The Low-grade Rocks of the Skålvær Area, S. Helgeland, and Their Relationship to High-grade Rocks of the Helgeland Nappe Complex

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Gustavson, M. 1975: The low-grade rocks of the Skålvær area, S. Helgeland, and their relationship to high-grade rocks of the Helgeland Nappe Complex. *Norges geol. Unders. 322*, 13–33.

The geological setting and petrology of low-grade rocks of the Helgeland Nappe Complex are discussed and it is concluded that the low-grade rocks are part of the nappe complex.

Correlations with similar low-grade sequences in (1) the Leka area on the coast some 90 km to the south, (2) part of the western Trondheim Region, and (3) the Köli part of the Seve–Köli Nappe Complex of Västerbotten, Sweden, are suggested. These correlations enable a better evaluation of the stratigraphical positions of parts of the high-grade sequences in Southern Helgeland than has hitherto been possible. Another conclusion which can be drawn is that there is no great difference between the eugeosynclinal deposits of the Nordland facies type and the Trondheim Region facies type.

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Introduction

The Skålvær area is situated south-west of Sandnessjøen at about 66°N latitude, and consists of a great number of small islands and skerries topographically belonging to the strandflat. The area is included in the general description of this part of S. Helgeland by Rekstad (1917). On the accompanying map on the scale 1 : 250 000, the Skålvær islands were given the symbols of mica schist and marble. The present writer visited the area in 1972 and 1973 during the course of a general mapping programme in Helgeland carried out by the Geological Survey of Norway (NGU) under the writer's leadership. It was immediately obvious that the metamorphic facies of the rocks was distinctly lower than in adjoining areas and thus called for special attention. The present paper is an account of the rock-types, their relations to the rocks of adjoining areas and some implications of these relations for the age and stratigraphy of the Caledonian rocks of southern Helgeland.

Geological setting

The main structural units of the Helgeland region are shown in Fig. 1. The easternmost parts of Norwegian territory consist of relatively low-grade (greenschist facies) rocks belonging to the Köli part of the Seve–Köli Nappe Complex (Kulling 1955; Zachrisson 1973); these rocks have been described by Strand (1953, 1955, 1958, 1960, 1963) and Foslie & Strand (1956). The

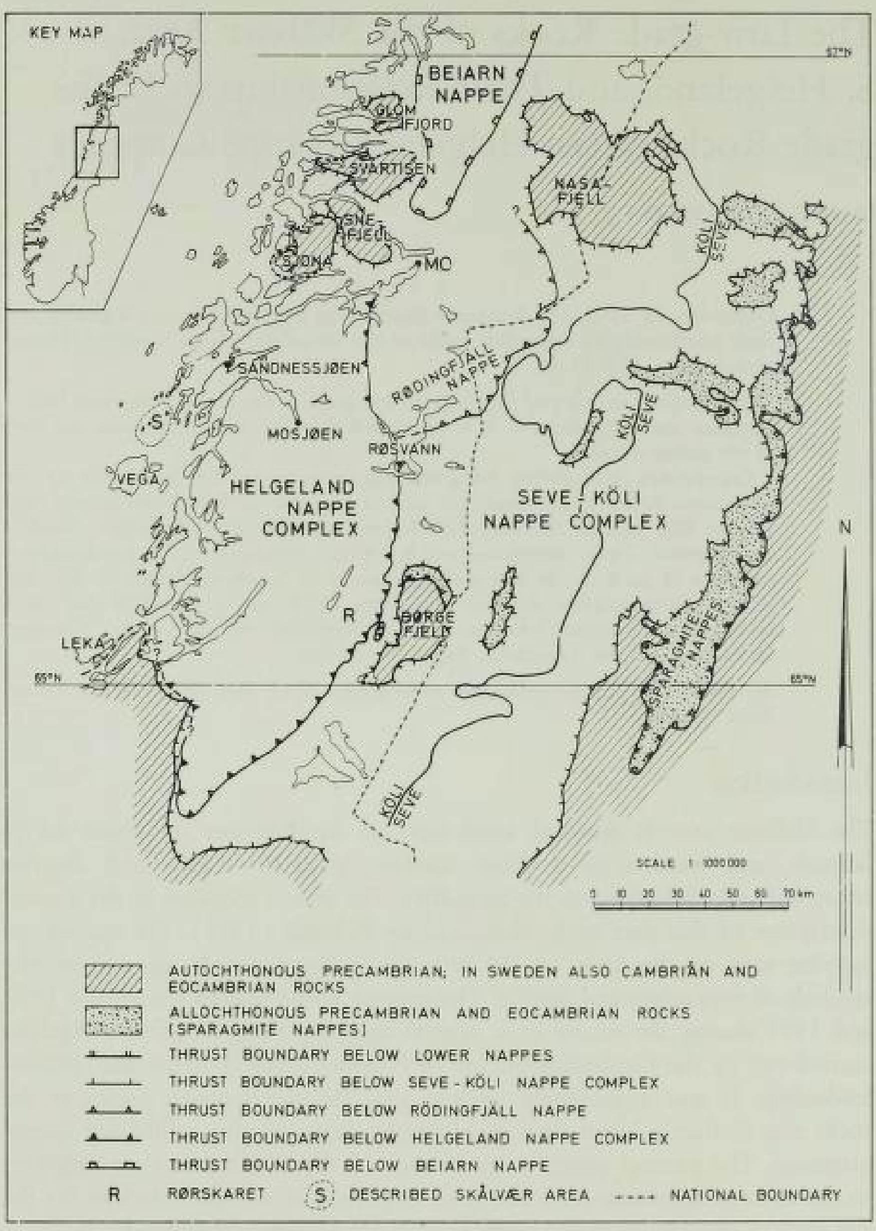

Fig. 1. Map showing the main litho-tectonic units of southern Helgeland and adjoining areas in Sweden.

Köli sequence is overlain to the west by the Rödingfjäll Nappe (Kulling 1955) and above this by the Helgeland Nappe Complex (Ramberg 1967; Gustavson 1973). In the southern part, the Helgeland Nappe Complex is in direct contact with the low-grade Köli rocks. Both the Helgeland and the Rödingfjäll Nappes are mainly in the almandine–amphibolite facies and are composed of approximately the same rock-types (mica schists and gneisses, calcareous mica schists, marbles, amphibolites, serpentinites and granitoid intrusive rocks). Descriptions of parts of the high-grade areas have been given by Ramberg (1967), Gustavson & Grønhaug (1960), Nissen (1965, 1974), Kollung (1967), Myrland (1972) and Gustavson (1973). The rocks of the Helgeland Nappe Complex extend to the coast and are also present in areas adjoining the Skålvær islands. An account of the rocks occurring immediately east of the Skålvær area has recently been presented by Nissen (1974).

In the northern area, medium- to high-grade rocks are also present in the Beiarn Nappe (Rutland & Nicholson 1965). The exact relations between the Beiarn Nappe and the Rödingfjäll and Helgeland Nappes are still not clear.

Precambrian basement is present east and south of the Caledonian nappes and also crops out in a number of tectonic windows within the nappe areas. In western areas of central and northern Nordland the crystalline basement has been Caledonised, whereas to the east the basement rocks are comparatively unaffected by the Caledonian deformation (Rutland & Nicholson 1965; Gustavson 1966, 1972; Nicholson & Rutland 1969). It is, therefore, likely that Caledonised Precambrian basement is present below the Caledonian nappes in the coastal area of southern Helgeland. Further discussion of this and other structural aspects within the region will be reserved for a separate paper.

Apart from the areas to the east of the Helgeland Nappe Complex, low-grade rocks have also been described from the Leka district to the south-west (Birkeland 1958; Prestvik 1972, 1974). The rocks there include mafic and ultramafic intrusives, metavolcanics and metasediments. Up to now, other occurrences of equally low-grade rocks have not been described from the coastal districts of this part of North Norway. However, during fieldwork in 1972 the present writer mapped metagreywackes and conglomerates of relatively low grade on the islands between Leka and Vega (Gustavson 1975).

Petrology

The main rock-types of the Skålvær area (Plate I) are dark phyllite and mica schist, conglomerate, dark dolomitic limestone or marble, greenstone and some light, fine-grained quartzo–feldspathic rocks which probably represent metamorphosed quartz–keratophyre. Structurally, the layering is steeply inclined to the east with a N–S strike in the central area. Way-up criteria have not been found. However, an interpretation of the probable relationship between the various rock-types is shown on the cross section in Plate I. This interpretation implies that the rocks can be arranged in the following tectono–stratigraphic sequence, from top to bottom:

Quartz keratophyre.
Dark phyllite and mica schist.
Dolomite conglomerate and metagreywacke.
Dark, dolomitic crystalline limestone and calcite marble.
Greenstone.

That this rock succession is also probably the correct age sequence is sup-

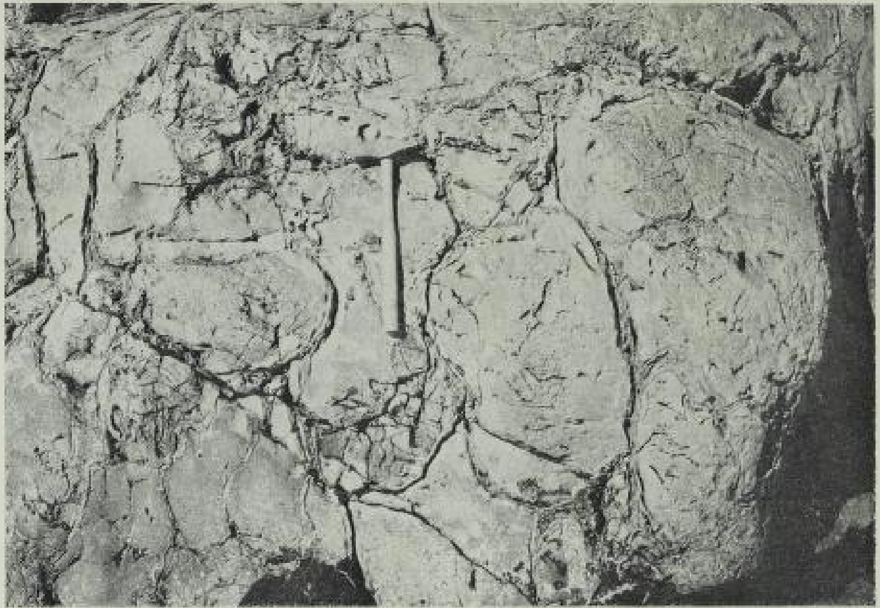

Fig. 2. Greenstone with pillow structure, Grundværsnavaren.

ported by the fact that dolomitic boulders are predominant in the conglomerate, although frequently of a paler type of dolomite than the adjoining dolomitic limestone.

Some details of the main rock-types are presented below.

GREENSTONE

Greenstone occurs on several small islands along a north-south line east of Skålvær (Plate I). The southernmost point where greenstones have been observed is on Grundværsnavaren, just west of Grundvær, and the northernmost locality on islands east of Ørnøyene (north of Skålvær, where the strike swings north-west). The effusive origin of the greenstones in this belt is fairly obvious, whereas greenstone-like rocks to the west of this, for instance on Bersøy and islands west of Lisøy, are probably metagabbros (p. 23).

The greenstones have a massive or schistose appearance. Where present, the schistosity is vertical-dipping and orientated N–S, parallel with the general strike of the layering. Massive greenstones frequently show pillow- or pillow-like structures (Figs. 2, 3). Definite pillows show sharp boundaries, are rather closely packed and measure up to 0.5 m in diameter (Fig. 2); more dubious smaller structures may represent either broken pillows or fragmented lava flow material, and these show diffuse boundaries (Fig. 3). The groundmass in the latter type of greenstone is unstratified and massive in structure.

The pillows generally have a homogeneous appearance but some of the larger ones (Fig. 2) show selective weathering with a great number of small pits on the surface, concentrated mainly in their central part. This would

Fig. 3. Massive greenstone with diffuse fragmental or pillow structure. Grundværsnavaren. The fragments are 10 to 15 centimetres across.

appear to be due to a higher content of carbonate minerals in the interior of the pillows.

A light to medium green colour is typical for the greenstone, pillows as well as groundmass. Mineralogically, it consists of varying amounts of albite, epidote, actinolite and chlorite and minor amounts of sphene and ore minerals. Carbonate is present in some specimens. The carbonate is mainly calcite but occasionally an ankeritic dolomite is present together with the calcite.

The chemistry of the greenstone has been investigated by the analysis of major elements in 3 specimens; these are shown in Table 1. Some trace elements of two of these rocks are listed in Table 2.

DARK CRYSTALLINE LIMESTONE AND MARBLE

According to the cross-section shown in Plate I, all carbonate rocks belong to one and the same stratigraphical unit. This interpretation seems probable but it cannot be proven beyond doubt.

The carbonate belt from Omnøy to Stakkøy in the central part of the area consists of fine-grained, dark and mostly dolomitic crystalline rocks. This is also true for rocks adjacent to the greenstones east of Skålvær, although in this case the calcite content is higher. In the eastern (Grundvær) and western (Kilvær–Tåvær) belts the carbonate rocks are generally calcitic, coarser grained and of a pale grey colour. As far as grain-size and colour are concerned, this is reflecting the increase in metamorphic grade outwards from the central parts of the Skålvær area. Also north of Kilværfjorden the marbles are gen-

Table 1. Chemical composition of greenstones, Skålvær[1] compared with average Storøya greenstone[2] and Skei greenstone[2], Leka, and with average ocean floor basalt[3] and average island arc tholeiite[4]

Wt %	72–40	72–08	72–24	Storøya greenstones	Skei greenstones	Average Ocean Floor Basalt	Average Island Arc Tholeiite
SiO_2	51.18	49.03	49.76	45.78	49.72	49.61	52.86
TiO_2	0.64	1.78	1.57	2.77	1.47	1.43	0.83
Al_2O_3	15.07	15.18	14.38	17.47	16.76	16.01	16.80
Fe_2O_3	0.19	0.78	1.26	5.49	2.49	12.63[5]	11.45[5]
FeO	7.81	9.36	9.77	6.78	7.78		
MnO	0.12	0.19	0.19	0.11	0.17	0.18	
MgO	9.47	6.72	7.99	4.19	5.45	7.84	6.06
CaO	10.53	11.72	9.33	9.34	4.71	11.32	10.52
Na_2O	3.25	3.09	4.00	3.39	3.61	2.76	2.08
K_2O	0.23	0.12	0.29	0.85	0.24	0.22	0.44
H_2O-	0.04	0.05	0.00	0.19	0.22		
H_2O+	1.69	1.56	1.57	2.29	3.32		
CO_2	0.03	0.74	0.11	1.69	3.64		
P_2O_5	0.01	0.08	0.09	n.d.	n.d.	0.14	
Total	100.26	100.40	100.31	100.04	100.58		

[1] Analyst: P.-R. Graff, Geol. avd., Norges geologiske undersøkelse.
[2] Average of 9 Storøya greenstones and 5 Skei greenstones, Leka, calculated from Prestvik (1974).
[3] From Cann (1971).
[4] From Pearce (1975).
[5] Total iron as Fe_2O_3.

Specimen localities:
72–40: Grunnværsnavaren (Coordinates on 1 : 100 000 map H 17: 1°28′ E of Oslo, 65°49′)
72–08: Lamskinnet (1°28′ E, 65°51,5′ N)
72–24: Ovnskjæret (1°28′ E, 65°50,5′ N)

Table 2. Trace element data of two greenstones, Skålvær[1], compared with average data of Storøya and Skei greenstones, Leka[2], and with average ocean floor basalt[3] and low potassium tholeiite[4]

Specimen	Rb	Sr	Ba	Zr	V	Ni	Co	Cu	Zn	Cr	Y
72–08	0	135	0	105	300[5]	45	30[5]	0	98	158	33
72–40	3	77	30	32	200[5]	102	60[5]	18	61	399	16
Storøya greenstones	19	410	125	220	300	90	40	55	–	–	–
Skei greenstones	10	115	45	65	385	30	35	60	–	–	–
Average OFB	1	130	14	95	–	97	–	77	–	297	29
Average LKT	5	207	–	52	–	–	–	–	–	160	19

[1] Analyses performed at Kjem. Avd., Norges geologiske undersøkelse, X-ray fluorescence method by G. Faye & M. Ødegård.
[2] Average of 8 Storøya greenstones and 5 Skei greenstones according to Prestvik (1974).
[3] From Cann (1971).
[4] From Pearce (1975).
[5] Semi-quantitative determination by optical spectrography.

Specimen localities:
72–08 and 72–40, see Table 1.

Fig. 4. Impure (?) marble with lensoid fragments of calcite marble. Grundvær.

erally grey, coarse-grained, calcitic rocks in accordance with the increasing metamorphic grade to the north.

Mineralogially the dark, fine-grained variety is composed of dolomite + calcite + muscovite ± chlorite ± quartz + pyrite + black organic 'dust'. The light grey marbles contain the same minerals with the exception of the black dust and in most cases with biotite replacing chlorite. The change from a dolomitic rock-type to a more calcitic one seems to be gradual. A support for this view that the light grey, coarse marbles have been transformed from the dark carbonate rocks in the central area by metamorphic processes is found in the Grundvær area where fragments or 'nodules' of dark carbonate with organic material are locally found as remnants within the light marble. The carbonate in these dark fragments is mainly calcite.

Types transitional between the dark and light marbles are also found in other localities, for example on Sørvær (north of Kilværfjorden) where the dark carbonate rocks have been only partially recrystallized, adjacent to quartz veins and in irregular patches, to a lighter-coloured coarse marble.

In the Grundvær area and on some small islands north of Skålvær, a rock-type composed of carbonate lenses in a carbonate groundmass (Fig. 4) is met with. Quartz lenses or pebbles of quartz have also been observed in a few cases. This rock-type is occasionally transitional into conglomerates described below and in the writer's opinion this proves that at least some of the marbles are metamorphosed calc-arenites.

Fig. 5. Calcareous mica schist with scattered pebbles and fragments of marble. Slåtterøy, N. of Skålvær.

DOLOMITE CONGLOMERATE AND METAGREYWACKE

Typical conglomeratic rocks are present only on the islands north of Skålvær. No sharp distinction can be drawn, however, between these normal conglomerates and calcareous mica schist with scattered boulders (Fig. 5) in other parts of the map area. The groundmass is largely the same and the pebbles or boulders vary only in abundance, not in type.

Fine-grained, grey-coloured dolomite or metalimestone constitutes the dominant boulder type; in many localities it is the only rock-type present. Clast size varies considerably from small fragments up to cobbles and boulders 20–30 cm across. The boulders are frequently lens-shaped and usually orientated with their longest axis within the schistosity (Fig. 5) although no preferred orientation has been detected. In a few cases quartz or quartzite fragments represent additional clast material. Granitoid pebbles have been observed on one small islet north of Skålvær.

As already mentioned (p. 16) the dolomite pebbles are usually of a somewhat paler colour than is typical for the dolomite and metalimestone described from the stratigraphically underlying unit. Similar types have been observed, however, and it must be concluded that the boulder material is of relatively local provenance and most probably derived from the subjacent metalimestone unit. The granitoid boulders are of a red to grey, medium-grained rock-type and are composed of heavily sericitized feldspar (probably both K-feldspar and plagioclase), quartz, muscovite and biotite (partly altered to chlorite). This rock-type is similar in its strong alteration to the predominant rock-type in the granitoid massif of Vega, some 20 km to the south. No safe conclusion can be drawn, however, about the origin of these pebbles.

The conglomerate groundmass consists of the same minerals as in the calcareous mica schist, mainly quartz, calcite, micas (occurring as biotite porphyroblasts in some rocks), chlorite, epidote and feldspar (mostly saussuritized plagiolase). Tourmaline and ore grains, commonly pyrite, are the usual accessories. Aggregates of quartz and some aggregates rich in calcite may represent recrystallized rock fragments.

The calcareous mica schist with or without boulders is occasionally laminated or banded, but the usual type is a rather massive rock (Fig. 5) with variations from strongly schistose to almost unfoliated. Judging from composition and structure it seems probable that the rock is a metamorphosed, strongly calcareous, lithic greywacke (Pettijohn 1957) or a calcarenite with transition to true conglomerate.

DARK PHYLLITE AND MICA SCHIST

Phyllite and mica schist form a stratigraphical unit above the calcareous mica schist or metagreywacke (Plate I, cross-section). On a smaller scale, dark phyllite is also intercalated in the metagreywacke unit.

The most common rock-type in this formation is a schistose or fissile dark grey or black phyllite. In some parts of the area a later crenulation cleavage is strongly developed. Especially in its northern parts the formation is represented by typical mica schists with a pronounced foliation. Mineralogically a certain content of carbonaceous matter is typical for the dark phyllite variants, giving a black streak. Quartz is present in considerable amounts in all types of phyllite. Plagioclase, usually albite, is also generally present in small amounts. The relative occurrence of other minerals is partly dependent on the position of the locality within the area and also on the changing metamorphic grade (p. 25). Muscovite, chlorite and biotite are common minerals in the central part of the area, while garnet, chloritoid and staurolite are present in the easternmost districts. Epidote, sphene, tourmaline and pyrite are common accessories. This phyllitic formation probably represents a metamorphosed argillite deposited in a marine environment and generally under somewhat reducing conditions.

QUARTZ KERATOPHYRE

White to grey, fine-grained rocks which probably represent metamorphosed quartz keratophyre are encountered in 4 subareas within the Skålvær area:

1. Buøy and adjoining islands south of Skålvær.
2. Brenna islands, north-west of Skålvær.
3. Kjeøy–Slåtterøy in the Skogsholmen area.
4. The small island Årbrauten, north of Kilværfjorden.

The rocks in question are partly quartz-rich, banded rocks (Fig. 6) and it

Fig. 6. Banded, metamorphosed quartz keratophyre. Hestøy, NE of Skogsholmen.

Table 3. Alkalies and silica content of quartz keratophyres, Skålvær area[1]

Weight %	SiO_2	Na_2O	K_2O	Specimen no.
1.	74.39	3.10	3.05	72–16
2.	73.87	6.80	0.75	72–32
3.	83.12	4.43	0.73	73–44

[1] Analyst P.-R. Graff, Geol. Avd., Norges geologiske undersøkelse.

Localities:
1. 72–16: Buøy (1°27′ E of Oslo, 65°51′ N)
2. 72–32: Hestøy (1°20′ E, 65°49′ N)
3. 73–44: Årbrauten (1°18′ E, 65°52′ N)

is difficult in the field to distinguish them from normal, metasedimentary quartzites. Banding such as that shown in Fig. 6, is less pronounced on Buøy, but intercalations of metasediments (phyllite and a dolomite layer) indicate a supracrustal origin also for this occurrence.

Quartz, muscovite, biotite and the accessories sphene, apatite and ore minerals are readily identified in thin-section. Albite is present, but because of a lack of twinning the amount cannot be easily determined. Partial chemical analyses of 3 specimens from different localities (Table 3), however, show that the amount of albite must be considerable. The dominance of Na_2O over K_2O in two of the specimens is probably valid for most rocks of this group in the area. Specimen 1 is somewhat atypical in that it has an unusually high muscovite content. The other two are comparable with most published analyses of quartz keratophyres from the Norwegian Caledonides (see Gustavson 1969, pp. 80–85 for a review). The banded varieties most probably

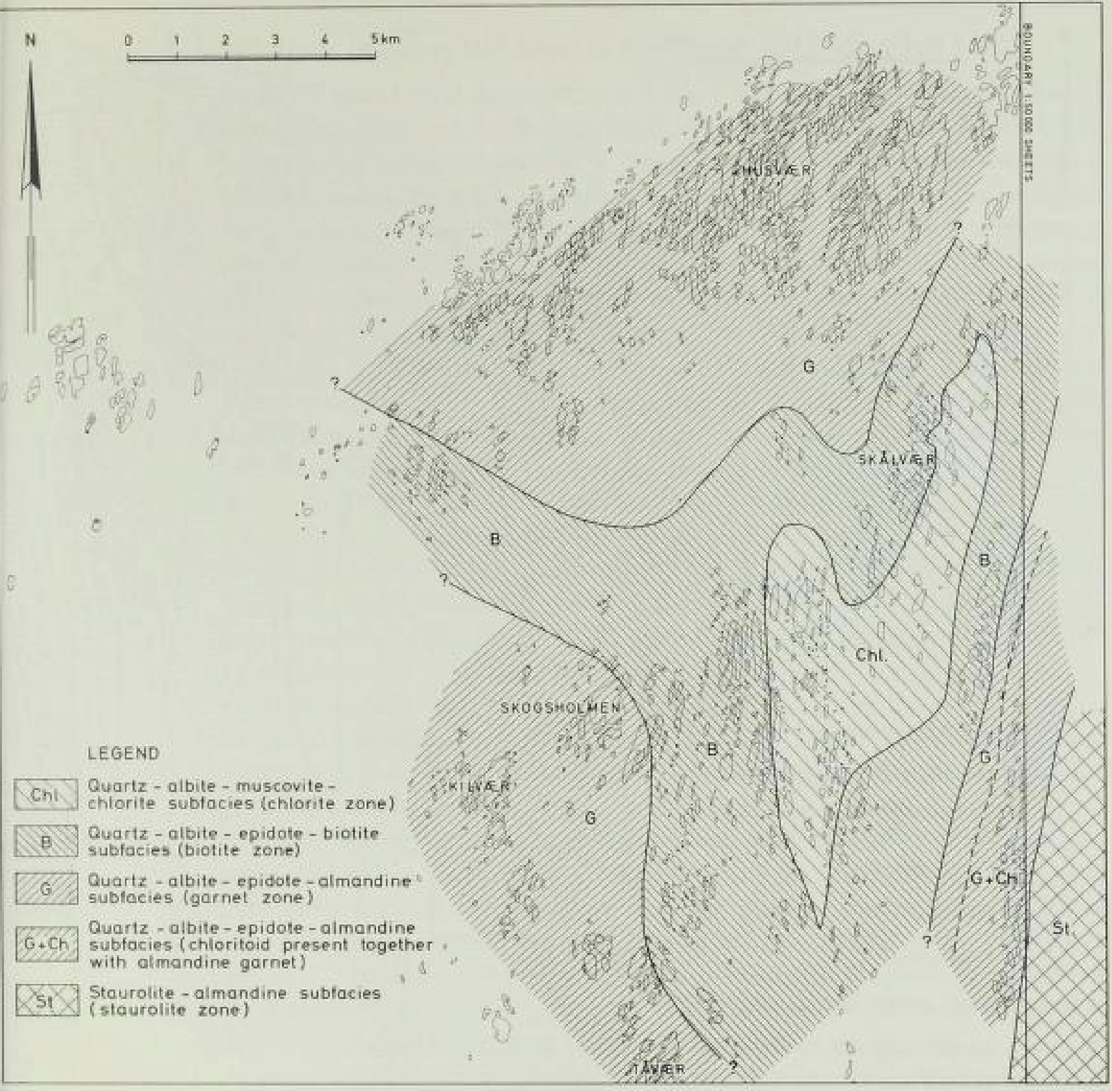

Fig. 7. Metamorphic facies distribution within the Skålvær area.

represent tuff material, whereas the more massive, poorly banded types (Buøy) may conceivably be lavas. Carbonate pebbles in the rock in a couple of localities in the Skogsholmen area show that incorporation of terrigenous sedimentary material may have occurred locally.

INTRUSIVE ROCKS

Within the low-grade area, *metagabbro* is the only intrusive rock-type, except for some rare dyke rocks of uncertain composition which will not be described here.

The metagabbros occur as lenses of different size in the metasedimentary

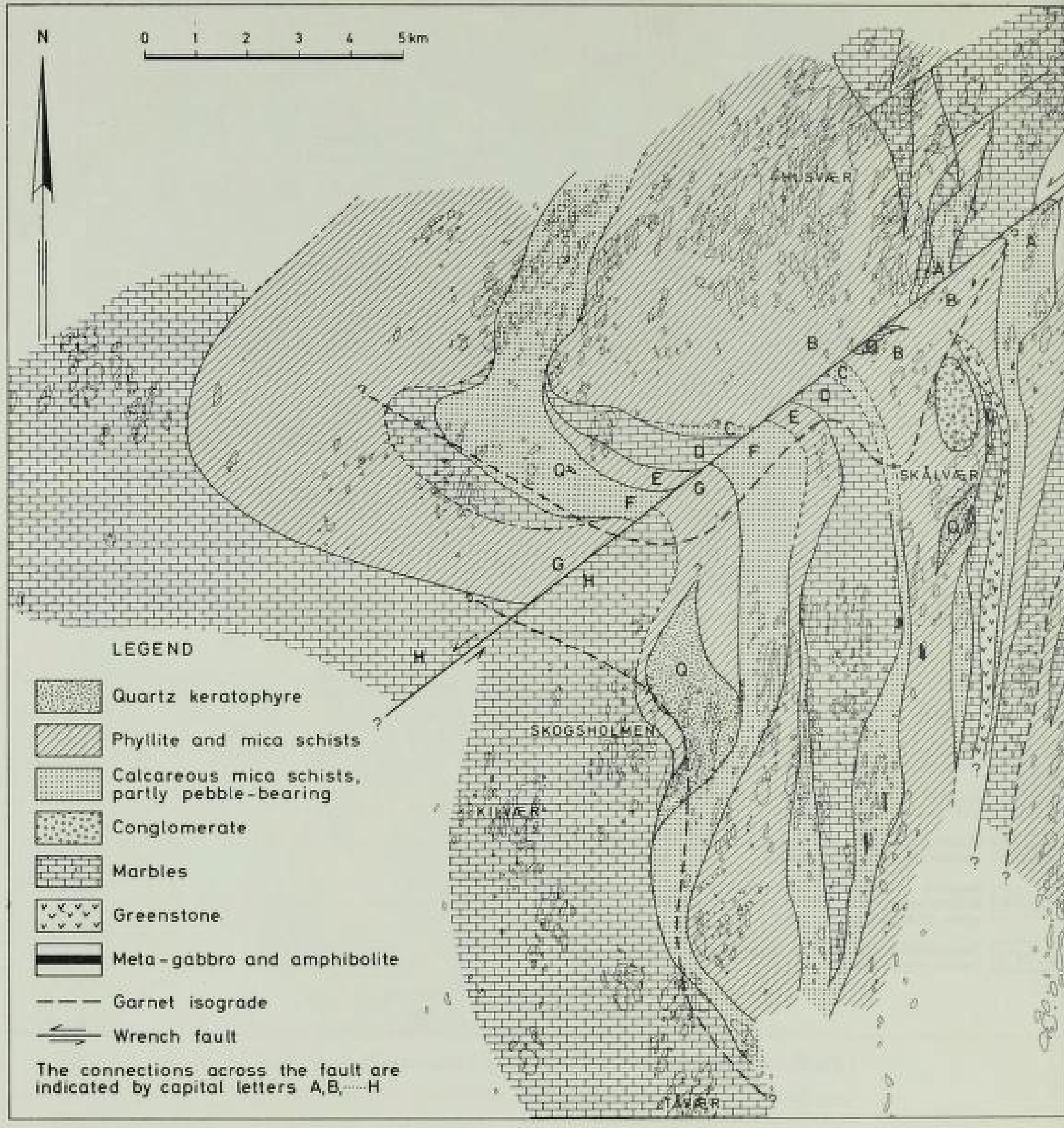

Fig. 8. Interpretation of the geological relationships in the Skålvær and neighbouring areas.

sequence. The lenses are usually small but occasionally form the major part of islands several hundred metres long in the strike direction. Except for the lens shape the rock is very similar to the greenstones but lacks the pillow structure and is always massive and usually coarser grained. The mineral assemblage is the same as in the greenstones: albite, chlorite, actinolite, epidote minerals, calcite and minor amounts of quartz and ore minerals.

A few dykes, from 0.5 to 2 m in thickness, with an appearance similar to the metagabbros have been observed on the northern tip of Skogsholmen and on islands north of Skogsholmen.

Relations between the areas of low-grade and high-grade rocks

From the petrological descriptions it is clear that the metamorphism is lowest in the central part of the Skålvær area, increasing outwards on all sides. The metamorphic facies distribution is shown in Fig. 7. The rocks of the central belt are metamorphosed in the muscovite–chlorite subfacies. The outward increase in metamorphic grade is especially well demonstrated in the eastern part of the map area, with the successive appearance of the biotite, garnet (chloritoid) and staurolite zones. It is noteworthy that chloritoid, which is considered stable throughout the entire greenschist facies of the Barrow-type facies series (Winkler 1965), does not appear here until well into the garnet zone.

Relations to the west and south are less distinctive because of the extensive occurrence of carbonate rocks and the greater distances between the islands, but nevertheless there is a clear tendency towards increasing metamorphic grade also in these directions. The situation to the north, in the strike direction, is of special interest; the author's interpretation of the relationship is shown in Fig. 8. In this reconstruction, a NE–SW fault line is inferred along Kilværfjorden. In general, the rocks north of this fault line are metamorphosed to a higher grade than those in the central Skålvær area. The presence of low-grade rocks just north of the fjord in Sørvær does show, however, that the differences in metamorphic grade are not a consequence of the inferred faulting. There does, in fact, seem to be a general and progressive increase in metamorphism to the north. Except for the greenstones, which have not been detected north of Kilværfjorden, all rock-types from the central area can also be recognized in the northern area, but in a higher metamorphic condition. The dark carbonate rocks of the central area, for example, have been transformed into pale grey, medium- or coarse-grained marbles in the north. In Sørvær (Plate I), transitions between darker, fine-grained and lighter, recrystallized marble can be observed. Phyllites and mica schists with muscovite–chlorite or biotite–muscovite parageneses south of Kilværfjorden are replaced to the north by garnet–mica schists or gneisses. Most important from a stratigraphical point of view is that the calcareous mica schists can be traced into the higher grade areas; this also includes the characteristic carbonate pebble-bearing variant of the schist, an observation which confirms that the same lithostratigraphical sequence is present in the high-grade as in the low-grade areas.

With regard to igneous rocks, these are less frequent in the northern area. Metamorphosed quartz keratophyre has been detected in only one locality on the north side of the fjord, on the small island Årbrauten (Plate I and Fig. 8). Metagabbro bodies are present, as amphibolite, to the north, but are generally smaller than in the central area.

From the structural point of view no significant differences between the central Skålvær area and adjoining areas have been detected.

Correlation of the Skålvær sequence with other areas and discussion of age relations

The medium- to high-grade rocks which surround the Skålvær sequence are very common rock-types in the southern Helgeland region and belong structurally to the Helgeland Nappe Complex. As no tectonic break can be detected, the low-grade rocks must also belong to this nappe. A correlation of the low-grade rocks with the established sequence in other areas can therefore also form a basis for stratigraphical correlations of the high-grade rocks. Such correlations have hitherto been almost impossible or at least very speculative.

So far, very few attempts to determine the probable age of the high-grade sequences have been made. By comparison with the partly fossiliferous Sulitjelma sequence, Bugge (1948) suggested an Upper Cambrian to Lower Ordovician age for the succession of the Rana area. A similar age was assumed, with due reservations, by Ramberg (1967) for the Kongsfjell Group in the Bleikvassli area, NW of Lake Røsvatn (Fig. 1). For the most part, however, such correlation has been restricted to the general assumption that high-grade rocks in Nordland are probably Cambro–Silurian in age (Holtedahl 1953; Strand 1960).

In the present area, according to the most plausible interpretation the greenstone with pillow structures is the lowermost, and probably oldest, member of the Skålvær sequence. In the central Norwegian Caledonides basic volcanics are known to occur mainly at two levels, one in the Lower Ordovician (Tremadocian) and represented by the Støren Group greenstones and its equivalents, and another in the Middle Ordovician (Llanvirn or Llandeilian) which is locally andesitic, e.g. the Hølonda porphyrite (Vogt 1945) of the Lower Hovin Group in the Trondheim Region.

In a description of the Leka area, situated some 90 km to the south of Skålvær, Prestvik (1974) distinguished two greenstone formations with different chemistry and stratigraphical position: the Storøya Formation of pillowed greenstone was correlated with the Støren greenstone of the Trondheim Region, while the greenstone and quartz keratophyre of the Skei Formation were suggested to be equivalents of the Hølonda porphyrite and Hareklett rhyolite tuff, and of other Middle Ordovician greenstones in the Grong–Snåsa area.

With regard to the 3 Skålvær greenstone analyses, on an alkali–silica diagram these plot in the field for subalkaline compositions (Irvine & Baragar 1971), while on an AFM diagram they do not show any clear separation into either the calc–alkaline or the tholeiitic fields since they plot along the field boundary of Irvine & Baragar. A comparison of the major elements and some trace elements of the Skålvær samples with those of the greenstones from Leka and with the element contents of average ocean floor and island arc volcanics is shown in Tables 1 and 2.

Table 1 shows that the SiO_2, TiO_2, total iron and K_2O contents of the Skålvær greenstones are similar to the average values of the Skei greenstones but differ considerably from the values for these oxides in the Storøya greenstones. The MgO values are higher in the Skålvær greenstones than in any of the Leka volcanics but closer to those of the Skei than to the Storøya greenstones. For Na_2O the values correspond equally well with the Skei and Storøya averages, while for CaO there is better correspondence with the Storøya greenstones. It should be noted here that the CaO values for the Skei greenstones are extremely low.

Of the trace elements the values for Zr, Sr, Cr, Nb and Y are most important for classification purposes (Pearce & Cann 1973). None of the present rocks have been analysed for Nb, and Y and Cr have not been determined for the Leka greenstones. A comparison with these rocks is therefore difficult. Sr values of the two Skålvær specimens correlate fairly well with the average of the Skei greenstones, while Sr of the Storøya greenstones is about four times as high. Sr, however, is considerably mobile during metamorphism and should be used with caution (Pearce & Cann 1973, p. 294). It should be remembered here that the Ca content is exceptionally low in the Skei greenstone. Zr values in the two Skålvær analyses are not comparable but both are somewhat closer to those in the Skei Formation than the Storøya. The same is true for Rb and Ba but in both cases the values are considerably lower for the Skålvær greenstones than for the Leka rocks.

The differences between the trace element values for the two analysed Skålvær greenstones are striking and would seem to indicate that specimens 72–08 and 72–40 represent two different magma types. This is evident when they are compared with the values for average ocean floor basalt and low potassium tholeiite (Table 2). Not much can be said from analyses of major and trace elements in only 2 or 3 specimens, but from Zr, Y and Cr in Table 2 and Ti and P in Table 1 it would seem that 72–08 (and 72–24?) is an ocean floor type basalt while 72–40 is low potassium tholeiite. This is also confirmed by plotting in the Pearce & Cann (1973) discriminant diagrams. This distinction is peculiar because as the map, Plate I, shows, the two lavas seem to belong to the same zone of volcanic rocks. Clearly, more analyses from different parts of the zone are needed in order to solve this problem. Although one cannot reach any safe conclusion based on these few analyses, the comparison of the available major and trace element data would, however, tend to suggest that the Skålvær greenstones may perhaps best be correlated with the greenstones of the Skei Formation. On Leka, these greenstones are stratigraphically overlain by greywackes and calcareous sandstone with some black schist and polymictic conglomerate. The greywackes also display graded bedding and some possible load cast structures (Prestvik 1974, pp. 70–73). A broad correlation of this sequence with the Skålvær succession therefore seems reasonable. Although the most typical polymict conglomerate with pebbles of igneous rocks (greenstone, quartz keratophyre, etc.) is absent in the Skålvær area, the metagreywackes, partly calcareous and partly with a conglomeratic development in both areas, point to a fairly similar depositional environment. Marble layers are also present in both areas but they are more abundant in the Skålvær area than on Leka.

On Leka, the quartz keratophyres seem to be more closely associated with the greenstones than is the case in the present area. According to the writer's interpretation, the quartz keratophyres occur as a separate unit in the upper part of the Skålvær sequence. In this respect the relationships are more akin to those of the western Trondheim Region, where the rhyolites and rhyolite tuffs are younger than the Middle Ordovician greenstone and andesite (Vogt 1945; Carstens 1960). In the Hølonda–Horg district of the Trondheim Region, greywacke-sandstones and shales have been described by Chaloupsky (1970) from the Krokstad Group (Middle Ordovician) and the Lower Sandå Group (Upper Ordovician). Polymict conglomerate or breccia are described from both groups. Similar lithologies are met with in other parts of the Trondheim Region (Roberts et al. 1970).

Lithologies similar to those in the Skålvær sequence have been described from the Hattfjelldal area east of the Helgeland Nappe Complex (Strand 1953, 1955). These rocks are situated structurally within the Köli part of the Seve–Köli Nappe and link up with low-grade rocks of the Grong area (Foslie & Strand 1956). The stratigraphy of the Köli rocks has been comprehensively described from the Bjørkvatten – Virisen area of Sweden (Fig. 1) by Kulling (1933, 1955, 1958). Recent investigations, especially by Zachrisson (1964, 1969), have made possible the correlation of areas to the south and west (towards the Norwegian border) with the Björkvatten – Virisen stratigraphy. Correlations with the western Trondheim Region were proposed by Gee & Zachrisson (1974).

Although situated within different structural units, it seems possible to correlate the Skålvær greenstone with parts of the Seima greenstones of S. Västerbotten (Kulling 1933). This fits in with a correlation of the Skålvær metagreywackes and conglomeratic rocks with the Gilliks Group. Rocks probably corresponding to the Gilliks Group are also present in the Hattfjelldal area (Strand 1963).

According to Kulling (1972, p. 244) certain fossil findings in the Gilliks Group 'lead to the conclusion that the Gilliks Group rocks are probably not older than Caradocian. It may be mentioned that the Slätdal–Vojtja rocks above the Gilliks Group are Upper Ashgillian'. In accordance with this, a correlation of the Skålvær conglomerate and metagreywackes with the Lower Sandå Group (as defined by Chaloupsky 1970) seems to be probable. This view corresponds roughly with earlier correlation of the Gilliks conglomerates with the Volla Conglomerate (Kulling 1955). If the conglomerate of the Skålvær area is an approximate time-equivalent of the Volla Conglomerate of the Hølonda–Horg area, then the quartz keratophyre may be more or less the same age as the Grimsås Rhyolite (Vogt 1945). As the acid volcanics are the uppermost formation in the Skålvær sequence, however, a precise correlation of this unit is difficult. In the Västerbotten area of Sweden for instance, there are acid volcanics also in the Silurian, e.g. the Stekenjokk Quartz–keratophyres of the Lasterfjäll Group (Zachrisson 1964, 1969). A summary of the various proposed correlations is shown in Table 4.

ble 4. Tentative correlation of S. Helgeland low-grade and high-grade sequences with the successions from some er areas in the central part of the Scandinavian Caledonides

Helgeland Nappe Complex (this paper)		Leka Prestvik (1974)	Central Västerbotten (Kulling 1933, 1955, 1958, 1972)	Western Trondheim region (Vogt 1945)[1]		
kålvær area	High-grade part					
?			Viris quartzite Lövfjäll phyllite Broken phyllite and sandst. (F)[2]	Sandå shale and sandstone Lyngestein conglomerate.	Horg Group	Llandovery
artz kerat. k phyllite mica schist	Mica schist and gneisses		Slätdal limest. (F)[2] Vojtja conglom. Gilliks Group	Hovin sandstone Grimsås rhyolite Volla congl.	Upper Hovin Group	Ashgill
tagreywacke dolomite glomerate.	Calcareous mica sch. and calcareous conglomerate.	Greywackes and calcareous sand-st. with dark schist and congl. layers.		Tømme beds (F)[2] Esphaug & Hare-klett rhyolite tuffs	Lower Hovin Group	Caradoc
lomite and ite marbles	Marbles			Svarttjern limest. Krokstad sandst. and shale Stokkvola congl.[3]		Llandeilo
eenstone	(Amphibolites)	Skei greenstone and quartz keratophyre	Seima greenstones	Hølonda andesite. Hølonda limest.[2]		Llanvirn
?		Feldspathic sandstone Marble		Hølonda shale Breccia. Langeland slate (F)[2]		Arenig
	Serpentinite conglomerate Quartzite	Polymict conglomerate	Rotik serpentinite congl. Quartzite congl.	Venna congl.		
	Rørskar amphibolites	Storøya greenst., agglomerate		Støren greenst.	Støren Group	Tremadoc
	Mica schists and gneisses with some marbles	Pelitic rocks and marble (Solsemøyene)		*Tectonic bound.*[4] Schists and gneisses	Gula Group	Cambro-Ordovician?[4] or Cambrian

djustments have been made because of new fossil evidence.
Dated by fossils (F).
According to Roberts (1975).
According to Gale & Roberts (1974).

Turning to the high-grade rocks of the Helgeland Nappe Complex, a direct continuation of the Skålvær sequence in the strike direction to the north has already been described. For other parts of the nappe complex, correlation is more difficult. The presence of dolomite or limestone conglomerate in association with calcareous mica schist of the type described from Skålvær in various places within the Helgeland Nappe Complex may form a basis for further correlation of these and adjoining rocks with parts of the Skålvær sequence (Table 4). In the eastern parts of the nappe complex (Gustavson & Grønhaug 1960; Gustavson 1973), the dunite conglomerate of Rörskarakselen ('R' on Fig. 1) may be a metamorphosed equivalent of the Lower Ordovician serpentine conglomerate of Otta (Strand 1951) and of a similar conglomerate occurring in the Ro Series of the Björkvatten–Virisen area (Kulling 1933, 1958). In the latter area the serpentine conglomerate is frequently associated with quartzite conglomerate. In the dunite conglomerate localities at Rörskarakselen, a quartzite is present immediately east of the conglomerate and can be followed for some kilometres to the north-east. A correlation of this dunite conglomerate/quartzite association with the serpentine and quartzite conglomerates of the Ro Series would seem quite reasonable.

Some 3 to 4 km west of the Rörskarakselen dunite conglomerate thick and extensive amphibolite layers occur within the succession. The present author has suggested that these might possibly represent metamorphosed lava (Gustavson 1973, p. 29). The presence of serpentinite bodies in the vicinity of the amphibolite layers may indicate a position relatively low in the stratigraphical column here, as serpentinitic intrusions tend to occur mainly in the older part of the sequence (Strand 1960, p. 176). It is also possible that the amphibolites of Rörskaret may be equivalent to the Lower Ordovician Støren greenstones of the Trondheim Region.

Although the preceding discussion has intended to show that a better correlation of the high-grade rocks of the Helgeland region now appears possible, much more work is required from the high-grade areas before a detailed and reliable stratigraphy can be presented. Table 4 must therefore be considered as rather tentative. The most difficult problem in future work will obviously be the positioning within the stratigraphical column of the considerable thicknesses of mica schists and gneisses. Present evidence would seem to indicate that these rocks occur both in the upper and in the lower part of the succession. For the lowermost parts of the high-grade succession (mica gneisses and marbles) a Precambrian age should also be considered.

Strand (1960) divided the eugeosynclinal rocks of the Norwegian Caledonides into two facies types: the Trondheim Region facies and the Nordland facies. Typical of the former are metasediments of greywacke-type and abundant basic volcanics, while thick sequences of metalimestones, dolomites and iron ore horizons are most characteristic of the latter. Strand (1972), however, also noted that, 'Volcanic rocks also occur in the Nordland sequences, especially in the lower parts, while rather thick limestones occur in the upper part of the sequence in the Trondheim region. There is perhaps no fundamental difference between the two type sequences'. The present work would appear to provide support for this latter reservation: because of their transitions into a typical Nordland facies sequence and their structural connection to the Helgeland Nappe Complex, the low-grade metavolcanics and metasediments of the Skålvær area, with their undoubted Trondheim region characteristics, provide some form of link between the two facies types.

Conclusions

The most important conclusions which can be drawn from the present study are as follows:

1. The low-grade rocks of the Skålvær area belong to the Helgeland Nappe Complex and not to a lower tectonic unit, i.e. Köli, which might be suggested from earlier knowledge of the S. Helgeland Region (Strand 1960).
2. Correlation of the low-grade sequence with Ordovician sequences in Central Västerbotten and in the western Trondheim Region seems probable.
3. Direct connections between low-grade and medium- to high-grade sequences in the coastal area show that at least parts of the high-grade sequence probably belong to the Ordovician.
4. From the stratigraphical correlations, it follows that the Helgeland Nappe Complex and the Seve–Köli Nappe Complex are to some extent composed of the same formations, although these are usually in a considerably higher metamorphic grade in the Helgeland Nappe Complex.
5. The Skålvær area may form a link between the Trondheim Region facies and the Nordland facies of eugeosynclinal deposits as defined by Strand (1960).

Acknowledgements. – I am greatly indebted to Dr. David Roberts for his critical comments and correction of the English in the first draft of the manuscript. I also wish to thank Professor Trygve Strand and Dr. George Gale for constructive criticism of the manuscript.

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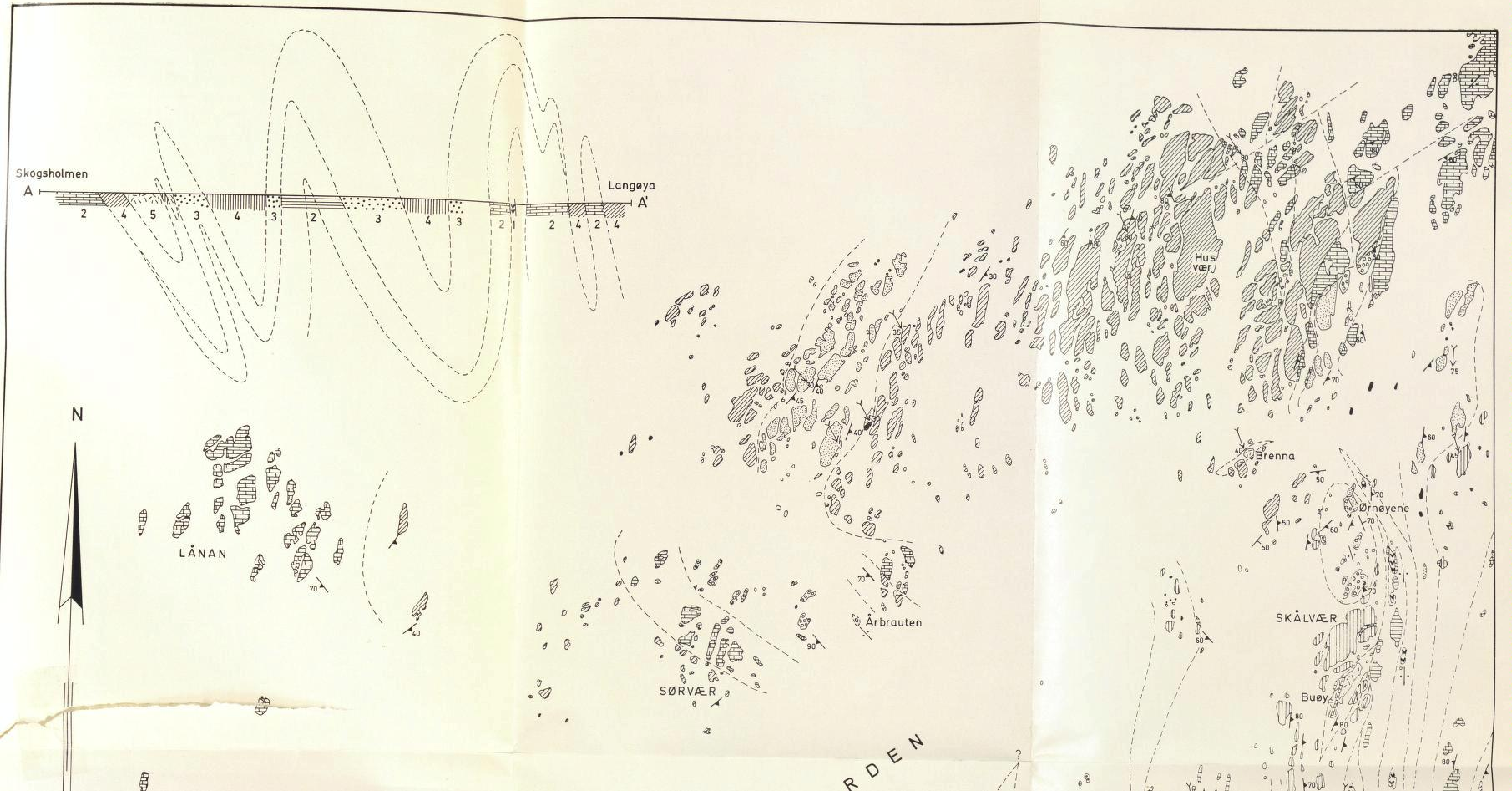
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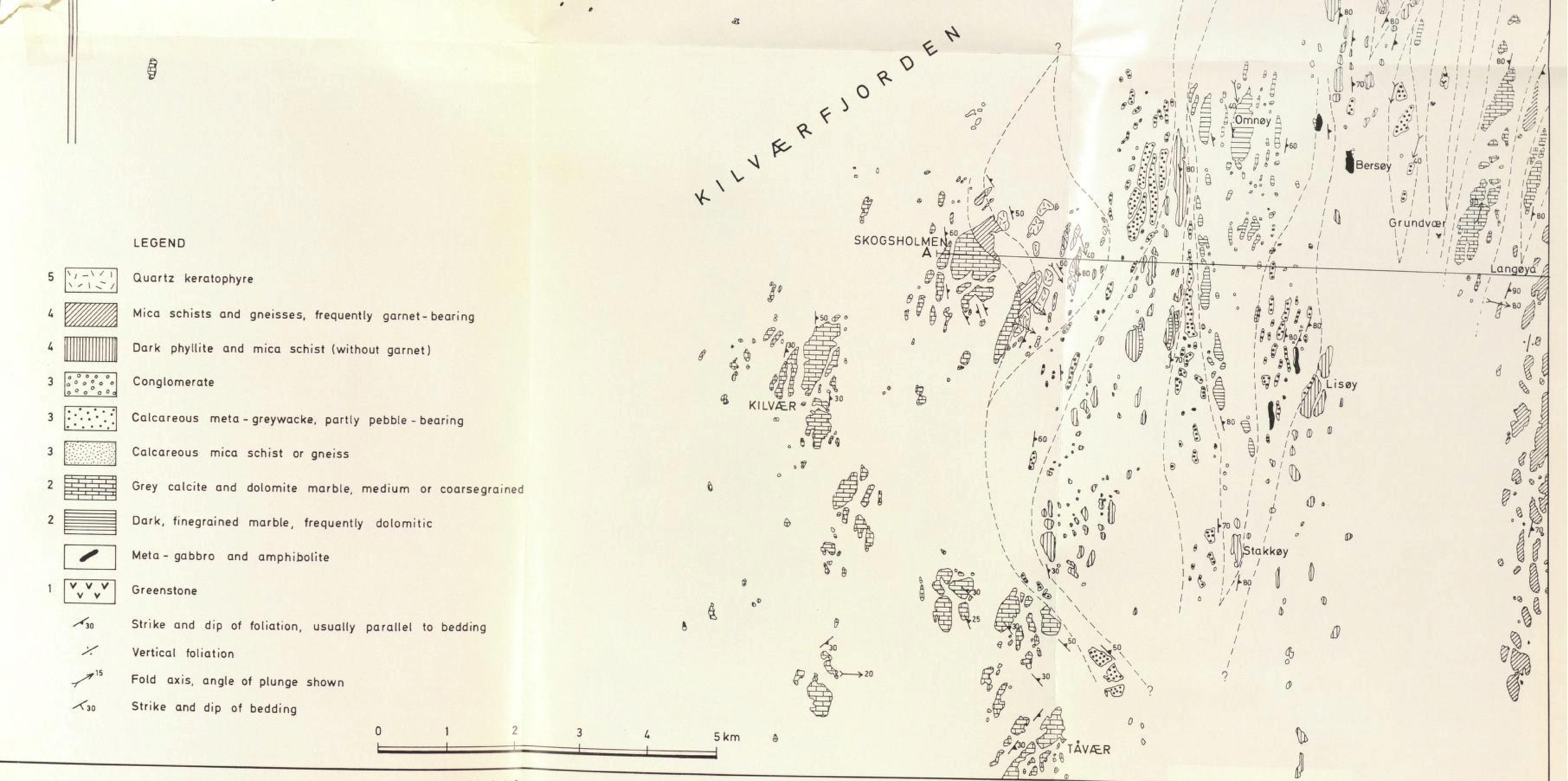

Plate I. Geological map of the Skålvær area and cross section showing the interpreted structural interrelationships of the main lithological units.