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Dolomite marble potential in the Ofotenfjord area.

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REPORT

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Summary:

This report will show the results obtained within the co-operative project concerning the dolomite marble potential in the Ofotenfjord area. The main objectives were to find dolostones which may be used in the industry as an industrial mineral.

In the entirely tectono-stratigraphic section of the area only two from three marble sequences are known to contain the major developments of the dolomite marbles. These are the Evenes and Hekkelstrand Marble. Two major units of dolomite marble have been documented in the Evenes Marble. One is near the structural base of the group, other is in the upper part of the Evenes Marble sequence.

Based on the limited mapping seven localities of dolomite marble have been selected in the Ofotenfjord area. Four occurrences of dolomite marble out of seven studied may be considered for future follow-up work. These are the dolomite marbles exposed at Ramstad, Sinklia, Skårnesdalen and Tjeldsundet. The Skårnesdalen occurrence is located in the Hekkelstrand Marble whereas the other three are a part of the Evenes Marble sequence. If all factors are considered (geographic location, accessibility, possible volume, quality, extraction) the Ramstad occurrence is considered to have the highest potential. The final assessment should include detail mapping of a limited area in order to evaluate the volume and distribution of different quality dolomite marbles.

Keywords: Marmor		
Dolomitt		
Industrimineral		Fagrapport

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1. INTRODUCTION

This study has been considered to be carried out as a part of the Project entitled 'Carbonate rocks of Norway: from basic research to industry', from one side, and as co-operative work with Franzefoss Bruk A/S with the financial support from the latter on the amount of 110,000 NOK. As a result the major objectives have been defined by Franzefoss Bruk A/S which are as follows:

- 1:50,000 mapping of the areas with major developments of carbonate formations on either sides of the Ofotenfjord, in Skånland, Evenes and Ballangen areas (1:50, 000 map sheets Tjeldsundet 1332 III, Evenes 1331 IV and Skjomen 1331 I, respectively; Fig. 1);

- identification of major developments of dolomite marble formations;

- geochemical (content of Mg, Fe, P, acid-soluble and SiO_2), petrographical study and whiteness measurements of thick dolomite marble units located relatively close to the shore-line in the Skånland and Evenes areas, and up to 20 km a way from the operating mining facilities of Franzefoss Bruk A/S in the Ballangen area.

The contract on joint project was officially approved and signed by Franzefoss Bruk A/S on 14^{th} of July 1997. The work started in August aiming the final report should be released by the end of November 1997.

2. GEOLOGICAL BACKGROUND

According to Gustavson (1966, 1972) the major tectonostratigraphic subdivisions of the Ofotenfjord area include, from bottom to top, the Narvik, Salangen (Upper Allochton), and Niingen (Uppermost Allochton) Groups. Later, Steltenpohl et al. (1990) have elevated the Salangen Group to a supergroup level and divided it into the Evenes and Bogen groups

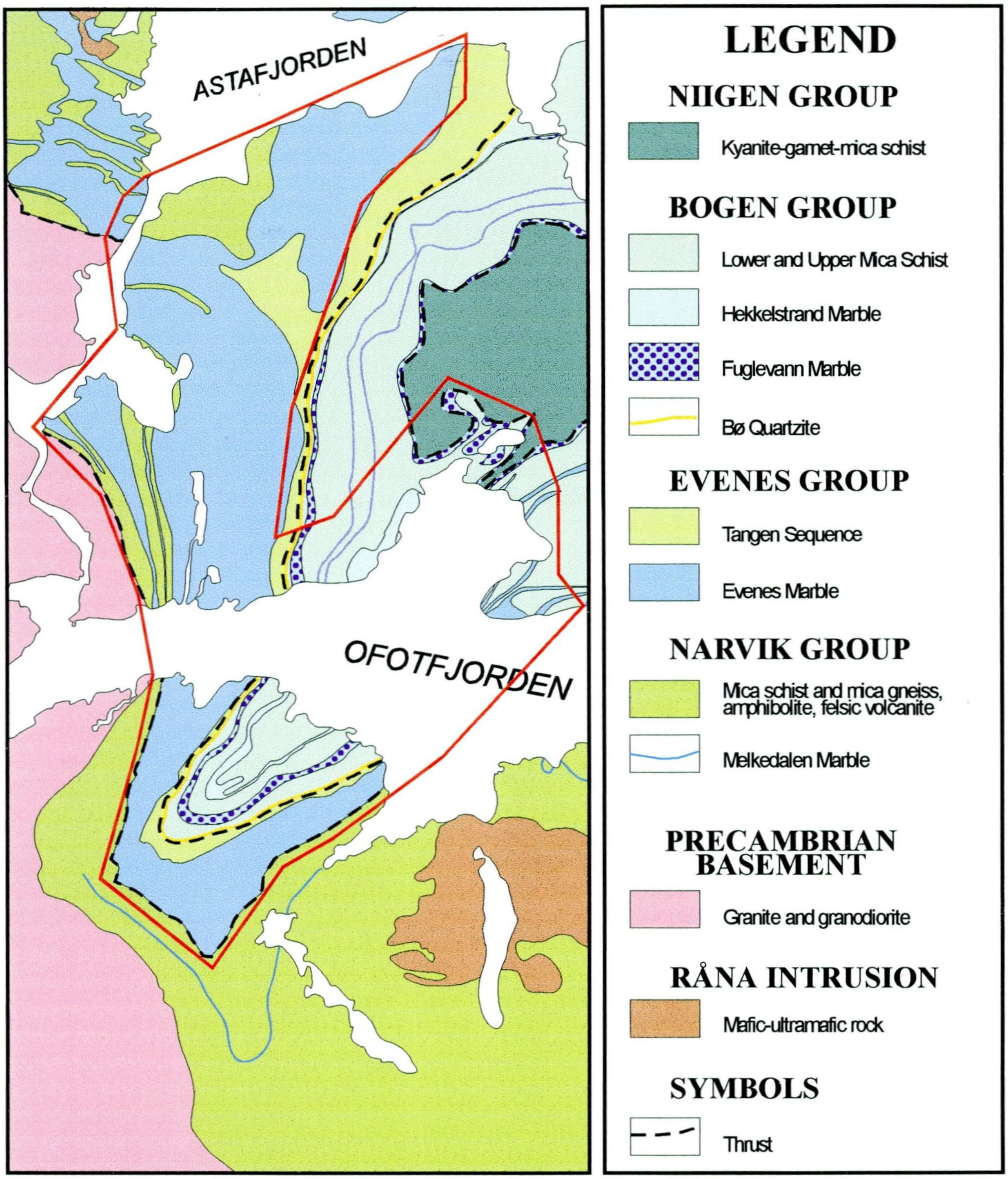

Figure 1. ***Simplified geological map (simplified after Gustavson 1973, Boyd & Søvegjarto 1983, Boyd et al. 1986) of the study area (outlined).***

According to Steltenpohl et al. (1990) the Evenes Group unconformably overlies the upper units of the Narvik Group with the Elvenes polymict conglomerate at the base (Fig. 2). The conglomerate unit consists of, from bottom to top, carbonates and schists (Sjurvatnet schist of Hodges 1985), and two distinct conglomerate facies (Foslie 1941). These are polymict conglomerates (diamictites of Steltenpohl et al. 1990) with both gabbroic matrix (lower member) and calcareous schist matrix (upper member). However, based on the geological observations from the western limb of the Ofoten synform, the Elvenes conglomerates were united with a 'mafic complex' (ophiolite fragments of Boyd 1983) into the Bjerkvik nappe (Boyd 1983): this rock assemblage has shown on the preliminary map-sheets Skjomen and Evenes (Boyd and Søvegjarto 1983, Boyd et al. 1986, respectively) in thrust contacts with both the Narvik and Evenes groups. The tectonic contacts have also been reported between the Evenes and Bogen groups and between the Bogen and Niingen groups (Steltenpohl 1987).

The Evenes Group is composed of (apart from the Elvenes Conglomerate) the Evenes Marble and the Tangen Sequence (Fig. 2, Steltenpohl et al. 1990). The Evenes Marble consists predominantly of calcite marbles (Evenes Marble). Intercalated with the marbles are minor, thin, discontinuous mica schist layers and diamictites (Steltenpohl et al. 1990). Variegated marbles (Leifset type), and white and grey dolomite marbles are minor though characteristic rock types of the Evenes Group. Both lithologies form either continuous layers or lenses. The Tangen Sequence contains a variety of mica schists. Minor rock types are thin layers or lenses of diamictites, matrix-suppoted conglomerates (with carbonate schist matrix), 'black schists', amphibolites and grey fine-grained dolomite marbles (Steltenpohl et al. 1990).

The Bogen Group is composed of the Bø Quartzite, Lower Mica Schist, Fuglevann Marble, Middle Mica Schist, Hekkelstrand Marble and Upper Mica Schist (e.g., Steltenpohl et al. 1990). The Bø Quartzite is a 1 to 200 m thick formation and it is one of the key marker in the area (Foslie 1941, Vogt 1942). Quartzites consist of quartz and minor mica, plagioclase, carbonates and others (Gustavson 1966). The Lower Mica Schist has a structural thickness of ca. 550 m. The formation is mainly composed of biotite-muscovite-quartz-plagioclase schists. The Fuglevann Marble is up to 200 m thick unit and consists of calcite marbles. Rare lenses of white dolomite marbles have been observed in the formation as well as discontinuous layers (up to 3 m thick) of garnet-mica schists which are intercalated throughout the marbles. Occurrences of iron ores are typical feature of the Fuglevann Marble (Foslie 1949, Gustavson

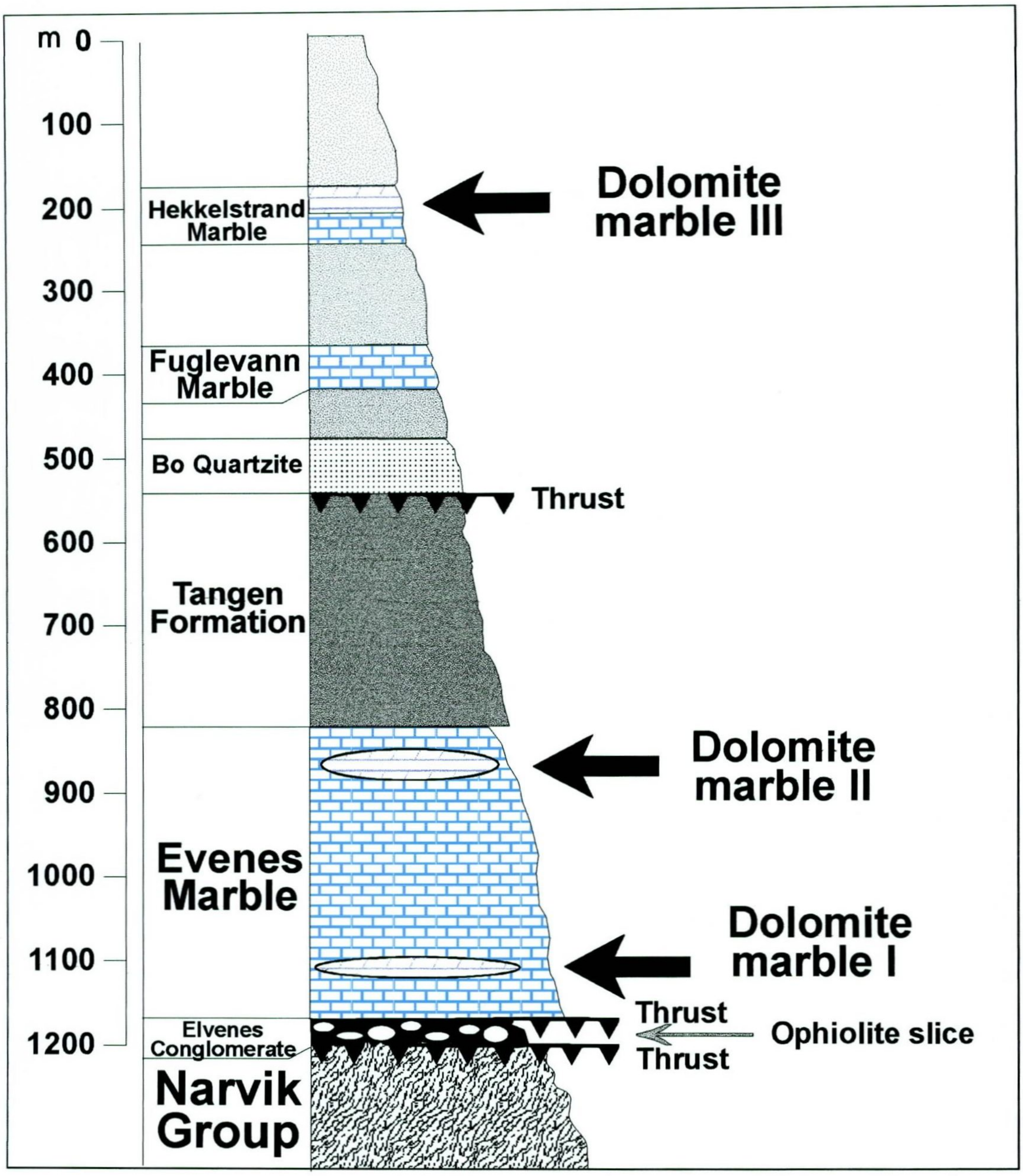

Figure 2. ***Simplified tectono-stratigraphic section of the Bogen and Evenes groups (modified from Steltenpohl et al. 1990).***

1966). The Middle Mica Schist is an approximately 400 m thick sequence of schist which are rather similar to those of the Lower Mica Schist (Steltenpohl et al. 1990). The Hekkelstrand Marble is a relatively pure carbonate sequence consisting of a ca. 40 m thick member of dark grey banded calcite marble beneath and a 100 m thick white to grey massive and banded dolomite member above. The dolomite marble unit contains the Hekkelstrand dolomite marble deposit which is commercially exploited. The Upper Mica Schist is the uppermost sequence of the Bogen Group. It has a thickness of 370 m and its bulk is made up of schists of a similar type to those which occur elsewhere within the Bogen Group. In places the schist contain Pb-Zn deposits (Juve 1967). The Djupviknes Quartzite is developed at the structural base of the schist unit.

The Niingen Group is the uppermost group in the Ofotenfjord area. The group is in thrust contact with the underlying rocks of the Bogen Group according to Karlsen (1988) and Karlsen & Andresen (1977). The main rocks of the Niingen Group are kyanite-garnet-mica schists with minor developments of trondhjemite lenses.

Based on the previous works (Foslie 1941, Vogt 1942, Gustavson 1966, Steltenpohl et al. 1990, Boyd and Søvegjarto 1983, Boyd et al. 1986) and our own study the lithostratigraphical units containing the major developments of marbles (both calcite and dolomite) are the Evenes Marble, Fuglevann Marble and Hekkelstrand Marble (Fig. 1). Some of these marbles have been correlated over long distances to the north with low-grade, fossiliferous, Late Ordovician-Silurian formations in the Upper Allochthon (e.g. Steltenpohl et al. 1990), equating with the Köli Nappes. An alternative correlation, on the other hand, has linked them with higher-grade rocks of uncertain, though probably Riphean to Vendian age, situated in the Uppermost Allochthon (e.g. Roberts & Gee 1985). Recently obtained $\delta^{13}C_{carb}$ and strontium isotopic data have indicated (Melezhik et al. 1997) that the Fuglevann and the lowermost part of the Evenes marbles are consistent with an apparent depositional age of 615-635 Ma. The $^{87}Sr/^{86}Sr$ and $\delta^{13}C_{carb}$ values of the upper portion of the Evenes carbonate sequence (variegated Leifset-type calcite marbles and associated calcite and dolomite marbles) may be indicating that these particular carbonates could be younger. Applying the Pb-Pb isochron method to the lowermost Evenes marbles has yielded an age of 600±80 Ma. The obtained date of 600±80 Ma has been considered to represent an age of metamorphism rather than of deposition (Melezhik et al. 1997), though this a matter of debate.

Only two from three marble sequences are known to contain the major developments of the dolomite marbles (Fig. 2). These are the Evenes and Hekkelstrand Marble. Two major units of dolomite marble have been documented in the Evenes Marble. One is near the structural base of the group, other is in the upper part of the Evenes Marble sequence (Fig. 2). The Hekkelstrand Marble contains one dolomite marble unit which forms the bulk of the formation (Fig. 2). The age of the two dolomite marble members within the Evenes Marble can be Late Ordovician-Silurian, given the long distance correlation between the Evenes Marble and the fossiliferous carbonates in the Balsfjord area is valid (Steltenpohl et al. 1990). This is also in agreement with the carbon and strontium isotope data (Melezhik et al. 1997a, b). The depositional age for the Hekkelstrand Marble remains unknown.

3. METHODS

In order to identify significant developments of dolomite marbles the existing preliminary map-sheets 1:50,000 have been used along with an additional mapping undertaken in the areas which have previously been poorly studied (e.g., western limb of the Ofoten synform in the Evenes area, central Skånland area). All the exposed and significant, for future commercial use, localities of dolomite marbles have been described in the field, and all necessary parameters, such as visible thickness, strike and dip, texture and structure of the rocks, have been recorded. Each locality has been characterised chemically and petrographically.

4. RESULTS FROM GEOLOGICAL MAPPING

All the significant localities of dolomite marbles which have become available in the course of mapping as well as those known from the previous work are shown on the maps (Appendices 1 and 2). These seven localities represent our best estimate for the economic potential of the area studied, to date. In terms of geological parameters the seven localities are not equal each other. Based on the field data (Table 1), and given the colour, thickness, lateral extension and degree of dipping are the major parameters which may be obtained in the

Table 1. Geological descriptions of the dolomite localities studied.

Locality	Geographic location	Stratigraphic position	Lithology	Thickness, m	Dip	Lateral extension, m	Remarks
Locality 1 (MP-96, MP-100, Ø 144-97, Ø 145-97, Ø 146-97)	*Tjeldsundet,* Tjeldsundet 1332 III, 563500E 7513550N	Evenes Marble, Upper Dolostone ?	White to grey, fine-grained, laminated dolostones; in places intercalated with dolomitised calcite marbles	50-80	60°	200?	On the coast, accessible by a paved road
Locality 2 (ED17, ED19, ED20, ED23, ED26, Ø 156-97, Ø 160-97,Ø 162-97)	*Ramstad,* Tjeldsundet 1332 III, 560950E 7603250N	Evenes Marble, Upper Dolostone ?	White to light grey, fine-grained, (sugar-like) massive to weakly banded dolostones; intercalation with calcite marble fairly common	50-100?	30°	Unknown, but may be considerable	1 km from the coast, accessible by a dirt road
Locality 3 (Ø 130-97, Ø 132-97)	*Boltåsen,* Tjeldsundet 1332 III, 570350E 7603500N	Evenes Marble, Upper Dolostone ?	White to light grey, fine-grained, massive to weakly banded dolostones	10?	35°	500?	Accessible by a paved road
Locality 4 (Ø 147-97, Ø 148-97)	*Blåfjellvatnet,* Tjeldsundet 1332 III, 573400E 7614950N	?	Light grey, fine-grained, massive to weakly banded dolostones	20?	40°	Unknown	Accessible by a dirt road
Locality 5 (Zn-1, Zn-2, Zn-3, Zn-4, Zn-5, Zn-6, Ø 369-97, Ø378-97)	*Sinklia,* Evenes 1331 IV, 574000E 7584000N	Evenes Marble, Upper Dolostone	White, fine-grained, massive (sugar-like) to weakly banded dolostones; subordinate breccias; occasional pyrite dissemination	ca. 200	60°	ca. 1500	Located on a steep slope, accessible by two dirt roads

Table continued.

Locality	Geographic location	Stratigraphic position	Lithology	Thickness	Dip	Lateral extension	Remarks
Locality 6 (Ø 167-97, Ø 168-97, Ø 169-97)	*Åsheim,* Evenes 1331 IV, 577930E 7586032N	Evenes Marble, Upper Dolostone	White, fine-grained, massive (sugar-like) dolostones		65°	200?	
Locality 7 (Bl57)	*Skårnesdalen,* Evenes 1331 IV, 571450E 7586425N	Hekkelstrand Marble ?	White, fine-grained, massive to weakly banded dolostones	ca. 30	60°	Unknown	Accessible by a dirt road, last 800 m by a tractor track

course of mapping and which may be implied for the economic assessment, all the localities may be clustered in three groups.

Group 1 has been estimated as having the highest degree of economic potential. Only Locality 2 at Ramstad can be assigned to this group. Although very restricted amount of detailed mapping work has been envisaged by the contract work, based on the data available we may assume that the dolomite marble unit can reach 50-100 m of thickness and may have a significant extension along the strike. The dolomite marble unit is characterised by rather uniform lithology and homogeneous white colour. The unit is gently diping and may be easily quarried. Some additional detailed mapping work is critical for the final evaluation of its economic potential.

Group 2, which only includes Locality 5 at Sinklia has the second priority. The dolomite marble unit at Sinklia has a thickness of 200 m which is the greatest thickness of all dolomite marble units in the study area. Although different lithologies compose the dolomite marble unit, the white, fine-grained, massive to weakly laminated marbles may be prevail over other varieties. Apart from the lithological inhomogeneity sporadically developed fine dissemination of pyrite can be an obstacle in case of the practical utilisation of this kind of dolomite marbles.

Group 3 is composed of the rest of the localities, namely Locality 1, 3, 4, 6 and 7. Although the dolomite marbles from this group are white in colour they share one particular deficiency which is either a limited thickness or a limited lateral distribution in those intersections which have been so far observed. This is a preliminary estimate based on limited data and can only be verified in case of more detailed and reliable work.

Based on pure geological grounds (probable depositional age of dolomite marbles and their position in the lithostratigraphical column) the seven localities indicated in Table 1 and briefly outlined above may be grouped in two populations. The first population , which is associated with variegated marbles (Leivset type) in the upper of the Evenes Marble sequence. These are the Baltåsen, Blåfjellvatnet, Ramstad, Tjeldsundet, Sinklia and, Åsheim occurrences. The second type, consisting only of the Skårnesdalen occurrence, may be considered to be an analogous to the Hekkelstrand Marble though apparently infolded into overlaying schist unit.

5. PETROGRAPHIC CHARACTERISTICS OF THE DOLOMITE MARBLES.

Table 2 summarises the main petrographic characteristics of dolomite marbles. This includes microtexture, grain size and abundance of non-carbonate minerals. Most of the dolomite marbles are fine-grained rocks with an average grain size less than 0.5 mm. The smallest grain size of 0.10-0.15 mm are typical feature of the Sinklia dolomite marbles. The majority of dolomite marbles consists of planar subhedral crystals of dolomite in hypidiomorphic mosaic (Fig. 3, ED17, ED23; Fig. 4, Ø132-97; Fig. 5, Ø147-97; as well as most of the dolomite marbles from Sinklia, Fig. 6). Deformation are equally expressed in all types of dolomite marbles in the development of a stretching lineation which in turn results in the formation of elongated crystals of dolomite. Although this type of texture has been documented in all dolomite marbles it is mostly developed at Ramstad (Fig. 3, ED19, ED26). Recrystallisation processes are voluminous and expressed by granoblastic texture and by the development of patches an veinlets of coarser crystals. Usually recrystallisation and grain-coarsening is accompanied by the introduction of calcium carbonate into the system. This results in the formation of calcite which replaces dolomite. Replacive calcite may occur either as 1 to 15 mm thick veinlets (Fig. 5, Ø147-97; Fig. 6, Zn-1) or as porphyroblasts developed in fine-grained dolomite matrix.

Non-carbonate minerals are mainly quartz (<0.5-10%, Fig. 3-7) and phlogopite (<0.5-2%, Fig. 3, 5, 6). Quartz always dominates over other non-carbonate minerals. The most impure dolomite marbles have been found at Blåfjellvatnet (Table 2). Some of dolomite marbles may occasionally contain minor pyrite (Sinklia) and feldspar (Ramstad, Ø156-97). The pyrite development is associated with the formation of the Sinklia deposit of sphalerite and pyrite ores and can be expected to die out when moving away from the Sinklia mineralised zone. Traces of microcline and plagioclase as well as sphene found at Ramstad are apparently associated with shearing and related metasomatic alteration. To what extent this process developed at Ramstad remains to be answered.

Table 2. Petrographic characteristics of dolostones from the Skjomen (1331 I), Evenes (1331 IV) and Tjeldsundet (1332 III) map sheets.

Sample nn	Texture	Grain size, mm			Non-carbonate minerals, %
		Min	Max	Average	
Locality 1, Tjeldsunet					
MP-96	Planar subhedral crystals in a hypidiomorphic mosaic with larger (up to 2mm) porphyroblasts of 'smoky' calcite with gas/fluid inclusions	0.01	0.20	0.16	Quartz-1, phlogopite <0.5
MP-100	Granoblastic	0.10	1.00	0.30	
Ø 144-97	Planar subhedral crystals in a hypidiomorphic mosaic	0.15	0.50	0.30	Quartz-3
Ø 145-97	Planar subhedral crystals in a hypidiomorphic mosaic with larger (up to 2mm) porphyroblasts of 'smoky' calcite with gas/fluid inclusions	0.10	0.50	0.25	Quartz-1, phlogopite-0.5
Ø 146-97	Planar subhedral crystals in a hypidiomorphic mosaic	0.10	0.30	0.20	Quartz-3, phlogopite-1
Locality 2, Ramstad					
ED17	Planar subhedral crystals in an irregular hypidiomorphic mosaic	0.10	1.00	0.25	Quartz-8
ED19	Granoblastic, stretching lineation defined by deformed grains	0.10	0.60	0.30	Quartz-2, phlogopite -2
ED20	Granoblastic, stretching lineation defined by deformed grains	0.20	0.80	0.50	Quartz-3, phlogopite <0.5
ED23	Planar subhedral crystals in an irregular hypidiomorphic mosaic	0.10	0.60	0.40	Phlogopite <0.5
ED26	Granoblastic, stretching lineation defined by deformed grains	0.30	1.00	0.50	Phlogopite <0.5
Ø 156-97	Porphyroblastic	0.50	5.00	2.00	Quartz-25, phlogopite-5, sphene <0.5, microcline-<0.5, plagioclase <0.5
Locality 3, Boltåsen					
Ø 130-97	Granoblastic	0.20	0.50	0.30	Quartz-15, phlogopite <0.5
Ø 132-97	Planar subhedral crystals in an irregular hypidiomorphic mosaic with patchy recrystallisation	0.20	0.40	0.25	Quartz-1, phlogopite <0.5

Table continued.

Sample nn	Texture	Grain size, mm			Non-carbonate minerals, %
		Min	Max	Average	
Locality 4, Blåfjellvatnet					
Ø 147-97	Planar subhedral crystals in a hypidiomorphic mosaic with patches (up to 2cm) of coarse (up to 2mm) nonplanar crystals of calcite	0.05	0.25	0.10	Quartz-9, phlogopite-2
Ø 148-97	Granoblastic	0.10	0.40	0.30	Quartz-11, phlogopite-1
Locality 5, Sinklia					
Ø 369-97	Planar subhedral crystals in a hypidiomorphic mosaic	0.005	0.20	0.10	
Ø 378-97	Planar subhedral crystals in a hypidiomorphic mosaic with larger (up to 2mm) porphyroblasts of 'smoky' calcite with gas/fluid inclusions	0.05	0.20	0.15	
Zn-1	Nonplanar crystals in a xenotopic mosaic	0.05	0.15	0.10	Quartz-2, phlogopite-2
Zn-2	Planar subhedral crystals in a hypidiomorphic mosaic	0.05	0.5	0.15	Quartz-0.5, phlogopite-1.5, pyrite <0.5
Zn-3	Planar subhedral dolomite crystals in a hypidiomorphic mosaic, 2-10 mm veinlets of coarse calcite	0.05	0.10	0.08	Quartz-4, phlogopite-4
Zn-4	Planar subhedral crystals in a hypidiomorphic mosaic	0.05	0.15	0.10	Quartz-1.5, phlogopite-1
Zn-5	Planar subhedral crystals in a hypidiomorphic mosaic 1-10 mm veinlets of coarse calcite with pyrite	0.05	0.15	0.10	Quartz-2, phlogopite-1.5, pyrite-1
Zn-6	Nonplanar crystals in a xenotopic mosaic	0.20	0.70	0.50	Quartz-8, plogopite-2.5
Locality 6, Åsheim					
Ø 167-97	Thin section are not available				
Ø 168-97	Thin section are not available				
Ø 169-97	Thin section are not available				
Locality 7, Skårnesdalen					
Bl57	Planar subhedral crystals in a hypidiomorphic mosaic	0.20	1.00	0.50	

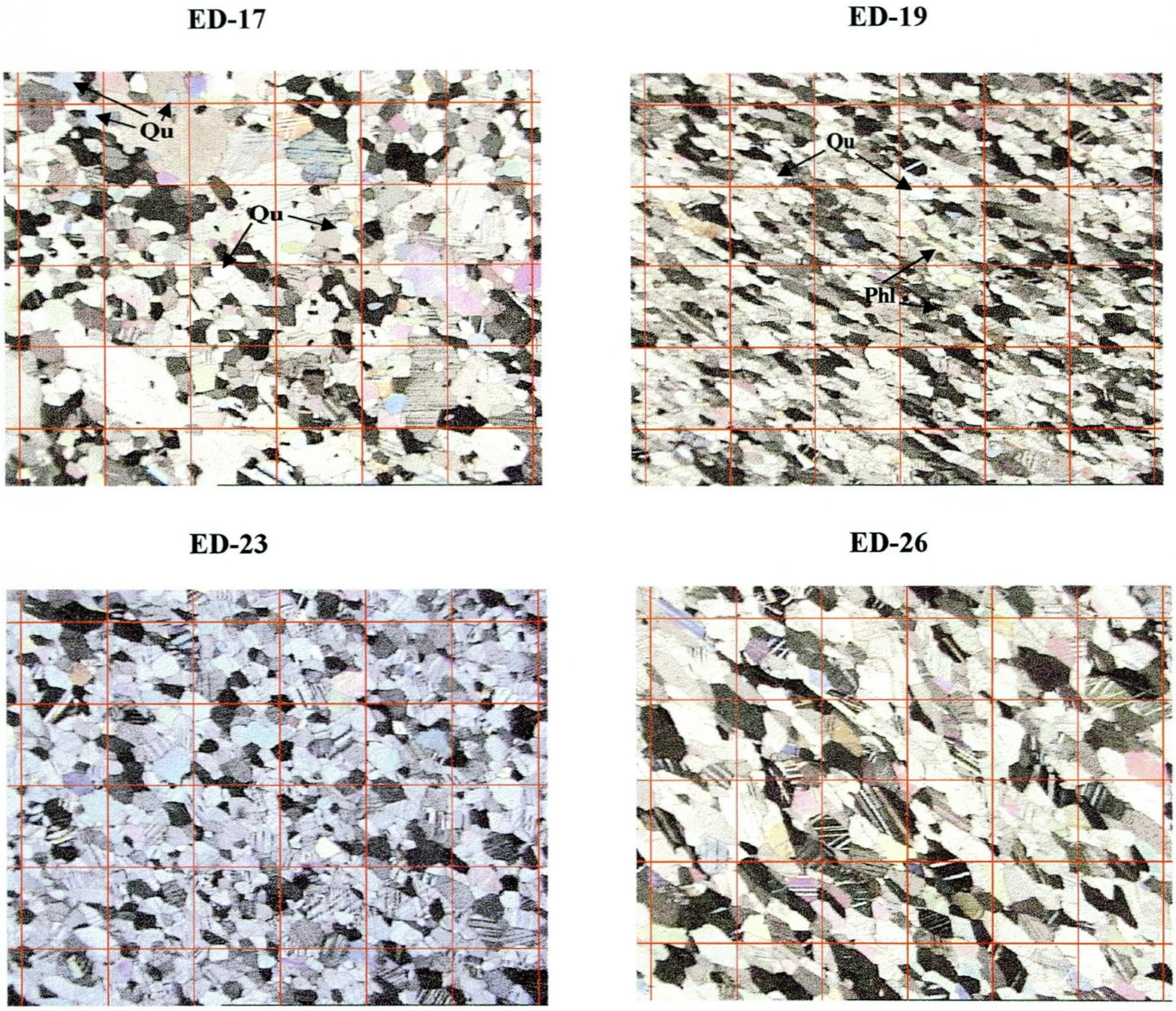

Figure 3. *Microtextures of the Ramstad dolomite marbles. Transmitted polarised light. Grid is 1 mm. Qu-quartz, Phl-phlogopite.*

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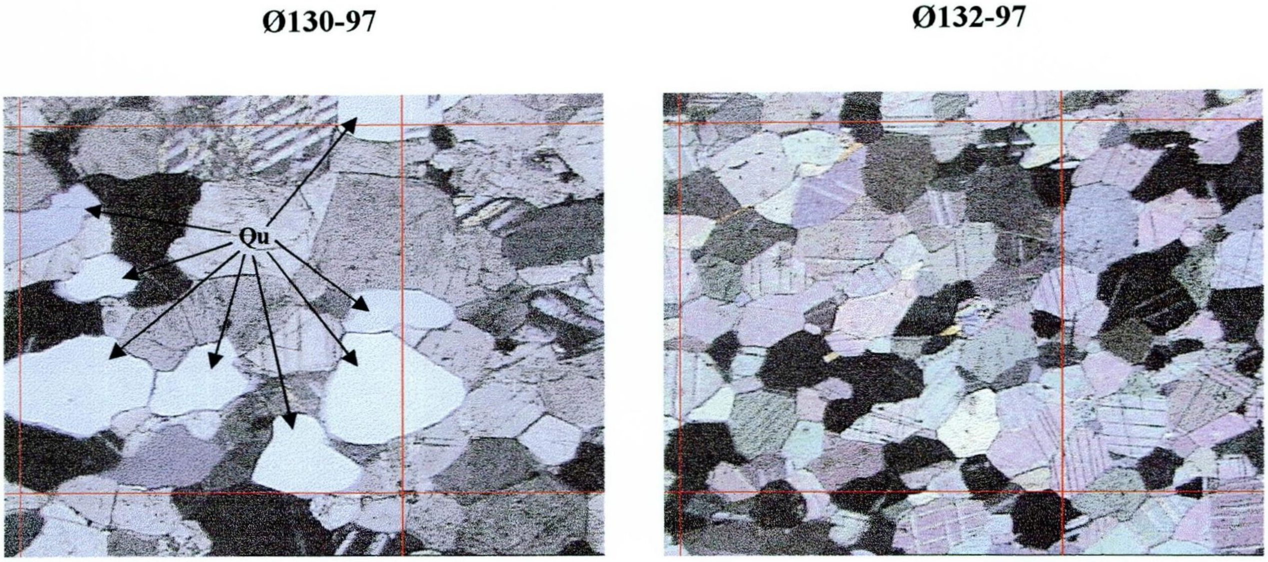

Figure 4. *Microtextures of the Boltåsen dolomite marbles. Transmitted polarised light. Grid is 1 mm. Qu-quartz.*

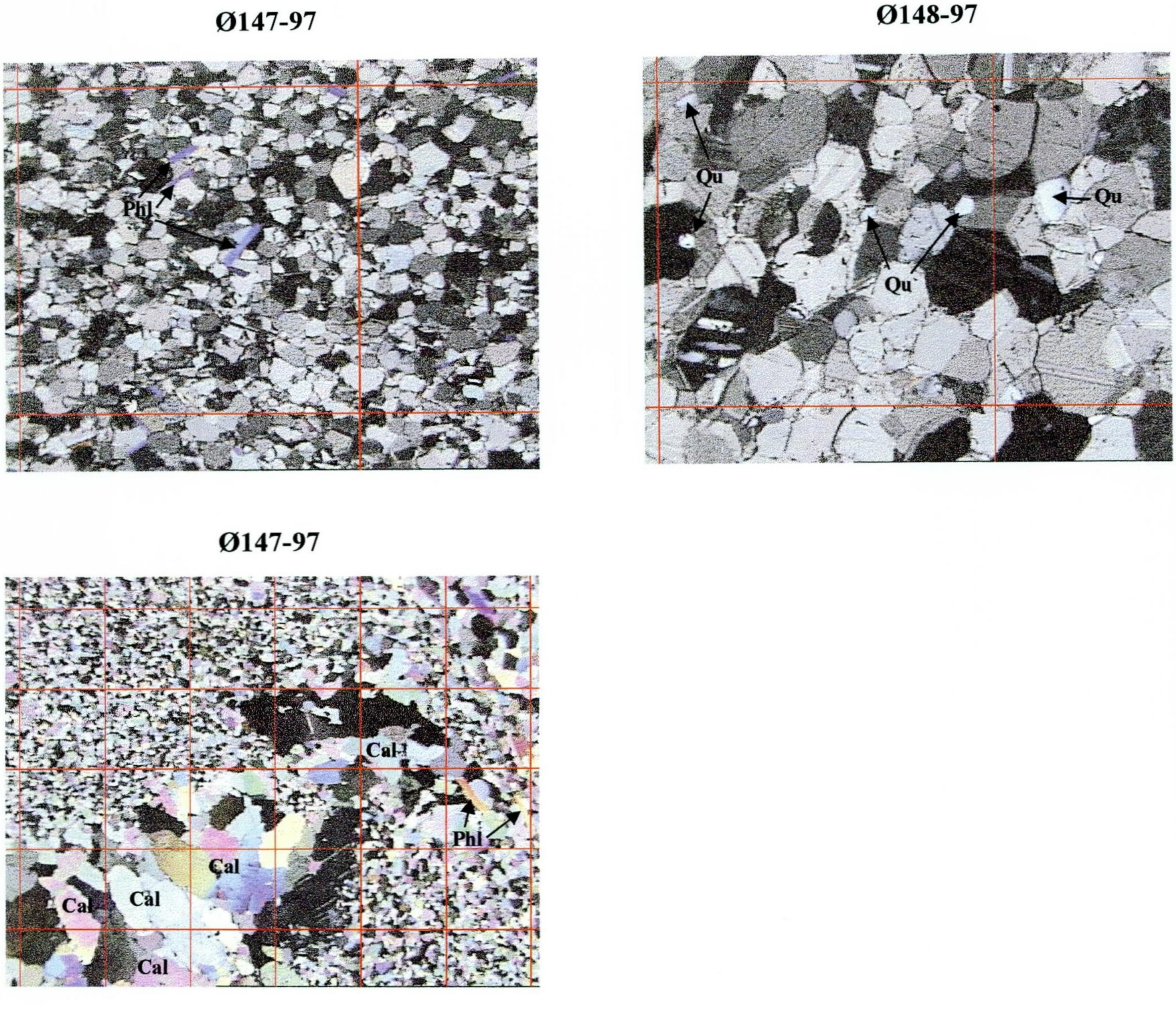

Figure 5. *Microtextures of the Blåfjellvatnet dolomite marbles. Transmitted polarised light. Grid is 1 mm. Qu-quartz, Phl-phlogopite, Cal-calcite.*

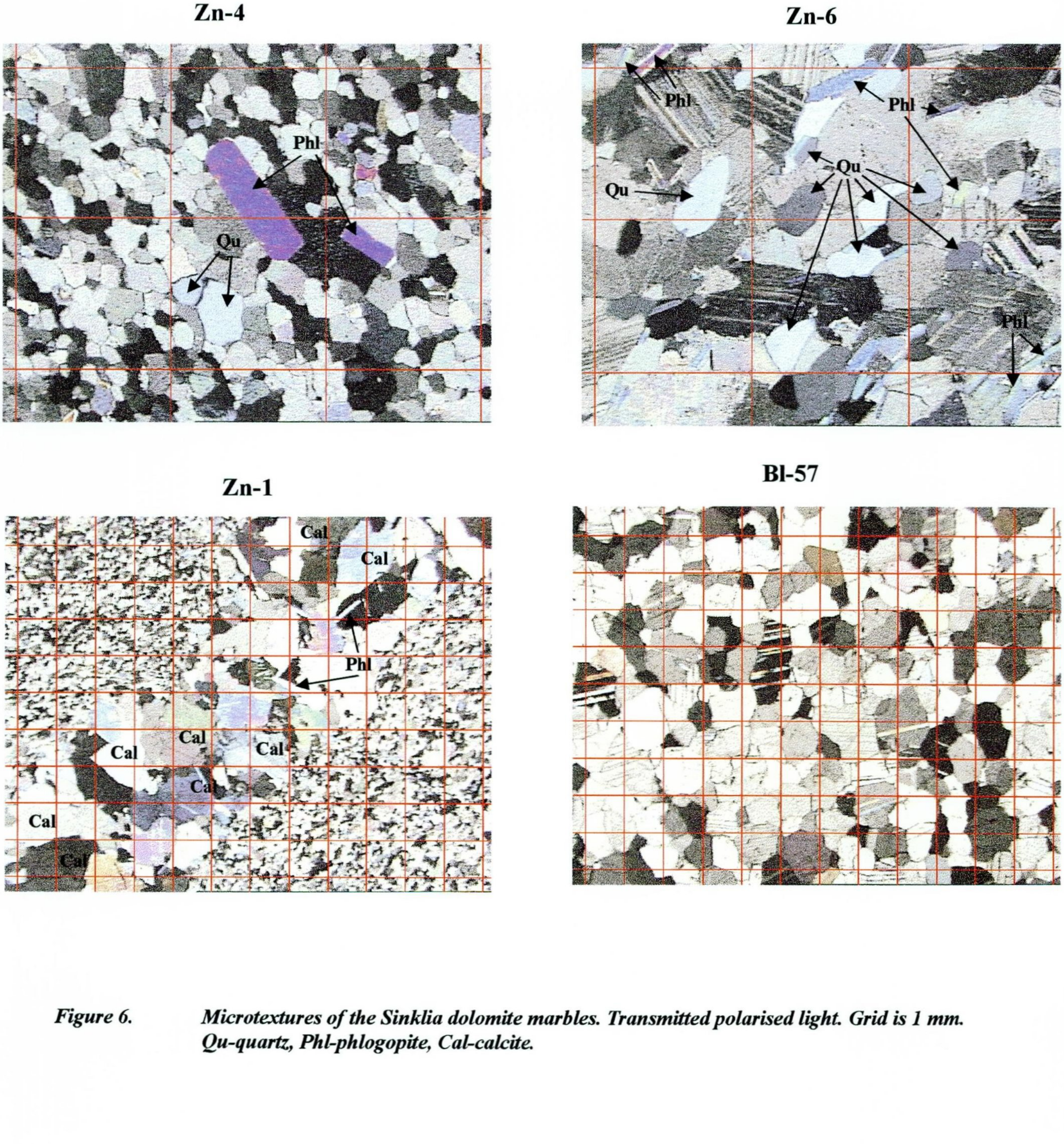

Figure 6. *Microtextures of the Sinklia dolomite marbles. Transmitted polarised light. Grid is 1 mm. Qu-quartz, Phl-phlogopite, Cal-calcite.*

6. CHEMICAL CHARACTERISTICS OF DOLOMITE MARBLES.

Major element abundances, including that of soluble MgO and CaO, as well as MnO and P_2O_5 contents are shown in Table 3. Based on the soluble MgO and CaO the apparent dolomite content has been calculated (stoichiometric dolomite, $CaMg(CO_3)_2$, contains 21.9%wt. MgO and 30.4%wt. CaO). This is also included in Table 3 and shown in the various cross-plots (Fig. 7). The SiO_2 vs. dolomite cross-plot demonstrates a strong negative correlation indicating that silica is the major component which dilutes the dolomite marbles. Taken the amount of dolomite is one of the major factors, which controls the quality of dolomite marbles as a commercial product, only four out of seven occurrences indicate a good potential. These are the dolomite marbles sampled at Ramstad (Ø156-97 excluded from diagram as being not representative), Sinklia, Skårnesdalen and Tjeldsunet. If some other geochemical factor is involved, e.g. Fe content, then the Sinklia dolomite marbles arew the worse of the four occurrences indicated above.

7. PHYSICAL PROPERTIES.

We will discuss here only reflectivity (brightness) values as these are only the data available to our disposal (the burning tests have been carried out at the Franzefoss laboratory). The results, accompanied by brief description of the analytical procedures, are presented in Table 4 and Fig. 8. The highest brightness values (up to 92, R457) have been measured from the Tjeldsundet and Ramstad samples. Although the entire range of reflectivity values observed for dolostones of the Ramstad occurrence is from 85 to 94, five samples from seven have the reflectivity above 90. As expected, there is a high covariance (r=0.83) between dolomite content and the brightness values. Also significant level of negative correlation has been detected between the reflectance and Fe content (r=-45, Fig. 8). We are not yet in the position to answer which species of Fe-bearing minerals are responsible for the brightness decrease, though we suspect that these could be either a Fe-bearing phlogopite or, perhaps, very minor amount of magnetite and/or graphite. If a serious need for more information should appear

Table 3. Chemical composition of dolomite marbles (%) from the Skjomen (1331 I), Evenes (1331 IV) and Tjeldsundet (1332 III) map sheets.

Sample nn												Acid soluble			Acid soluble	
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MgO	CaO	Na_2O	K_2O	MnO	P_2O_5	S_{tot}	$MgCO_3$**	$CaCO_3$**	Dolomite**	MgO	CaO
Locality 1, Tjeldsunet																
MP-96*	1.51	0.18	0.24	0.009	22.71	30.10	-	0.067	0.007	0.09	-	n.d.	n.d.	n.d.	n.d.	n.d.
MP-100*	0.06	0.03	0.14	-	22.80	30.72	-	0.006	0.007	0.09	-	n.d.	n.d.	n.d.	n.d.	n.d.
Ø 144-97	2.82	0.06	0.13	-	23.21	29.91	-	0.041	0.005	0.04		44.5	52.0	96.5	21.19	29.22
Ø 145-97	1.43	0.25	0.33	0.01	22.51	30.79	-	0.101	0.016	0.06		42.9	54.2	97.1	20.42	30.47
Ø 146-97	3.47	0.74	0.30	0.03	21.16	30.42	-	0.317	0.011	0.09		40.6	53.7	94.3	19.32	30.17
Locality 2, Ramstad																
ED17	8.36	0.02	0.09	-	17.39	31.75	-	0.019	0.002	0.06	-	34.2	56.4	90.7	16.30	31.70
ED19	2.40	5.34	0.14	-	22.61	30.07	-	0.030	0.005	0.08	-	43.3	53.3	96.6	20.60	29.94
ED20	3.51	0.06	0.29	-	20.94	31.26	-	0.035	0.011	0.12	-	38.6	55.6	94.3	18.40	31.26
ED23	0.15	0.03	0.14	-	23.66	30.43	-	0.041	0.010	0.05	-	45.4	53.0	98.4	21.61	29.77
ED26	0.11	0.02	0.19	-	23.69	30.36	-	-	0.012	0.05	-	45.4	53.4	98.8	21.61	30.02
Ø 156-97	25.29	2.64	0.35	0.04	19.16	22.00	0.22	0.617	0.009	0.12	-	31.3	34.9	66.2	14.91	19.59
Ø 162-97	1.67	0.11	0.27	0.01	23.27	30.37	-	0.055	0.021	0.08	-	44.4	52.5	96.2	21.10	29.49
Locality 3, Boltåsen																
Ø 130-97	16.53	0.07	0.22	-	19.7	26.18	-	0.035	0.014	0.04		37.1	46.1	83.2	17.66	25.90
Ø 132-97	1.23	0.11	0.19	0.01	22.99	30.46	-	0.067	0.012	0.06		44.0	53.5	97.5	20.96	30.04

Table continued.

Sample nn												Acid soluble			Acid soluble	
	SiO2	Al2O3	Fe2O3	TiO2	MgO	CaO	Na2O	K2O	MnO	P2O5	S_{tot}	$MgCO_3$**	$CaCO_3$**	Dolomite**	MgO	CaO
Locality 4, Blåfjellvatnet																
Ø 147-97	10.49	1.02	0.34	0.04	20.83	27.36	-	0.483	0.008	0.04		37.9	48.1	86.0	18.07	27.01
Ø 148-97	11.63	0.36	0.20	0.02	20.97	27.16	-	0.217	0.008	0.02		40.4	47.1	87.1	19.04	26.45
Locality 5, Sinklia																
Ø 369-97	1.03	0.15	0.41	0.01	23.1	30.58	-	0.081	0.024	0.05		43.9	53.7	97.6	20.92	30.17
Ø 378-97	2.55	0.35	0.66	0.01	22.51	29.99	-	0.161	0.045	0.06		44.4	52.7	97.1	21.15	29.62
Zn-1*	3.09	0.58	0.87	0.026	21.25	29.11	-	0.327	0.052	0.04	-	n.d.	n.d.	n.d.	n.d.	n.d.
Zn-2*	1.47	0.27	0.32	0.013	22.45	29.77	-	0.226	0.031	0.04	-	n.d.	n.d.	n.d.	n.d.	n.d.
Zn-3*	4.91	1.09	0.75	0.064	20.81	28.61	-	0.553	0.036	0.07	-	n.d.	n.d.	n.d.	n.d.	n.d.
Zn-4*	1.94	0.36	0.56	0.035	21.67	30.32	-	0.176	0.049	0.03	-	n.d.	n.d.	n.d.	n.d.	n.d.
Zn-5*	2.91	0.56	2.16	0.020	20.79	28.36	-	0.289	0.063	0.03	0.57	n.d.	n.d.	n.d.	n.d.	n.d.
Zn-6*	9.36	1.54	1.03	0.079	5.34	43.17	-	0.631	0.061	0.06	-	n.d.	n.d.	n.d.	n.d.	n.d.
Locality 6, Åsheim																
Ø 167-97	2.29	0.67	0.72	0.031	21.53	29.97	-	0.203	0.037	0.07		41.2	53.6	94.9	19.63	30.13
Ø 168-97	2.83	0.96	0.54	0.045	20.81	30.41	-	0.314	0.016	0.08		40.0	54.1	94.1	19.05	30.41
Ø 169-97	6.23	1.55	0.42	0.069	19.06	29.56	-	0.589	0.006	0.71		36.1	53.7	89.8	17.19	30.16

Table continued.

Sample nn												Acid soluble			Acid soluble	
	SiO2	Al2O3	Fe2O3	TiO2	MgO	CaO	Na2O	K2O	MnO	P2O5	S_{tot}	$MgCO_3$**	$CaCO_3$**	Dolomite**	MgO	CaO
Locality 7, Skårnesdalen																
Bl57	0.57	-	0.16	-	23.47	30.69	-		0.005	0.04	-	45.0	53.1	98.1	21.43	29.81

*Samples from previous work.

**Calculated values.

n.d., not determined; dashes, below detection limit. Detection limits are: <0.01, <0.004, <0.01, 0.003, <0.01 for Al_2O_3, TiO_2, Na_2O, K_2O, S_{tot}, respectively.

Analysts: XRF - Bjørn Nilsen, CaO & MgO acid soluble - Johs. Rye Røste, S - Anne Nordtømme.

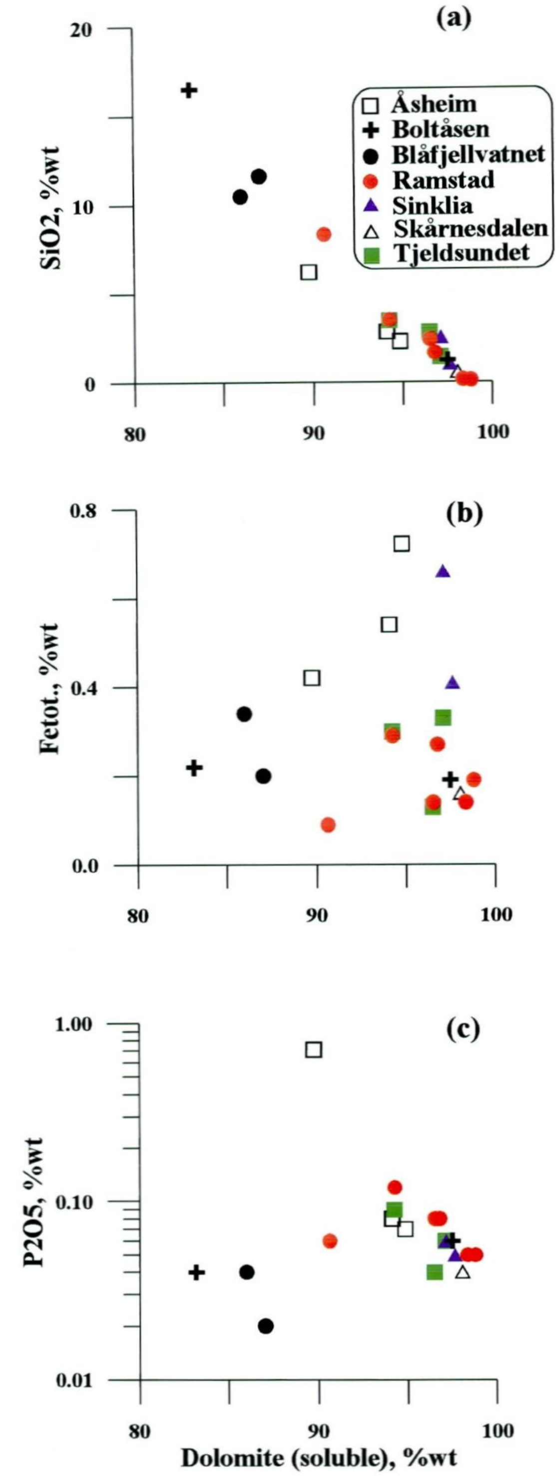

Figure 7. *SiO_2-dolomite, Fe_{tot}-dolomite, P_2O_5-dolomite cross-plots.*

Table 4. *Reflectance values of the studied dolomite marbles.*

Sample nn	Filter	%
Locality 1, Tjeldsundet		
Ø144-97	FMX	94.7
	FMY	94.3
	FMZ	92.3
	R457	92.4
Ø145-97	FMX	91.2
	FMY	90.2
	FMZ	84.8
	R457	84.9
Ø146-97	FMX	94.3
	FMY	93.9
	FMZ	91.4
	R457	91.4
Locality 2, Ramstad		
ED17	FMX	91.6
	FMY	91.4
	FMZ	90.2
	R457	90.2
ED19	FMX	87.0
	FMY	86.9
	FMZ	86.6
	R457	86.6
ED20	FMX	94.0
	FMY	93.7
	FMZ	92.2
	R457	92.2
ED23	FMX	93.8
	FMY	93.5
	FMZ	92.3
	R457	92.3
ED26	FMX	93.8
	FMY	93.6
	FMZ	92.6
	R457	92.6
Ø156-97	FMX	85.5
	FMY	84.8
	FMZ	82.5
	R457	82.5
Ø162-97	FMX	92.7
	FMY	92.3
	FMZ	92.3
	R457	90.2
Locality 3, Boltåsen		
Ø130-97	FMX	90.8
	FMY	89.8
	FMZ	84.7
	R457	84.8
Ø132-97	FMX	93.0
	FMY	92.3
	FMZ	89.3
	R457	89.3
Locality 4, Blåfjellvatnet		
Ø147-97	FMX	87.0
	FMY	86.1
	FMZ	82.2
	R457	82.3
Ø148-97	FMX	89.6
	FMY	88.9
	FMZ	85.3
	R457	85.4
Locality 5, Sinklia		
Ø369-97	FMX	91.8
	FMY	91.2
	FMZ	88.0
	R457	88.1
Ø378-97	FMX	87.4
	FMY	86.6
	FMZ	82.2
	R457	82.2
Locality 6, Åsheim		
Ø 167-97	FMX	92.8
	FMY	92.3
	FMZ	89.4
	R457	89.4
Ø 168-97	FMX	88.3
	FMY	86.9
	FMZ	82.6
	R457	82.7
Ø 169-97	FMX	92.6
	FMY	92.1
	FMZ	89.2
	R457	89.3
Locality 7, Skårnesdalen		
B157	FMX	91.1
	FMY	90.9
	FMZ	89.8
	R457	89.8

Measured on pressed powder (74μm) pellets, using a Zeiss ElrephoMat DFC 5 photometer and a $BaSO_4$-standard (DIN 5033). The reflectance values are shown separately for different wave-lengths (filters): FMX (red-amber, 600nm), FMY (green, 550nm), FMZ (blue, 450nm), R457 (brightness, 457nm). Analysts: J.R. Røste.

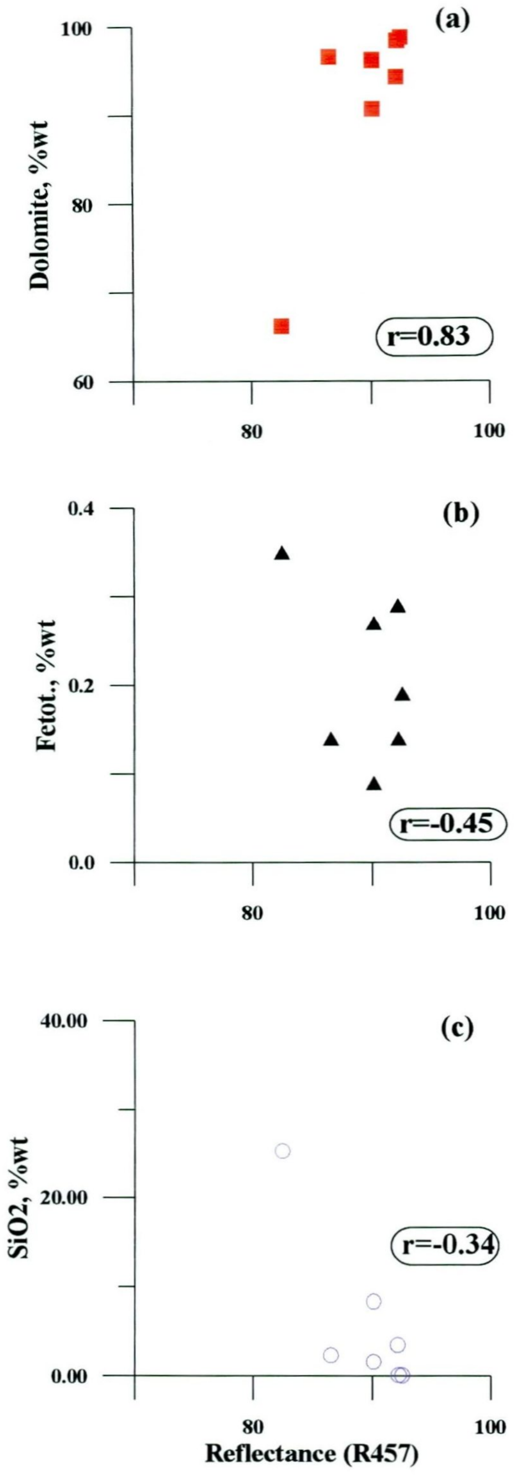

Figure 8. *SiO_2-brightness, Fe_{tot}- brightness, P_2O_5- brightness cross-plots.*

then a detailed mineralogical investigation would be required such as a microprobe and electron microscope studies. Based on the data available the Tjeldsundet and Ramstad dolomite marbles are the best material in terms of the reflectivity and brightness values.

8. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK.

Four occurrences of dolomite marbles out of seven studied may be considered for future follow-up work. These are the dolomite marbles exposed at Ramstad, Sinklia, Skårnesdalen and Tjeldsundet. If all the factors are considered (geographic location, accessibility, possible volume, quality, extraction) the Ramstad occurrence is estimated to have the highest potential. The final assessment of the Ramstad occurrence should include detail mapping of a restricted area in order to evaluate the volume and distribution of different quality dolomite marbles.

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GEOLOGISK KART SKÅNLAND, EVENES, TJELDSUND, NORDLAND OG TROMS

Geologisk kartgrunnlag: Ofoten M1 : 100 000 (M. Gustavson 1972)
(Kartet er laget digitalt med hjelp av ArcInfo av T. Sørdal. 1997)

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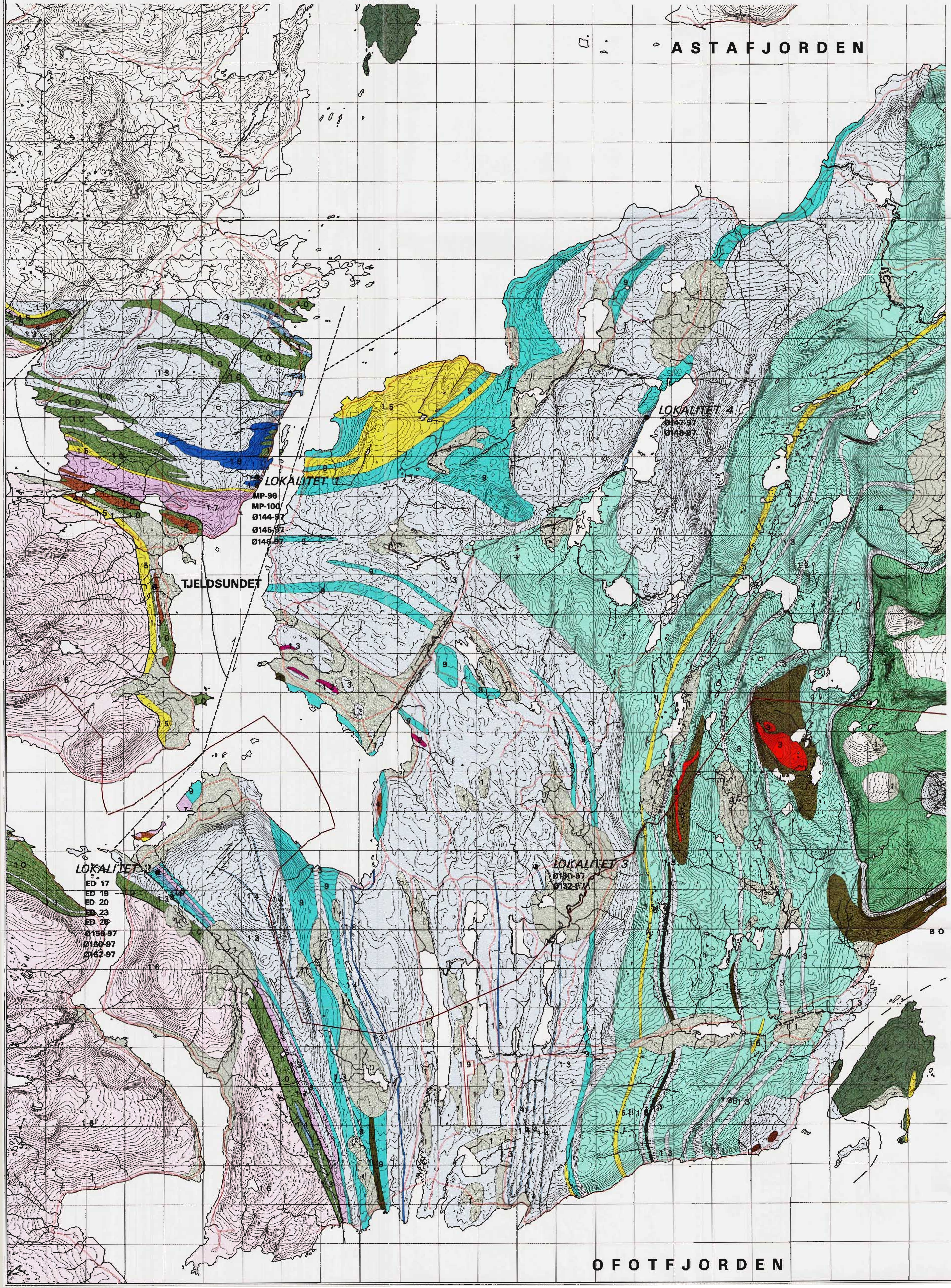


TEGNFORKLARING

- 1 Kvartære avsetninger

ERUPTIVBERGARTER (Kaledonske)

- 2 Kvartsnoritt, Rånamassivet
- 3 Granittoide bergarter
- 4 Amfibolitt

METAMORFE SEDIMENTER
(Sen proterozoisk til kambrosilursk).

- 5 Glimmergneiser i Niingen-gruppen (Med granitoide ganger og årer)
- 6 Glimmergneiser i Niingen-gruppen (Uten granittoide ganger)
- 7 Glimmerskifre og -gneiser i Bogen-gruppen. (Med granittoide ganger og årer)
- 8 Glimmerskifre og -gneiser i Bogen-gruppen. (Uten granittoide ganger)
- 9 Glimmergneiser i Narvik-gruppen
- 10 Glimmerskifre i lave nivåer
- 11 Jernmalmførende glimmerskifre
- 12 Konglomerat og konglomeratisk kalkglimmerskifer
- 13 Kalkspatmarmor.
- 14 Dolomittmarmor.
- 15 Kvartsitt
- 16 Fargebåndet kalkspatmarmor.

BUNNMASSIVET (Grunnfjell)

- 16 Granitt og granittisk gneis
- 17 Gneisaktig granitt, kaledonsk deformert og skjøvet

GEOLOGISKE SYMBOLER

- Viktig bergartsgrense/ mulig skyvegrense.
- Skyvegrense/ antatt skyvegrense.
- Forkastning
- Prøvelokalitet

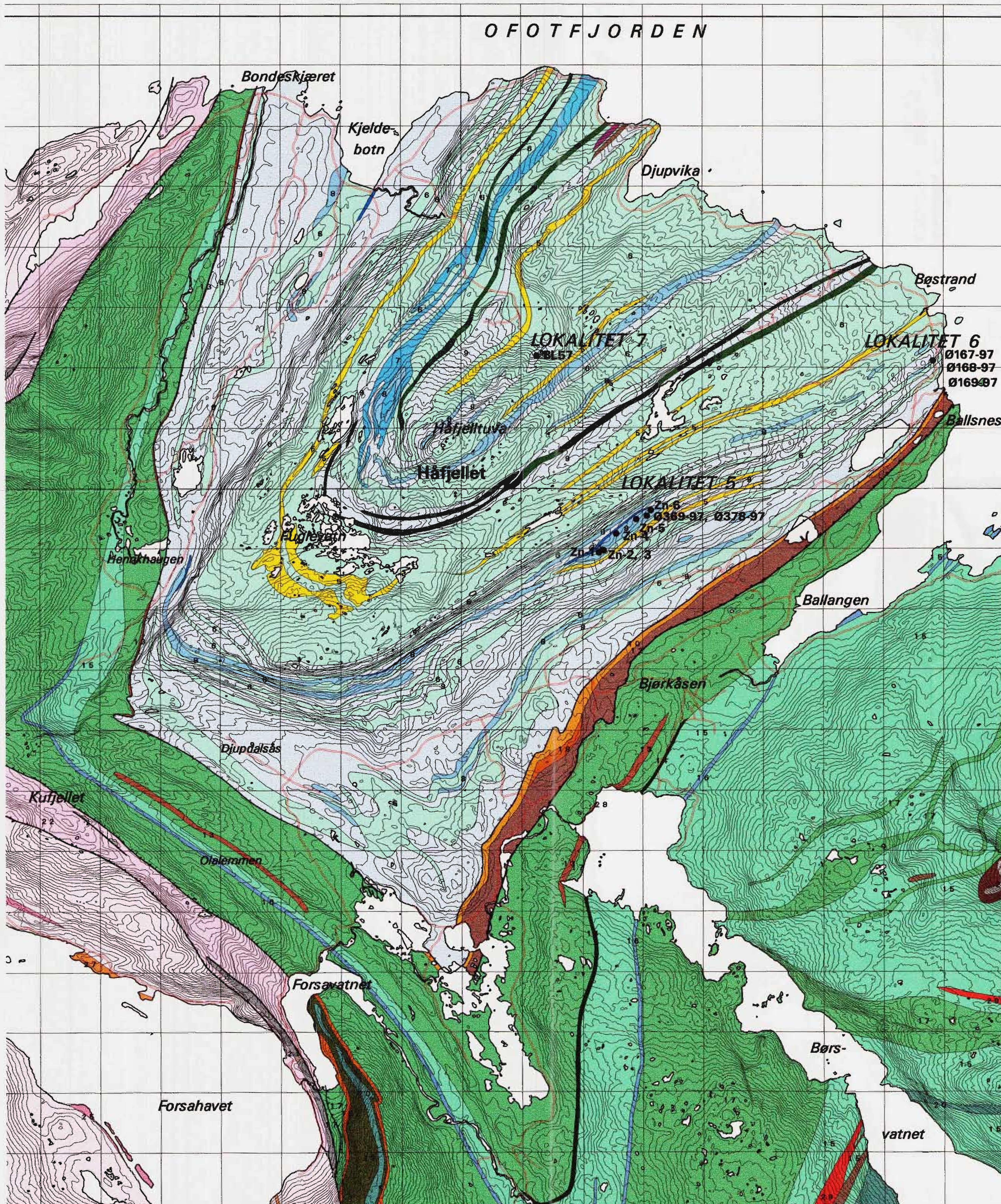
Målestokk
0 5 Km.

NGU Rapport nr. 97.184 Kartbilag 01

GEOLOGISK KART BALLANGEN M1:50 000

NGU Norges geologiske undersøkelse

Geologisk kartgrunnlag: Boyd, R. & Søvegjarto, U. 1983.
Boyd, R., Hodges, K.V., Steltenpohle, M. & Søvegjarto, U. 1986.
(Kartet er laget digitalt med hjelp av ArcInfo av T. Sørdal. 1997)



TEGNFORKLARING

Overskjøvne bergarter av antatt proterosoisk til kambrosilursk alder.
Salangendekket: Øverste Allokton (Staurolitt-amfibolitt facies).

- 1 Amfibolitt.
- 2 Granittisk kvarts-feltspatgneis (antatt omdannet granitt).
- 3 Tremolitt-diopsid skarn.
- 4 Granat-hornblende-karbonatglimmerskifer / Soner av hematitt-magnetitt jernformas
- 5 Kvartsitt.
- 6 Granat-kvarts glimmerskifer.
- 7 Båndet kalkglimmerskifer og granat-biotittskifer.
- 8 Dolomitt.
- 9 Kalkspatmarmor.
- 31 Fargebåndet kalkspatmarmor.

Bjerkvikdekket: Øvre Allokton (Grønnskifer facies) (Antatt over-ordovicisk til undersilursk alder).

- 10 Konglomerat delvis med mafiske boller, arkose / Tynne soner av samme bergart.
- Metatonalitt.
- 12 Tektonisert mafisk kompleks (gabbro, diabas, trondhjemitt, kloritt-/kalkfylitt)

Narvikdekket: Øvre Allokton (Kyanitt-Amfibolitt facies).

- 13 Sulfid-grafitt-amfibolrik gneis /Tynne soner av samme bergart.
- Jernformasjonen.
- 15 Granat-glimmergneis med lag av kvarts-feltspatgneis.
- 16 Melkedalskalken.
- 17 Sulfid- og grafittførende skifer, delvis kvartsskifer.
- 18 Migmatittisk gneis.
- Grå muskovittskifer.
- 20 Kalkglimmerskifer/kalksilikatbergart, delvis grafitt-/sulfidførende.
- 29 Trondhjemitt.

Abiskodekket: (Mellomste dekkekompleks, granat-amfibolitt facies).

- 21 Kvarts-feltspatgneis (antatt omdannet sediment) med lag av glimmergneis, og kvartsitt og linser av metagranitt.
- 22 Metagranitt med lag av glimmergneis.
- 23 Peridotitt

Stedegne bergarter av proterozoisk alder. (Grunnfjell).

- 24 Granitt, granittisk gneis.
- 25 Dioritt, diorittisk gneis / med mafiske xenolitter.
- 26 Gabbro. amfibolitt, diabas og folierte ekvivalenter.
- 27 Grå kvarts-feltspatgneis, delvis amfibolførende.

Geologiske symboler

- Skyvegrense under Salangsdekket.
- Skyvegrense under Bjerkvikdekket.
- Skyvegrense under Narvikdekket.
- Skyvegrense under Abiskodekket.
- Forkastning / mindre skyvesone.