554.8105 NOR
Norges geologiske under
Bulletin 1-
UTGÅTT FRA
... BIBLIOTEK
11030033067001 48

...ånes Area, Rana,

SVEIN GJELLE

Gjelle, S. 1978: Geology and structure of the Bjøllånes area, Rana, Nordland. *Norges geol. Unders. 343,* 1–37.

The field relationships of rock groups of three tectonic units from the area west of the Lønsdal basal massif are outlined and the lithologies and mineral assemblages are described. Chemical analyses of marbles and amphibolites are presented and discussed in relation to analytical data from neighbouring areas of the Caledonides. Most of the amphibolites are shown to be of igneous origin and subalkaline, but their precise nature is uncertain.

The structures recorded suggest four phases of Caledonian deformation. The F_1 phase probably had axes orientated roughly E–W which is also the axial trend of the F_2 phase. The first deformation produced minor isoclinal folds, the main foliation and one possible thrust zone. The second phase gave rise to relatively tight mesoscopic and macroscopic folds. The F_3 phase, approximately N–S oriented, deforms the earlier structures and is responsible for the main lithological outcrop pattern. The thrusting of the middle and the upper unit is thought to be connected with this deformation phase.

Possible correlations of the Bjøllånes rocks with those from neighbouring areas of the Caledonides in Norway and Sweden are proposed. There would seem to be good evidence that the Rödingsfjäll Nappe is situated at a tectonically higher level than the Gasak Nappe which previously was supposed to be in an identical tectonic position.

S. Gjelle, Norges geologiske undersøkelse, P.O.Box 3006, N–7001 Trondheim, Norway

Introduction

The Bjøllånes area is situated in the county of Nordland, Northern Norway, about 40 km north-east of Mo i Rana (Fig. 1). Topographically the area is characterized by a series of north-south trending valleys with mountains in between reaching altitudes of 1000–1400 m. Outcrops are generally good except in the valley bottoms. Quaternary terraces in Bjøllådalen make this valley one of the most covered areas in the district. During the summers of 1970–72 the author carried out field investigations in the Bjøllånes area for a cand. real. thesis at the University of Oslo (Gjelle 1974). This paper summarizes the results of these investigations. The earliest work in the Rana district includes that of Vogt (1890, 1894), Rekstad (1913) and Oxaal (1919). This was followed by Holmsen's (1932) 1:250 000 map description while parts of the present area have been discussed in papers by Bugge (1948), Strand (1972) and Rutland & Nicholson (1965). Wilson & Nicholson (1973) have carried out Rb-Sr dating of granitic gneisses from basal massifs of the central parts of Nordland, and the Nasafjäll massif, which crops out in the eastern part of the area, was included in their study. In addition, it should be mentioned that the area south-west of Bjøllånes has been described by Søvegjarto (1972) in a cand. real. thesis.

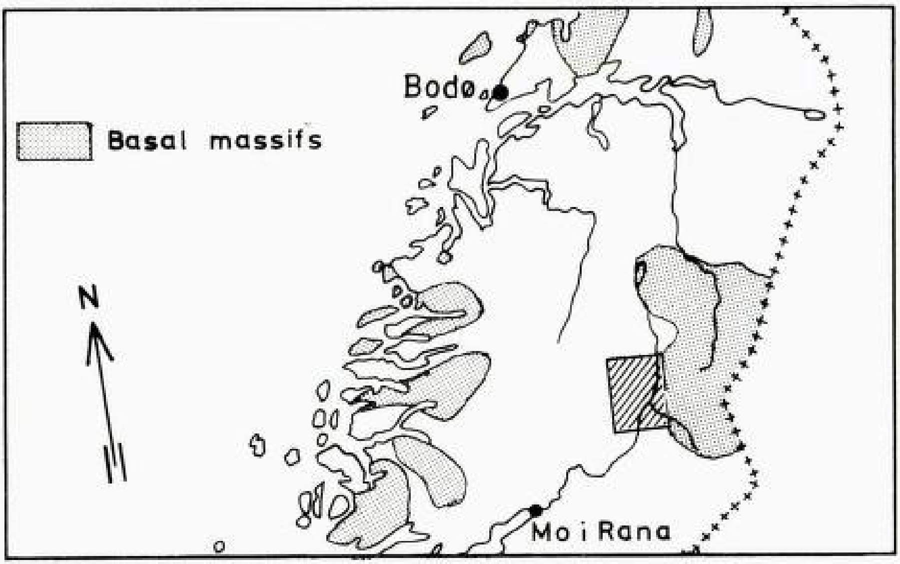


Fig. 1. Simplified map of the central part of Nordland showing the location of the area.

GEOLOGICAL SETTING

A characteristic feature of the geology in this central part of the Scandinavian Caledonides is that the basal massifs which in the west were strongly deformed in Caledonian time whereas those in the east towards and beyond the Swedish border appear almost undeformed (Rutland & Nicholson 1965). Previously, many geologists considered the western 'granite' massifs to be Caledonian intrusives, but more recent investigators have established that they represent Precambrian basement rocks (Hollingworth et al. 1960; Rutland & Nicholson 1965).

Overlying the basal massifs are thick metasedimentary sequences consisting of pelitic to psammitic rocks and limestones with metavolcanics as a subordinate constituent. Caledonian intrusives are relatively uncommon, except in the southern part of Nordland.

Structurally the Bjøllånes area is rather complicated. Lack of fossils has made it almost impossible to establish a stratigraphy which can be readily correlated with successions in other parts of the Caledonides. Correlations must be based on lithostratigraphy and tectonostratigraphy and are therefore not very reliable.

A series of nappes has been described from both sides of the international border. In Sweden the nappes are generally discordant and easily distinguished as nappes, whereas on the Norwegian side of the border most of the allochthonous units are of the conjunctive type (Rutland & Nicholson 1965), particularly in the western areas. Both the continuation of the Swedish nappes on to Norwegian territory and their actual origin have been much debated. Most geologists seem to prefer the theory of nappes rooting off the Norwegian coast, while some hold the opinion that the site of deposition of the Seve–Köli rocks could possibly have been in Nordland above the now exposed basement areas (Nicholson & Rutland 1969).

Tectonostratigraphic succession

The rocks of the area can be subdivided into three allochthonous units lying above the Precambrian Lønsdal (or Nasafjäll) basal massif. Each unit is further divided informally into groups comprising a series of different rock formations. The tectonostratigraphic succession is presented in Table 1 and the distribution of the groups shown in Fig. 2.

Table 1. Tectonostratigraphic succession

Upper Thrust Unit (The Rödingsfjäll Nappe)		DUNDERLAND GROUP Marbles, mica schists, amphibolites
		ØRTFJELL GROUP Mica schists, quartzites, various igneous rocks
		KJERRINGFJELL GROUP Gneisses, quartzites, various igneous rocks
		GILA COMPLEX Gneissic granite, mica schists, amphibolites
	Thrust zone	— — — — — — — — — —
Middle Thrust Unit		TESPFJELL GROUP Mica schists, quartzites, marbles, various igneous rocks
	Thrust zone	— — — — — — — — — —
Lower Thrust Unit		BJØLLÅDAL GROUP Mica schists, marbles, amphibolites, metaperidotites
		RAUDFJELL GROUP Mica schists, marbles, quartzites
	Thrust zone	— — — — — — — — — —
		LØNSDAL BASAL MASSIF with autochthonous cover

LITHOLOGIES OF THE VARIOUS ROCK GROUPS

The Lønsdal basal massif. – The Precambrian Lønsdal basal massif is exposed in the eastern part of the area around Saratuva (Fig. 2 and Plate 1). Only a small part of the massif has been surveyed. The rock exposed here is a porphyritic granite with gneissic structure defined by a foliation which is parallel to the schistosity in the overlying metasediments. The foliation gradually diminishes away from the contact. The uppermost part of the Precambrian massif seems to consist of a metasediment derived from the granite itself; the thickness

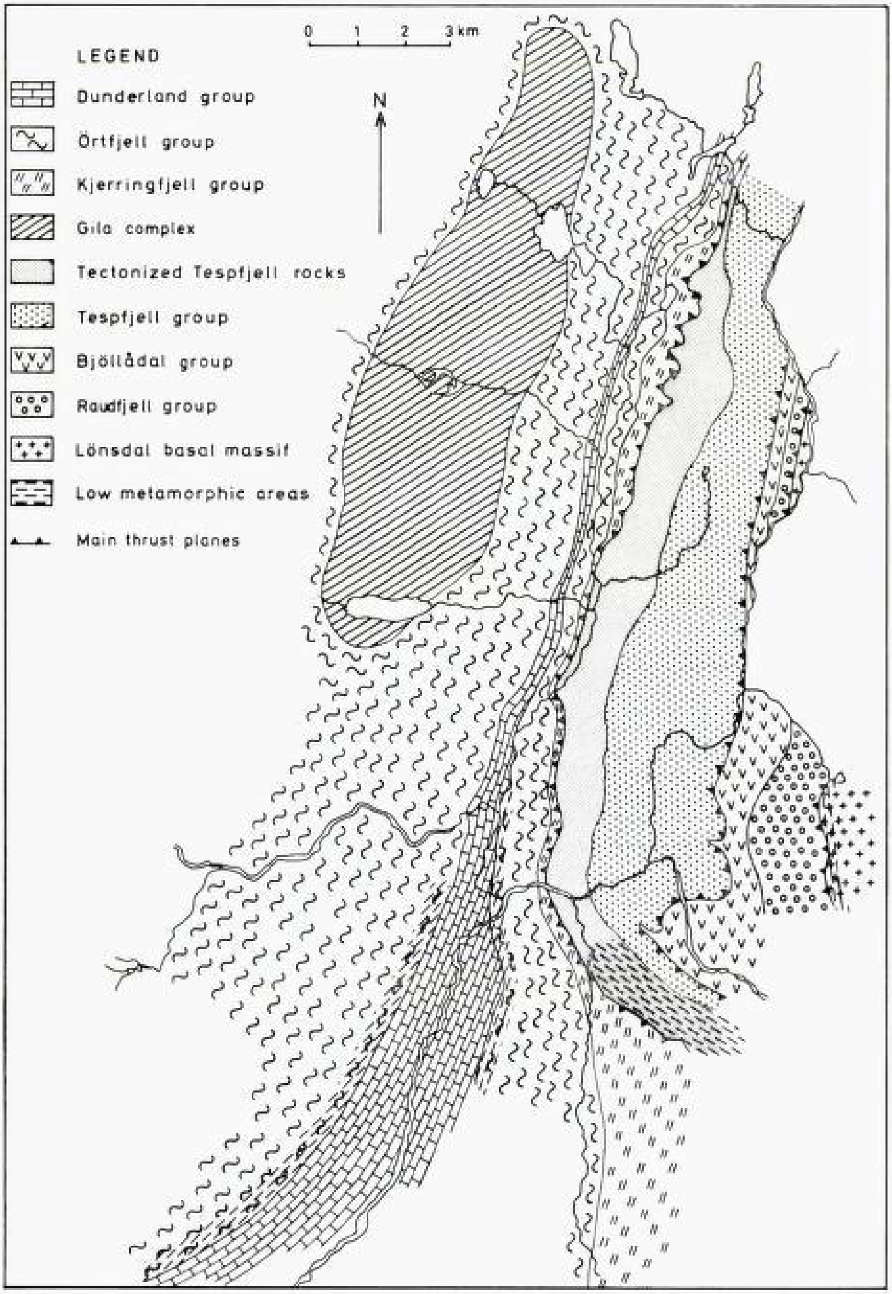


Fig. 2. Map showing the principal rock units and zones of low metamorphic grade.

of this is usually less than one metre. Above this is a brown-coloured, finely laminated, quartz-rich, graphitic mica schist with a thin quartzite horizon, which possibly represents an autochthonous/parautochthonous sequence. The total thickness of this schist sequence is generally less than 10 m. It has not been possible to determine whether or not this schist really constitutes an autochthonous cover. It could conceivably be part of the overlying Lower Thrust Unit, but no discordance or traces of cataclasis have been found here. The only indications of thrusting are that the overlying sequence, the Raudfjell group, has a higher metamorphic grade than the granite and its in situ sediment cover, and that the basement granite is foliated parallel to the contact. Geologists who have been working in neighbouring areas both to the north and to the south have, however, described thrust planes occurring immediately above a graphite schist lying directly upon the basal massif (Steenken 1957; Marklund 1952). Another possible indication of thrusting is provided by granulated quartz grains in the quartz-mica schist and in the overlying calcareous schist and limestone. For these reasons the graphitic quartz-mica schist is not regarded as part of the Lower Thrust Unit.

The Lower Thrust Unit

The Raudfjell group. – The tectonically lowermost group in the Lower Thrust Unit is the Raudfjell group, which consists predominantly of quartz–mica schists with calcareous mica schists and a few layers of calcite marble, 4 to 10 m thick. At the bottom there is a metalimestone which in part is richly contaminated by pelitic material. The total tectonic thickness of the Raudfjell group succession is somewhere between 500 and 800 m. (The tectonic thickness is taken as the thickness measured between the upper and lower boundaries of the succession disregarding the possibility of repetition of strata.)

No igneous rocks have been found within the sequence, but as only a small part of it has been investigated and the degree of exposure is poor, they may well be present locally.

The Bjøllådal group. – The Bjøllådal group has a very characteristic rock association, distinguishing it very clearly from the other groups. It consists mainly of a sequence of different types of calcareous mica schists rich in thin amphibolite layers and a few thin marble horizons (both dolomite and calcite marble) of limited extent. In addition to this there is a string of stratabound metaperidotite bodies varying in size from a few metres to about 750 metres in length. It has not been possible to establish an internal stratigraphy for the group, the tectonic thickness of which varies between 300 and 500 m.

The Middle Thrust Unit

The Tespfjell group and rocks of the tectonized zone beneath the Rödingsfjäll Nappe. – The Middle Thrust Unit consists of only one rock group here called the Tespfjell group, but rocks occurring in a strongly tectonized zone directly beneath the basal thrust of the Rödingsfjäll nappe are also thought to belong to this succession. The lithostratigraphy of this group can be well demonstrated in a traverse across Tespfjell.

Top	Marble
	Mica schist, metaquartzites, meta-arkoses
	Amphibolite
	Calcite marble
	Calcareous mica schist with amphibolite
Bottom	Dolomite marble

Two horizons of metamorphosed quartz–andesite occur as layers within the uppermost marble (the Hjartås marble). They have a maximum thickness of 4–5 m and can be traced for a distance of at least 1 km. At the southern end of Tespfjell a similar rock type is found within the marble sequence of the tectonized zone, such that it is likely that these two marbles are one and the same.

In addition to rocks similar to those of the Tespfjell group, the tectonized zone beneath the Rödingsfjäll Nappe also includes a hornblende schist and a pink, pure calcite marble with a thickness of about 1 m. A typical feature of these rocks is their more or less strongly developed cataclastic character.

The Upper Thrust Unit

The Gila complex. – The Upper Thrust Unit has been divided into four rock groups: the Gila complex, the Kjerringfjell group, the Ørtfjell group and the Dunderland group. The Gila complex, which consists predominantly of a gneissic granite with some layers of metasediment, forms the lowermost part of a rather large dome structure. The boundaries towards the superposed sequence of metasediments seem to be concordant wherever they have been observed, and no sign of tectonic movements has been found. As the eastern nappes are reported to wedge out westwards (Nicholson & Rutland 1969, Zachrisson 1969) this complex could represent the pre-Caledonian basement with a recrystallized slide contact towards the metasediments above and thus not belong to the Upper Thrust Unit. Another possible explanation is that the granite is an early intrusion pre-dating the Caledonian deformation or associated with the earliest Silurian deformation phase. Evidence supporting this view include discordant igneous contacts between mica schist and granite *within* the massif, xenoliths of varying sizes and lack of contact metamorphism in the surrounding metasediments.

The tectonic position at the core of a large antiformal structure appears to indicate that it is a basement granite remobilized during the Caledonian orogenesis.

The Kjerringfjell group. – This sequence, which occurs directly above the Rödingsfjäll Nappe thrust, is dominated by gneisses of different types and also includes a variety of igneous rocks. The principal lithologies are paragneisses, orthogneisses and diorites with minor occurrences of amphibolite, serpentinite (one small body recorded so far) and quartzite. In the south the group covers a considerable area around the Kjerringfjell massif, while to the north the group can be traced as a thin zone of heterogeneous gneissic rocks which are markedly different from the adjoining mica schists. Orthogneisses present at the base of the Kjerringfjell group may represent a slice of Precambrian basement.

No continuous thrust plane beneath the group can be demonstrated, but cataclastic rocks ranging from protomylonites to ultramylonites and blastomylonites can frequently be found along the zone where the thrusting is believed to have taken place. The northernmost outcrop of true cataclastic rocks within this zone is approximately 1 km north of Storbekken (O–12, Plate 1) and exposes an ultramylonite of a few metres thickness. Further north it is very difficult to establish the precise boundary between the Kjerringfjell group and the underlying Tespfjell group because of minor differences in lithology and equal grade of metamorphism. The thrust plane is here tentatively placed beneath a quartzite which usually shows strong cataclasis.

The Ørtfjell group. – The Ørtfjell group has its main outcrop extent in the western and south-western parts of the region. On the map it is divided into a western and an eastern zone by a strip of Dunderland group lithologies. To the west it is tectonostratigraphically underlain by the Steinfjell group and to the east by the Kjerringfjell group. Wherever the boundaries between either of these groups are exposed they are concordant and show no traces of thrusting.

The internal lithostratigraphy of the western and eastern parts of the group is shown in Table 2. The main lithologies are mica schists (or locally, mica gneisses) of different types and with a composition which indicates a similarity to metamorphosed greywacke or subgreywacke. In addition, the sequence also includes quartzites, marbles, amphibolites and acid igneous rocks. The marble formation is quite heterogeneous while the lowermost mica schist formations show the same characteristic features over large areas. Small discordant pegmatites are fairly abundant in the Ørtfjell area. At Kvitvasselv (Plate 1, K, L, M –13) the total tectonic thickness of the group is about 2 km.

The upper part of the Kjerringfjell group is possibly equivalent to the lowermost formations of the Ørtfjell group, the only difference being that the former is much more intruded by igneous rocks than the latter.

Table 2. Camparison of the lithostratigraphical sequence of the eastern and western parts of the Ørtfjell group

West	East
Quartzite and garnet–mica schist	Quartzite and garnet–mica schist
Marble	Marble
Garnet–mica schist with metarhyolites	
Calcareous garnet–mica schist	Garnet–mica schist
Garnet–mica schist	
The Steinfjell group	The Kjerringfjell group

The Dunderland group. – The structurally highest part of the Upper Thrust Unit, the Dunderland group, consists of a lower marble formation including both dolomite and calcite marbles, calcareous mica schists, garnet–mica schists and amphibolites, and an upper garnet–mica schist formation comprising quartzites and amphibolites. The lithologies of the upper formation are very similar to those of the Ørtfjell group, and Søvegjarto (1972) has in fact ascribed them to this group. Two different iron ore horizons are associated with the marble formation. These ores are mined by A/S Rana Gruber in Dunderlandsdalen south-west of the area investigated by the author. This is also the main outcrop area of this group. The rocks have been described in great detail by Bugge (1948) and Søvegjarto (1972).

Petrography

The petrographical descriptions which follow are relatively brief and generalised although the amphibolites and metaperidotites are given a more thorough treatment than the other rock-types. Detailed descriptions are given by Gjelle (1974). In order to avoid repetition only the principal lithological types are distinguished and reference made to variations from group to group where necessary.

MARBLES

Marbles are fairly abundant within the mapped area. They vary in tectonic thickness from less than 1 m up to the 250 m calculated for the dolomite of the Dunderland group south-west of Bjøllånes (Plate 1, K–20). A range in composition is found from pure marbles to metalimestones containing a variable amount of terrigeneous material, and to calcareous mica schists. The clastic material is mostly concentrated in thin layers alternating with the marble. Partial chemical analyses are presented in Table 3 (some modal analyses are given in Gjelle (1974)).

In dolomite marbles, dolomite comprises usually more than 90% of the rock. Calcite crystals are evenly distributed throughout and have a smaller grain-size than the dolomite crystals (0.05–0.1 mm for calcite compared with 0.2–0.3 mm for dolomite). This situation is reversed for the calcite marbles. Some marbles are finely banded or laminated with 1 mm to 1 cm thick calcite-rich bands alternating with dolomite-rich layers. The bands have sharp non-gradational boundaries. All observations point to a pre-metamorphic, pre-deformational origin for the dolomite, but whether it was formed by primary precipitation from seawater or as an early metasomatic product in unconsolidated sediments is impossible to decide.

In a discussion of the origin of dolomite marbles in the Kongsfjell area about 40–50 km south of Mo i Rana, Ramberg (1967) considered the alteration between calcite and dolomite layers to be due to small stratigraphical differences in the grade of dolomitization of primary calcite-rich layers, and that the minor differences thus formed were enhanced by later metamorphic processes.

Table 3. Partial chemical analyses of the marbles

Group	Specimen	Weight percentage CaO	Weight percentage MgO	Amount of insoluble*) components (Weight percentage	Calcite–dolomite ratio based on the chemical anlysis	Calcite–dolomite ratio based on the mode (Gjelle 1974)
Tespfjell group	d 11	31.1	20.8	0.1	4.1 : 95.9	–
	d 12	30.8	20.0	2.3	5.5 : 94.5	–
	k 13	49.3	2.3	5.1	88.7 : 11.3	–
	k 17	39.2	8.7	9.8	54.9 : 45.1	82.7 : 17.3
	k 16	52.1	0.7	3.9	96.6 : 3.4	99.5 : 0.5
	k 14	49.0	2.4	5.4	88.1 : 11.9	87.4 : 12.6
Ørtfjell group	k 1	53.3	1.0	1.5	95.3 : 4.7	
	k 2	43.0	2.1	15.8	88.2 : 11.8	
	k 7	52.3	0.9	4.7	95.7 : 4.3	
	k 8	32.3	4.4	26.6	69.9 : 30.1	77.2 : 22.8
	d 9	47.9	6.1	1.0	71.6 : 28.4	
Dunderland group	d 4	28.9	18.6	8.1	6.0 : 94.0	6.0 : 94.0
	k 5	50.3	2.3	4.0	88.9 : 11.1	
	k 6	51.3	1.0	3.5	95.1 : 4.9	92.0 : 8.0

*) Not soluble in HC1

Analyst E. Sletten, A/S Norsk Jernverk, Mo i Rana.

Specimen localities: *Tespfjell group:* d 11: Lowermost dol. horizon (Q–12). d 12: Upper dol. horizon (Q–12). k 13: Calcite marble above d 12 (Q–12). k 17: Hjartåsen railway station (O–20). k 16: Road-cut east of Messingåga ,Storvoll (N–20). k 14: Railway cut west of Messingåga (N–20). *Ørtfjell group:* k 1: Central marble horizon 2.5 km SSW of Svarttj. (D–27). k 2: Southern marble horizon 2.5 km WSW of Svarttj. (D–27). k 7, k 2, k 9: Railway cut at Storvoll, 1.25 km west of Messingåga (M–20). *Dunderland group:* d 4: Dolomite marble from the southeastern side of Ørtfjell, 2 km south of Bredek (K–19). k 5: Calcite marble beneath the dolomite marble 2 km south of Bredek (K–19). k 6: Railway cut 2–2.5 km west of Messingåga (L–21).

QUARTZITES

Quartzites, including feldspathic quartzites, are of minor importance in the area, but are useful as stratigraphic marker horizons. A combination of limited thickness and sparse exposure, however, has made them difficult to map.

The quartzites are fine-grained, weakly to distinctly foliated, and the colour varies from light pink to greenish blue and dark greyish blue. They are usually thin-bedded. Quartz, plagioclase, muscovite and sometimes biotite can be identified in hand specimens.

Among the accessory minerals are garnet, apatite, sphene, zircon, rutile, tourmaline (schorl), pyrite, ilmenite and hematite. The plagioclase ranges in composition from An_{20} to An_{30} (U-stage determinations). The texture of the quartzites is dominantly granoblastic, although some tectonically disturbed varieties show dimensionally oriented fabrics. The more mica-rich varieties show lepidogranoblastic textures. Strong granulation occurs especially in the quartzite near the thrust plane of the Rödingsfjäll Nappe. Sometimes feldspar porphyroclasts occur as augen in the quartzite.

Table 4. Modal analyses of the mica schists

Specimen	355	309	137	357	024	389	343	14E45	156	224	1A65	54	166	359
Quartz	33	37	39	44	30	53	54	60	39	36	33	24	41	48
Plagioclase	36	8	6	22	1	2	20	2	29	12	22	22	10	3
Microcline	–	–	–	–	–	–	–	–	1	–	–	–	–	–
Calc./dol.	13	2	–	–	–	–	1	–	1	–	16	–	–	1
Muscovite	tr	8	35	12	46	43	17	20	29	20	7	2	3	11
Biotite	24	42	10	16	2	tr	7	–	–	20	16	3	26	20
Chlorite	tr	tr	tr	1	11	1	–	–	–	tr	tr	22	tr	3
Amphibole	–	–	–	–	8	–	–	–	–	–	tr	2	–	6
Kyanite	–	–	–	–	–	–	–	–	–	–	2	–	–	tr
Garnet	1	–	8	3	tr	–	–	–	–	6	2	–	2	2
Epidote	3	–	–	–	tr	–	tr	1	–	1	–	17	17	2
Staurolite	–	–	–	–	–	–	–	–	–	3	–	–	–	–
Other acces.	tr	3	2	2	2	1	1	17	1	2	2	8	tr	4

tr = traces
– = not observed
Localities: *Bjøllådal group*: 355: Bjøllådalen (S–9). 309: 0.5 km E of railway (R–20). *Tespfjell group*: 137: Central Tespfjell (P–14). 357: Northern Tespfjell (R–8). 024: Road cut E of Messingåga (N–20). 389: 2 km S of Hjartåsen st. O–22). *Ørtfjell group*: 343: Northeastern ridge of Ørtfjell (I–21). 14E45: Strandjordelv 0.5 km SW of Svartjern (F–27). 156: At trig.point 568 N of Bredek (L–17). 224: Bredekfjell, 2 km S of Kvitvann (J–15). 1A65: Stormdalen (H–19). 54: E of Tespa/Stormdalselv (L–18). *Dunderland group*: 166: 0.5 km SSW of Stormdalshei (L–20). 359: Road cut at Messingslett bridge (J–23).

META-ARKOSES

Meta-arkoses occur interbedded with mica schists and quartzites, especially in the Tespfjell group, and are of minor importance in the area. They are usually well banded, foliated and of grey-white coloration. Modal feldspar contents vary from 23 to 56% with plagioclase (An_{25}–An_{28}) predominating over microcline (Gjelle 1974).

Accessory minerals include muscovite, garnet, hornblende, apatite, sphene, rutile, zircon and opaques. The meta-arkoses show fine-grained, lepidogranoblastic matrix textures with plagioclase porphyroblasts up to 3–4 mm across.

MICA SCHISTS

The mica schists constitute the most abundant rock-type in the area and occur in all groups. The Ørtfjell and Raudfjell groups consist almost exclusively of different types of mica schist. According to their mineralogy the most frequent types are garnet–mica schist, calcareous mica schist, calcareous garnet–mica schist, horneblende–mica schist and biotite–muscovite schist. Table 4 shows that the mineralogy varies within wide limits.

The accessory minerals include apatite, sphene, tourmaline (dravite and schorl), zircon, rutile and ore minerals (pyrite, in fact, is a major constituent of specimen 14E45). The textures of the schists are usually lepidoblastic, often with porphyroblasts of garnet or amphibole. Plagioclase composition varies from An_{35-37} in the Bjøllådal group, to An_{16-24} in the Tespfjell group and to An_{17-47} in the Ørtfjell group (but one example from Spruttjønn in the Ørtfjell group was determined at An_5). In the Gila complex schists plagioclases fall in the range An_{18} to An_{26}. Schists of the Dunderland group show oligoclase compositions according to the refractive indices observations relative to quartz. Normal zoning in some plagioclases of the Ørtfjell group is encountered.

MICA GNEISSES

Gradual transitions occur between the mica schists and the mica gneisses. The gneisses are more massive and less homogeneous and display lithological banding. They occur mainly in the upper part of the Kjerringfjell group. Mineralogically they are similar to the schists. Plagioclases show a compositional range from An_{19} to An_{35}. Accessory minerals include apatite, tourmaline, sphene, rutile and pyrite.

Textures in the mica gneisses vary from porphyroblastic to lepidogranoblastic; the porphyroblasts are of feldspars, hornblende, garnet and sometimes muscovite.

ORTHOGNEISSES

The orthogneisses, which are poorly foliated and almost white, occur predominantly in the lower part of the Kjerringfjell group. The structurally lowermost gneisses have been affected by cataclasis during nappe emplacemen. The principal minerals are plagioclase, quartz and epidote/clinozoisite/zoisite which together constitute about 80–90% of the rock. The major part of the epidote family minerals originates from saussuritization of plagioclase. These gneisses also have about 10% of white mica, some of it formed by sericitization of plagioclase while some is primary muscovite.

Biotite, apatite, sphene, rutile and ore minerals are included among the accessories. Chlorite is a secondary mineral after biotite.

Textures of the orthogneisses vary from porphyroblastic to lepidogranoblastic with plagioclase forming the porphyroblasts. In one specimen these plagioclases from 2 km north of Storvoll were determined as having an An content of 28% while in another an outer rim of plagioclase gave An_5 with the core showing An_{18} (U-stage determinations). In this case the outer rim represented a late growth zone. Likewise, a composition of An_5 has been determined in a narrow zone around inclusions of clinozoisite crystals in plagioclase, a feature thought to be associated with saussuritization. Sericitization and saussuritization of plagioclases are commonly observed phenomena in the southern part of the Kjerringfjell group.

GNEISSIC GRANITES

Granites displaying a gneissic texture occur in two main areas: in the east in the basement complex and in the north-west in the Gila complex. Only a very small area of the granite belonging to the Lønsdal basal massif has been investigated. The granite here is greyish white with a faint pink coloration which gradually disappears towards the boundary against the overlying metasediments. K-feldspar phenocrysts about 1 cm across and a faint but distinct foliation give the rock an appearance similar to that of augen gneiss. This foliation seems to

Table 5. Modal analyses of the gneissic granites

Specimen	LØNSDAL BASAL MASSIF 149	313	314A	GILA COMPLEX 145	254	257
Quartz	30	37	39	32	38	44
Plagioclase	17	14	14	12	18	10
Microcline	46	44	37	40	28	32
Muscovite	3	1	3	6	14	13
Biotite	3	4	4	9	1	–
Accessories	1	–	3	1	1	1

Localities: 149: West–northwest of Saratuva (S–18). 313: Southwest of Saratuva 50 m from the boundary (S–19). 314A: 1 m from the boundary, southwest of Saratuva (S–19). 145: At the western boundary ca. 1.5 km north of Kvitvann (I–11). 254: At the eastern boundary at the northern end of Midtvann (N–5). 257: Near the eastern boundary ca. 0.5 km north of Midtvann (N–4).

gradually disappear towards the interior of the massif. Quartz, microcline and plagioclase are the main minerals constituting more than 90% of the rock. The usual texture is porphyritic. The plagioclase is an albite with 3–4% of the An component. The microcline phenocrysts show patch–perthites and are situated in an anhedral–granular groundmass of quartz, microcline and plagioclase. The grain-size of the matrix ranges from 0.1 mm up to 1 mm while the phenocrysts range up to 1 cm. Muscovite and green and dark brown, almost black, biotite are common minerals. The biotite often shows alteration to chlorite. Accessory minerals include sphene, apatite and magnetite.

The gneissic granite of the Gila complex is strongly foliated, almost white and carries occasional dark, irregular, mica-rich inclusions which resemble xenoliths. Microcline and plagioclase crystals about 2–3 mm across are evenly distributed in a fine-grained matrix sometimes with an anhedral–granular texture and sometimes with a lepidogranoblastic, gneissic texture. The plagioclase composition varies from An_{29} to An_{36} (4 U-stage measurements). This granite contains more muscovite than the former (ca. 10% versus 3%) and a few accessory minerals such as garnet, epidote, clinozoisite, orthite and zircon. Three growth zones are recorded in some of the epidote minerals and always the core is an orthite. The mineralogical composition of these granites is compared in Table 5.

METARHYOLITES

At two different levels in the Ørtfjell area (Ørtfjell group) a greyish white, poorly foliated, fine-grained rock is found concordantly interbanded with the mica schists. The principal minerals are microcline and quartz; subordinate amounts of plagioclase, biotite and muscovite are present, while accessory minerals include epidote, sometimes with an orthite core, clinozoisite, apatite, sphene and ore minerals. The average grain-size is about 0.1–0.3 mm and the texture is allotriomorphic–granular. U-stage determination of the plagioclase seems to indicate a volcanic origin as the $2V_x$ value is as low as 79° and the An content is about 26% (Burri et al. 1967). Based on the characteristics of the plagioclase and the field occurrence, the rock is considered to be of extrusive origin and probably representative of rhyolitic lava or tuff.

Table 6. Chemical composition of amphibolites from the Bjøllånes area and some other areas in Nordland

Sample no.	225	260	305	326	352	367	387	388	397
SiO_2	52.25	48.87	46.90	50.14	50.06	48.74	47.82	47.86	43.98
TiO_2	2.13	1.15	4.38	0.67	2.15	1.93	2.45	1.83	4.81
Al_2O_3	14.89	15.19	13.69	15.18	14.06	14.78	15.67	15.71	14.23
Fe_2O_3	5.00	5.37	7.70	2.23	2.79	1.72	2.44	1.84	4.75
FeO	8.40	5.01	7.96	9.04	10.49	9.87	9.02	8.16	10.85
MnO	0.20	0.28	0.23	0.19	0.23	0.18	0.22	0.16	0.26
MgO	5.64	7.99	5.77	8.28	6.37	8.82	8.64	8.41	6.47
CaO	8.27	13.48	8.42	11.59	10.01	11.05	10.05	10.74	10.41
Na_2O	2.67	0.74	3.15	1.46	2.01	1.05	2.35	2.72	1.61
K_2O	0.27	0.48	0.52	0.39	0.36	0.31	0.33	0.20	0.30
P_2O_5	0.19	0.16	0.71	0.07	0.23	0.29	0.35	0.28	0.67
CO_2	–	0.99	–	–	–	–	–	2.04	–
H_2O+	1.20	1.30	1.20	1.93	2.16	2.23	1.78	1.06	1.47
	101.14	101.01	100.63	101.17	100.92	100.97	101.12	101.01	99.81

Table 6. Contin.

	405	407	409	a	b	1a	2a
SiO_2	48.32	46.67	45.12	49.34	49.40	48.53	49.66
TiO_2	1.26	2.09	2.88	1.28	1.88	1.42	1.56
Al_2O_3	14.30	12.44	15.72	12.89	11.05	15.48	15.66
Fe_2O_3	2.18	4.80	4.32	2.74	4.72	0.75	2.36
FeO	10.51	8.89	8.91	8.78	8.89	10.64	7.27
MnO	0.20	0.27	0.28	0.13	0.24	0.25	0.17
MgO	8.15	9.17	8.40	9.90	8.11	6.68	7.53
CaO	9.41	8.45	8.25	9.93	11.50	10.84	10.57
Na_2O	2.08	2.36	2.96	2.43	2.55	2.79	2.77
K_2O	0.49	0.52	0.22	0.31	0.50	0.66	0.46
P_2O_5	0.09	0.20	0.41	0.11	–	0.21	0.15
CO_2	2.13	1.63	0.64	–	–	0.15	0.38
H_2O+	1.32	2.35	2.32	1.99	1.57	1.34	1.35
	100.44	99.84	101.43	98.83	100.42	99.74	99.89

Localities: *Bjøllådal group*: 305: Møllebekken (Q–20). 405: Railway cut south of Møllebekken (Q–21). 407: Ca. 1.5 km southeast of Hjartåsen (P–21). *Tespfjell group*: 397: Central eastern Tespfjell (Q–12). *Kjerringfjell group*: 326: 2.5 km northwest of Kjerringvann (N–26). 367: 1 km southwest of Storburtj. (O–24). *Gila complex*: 260: Near the northwestern boundary of the complex (M–20). *Ørtfjell group:* 225: Bredekfjell 1.5 km south of Kvitvann (I–15). 352: Messingen at the western boundary of the marble (M–23). 387: Ca. 1 km northwest of trig.point 1284 m, Ørtfjell (G–22). 388: Ca. 3 km northwest of Rundtind (E–21). *Dunderland group:* 409: North of Stormdalshei (L–20). a, b: Kongsfjell (Ramberg 1967). 1a, 2a: Ofoten (Gustavson 1969).

AMPHIBOLITES

Amphibolites are abundant in the Bjøllådal group and occur less frequently in the other groups. In the Raudfjell group, no amphibolites have so far been observed by the author. Their thickness usually varies from a few decimetres to less than 10 m, although an amphibolite in the Bjøllådal group about 2 km south-east of Hjartåsen railway station has a possible maximum thickness of about 40 m. Exposure is poor, however, so that we might in fact be dealing

Table 7. The origin of the amphibolites

	Method	Igneous	Sedimentary	Unclassified
1)	(Al+Fe+Ti)/3–K versus (Al+Fe+Ti)/3–Na (Moine & de la Roche, 1968)	326, 387, 388 352, 405, 407		225, 260, 305, 367, 397, 409
2)	Al+Fe+Ti versus Ca+Mg (Moine & de la Roche, 1968)	225, 260, 305, 326, 352, 367, 387, 388, 405, 407		397, 409
3)	Niggli parametres after Leake (1964)	All fit the Karroo trend		
4)	MgO, FeO, CaO triangle after Walker et al. (1960)	225, 305, 352, 367, 387, 388, 397, 405, 407, 409	260	326
5)	Discrimination formula after Shaw & Kudo (1965)	225, 305, 352, 367, 387, 388, 397, 405, 407, 409	260, 326	
6)	Oxidation ratio $(2Fe_2O_3 \cdot 100)/(2Fe_2O_3 + FeO)$ after Chinner (1960) and Elliott & Cowan (1966)	intrusive: 326, 367, 387 388, 405, 352, extrusive: 225, 397, 407, 409 tuffaceous ? 305	260	

with several thin amphibolite layers. The same applies for an amphibolite in the Dunderland group west of Storvoll; here the maximum thickness is about 20 m. All the amphibolites observed in the area have concordant boundaries with the adjacent metasediments. The amphibolites are mostly foliated, usually with parallel-oriented amphibole crystals. The rocks are commonly massive and of dark greenish colour. The texture usually is nematoblastic, sometimes also porphyroblastic with hornblende crystals up to 2–3 mm long in a fine-grained matrix. Plagioclase compositions are from An_{17} to An_{26} in the Bjøllådal group amphibolites, and between An_{20} and An_{30} in the Kjerringfjell and Ørtfjell groups. Accessories are ore minerals such as pyrite, pyrrhotite, ilmenite and magnetite as well as apatite, rutile, sphene and, rarely, muscovite. In an attempt to determine the origin of the amphibolites an X-ray fluorescence analysis programme was carried out, giving the main element compositions of a selected number of specimens. Several other methods were also adopted for the same purpose; for descriptions and discussions of these methods the reader is referred to Walker et al. (1960), Leake (1964), Shaw & Kudo (1965), Elliott & Cowan (1966), Moine & de la Roche (1968) and Gjelle (1974).

The chemistry of selected amphibolites is presented in Table 6: modes, mesonorms and catanorms may be found in Gjelle (1974). In addition, the likely origins of the amphibolites — igneous or sedimentary — as suggested by the above mentioned methods are summarized in Table 7 from which it is evident that specimen no. 260 is clearly different from all the others. One of

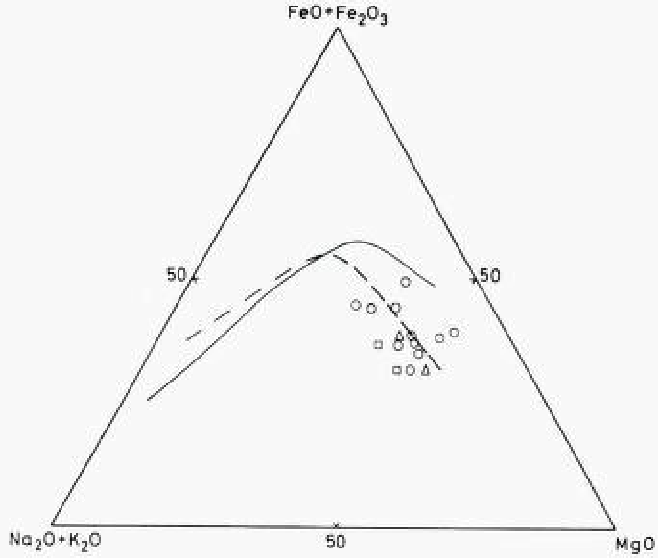


Fig. 3. The amphibolites plotted on an AFM diagram. Solid line after Kuno (1968), dashed line after Irvine & Baragar (1971). Dots - Bjøllånes area: squares - Ofoten area; triangles - Kongsfjell area.

Table 8. The suite index of Rittmann applied to the amphibolites

Specimen	Rittmann's index $S = \frac{(Na_2 + K_2O)^2}{SiO_2 - 43}$
225	1.0
305	3.5
326	0.5
352	1.0
367	0.5
387	1.5
388	2.0
397	3.5
405	1.0
407	2.5
409	5.0
Kongsfjell a	1.2
Kongsfjell b	1.5
Ofoten 1a	2.2
Ofoten 2a	1.6

the methods described by Moine & de la Roche (1968) indicates an igneous origin; the others point towards a sedimentary or in one case unclassified origin. Specimen no. 326 is identified as a metasediment by Shaw & Kudo's (1965) discrimination formula while the other methods, except that of Walker et al. (1960) indicate an igneous mode of formation. Compared with the other samples specimen no. 326 has an unusually low TiO_2 value, but at the same time the Fe oxidation ratio is very low. Considering all the available evidence an

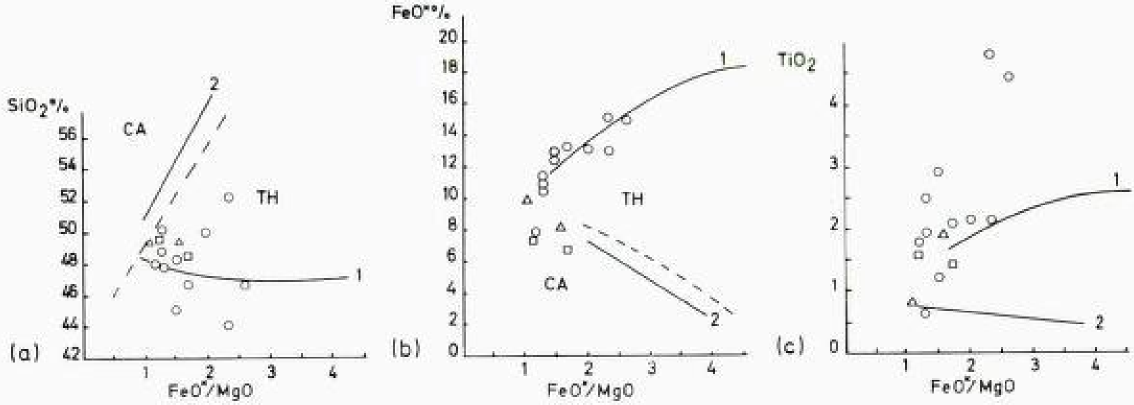


Fig. 4. Variation diagram after Miyashiro (1974) showing the tholeiitic character of the amphibolites. Solid lines showing typical tholeiitic (1) and calc–alkaline (2) trends. The dashed lines in (a) and (b) separate the fields of the tholeiitic (TH) and calc–alkaline (CA) series. $FeO^x = FeO + 0.9\ Fe_2O_3$. Symbols as in Fig. 3.

igneous origin is suggested for this sample. All the other analysed samples are considered to have had an igneous derivation.

An attempt to classify the igneous amphibolites based on the major elements has been carried out. The suite index of Rittman (1962) shows that the amphibolites have a calc–alkaline character (Table 8). On an AFM diagram (Fig. 3), following Kuno (1968) all of the amphibolites fall into the calc–alkaline field whereas Irvine & Baragar's (1971) subdivision is less definitive. Fig. 4 shows the ratio total FeO to MgO versus SiO_2, total FeO and TiO_2, respectively (Miyashiro 1974). All these diagrams show that the amphibolites have a tholeiitic nature.

A comparison with published major element data on basic igneous rocks from other areas in Nordland reveals that the amphibolites of the Ofoten area (Gustavson 1969) and the amphibolites of the Kongsfjell area (Ramberg 1967) have similar chemistries (Table 6 and Figs. 2 and 3). From this one can conclude that these rocks seem to have a tholeiitic affinity rather than a calc-alkaline, but as only main element chemistry is available it is difficult to reach a safe conclusion.

METAPERIDOTITES

Apart from one small body in the Kjerringfjell group all ultramafic rocks occur in the Bjøllådal group. They vary in size from small lenses of a few metres to the largest body measuring about 750 m × 250 m in outcrop.

A few kilometres north of the area described here a series of ultramafic bodies are found, all of them belonging to the Bjøllådal group. The rocks are situated in calcareous mica schists, but because of lack of exposure the actual contacts could not be studied in detail. One of the small lenses shows an exposed contact, however, and here an intense shearing and crushing of the rocks can be demonstrated. No contact aureole has been found in the surrounding mica schists. Most of the bodies consist predominantly of serpentine with relict crystals of olivine (forsterite, $2V_z = 85°–90°$) and/or orthopyroxene (nstatite/bronzite). Usually the serpentine constitutes more than 50% of the mode. The forsterite and the enstatite interdigitate with serpentine flakes. Talc and magnetite are common.

One of the biggest of the ultramafic bodies, namely that occurring west of Bjøllåga in Bjøllådalen (Plate 1, R–9/10), has a more complex mineral composition. Its interior part is composed almost exclusively of clinopyroxene, the optical data indicating this to be an augite. The structure of the pyroxenite is porphyroclastic. Augite crystals 1–3 mm across are surrounded by smaller grains (less than 0.3 mm across) of the same mineral, the latter having been formed by crushing and recrystallization of the former. Secondary growth of Mg–chlorite (Albee 1962) is limited. It is found along fractures in the rock and also in a rew randomly distributed aggregates where it seems to have replaced another mineral, probably orthopyroxene. Other secondary minerals in the fractures also include dolomite and magnesite.

Another rock-type in this body consists of augite, hornblende, epidote and a green spinel (pleonaste?). This is a fine-grained rock where most of the minerals are 0.1 mm or less across except the hornblende and epidote which measure up to 0.5 mm. Other minerals present are apatite, sphene, magnetite an chalcopyrite. Mg–chlorite and tremolite occur in fractures within this particular body. This rock would correspond to the hornblende–spinel–peridotite facies of O'Hara (in Wyllie 1967). In the western part of this ultramafic body a garnet amphibolite has been found, measuring 20–30 m × 6—8 m. It is a dark greenish rock with red-brown garnets and displays a porphyroblastic–nematoblastic texture with traces of cataclasis. The garnet is usually less than 1 cm across and xenoblastic. It has a refractive index of 1.755; lattice constant a = 11.62 Å and 11.67 Å (a double peak on the diffractometer), and a chemistry indicating: Alm. 34.3 – Andr. 21.2 – Gross. 18.5 – Pyr. 24.8 – Spess. 1.2 determined by electron microproble work.

The clinopyroxene of this amphibolite has optical data consistent with both diopside and omphacite. Electron microprobe determination gives a chemical composition where Ca, Mg and Fe^{II} are the dominant cations. Subordinate amounts of Al, Na and Ti are also present. It is always mantled by an amphibole with optical properties signifying hornblende and this in turn is partly converted to Mg–chlorite. Epidote is present as aggregates of fine-grained crystals associated with hornblende. Only small traces of talc are found. Accessory minerals are rutile, sphene, ilmenite, chalcopyrite and (?)chalcostibite. Dolomite or magnesite occurs in fractures. Originally this ultramafic body would appear to have consisted of garnet and clinopyroxene. Later it has been affected by cataclasis possibly simultaneously with its emplacement into the surrounding mica schist. Access of water caused the pyroxene partly to change to hornblende. Subsequently secondary chlorite was formed and this sometimes shows kink zones indicating a later phase of tectonic movements. The latest mineral growth is that of carbonate minerals in fractures. The marginal zone of the ultramafic bodies in most cases consists of serpentine with minor relics of olivine and–or pyroxene, and in a few cases it consists of Mg–chlorite and tremolite. The latter assemblage, however, is usually found in megascopic fracture zones through the rock.

In the observed parageneses, listed below, the minerals in parentheses are believed to be of a late metamorphic origin.

Clinopyroxene + garnet + (hornblende + epidote).
Clinopyroxene + spinel + (hornblende + epidote).
Forsterite + orthopyroxene + (serpentine).
Clinopyroxene + orthopyroxene (only as minor relics) + (Mg–chlorite).
Orthopyroxene + (serpentine + magnesite (?) + talc).
Forsterite + (serpentine + magnesite (?) + talc).
Forsterite + orthopyroxene + (magnesite (?) + talc + Mg–chlorite).
(Tremolite + Mg–chlorite).

A later publication will consider the problems posed by these exotic parageneses.

OTHER IGNEOUS ROCKS

Of minor importance are a few other rock-types of igneous origin. Modal analyses of most of these are given in Gjelle (1974). In the Bjøllådal group (Plate 1, P–21), a rock of andesitic composition occurs together with an amphibolite identified as a basaltic lava.

In the Tespfjell group within the upper marble at Tespfjell (Plate 1, O–14) two different levels of a quartz andesite of about 4–5 m thickness are found and at Hjartåsen railway station (Plate 1, O–20) two levels of 2–3 m thickness of another igneous rock-type, a meta-basalt, are found within the same marble.

In the tectonic zone beneath the Rödingsfjäll Nappe, an alkali granitic intrusive occurs as a lens-shaped body about 500 m in length. Within the Kjerringfjell group igneous rocks of granitic, quartz dioritic and dioritic composition are found in addition to the orthogneisses.

Metamorphism

The granite gneiss of the *Lønsdal basal massif* shows a mineral assemblage of quartz, albite, microcline, muscovite and biotite – a typical 'granite' paragenesis. A slight chloritization of the biotite indicates a lower greenschist facies metamorphism. The paragenesis of the autochthonous metasediment of residual character is:

quartz + albite + muscovite + biotite/chlorite

which indicates the Bl. 2 subfacies of Winkler (1967). Areas of low-grade metamorphism (i.e. greenschist facies) are depicted in Fig. 2.

The parageneses of the *Raudfjell group* include the:

quartz + calcite + oligoclase (An_{28}) + muscovite + biotite

assemblage of the calcareous mica schists and the:

quartz + oligoclase + garnet + muscovite + biotite

assemblage of the garnet–mica schists. A metamorphic grade corresponding to somewhere near the boundary between the upper greenschist facies (B 1.3) and the lower amphibolite facies (B 2.1) would satisfy these parageneses. One can thus conclude that there is a sharp metamorphic discontinuity between the autochthonous basal cover and the Raudfjell group, thus providing evidence for the existence of a late thrust zone at this level.

The calcareous mica schists of the *Bjøllådal group* show the assemblages listed below:

quartz + calcite + oligoclase + epidote + hornblende + muscovite
+ biotite
quartz + calcite + andesine (An_{35-37}) + epidote
+ garnet + muscovite + biotite

The amphibolites have:

quartz + oligoclase + epidote + hornblende ± garnet + biotite

as the typical paragenesis. According to Winkler (1967) these should correspond to the lower amphibolite facies, B 2.1 or B 2.2. A slight chloritization of garnet and biotite is attributed to a later retrogressive metamorphic phase observed almost everywhere in the mapped area. The relict paragenesis of one of the metaperidotites discussed earlier represents the P–T conditions to which the rocks have been exposed prior to the regional metamorphism of the area and prior to its emplacement into its present position.

Parageneses of the metasediments belonging to the *Tespfjell group* include:

quartz + oligoclase (An_{25}) ± clinozoisite ± garnet + muscovite
+ biotite
quartz + oligoclase + clinozoisite + muscovite + biotite
+ K-feldspar
quartz + oligoclase (An_{25}) + clinozoisite + hornblende ± garnet
+ muscovite + biotite
quartz + andesine (An_{36}) + clinozoisite + garnet + muscovite
+ biotite

These also correspond to the B 2.1 or the B 2.2 subfacies of the amphibolite facies of Winkler (1967). In addition, a late chloritization of the ferromagnesian minerals is recorded.

Typical mineral assemblages of the rocks belonging to the *tectonized zone* beneath the Rödingsfjäll nappe are listed below:

(1) quartz + zoned plagioclase (An_{16}–An_0) + epidote + hornblende + biotite
(2) quartz + plagioclase (An_{25}) + epidote + hornblende + garnet + muscovite + biotite
(3) quartz + plagioclase (An_{20}) + epidote + hornblende + garnet
(4) quartz + garnet + muscovite + biotite + chlorite
(5) quartz + plagioclase (albite ?) + muscovite + chlorite (mylonite)

The mylonite assemblage (5) has recrystallized in the lower greenschist facies, B 1.1. The other assemblages could all well belong to the lower amphibolite facies (B 2.1), although (4) would seem to have been a stable B 1.3 assemblage. The latter, from the area south of Hjartåsen, possibly provides evidence of a metamorphic gradient with increasing metamorphic grade northwards for the thrust zone rocks. Strand (1972) and Øines (pers. comm. 1973) have reported low-grade rocks at the corresponding tectonic level at Krokstrand about 4 km south-east of the Bjøllånes area, and in the northern part of the area only amphibolite facies rocks have been observed except where the mylonites are present. South of Bjøllånes no unambiguous traces of amphibolite facies rocks have been found at this level. The cause of his could be either the above-mentioned metamorphic gradient combined with the later B 1.1 subfacies (chloritization phase), or that the rocks in this area have been slowly exposedt to lower pressure and temperature conditions after the metamorphic peak of B 2.1/B 2.2 so that stable B 1.3 parageneses have been developed. Later, all parageneses have been exposed to lower greenschist facies giving the chloritization of Fe–Mg minerals.

The assemblages:

quartz + andesine (An_{29-36}) ± epidote ± garnet + muscovite +biotite + microcline

of the granite gneiss and

quartz + oligoclase (An_{17-26}) + epidote ± garnet ± hornblende + muscovite + biotite

of the mica schists, both belonging to the *Gila complex*, correspond to the lower amphibolite facies.

A special mineral assemblage from one of the mica schist horizons in the Gila complex is composed of:

quartz + calcite + plagioclase (low R.I., albite?) + epidote + amphibole (probably actinolite) + muscovite + biotite

This could represent either a B 1.3 paragenesis or a relict albite–epidote– hornfels facies (Winkler 1967) connected with the granitic intrusion. The last possibility seems to be the most likely one. As no traces of a contact metamorphism have been found anywhere else around the granitic gneiss the conclusion must be that regional metamorphism was the later of the two.

The typical parageneses:

quartz + plagioclase (An_{19-38}) + epidote + garnet ± hornblende + muscovite + biotite
quartz + oligoclase (An_{25-28}) + epidote + muscovite + biotite + microcline
quartz + epidote + muscovite + kyanite (?)

of the *Kjerringfjell group* can all be attributed to the B 2.1 or the B 2.2 subfacies of the amphibolite facies.

The usual chloritization of Fe–Mg minerals is recorded and in addition strong saussuritization and sericitization of the feldspars has been observed in the gneisses in the southern area, especially in the lower part of the group. This phase is either post-deformational or contemporaneous with the thrusting.

Mineral assemblages typical for the metasediments of the *Ørtfjell group* are listed below:

(1) quartz + albite ± epidote + garnet + muscovite + biotite
(2) quartz ± calcite + plagioclase ± epidote + muscovite + biotite
(3) quartz + plagioclase ± epidote + garnet + muscovite + biotite
(4) quartz + plagioclase + epidote + garnet + staurolite + muscovite + biotite
(5) quartz + plagioclase ± epidote + garnet + kyanite + muscovite + biotite
(6) quartz + plagioclase + epidote + garnet + hornblende + biotite

The plagioclase is varying in composition from oligoclase to a Ca-rich andesine. All parageneses except (1) and (2) are in agreement with a metamorphic grade corresponding to the B 2.1 or the B 2.2 subfacies of the amphibolite facies (Winkler 1967). Paragenesis (5) from southwestern Ørtfjell just off the map indicates B 2.2. conditions. The parageneses (3), (4) and (6) belong to the B 2.1 subfacies. Parageneses (1) and (2) from the border zone towards the Dunderland group west of Dunderland railway station suggest B 1.3 subfacies conditions. These greenschist facies assemblages are confined to a narrow zone about 15 km long and less than 300 m wide (usually much less) along the boundary between the two groups, extending from the southwestern part of the area to west of Bjøllånes. This zone has not been investigated further north. Along the eastern side of the Dunderland group outcrop, at the top of the Ørtfjell group there is a similar zone of low metamorphic grade. This stretches from the southern boundary of the mapped area to east of Bredek. The thickness of the zone is less than 150 m in the south, diminishing northwards; its extension further north has not been investigated. The chloritization in this eastern zone is particularly prominent, giving the mica schists a distinctive green colour. Chlorite pseudomorphs after garnet are common. The reason for the occurrence of this low-grade zone is not clear. It might be that the boundary between the two groups is a tectonic one, representing a thrust plane at least earlier than the F_3 deformation phase. On the other hand, this phenomenon could also be due to minor movements between the groups accompanied by a

Fig. 5. Isoclinal F_1 fold in the marble at the Hjartåsen railway station (O–20).

new metamorphic episode of lower grade or retrogression of the main one. Small movements between the main rock units after the peak of metamorphism (for instance during the F_3 phase) could have provided an easier access for aqueous solutions along these boundaries than elsewhere, thereby producing a stabilized greenschist (B 1.3) subfacies paragenesis; subsequently the garnet and biotite were chloritized.

In the mica schists of the *Dunderland group* the following mineral assemblages have been found:

quartz + anthophyllite + garnet + muscovite + biotite
quartz + garnet + staurolite + muscovite
quartz + oligoclase + epidote + hornblende + muscovite + biotite
quartz + oligoclase + garnet + kyanite + muscovite + biotite

These parageneses belong to the B 2.1 subfacies of the amphibolite facies.

Tectonic structures

MINOR STRUCTURES

Only the main features of the structural geology of the Bjøllånes area are considered in this paper. For a more detailed discussion, see Gjelle (1974).

Based on fold interference relationships four phases of folding have been recognized. The oldest phase, F_1, gave rise to isoclinal, similar folds in quartzites and marbles, and rootless intrafolial folds (Turner & Weiss 1963) of thin quartzite layers in mica schists and gneisses (Fig. 5). Folds of F_1 age deform

Fig. 6. F_2 folds with axial-plane cleavage S_2 developed as a fracture cleavage. Ørtfjell group, Rundtind area (H–22).

the primary bedding, S_0. Where the deformation has been extremely intense the bedding has been transposed into a new foliation, S_1, coincident with the axial-planes of the F_1 folds. S_1, which is the principal schistosity in the rocks, generally appears to be parallel to the bedding, but at the hinges of the F_1 folds it is clearly intersecting S_0. Only few observations of F_1 axes have been made, these showing an east-west orientation. The peak om metamorphism was reached during this deformation phase.

The S_1 foliation is affected by at least two later phases of folding, designated F_2 and F_3. The F_2 generation has a roughly E–W axial trend, although the small-scale fold-axes and axial-planes show considerable variations in orientation. The folds are relatively tight, and only occasionally is an axial-plane cleavage, S_2, developed (Fig. 6).

Fig. 7 depicts the main structural elements at the Hjartåsen quarry. The S_1 poles define a girdle axis approximately coincident with the axis defined by the S_2 pole girdle. Both girdle axes are taken to represent the F_2 axial trend. The F_2 axes and L_2 lineations are orientated with a sharp maximum around the girdle axis (the F_2 axis). As the L_1 lineations are disposed at an extremely acute angle to the E–W F_2 axes this could be regarded as an indication that the original orientation of the F_1 axes was also approximately E–W. The structural relationships east of Hjartåsen (Fig. 8) also suggest an E–W to SW–NE orientation of the F_1 lineations. The S_1 pole girdle axis defines the F_2 plunge at 30° towards 255–260°.

The F_3 generation of folds is responsible for the main distribution of lith-

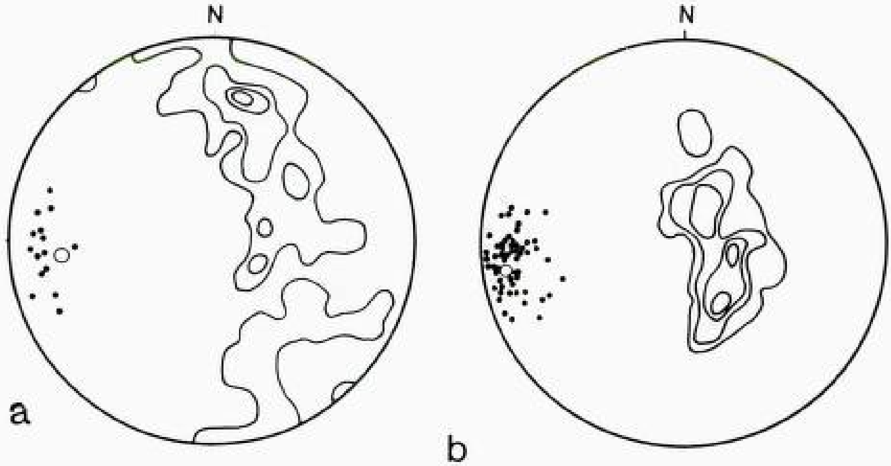


Fig. 7. Structural elements at the Hjartåsen quarry (O–20). Dots – lineations; circle – axis to pole-girdle.

a) L_1 lineations and S_1 poles (52 poles contoured).

b) L_2 fold axes/lineations and S_2 poles (23 poles contoured).

Contour intervals at 0, 5, 10 and 15%. All stereograms are equal-area lower hemisphere projections.

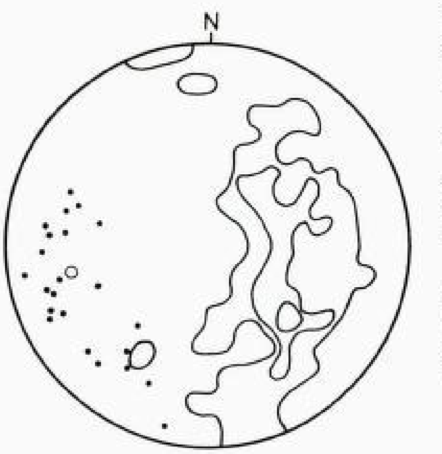


Fig. 8. Structural elements east of Hjartåsen (R–19). 22 L_1 lineations (dots); 63 S_1 poles contoured. Contour intervals at 0, 5 and 10%. Circle: girdle axis.

ologies on the map. This deformation produced large N–S trending folds with axial-planes dipping vertically or steeply towards the west.

Structural elements in the southern and northern parts of the dome structure in the Steinfjell area are shown in Fig. 9. The axes to the S_1 pole girdle parallel the F_3 axial trend; and the mesoscopic F_3 fold-axes and lineations recorded show pronounced maxima around these axes. One or two of these folds could possibly be of F_2 age since it is often difficult to differentiate between the mesoscopic F_2 and F_3 structures in the field.

In the Tespfjell area the F_2 and F_3 folds interfere with each other in such a way that only restricted areas of a few hundred square metres show structural homogeneity with respect to the S_1 foliation and to the F_2 or the F_3 linear structures. One such area due west of the trigonometrical point 1099 m on Tespfjell is illustrated by the stereogram of Fig. 10. Here the S_1 poles define a girdle axis, F_2. Two intersecting lineations are plotted; one roughly N–S orientated,

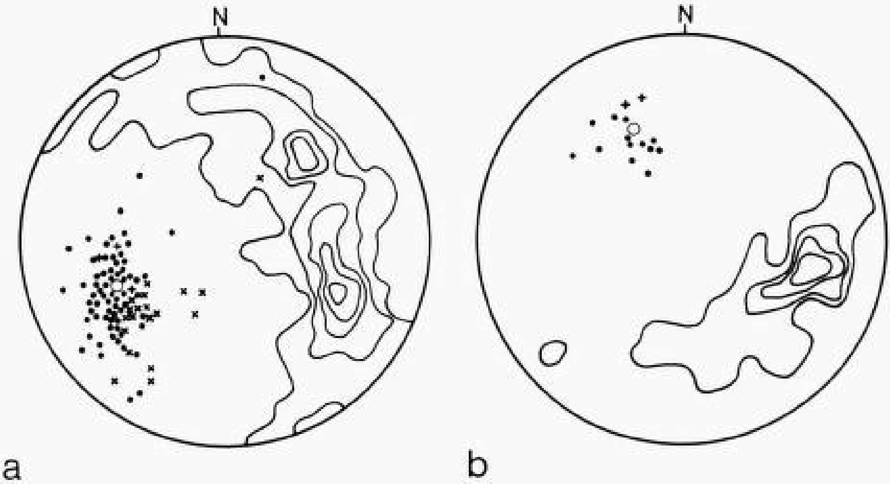


Fig. 9. Structural data from the southern (a) and northern (b) Steinfjell area. Dots – L_3 lineations; crosses – F_3 axes; circle – girdle axis.

a) 22 F_3 axes; 66 L_3 lineations; 184 S_1 poles contoured. Contour intervals: 0, 2.5, 5, 7.5, and 10%.

b) 2 F_3 axes; 13 L_3 lineations; 40 S_1 poles contoured. Contour intervals: 0, 5, 10, and 15%.

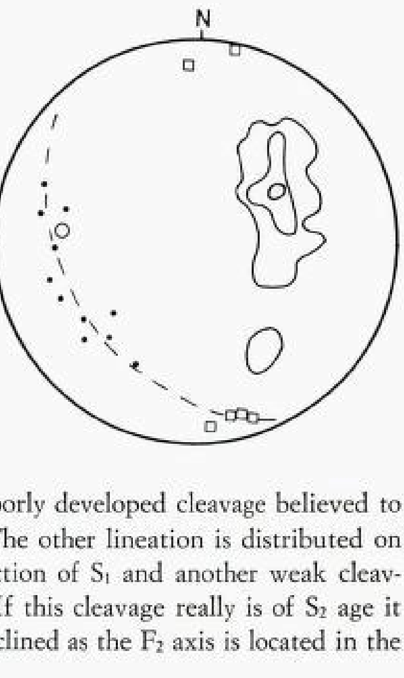
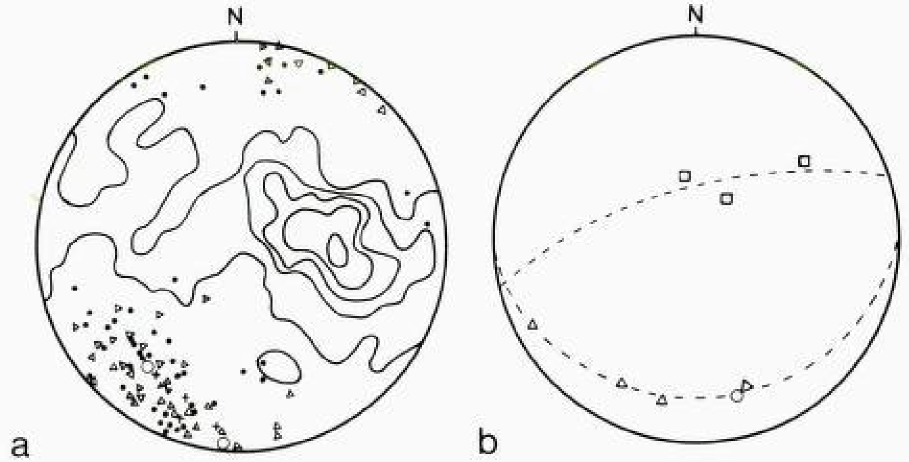


Fig. 10. Structural elements from a small area on central Tespfjell (P–9). 6 L_3 lineations (squares); 12 L_2 lineations (dots); and 16 S_1 poles contoured. Contour intervals at 0, 12.5 and 25%. Circle – girdle axis.

stems from the intersection of S_1 with a poorly developed cleavage believed to be of F_3 age, and is thus an L_3 lineation. The other lineation is distributed on a great circle and results from the intersection of S_1 and another weak cleavage defined by parallel-orientated biotite. If this cleavage really is of S_2 age it would imply that the F_2 folds are almost reclined as the F_2 axis is located in the foliation-plane with a pitch of about 60°.

Structural relationships in the southern Tespfjell area are illustrated by Fig. 11. The F_3 phase is dominant in this area, but the rather broad S_1 pole belt is mainly due to the interference from the F_2 phase. The strong concentration of poles in the eastern half of the stereogram is a result of the vergence of the F_3 folds towards the east. The attitude of the axial-planes varies from approximately vertical to dipping steeply towards the west. A small flexure in the axial-plane of the major F_3 structure causes the F_3 axial trend to swing from SSW–NNE to N–S and then to SSE–NNW when going from north to south. Within small areas of up to a hundred square metres one can find F_2 axes which are distributed on great circles. An example is shown in Fig. 11b from a locality



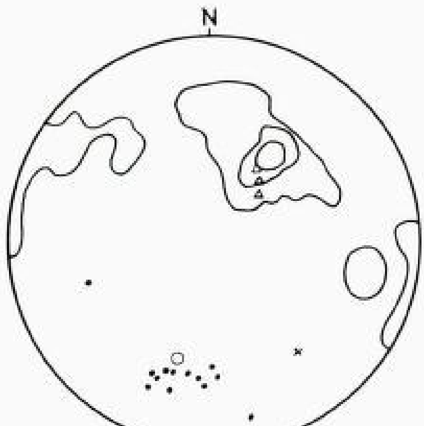


Fig. 11. Structural data from the southern Tespfjell area.
a) 4 F_3 axes (crosses); 44 F_2 axes (triangles); 48 L_3/L_2 lineations (dots); 142 S_1 poles contoured. Contour intervals at 0, 2.5, 5, 7.5, and 10%. Circle – girdle axis.
b) 4 F_2 axes (triangles); 3 S_2 axial-planes (squares).

Fig. 12. Structural elements at the front of the Rödingsfjäll Nappe south of Hjartåsen (P–23). 12 F_4 axes and lineations (dots); 1 F_3 axis (cross); 3 S_3 poles (triangles); 21 S_1 poles contoured. Contour intervals at 0, 10, and 20%. Circle – girdle axis.

on southern Tespfjell about 1.5 km north of Bjøllånes. Four axes of F_2 folds are distributed along a great circle, and their axial-planes have attitudes which indicate that the orientation of the folds results from their deformation by the SSW–NNE orientated F_3 folds. Most of the fold axes and lineations measured in this area are older than F_3. Only four mesoscopic folds have been identified as being of certain F_3 age in the entire southern Tespfjell area.

A younger phase of deformation is recorded in the south-eastern area where F_4 structures fold of the F_3 axial-planes in wide open folds. The axial trend of the F_4 folds is approximately perpendicular to the thrust front of the Rödingsfjäll Nappe. Fig. 12 shows the structural elements in a small area at the thrust front of the Rödingsfjäll Nappe south-southeast of Hjartåsen. The S_1 poles define a girdle axis plunging at 40° towards 200° which represents the latest deformation phase, F_4.

The thrust zone in Bjøllådalen between the Tespfjell and Bjøllådal groups exposes rocks which show phyllonitic and mylonite textures (Higgins 1971) in thin-section. In addition to this there is a pronounced break of slope along the zone on the western side of the Bjøllådal valley. Another thrust zone is located southeast of Kjerringvann within the Kjerringfjell group. Its regional extent is not clear; quite likely it represents only a local thrusting, with imbrication, within the group. Paragneisses are displaced towards the northeast relative to the underlying orthogneisses and mylonite occurs along the thrust plane.

All these thrust zones are considered to be of F_3 age. The postulated thrust beneath the Raudfjell group around the Lønsdal basal massif must be older than the regional metamorphism in view of the metamorphic discontinuity beneath it. This boundary is also affected by F_2 structures north of the mapped area, so that this thrusting must have occurred either during or immediately following the F_1 deformation phase.

It is tempting to correlate the deformation phases F_1, F_2 and F_3 with those described by Rutland & Nicholson (1965) from the coastal district between Mo i Rana and Bodø. The orientation of the fold axes seems to be roughly the same and the F_1 phase produced minor isoclinal folds with a penetrative axial-plane schistosity in both areas. Major isoclines are not found in the Bjøllånes area. The only possible F_1 nappe structure here is the one immediately above the Lønsdal basal massif. The possibility that the Rödingsfjäll Nappe boundary in the north has been affected by the F_2 phase while in the south it seems to be connected with the F_3 movements may be an indication that deformation has been more or less continuous from one phase to another, as described by Rutland & Nicholson. Another possibility is that the Rödingsfjäll Nappe is originally a conjunctive F_1 nappe reactivated during the F_3 phase in the southern part of the investigated area, where it is now disjunctive.

The fold phases described by Ramberg (1967) from the Kongsfjell district include an F_1 episode with isoclinal similar folds with axes showing two principal trends, SSW–NNE and WNW–ESE, an F_2 phase with SSW–NNE trend and an F_3 phase recorded only at the front of the Helgeland Nappe (Ramberg, in a lecture at Det Nordiske Geologiske Vintermøte i Åbo, 1966). The axial-plane traces from the Kongsfjell area seem to indicate that the F_1 phase was axially oriented roughly E–W and the F_2 phase roughly aligned N–S. The F_1 phase could then possibly be identical in the two areas while the F_2 phase of Ramberg (1967) would correspond to the F_3 phase in the Bjøllånes area. The F_4 folds observed in the southern part of the investigated area and with an orientation roughly perpendicular to the nappe front would appear to be identical to similar structures observed further south by Ramberg (pers. comm. 1976). Folds of this phase always seem to be perpendicular to the nappe front regardless of the orientation of the front itself.

MAJOR FOLDS AND THRUSTS

The profile shown in Fig. 13 depicts an interpretational section through the study area. The Gila gneissic granite forms the core of a large, dome-shaped, elongated structure with an axial-plane striking at 020° and dipping west at about 60°. In the southern part of the area the axial-plane is vertical and strikes almost east-west (080°). The axis plunges about 25° west in the south-

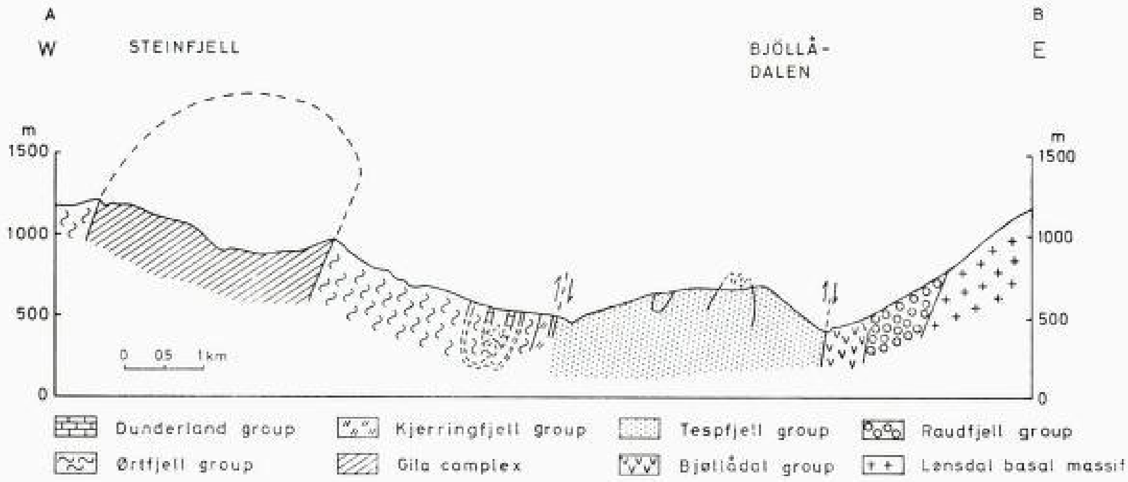


Fig. 13. Simplified profile along the line A–B on the map, Plate 1.

ern Ørtfjell area, increasing to 40° in the northern Ørtfjell–Bredek area. In the northern Steinfjell area the axial plunge is about 40° to the NNW.

East of the antiform is a synform directly involving rocks of the Ørtfjell and Dunderland groups, which follows the valley of the Tespa river. Exposure here is poor. The mica schists in the core of the synform have been interpreted as Ørtfjell group rocks by Søvegjarto (1972), but the present author distinguishes them as an upper mica schist formation in the Dunderland group. This latter interpretation seems to fit the profiles of Søvegjarto (1972) better than other interpretations (Gjelle 1974). A N–S profile across Dunderlandsdalen just southwest of the present area reveals the fold pattern and relationships shown in Fig. 14. The interpretation described above implies that the rocks between the Dunderland group and the Kjerringfjell group belong to the Ørtfjell group. The westernmost marble horizon could thus be the same as that running from the east side of Jarfjell (Plate 1, M–28) across Storvoll and continuing further north. The latter has been mapped by Søvegjarto as a continuous horizon all the way to the Langvatn area, north of Mo i Rana. An interesting feature is the low metamorphic grade (B 1.3 of Winkler (1967)) of the uppermost Ørtfjell group rocks compared with the adjacent rocks of the Dunderland group (B 2.1–B 2.2). This feature is recorded in the area from Bredek southwards and could possibly be regarded as evidence of movement between the two groups. Further north the metamorphic grade of the rocks along this boundary has not been investigated. Søvegjarto (1972) report local discordances of late F_1 or younger age between the two groups in the Storforsheia area. A few observations thus appear to indicate that the Dunderland group may constitute a separate tectonic unit and has been affected by a late F_1 thrusting, similar to the Beiarn Nappe of Rutland & Nicholson (1965). To the present author the discontinuity and the lower metamorphic grade are rather the result of minor local sliding and thrusting between the two groups during the different deformation phases.

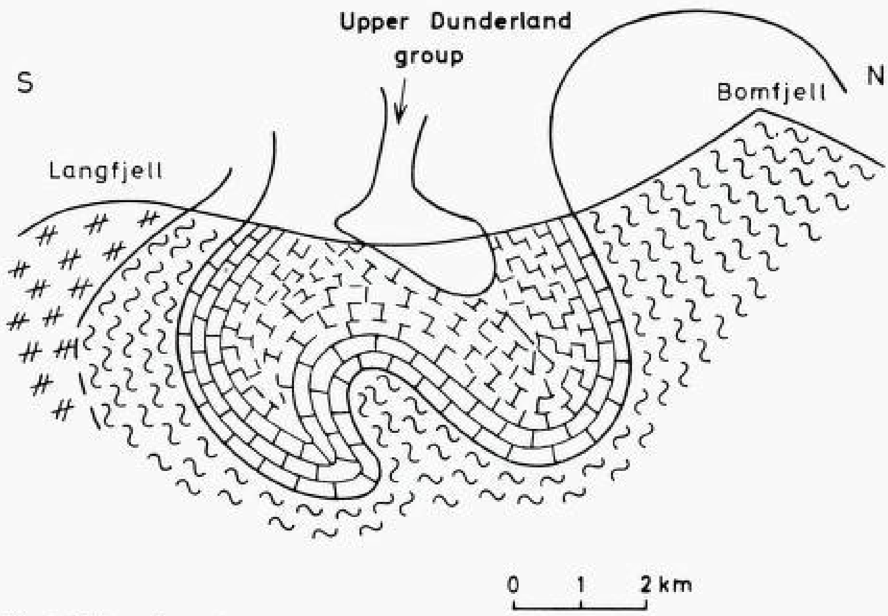


Fig. 14. The relationship between the different groups in Dunderlandsdalen as interpreted by the author, based on a profile constructed by Søvegjarto (1972); not drawn to scale.

The Rödingsfjäll Nappe ,which has quite a clear thrust front in the southern part of the area, becomes more and more vaguely defined northwards. It would seem as if the thrusting dies out and that there is a primary contact between the Kjerringfjell group and the underlying rocks. Such an interpretation, however, would imply an older age for the Tespfjell group relative to the Ørtfjell group. As the latter is supposed to rest on Caledonized basement, this group should be the older of the two. Thus the thrust zone is thought to exist beneath the Kjerringfjell group also in the north.

At Storbekken (Plate 1, O–13) there are exposures of ultramylonite of up to 10 m thickness over a distance of at least 500 m. Around the Tespfjell 1099 m trig.point (Plate 1, Q–9 there is a zone of 'augen gneiss' development. Augen of both microcline and plagioclase can be seen in the mica schist/gneiss of the formation immediately beneath where the thrust zone is supposed to occur.. On a microscopic scale evidence of thrusting is indicated by a greater degree of cataclasis along this zone than anywhere else in the area.

The Tespfjell group located beneath the thrust front of the Rödingsfjäll Nappe shows great lithological similarities to the Dunderland group, a fact which might suggest that the two groups are identical. They are tectonically separated from each other by the Rödingsfjäll thrust and by the intervening Ørtfjell group rocks belonging to the eastern limb of the Tespa syncline. The Tespfjell group rocks are squeezed together into a series of tight F_3 folds with vergence towards the east and with N–S trending axial-plane traces.

Another thrust zone separates the Tespfjell group from the Bjøllådal group.

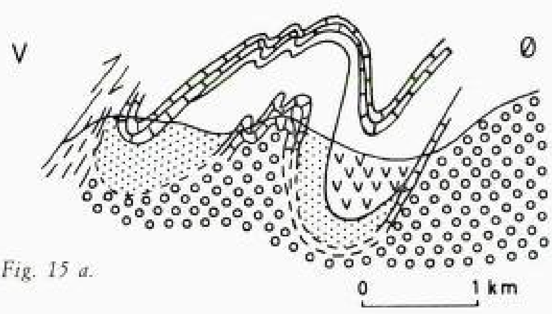


Fig. 15 a.

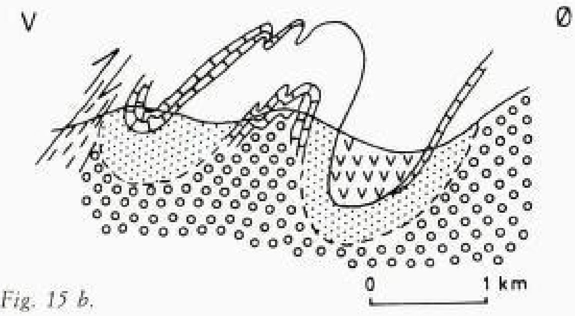


Fig. 15 b.

Fig. 15. Two alternative interpretations of the position of the Bjøllådal group. Generalized sections across Tespfjell–Bjøllådal about 6 km north of Bjøllånes. Symbols as in Fig. 2.

Because of heavy overburden in the critical area at Hjartåsen it is not quite clear as to which of the deformation phases it should be linked. It could well be due to a local splitting of the Rödingsfjäll thrust zone. The great similarities of the Tespfjell and Dunderland groups are in accordance with this view, as are the almost identical trends of the zones. Almost everywhere along the boundary between the two groups in the Bjøllådalen valley the formation is steep to vertical. This could be due to the compression which gave rise to the almost upright F_3 folds at Tespfjell and need not imply the presence of a root zone to the Bjøllådal group. From a lithological point of view the Bjøllådal group probably does not constitute a complementary synform to the easternmost antiform of Tespfjell (Fig. 15a). This would imply that the Bjøllådal group wedges out rapidly westwards and that the Tespfjell group likewise wedges out in the opposite direction. The lithologies of the two units seem to be too different to be explained as primary lateral facies variation. Besides, the Tespfjell group has a clearly recognizable internal stratigraphy while it seems impossible to establish a stratigraphy in the Bjøllådal group. This interpretation (Fig. 15a) would also imply that the Bjøllådal group is the younger of the two and with the Hjartås marble as the uppermost unit within this group instead of within the Tespfjell group.

Another interpretation is sketched in Fig. 15b, but also here the great lateral facies variations over relatively short distances make the interpretation appear very unlikely. Besides, the relationship between the Bjøllådal group and the Hjartås marble at Hjartåsen shows that the marble is lying above the Bjøllådal group. Because of the overburden it is possible that the map of this small area is incorrectly interpreted. An alternative interpretation is shown in Fig. 16;

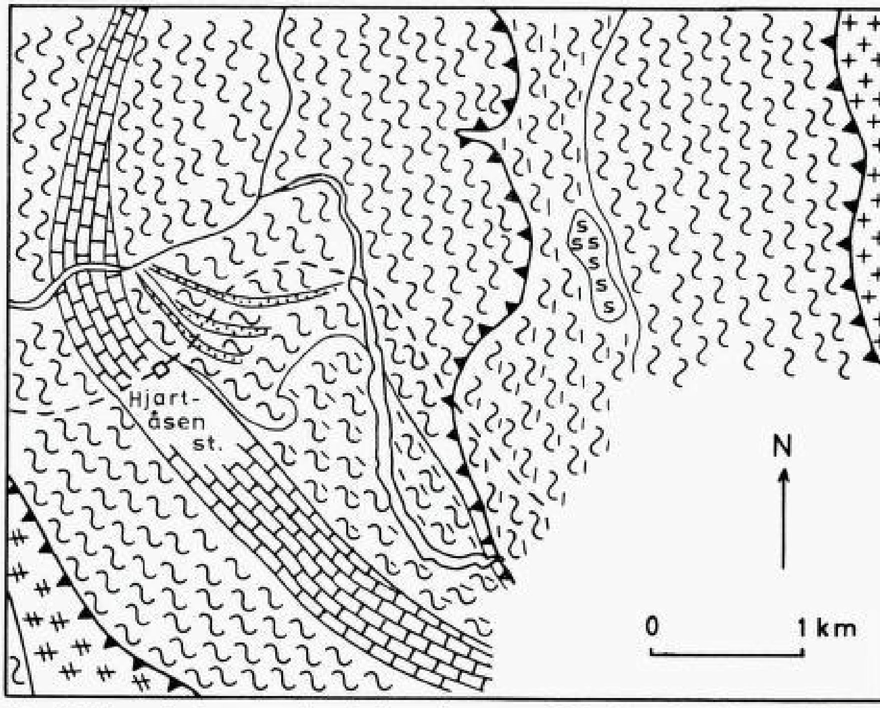


Fig. 16. Alternative interpretation of the geology around Hjartåsen. Symbols as in Plate 1.

this necessitates the acceptance of great variations in facies over short distances. In both interpretations we would have a teconically unbroken sequence of rocks between the Lønsdal basement window and the Rödingsfjäll thrust zone consisting of the Raudfjell, Tespfjell and Bjøllådal groups.

Another difficulty with these interpretations is the relatively abundant occurrence of basic igneous rocks in the Bjøllådal group while in the Raudfjell group none has been recorded so far within the mapped area.

It should be pointed out, however, that only a small area of the Raudfjell group has been investigated and, further, that the area is not too well exposed. Steenken (1957) in the Saltdal area north of the basement window and Marklund (1952) south of the window both describe igneous rocks in units which are probably correlatable with the Raudfjell group.

Regional correlations and considerations

SALTDAL–SULITJELMA

Table 9 shows an attempted tectonostratigraphic correlation with sequences in the Saltdal–Sulitjelma region north of the Lønsdal basal massif and the Västerbotten–Southern Norrbotten region in the south. Some comments are needed in connection with these proposed correlations. The Raudfjell group has a graphitic quartz–mica schist of less than 10 m thickness at the bottom which must be equivalent to Steenken's (1957) graphite schist formation. Both are

Table 9. Proposed tectonostratigraphic correlation with the Västerbotten–southern Norrbotten region and the Saltdal–Sulitjelma region

SARVAS (Marklund 1952)			AIVO-SARVAS (Kulling 1972)	BJØLLÅNES (Gjelle 1974)		SALTDAL (Steenken 1957)	SALTDAL (SULITJELMA) (Nicholson 1973)
				Mica schists Quartzites and marbles	Ørtfjell group	Plagioclase - poor mica schists of the calciferous mica schist formation	Conglomerate Quartzite Marble Mica schist
			(The Rödingsfjäll nappe)	Orthogneisses and para-gneisses	Kjerring-fjell group	Biotite-rich microcline gneisses of the calciferous mica schist formation	Biotite-microcline gneiss
		Vojtja conglomerate	The Storfjäll nappe Quartzites (Viris) Calciferous sediments (Løvfjäll) Slätdal limestone Vojtja quartzite congl.	Marbles Mica schists Quartzites	Tespfjell group	Part of the north-western part of the calcifereous mica schist formation	Fauske
GILLIKS SERIES	Vuorgin Form.	Phyllite Conglomerate Limestone Calcareous arkoses	Tjanga limestone	Marbles Calcareous mica schists Amphibolites	Bjøllådal group	Amphibolite - staurolite gneiss formation	Marble Group
	Gilliks	volcanics	Gilliks Group				
SARVA SERIES	Lospas Form.	Limestone Phyllite Quartzite	(Greywackes, schists, quartzites, conglomerates)	Marble		Calciferous mica schist formation (eastern part)	Sulitjelma schist sequence (Gasak)
	Tjakkik Form.	Phyllites Quartzites	Greenstones Quartzites	Various mica schists with thin quartzite layers	Raudfjell group		Furulund Group Sjönstå Group
MUSKET SERIES	Jullega Form.	Limestone Schists	Pieske Group	Marble calciferous mica schist		(Marble at the bottom)	Pieske Marble
	Tjäula Form.	Tuff Limestone Greenstone Phyllite Quartzite	Metamorphic sediments and volcanics	Graphite schist with quartzite Basement		Graphite schist Granite-gneiss formation	Psammite graphite schist Granitic gneiss
	Klippo Form.	Schists greywackes Limestone (Pieske) Garnet mica schist	Limestone				
	Skertas Form.	Graphite schist Quartzite Basement	Autochthonous sediments Basement				

situated directly on basement rocks of the Lønsdal massif. Steenken also describes 'thinly layered, usually white quartzites' between the graphite schists and the calciferous mica schist formation which has a limestone horizon at the bottom. This is the same sequence as occurs east of Bjøllånes, but because of the small thickness of each rock-type the individual horizons have all been included in the Raudfjell group. In Table 9, however, the graphite schists have been separated from the group.

The 'calciferous mica schist formation' of Steenken covers a wide area and is subdivided by a downfolded unit, called the'amphibolite–staurolite gneiss formation', with an intervening thrust-plane. The latter formation divides the former into a southern and southeastern part and a northwestern part. The southern/southeastern part must correspond to the main part of the Raudfjell group (excluding only the graphitic quartz-mica schist at the bottom) while the northwestern part of the formation in the present author's view corresponds to a higher tectonic level and is probably an entirely different rock unit.

The correlation of the Bjøllådal group with the amphibolite–staurolite gneiss formation seems to be on relatively safe ground. The most conspicuous common features of the two units are the occurrence of metaperidotites and the abundance of amphibolites.

Comparing the maps of Steenken (1957) and Nicholson (1973), both from the same area, makes it clear that Nicholson too regards the northwestern part of the calciferous mica schist formation as a separate unit different from the south-eastern part. In fact, he includes part of the formation bordering the north-western side of the amphibolite–staurolite gneiss formation with the latter, attributing these rocks to the Fauske Marble Group of Nicholson & Rutland (1969). Tectonically overlying the Fauske Marble Group is a biotite microcline gneiss which is equivalent to rocks belonging to the calciferous mica schist formation of Steenken. A marble horizon constituting the top of the Fauske Marble Group and situated within the calciferous mica schist formation would possibly be equivalent to the Hjartås marble of the Tespfjell group, and the biotite–microcline gneiss could then correspond to the Kjerringfjell group. More detailed mapping is necessary, however, before complete reliance can be placed on these correlations.

Nicholson's (1973) map shows that the rocks of the Sulitjelma region are overlain by the Fauske Marble Group and also by the amphibolite–staurolite gneiss formation of Steenken. It can be concluded from this that the Sulitjelma rocks including the Gasak Nappe of Kautsky (1953) must belong to a tectonostratigraphic level lower than the Rödingsfjäll Nappe, in fact lower than the Bjøllådal group. The Sulitjelma rocks as far down as the Furulund schist (Sjøgren 1900) have thus been more or less wedged out on the west side of the Lønsdal basal massif and correspond to a level beneath the Bjøllådal group (i.e. within or above the Raudfjell group). The phenomenon of rock units thinning and wedging out towards the west has been described by Nicholson & Rutland (1969) and Zachrisson (1969) from adjoining areas. From Nicholson's map the correlation of the Fauske Marble Group with the Bjøllådal and Tespfjell groups would seem to be quite reasonable, but some comments are necessary in this connection.

Because of the thrusting between the Bjøllådal and Tespfjell groups and the dissimilarity of their rock successions, it is difficult to accept that they could belong to one unit (i.e. equivalent to the Fauske Marble Group). Correlation of the Tespfjell group with the Fauske Marble Group lends support to the assumption that the former is equivalent to the Dunderland group, as the Fauske Marble contains iron ore of the Dunderland type (the Neverhaugen deposits, Vogt 1910). In addition, the Dunderland group and the Fauske Marble Group are dominated by carbonate rocks. It is, however, not impossible that the latter is directly continuous with the Dunderland group. If this really is the case, then it would also follow that the Rödingsfjäll Nappe has the same tectonostratigraphic position as the Gasak Nappe of Sulitjelma. However, providing the correlation of the amphibolite–staurolite gneiss formation with the Bjøllådal group is correct, then the Gasak Nappe must belong to a tectonic level lower than the Rödingsfjäll Nappe. Only further detailed mapping can clarify this problem.

VÄSTERBOTTEN – SOUTHERN NORRBOTTEN

Kulling (1972) has described three nappes in north-western Västerbotten, namely the Seve–Köli Nappe, the Storfjäll Nappe and the Rödingsfjäll Nappe, which cross the national border between the southernmost end of the Lønsdal basal massif and Lille Umevann about 40 km further south-west.

The Rödingsfjäll Nappe, the lower parts of which correspond to the Kjerringfjell group, is the uppermost nappe unit on the Swedish side of the border. Beneath it is the Storfjäll Nappe, the lower border of which according to Kulling (1972) is 'admittedly based on relatively little field evidence'. Kulling has drawn it between the Sarvas and the Gilliks Series of Marklund (1952) about 5 km south of the border between Norrbotten and Västerbotten, but the continuation towards the Norwegian border is not clear.

The basal thrust of the Seve–Köli Nappe must be found beneath the Raudfjell group. The stratigraphy described by Marklund (1952) from the Sarvas area south of the Lønsdal massif seems to be mostly missing in the Bjøllånes area (Table 9). The Skertas Formation of Marklund (1952), consisting of arkoses, quartzites and graphite schist is almost certainly equivalent to the rusty graphite schist and quartzite lying immediately above the basal granite.

The lowermost marble of the Raudfjell group is considered to be equivalent to the marble of the Jullega Formation of Marklund and to the marble of the Pieske Group of Kulling (Øines, pers. comm. 1974). If this interpretation is correct this would mean that the Klippo and Tjäula Formations are missing in the Bjøllånes area, having probably been cut out by the thrust plane above the Skertas Formation. As well as the notable metamorphic break mentioned earlier, the tectonic discordance reported by Marklund, Kulling and Steenken provides evidence of a thrust plane beneath the Raudfjell group.

The Tjakkik and Luspas Formations of the Sarvas Series (Marklund) should broadly correspond to lithologies of the Raudfjell group, while the Gilliks volcanics and the lower part of the Vuorgin Formation are possibly equivalent to the Bjøllådal group. No metaperidotites, however, are described from the Sarvas area. They are found on the Norwegian side of the border, but it is not yet clear to which tectonostratigraphic level they belong. If there is a tectonic break beneath the Bjøllådal group, as maintained by Steenken (1957), then the correlation of this group with the Gilliks Series becomes more uncertain.

According to Kulling (1972) the entire stratigraphy of Marklund (1952) belongs to the Seve–Köli complex; the same possibly holds for the Bjøllådal group while another possible counterpart of this group, the Mesket lava of Quensel (1922), belongs to the Storfjäll Nappe. The rocks north of Södra Storfjäll, which very much resemble the Bjøllådal group sequence, are ascribed to the Storfjäll Nappe by Kulling (1972) while Zachrisson (1969) regards them as belonging to the lower part of the Köli unit (the Tjopasi Group). In the upper part of the Seve and the lower part of the Köli, Zachrisson describes a strong concentration of ultrabasic rocks. It is tempting to correlate this zone with the Bjøllådal group sequence such that this group represents the top of the Seve complex and that the overlying Tespfjell group is an equivalent unit to the Storfjäll Nappe. On the other hand it is equally possible that the Tjopasi Group should be correlated with the Bjøllådal group, a correlation which does not interfere with recognition of the equivalence between the Storfjäll Nappe and the Tespfjell group.

To carry the correlations a bit further it is worth mentioning that Zachrisson (1969) correlates the lower part of the Tjopasi Group with the Rotik 'Series' and the Mesket 'Series' of Kulling (1933) which again are approximately equivalent to the Ro 'Series' and the Seima 'Series', respectively, of Kulling (1958). All this adds up to the rather uncertain conclusion that the Bjøllådal group is possibly of Lower or Middle Ordovician age.

THE COASTAL DISTRICTS OF NORDLAND: MO I RANA TO BODØ

The rock sequence above the basal massifs described by Hollingworth et al. (1960), Nicholson & Walton (1963), Rutland & Nicholson (1965) and Wells & Bradshaw (1970) from the Glomfjord area, the Meløy Group, is quite similar to that above the Lønsdal basal massif. It consists of psammitic to pelitic schists, hornblende schists, calcareous mica schists and marbles. From Holmsen's (1932) map it can be seen that ultramafic rocks also occur within the group. The sequence is described as parautochthonous (Hollingworth et al. 1960) and is quite similar to that of the Raudfjell and Bjøllådal groups. The Sokumfjell Marble Group belonging to the Beiarn Nappe (Rutland & Nicholson 1965) is a structurally higher unit than the next group in the Bjøllånes area, the Tespfjell group. As discussed earlier, the latter can probably be correlated with the Fauske Marble Group which again is correlated with the Saura and the Gildeskål Marbles (Rutland & Nicholson 1965), all of which are belonging to a middle tectonic unit beneath the Beiarn nappe.

The Hjartås Marble of the Tespfjell group is far more likely to be equivalent to the Fauske marbles than to the Pieske marbles, as suggested by Strand (1972) and Nicholson (1973). At least, the Pieske marble belongs to a lower tectonic level than the other two marble formations, but one cannot exclude the possibility of an identical age.

The Rödingsfjäll Nappe most probably belongs to a tectonic level between the Fauske Marble Group and the Beiarn Nappe, and the biotite–microcline gneiss of Nicholson (1973) is a likely unit for correlation with the Kjerringfjell group. Nicholson even suggests the possibility that this gneiss represents the lowermost unit in the east of the Beiarn Nappe. If this is so, then the Rödingsfjäll Nappe must be included in Nicholson's (1973) Fauske Marble Group somewhere between the rocks referred to as the amphibolite–staurolite gneiss formation of Steenken (1957) and the biotite–microcline gneiss of Nicholson (1973). The Beiarn Nappe might then correspond to the Helgeland Nappe, (Ramberg, in a lecture at Det Nordiske Geologiske Vintermøte i Åbo, 1966). As the description of these nappes seems to indicate that they are of different age, this correlation is not very likely. It is hoped that the mapping now in progress in the area between Rana and Salten west of the Lønsdal basal massif will eventually clarify these problems.

Acknowledgements. – I thank Professor J. A. W. Bugge who has been my supervisor during the field work, Dr. I. B. Ramberg and Dr. M. Gustavson for discussions and for their critical reading of the manuscript, and Dr. D. Roberts for suggesting improvements and correcting the English text. Dr. O. H. J. Christie was helpful in giving advice during the preparation of the manuscript. Thanks also go to E. R. Neumann for helping with the microprobe work. Money to finance the field work was generously provided by A/S Norsk Jernverk, Rana Gruber.

REFERENCES

Albee, A. L. 1962: Relationships between the mineral association, chemical composition and physical properties of the chlorite series. *Amer. Mineral. 47*, 851–870.

Bugge, J. A. W. 1948: Rana Gruber. *Norges geol. Unders. 171.*

Burri, C., Parker, R. L. & Wenk, E. 1967: *Die optische Orientierung der Plagioklase,* häuser Verlag, Basel–Stuttgart.
Unterlagen und diagramme zur Plagioklasbestimmung nach der Drehtischmetode. Birk-

Chinner, G. A. 1960: Pelitic gneisses with varying ferrous/ferric ratios from Glen Clova, Angus, Scotland. *J. Petrol. 1*, 178–217.

Elliott, R. B. & Cowan, D. R. 1966: The petrochemistry of the amphibolites of the Holleindalen greenstone group, Jotunheimen, Norway. *Norsk geol. Tidsskr. 46*, 309–325.

Gjelle, S. T. 1974: *En petrografisk/strukturgeologisk undersøkelse i Bjøllånesområdet, Rana.* Cand. real. thesis, Univ. of Oslo.

Gustavson, M. 1969: The Caledonian Mountain Chain of the Southern Troms and Ofoten Areas. Part II. Caledonian Rocks of Igneous Origin. *Norges geol. Unders. 261.*

Higgins, M. W. 1971: Cataclastic Rocks. *Geological Survey Professional Paper 687.* U.S. Department of the Interior. Washington, 97 pp.

Hollingworth, S. E., Wells, M. K. & Bradshaw, R. 1960: Geology and structure of the Glomfjord region. *Int. Geol. Congr. 21st. Copenh. Rep. Sess. Norden XIX*, 33–42.

Holmsen, G. 1932: Rana. *Norges geol. Unders. 136.*

Irvine, T. N. & Barager, W. R. A. 1971: A Guide to Chemical Classification of the Common Volcanic Rocks. *Canadian J. Earth Sci. 8*, 523–548.

Kautsky, G. 1953: Der geologische Bau des Sulitelma–Salojauregebietes in den nordskandinavischen Kaledoniden. SGU Ser. C. No. 528, Årbok 46, 1952.

Kulling, O. 1933: Bergbyggnaden inom Björkvattnet – Virisen-området i Västerbottensfjällens centrala del. *Geol. Fören. Stockh. Förh. 55*, 167–422.

Kulling, O. 1958: Om begreppen vojtjakonglomerat, rokonglomerat och mesketlava i Västerbottensfjällen. *Geol. Fören. Stockh. Förh. 80*, 226–234.

Kulling, O. 1972: The Swedish Caledonides. *In* Strand, T. & Kulling, O.: *Scandinavian Caledonides*, Wiley – Interscience, London.

Kuno, H. 1968: Differentiation of Basalt Magmas. *In* Hess, H. H. & Poldervaart, A. (eds.) *Basalts.* John Wiley & Sons, New York.

Leake, B. E. 1964: The Chemical Distinction between Ortho- and Paraamphibolites. *J. Petrol. 5*, 238–254.

Marklund, N. 1952: A Cambro–Ordovician Type-section in the Sarvas Region S.E. of Nasafjäll, Lapland, and Problems suggested thereby. *Geol. Fören. Stockh. Förh. 74*, 353–384.

Miyashiro, A. 1974: Volcanic rock series in island arcs and active continental margins. *Am. J. Sci. 274*, 321–355.

Moine, B. & de la Roche, H. 1968: Géochimie. – Nouvelle approche du problème de l'origine des amphibolites à partir de leur composition chimique. *C.r. Acad. Sci. Paris, 267, ser. D*, 2084–2087.

Nicholson, R. 1973: The Vatnfjell Fold Nappe Complex of Saltdal, North Norway. *Norsk geol. Tidsskr. 53*, 195–212.

Nicholson, R. & Rutland, R. W. R. 1969: A Section across the Norwegian Caledonides; Bodø to Sulitjelma. *Norges geol. Unders. 260.*

Nicholson, R. & Walton, B. J. 1963: The structural geology of the Navervatn–Storglomvatn area, Glomjord, Northern Norway. *Norsk geol. Tidsskr. 43*, 1–58.

O'Hara, M. J. 1967: Mineral facies in ultrabasic rocks. *In* Wyllie, P. J. (ed.) *Ultramafic and related rocks.* John Wiley & Sons, New York, 7–18.

Oxaal, J. 1919: Dunderlandsdalen. *Norges geol. Unders. 86.*

Quensel, P. 1922: Nya problem inom Västerbottens fjällområden. *Geol. Fören. Stockh. Förh. 44*, 674–677.

Ramberg, I. B. 1967: Kongsfjell-områdets geologi, en petrografisk og strukturell undersøkelse i Helgeland, Nord-Norge. *Norges geol. Unders. 240.*

Rekstad, J. 1913: Fjeldstrøket mellem Saltdalen og Dunderlandsdalen. *Norges geol. Unders. 67.*

Rittmann, A. 1962: *Volcanoes and their activity.* John Wiley & Sons, London.

Rutland, R. W. R. & Nicholson, R. 1965: Tectonics of the Caledonides of part of Nordland, Norway. *Q. J. Geol. Soc. Lond. 121*, 73–109.

Shaw, D. M. & Kudo, A. M. 1965: A test of the discriminant function in the amphibolite problem. *Mineral. Mag. 34*, 423–435.

Sjögren, H. 1900: Öfversigt af Sulitelma-områdets geologi. *Geol. Fören. Stockh. Förh. 22*, 437–462.

Steenken, W. F. 1957: Geology and petrology of the region south of Russånes, Saltdal, Norway. *Univ. van Amst. Geol. Inst., Meded. 244.*

Strand, T. 1972: The Norwegian Caledonides. *In* Strand, T. & Kulling, O.: *Scandinavian Caledonides.* Wiley–Interscience, Lond.

Søvegjarto, U. 1972: *Berggrunnsgeologiske undersøkelser i Dunderlandsdalen, Nordland.* Cand. real. thesis, Univ. of Oslo.

Turner, F. J. & Weiss, L. E. 1963: *Structural analysis of metamorphic tectonites.* McGraw-Hill, New York.

Vogt, J. H. L. 1890: Salten og Ranen. *Norges geol. Unders. 3.*

Vogt, J. H. L. 1894: Dunderlandsdalens jernmalmfelt. *Norges geol. Unders. 15.*

Vogt, J. H. L. 1910: Norges jernmalmforekomster. *Norges geol. Unders. 51.*

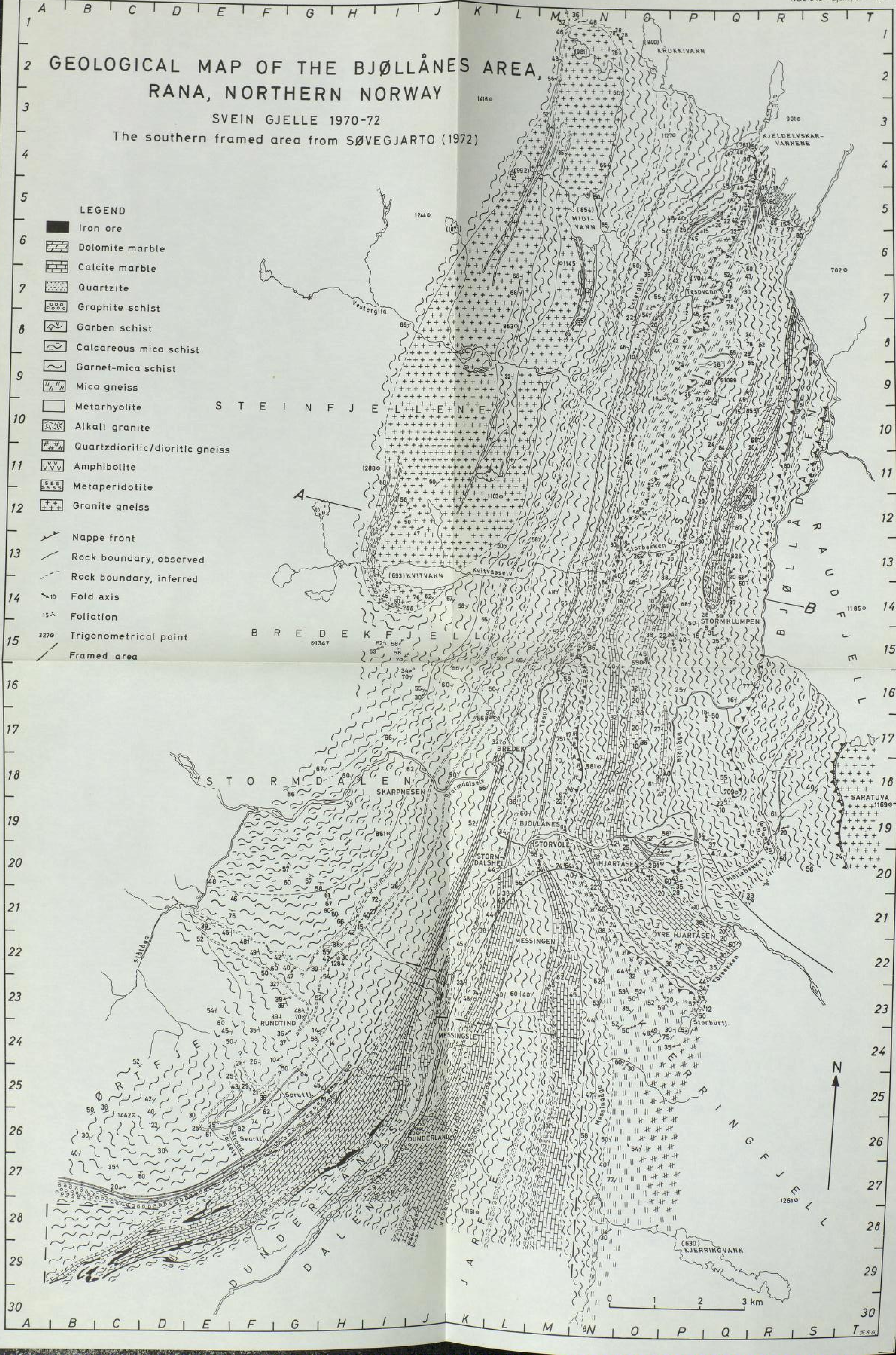
Walker, K. R., Joplin, G. A., Lovering, J. F. & Green, R. 1960: Metamorphic and metasomatic convergence of basic igneous rocks and lime-magnesia sediments of the Pre-Cambrian of northwestern Queensland. *J. geol. Soc. Aust. 6*, 149–177.

Wells, M. K. & Bradshaw, R. 1970: Multiple foldin in the Sørfinnset area of Northern Norway. *Norges geol. Unders. 262.*

Wilson, M. R. & Nicholson, R. 1973: The structural setting and geochronology of basal granitic gneisses in the Caledonides of part of Nordland, Norway. *J. Geol. Soc. Lond. 129*, 365–387.

Winkler, H. G. F. 1967: *Petrogenesis of metamorphic rocks.* 2nd. ed., Springer-Verlag, Berlin.

Zachrisson, E. 1969: Caledonian geology of Northern Jämtland – Southern Västerbotten. *Sver. geol. Unders., Ser. C, Yearb. 64, 1970*, 1–33.


GEOLOGICAL MAP OF THE BJØLLÅNES AREA, RANA, NORTHERN NORWAY
SVEIN GJELLE 1970-72
The southern framed area from SØVEGJARTO (1972)
LEGEND
Iron ore
Dolomite marble
Calcite marble
Quartzite
Graphite schist
Garben schist
Calcareous mica schist
Garnet-mica schist
Mica gneiss
Metarhyolite
Alkali granite
Quartzdioritic/dioritic gneiss
Amphibolite
Metaperidotite
Granite gneiss
Nappe front
Rock boundary, observed
Rock boundary, inferred
Fold axis
Foliation
Trigonometrical point
Framed area
STEINFJELLENE
BREDEKFJELL
STORMDALEN
ØRTFJELL
DUNDERLANDSDALEN
JARFJELL
KJERRINGFJELL
BJØLLÅDALEN
RAUDFJELL
KRUKKIVANN
KJELDELVSKARVANNENE
MIDTVANN
KVITVANN
Kvitvasselv
Vestergila
Østergila
Storbekken
STORMKLUMPEN
SARATUVA
BREDEK
SKARPNESEN
Stormdalselv
BJØLLÅNES
STORVOLL
STORMDALSHEI
HJARTÅSEN
ØVRE HJARTÅSEN
MESSINGEN
MESSINGSLETT
DUNDERLAND
RUNDTIND
Sprutti
Svarttj.
Strandjordelv
Storburtj.
KJERRINGVANN
Stilåga
Bjellåga
Messingåga
Tespvann
Tespa
Møllebekken
Tørbekken
0 1 2 3 km
N
A
B