting of sandstones and quartzites. The structural trend is roughly N-S. The metamorphism is low in the central parts (low to very low grade) and high in the outer parts near the gneiss complexes (medium grade). A N-S trending fault zone (offset 3-4 km?) divides the greenstone belt into an eastern and a western part, but relatively certain correlations can be made between the two parts (Table 1).

The Gål'denvarri Formation, which consists mainly of basic volcanic rocks, constitutes the oldest rock unit in the eastern part. Above the Gål'denvarri Formation lie the quartzites of the Masi Formation with an angular unconformity. In the northern areas the Gål'denvarri Formation is missing and the Masi Formation lies directly on the Jer'gul Gneiss Complex. The youngest formations to the east are the volcano-sedimentary Suoluvuobmi Formation and the mostly volcanic Lik'ča Formation.

In the western part of the greenstone belt the Čas'kejas Formation, which consists of basaltic volcanites and subordinately pelitic rocks, constitutes the oldest rock. Above this lies the pelitic Bik'kačåkka Formation. The youngest unit here and probably for the whole Finnmarksvidda is the terrigenous Čaravarri Formation.

The lithostratigraphy of the Kautokeino Greenstone Belt presented here is mainly based

on work in the northern areas (Solli & Sandstad 1984). To the south Olsen & Nilsen (1985) have proposed another subdivision. Most of their formations can easily be correlated with those in the north. Some of the north-south correlations are not straightforward, in particular in the upper part of the succession (see Table I, and discussion p. 17).

Gål'denvarri Formation

Name: Gål'denvarri is the name of a little summit located on the map-sheet M711 1933 IV Masi, about 10 km south of the settlement Masi (UTM 040 945). The name Gål'denvarri formation was introduced by Solli (1983). It was previously included in the Časkias Group by Holmsen et al. (1957).

Type area: Area on the eastern side of Gål'denvarri.

Thickness: Estimated to a minimum of 1500 m.

Lithology: In the type area the formation is dominated by green to light green amphibolites. They are fine to medium grained, and foliated and often show a faint banding which may be primary layering. Locally volcanic breccias and amygdules are preserved. The amphibolites are thought to represent metamorphosed lavas and tuffs. Near Garguluobbal (UTM 170 950) quartz-rich schists and feldspathic sandstones constitute the main part of the formation. Schists may also occur as thin layers within the amphibolites. The Gål'denvarri formation is metamorphosed in medium-grade metamorphism. Low TiO_2 content and relatively high MgO content are characteristic for the Gål'denvarri amphibolites, which are classified by Solli (1983) as tholeiitic basalts. The geochemical signature of the amphibolites differs considerably from that of the remaining volcanites of the Kautokeino Greenstone Belt.

Boundaries: Where observed the lower boundary of the formation is intruded by granites and granodiorites. The formation unconformably underlies the Masi Formation.

Correlation: The formation is correlated with the Vuomegielas Formation (this paper). It may also be correlated to the Baharav'dujav'ri formation which occurs east and south of Kautokeino (Olsen & Nilsen, 1985).

Age: (?)Archean, (?)Early Proterozoic.

Masi Formation

Name: Masi is the largest settlement in the northwestern part of Finnmarksvidda. The designation Masi Quartzite was introduced by Holmsen et al. (1957), and later names like Masi Group (Oftedahl 1980), Masi quartzite formation (Solli & Sandstad 1984) and Masi formation have also been used. The status of the unit is here proposed changed and formalized to Masi Formation.

Type area: The lower part of the formation may be studied in the Gårzivarri area (UTM 030 910), and the upper part in the Big'gevarri area, about 15 km SSW of the settlement of Masi, on map sheet Masi (M711, 1933 IV).

Thickness: Estimated to be on the order of 500 - 1000 m.

Lithology: The base of the formation is a conglomerate with thickness normally about 5 m, but it may be as thick as 50 m. The pebbles consist of granitic gneisses, quartz and quartzite. The matrix is often calcareous. Above the conglomerate is thick red to grey feldspathic quartzite about 50 m. The bulk of the formation consists of a fine-grained quartzite, white to pink in colour. It is often characterized by a fine lamination caused by a change between feldspar-bearing and feldspar-free layers. Layers of conglomerate up to 10 m thick may also occur within the quartzite. Locally cross-bedding may be seen. The presence of the chrome mica, fuchsite is characteristic for the quartzite, causing in places a green coloration of the rock (Holmsen et al.1957, Solli 1983).

Boundaries: The Masi Formation unconformably overlies the Gål'denvarri Formation. The upper boundary, against the Suoluvuobmi Formation, is placed at the transition between a quartzite and an albite felsite.

Correlation: The formation is correlated with the Skuvvanvarri Formation. Holmsen et al. (1957) have also correlated this formation with the Addjit (earlier spelled Agjet) Quartzite (Addjit formation of Olsen & Nilsen, 1985) cropping out c. 10 km west of Kautokeino. The Addjit Quartzite is overlain by the Čas'kejas Formation.

Age: Early Proterozoic.

Suoluvuobmi Formation

Name: Suoluvuobmi is the name of a well known mountain resort on the main road between Alta and Kautokeino. The name Suoluvuobmi formation was introduced by Solli (1983).

Type area: No complete profile has been found, but good sections are found in Årvusvarri east of Masi, west of lake Biggejav'ri (western part of map-sheet Masi 1:50 000, M711, 1933 IV) and north to northwest of lake Soag'nujav'ri (northern part of map-sheet Čarajav'ri 1:50 000, M711, 1833 I).

Thickness: In the range of 1 - 2 km.

Lithology: Lithologic heterogeneity and lateral facies variations are characteristic for this volcano-sedimentary unit. At the base of the formation there are albite felsites, bedded, and in places finely laminated. In one locality (Habatbakte, UTM 036 016) pyroclastic textures have been found, testifying to volcanic origin of at least parts of the albite felsites. Above the albite felsites there occur amphibolites, green to dark green, medium to fine grained, interpreted as lavas and tuffs. Near the bottom of the amphibolites there are found ultrabasic rocks, interpreted as komatiitic lavas. The thickness of the amphibolites is in the range of 3-400 m. Above this is a series of mica schists or phyllites, of a total thickness of about 500 - 1000 m. Amphibolites of supposed volcanic origin, varying in thickness from a few meters up to several hundred meters are intercalated in the mica schists. Graphite schists and albite-felsites are also characteristic for the Suoluvuobmi Formation. In the upper part of the formation these two rock types seem to be closely associated, and they often occur close to the boundaries between amphibolites and mica schists. In the mica schists are also some layers of marble and quartzite (Solli 1983, Holmsen et al. 1957).

Boundaries: The lower and upper boundaries show sedimentary transitions into the Masi and the Lik'ca Formations, respectively.

Correlation: The formation is correlated with (part of) the Čas'kejas Formation (this paper) and the Av'zi Formation (Olsen & Nilsen 1985).

Age: Early Proterozoic.

Lik'ča Formation

Name: Davvi (meaning north in Lappish) Lik'ča is a 828 m high mountain located about 5 km east of the lake Čarajav'ri in the northwestern part of the map-sheet M711 1833 I Čarajav'ri. The name Lik'ča Formation is used here for the first time.

Type area: A W-E profile from the southern end of lake Čarajav'ri across Davvi Lik'ca and Garanasčåkka (UTM 744 014 - 820 020).

Thickness: An apparent thickness of about 7-8 km.

Lithology: The formation is dominated by basic volcanites. The eastern (lowermost) parts are dominated by massive lavas and pillow lavas, while in the western parts tuffs are more prominent. Primary volcanic textures are seen through the whole sequence. The volcanites have tholeiitic basalt chemistry. Subordinate layers of graphitic schists, sandstones and dolomites are found in this volcanic sequence. A green sandstone member (about 100 m thick) occurs in the lowermost part of the formation while the upper 1-2 km of the section consist of grey, green and red mudstone, partly graphite bearing. Some quartzites and dolomites also occur. To the south of the type section the upper parts of the formation consist of albite-rich rocks (albite felsites). The metamorphism is low grade to very low grade.

Boundaries: The formation overlies the Suoluvuobmi Formation with a transitional stratigraphic contact. The upper boundary is everywhere fault bounded.

Correlation: The formation may be correlated to parts of the Čas'kejas Formation and parts of the Stuorajav'ri formation (Olsen & Nilsen 1984). The uppermost mudstone may be correlated to the Bik'kacåkka Formation (this paper).

Čas'kejas Formation

Name: Čas'kejas is the name of the mountain where the Bidjovagge copper-gold deposit is located, 40 km NW of Kautokeino. The name Časkias Group has previously been used for all the basic metavolcanic rocks ('greenstones') of the western part of Finnmarksvidda (Holmsen et al. 1957). The new term Čas'kejas Formation is restricted to the rocks in the westernmost part of this area.

Type area: The lower part of the formation is best exposed on both sides of main road 96 on the Čas'kejas mountain. The upper part is best seen 12 km northeast of the Bidjovagge copper-gold deposit on the hills Jægeloai'vi and Doaresvarri (eastern side of map sheet M711, 1833 IV Mållejus).

Thickness: Estimated to about 4 km. Interpretation of gravimetric measurements gives a

maximum depth of the rocks in a folded basin to about 5 km (Olesen et al. 1984, Olesen & Solli 1985).

Lithology: The lower part of the formation consists of banded and massive amphibolites and greenstones. They are mainly assumed to represent metamorphosed tuffs and tuffites, but pillow lavas, included in the Stuorajav'ri formation of Olsen & Nilsen (1985), are exposed east of Stuorajav'ri, 20 km southeast of the type area. The volcanic and volcanosedimentary rocks are intruded by synvolcanic diabase sills and interbedded with thin and subordinate beds of carbonate, albite felsite and graphitic schist. The mafic rocks have tholeiitic basaltic chemistry (Sandstad 1983). The upper part of the formation consists of pelitic rocks including mica schist and phyllite with some graphitic schist and carbonate beds. Metavolcanites are subordinate. The rocks were metamorphosed in the low-grade facies varying from the low temperature end in the east to the high temperature end in the west (Sandstad, unpublished data).

Boundaries: No exposures of the lower boundary are found. The formation has either a tectonic contact to or seems to lie conformably on the Rais'ædno Complex (Fareth et al. 1977) in the northwestern part of the Kautokeino Greenstone Belt. The contact zone is, in addition, intruded by younger granitic to trondhjemitic rocks. Further south, 6 km west of Kautokeino, the contact to an underlying quartzite (Addjit formation) which might be correlative to the Masi Formation, appears to be normal stratigraphic (Holmsen et al. 1957). The upper boundary is transitional and placed beneath the conformably overlying feldspathic sandstone of the Bik'kacåkka Formation.

Correlation: Based on lithological and chemical data the formation is correlated with the Nussir Group of the Repparfjord-Komagfjord Window (Pharaoh et al. 1983), Kvenvik greenstone of the Alta-Kvænangen Window (Zwaan & Gautier 1980), parts of the Av'zi formation further south and Lik'ča and Suoluvuobmi Formations in the eastern part of the Kautokeino Greenstone Belt. Correlation with the Stuorajav'ri formation is uncertain. This is partly caused by poor exposure in the key area along the Stuorajav'ri lake (M711 map-sheets 1833 III and 1833 IV) and partly by no sharp difference in lithology, geochemistry or degree of metamorphism which would permit a clear separation between the Čas'kejas and Stuorajav'ri volcano-sedimentary units. One of the authors (J.S.S.) assumes that the Stuorajav'ri formation represents a proximal volcanic deposition while the Čas'kejas Formation is dominated by distal volcanic products.

Age: An Early Proterozoic age is suggested by Sm-Nd dating at 2279 ± 300 Ma (Krill et al. 1985).

Bik'kačåk'ka Formation

Name: Bik'kačåk'ka is a mountainous area west of Čaravarri (in the extreme eastern part of map-sheet M711 1833 IV Mållejus). Bik'kacåkka Formation is a new term introduced here.

Type area: The sequence is not completely exposed in any profile. The lowermost member can be seen north and south of the lake Vuol'bmajav'ri (UTM 700 935, 1833 IV Mållejus), while the uppermost part of the sequence is best exposed on the western slope of Stuora Bik'kacåkka.

Thickness: Estimated to about 1000 - 1500 m.

Lithology: The lower member consists of a massive fine- to medium-grained, white to yellowish white feldspathic sandstone and subordinate thin beds of greyish green limestone. The sandstone is weakly layered and no other sedimentary structures are seen. The member is up to 500 m thick and seems to wedge out both to the north and south. The upper member is composed of dark grey, reddish brown and green, fine-grained shale and argillite with intercalations of massive, grey and green siltstone. The shale can be highly schistose and finely laminated. It is metamorphosed in very low to low grade facies.

Boundaries: The lower boundary is transititional and is located at the bottom of the feldspathic sandstone. Partial intertonguing between the sediments of the Čas'kejas and Bik'kačåk'ka Formation is assumed. The distinguishing features are the lack of both graphitic schists and metavolcanites in the Bik'kačåk'ka Formation. The upper boundary is sharp and marked with the deposition of the feldspathic sandstones of the Čaravarri Formation.

Correlation: Lithostratigraphically, the forma-

tion correlates with the Storviknes dolomite and slate of the Alta-Kvænangen Window (Zwaan & Gautier 1980) although they are of differing sedimentary facies.

Age: Assumed Early Proterozoic.

Čaravarri Formation

Name: Čaravarri is a prominent mountain ridge 40 km north of Kautokeino. The designation Čaravarre Grit was introduced by Holmsen et al. (1957, s. 23) while Oftedahl (1980) and Torske & Bergh (1984a) include that unit and the Bik'kačåk'ka Formation (as proposed in this paper) in the Čaravarre Group. The rank is here proposed changed to Caravarri Formation which includes just the coarse-clastic former 'Grit'-unit.

Type area: The formation is well exposed on the mountain ridge, and complete sequences of the rock types are best seen on Gæsvarri and Njar'gavarri (southwestern corner of map-sheet M711 1833 I Čarajav'ri).

Thickness: Estimated to c. 4200 m (Torske & Bergh 1984b).

Lithology: A medium- to coarse-grained, grey and reddish grey feldspathic sandstone is the predominant rock type. In addition there occur beds of siltstone, pebbly sandstone and conglomerate, both pebble- and matrix-supported. The pebbles consist mainly of quartzite and jasper, and in varying amounts carbonate rocks, greenstone, mudstone and granite. The rocks are thickly bedded, either massive or exhibiting tabular- or trough-shaped cross-bedding showing younging of the beds to the east, i.e. right way up. The formation consists of upward-coarsening sequences and has been interpreted as alluvial, consisting mainly of braided stream deposits with subordinate debris-flow accumulations (Torske & Bergh 1984b).

Boundaries: The lower boundary is sharp stratigraphic with the Čaravarri Formation concordantly overlying the Bik'kačåk'ka Formation. The Čaravarri Formation is considered to be the uppermost Proterozoic supracrustal rock unit of Finnmarksvidda.

Correlation: Skoadduvarri sandstone, in the Alta-Kvænangen tectonic window.

*Age:*Uncertain. Possibly Early Proterozoic.

Karasjok Greenstone Belt

Introduction

The Karasjok Greenstone Belt as defined here, embraces the supracrustal sequences east of the Jer'gul Gneiss Complex and west of the Tanaelv Migmatite Complex (Plate 1). The greenstone belt continues southwards across the border between Finland and Norway and northwards up to the head of Porsangerfjord where it disappears beneath the Caledonian nappes. Rock units of the northern Karasjok Greenstone Belt continue also westward, towards Iešjav'ri (Plate 1). The Vuomegielas Formation, interpreted as the lowermost volcanic unit and the Skuvvanvarri Formation, an extensive terrigenous sequence next to it, occur in this western Iešjav'ri - Skoganvarre district (cf. Siedlecka 1985); the latter formation continues all the way south along the western margin of the belt.

The bulk of the volcano-sedimentary sequence of the belt is assigned to the Iddjajav'ri Group subdivided over most of the Karasjok Belt into the Gål'lebai'ke, Bakkilvarri and Rai'tegår'ôzi Formations. This group is overthrust by the Tanaelv Migmatite Complex from the east.

In the Iešjav'ri area the formations of the Karasjok Greenstone Belt are cross-cut by the N-S trending Stabbursdalen - Iesjav'ri Fault Zone (Plate 1, Table 1). Rocks west of the fault zone belong to the Suoluvuobmi and Masi Formations of the Kautokeino Greenstone Belt.

Vuomegielas Formation

Name: Voumegielas is an elevated area located about 1 - 2 km north of the lake Iešjav'ri, in the southernmost part of the map-sheet Čåkkarašša M711 1934 I. The name has not been previously used in the geological literature.

Type area: Voumegielas

Type profile: A continuous profile is not exposed. The best section is along the E-W power line crossing the area (UTM 930 430 - 955 435). According to the present tentative interpretation (Siedlecka, 1985) the formation forms an anticline and is thus repeated in the Voumegielas section.

Thickness: The maximum thickness is estimated at about 700 m.

Lithology: In the type area the formation is fairly homogeneous, consisting of dark green to dark grey finely to medium crystalline, foliated amphibolites exhibiting homogene-

ous texture and composition. Subordinately, there occur biotite-rich and argillitic layers. Some of the amphibolites exhibit high MgO (c. 18 %) and low TiO_2 (0.1 %) content.

Boundaries: The lower boundary of the formation is not exposed, but it is assumed that the formation unconformably overlies the Jer'gul Gneiss Complex (cf. Siedlecka 1985). The formation is overlain by the Skuvvanvarri Formation, and there seems to be an interfingering between rocks of these two formations as seen immediately north of Ieš-jav'ri (northernmost part of map sheet Ieš-jav'ri M711 1934 II).

Correlation: The Vuomegielas Formation is tentatively correlated with the Gål'denvarri Formation on the basis of its stratigraphic position and geochemistry.

Age: ?Early Proterozoic.

Skuvvanvarri Formation

Name: Skuvvanvarri is a 300 m high hill located southeast of the lake Bajitjav'ri in the southern part of map-sheet M711 2034 IV Skoganvarre. The name was informally introduced by Siedlecka (1984) and has been used by Often (1984). Earlier, Oftedahl (1980, table p. 15) referred to the 'Skoganvarre basal conglomerate', a rock described by Skålvoll (1964) from a locality near the Skoganvarre settlement. Pharaoh (1984) used the name 'Skoganvarre formation' for the same rocks. Earlier the rocks assigned to the Skuvvanvarri Formation and terrigenous rocks belonging to other rock units (Masi Formation, parts of Iddjajav'ri Group) were together mapped as 'meta-arenite and basal conglomerate' (Skålvoll 1972).

Type profile: Because of considerable lateral variations of sedimentary facies, no single profile is typical. Good sections showing variations in development may be seen on the Skuvvanvarri hill, along Lævnjašjåkka (between UTM 110 - 145 E, M711 2034 IV Skoganvarre) and south of Coal'bme - Lik'-čajav'ri (between UTM 315 - 327, M711 1934 II, Ieš jav'ri).

Thickness: Varies laterally from a few metres to several hundred metres. The maximum exposed thickness in the Skuvvanvarri area is estimated at about 1000 m.

Lithology: The formation consists of three main rocks: Conglomerate, sandstone and mudstone. The conglomerate is the most characteristic rock type of the formation. It is light-coloured, very coarse- to fine-grained, polymict and exhibits a matrix-supported texture. The matrix itself is a mixture of mica, fine crystalline quartz and varying amount of carbonate. The sandstones vary from feldspathic to fairly pure quartzites, and are pink, white or green (fuchsite quartzite). The mudstones, grey to variegated, are similar to the matrix of the conglomerates.

Boundaries: An angular unconformity with the Jer'gul Gneiss Complex marks the lower boundary of the formation. It overlies, and interfingers with the amphibolites of the Vuomegielas Formation. The thrust at the base of the Iddjajav'ri Group constitutes the upper boundary of the formation.

Correlation: Because of its stratigraphic position and lithology the formation is correlated with the Masi Formation of western Finnmarksvidda. Tentatively it is correlated with part of the Saltvann Group in the Komagfjord Window and the Russeluft Formation in the Altenes Tectonic Window.

Age: Assumed Early Proterozoic.

Iddjajav'ri Group

The Iddjajav'ri Group comprises the part of the Karasjok Greenstone Belt characterized by volcanic and sedimentary rocks lying above the terrigenous Skuvvanvarri Formation. The group consists of three formations, Gål'-lebai'ke, Bakkilvarri and Rai'tegår'ži, and is assumed to form a continuous volcano-sedimentary pile. Considerable tectonic disturbances make this assumption uncertain.

Gål'lebai'ke Formation

Name: Gål'lebai'ke is Lappish for gold cabin and refers to the old alluvial gold-field downstream from the Storfossen rapids in the river Karašjåkka, ca 32 km southwest of the town of Karasjok. The name Gål'lebai'ke Formation is first introduced here.

Type area: Storfossen gold field.

Type profile: SW-NE profile from Storfossen (Stuorragår'ži) to about 1 km east of the cabin (UTM 144 890 - 164 905, M711 2533 IV). The same lithologies can be studied in a more accessible but less continuous profile NW-SE from the river Karašjåkka across the road Karasjok-Bieskenjarg (UTM 290 045 -

293 030, M711 2033 IV). In the excellently exposed Lakselv area the correlative formation is seen in a profile from the main road E6 to the mountain Lavvoai'vi (UTM 222 623 - 235 632, M711 2034 IV).

Thickness: Estimated to 1000-1500 m. The thickness seems remarkably consistent along the length of the greenstone belt.

Lithology: In the type area the formation is characterized by a mixed lithology of sedimentary and volcanic origin. The amount of volcanites decrease towards the north where psammitic rocks dominate. Quartz mica schists, quartzites (some fuchsite-bearing), mica schists, graphitic schists, amphibolites, amphibole-bearing gneisses, metakomatiites and banded iron formations are found throughout the sequence and minor carbonate layers are usually found near the top of the formation. The sequence normally passes from ultramafic/mafic volcanites in the lower part into sediments in the upper part. The formation is metamorphosed in upper greenschist to lower amphibolite facies and has a strong schistose foliation.

Boundaries: The lower boundary, against the Skuvvanvarri Formation is tectonised where observed. The Lavvoai'vi profile south of Lakselv shows a probable primary lower boundary: a gradual sedimentary transition from the coarse clastics of what is thought to correlate with the Skuvvanvarri Formation into quartzo-feldspathic schists of the Gål'lebai'ke Formation. The upper boundary is transitional and defined as the top of the uppermost major metasedimentary layer.

Correlation: There is no continuation in the field into equivalent units, but a correlation with the Suoluvuobmi Formation is suggested because of the lithologic similarities and the stratigraphic position above the Skuvvanvarri/Masi Formations.

Age: There are no datings, but an Early Proterozoic age is assumed.

Bakkilvarri Formation

Name: Bakkilvarri is a low relief rounded mountain 13 km southwest of the town of Karasjok. The name Bakkilvarri Formation is first introduced here.

Type area: Western slope of Bakkilvarri.

Type profile: NW-SE profile from the road Karasjok-Bieskenjarg to the top of Bakkilvarri (UTM 292 029 - 310 000, M711 2033 IV and 2033 I).

Thickness: About 2 km in profiles with no obvious tectonic repetitions. Elsewhere extremely variable, in large areas the apparent thickness is several kilometers.

Lithology: Mafic to ultramafic metavolcanites with very minor metasediments. Amphibolites, representing tholeiitic basaltic volcanic rocks and sills dominate. Another important rock type is that of the chlorite-amphibole rocks with komatiitic composition, often with preserved volcanic textures such as pillow lavas, agglomerates and other volcanic breccias. These rocks were called picrites by Skålvoll (1972) and described by Wennervirta (1969) and Henriksen (1983). Banded iron formations are associated with the ultramafic volcanites. Metamorphic grade is lower to upper amphibolite facies and the formation has a strong schistose foliation.

Boundaries: The lower boundary is transitional and the Bakkilvarri Formation starts with a sudden increase in volcanic activity resulting in a pile of mafic volcanites in contrast to the sediment-dominated upper part of Gål'lebai'ke Formation. In most areas the boundary is disturbed by thrusting. The upper boundary against the volcano-sedimentary Rai'tegår'ži Formation is in some areas well defined by the start of a major period of sedimentation, in other areas the boundary is diffuse and defined only by a higher influx of sedimentary material.

Correlation: A correlation is suggested with the lower part of Lik'ča Formation and possibly with the Nussir Group in the Komagfjord Window (Pharaoh et al. 1983).

Age: Sm-Nd dating of komatiites (Krill et al. 1985, this volume) gives 2085 ± 85 Ma, indicating an Early Proterozoic age.

Rai'tegår'ži Formation

Name: Rai'tegår'ži is a well known waterfall in the river Karašjåkka about 27 km southwest of Karasjok. The name Rai'tegår'ži Formation is suggested here for the first time.

Type area: Rai'tegår'ži area.

Type profile: From Liep'pesavo to Šuolgaskaideladdo (UTM 223 921-229 911, M711 2033 IV).

Thickness: Maximum possible thickness is several kilometers.

Lithology: Aluminous mica gneisses and schists, medium to coarse grained amphibo-

lites and amphibolitic schists strongly deformed and metamorphosed in upper amphibolite facies. The amphibolites are considered to be genetically similar to those of the Bakkilvarri Formation.

Boundaries: The lower boundary is probably a primary conformable contact with the uppermost volcanics of the Bakkilvarri Formation. The upper boundary is tectonic against the overthrusted Tanaelv Migmatite Complex.

Correlation: Possible correlation with the upper part of Lik'ča Formation.

Age: Probably Early Proterozoic based on dating of the Bakkilvarri Formation.

Tanaelv Migmatite Complex

Name: Barbey et al. (1980, 1982) introduced the term Tana River Belt, or simply Tana Belt, for the rocks west of the Lapland granulite belt. These rocks were earlier referred to as the 'southwest marginal zone' and part of the 'west Inari schist zone' by Meriläinen 1976. They were also called the 'hornblende gneiss unit' by Henriksen (1983) and the Gåššjåkka migmatites by Krill (1984a). Here the term Tanaelv is preferred, because the name Tana is associated with the district of Tana far to the east and unrelated to this rock unit. Tanaelv is the Norwegian name meaning Tana River.

Type area: The 7 km long Gåššjåkka river profile just west of the Finnish border on map-sheet 2033 II Galmatskai'di. Another important profile is seen along highway E6 and the river Tana 13-28 km east of Karasjok (map-sheet 2033 I Karasjok).

Thickness: Estimated to about 1000 - 3000 m.

Lithology: Garnet-bearing hornblende-plagioclase gneisses of intermediate composition are characteristic. Amphibolite, granite gneiss, and small ultramafic bodies are common. In the type area the rocks are injected by younger microcline granites and have the appearance of injective migmatite. Elsewhere the rocks are partially anatectic and high-grade metamorphic gneiss. Most of the rocks are interpreted as metavolcanics.

Boundaries: Both the upper and lower boundaries of the Tanaelv Migmatite Complex appear to be concordant, tectonized contacts formed at high metamorphic grade. They are interpreted as thrust contacts.

Age: The late-kinematic granites south of Karasjok intruded at about 1750 Ma (Krill et al. 1985). Older dates, obtained from Tanaelv rocks in Finland, include a granitic gneiss giving a U-Pb date of 2360 Ma (Merläinen 1976) an anorthosite giving a U-Pb date of 1906 Ma, and a pyroxene amphibolite giving a Rb-Sr date of 1816 Ma (both by Bernard-Griffiths et al. 1983). The Tanaelv Migmatite Complex probably includes rocks of various ages and origins, metamorphosed at high grade.

Levajok Granulite Complex

Name: Levajok is a small settlement and mountain resort 80 km northwest of Karasjok along the river Tana and highway E6 (map-sheet 2134 I, Viddasoav'vi). The name Levajok Granulite Complex is introduced here to designate the Norwegian part of the well known Lapland granulite belt.

Type area: Roadcuts along highway E6 and the river Tana (map-sheet 2134 I Viddasoa'vi, 2134 IV Rastigaissa, 2134 III Valljåkka).

Thickness: The true stratigraphic thickness is unknown, but the thickness measured normal to the foliation is about 30 000 m.

Lithology: There are two main rock types; garnet-quartz-feldspar gneiss, and hypersthene-plagioclase gneiss. The light coloured garnet-quartz-feldspar gneisses commonly contain both K-feldspar and plagioclase, as well as biotite, and sillimanite. Some cordierite, graphite, and hypersthene occur locally. Due to their high Al- and Si-contents, they are interpreted as paragneisses. They have been thoroughly recrystallized and no sedimentary textures or structures are seen. Some early migmatitic textures are preserved, but even these were mostly recrystallized during later deformation. The hypersthene-plagioclase gneisses are interpreted as orthogneisses. They form continuous map units with remarkably consistent thickness and appearance. Most of the mapped units are relatively homogeneous and massive, and are interpreted as strongly deformed plutonic rocks, probably intruded during the granulite-facies metamorphism. Some of the mapped units may include metavolcanic rocks or tectonized remnants of the basement gneisses for the metasediments.

Boundaries: The rocks immediately above and below the Levajok Granulite Complex were also metamorphosed at granulite

facies, but the lithologic contacts are sharp. Along the western contact, the granulite rocks overlie the gneisses of the Tanaelv Migmatite Complex. Intense deformation near the contact and the general metamorphic inversion indicate that the granulite complex was thrust over the Tanaelv Migmatite Complex. On the eastern side, heterogeneous, layered gneisses of the Baisvarri Gneiss Complex overlie the granulites with a sharp contact. Abundant granitic to granodioritic intrusive rocks of the Baisvarri Gneiss Complex are not seen in the Levajok Granulite Complex, so the Baisvarri Complex was presumably thrust over the Levajok Complex after the intrusions. Structures and foliation within the Baisvarri Complex become parallel to the Levajok granulite foliation within about a thousand meters of the contact.

Correlation: The Levajok Granulite Complex is the northern part of the Lapland granulite belt. The Finnish parts of this belt have been mapped and described (Meriläinen 1965, 1976), and studied petrologically (Hörmann et al. 1980) geochronologically (Bernard Griffiths et al. 1984), and geochemically (Barbey et al. 1982).

Age: Meriläinen (1976) interpreted whole-rock Pb-Pb isotopic results to indicate an Archean age of early metamorphism, but Bernard-Griffiths et al. (1984) show the date to be unrealistically old. On the basis of Rb-Sr, U-Pb and Sm-Nd study, Bernard-Griffiths et al. (1984) interpret the age of granulite metamorphism and intrusion of some of the hypersthene-plagioclase gneisses to be about 1.9 - 2.0 Ma. No reliable older dates have been obtained.

Baišvarri Gneiss Complex

Name: Baišvarri is a mountain with abundant bedrock exposure in map-sheet 2135 II Ul'-lugai'sa. The name has not been used previously in the geological literature, and the gneiss complex itself has not been named.

Type area: Roadcuts along E6 between Borsejåkka and Polmak provide the best exposures.

Lithology: The Baišvarri Gneiss Complex is a composite unit. The eastern part consists of heterogeneous layered gneiss as well as granitic rocks with lenses and layers of amphibolite and schist. The central part is a large body of hornblende-bearing quartz diorite characterized by porphyric plagioclase. It is intrusive into the western gneisses, but the eastern contact is poorly defined. The eastern gneiss consists of hornblende-rich dioritic to quartz-dioritic gneiss. The complex has not been studied in detail.

Boundaries: The western boundary is concordant to the rocks of the Levajok granulite belt. The gneisses contain dark feldspars and hypersthene, showing that they were metamorphosed under granulite facies conditions. The eastern contact has not been described or observed by the authors.

Correlation: The complex is known as the granite-gneiss complex in Finland, where it has been mapped and described by Meriläinen (1965, 1976).

Age: Dating shows that the granite-gneiss complex in Finland contains both Archean and early Proterozoic rocks (Meriläinen 1976).

Correlations and discussion

The lithostratigraphy and lithostratigraphic correlations proposed in this paper are summarized in Table 1. In these correlations we suggest that the bulk of the supracrustal sequence of the Kautokeino and Karasjok Greenstone Belts are correlative.

The age and the relationship between the supracrustal sequences of these two belts have been in focus for some time and both Archean and Proterozoic ages have previously been suggested. An Archean age was assumed for the Karasjok Greenstone Belt because of its southward continuation and merging into the presumed Archean Kittilä greenstones in northern Finland. The lower parts of the Kautokeino Greenstone Belt have been considered as possibly Archean (e.g. Solli 1983), while others have correlated the entire belt with the Early Proterozoic Kiruna-Vittangi greenstones (Pharaoh & Pearce 1984). In an indirect way, there have thus been expressed opinions that the Karasjok and Kautokeino Greenstone Belts may be of different ages and that they developed independently. The new radiometric ages, though still limited in number support most of our lithostratigraphic correlation. Krill et al. (1985) have shown that the unconformity between the Jer'-gul Gneiss Complex and the sedimentary cover

is Early Proterozoic, and that the volcanites of the Čas'kejas and the Bakkilvarri Formations (Kautokeino and Karasjok Greenstone Belts, respectively) originated in the Proterozoic era.

The Rai'sædno and Jer'gul Gneiss Complexes are correlated and interpreted as parts of a protocontinent consolidated in Archean Early Proterozoic time. Both the Rai'sædno Complex, and the Jer'gul Gneiss Complex appear to include some supracrustal rocks which could be correlated to cover units. In the Lakselv valley, north of Skoganvarre (Plate 1) a restricted occurrence of gneiss (the Lævdnjavarri gneiss of Pharaoh 1980) in the allochthon of the Karasjok Greenstone Belt may indicate that the Jer'gul continental crust extends eastward. The Baišvarri Complex, as discussed later, belongs to an eastern craton (cf. Barbey et al. 1980, 1984) which might have been in continuity with the Jer'gul crust prior to the formation of the Karasjok Greenstone Belt and the Levajok Granulite Complex.

As shown in Table 1, a pronounced unconformity (the Čaddjejåkka Unconformity, Siedlecka 1985) between the Jer'gul Gneiss Complex and the Masi- and Skuvvanvarri Formations, is mappable in the eastern and northern parts of Finnmarksvidda. In the west an unconformity occurs between the Masi Formation and the (underlying) Gål'denvarri Formation (Table 1). Another unconformity is assumed to occur beneath the Gål'denvarri Formation based on the fact that this formation is a volcanic unit resting upon a gneissic crust. It is not certain which of these unconformities should be correlated with the Čaddjejåkka Unconformity. We assumed in our favoured interpretation (Table 1) that the Čaddjejåkka Unconformity continues beneath the Gål'denvarri Formation, which is correlated with the Vuomegielas Formation further to the north. Towards the south, the Gål'denvarri Formation is correlated with the Baharavdujav'ri formation of Olsen & Nilsen (1985) on the basis of petrographic similarities and of an analogous stratigraphic position (Table 1). Olsen & Nilsen (1985 this volume), however, suggest that the Baharavdujav'ri formation is intruded by Archean gneisses. This interpretation, though not yet well documented, questions the correlation between the Baharavdujav'ri-, Gål'denvarri- and Vuomegielas Formations. It also questions the location of the Čaddjejåkka Unconformity in the Kautokeino Greenstone Belt, and, consequently, the ages and correlations of the volcanites subjacent to the Masi- and Skuvvanvarri Formations.

In spite of these uncertainties, an early stage in the development of the Kautokeino Greenstone Belt appears to have involved rifting and volcanic activity. These events were much more restricted in the Karasjok Greenstone Belt. The Vuomegielas Formation, and the metavolcanites recently mapped in the northeastern part of the Jer'gul Gneiss Complex (Nilsson 1985, personal comm.) have similarities to the Gål'denvarri amphibolites, and may be representative of this episode. There are no deposits testifying to rejuvenation of relief except for the correlative sequences in the tectonic windows (Table 1). The Holmvatn Group contains in its lower part alluvial-fan, debris-flow conglomerates underlying the volcanic upper portion of the group (Pharaoh et al. 1983).

The next stage in the development was dominated by terrigenous sedimentation of the Addjit, Masi, Skuvvanvarri, and Russeluft Formations and the Saltvann Group (Table 1). The latter consists mainly of fluvial accumulations derived first from a fault-bounded upland to the north, northwest and then from a new southerly source area (Pharaoh et al. 1983). Sandstones and conglomerates of the Russeluft Formation at Altenes may well represent a continuation of the alluvial depositional system of the Saltvann Group.

The Skuvvanvarri and Masi Formations consist of both alluvial and coastal marine sediments. The distribution of facies suggests location of a major fault-bounded upland to the east and northeast, and an overall rugged topography invaded by the sea probably from the west and southwest (Siedlecka 1984, 1985).

A new rifting stage, post-dating the widespread terrigenous sedimentation, resulted in extensive volcanic activity. This time, larger basins developed, accumulating the main volcanic sequences of the Kautokeino- and Karasjok Greenstone Belts, of the tectonic windows and of the Njallajåkka Complex. Lateral variations in intensity of volcanism as well as an episodic character of the extrusions of lavas and pyroclastics resulted in the mosaic of volcanic and volcanosedimentary formations. Although we are not yet able to outline a detailed history of this development, some major similarities and differences between the Kautokeino and Karasjok basins (and their prolongation in the windows) may be pointed out.

A gradual increase in volcanic activity, at the expense of terrigenous sedimentation, can be traced in both rift basins, culminating in basaltic (including komatiites) piles of the Čas'kejas, (?)Stuorajav'ri, Lik'ča and Bakkilvarri Formations and of the Kvenvik greenstone, parts of Turelv formation and the Nussir Group. Ceasing of this activity is recorded by the Bik'kačåk'ka Formation and the Rai'tegår'zi Formation.

Otherwise, the Kautokeino and Karasjok Belts show more differences than similarities in both basin development and basin deformation. As pointed out by Krill (1985) and Often (1985), formation of the initial rift, followed by accretion of the oceanic crust resulted in development of the Karasjok basin, which might have reached considerable dimensions.

The Kautokeino basin, on the contrary, seems to have been an intracratonic rift, filled with volcanites and sediments, indicative of low relief, which never reached the stage of an oceanic spreading zone. The final episode was marked by rifting, rejuvenation of relief, and accumulation of continental coarse clastics of the Čaravarri Formation and its deltaic equivalents in the Upper Raipas Group (Torske & Bergh 1984a), (?)and of the Stuorajav'ri Formation (cf. Olsen & Nilsen 1985). This episode is not recognized in the Karasjok Belt.

The development pattern in these two basins continued to be different during the deformational stage. What we can envisage in the Karasjok basin is a change in the sense of relative movement of the Jer'gul and Baisvarri continental areas causing compressional stress and eventual thrusting of the volcanics and sediments (Iddjajav'ri Group, Tanaelv Migmatite Complex and Levajok Granulite Complex) upon the continental crust (Jer'gul Complex and autochthonous sediments). The thrust is clearly demonstrable in the northern part of the belt (Pharaoh 1984, Siedlecka 1984, 1985). Further to the south, the allochthonous nature of the belt is suggested by the overall deformational pattern.

The Kautokeino Greenstone Belt is autochthonous, presumably deformed simultaneously with the thrusting of the Karasjok Greenstone Belt and the superjacent granulites. Recently, gravitational tectonics were also proposed as an explanation for the structure of the Kautokeino Greenstone Belt (Olesen & Solli, 1985).

Sørvaranger District (E. Iversen & B. Lieungh)

Introduction

Extensive mapping and prospecting for iron ore have been carried out by A/S Sydvaranger since 1955 over most of the Sørvaranger District. Simultaneously, in collaboration with A/S Sydvaranger, A/S Sulfidmalm has carried out an intensive prospecting for nickel in the Pasvik and Polmak areas. Much of this earlier work was led by J.A.W. Bugge who subdivided rocks of the Sørvaranger District into three orogenic units separated by major breaks: (1) the old pre-Karelian basement, (2) the Karelian supracrustal Bjørnevann formation and (3) the Late- (or post) Karelian Petsamontunturit formation. The 'basement' includes predominantly gneisses which were referred to under various petrographic and/or geographic names (Bugge 1960, 1978, 1980, Bugge & Iversen, 1981). Some of the Karelian and post-Karelian rocks of Bugge (1960) have also been named and described in some more detail because of their importance for either regional interpretations or for economic geology (e.g. Bjørnevann conglomerate, Bjørnevann gneiss, Neverskrukk conglomerate, etc.). More recently, investigations carried out by one of us (EI) in collaboration with J.A.W. Bugge and A. Berthelsen have provided some new information and a better understanding of the geology of the area, in particular with respect to the Archean (pre-Karelian and Karelian) part of the district. Equally, the more recent work on the post-Karelian rocks, carried out by the second author (BL) made possible a subdivision and description of rock units of the bulk of the Proterozoic (post-Karelian) part of the stratigraphy in the Pasvik and also in the Polmak area aproximately 100 km further west.

The second author (B.L.) has also described two Archean volcano-sedimentary formations (Føllvatnet Formation and Gjøkvatnet Formation) as well as the Archean gneisses in the South Pasvik area (south of the Proterozoic rocks, Plate 1 and Fig. 2). Because of the paucity of exposures in the area one is dependent upon the information obtained from the numerous drillholes and extensive electromagnetic/magnetic ground survey carried out. This was done as a joint effort by A/S Sulfidmalm and A/S Sydvaranger in the years 1978-82 in prospecting

for Ni-deposits in Pasvik.

It has not been possible at this stage to correlate the south Pasvik Archean rocks with the Archean rocks of the central Sørvaranger District (Plate 1). The relationships between the various Archean rock units in the south Pasvik area are also uncertain because of the total lack of information on their boundaries.

Rock units of the Sørvaranger District are systematically described for the first time in the text which follows. Some correlations are also proposed and discussed, as summarized in Table 1.

Archean rocks of the central and eastern areas (Iversen)

The Archean rocks have a regional NW-SE strike over most of the area with a general, steep northeasterly dip. The rock units are described from southwest to northeast (across strike), which is not necessarily their actual stratigraphic order.

Čappeskaidi Gneiss Complex

Name: Čappeskaidi is an elevated area located southeast of Polmak, map-sheet 2335 III, Varangerbotn. The name Čappeskaidi gneiss was introduced by Bugge & Iversen (1981). Formerly, the unit was a part of the undivided basement gneiss (the pre-Karelian complex).

Type area: The unit occupies the northwestern part of the Archean gneisses between Polmak and Neiden. Rocks of this unit are well exposed in the elevated parts, but are otherwise covered by till, lakes and swamps. Roadcuts between Polmak and Tana-bru (east side of the Tana river) and a reindeer-slaughter station south of Neiden give the best exposures (map-sheet 2334 II, Neiden, UTM 850 320).

Lithology: The Čappeskaidi Gneiss is dominated by light-grey granitic gneisses and mica gneisses with a brown colour due to weathering of biotite. Most of the area is migmatized and lenses of granitic material are common. In addition, bands of amphibolite 1-20 m wide occur throughout the area. The rocks are in high metamorphic grade in the northwestern part (Bugge, pers. comm.). In the central area, the Gæccoaivi Granite cuts through the unit (Plate 1).

Boundaries: The southwestern boundary, against the younger Petsamo Group, is tectonic. However, strongly deformed conglomerate is found in the boundary zone; it is correlated with the Neverskrukk Formation and this suggests an originally unconformable contact between these two units. The boundary with the Garsjø Group (Neiden area) has not been investigated and its nature remains unknown. The Čappeskaidi Gneiss is considered to be the oldest unit of the northwestern part of the Sørvaranger District (Table 1).

Age: Archean; the unit is intruded by the 2.5 Ma. Neiden Granite Complex (see below).

Svanvik Gneiss

Name: Svanvik is a small village on the Pasvik river about 35 km south of Kirkenes. The name Svanvik gneiss was introduced by Bugge & Iversen (1981). Formerly the unit was a part of the undivided pre-Karelian basement gneiss complex.

Type area: The gneiss unit occupies the area between the Pasvik river (the border to the USSR) and the Neiden granite close to Finland. The northern part of the area is well exposed but there are no roads in this part. Good exposures in road cuts are only found north of Svanvik, UTM VC 846 132 (map-sheet 2434 II, Kirkenes).

Lithology: Granitic gneiss with a weak foliation constitutes the predominating rock type. Locally, there occur banded varieties exhibiting intensive mesoscopic folding. On Hessengåsen and Brannfjellet there are banded amphibolites which have a general north-south trend.

Boundaries: The lower boundary is unknown. The Svanvik Gneiss is the lowermost unit, as is the Čappeskaidi Complex further to the west. These units are separated by the intrusive Neiden Granite Complex and may represent parts of one large gneiss complex (Plate 1). The boundary with the Garsjø Group is probably of tectonic nature (Fig. 1). The unit is overlain to the south by the Petsamo Group with a tectonic contact. The Petsamo Group is thought to be thrusted above the gneiss, but the length of the tectonic transport is unknown.

Correlation: The Svanvik Gneiss has the same position as the Čappeskaidi Gneiss, occur-

ring between the Petsamo Group and the Garsjø Group. The rock types in these two units are, however, different.

Age: Archean: The unit is intruded by the 2.5 Ma. Neiden Granite Complex.

Garsjø Group

Name: The lake Garsjøen is the largest lake south of Varangerfjord and is situated c. 50 km west-northwest of Kirkenes. It lies in the central part of the iron ore-bearing rock unit previously included in the Bjørnevann Group (Bugge & Iversen 1981). The name Bjørnevann is retained here for the iron ore-bearing unit in the mining district (Plate 1).

Type area: The well exposed mountainous area west of the head of Langfjorden (Fig. 1). Excursion localities are road cuts at Neidenfjorden, UTM PT 025 377, map-sheet 2434 III Høybuktmoen.

Lithology: The group is dominated by mica schists and mica gneisses. Quartzite and associated quartz-rich metasedimentary rocks are also common. In parts of the unit there occur fairly large bodies of granitic gneisses. It is still unknown whether these gneisses are intrusions or older gneisses that were thrusted or folded into the predominant rocks. The banded iron ore is the only marked horizon and it is associated with amphibolites and the quartz-rich metasedimentary rocks. The thickness of the ore is usually between 2 and 10 m, locally up to 15 m. The amphibolites are mostly 10 - 40 m thick but southeast of Langfjorden they reach several hundred meters in thickness. The ore, however, does not increase in thickness. The recurrence of the iron ore west of Neiden is the result of large-scale folding.

Boundaries: The lower boundary with the Svanvik Gneiss is identified as a thrust zone west of Langfjordbotn. It has not been investigated elsewhere. The boundary with the Varanger Gneiss is probably tectonic.

Correlation: The group was earlier correlated with the Bjørnevann Group of the mining district; this possibility is kept open, although other interpretations are also possible (see discussion, p. 26).

Age: Archean: the group is intruded by the Neiden Granite Complex, for which a Rb-Sr date of about 2550 Ma has been obtained (A. Råheim, unpubl. data).

Varanger Gneiss Complex

Name: The name was introduced by Bugge & Iversen (1981). Formerly the complex was part of the undivided pre-Karelian basement gneiss complex.

Type area: The complex occupies the area south of Varangerfjord, west and northwest of Kirkenes, and no particular area may be pointed out as typical. The rock types are well exposed in road cuts on the main road (E6) between Neiden and Karlebotn, and west of Høybuktmoen (UTM 059399, map-sheet 2434 III Høybuktmoen).

Lithology: Banded and strongly folded grey gneiss, probably of tonalitic/ granitic composition, is the main rock in the Varanger Gneiss Complex. The banded gneiss may be of sedimentary origin. A more homogeneous granitic gneiss is also common. Foliated, light-coloured intrusive granitic rocks represent younger generations of rocks in this complex. Undeformed pink and light granites represent the youngest rocks. Locally there occur inliers of iron-ore-bearing amphibolites and schists of volcanic and sedimentary origin. These might be tentatively correlated with either the Bjørnevann or Garsjø Groups.

Boundaries: There are tectonic boundaries against the Bjørnevann- and Garsjø Groups. Mylonites can be seen at the eastern shore of Langfjorden.

Age: Archean.

Bjørnevann Group

Name: Bjørnevann is the lake which gave the name to the settlement Bjørnevatn when the iron ore production started. The lake is now drained and constitutes the main mining area. The names Bjørnevann gneiss and Bjørnevann formation were previously used for all the mica schists and gneisses containing banded iron ores (Bugge 1960). These rocks have been given a group rank by Bugge & Iversen (1981). The Bjørnevann Group is now restricted to the iron-mining district of Kirkenes, the iron-bearing rocks of the Neiden area being included in the Garsjø Group (see above and Plate 1).

Type area: The mine district with the iron ores. This is also the most structurally complicated area.

Lithology: The Bjørnevann Group is a volcano-sedimentary sequence. The rocks generally

have a N-S to a NW-SE trend with an east-northeast dip. The oldest rock units probably occur in the western part, but the primary age relationships of the rock units are uncertain due to strong folding and several internal thrust zones. The group consists of six formations (Fig. 1) which are briefly described below in ascending order.

Correlation: The Bjørnevann Group can be correlated with the Garsjø Group. The most important evidence supporting this correlation is that both groups contain banded iron ores in connection with amphibolitic volcanic rocks. The metasediments are also similar, though the Garsjø Group has not been investigated in any detail. In the Bugøyfjord and Bugøynes area, there are two downfolded basins which contain sediments and banded iron formations (Table 1). The stratigraphy of sequences in both basins is similar, justifying the correlation between them. With which of the groups, Garsjø or Bjørnevann, these sequences can be correlated is uncertain, but on account of their position a correlation with the Bjørnevann Group is most probable (see Plate 1). The Jarfjord Gneiss contains mica gneiss and mica schist identical with the mica schists of the Bjørnevann Group exposed in the Ropelv area and on Skogerøy, a large island c. 10 km northwest of Kirkenes (Plate 1). This suggests that correlation between these groups is possible. This assumption is supported by scattered observations of quartz-banded iron ores occurring within the Jarfjord Gneiss southwest of Kobbholmfjorden, a few kilometres west of Grense Jacobselv (Plate 1).

Age: Archean; the Neiden Granite, c. 2.5 Ma. old, intrudes rocks of the Garsjø Group which may be equivalent to the Bjørnevann Group.

Nosfjellet Formation

Name: The formation is named after the mountain Nosfjellet south of Høybuktmoen airport (Fig. 1). The name was introduced by Berthelsen, 1982 (internal report to A/S Sydvaranger). The formation was earlier a part of the undivided Bjørnevann gneiss (Bugge 1960).

Type area: The unit occurs along the eastern shore of Langfjorden and is probably the lowest unit of the group. Type areas are Nosfjellet and the steep mountain side on the east shore of Langfjorden (UTM 113 370, 133 347 map-sheet M711 2434 III Høybuktmoen).

Lithology: The unit consists mostly of quartz-rich sediments, but amphibolites and ultramafic rocks are found along Langfjorden and on Nosfjellet. West of Høybuktmoen there are iron ores associated with quartzites and amphibolites. Strongly deformed granitic gneisses occur in part of the formation. They may be either strongly deformed early intrusions or tectonic slices of an older granitic gneiss.

Boundaries: The lower boundary is tectonic; mylonites found at the eastern shore of Langfjorden cut through the lowermost part of the formation.

Høgfjellet Formation

Name: The formation is named after Høgfjellet, a mountainous area at Langfjorden. It was introduced by Berthelsen, 1982 (internal report to A/S Sydvaranger). Formerly the formation was part of the undivided Bjørnevann group of Bugge & Iversen (1981).

Type area: The type area is at Høgfjellet west of the road to Pasvik (UTM 143 286 map-sheet 2434 III Høybuktmoen).

Lithology: The formation consists of grey mica schist with zones of more quartz-rich metasediments and of three layers of amphibolite, with locally preserved agglomeratic structures.

Boundaries: The lower boundary, where observed, is tectonic. The boundary with the Pesktind Formation is discordant and is interpreted as possibly tectonic (see below).

Pesktind Conglomerate Formation

Name: The formation is named after the mountain Pesktind between the mines and the road to Pasvik. It was introduced by Berthelsen, 1982 (internal report to A/S Sydvaranger). The earlier name was Bjørnevann conglomerate (Bugge 1960). The name is changed, because Bjørnevann is used for the whole group.

Type area: Typical exposures are by the road to Pasvik, UTM 150 306, map-sheet 2434 III Høybuktmoen, and along the old shores of the now drained Bjørnevatn.

Lithology: The conglomerate consists, 99 %, of

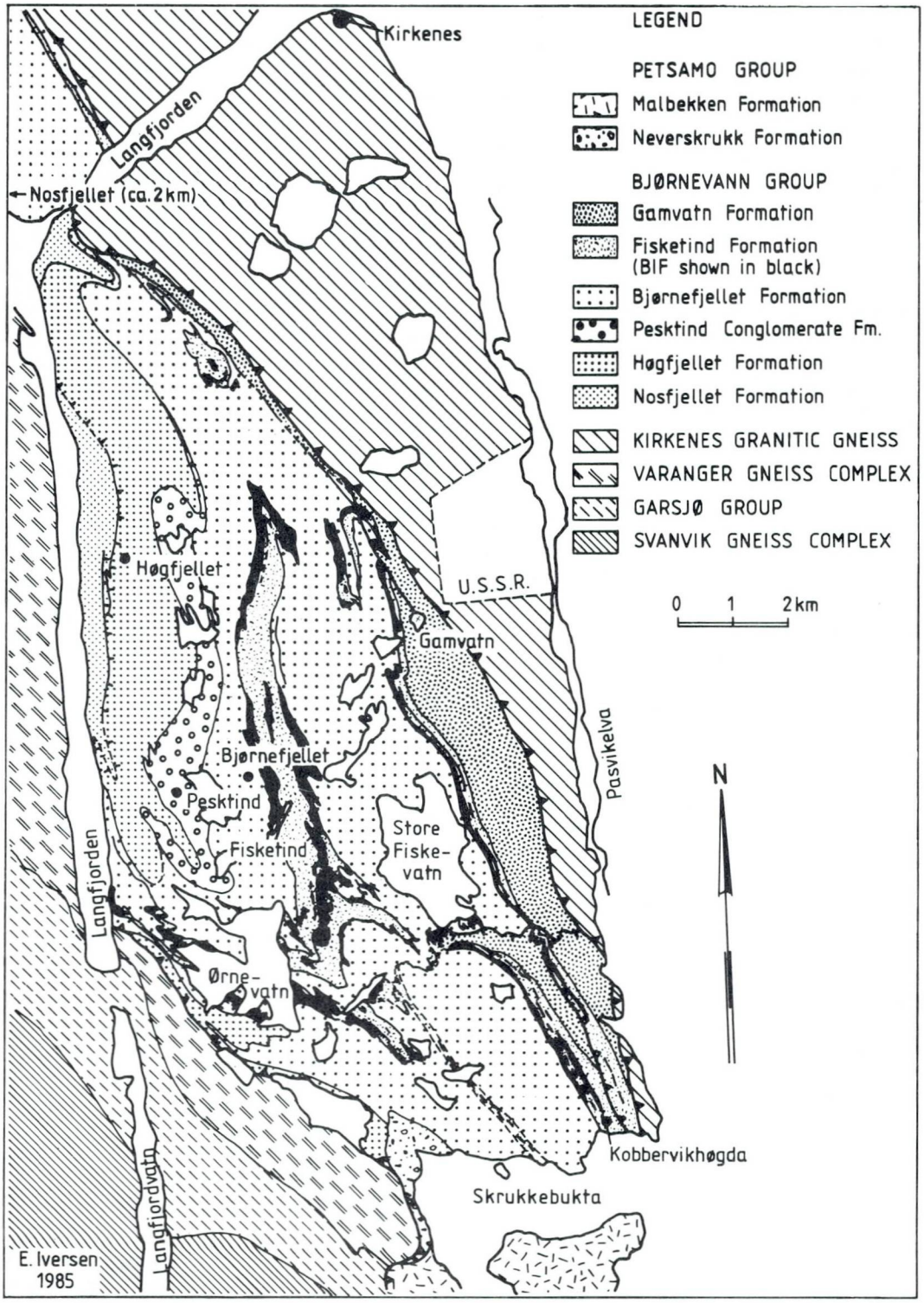

Fig. 1. Lithostratigraphic map of the central Sørvaranger District. By E. Iversen.

well rounded granitic pebbles and cobbles, varying in size from 5 cm to more than one meter. The remainder of the pebbles are amphibolite and clay-rich metasediments and are seldom more than 5 cm across. The conglomerate is matrix-supported and the matrix is pelitic. Parts of the conglomerate are very strongly deformed, and in many areas the flattened and stretched pebbles are isoclinally folded. The Kirkenes Granitic Gneiss is considered to be a possible source rock for the conglomerate.

Boundaries: The lower boundary is sharp and cuts discordantly the rocks of the Høgfjellet Formation. It is interpreted as tectonic because the conglomerate is never found in contact with granitic rocks that can be the source for the pebbles. The precise nature of this contact throughout the area remains uncertain. A thrust plane occurs between the Høgfjellet and Pesktind Formations in strongly deformed areas (Berthelsen, pers. comm.). In other places, the contact between the (underlying) schist and the undeformed conglomerate may be primary. However, the fact that the conglomerate is never found resting on granites (source rock for the pebbles) suggests that this contact too is tectonic. The upper boundary is also believed to be tectonic. The precise character of this boundary, however, remains uncertain because of later folding.

Bjørnefjellet Formation

Name: The formation is named after Bjørnefjellet, a mountain west of the mine area. It was introduced by Berthelsen, 1982 (internal report to A/S Sydvaranger). The formation was earlier part of the undivided informal Bjørnevann gneiss.

Type area: The type area is near the mines at Bjørnevatn. UTM 842 311 map-sheet 2434 II Kirkenes.

Lithology: The formation consists of homogeneous light-grey quartzite and quartz-rich mica- and feldspar schists. Locally a metarhyolite occurs at the top of the formation.

Boundaries: The lower boundary with the Pesktind Formation is locally tectonized by a late small thrust zone. Its precise character elsewhere remains uncertain because of strong folding, but it is believed to be tectonic (see above). The upper boundary against the volcano-sedimentary Fisketind Formation is stratigraphic, well defined by the start of the ore sedimentation.

Fisketind Formation (Banded Iron Formation, BIF)

Name: The formation is named after the mountain Fisketind in the mining area. The name was introduced by Berthelsen, 1982 (internal report to A/S Sydvaranger). It was earlier informally designated as 'Malmformasjonen' (the ore formation) or 'Hornblende gneiss with ore' or 'quartz-banded iron ore' (Bugge 1960).

Type area: The formation was previously well exposed in the mining district. Now, the mountain Fisketind (UTM 849 255) is the only exposed area in the mine area because of the development of the mining. Other good exposures are on Koppervikhøgda near the Pasvik river (Fig. 1) (UTM 885 215 map-sheet 2434 II Kirkenes).

Lithology: The formation consists of amphibolites and quartz-banded iron ore (BIF). Two horizons of iron ore, separated by amphibolite, are in production in the mine area. Pillow structure is preserved in the amphibolite roofing the ores at Koppervikhøgda, testifying to their volcanic origin. In the central part of the area the BIF and the amphibolite form a very large synform. The open pit production area of A/S Sydvaranger is located in the limbs of this structure. The iron-bearing strata are considered to be volcanic-exhalative deposits. They are always banded, the magnetite-rich bands alternating with quartz-rich bands each about 2-10 mm thick. The quartz bands are interpreted as chemical precipitates. The other minerals are green hornblende, grunerite, epidote, biotite and hematite. Traces of pyrite and chalcopyrite are present. The amount of grunerite $(Mg, Fe)_7Si_8O_{22}(OH)_2$ varies considerably. Its presence indicates that the iron chlorite, greenalite, which has nearly the same chemical composition, was present in the unmetamorphosed iron formation. Of the two horizons of iron ores the upper one is the best; it consists of more than 50 % magnetite (30 - 35% Fe magn.), while the lower horizon varies between 10 - 30% Fe magn.

Boundaries: The lower boundary is sharp and well defined by the first appearance of the ore-bearing banded metasedimentary rock. The upper boundary is well defined by the

start of the sedimentation of the Gamvatn Formation.

Gamvatn Formation

Name: Gamvatn is a lake close to the Soviet border (Fig. 1). The name is introduced here for the first time. The formation was earlier part of the undivided Bjørnevann gneiss.

Type area: The formation is well exposed in the mountaineous areas around Gamvatnet, southwest of the Soviet village of Boris Glebb (UTM 865 295 map-sheet 2434 II Kirkenes).

Lithology: The formation is homogeneous, consisting of quartz-rich biotite schist.

Boundaries: The lower boundary is stratigraphic. The upper boundary is tectonic: the Kirkenes Gneiss Complex is thrusted above the Gamvatn Formation.

Kirkenes Granitic Gneiss Complex

Name: Kirkenes is the main town of Sørvaranger, and the processing plant for the A/S Sydvaranger iron ore is located here. The name Kirkenes Granitic Gneiss Complex was introduced by Bugge & Iversen (1981). Formerly, the unit was a part of the undivided pre-Karelian basement gneiss complex.

Type area: The unit occupies the area around Kirkenes and typical rocks are found in the roadcuts from Kirkenes to Jakobsnes. Roadcuts east of Hesseng are type localities (UTM 842 338, map-sheet 2434 II Kirkenes).

Lithology: Grey foliated granite/tonalite, cut through by several generations of younger granites, is predominant. Deformed amphibolites are also found. Pink and red undeformed pegmatites and small granite bodies are the youngest intrusive rocks of the complex.

Boundaries: The lower boundary of the Kirkenes Granitic Gneiss Complex is tectonic and represents the largest and most important thrust zone found in Sørvaranger. The Kirkenes granitic gneisses are believed to have been transported at least 15 km over the Bjørnevann Group (Berthelsen, pers. comm. 1984). The nature of the boundary to the Jarfjord Gneiss is unknown, because of poor exposure and insufficient mapping.

Correlations: Parts of the more massive Varanger Gneiss Complex may perhaps be correlated with the Kirkenes Granitic Gneiss.

Age: Archean. The evidence is circumstantial; the red pegmatites and granites dissecting the complex (see above) are considered comagmatic with the granites intruding the Jarfjord Gneiss. The latter granites have yielded a Rb-Sr age of 2555 ± 36 Ma (Råheim & Bugge, unpublished data).

Jarfjord Gneiss

Name: Jarfjord is a N-S-oriented fjord in the easternmost part of the Sørvaranger district, c. 20 km east of Kirkenes (Plate 1). The name Jarfjord gneiss was used informally in internal reports written for Sydvaranger A/S by H. Lien, and the name Jarfjord Group was used by Bugge & Iversen (1981).

Type area: The unit occupies the eastern part of Sørvaranger. Typical areas are at Jarfjordfjellet and in Grense Jakobselv close to the Soviet border. (UTM 060 366 map-sheet 2434 II Kirkenes and UTM 150 443 map-sheet 2534 IV Grense Jakobselv).

Lithology: The Jarfjord Gneiss is dominated by biotite gneiss, mostly strongly migmatized with the exception of a restricted area in the southwest. The migmatization increases eastwards and in the southeast large parts of the area are dominated by granites connected with the migmatites. In the northeast, in the area of Grense Jakobselv, the migmatitic rock is locally strongly foliated and bands of more amphibolitic composition are also observed. In the coastal area, north of the road to Grense Jakobselv, several large monzonitic intrusions occur. Large bodies of red granite and pegmatites are also present here. The monzonites and granites are not included in the Jarfjord Gneiss.

Boundaries: A fault separates the Jarfjord Gneiss from the Kirkenes Granitic Gneiss Complex along the river Karpelven in Jarfjord. The fault also separates the Jarfjord Gneiss from the Bjørnevann Group (Plate 1).

Correlation: A preliminary investigation suggests that the Jarfjord Gneiss and the Bjørnevann Group probably represent correlative units.

Age: Archean. The red granites mentioned above are dated to 2555 ± 36 Ma by the Rb-Sr whole-rock method (Råheim & Bugge, unpublished data). On the basis of its heavy

deformation and migmatization the unit was earlier believed to include the oldest rocks of the Sørvaranger district. A new model proposed by Berthelsen (1982, A/S Sydvaranger internal report) suggests that the Jarfjord Gneiss is a younger part of the Archean crust located close to a subduction zone, where the heavy migmatization has taken place.

Neiden Granite Complex

Name: Neiden is a small settlement about 40 km west of Kirkenes. The name Neiden granite was established by Wiik (1966).

Type area: The intrusion occupies a circular area south of Neidenfjorden. The main rock type is well exposed in roadcuts (E6) in Munkefjord UTM 951 299, map-sheet 2434 III Høybuktmoen.

Lithology: The Neiden Granite Complex consists of different granitic and granodioritic intrusions. An outer zone of granodiorite lies around different types of granites and porphyry granites. The porphyry types were earlier described as augen gneiss. The complex has been studied and described in detail by Wiik (1966).

Boundary: Deformed intrusive.

Age: Archean. The oldest Rb-Sr whole-rock dates in the Complex are around 2,550 Ma (Meriläinen 1976, Råheim, unpubl. data), but parts of the complex are younger (Krill et al. 1985).

Correlation: The Gæccoaivi Granite (Plate 1) may be correlative with the Neiden Granite Complex.

Discussion

The main unsolved problem of the Archean geology of the Sørvaranger District concerns the relationship between the Bjørnevann and the Garsjø Groups. Associated with this problem is the question as to what extent plate tectonic processes have been involved in the deformation of the rocks.

Two alternative models have been proposed for the sequence of events and Archean stratigraphy of the Sørvaranger District. In the earlier model (Bugge 1960, 1978, 1980) it was suggested that the older pre-Karelian basement, including the rocks now described as the Čappeskaidi, Svanvik, Varanger and Jarfjord Gneiss Complexes, was deformed and metamorphosed at an early stage. Subsequently the sediments and volcanites of the Bjørnevann and Garsjø Groups were accumulated in basins which formed on this basement. These supracrustal sequences and their basement were then deformed through a large-scale gravity folding. This model implies that the Bjørnevann and Garsjø Groups are time- correlative and constitute a younger element of the Archean rocks of the district.

In an alternative model Berthelsen (1982) suggests that the western units, the Čappeskaidi, Varanger and Svanvik Gneiss Complexes, constituted an Archean basement complex on which the sediments and volcanites of the Garsjø Group accumulated during an older episode. The model suggests subsequent development of a subduction zone northeast of the Jarfjord Gneiss with a slab dipping down towards the southwest. Calc-alkaline magmas developed by partial melting of the slab gave rise to the development of the Kirkenes Gneiss. The generation of the monzonitic magmas now found in the northern part of the Jarfjord Gneiss and in the Bjørnevann Group is believed to have come from a younger plate-tectonic situation where a subduction zone is assumed to have been active farther to the northeast outside the present Sørvaranger area and with a northeasterly sense of movement. Xenoliths of mica schists, very similar to the schist in the Gamvatn Formation, are present in the Kirkenes Granitic Gneiss, suggesting that the age of the Kirkenes Gneiss is younger than the sediments of the Bjørnevann Group. The Pesktind Formation contains granitic pebbles that have retained an isotropic fabric during sedimentation. This shows that they were derived directly from unstrained magmatic rocks and not from older deformed granitic gneiss. The most probable source for the pebbles is the Kirkenes Granitic Gneiss. This means that the Pesktind conglomerate might be the youngest unit in the Bjørnevann Group separated from the reminder of this group by an unconformity and subsequently thrusted to its present position. According to this model the upper units in the Bjørnevann Group, the Bjørnefjellet, Fisketind and Gamvatn Formations, are older than the Pesktind Formation and have been thrust upon it during a rather early stage of deformation. The thrust zones have subsequently been folded and transected by younger thrusts.

Summing up, although the Bjørnevann Group consists of mappable, fairly well defined

formations, the stratigraphy within the group remains uncertain. The western part of the Sørvaranger District has not been investigated in detail, and several questions remain to be solved. The main problem is the position and development of the Garsjø Group. Gneiss units in this group might either be intrusive, or represent older slices of basement gneiss thrusted or folded into their present position. The thin zones of metasediments, metavolcanites and iron ore observed in the Varanger Gneiss Complex west of Bugøyfjorden possibly divide the Varanger Gneiss Complex into two parts.

The models discussed above for the Archean geology in the Sørvaranger District are thus tentative. The investigations currently in progress in this area will provide new data necessary for the construction of better founded and more detailed models which may change and refine some of the correlations shown in Table 1.

Archean and Early Proterozoic rocks of the southern Pasvik and western Polmak parts of the Sørvaranger District (Lieungh)

Neverskrukk Formation

This formation has earlier been interpreted as the lowest part of the Petsamo Group. For reasons described below it is now excluded from this group.

Name: Neverskrukk bukt (renamed to Skrukkebukta, UTM 860 203 map-sheet 2434 II Kirkenes, see Fig. 2) is a small bay in the Pasvik river, approximately 11 km south of the mining town Bjørnevann. Formerly, this formation was called the Tøllevin-conglomerate (an old Finish term, Wegmann 1929) and the Neverskrukk conglomerate (Bugge 1960). The name Neverskrukk Formation is here introduced formally for the first time.

Type area: The Pasvik area. The formation is well exposed in several roadcuts close to Brattli (UTM 860 203 map-sheet 2434 II Kirkenes).

Thickness: Due to the nature of the deposit, the thickness varies from 0 to approximately 200 m.

Lithology: This is a polymict conglomerate containing a wide range of angular to well rounded pebbles. The conglomerate shows a major overall fining-upwards sequence with considerable variation in composition and texture from base to top. Locally, it can be subdivided into three distinctive lithofacies.

a) A poorly sorted clast-supported conglomerate, containing large, well rounded boulders (some angular pebbles are present) occurs at the bottom. A number of small discontinuous sand and fine gravel lenses are present, generally exhibiting good trough cross-bedding.

b) Well-bedded conglomerate layers, up to 1 m in thickness, separated by thinner sandstone beds constitute the middle part of the formation. The conglomerate is mainly matrix-supported and contains poorly rounded pebbles suggesting a deposition by debris flow. There are few clast-supported beds containing well-rounded pebbles (stream flow deposits). The sandstone layers contain small rounded pebbles and exhibit fine channel structures and cross-bedding, indicating a braided stream environment.

c) The uppermost lithofacies consists of gravelly sand, mainly with rounded fragments, showing good channel structures and cross-bedding. Interbedded with these are coarser matrix-supported conglomerate beds, with a lower degree of pebble rounding. This lithofacies may be interpreted as a more distal portion of the braided alluvial system. Observed sedimentary structures all indicate right way up. The formation as a whole is interpreted as having originated by a transition from a choked youthful river, or a proximal part of an alluvial fan, through a progressively more distal portion of the alluvial fan.

Boundaries: The formation rests on an uneven erosional surface of various older rocks (Bugge 1960). Immediately beneath the contact there occurs a weathered horizon, in places with fragments, possibly representing a regolith developed on the surface of rocks of the Bjørnevann Group, the Varanger Gneiss Complex, the Garsjø Group, Svanvik Gneiss (Pasvik area) and the Čappeskaiddi Gneiss Complex (Polmak area). The composition of the weathered horizon changes depending on the source rock, and creates in places a very diffuse transition from the source rock to the basal sediments. The nature of the upper boundary is uncertain (see below).

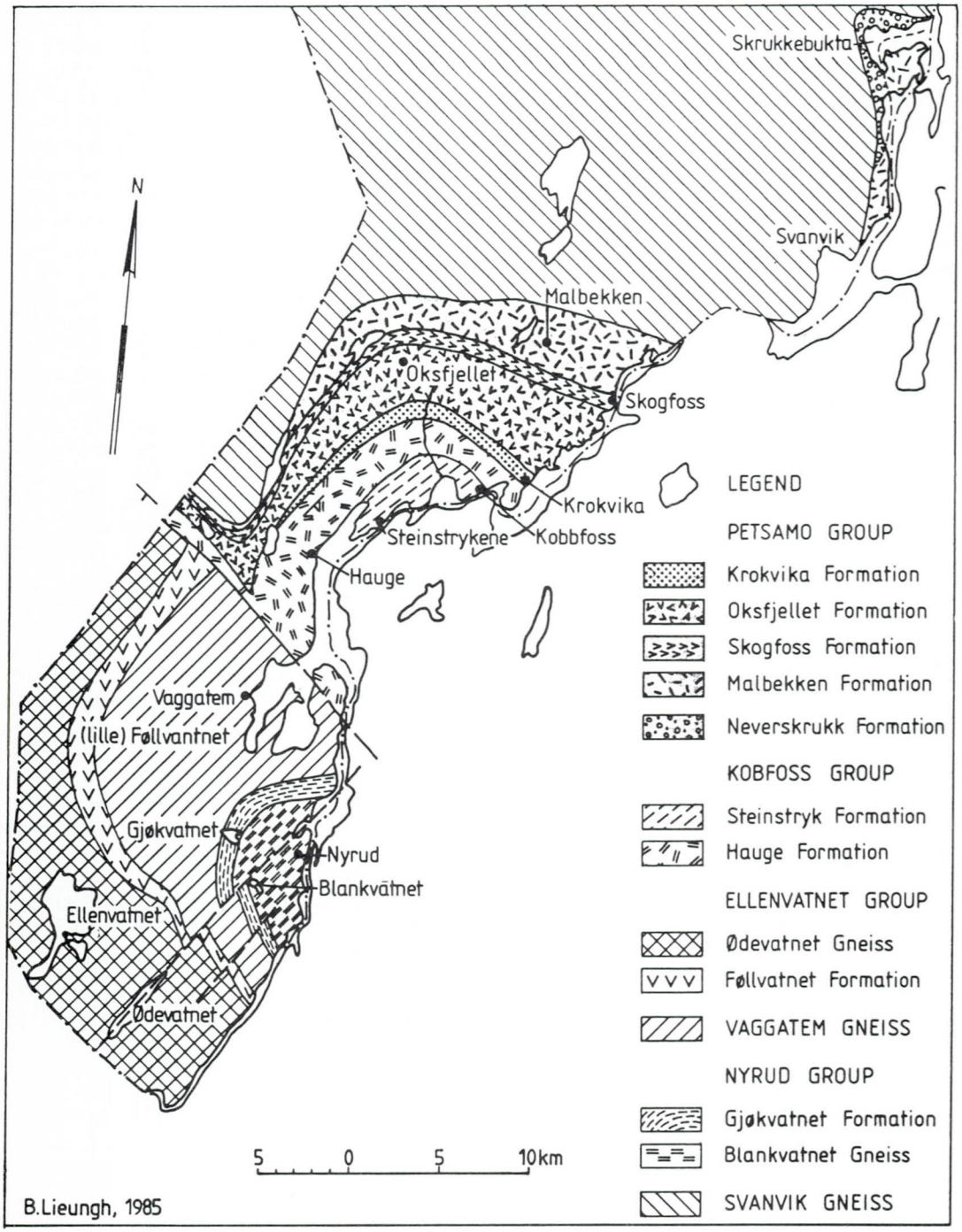

Fig. 2. Lithostratigraphic map of the Pasvik area. By B. Lieungh.

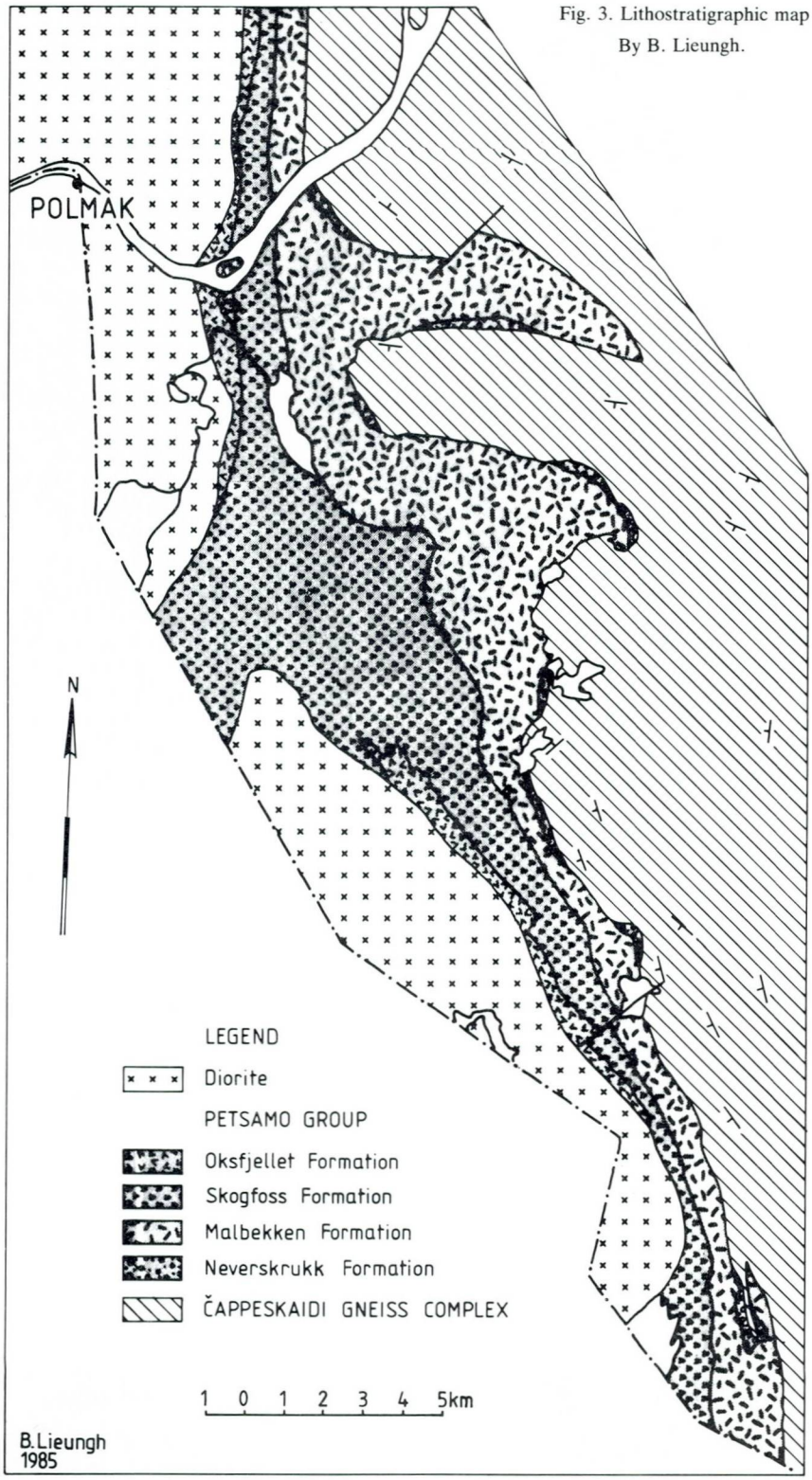

Fig. 3. Lithostratigraphic map of the Polmak area. By B. Lieungh.

Correlation: A similar conglomerate occurs in the same position in the Polmak area (Fig. 3).

Age: Between 2550 Ma. (granite intrusions in the Bjørnevann-Garsjø groups) and 1800 Ma. (Petsamo Group). See above and Krill et al. (1985).

General remarks: In the Sørvaranger District the Neverskrukk Formation shows up as a discontinuous deposit ((occurrences in depressions), resting on an Archean erosional surface. It extends from the eastern side of the Petchenga mountains (USSR) in the east, through Pasvik to the Polmak area in the west. Dykes of fine-crystalline diabase cross-cut the Neverskrukk Formation and are fairly common in the subjacent gneisses. Their absence in the overlying formations of the Petsamo Group suggests a break; a slight increase in degree of deformation in the upper part of the Neverskrukk Formation suggests a possible overthrust of the Petsamo Group upon the Neverskrukk Formation.

Petsamo Group

Name: This group has earlier been called the Tunturi formation (Wegmann 1929) and later the Petsamontunturit or Petsamo formation (Bugge 1950, 1980). The name Petsamo is retained and the unit is here given a group rank. For the reasons discussed above the Neverskrukk Formation is excluded from the Petsamo Group. The group is subdivided into four formations described below in ascending order.

Thickness: The whole group has an estimated total thickness varying from 1,500 to 5,000m.

Malbekken Formation

The formation contains a large number of amygdaloidal and amygdale-free lava-flow units. In the upper part, limestone and quartzite are found. A porphyry with asteroidal aggregates of plagioclase crystals is typical for the lowermost part of the formation and limestone and quartzite are characteristic for its upper portion.

Name: Malbekken (UTM 01,02 map-sheet 2433 IV Skogfoss) is a small stream in Pasvik valley, approx. 6 km northwest of the little 'village' Skogfoss. The name is here formally introduced for the first time.

Type area: The following localities can be recommended: Porphyritic lava with asteriated plagioclases: Roadcut (UTM 869 116) map-sheet 2433 I Svanvik
Amygdaloid free lavas: Hill (UTM 876 885) map-sheet 2433 II Kirkenes
Amygdoidal lava: Roadcut (UTM 063 006) map-sheet 2433 IV Skogfoss
Limestone: Shore (UTM 012 021) map-sheet 2433 IV Skogfoss
Quartzite: Slope (UTM 033 006) map-sheet 2433 IV Skogfoss
Excellent outcrops of amygdaloidal/amygdale-free lava can be visited in the dried out bottom of the Pasvik river, downstream from the Skogfoss hydro-electric power station: (UTM 060 984) map sheet 2433 IV Skogfoss. Care has to be taken for accidental and illegal crossing of the USSR border, and the danger of sudden outlet of water from the hydro-power dam.

Thickness: Varies from 50 m to c. 2100 m (estimated).

Lithology (in ascending order): a) A basic rock with porphyritic texture. It contains pyroxene phenocrysts and characteristic asteroidal plagioclases. The occurrence of this rock type both in Pasvik and in the Polmak area in the same stratigraphic position suggests an eruptive rather than a subvolcanic origin for this rock. b) Amygdaloidal lava. This unit consists of numerous flows which vary in thickness from 0.5 m to some 5 m. The flows vary from massive lavas with few amygdales, to highly amygdoidal flows. In some flow units amygdales are concentrated at the top of the flow and have a scoreaceous appearance, indicating eruptions under subaerial conditions. Other flow units are separated by bedded laminated tuffs indicating a subaqueous origin for both lavas and tuffs. A few, elongated pillow-like structures, are reminiscent of lava tubes. Preliminary old assays indicate an andesitic composition for the amygdaloidal lava, but some doubts are placed on these results because of the varying amount of amygdules in the assayed samples. c) Koievann quartzite and limestone. In the upper part of the formation a thin horizon of quartzite is present and upon this, a thin white limestone. The name Koievann is introduced here as an informal member.

Boundaries: Gorbinov (1968) proposed an overthrust between equivalents of the Malbek-

ken and Skogfoss Formations on the Russian side of the border. In this work the boundary is interpreted as concordant and probably transitional. The lower boundary is probably tectonic (see p. 208).

Correlation: The Malbekken formation also appears 100 km further west, in the Polmak area, in the same position. The amygdaloidal lava occurs in the Polmak area as separate beds with quartz-filled and feldspar-filled amygdales. Both the amygdaloidal and the porphyric lava with asteroidal aggregates of plagioclases are observed in the same stratigraphic position. A thick white quartzite containing ripple marks is correlated with that in the Koievann area. A limestone overlying this quartzite in the Polmak area correlates well with the Koievann limestone in Pasvik. From a short visit to the Gievdnjeguoika area (Kautokeino river, central inner Finnmark), similarities have been observed between the amygdaloidal lavas of the Malbekken Formation and those of the Gål'denvarri Formation. The Malbekken Formation correlates with similar rocks in the Pechenga Complex on the Russian side of the border.

Age: According to various Russian maps, this formation is of Lower Proterozoic age.

Skogfoss Formation

This formation contains acidic and basic volcanites, and is an excellent marker unit on account of its magnetite content which gives continuous regional magnetic anomalies.

Name: Skogfoss (UTM 060 984 map-sheet 2433 IV Skogfoss) is the name of a little village with a hydro-electric power station in the Pasvik valley, approx. 65 km south of Kirkenes. The Skogfoss Formation is formally established here for the first time. The name has once been used (Oftendahl 1980) for the entire Petsamo Group as defined here.

Type area: The Svartfjellet area (UTM 045 985 map-sheet 2433 IV Skogfoss) is the best place to study the rocks of this formation. A small roadcut in a magnetite-chert (UTM 057 983 on the same map-sheet) is also worth a visit.

Thickness: The formation has its greatest thickness of ca. 500 m just west of Skogfoss, but thins out to less than 10 m towards the southwest.

Lithology: In the Pasvik area there is an acidic rock in the lower part of the formation, with large elongated vesicles filled with feldspar and epidote. Grey to pink quartz-keratophyres and dark-green aphanitic amphibolites are the main rocks in this formation. Some of these rocks have a high content of magnetite, and are very fine-grained, nearly felsitic. The fine-grained magnetite-rich rocks are probably magnetite-cherts. A very fine-grained (aphanitic) dark-grey basic rock occurs in the upper part. Numerous small transecting veins and flakes of red-coloured feldspathic material occur in the lower parts of the formation. Pink porphyritic rock-types occur in subordinate amounts.

Boundaries: The lower boundary is assumed to be transitional (see above); the upper boundary is assumed primary, but this is uncertain because of lack of exposure. In the Polmak region this formation appears as a mafic rock containing laminated chert (in the south), with a transition to thick horizons of intermediate tuffs, commonly with magnetite, in the north. Within this sequence chert intercalations are common, with white-grey, black and pink colours. Higher up there occurs a unit of interbanded basic volcanic rocks, white banded keratophyres and intermediate tuffs. This is succeeded by a thick sequence of white, magnetite-bearing massive keratophyre which is partly altered into quartz-sericite schist. In addition, there are centimetre-thick chlorite-rich bands showing graded bedding reminiscent of turbidites. In the northernmost part of the Polmak area, close to the Tana river, there are acidic volcanites similar to those in Pasvik. Numerous beds of white quartzite c. 1-2 m thick are alternating with these acidic volcanites. Some of the rocks of this formation may represent welded tuffs or ignimbrites, with lithic fragments. On the other hand, observations of twisted and 'folded' fragments may indicate a turbulent lava and ash-flow, or an erosion of the lava surfaces.

Age: Rb-Sr age determination: 1795 ± 61 Ma (Råheim & Bugge, unpublished data).

Oksfjellet Formation

Name: Oksfjellet (UTM 933 012 map-sheet 2333 I Vaggatem) is the name of a hill-complex ca. 13 km west of Skogfoss, in the Pasvik valley. The name is introduced here for the

first time. The formation can be subdivided into 3 informal members: a) greenstone/greenschist with limestone and quartzite beds; b) calcareous phylites and tuffites with sulphides; c) matrix-supported conglomerate. It also contains possible ultramafic lavas.

Type area: The easiest accessible section is along the main road 885 from Skogfoss to Krokvika (Fig. 2). Because of the complexity of the formation, the following localitites can be recommended: Pillow lava and pillow breccia: UTM 053 972 map-sheet 2433 IV Skogfoss. Phyllite and tuffite: UTM 040 964 map-sheet 2433 IV Skogfoss. Mudflow: UTM 035 963 map-sheet 2433 IV Skogfoss. Ultramafites: UTM 915 000 map-sheet 2433 IV Skogfoss.

Thickness: Variable; from 2200 m in the main and eastern area, decreasing rapidly to 1100 m and 300 m in the other parts of the area. A tectonic repetition resulting from isoclinal folding is possible.

Lithology: This is a complex formation of pillow-lavas, pillow-breccias, massive and schistose greenstones and greenschists with several beds of calcareous sulphide-bearing phyllites, mica schists and chloritic tuffs. Intrusions or, more probably, boudinaged ultramafic lavas, are mainly situated in the phyllitic-tuffitic parts of the sequence. At least one, possible two, beds of quartzites and limestones occur in this formation. Polymict matrix-supported conglomerate, containing fragments up to 50 x 200 cm, of all the above-mentioned rock types occurs in the upper part. Sandstone dykes dissect this conglomerate which is interpreted as a submarine debris-flow deposit. It is interesting to note that it contains large ultramafic fragments suggesting an extrusive origin for at least some of the ultramafic rocks. Preliminary old chemical assays indicate that the greenstones may be representative of tholeiitic basalts.

Boundaries: Not exposed, probably concordant.

Correlation: Sandstones/conglomerates reported on the Russian side may correlate with the debris-flow unit in the Pasvik area. This formation is not very well represented in the Polmak area, mainly because of the diorite intrusion invading its upper part. Greenschists/greenstones, calcareous phyllites and small bodies of ultrabasic rocks are present, however. The formation is fairly thin in that area. According to Russian maps this formation can be correlated with 'the northern zone' of the Pechenga Complex.

Age: Early Proterozoic according to various Russian maps.

Krokvika Formation

Name: Krokvika (UTM 020 950 map-sheet 2433 IV Skogfoss) is a small bay in the Pasvik river. The name is used here for the first time and the unit is here formally established as the Krokvika Formation.

Type area: Roadcuts west of Krokvika (UTM 008 942 map-sheet 2433 IV Skogfoss) are the best places to visit the formation.

Thickness: The formation has only been mapped in the eastern part, mainly because of overburden. The approximate thickness is 200 m, but it probably thins out to zero in southern and western areas.

Lithology: Grey-green phyllites with siltstones and fine-grained sandy beds occur in the lower part together with some greenstone and greenschist. In the upper part there is a grey-green garbenschist with subordinate pyrite-bearing phyllites. Calcareous schists with sulphides have been observed in drill-cores. In the uppermost part a sericite schist with a lustrous surface is common in eastern areas.

Boundaries: The sericite schist in a way represents the transition to the overlying mica gneiss in the Hauge Formation (Kobbfoss Group). A rapid change in metamorphic grade, and indications of mylonites in the lower part of the overlying Hauge formation, may point to a thrust plane between the formations.

Correlation: The formation is not found in the Polmak area, mainly because of the presence of a large diorite intrusion. According to an earlier Russian description the Krokvika Formation and even the upper part of the Oksfjellet Formation can be placed in the Tundra Formation. Later Russian information seems to restrict the term Tundra to mica gneisses assigned here to the Kobbfoss Group.

Age: Early Proterozoic according to the Russian data.

Kobbfoss Group

Kobbfoss (UTM 991 931 map-sheet 2433 IV Skogfoss) is the name of a rapids in the Pasvik river. It is here formally established as the Kobbfoss Group, composed of the Hauge and Steinstryk Formations.

Hauge Formation

Name: This is here formally established as the Hauge Formation, named after the farm Hauge (UTM 891 897 map-sheet 2333 I Vaggatem).

Type area: Several small roadcuts along the Nordvestbukta (bay), (UTM 920 931 on map-sheet 2333 I Vaggatem), provide the easiest access to the rock type.

Thickness: Approximately 1500 m.

Lithology: The formation consists of a uniform and lustrous quartz-sericite gneiss, partly mylonitic toward the underlying Krokvika Formation. There are some few observations of possible quartz-banded iron ore. Discontinuous beds of magnetic amphibolites occur. The quartz-sericite gneiss shows a low but distinct radiometric activity.

Boundaries: Thin mylonitic layers indicate a thrust contact between the Petsamo Group and the Hauge Formation. There is also an upward increase in metamorphic grade within the Hauge Formation.

Correlation: At this stage it is impossible to correlate this formation with any rock type in other parts of the East Finnmark area. On the Russian side this formation is called mica-quartz-feldspar schist of the Tundra Series.

Age: An Early Proterozoic - Late Archean age has been suggested by Russian workers.

Steinstryk Formation

Name: Steinstryk (UTM 936 918 map-sheet 2333 I Vaggatem) is the name of several small rapids in the Pasvik river. It is here formally established as the Steinstryk Formation.

Type area: Hóargóabahta (peninsula) (UTM 980 926 map-sheet 2433 IV Skogfoss) is among the best places to visit the formation.

Thickness: More than 1000 m.

Lithology: Light-coloured garnet-bearing mica gneiss and darker biotite-hornblende gneiss are the most common rock types. A dark hornblende gneiss with stringers of carbonate and garnet amphibolites is also represented.

Boundaries: The upper part of the formation is located on the Russian side of the border. The formation seems to rest concordantly upon the Hauge Formation.

Correlation: The formation crosses the Russian border and is there called 'biotite-feldspar gneisses and schists'.

Age: Early Proterozoic - Late Archean (according to various Russian maps).

Nyrud Group

Name: Nyrud (UTM 891 726 map-sheet 2333 II, Krokfjellet) is the name of a farm in the Pasvik valley. It is here formally established as the Nyrud Group, composed of the Blankvatnet Gneiss and the Gjøkvatnet Formation.

General: An extremely low degree of exposure complicates the mapping. Numerous drillcore sections from the ore-prospecting have been used successfully in mapping and interpretations.

Blankvatnet Gneiss

Name: Blankvatnet is a small lake (UTM 857 865 map-sheet 2333 II Krokfjellet), a couple of km southwest of Nyrud. It is here formally introduced as the Blankvatnet Gneiss.

Type area: The best exposures are found on the east side of a timber-road to Tommamoen (UTM 842 730 map-sheet 2333 II Krokfjellet).

Thickness: Uncertain.

Lithology: The main rock-type is a white plagioclase gneiss, partly mica-bearing and with subordinate mica schist and hornblende--bearing granitic gneiss.

Boundaries: No data.

Correlation: According to the Russian maps this can be included into the 'biotite-plagioclase gneiss and migmatites', in the 'Middle group' of the Kola series.

Age: According to Russian maps this formation is Archean.

Gjøkvatnet Formation

Name: Gjøkvatnet (UTM 835 730 map-sheet 2333 II Krokfjellet) is a lake in the Pasvik valley. It is here formally established as the Gjøkvatnet Formation.

Type area: There is no good type locality, because of the lack of exposures. The best sections are seen in the various drillcores made by

Sulfidmalm A/S and Sydvaranger A/S during the period of 1979-80. These are still (1985) available in the Pasvik core storage. A small exposure in a roadcut at UTM 878 746, map-sheet 2333 II Krokfjellet, shows the mica schist and mica gneisses.

Thickness: Appoximately 1000 m - 1500 m.

Lithology: The formation consists of coarse lustrous mica gneiss/schist, calcareous schists with bands of sulphides, massive and schistose amphibolites (possible metavolcanites), hornblende gneisses, and concordant pyroxenite-peridotite bodies. Discontinuous peridotite bodies are interpreted as boudinaged layers. The mica gneisses and schists of this formation are very similar to the sericite-mica gneisses and schists in the Hauge Formation, but lack the distinct radiometric activity of the latter. The formation is interpreted as a volcano-sedimentary formation.

Boundaries: There are no direct observations, but according to the regional picture one should expect the formation to be overthrust by the Vaggatem Gneiss.

Correlation: According to the Russian maps this formation is included in the 'biotite-plagioclase gneiss and migmatite' of the 'Middle Group' in the Kola Series.

Age: According to unpublished Russian maps this unit is of Archean age.

Vaggatem Gneiss

Name: Vaggatem (UTM 853,80 map-sheet 2333 II Krokfjellet) is a small village in the upper Pasvik valley. The name Vaggatem Gneiss is here formally given to a group of undifferentiated granites and granitic gneisses in a dome-like structure in the central South Pasvik area (Fig. 2, Plate 1).

Type area: No particular area may be pointed out as typical, mainly because of poor exposure and of insufficient work done on rocks of this group. Easily accessible exposures are located close to the road at UTM 796 750, map-sheet 2333 II Krokfjellet.

Thickness: Unknown.

Lithology: The Vaggatem Gneiss includes a group of granites and granitic gneisses occurring in a dome-like structure in the Central South Pasvik area. The granitic gneisses are coarse-grained and grey to pink in colour. This pink coloration contrasts sharply with the predominantly grey coloration observed in the other gneissose rock units in the area.

Boundaries: In northern areas the Vaggatem Gneiss and the Nyrud Group are most probably cut by a fault, separating the Petsamo and Kobbfoss Groups. In the southwest the Ellenvatnet Formation is resting discordantly upon the Vaggatem gneiss-granite dome. In the southeast, the Vaggatem Gneiss (together with the Ellenvatnet Group) seems to be thrust upon the Nyrud Group.

Correlation: No correlative units are known.

Age: Probably Archean.

Ellenvatnet Group

Name: Ellenvann (UTM 760 690 map-sheet 2333 II, Krokfjellet) is a lake in South Pasvik. The Ellenvann Group is formally established here, containing the Føllvatnet Formation and the Ødevatnet Gneisses.

Føllvatnet Formation

Name: Lille Føllvatnet (UTM 775 815 map-sheet 2333 II, Krokfjellet) is a lake in the western part of South Pasvik. It is here formally established as the Føllvatnet Formation.

Type area: Because of lack of exposure, there is no single area that can be recommended as a 'type area'. Drillcores from A/S Sydvaranger's drilling in 1965 provide the best sections. The cores are still (1985) available at a core storage in Kirkenes Ore Processing Plant.

Thickness: Approximately 750 m - 1000 m.

Lithology: This formation includes: mica schist, mica gneisses, massive and schistose amphibolites (metagreenstone/schist), quartz-magnetite rocks, traces of a limestone bed (indicated by several boulder trains), thin graphite-sulphide beds and larger bodies of possibly intrusive peridotite-pyroxenite. The formation is interpreted as a volcano-sedimentary formation. The pyroxenite-peridotite bodies are mainly represented as isolated bodies in one 'stratigraphic position', and may as well be boudinaged relics of old ultramafic extrusive rocks.

Boundaries: Unknown.

Correlation: The lithological similarities between the Gjøkvatnet and the Føllvatnet Formations may indicate a connection between these two units, probably through a tight and

overturned (towards the east) isoclinal fold structure. The key to this problem is located on the Russian side of the border.

Ødevatnet Gneiss

Name: Ødevatnet (UTM 790 630 map-sheet 2333 II, Krokfjellet) is a lake in the South Pasvik National Park. The name Ødevatnet Gneiss is formally introduced here.

Type area: Because of the little work done on this heavily drift-covered unit, there is no recommended type area, but easily accessible exposures of the gneisses are located close to the road at UTM 825 653.

Thickness: Uncertain.

Lithology: Mainly consisting of biotite gneisses and granitic gneisses which are intruded by larger bodies of olivine gabbro. Large areas of the gneisses are situated within the South Pasvik National Park.

Boundaries: Not exposed.

Correlation: No data.

Age: Probably Archean.

Acknowledgements.

We are grateful to Tomas Sjöstrand and Tore Torske for their critical comments on parts of the manuscript.

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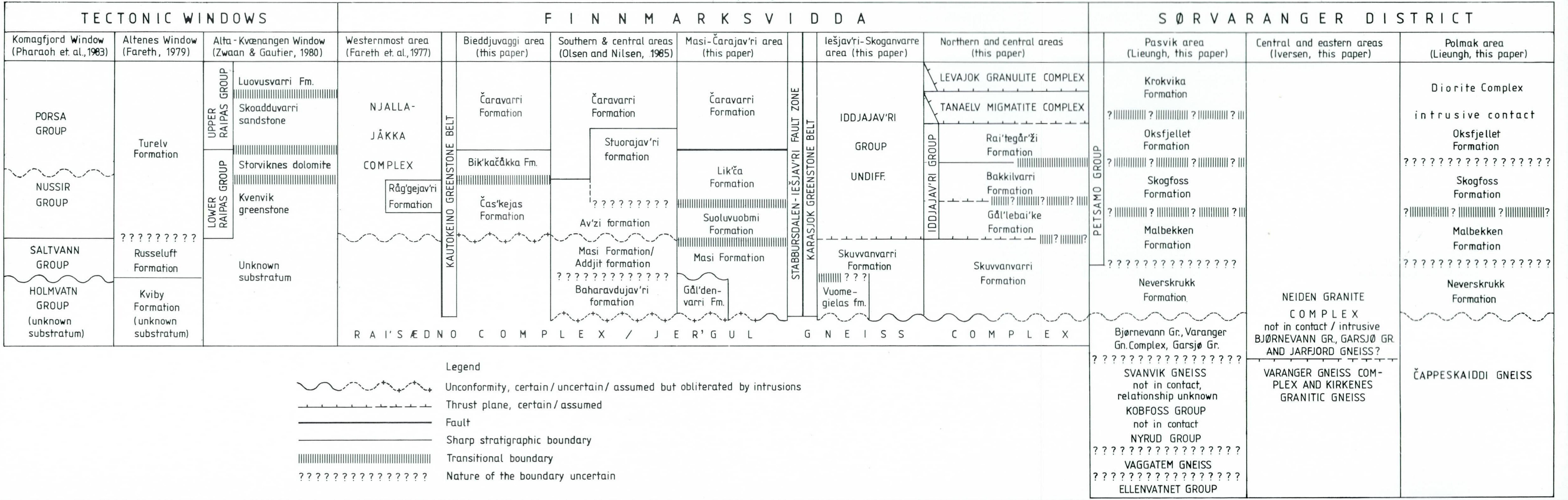
LITHOSTRATIGRAPHY AND CORRELATION OF THE OLDER PRECAMBRIAN ROCKS IN FINNMARK

Compiled by A. Siedlecka



LITHOSTRATIGRAPHIC MAP OF OLDER PRECAMBRIAN ROCKS IN FINNMARK

Compiled by A. Siedlecka