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Status report on talc prospecting

in Helgeland, Norway

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Summary:
A prospecting programme for talc has been carried out in Helgeland. The results are both good and bad;
A new talc deposit has been found in Kvanndalen, a few km west of Altermark. The deposit contains the mineral assemblage talc-breunnerite-olivine. Only parts of the deposit are exposed, and the size is not yet known, except that the maximum width is around 50 metres. To be able to use the ore, there must either be a market for the assemblage talc-breunnerite-olivine, or it must be possible to remove the olivine. A further deposit of interest occurs in Misvær.
Otherwise, talc is rather uncommon in the numerous ultramafic lenses around the Høgtuva-, Sjona- and Svartisen windows. The ultramafic lenses are dominated by the metamorphic assemblage enstatite-anthophyllite-carbonate with or without olivine. It is concluded that the metamorphic grade has, in general, been too high in the western area and that possible pre-existing talc-carbonate assemblages have been altered to the minerals above.
The deposit in Kvanndalen probably represent the margin of what can be termed the Altermark Talc Province. Only olivine has been included in the talc-carbonate assemblage, while bodies further to the west carry olivine, enstatite and anthophyllite.

Keywords: Industrimineraler	Ultramafisk bergart	
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Introduction

Ultramafic lenses situated in the Rödingsfjället Nappe Complex in the Altermark area (Photo 1) contain ultramafic talc-carbonate deposits of high quality. The talc-carbonate assemblage has been formed by regional metamorphism at temperatures around 640 °C at pressures of 7–10 Kb (Karlsen 1995). A great number of ultramafic lenses occur in the Rödingsfjället Nappe Complex around the basement gneiss regions of Høgtuva, Svartisen and Sjona. Some of them are known to be sagvandites (mixture of carbonate and enstatite), some are known to be orthopyroxenites, while some are known to be peridotites and harzburgites. In addition, some of the ultramafites are known to contain talc (Korneliussen 1977).

In co-operation with Norwegian Talc AS, the ultramafic lenses have been investigated. The primary goal in the present work is 1) to find if there are talc deposits in this area, in addition to those in Altermark, and 2) to establish a model that explains the zoning patterns in the ultramafites and the occurrences of talc relative to the regional metamorphic evolution. The present report focuses on talc prospecting.

Previous work

The Altermark area has been described in detail by Karlsen (1995). Outside the Altermark area, no significant prospecting for talc has been carried out in the coastal area of Helgeland, with the exception of a reconnaissance study carried out by Olerud in 1992 (pers. comm.). However, some descriptions have been made that focus on the origin of the ultramafic lenses, or to the occurrences of platinum group elements (PGE) and of nickel and chromium in the ultramafites. In some of these reports there are a few comments on talc occurrences, for example by Korneliussen (1977), who investigated the potential of economic minerals in the Lurøy and Rødøy communities.

The origin of the ultramafic lenses is important, not only with regard to the history of the orogenesis (mountain building), but also with respect to economic aspects. Occurrences of talc in ultramafic rocks are intimately connected to the geological history; since, in order to form talc, the chemistry, and by implication, the geological setting, must be suitable. After the original formation, the rock has undergone a deformational and metamorphic history. To obtain talc, the deformational, and especially the metamorphic settings must be appropriate.

Bucher-Nurminen (1988) developed a model that attempted to explain the origin of the ultramafites in broad terms. One of his conclusions was that the ultramafites are allofacial, i.e. their metamorphic evolution is different from the regional metamorphism found in the country rocks. Furthermore he believed that the ultramafic lenses are remnants of sub-continental mantle, and not remnants of the mantle beneath the ocean floor – a model that is more common. Bucher-Nurminen (1991) made a genetic model for the ultramafic rocks in the Norwegian part of the Caledonides. In this connection, the ultramafic rocks and some of the surrounding rocks in Altermark were investigated. The metamorphic conditions were interpreted to be about 480 – 520 °C at 4 - 6 Kb. The interpretation was partially based on the occurrence of the mineral assemblage Gnt + Chl + Bi in metapelites, which he believed represented a paragenesis. Later work by Karlsen (1995) showed that this interpretation is

somewhat incorrect and that the metamorphic peak reached around 640 °C at 7-10 Kb; i.e. significantly higher. Such metamorphic conditions are close to the upper stability field of talc-carbonate rocks. By increasing the temperature, the mineral phase olivine will form. By increasing the CO_2 pressure or the temperature the minerals anthophyllite and eventually enstatite will form.

Another paper dealing with the genesis of minerals in the ultramafites was written by Bakke & Korneliussen (1986). These authors describe the occurrence of so-called jack-straw textured olivine in ultramafites at Nordværnes at the coast of Helgeland.

Some talc-bearing rocks are registered in NGU's database on industrial minerals and especially on dimension stone. Some of these deposits have been visited in the present work.

Geological setting

Two major Caledonian Nappe Complexes dominate the coast of Helgeland; the Rödingsfjället Nappe Complex and the Helgeland Nappe Complex. Both complexes consist of multi-deformed nappes carrying different amounts of psammitic, pelitic and calcareous schists and gneisses, amphibolite, marbles, gabbros and granitoid intrusions (Gustavson & Gjelle 1991). Ultramafic lenses occur widely in the coastal area of Nordland, especially within the Rödingsfjället Nappe Complex.

A characteristic feature of coastal Helgeland area is the occurrence of large windows consisting of Precambrian rocks. The origin of the windows, which are termed the Sjona-, Høgtuva-, and the Svartisen windows, are controversial. Some researchers believe that the Precambrian rocks defined the basement for the Caledonian Nappes when they were thrust onto the continental crust, and later became folded together with the Caledonian cover (e.g. Gustavson & Gjelle 1981). Others believe they are parts of a major crystalline nappe which included the Precambrian rocks in Lofoten and Nasa (e.g. Hossack & Cooper 1986). A third alternative is that they represent the cores of major basement involved nappes where the faults root into the sub-continental mantle (e.g. Bucher-Nurminen 1988). All these models touch upon the emplacement history of ultramafic lenses and their metamorphic history and thereby have major implications for occurrences of talc.

Locality description

Locality: 98_1 Bjørnålia (Fig. 1, Photo 2)

The old soapstone-quarry is 100 metres long, 50 m wide, 30 m deep (Photo 2). From this quarry, soapstone has been delivered to the Nidaros Cathedral in Trondheim in the years 1897-1960 (Alnæs 1995). The soapstone and the quarry occur along the western border of a serpentinite that continues 3-400 metres towards south; together, the ultramafic lens is around 600 metres long. The general foliation is 196/80-90°. A 5 m thick talc-bearing chlorite schist occurs along the westernmost boundary. In the southern part, a gabbro is associated with the serpentinite. A depression in the southern part, 20 – 30 metres wide, may reflect the existence of a talc-bearing rim (not exposed). Exposures of chloritite is found in the westernmost part of this depression. The soapstone is dark coloured and fine-grained. Microscopic investigation indicates that the soapstone is composed of chlorite and amphibole, while talc only occurs in very minor amounts (samples 98_1a, 98_1b & 98_1c, Table 1).

Locality: 98_2 Luktvannet (Fig. 2)

A small ultramafic lens occurs along the road around Luktvannet, a few km north of Mosjøen. The ultramafite is a greenish pyroxenite/hornblendite, which is pseudomorphosed to talc in a thin zone in the rim. The talc-potential is very low.

Locality: 98_3 Kvalvik/Fjøshagen (Fig. 3)

This is an ultramafic lens dominated by enstatite-peridotite. No reaction rim is observed, only slightly more parallel oriented enstatite along the boundary. The talc potential is very low.

Locality: Nordværnes (Figs. 3 & 4; Photo 6)

A sizeable ultramafic lens, described by Korneliussen (1976) and Bakke & Korneliussen (1986), occurs at Nordværnes. The ultramafic body has a core of partly serpentinised dunite surrounded by talc- and dolomite-bearing olivine orthopyroxenite with a rim of well-developed jack-straw textured olivine orthopyroxenite along the contact with the country rocks. Minor amounts of talc are observed together with tremolite as a pseudomorphic alteration of bronzite. Otherwise, talc occurs in a few 0.5-2 m thick veins that crosscut the ultramafic body, together with olivine, carbonate and, in some cases, bronzite (Bakke & Korneliussen 1986).

Locality: 98_4 Sjåvika (Fig. 3, Photo 3)

The ultramafic lens is dominated by enstatite, but with minor amounts of olivine. No talc alteration is observed.

Locality: Steintuva (Fig. 3)

The ultramafite contain orthopyroxene in the core that may be primary, while the rest of the body consists of metamorphic orthopyroxene and olivine. Some amphibole of secondary origin is also present. No talc is observed.

Locality: 98_10 Hestmann, body 1, northern part (Fig. 3)

The ultramafic lens is an orthopyroxenite. No reaction rim is found, except for a very thin chlorite zone (20 cm). A weakly developed foliation occurs along the border. A joint cuts the body, but does not contain talc. Some smaragdite is present.

Locality: 98_10 Hestmann, body 2 (Fig. 3)

Similar to 98_10, body 1.

Locality: 98_11 Rødøya outside Hestmann (Fig. 3)

The ultramafite is an orthopyroxenite. 1-2 cm of talc occurs between smaragditite (0-2 cm, locally 5-10cm) in the rim and the orthopyroxenite. The ultramafite is associated with an amphibolite; garnet-mica gneiss is also present.

Locality: Western part of Hestmann (Fig. 3; Photo 9)

View towards Hestmann from the west. From the distance, most of the Hestmann island appears to be part of a mafic/ultramafic complex, as is the small islands like Teistholmen and Kalvdalsholmen west of Hestmann. No talc is observed on the small islands.

Locality: 98.12 Bukkøya, south of Hestmann (Fig. 3)

This is a mafic/ultramafic complex, in which the mafic part is composed of garnet-amphibolite while the ultramafic part is composed of coarse-grained enstatite orthopyroxenite. Along the mafic/ultramafic contact the amphibolite is coarse-grained (~ 1 m thick). The mafic part is intruded by pegmatitic trondhjemite with a large number of coarse-grained books of mica and tourmaline. No talc is observed.

Locality: 98_13 Store Esjeholmen (Fig. 3)

The ultramafic lens is composed of enstatite + some olivine. Primary banding is observed. The ultramafite is more olivine-rich than the ultramafites described so far. No talc is observed.

Locality: 98_14 Store Esjeholmen, southern part (Fig. 3; Photo 24)

Garnet-amphibolite surrounds the ultramafites, which can be termed enstatite-rich harzburgite and garnet peridotite. The reaction rim is composed of an irregular thin smaragditite. The amphibolite consists of garnet bands closest to the ultramafite. A trondhjemite cuts the ultramafite. A few enstatite/chrysotile veins are observed. White, pure magnesite is observed in a thin (1 cm) vein.

Locality: 98_15 Rødøy (Fig. 3)

The island contains two areas with ultramafite;
At the northernmost area, a talc-carbonate rock containing three types of ultramafite are observed:

1. Dunite with light brown weathering colour.
2. A dark greenish rock without brown weathering colour.
3. Olivine-enstatite rock

No reaction zone is observed towards the country rock, and the talc potential is considered as very low. In the southernmost area, the ultramafite is the same type as most localities along the coast of Helgeland, and consists of enstatite and olivine. The talc-potential is considered as low.

Locality: 98_16 Nordfjordnesset (Fig. 3; Photos 7 & 8)

Enstatite-rich ultramafite with dm-scale radial aggregates of enstatite and olivine towards the rim. Reaction zones in the rim are well developed, but with very limited amounts of talc. The core is dominated by enstatite, while the rim contains jack-straw textured enstatite/olivine (?), followed by a thin zone of talc-carbonate (a few dm), strongly green-coloured smaragditite, biotitite, and finally, quartz and amphibole. The talc in the talc-carbonate zone is badly developed.

Locality: 98.17 Lemstein (Fig. 3; Photo 12)

A big ultramafic lens is drawn on the preliminary map-sheet Svartisen 1928 II (Johnsen 1983). The access to the ultramafic lens is rather difficult and time-consuming due to the extremely steep topography. For this reason, only loose blocks occurring below the ultramafite body have been studied. Many of the blocks are talc-bearing and contain the minerals talc (~ 30%), magnesite (~ 40%) and enstatite (~30%); they could be termed sagvandite. In other blocks, talc is missing and the rock contains only coarse-grained magnesite + enstatite. The enstatite occurs as radial aggregates in a matrix of magnesite.

Locality: 98_18 Hellarvika (Fig. 3; Photos 10 & 11)

A relatively coarse-grained magnesite-talc-enstatite lens is situated within a garnet-mica-schist with a strike/dip of 354/48°. The deposit has a width of 30 m, a height of 5-10 m above surrounding surface, while the length is unknown. Microscopic studies show that enstatite is the dominant mineral, but with contents of olivine, carbonate (breunnerite), talc and amphibole in less amounts (sample 98_18 & 98_18b, Table 1).

Locality: 98_19 Esjeholmene (Figs. 3 & 9)

Zoned ultramafite with talc-carbonate-enstatite in the rim and serpentinite in the core. Much of the core has been weathered out, while the rim sticks up. The core is intruded by a vein of white talc with a thickness of 1-2 m. Country rocks are amphibolite and garnet mica schist. Microscopy of the talc vein shows that the rock is very fine-grained and consists of talc and carbonate (breunnerite) as the primary minerals, with traces of chlorite and magnetite (sample 98_19, Table 1).

Locality: 98_20a Esjeholmen (Figs. 3, 10 & 11; Photos 4 & 5)

The ultramafite is an orthopyroxenite defined by up to 5 cm long enstatite porhyroblasts with jack straw olivine up to 1 m long presented next to the rim. In the contact with the country rock (amphibolite) an additional 1 m thick reaction rim of green-coloured smaragditite occur. The entire body represents a heavily altered orthopyroxenite.

Locality: 98_20b Grønnøy (Fig. 3)

Ultramafite lenses dominated by enstatite, but with many internal greenish zones, probably representing altered chloritite (these have not yet been investigated microscopically). The body is intruded by a number of trondhjemite veins. Between and around the ultramafic lenses amphibolite and calc-silicate rocks occur. No talc is observed.

Locality 98_21: Engavågen (Fig. 3)

The ultramafic lens is dominated by enstatite. No talc is observed.

Locality: 98_24 Ørnes (Fig. 3)

Ultramafite just north of Ørnes. According to the literature this is a "sagvandite". The body is very similar to the ultramafites described earlier with enstatite as a dominant mineral and with breunnerite as an additional mineral. The body has not been investigated microscopically. Veins of trondhjemite together with amphibolite cut the body. A greenish amphibolite is present south of the ultramafic boundary. Talc occurrences are not detected.

Locality: 98_25 Tollådalen (Fig. 5)

A dark greenish/black metapyroxenite and a dunite define the ultramafic part of a meta-gabbro/amphibolite /ultramafite complex. No talc is detected.

Locality: 98_30, Stolpelia, Misvær (Fig. 6; Photo 13)

A small pit in soapstone. The pit seems to have a length around 30–40 m and a width around 20 m. According to rumours, test-mining were carried out in 1960. NGU investigated the deposit during 1985-1986, partly by drilling (Lund 1986a, b). A total of 37,000 tonnes of ore were proven by the drillings. Later, the deposit has been placed under protection because of the existence of heritage relicts.

The talc-bearing rock at the deposit occurs as a lens within a pyroxenite. According to the map-sheet Misvær (Solli et al. 1992), several other lenses occur within the pyroxenite, but these have not been investigated for talc. The soapstone is fine-grained and apparently of rather good quality. It contains much talc and little magnesite, but is rich in pyrite. Microscopy shows that very fine-grained talc and some chlorite define the groundmass around larger grains and aggregates of carbonate (Sample Mis_tak, Table 1). The soapstone contains a few chlorite zones, sometimes with some biotite. The foliation is variable, but generally the strike is 160° with a dip of 35° towards the Southwest.

Locality: Druåsen, Misvær (Fig. 6; Photo 14)

Talc-carbonate rock around a big body of serpentinite. At the investigated locality a ca. 8-10 m wide talc-carbonate bearing zone at the contact between serpentinite and the country rock is exposed. The rock is rather dark grey and schistose. Microscopy shows that talc, chlorite and amphibole are the main minerals (Samples Mi3_98 & Mi4_98, Table 1). The content of amphibole makes the investigated part of the deposit uninteresting for future exploitation. At another locality, near the sea, only a few cm of talc-carbonate is exposed. It is a possibility that larger areas of talc exist around the very big ultramafites.

Locality: Leirskarddalen (Figs. 2 & 9; Photo 15)

This is an old pit around 10 m and 2 m deep in soapstone/talc-carbonate. A block has recently been removed (Photo 15). The soapstone is a light coloured talc-carbonate rock that is rather similar to the Altermark type, with carbonates up to 2 cm in size. Unfortunately, the rock contains fibrous amphibole in addition to talc and carbonate, at least in the area where the last block has recently been taken out. The talc-carbonate contains an alteration zone of smaragditite (thin) and chloritite. The foliation around the pit is around horizontal. The country rock is not exposed. The western boundary is present around 20 m from the pit. The orientation of the layering is here around 218°/60°. Towards east and north, the boundary is not exposed, and towards south the ultramafite is eroded away. From the field observations, the ultramafic lens seems to be quite small. Microscopy shows that the rock contains talc and carbonate as the primary minerals, but with much anthophyllite as a third component (Sample Leir 1, Table 1).

Locality: Kvanndalen (Figs. 3, 7 & 14; Photos 16, 17 & 18)

A new deposit was discovered in Kvanndalen. Three exposures have been found so far of this deposit, which generally contains the assemblage talc-carbonate-olivine. The rock is rather coarse-grained and contains jack-straw olivine. The ore is situated in a depression. It has a maximum width around 50 metres while the length along strike is unknown. A small lake occupies most of the depression and the surface exposure of the ore is therefore limited.

K1 (easternmost lens): The jack-straw olivine is up to 10-15 cm. Some amphibole is present close to the lake, but this could be associated with a penetrating chlorite zone. Also observed was a 2 cm wide vein of tremolite. The talc is very light-coloured and has apparently a very high whiteness. The easternmost lens is around 10 m wide and 15 m long. However, its boundaries are not exposed. Microscopic investigation of one sample (Kvann K1G, Table 1) indicates that parts of the ore at this locality is olivine rich (ca. 50%) but with a talc content of around 32%.

K2: Two types of ore are present: 1) green-coloured talc-carbonate with some jack-straw olivine, and 2) talc-olivine (jack-straw), where the first one dominates. The talc-olivine seems to occur as lenses in talc-carbonate-olivine. The talc in both types is apparently of high quality. Microscopic investigation of the first type shows that the ore contains around 35% talc + 35% breunnerite + 35% olivine.

K3 (westernmost lens): Talc-carbonate with jack-straw olivine; coarse-grained. A vein dominated by chlorite vein crosscuts the body.

In general, the olivine in the Kvanndalen deposit is rather coarse-grained and idioblastic and its grain boundaries are rather well defined. The talc is often coarse grained and idioblastic. The carbonates are breunneritic with high Fe/Mg-ratio. A relatively high Fe/Mg-ratio is also indicated for the olivine. Nickel is situated within the structures of the talc, olivine and carbonates. The magnetite contains some Cr in the core, but is otherwise pure Fe_3O_4.

The deposit could be of commercial interest if:
1. it is possible to use the rock as it is, but with magnetic separation of the magnetite, and,
2. if it is possible to remove the olivine in addition to the carbonate. If so, the metamorphic olivine could be a possible additional product. However, a high content of Fe is disadvantageous.

To be able to know if the deposit is of economic interest, it is necessary to investigate the size of the deposit by magnetometry. Also, the different varieties of talc-bearing rocks should be sampled for product-testing.

Locality: Øvre Fagervollvann (Fig. 3)

An ultramafic lens situated just east of the lake Øvre Fagervollvann is dominated by the minerals enstatite and olivine, with less amounts of carbonate and talc (samples ØF1, ØF1UM, ØF1UM2, Table 1). In the core, veins of anthophyllite crosscut the enstatite-olivine-carbonate assemblage. Close to the country rock, anthophyllite dominates (sample ØF1anth, Table 1) in a 30 cm wide zone. A thin zone containing smaragdite and chlorite occurs between the anthophyllite dominant part and the country rocks. The country rocks are dominated by garnet-mica-schist, but along the strike close to the body amphibolite occurs and the garnet-mica-schist is graphitic. The ultramafite has no talc-potential.

Locality: Body 1 Loftet (Figs. 8 & 12)

The ultramafic body is situated within a garnet-2-mica-schist. Most of the ultramafic body is dominated by anthophyllite with subordinate amounts of enstatite, while carbonate and talc occur in minor amounts (sample Lof 2 & 2b, Table 1). In the rim, carbonate is more common and occurs together with enstatite and anthophyllite in about equal amounts, while talc is present in subordinate amounts (sample Lof 1, Table 1).

Locality: Body 2 Loftet (Fig. 8; Photo 19)

The ultramafic rock is made up of anthophyllite, breunnerite and chlorite (sample Lof 3, Table 1). The anthophyllite is of secondary origin relative to the carbonate-chlorite, and occurs in widespread veins. The body appears above a 5 metres thick calcite marble, which in turn appears on top of a garnet-2-mica-schist. In the rim of the ultramafites green-coloured smaragditite appears as fibrous aggregates. Also chloritite appears in the rim (Lof 4, Table 1).

Locality: Body 3 Loftet (Fig. 8)

The core (most of the body) contains carbonate and minor talc intruded by numerous veins of anthophyllite crosscutting the carbonate (+ talc) assemblage.

Locality: Body 4 Loftet (Figs. 8 & 13; Photos 20, 21, 22 & 23)

The ultramafic body is situated within calcite marble, amphibolite and garnet-2-mica-schist. Anthophyllite, enstatite, carbonate and talc are the dominant minerals (samples Lof 6 & 6b, Table 1). Along the rim, the body is more light-coloured and coarse-grained without the typical rusty weathering colour and is dominated by enstatite (Lof 7, Table 1).

Locality: Body 5 Loftet (Fig. 8)

The biggest ultramafite of the investigated lenses at Mel-loftet was difficult to reach and only a reconnaissance study was made from helicopter. No pure talc or talc-carbonate rocks were observed and the body proved to be quite similar to those described above.

Table 1: Approximate mineralogical content (vol. %) of talc-bearing or talc-associated rocks.

Locality	Name	Talc	Carb.	Chlor.	Enstat.	Olivine	Amph.	Magn.	Sulph.	Serp
98_1a	Bjørnålia		3	35			60			
98_1c	Bjørnålia	5	5	45			45			
98_1d	Bjørnålia	5	5	60			30			
ØF1	Ø. Fagervollvann	10	10		30	35	15			
ØF1 UM	Ø. Fagervollvann	15	20	1	25	35		x		
ØF1anth	Ø. Fagervollvann	5	30	x			60			
ØF2smar	Ø. Fagervollvann			55			40	x		
ØF UM2	Ø. Fagervollvann	15	20		20	40		X		
KvannK1G	Kvanndalen, K1	32.2	10.2	1.7		50		2.1		2.8
KvannK2F	Kvanndalen, K2	35	35	2		25		5		
Leir 1	Leirskarddalen	25	40	3			30		x	
98_18	Hellarvika	10	10		50	15		2		
98_18b	Hellarvika	5	20		30	20	20	X		
98_19	Esjeholmene	50	45	3				x		
Mis_tak	Stolpelia, Misvær	40	40	20					x	
Mi3_98	Druåsen, Misvær	40	10	30			20			
Mi4_98	Druåsen, Misvær	40	10	30			20			
Lof 1	Mel-loftet	10	40		40		50	3		
Lof 2	Mel-loftet	5	5		10		70	-		
Lof 2b	Mel-loftet	Tr	20	Tr	70		5	-		
Lof 3	Mel-loftet	Tr	30	30	-		40	-		
Lof 4	Mel-loftet	-	20	80	-		-	-		
Lof 6	Mel-loftet	65	-		10		20	-		
Lof 6b	Mel-loftet	3	30		20		40	10		
Lof 7	Mel-loftet	Tr	-		15		80	1		

Metamorphic conditions

The metamorphic conditions for the ultramafites and their zoning patterns are not the main issue of this report, but some comments are nevertheless made since they are of critical importance for the understanding of talc-occurrences and future prospecting.

Serpentinites are altered to talc-carbonate when the temperature reaches 400-500 °C at ca. 4 Kb pressure (Johannes 1969):

$$2\ \text{Serp} + 3\ CO_2 = 1\ \text{talc} + 3\ \text{Mgs} + 3\ H_2O$$

According to Mellini et al. (1987) and O'Hanley et al. (1989) the antigorite (serpentine) is stable all the way up to 600 °C at 8 Kb. The talc-carbonate assemblage is stable between 490-660 °C (Johannes 1969). In order to achieve a talc-carbonate assemblage, a certain amount of CO_2 must be present in the metamorphic fluid. However, when the CO_2 pressure is increased, or the temperature is increased, anthophyllite will form at the expense of talc and carbonate at similar temperatures (Johannes 1969, Winkler 1979):

$$2\ \text{talc} + 1\ \text{Mgs} = 1\ \text{Antho} + H_2O + CO_2$$

At even higher CO_2 pressure, enstatite will form due to the following reaction:

$$1\ \text{Antho} + 1\ \text{Mgs} = 4\ \text{Enstatite} + 1\ H_2O + 1\ CO_2$$

Olivine will form from all the above-mentioned parageneses simply by increasing the temperature, for example:

$$1\ \text{Enstatite} + 2\ \text{Mgs} = 2\ \text{Forsterite (olivine)} + 2CO_2$$

Concerning the ultramafites around the Sjona, Høgtuva and Svartisen windows the field observations can be put together with theory above as follows:

1. The occurrences of olivine in the ultramafites in the coastal area in the west (e.g. Nordværnes) implies a significantly higher peak metamorphism than in Altermark. A similar conclusion can be made from the Kvanndalen talc-carbonate-olivine deposit just west of Altermark.
2. The occurrences of anthophyllite-magnesite and enstatite-magnesite north of Altermark (e.g. at Mel-Loftet) can be explain by higher CO_2 pressure than in Altermark, and possibly also by a slightly higher temperature.

Conclusions

1. The reconnaissance work on talc in the Helgeland area indicates that talc deposits of economic interest are present in 1) the Kvanndalen area, west of Altermark, 2) in Misvær.
2. The Kvanndalen deposit contains metamorphic olivine, in addition to the common talc and carbonate. The talc itself is of high quality. The likelihood that the deposit could be exploited depends on whether or not it is possible to use the rock as an ore in its present form, or to remove the olivine.
3. In the Misvær area, the deposit termed Stolpelia contains around 40% talc and, in addition, 40% carbonate and 20% chlorite. The size of the deposit is limited.
4. The mineralogical content and the zoning pattern of the ultramafites west of Altermark clearly indicate that the western coast of Helgeland outside Mo i Rana can be ruled out as a target for talc-prospecting.

Recommendation

1. Investigation of the Kvanndalen deposit by magnetic measurements, in order to obtain more information of its size.
2. Collect unweathered samples from the Kvanndalen deposit for microscopy and analysis.
3. Geological mapping in the area between the Kvanndalen deposit in the west and Straumdalen in the east.
4. Investigation of the potential of the Misvær deposit.
5. Completion of reconnaissance work in the Mo i Rana - Saltdalen area.
6. Reconnaissance work in the area Mo i Rana – Mosjøen, with special attention given to the coastal area.
7. Investigation of talc-occurrences at Rødøy, close to Tjøtta.

References

Alnæs, L., 1995: Kvalitet og bestandighet av naturstein. Påvirkningsfaktorer og prøvemetoder. Doktor Ingenør-thesis. NTNU, Trondheim.

Bakke, S. & Korneliussen, A., 1986: Jack-straw-textured olivines in some Norwegian metaperidotites. Norsk Geologisk Tidsskrift, volume 66, no. 4. pp. 271-276.

Bucher-Nurminen, K., 1988: Metamorphism of ultramafic rocks in the Central Scandinavian Caledonides. In: Kristoffersen, Y. (editor): Progress in studies of the lithosphere in Norway. Norges geologiske undersøkelse, Spec. Publ. 3, 86-95.

Bucher-Nurminen, K., 1991: Mantle fragments in the Scandinavian Caledonides. Tectonophysics 190, 173-192.

Gjelle, S. Gustavson, M., Quale, H. & Skauli, H, 1985. Bedrock map Melfjord 1928 III, 1:50 000, preliminary version. Norges geologiske undersøkelse.

Gustavson, M., 1982: Bedrock map Mosjøen, 1:250 000. Norges geologiske undersøkelse.

Gustavson, M., Blystad, P., 1995: Bedrock map Bodø, 1:250 000. Norges geologiske undersøkelse.

Gustavson, M. & Gjelle, S., 1981: Regional geology of central Nordland. Earth evolution sciences 1, p. 6-13.

Gustavson, M. & Gjelle, S., 1991: Bedrock map Mo i Rana, 1:250 000. Norges geologiske undersøkelse.

Hossack, J.R. & Cooper, M.A., 1986: Collision tectonics in the Norwegian Caledonides. In: Coward, M.P. & Rice, A.C.(eds.): Collision Tectonics. Geological Society Special Publication 19, 287-304. Blackwell Scientific Publications, Oxford, London, Edinburgh, Boston, Palo Alto,, Melbourne.

Johannes, W., 1969: An experimental investigation of the system $MgO-SiO_2-CO_2$. Am.J.Sci. 267, 1083-1104.

Johnsen, S.O., 1983: Bedrock map Svartisen 1928 II, preliminary version. Norges geologiske undersøkelse.

Karlsen, T.A., 1995: Geological and geophysical studies of ultramafite associated talc deposits, Altermark, Northern Norway. Dr.Ing. thesis 1995:49, NTH.

Korneliussen, A., 1976: Malmgeologisk undersøkelse med henblikk på økonomisk utnyttelse av kromittforekomster på kartbladene Rødøy og Lurøy i Nordland. Unpublished thesis. Geol. Inst., NTNU, Trondheim.

Korneliussen, A., 1977: Kromitt, sulfider, olivin, talk og magnesitt i alpintype perido- titter, Æsjeholmene, Lurøy og Rødøy kommuner, Nordland. NGU-report 1430/22A. Norges geologiske undersøkelse.

Lund, B., 1986a: Sonderende undersøkelse av kleberstensforekomster ved Misvær og Stolpelia. NGU-rapport 85.204.

Lund, B., 1986b: Diamantboring av klebersteinforekomster ved Stolpelia. NGU-rapport 86.229.

Mellini, M., Tromsdorff, V. & Compagnoni, R., 1987: Antigorite polysomatism: behaviour during progressive metamorphism. Contrib.Mineral.Petrol. 97, 147-155.

O'Hanley, D.S., Chernosky, J.V.Jr. & Wicks, F.J., 1989: The stability of lizardite and chrysotile. Can. Mineralogist, v.27, 483-493.

Solli, A., Farrow, C.M. & Gjelle, S., 1992: Bedrock map Misvær 2029 II, 1:50 000. Norges geologiske undersøkelse.

Winkler, H.G.F., 1979: Petrogenesis of metamorphic rocks, 5.ed., Springer Verlag, New York – Berlin.

Figures and photos

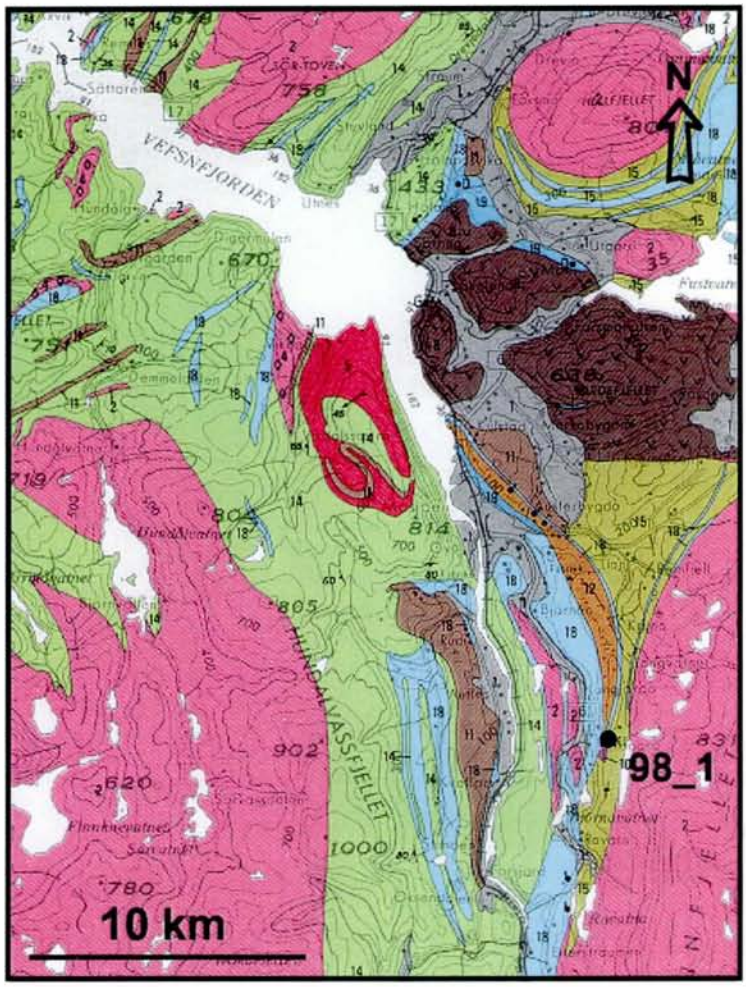

Figure 1: Location of the Bjørnålia soapstone deposit south of Mosjøen. Map-sheet Mosjøen 1:250000 (Gustavson 1982).

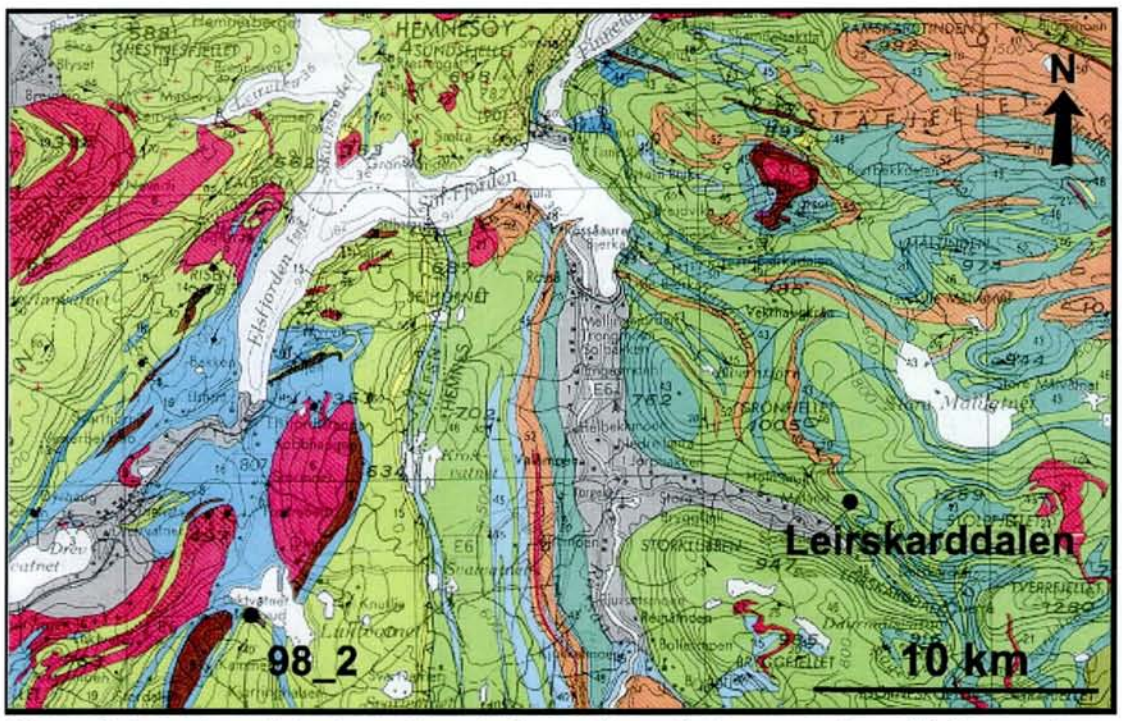

Figure 2: Location of the investigated ultramafite at Luktvannet (Loc. 98.2), and the soapstone deposit at Leirskarddalen (Loc. Leirskarddalen), to the right. Geological map: Mo i Rana, 1:250000 (Gustavson & Gjelle 1991).

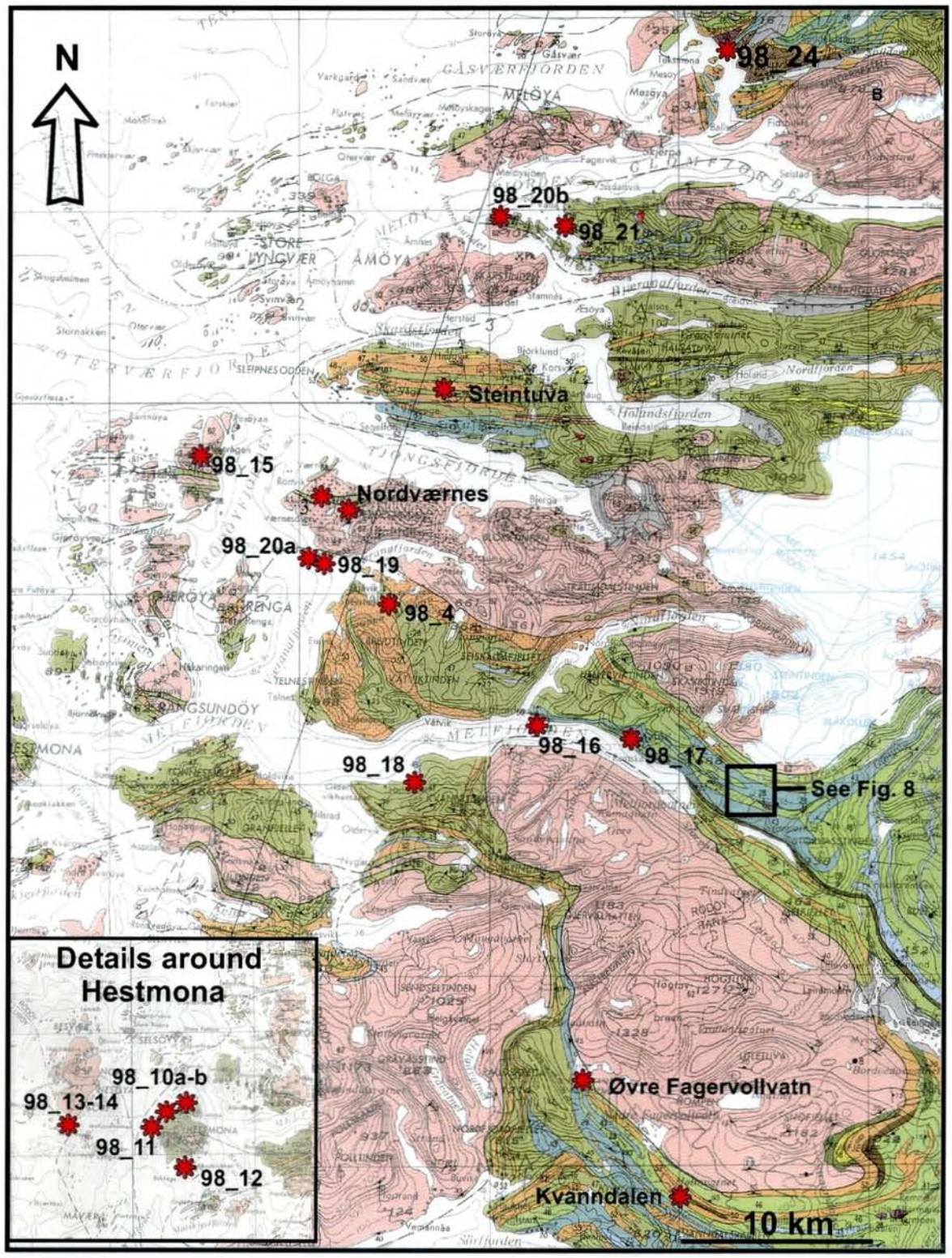

Figure 3: Locality map for the investigated ultramafites at western Helgeland. Map-sheet Mo i Rana 1:250000 (Gustavson & Gjelle 1991).

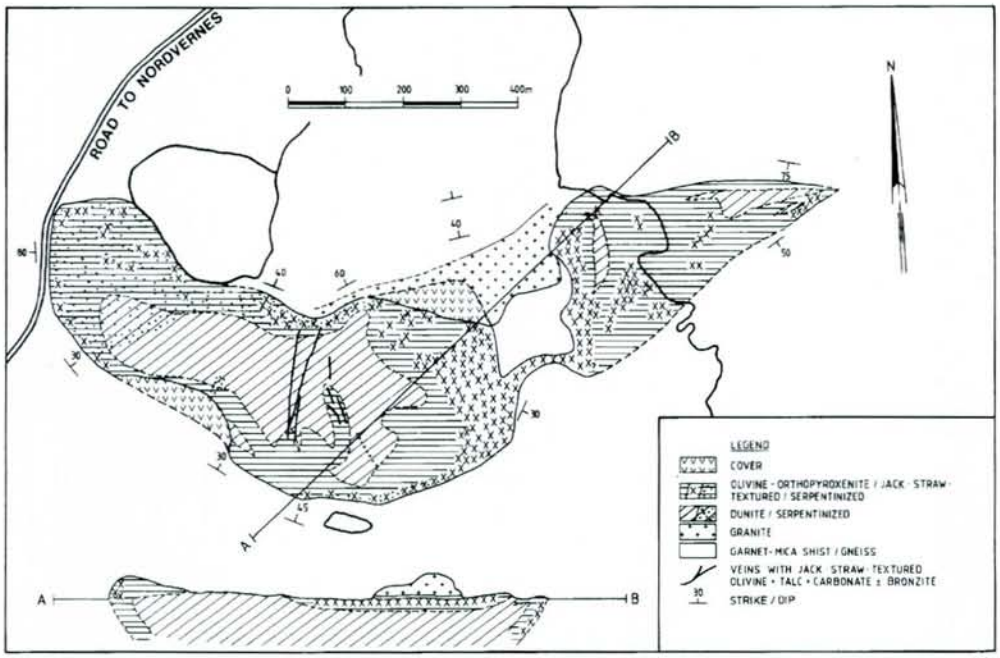

Figure 4: Geological map of the Nordværnes ultramafic body (from Bakke & Korneliussen 1986).

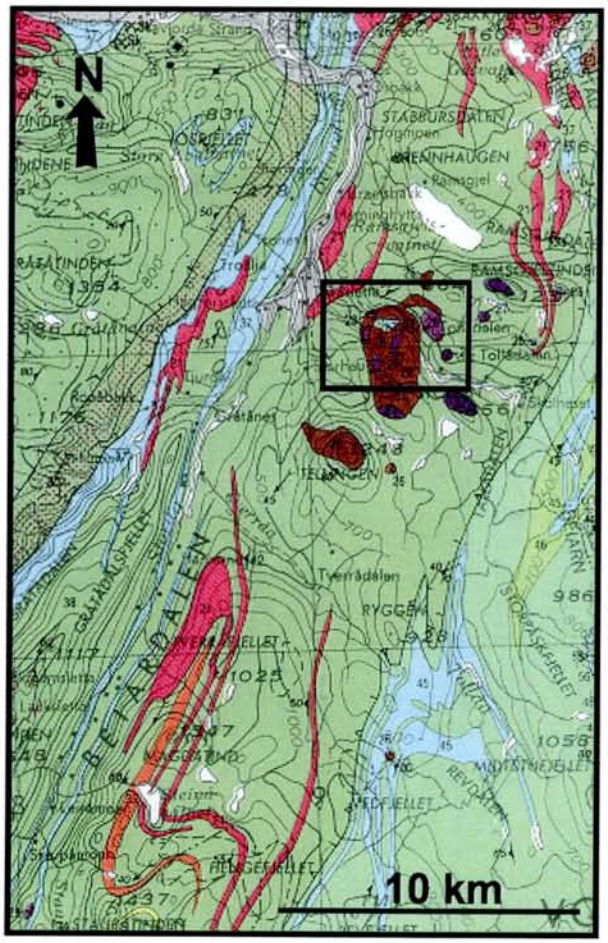

Figure 5: Location of investigated ultramafites at Tollådalen. Geological map: Mo i Rana, 1:250 000 (Gustavson & Gjelle 1991).

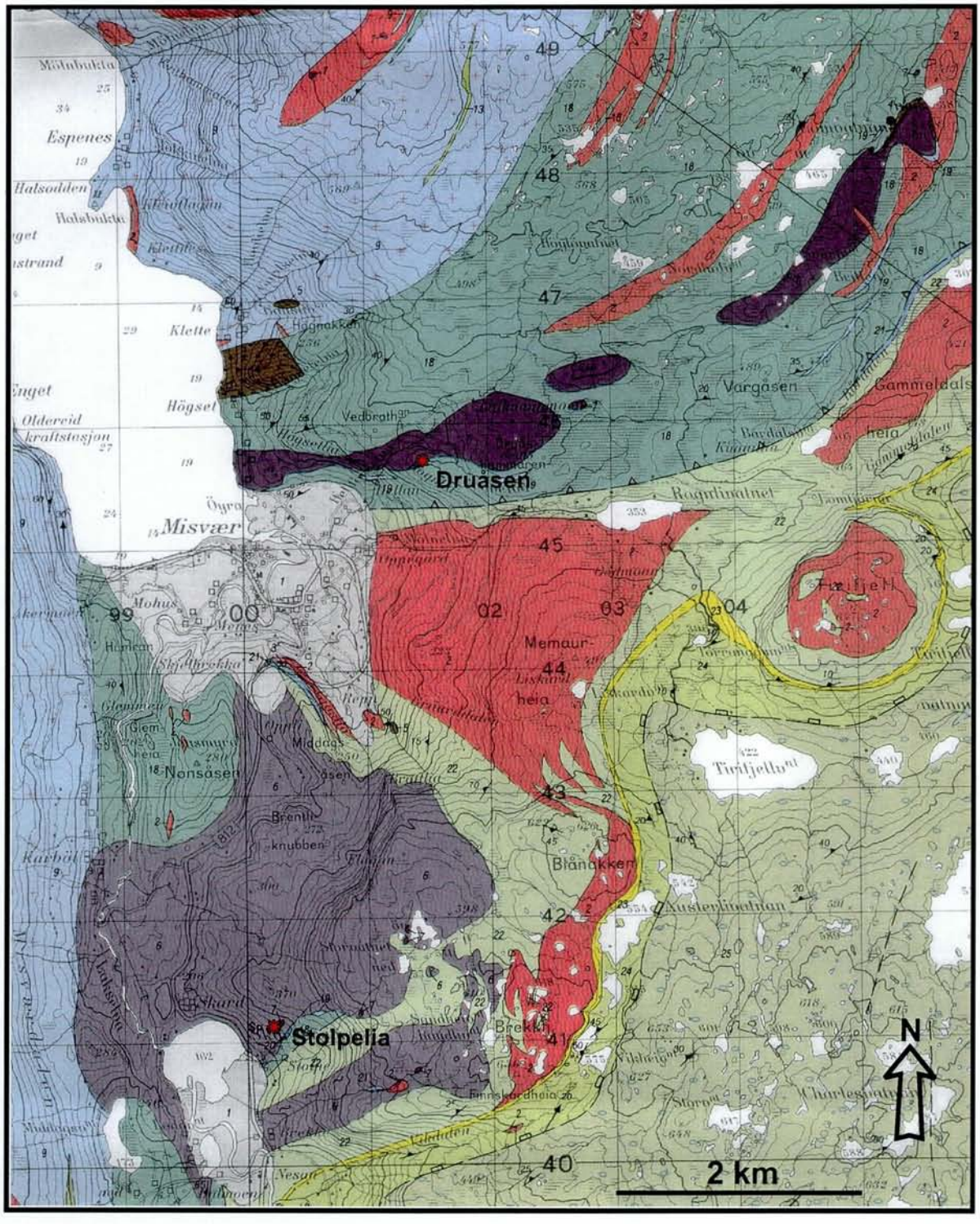

Figure 6: Locality map of investigated deposits in Misvær. Map-sheet Misvær 2029 II, 1:50000 (Solli et al. 1992).

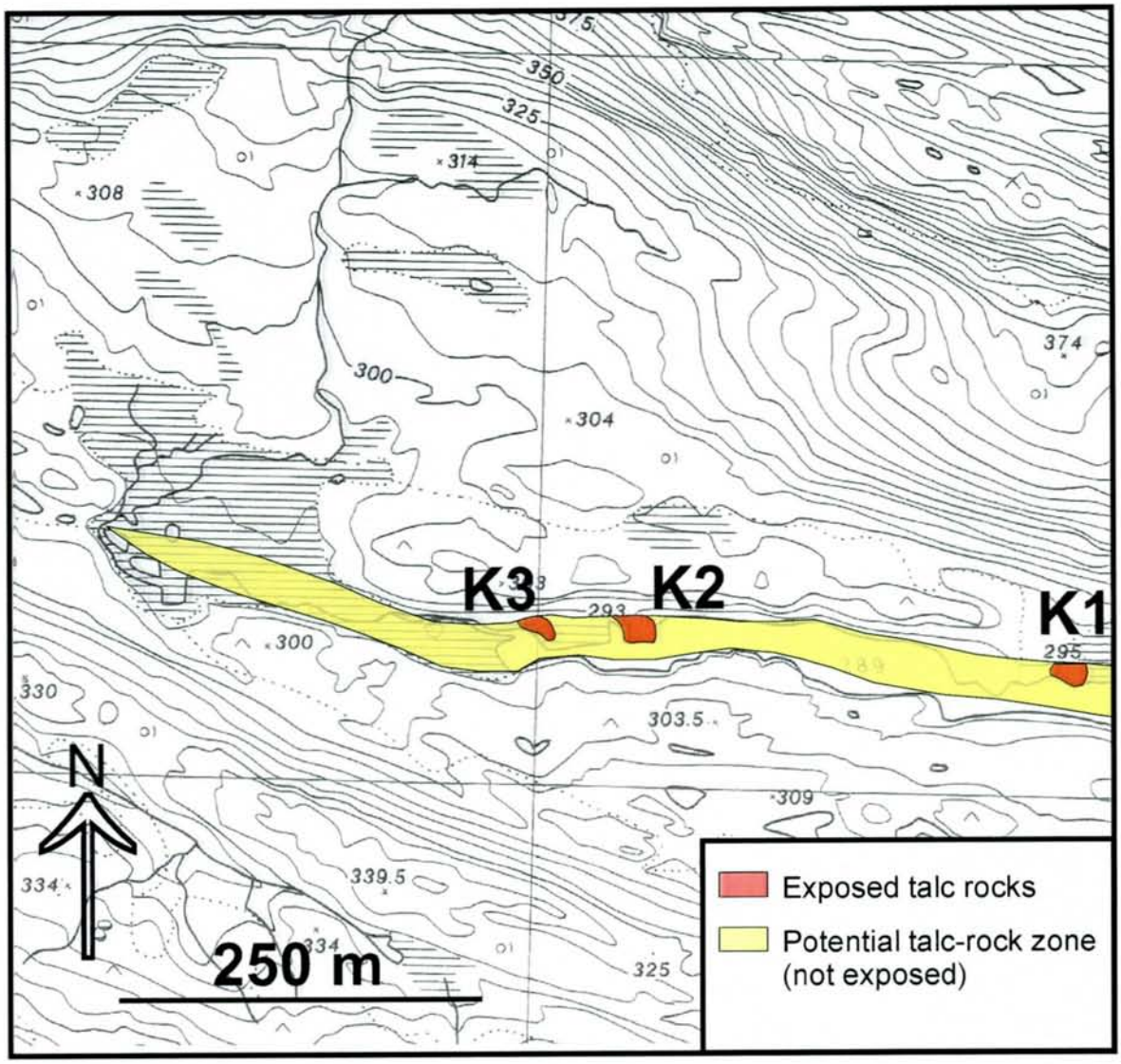

Figure 7: Detailed map of the Kvanndalen deposit showing the observed exposures of talc-carbonate-olivine rock and possible extent of the talc-bearing rock. Topographic map: Holmvannet, DR 194-5-3, Scale: 1:5000.

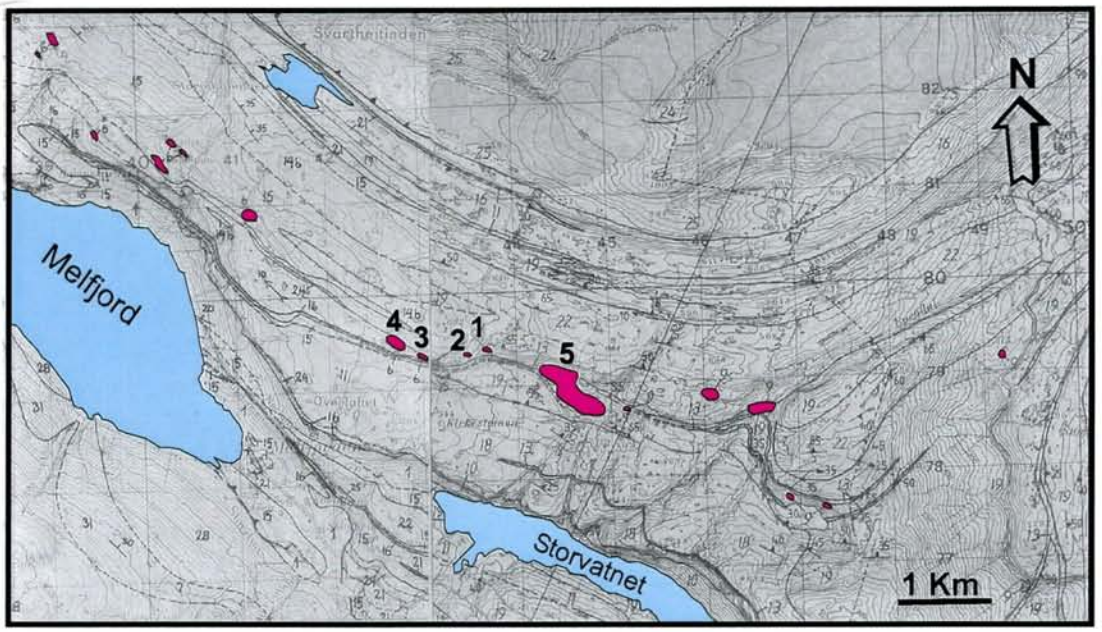

Figure 8: Location of investigated ultramafic bodies at Mel-Loftet. Geological maps: Svartisen 1:50000 (Johnsen 1983) & Melfjord 1:50000 (Gjelle et al. 1985).

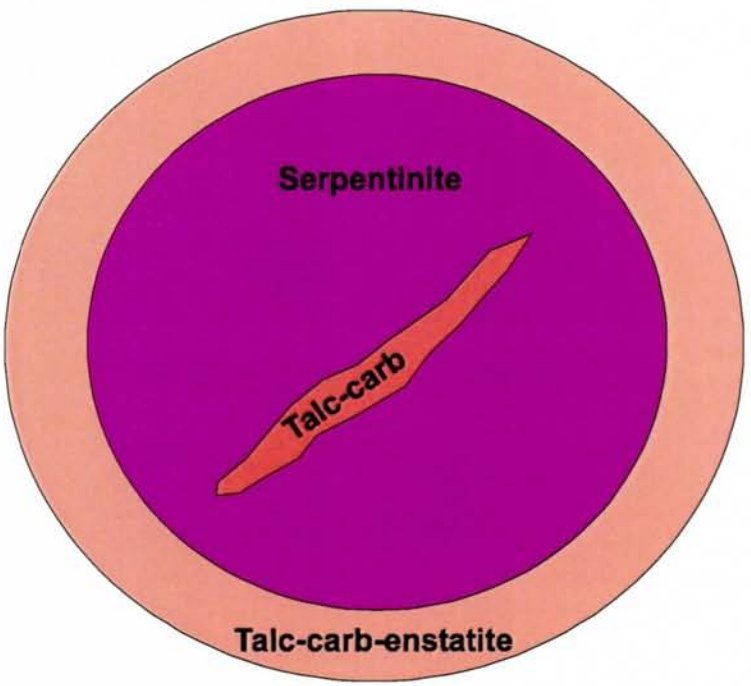

Figure 9: Simple model to illustrate the zoning pattern in the ultramafite at Esjeholmene (Loc.98_19).

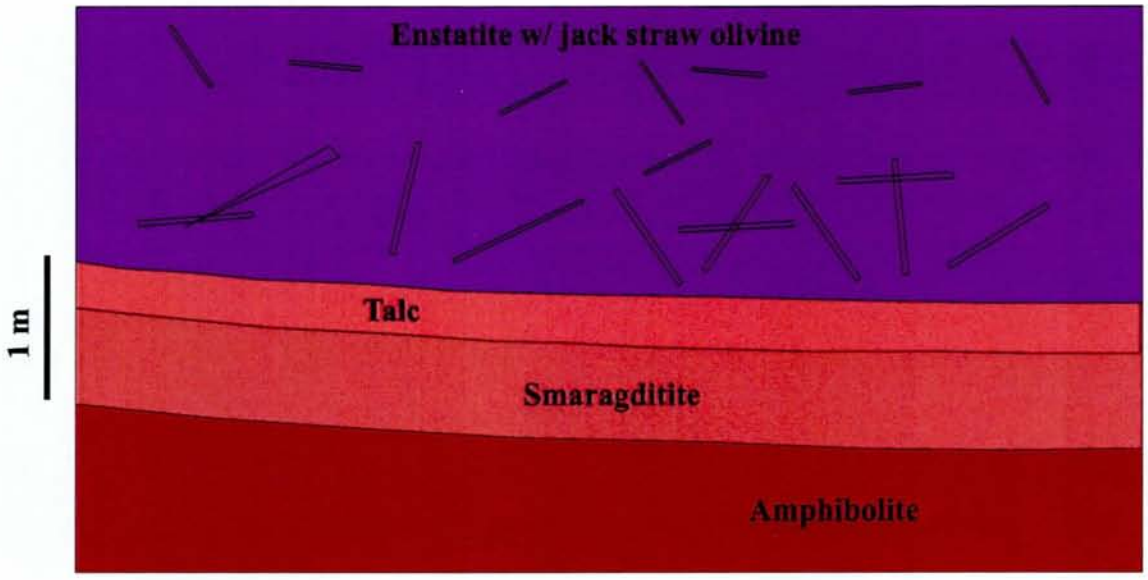

Figure 10: Sketch of the rim zone of lens 2, Esjeholmen (Loc. 28_20a).

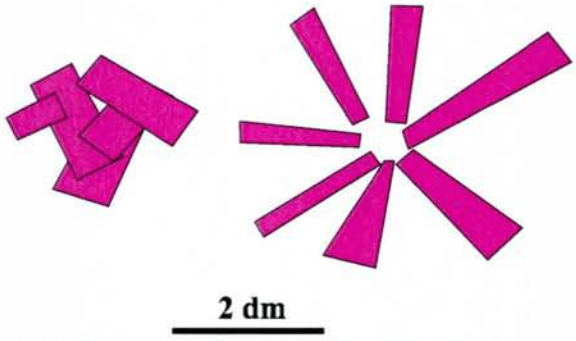

Figure 11: Sketch that illustrates different crystal shapes of enstatite in orthopyroxenite: the one to the left is common in the ultramafic core, while the one to the right is common in the rim. The one to the right is at some localities very coarse-grained just as jack straw olivine.

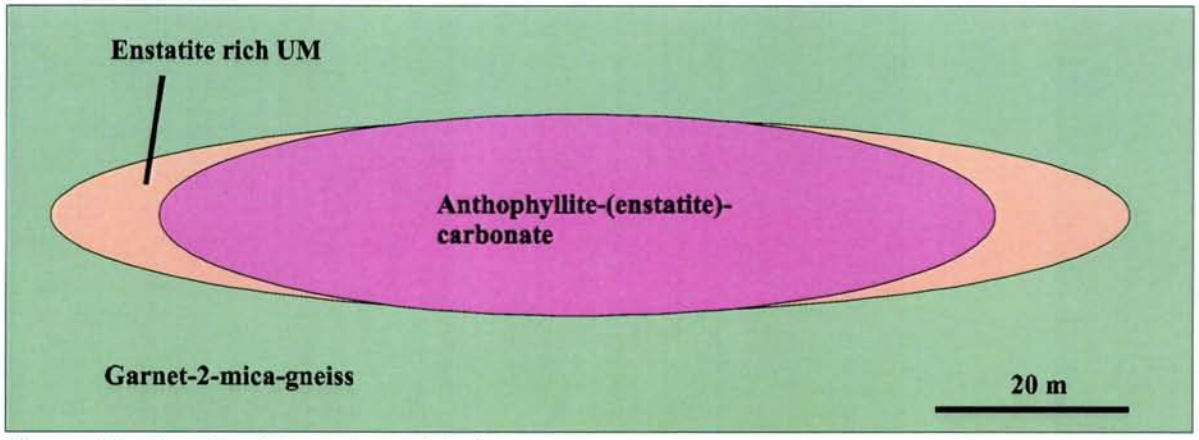

Figure 12: Sketch of Body 1, Mel-loftet.

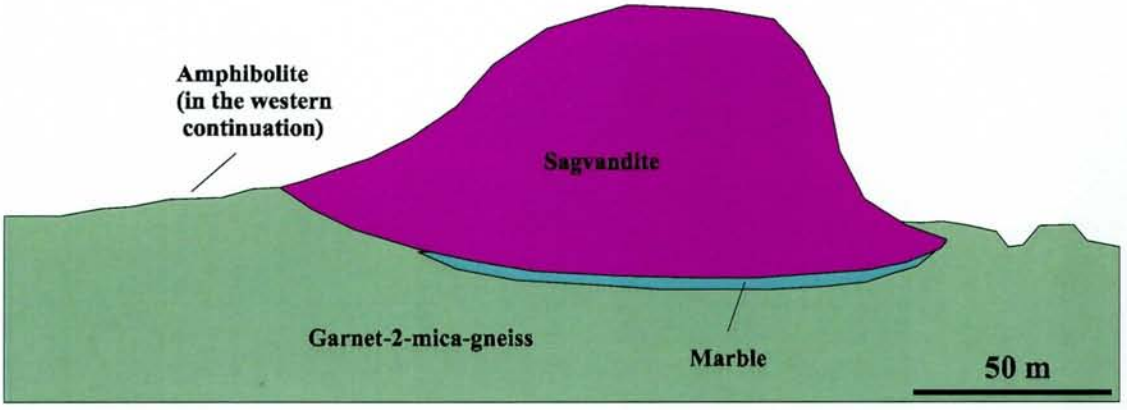

Figure 13: General geological setting of Body 4, Mel-loftet.

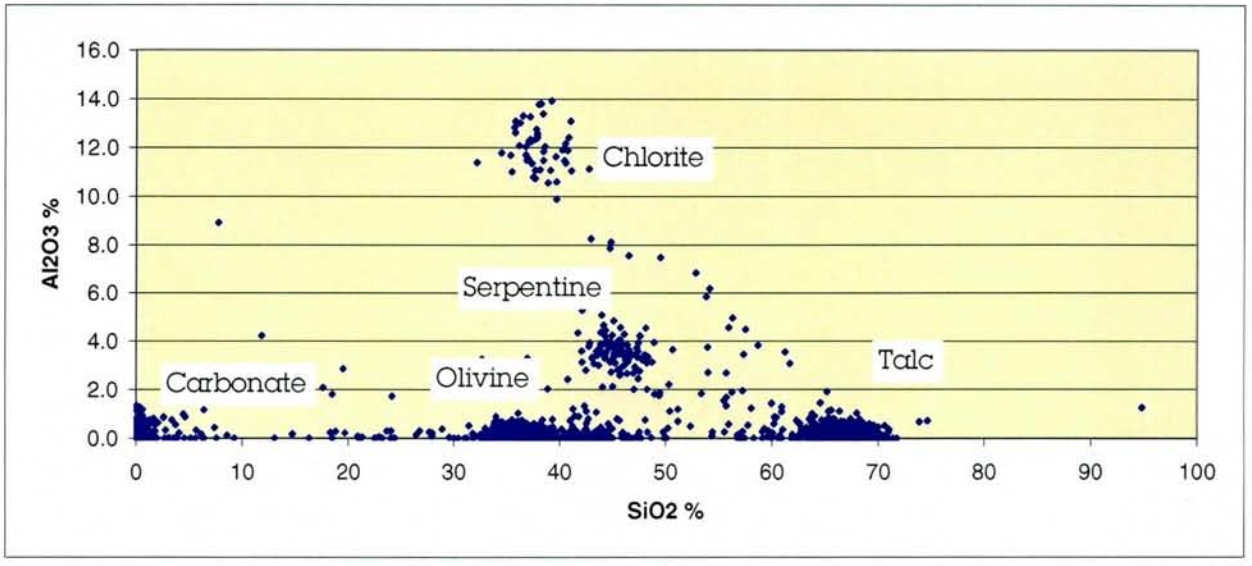

Figure 14: Variation diagram of a thin section from the Kvanndalen deposit, illustrating the mineralogical content. The data has been obtained from automatic EDS microprobe analyses.

Photo 1: The Altermark talc mine is situated in an area rich in talc compared to neighbouring areas. The area from the Kvanndalen deposit in the west to Langvannet can be termed the "Altermark talc province".

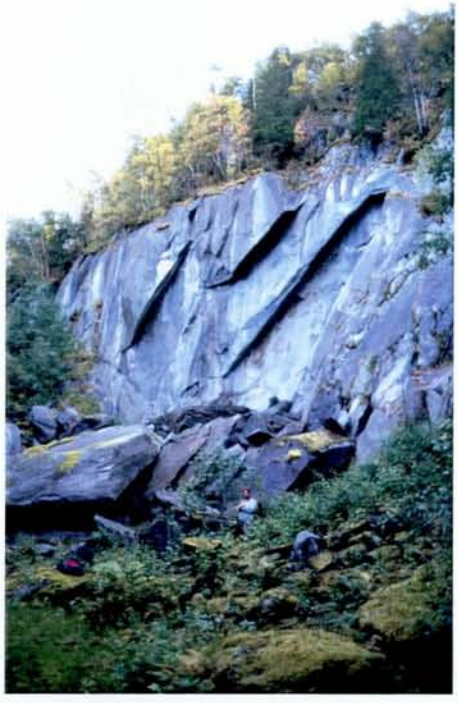

Photo 2: The soapstone quarry of Bjørnålia (Loc. 98_1). The deposit is rich in chlorite and amphibole, but poor in talc. The soapstone is used at Nidaros Cathedral in Trondheim and the quarrying took place in the period around 1897-1960 (Alnæs 1995).

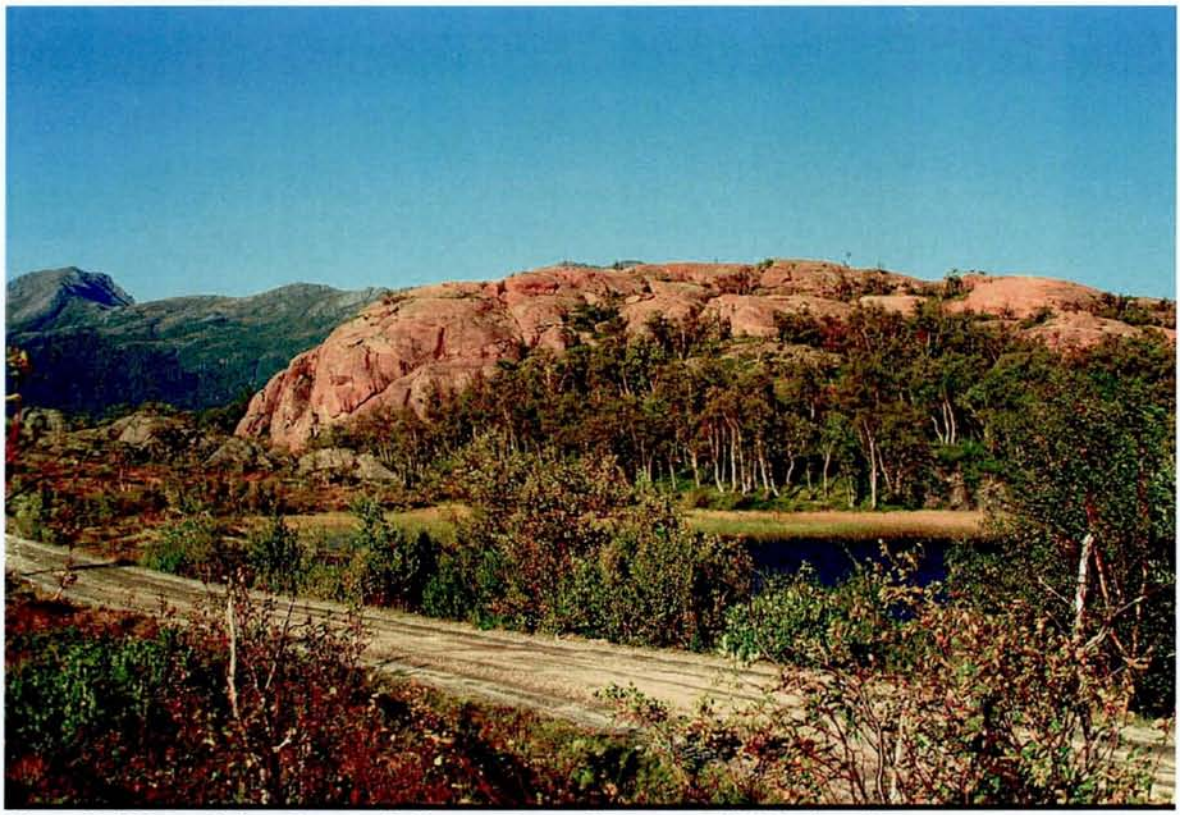

Photo 3: Most of the ultramafic lenses along the coast of Helgeland have a rusty appearance and define topographical heights. The rusty colour arrives from weathering of olivine and orthopyroxene. Locality: 98_4, Sjåvika.

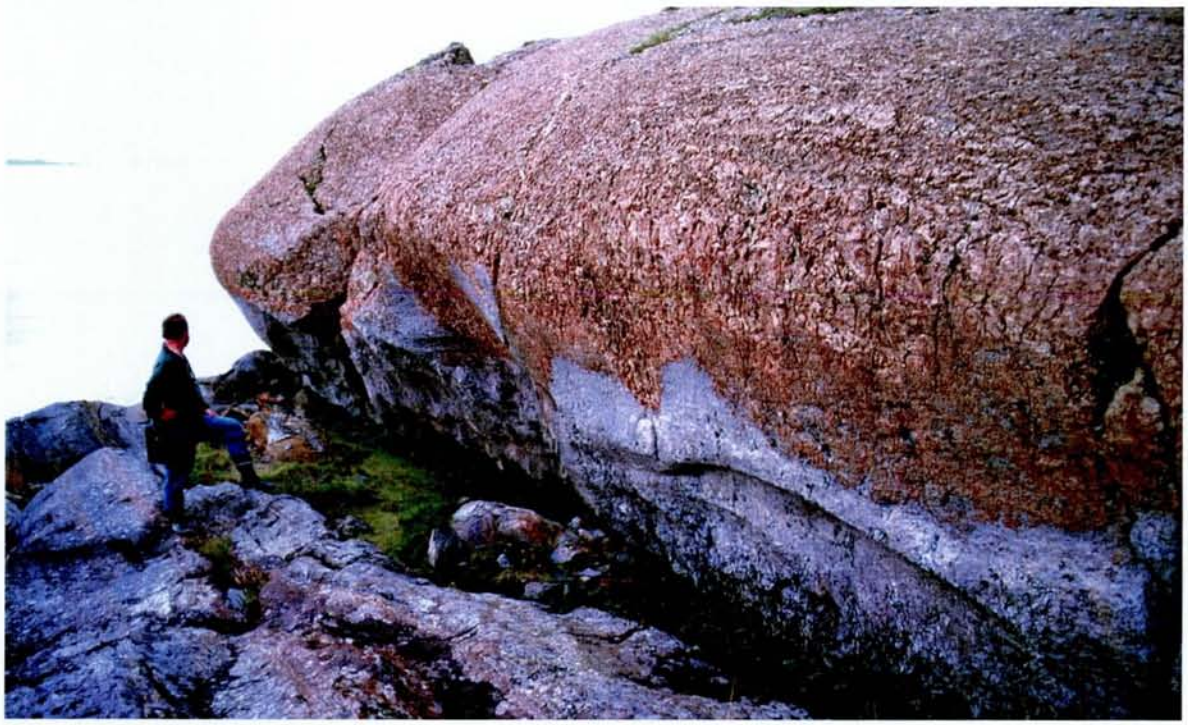

Photo 4: At Esjeholmen the ultramafites are dominated by enstatite, but contains jack-straw textured olivine up to 1 meter long towards the rim (brown-coloured). At the contact between the ultramafite and the amphibolite (to the left) a one meter thick zone of green-coloured smaragditite appears. Locality: 98_20a: Esjeholmen.

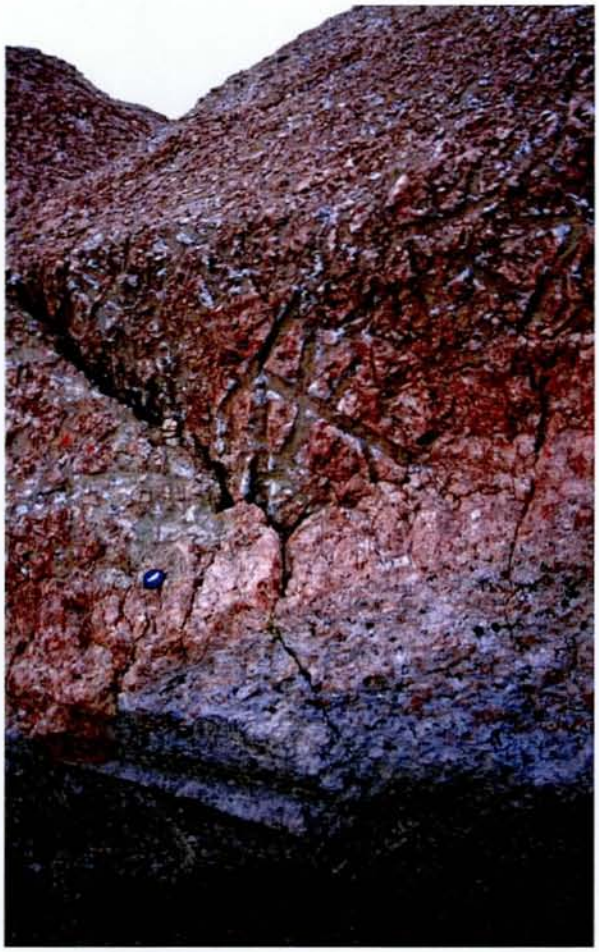

Photo 5: Close-up view of the ultramafite in photo 4 showing the jack-straw textured olivine (long needles) surrounded by enstatite. Locality: 98_20a: Esjeholmen.

Photo 6: Jack-straw textured olivine at the rim of the Nordværnes ultramafite. Locality: Nordværnes.

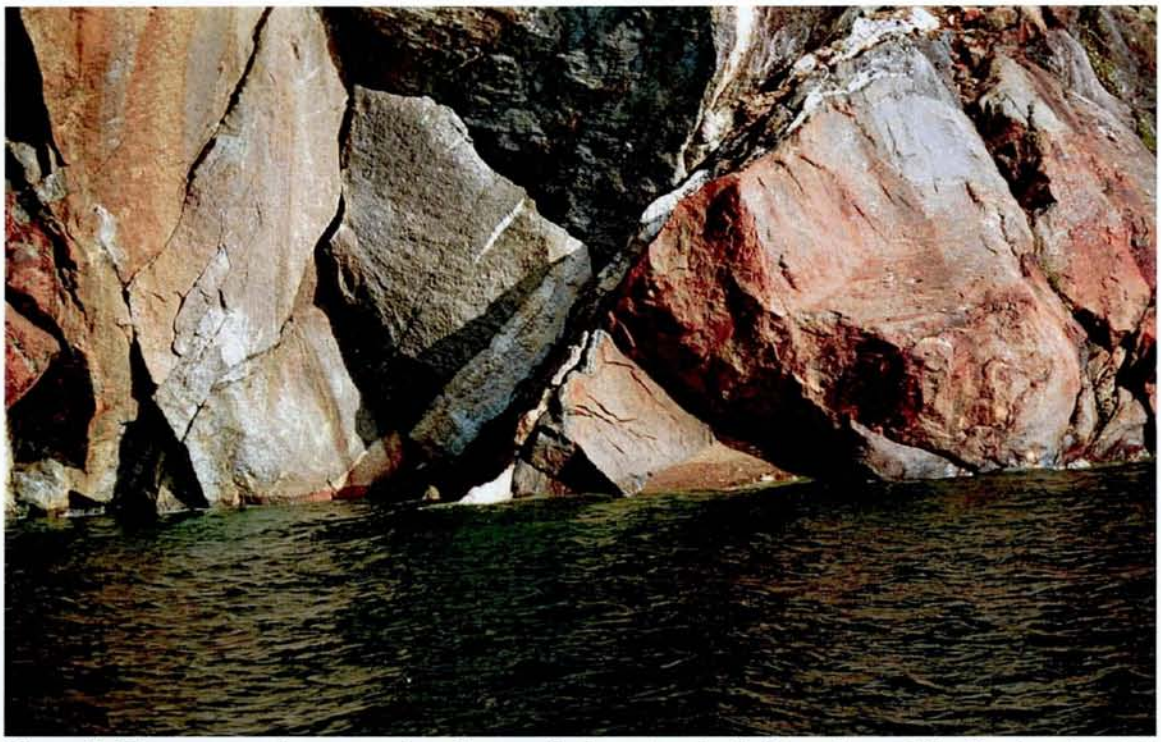

Photo 7: The contact between the ultramafic lens (to the left) and amphibolite (to the right) is defined by a one meter thick alteration zone. Locality: 98.16, Norfjordnesset, Melfjord.

Photo 8: Close up view of the contact between the ultramafite and the amphibolite shown in the photo above.The ultramafite (to the left) is an olivine orthopyroxenite with jack straw textured olivine and enstatite towards the rim. The reaction rim (light coloured) consists of talc-carbonate (~ 2-3 dm) and smaragditite (~ 8 dm) followed by a thin dark-coloured biotitite, a thin quartz-zone with amphibole, and, at last, the amphibolite. Locality: 98.16, Norfjordnesset, Melfjord.

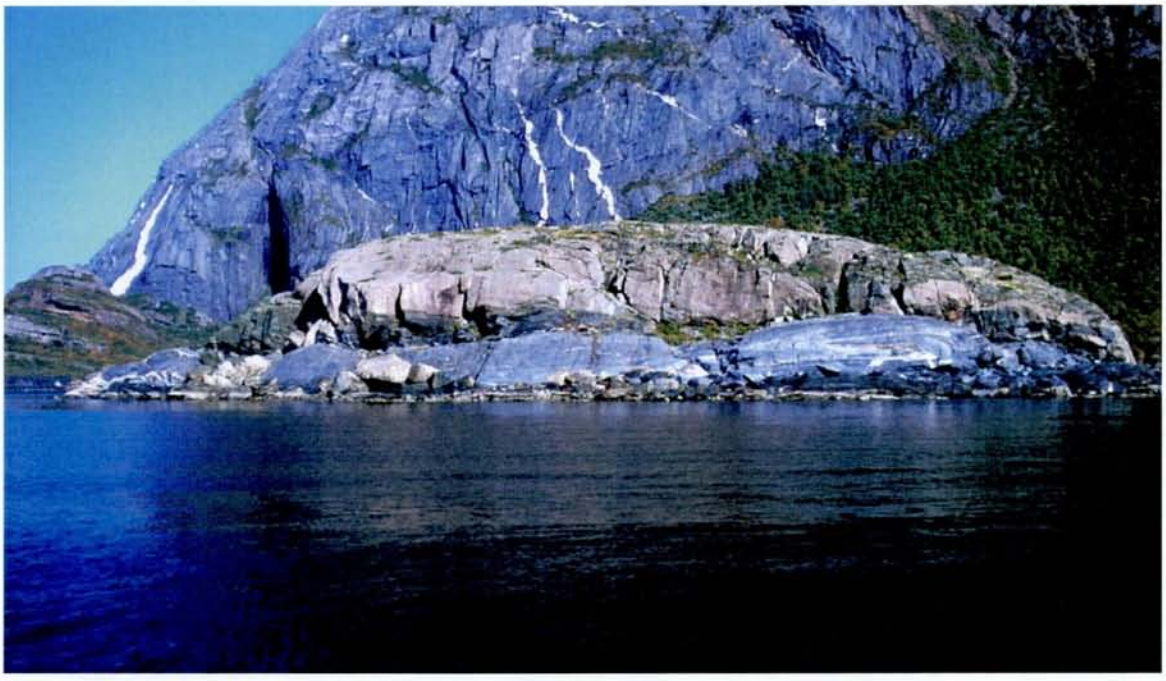

Photo 9: View from the west of the island of Hestmannen (behind) with a small island composed of orthopyroxenite (brown-coloured) and amphibolite (grey) in the foreground. Much of the Hestmannen-island and the nearby small islands are composed of a mafic-ultramafic complex, in which the mafic part consists of amphibolite with dikes of trondhjemite, and the ultramafic part consists mainly of orthopyroxenite.

Photo 10: View of The Hellarvika ultramafite, Melfjord. Locality: 98_18, Hellarvika, Melfjord.

Photo 11: Close up view of the "soapstone" at Hellarvika, showing crystals of enstatite in a matrix of carbonate and minor talc. Locality: 98_18, Hellarvika, Melfjord.

Photo 12: Below the ultramafite termed Lemstein, huge blocks of ultramafite contain around 30 % talc (light-coloured) in addition to enstatite and breunnerite (brown-coloured). Locality: 98_17 Lemstein, Melfjord.

Photo 13: The Stolpelia soapstone deposit is, besides the Kvanndalen deposit, the most interesting when it comes to quality as it has a rather high talc content. Mapping and drilling have been carried out by NGU in 1985/86, and the deposit has been estimated to contain 37000 tonnes of ore. Locality: 98_30, Stolpelia, Misvær.

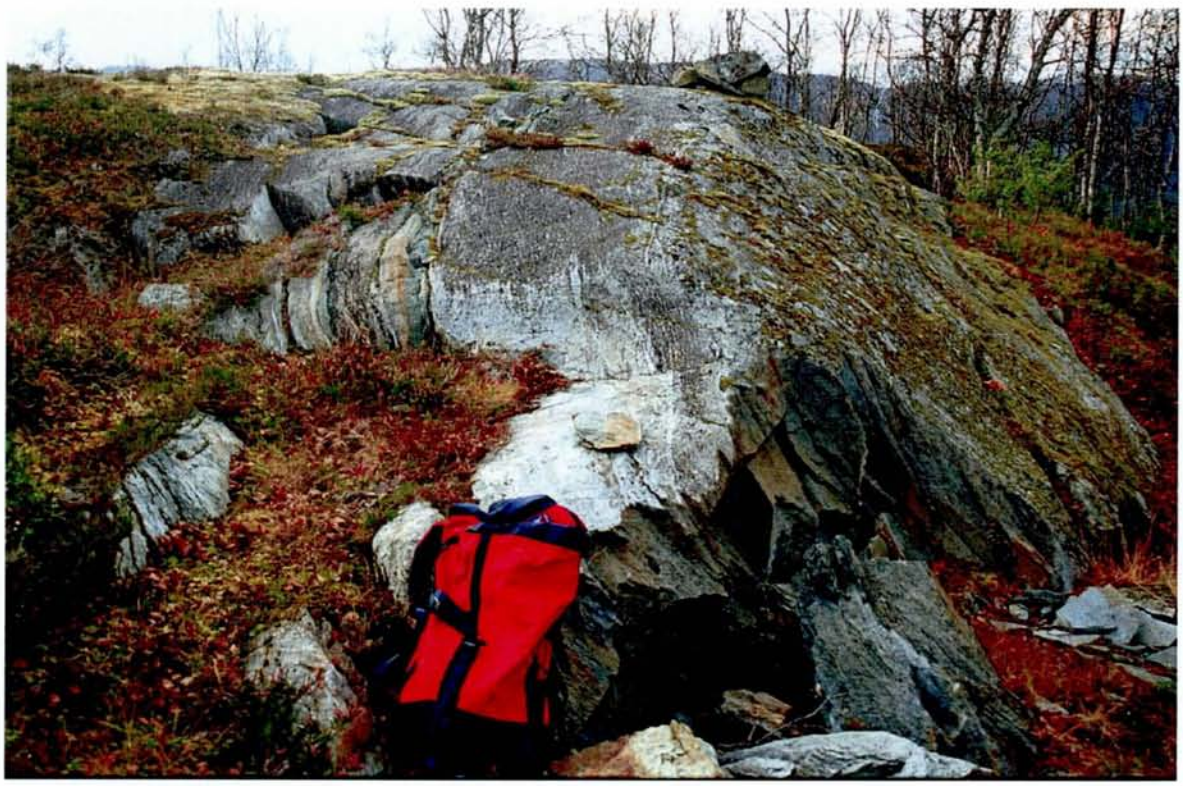

Photo 14: An 8-10 metres wide talc-carbonate bearing alteration zone is located between a serpentinite (to the right) and country rocks (to the left) at Druåsen in Misvær.

Photo 15: At Leirskarddalen south-east of Mo i Rana there is a pit, 10x20 metres, in a rather light-coloured talc-carbonate-amphibole rock. As can be seen on the photograph, a sample for dimension stone has recently been removed. Except for the content of amphibole, the rock is rather similar to the talc-carbonate rocks in Altermark. Locality: Leirskarddalen.

Photo 16: Overview of the talc-carbonate-olivine exposures at Kvanndalen, a few km west of Altermark. The talc-bearing rock occurs in a depression situated within garnet-mica-schist (to the right) and a mixture of amphibolite, marble and garnet-mica-schist (to the left). The extension along the strike is not known. Locality: Kvanndalen.

Photo 17: Close-up view of the second of three exposures of talc-carbonate-olivine rock at Kvanndalen. In the picture two different grain sizes occur: a coarse grained variety is floating in a more fine-grained variety. Locality: Kvanndalen.

Photo 18: Close up view of an olivine rich variety of the talc-carbonate-olivine rock at Kvanndalen, showing the brown-weathering jack-straw olivine in a matrix of light-coloured talc and carbonate. Locality: Kvanndalen.

Photo 19: At Mel-loftet the ultramafic lenses are easy to recognise, as they are rusty weathered and define topographical heights. All investigated ultramafites are sagvandites that are thoroughly metasomatically altered, consisting of the minerals enstatite + magnesite + anthophyllite + minor talc. Locality: Body 2, Mel-loftet.

Photo 20: Close-up view of the enstatite-magnesite-anthophyllite rock that is common in the core of the ultramafites at Mel-loftet. Locality: Body 4, Mel-loftet.

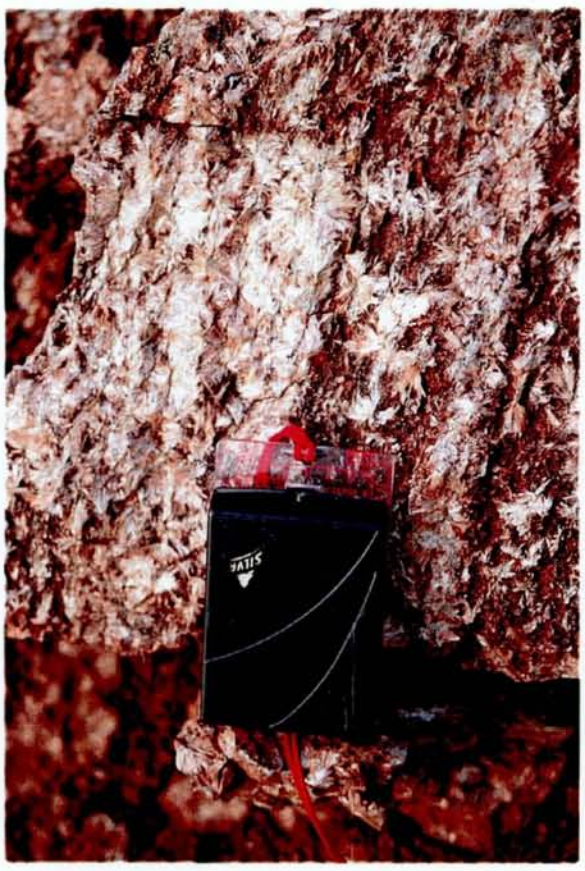

Photo 21: Close-up view of radial aggregates of anthophyllite (light coloured). Body 4, Mel-loftet.

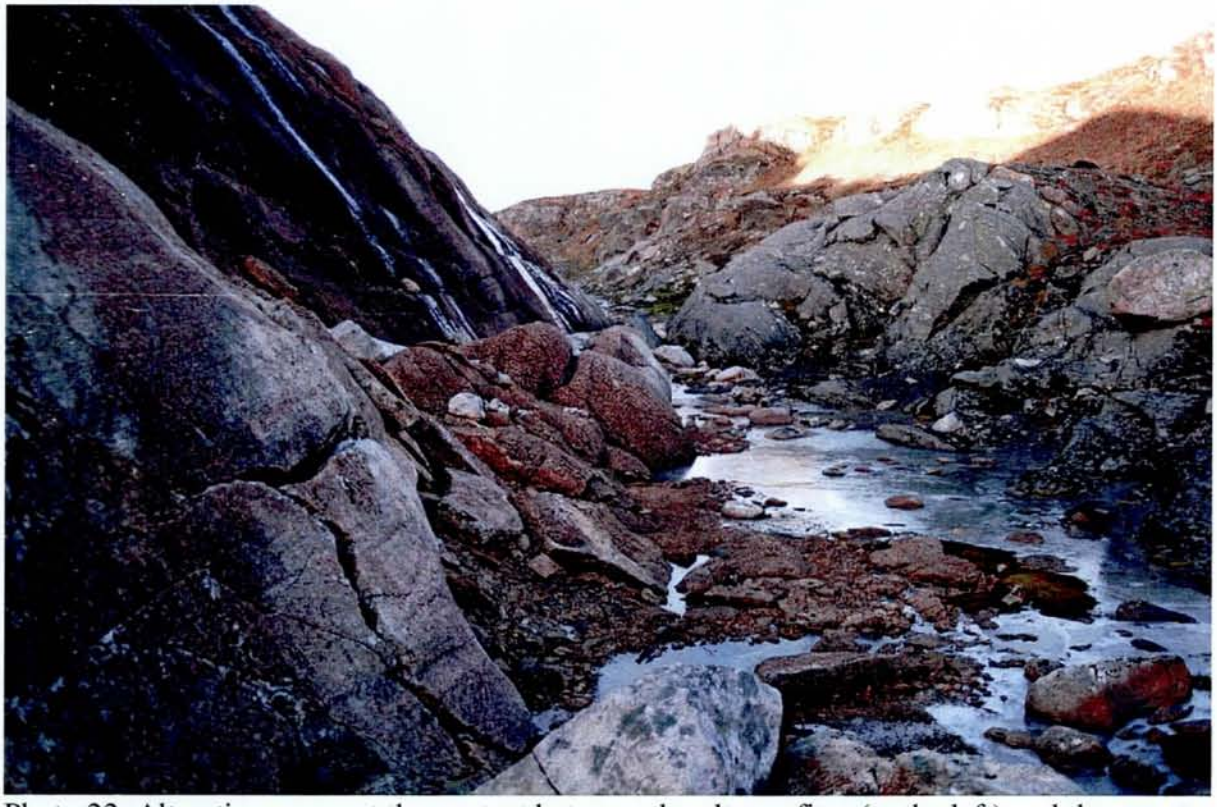

Photo 22: Alteration zones at the contact between the ultramafites (to the left) and the country rock (to the right) are observable at the Mel-loftet ultramafites, but they are much less distinct than in Altermark. Locality: Body 4, Mel-loftet.

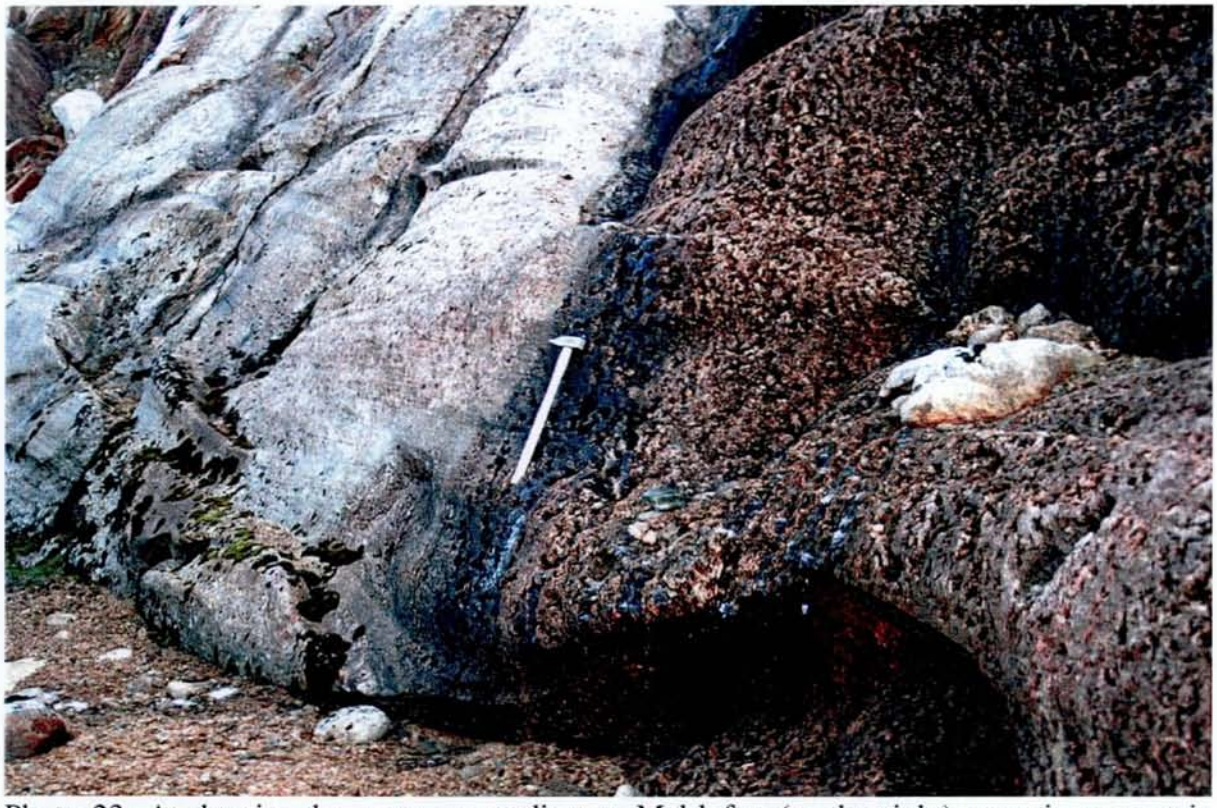

Photo 23: At the rim the rusty sagvandites at Mel-loftet (to the right) sometimes contain zones made up of only enstatite (to the left). Body 4, Mel-loftet.

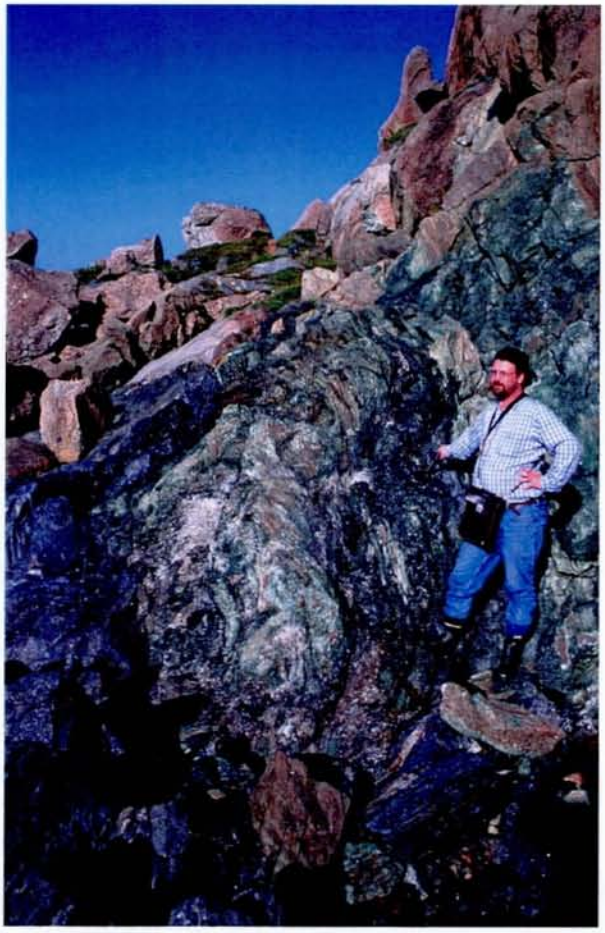

Photo 24: At Store Esjeholmen the ultramafite consists of orthopyroxene and olivine. Garnet peridotite is also observed, and shows that the metamorphism has reached very high levels. Despite this, primary layering is observed in the rock. In the rim, towards amphibolite, only a zone of smaragditite occur, while talc is absent. Locality: 98_14, Store Esjeholmen.