3. On a dolomitic pseudo-conglomerate of probably ultrabasic origin from Dalovardo in the Caledonides of Västerbotten

By

Folke G. Back

The material described in this paper has been collected in the summer of 1957 in the course of mapping activities for the Boliden Mining Company at Dalovardo in the north-western Caledonides of Västerbotten. The mapping was carried out under the leadership of Dr. Nils Marklund.

The examined occurrence of talc-schists and chlorite-schists with inclusions of dolomite at Dalovardo forms part of the sequence overlying the so-called Dalovardo arkose, a stage in the Mesket Series of the Västerbotten Mountains proper (MARKLUND, 1956). The approximate extension of the Dalovardo arkose can be seen on Fig. 1. According to MARKLUND the arkose seems to belong to the upper Middle or Upper Ordovician.

In 1957 MARKLUND and the present author carried out a detailed mapping on a fairly large scale of the northern part of the region between Dalovardo and Birdotjärro. The part of the sequence shown on the sketch-map, Fig. 2, attracted attention by the occurrence of a horizon with conglomerate-like structure in the series of chlorite-schists which overlie the Dalovardo arkose between Dalovardo and Birdotjärro. Here the strike of the rocks is rather variable, the dip being on the whole rather gentle (15–30°) towards west to south. In Section, Fig. 4, the following sequence of strata has been measured in descending order:

Talc-schist.		Spec. 1562
Chlorite-schist	10–15 cm . . .	Spec. 1563
Upper part of the "conglomeratic" schist. .	20 cm . . .	Spec. 1564
Middle part of the "conglomeratic" schist .	30 cm . . .	Spec. 1565
Lower part of the "conglomeratic" schist. .	20 cm . . .	Spec. 1566
Chlorite-schist	20 cm . . .	Spec. 1567 A, B
Talc-schist.		Spec. 1568

The "conglomeratic" horizon is characterized by ovoid pebbles of dolomite, to which on account of their feeble resistance is due a characteristic sculpture on the weathered surface (Fig. 5). The total thickness reaches 70 cm. In the "conglomeratic" horizon itself a central zone, 30 cm thick, with large pebbles

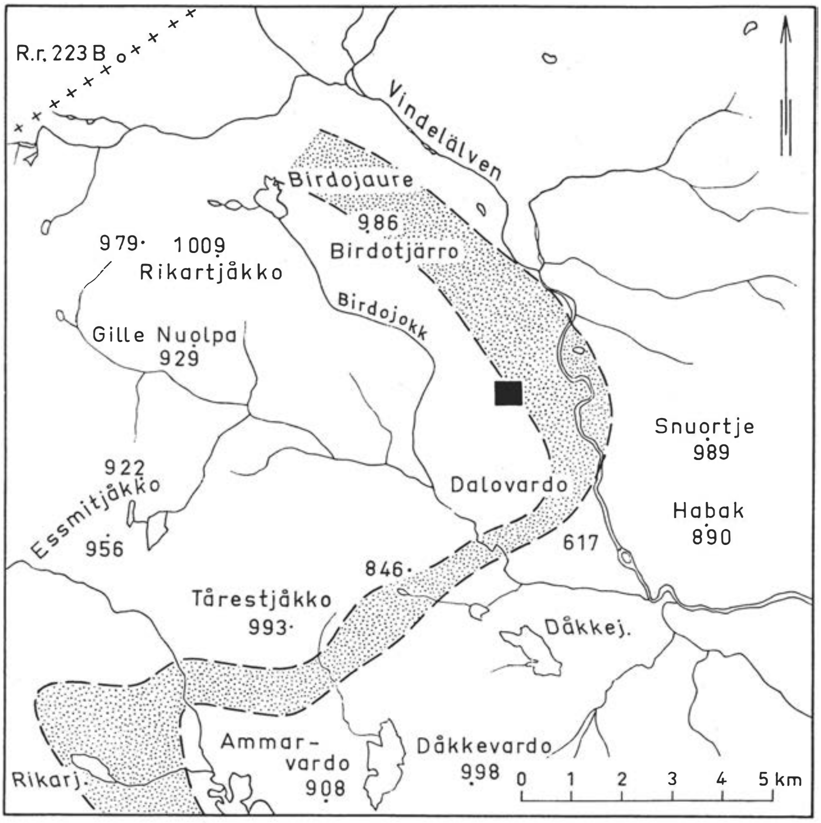

Fig. 1. The approximate extension of the Dalovardo arkose according to N. Marklund (1957).

(up to 25 cm) is distinguished. Most of them are 8–12 cm. The material of the pebbles exhibits furthermore transitions to "boudinaged" layers with a thickness of about 3–4 cm. On either side of the central zone, separated from it with sharp boundary, occurs a zone, 20 cm thick, with carbonate pebbles of considerably smaller size, varying from some millimetres to one or two centimetres (Fig. 3). The "conglomeratic" horizon is intercalated in chlorite-schists, merging into talc-schists which form the top and the bottom of the section.

Owing to scarceness of exposures the "conglomeratic" horizon could be followed over a distance of about 50 m only.

An occurrence of schistose peridotite in zoisite-amphibolite (Grip, 1933) from Stråttekjaure, Ammarfjället, described by Du Rietz (1935) shows a similar weathering surface with numerous ovoid cavities due to dissolved accumulations of carbonate.

Some 20 m north of the "conglomeratic" schist of Section 1, a horizon of dolomitic chlorite-schist probably of similar nature extends conformably to the

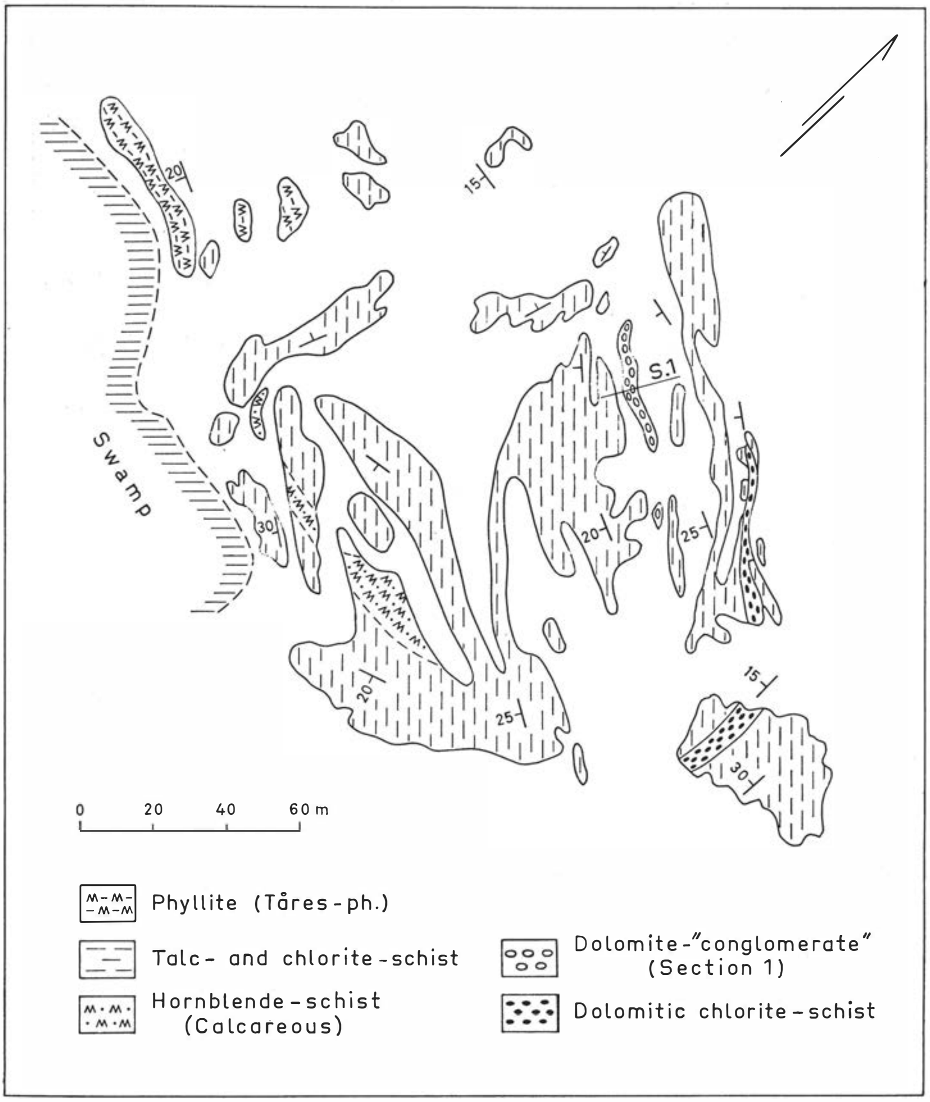

Fig. 2. Geological sketch-map of the area.

former (Fig. 2). Here, however, "conglomeratic" pebbles are lacking and the dolomite is present as porphyroblasts poikilitically studded with small grains of quartz. The dolomitic chlorite-schist is intercalated in talc-schist of the same kind as in the section dealt with above. The strike of the horizon is on the whole SE–NW, but turns towards the south in the south-eastern part. The intergration analysis of this chlorite-schist (Spec. 1583, Table 3) shows that its mineral composition is rather similar to that in Section 1. Fig. 4 shows, where in Section 1 the thin sections have been taken. When taking the hand specimens,

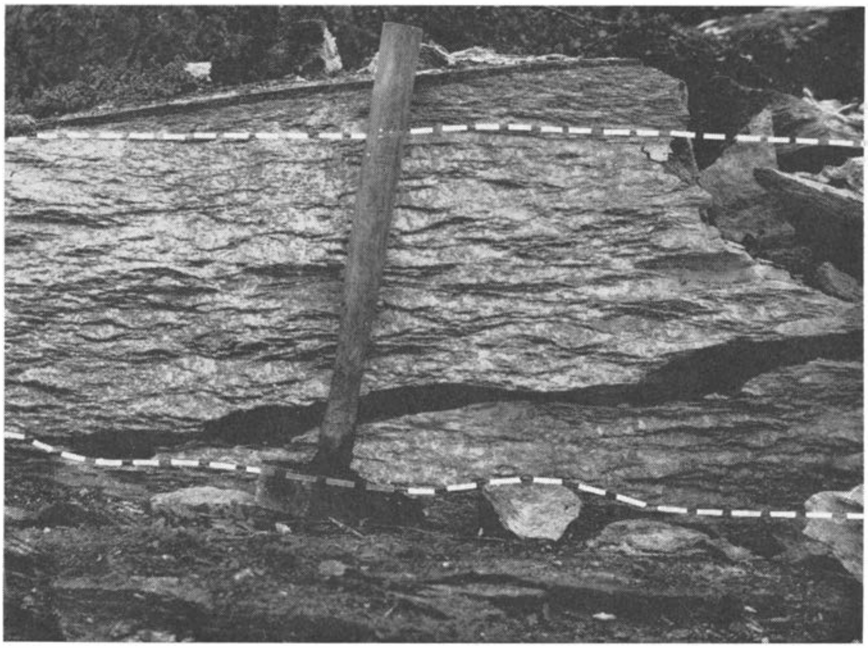

Fig. 3. The middle part of the "conglomeratic" schist with sharp boundaries against the upper and lower parts.

the orientations of some s-surfaces appearing in the rocks have been recorded. In Section 1, the planes of schistosity have a strike of N 60°W, dipping 30° towards S 30°W. In the following the rocks of Section 1 are described in ascending order from bottom upwards.

Spec. 1568. — The rock is a greyish-green talc-biotite-schist fairly rich in quartz. The distance between the s-surfaces is rather uniformly 1–1.5 mm. The texture is lepidoblastic with porphyroblastic scales of biotite and grains of ore. The size of the rounded scales of biotite is about 0.5 mm. $2V_\alpha$ of the biotite is 10–15°. It exhibits a poikiloblastic texture with small enclosed grains of quartz. The main components of the schist are talc in small scales, fine-grained quartz, and plagioclase. For the composition and the optical properties of the plagioclase, see Spec. 1567 A. The plagioclase never exhibits cleavage, nor twinning. Owing to the difficulty to distinguish the fine-grained quartz from the plagioclase under the microscope these two minerals have been counted together in the intergration analysis, the free quartz afterwards being determined chemically according to the phosphoric acid method of Hirsch and Dawihl (1932). The modal composition of the schist is given in Table 3, Spec. 1568. Talc enters with more than 50%. Its colour is pale-green. A pronounced orientation parallel to the schistosity is observed. Grains of ore and crystals of apatite are fairly abundant. Neither carbonate nor chlorite have been observed.

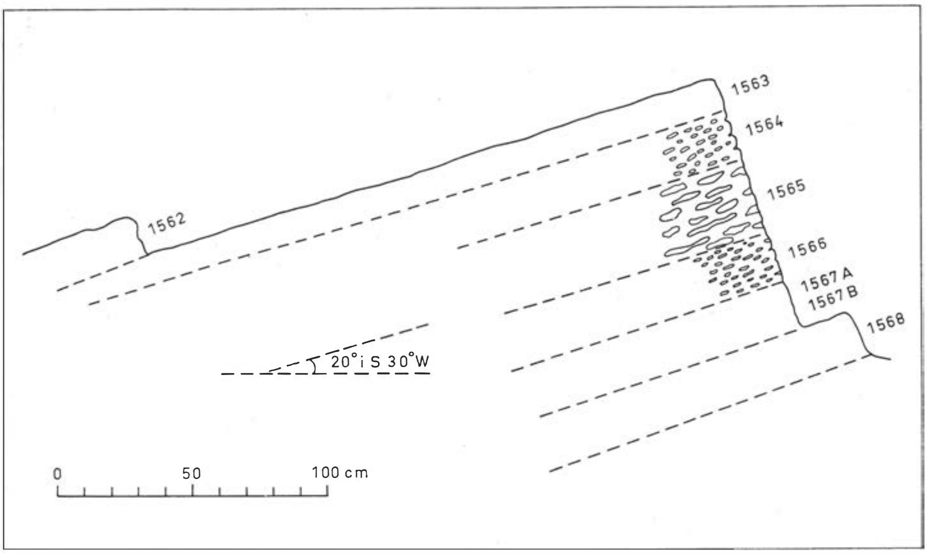

Fig. 4. Section 1.

Spec. 1567 B. — Chlorite-biotite-schist. The mica minerals are not as strongly concentrated along the s-surfaces as in Spec. 1568, but are more uniformly distributed over the thin section. The texture is, however, still distinctly lepidoblastic. The brown scales of biotite, enclosing small grains of quartz, retain their distribution, and are in part orientated with the (001)-faces perpendicular to the s-surfaces. Here and there, fairly large grains of quartz and plagioclase are interspersed. Chlorite occurs as a small-meshed network. It exhibits no anomalous interference colour. Occasionally chlorite and biotite are intimately intergrown, and the chloritization of the latter in its outer portions is clearly visible. The amount of talc is 0.5 %. The distinction between this mineral and eventual muscovite is difficult, however, distinct dispersion $r > v$ and $2V_\alpha = 20°$ make it probable that we have to do with the former. The modal composition of the chlorite-schist is found in Table 3, Spec. 1567 B.

The grains of ore consist at least in part of ilmenite, as indicated by local occurrence of marginal leucoxene. The presence of grains of biotite orientated perpendicularly to the schistosity has been mentioned above. This becomes more conspicuous higher in the section, since we find there real *querglimmer* indicative of the appearance of a second generation of biotite. Titanite and apatite enter accessorily.

Spec. 1567 A. — The chlorite-schist has here become still more homogenized, although certain light bands, richer in quartz and plagioclase can be observed. Most of the grains of the quartz and the plagioclase exhibit an elongated shape parallel to the schistosity. Porphyroblasts of biotite and light-green mica

Table 1. Chemical and mineralogical composition of Spec. 1567 A.

Analyst: Centrala Analyslab., Uppsala.

Oxides	Weight, %	Niggli values	Mineralogical composition		
			Mineral	Mode determ.	Mode cal.
SiO_2	60.17	si = 207.6	Quartz	46.9	26.5 [1]
TiO_2	0.96	ti = 3.1	Plagioclase		34.8 (Ab_{85})
Al_2O_3	15.00	al = 30.5	Chlorite	42.5	29.7
Fe_2O_3	0.19	fm = 47.4	Biotite	3.6	2.4
FeO	6.63	c = 8.2	Fuchsite	2.3	1.4
MnO	0.063	alk = 13.9	Dolomite	1.7	3.0
MgO	5.37	k = 0.06	Ore and accessories	3.0	2.2
CaO	2.21	mg = 0.6			
Na_2O	3.91	c/fm = 0.2			
K_2O	0.39	qz = + 51.9			
P_2O_5	0.142	co_2 = 5.4			
CO_2	1.14	p = 0.2			
$H_2O^{+105°}$	2.85	s_2 = 0.0			
S	0.002				
Cr	+				
	99.027			100.0	100.0

[1] Chemically determined. Anal: B. Almqvist.

(fuchsite) occur. Now, carbonate has made its appearance in the form of dolomite in thin bands or lenses (2 mm). The plagioclase is still without cleavage and twinning. The size of the grains of quartz and plagioclase varies between 25 and 75 μ. Chlorite appears in abundance in the shape of rounded scales (ca. 25 μ) orientated parallel to the principal s-surface. $2V_\gamma$ is small and positive. X = Y = pale yellowish-green, Z = colourless to pale-green, $n_\alpha = n_\beta = 1.616$ (according to the immersion method), $n_\gamma - n_\alpha = 0.002–0.008$.

The chemical and the modal composition of the schist (Table 1) indicate that the chlorite is very rich in Al. Biotite and pale-green mica (fuchsite) occur as *quer-glimmer*. Also apatite and titanite are again encountered, the latter often intimately associated with the biotite. As in Spec. 1568, the ilmenite is surrounded by a fringe of leucoxene. Potassium felspars are missing altogether, as is proved also by the chemical analysis.

A method, described by KAHMA and MIKKOLA (1946), has been tried for determining the modal composition of the schist and, at the same time, the lowest refractive index of the respective minerals. It proved, however, to be of limited applicability in this case but resulted, nevertheless, in a good determination of $n'_\alpha = 1.537–1.539$ for the plagioclase answering to the composition Ab_{87-79} (TSUBOI, 1923).

The Niggli values of the chlorite-schist are given in Table 1. Compared

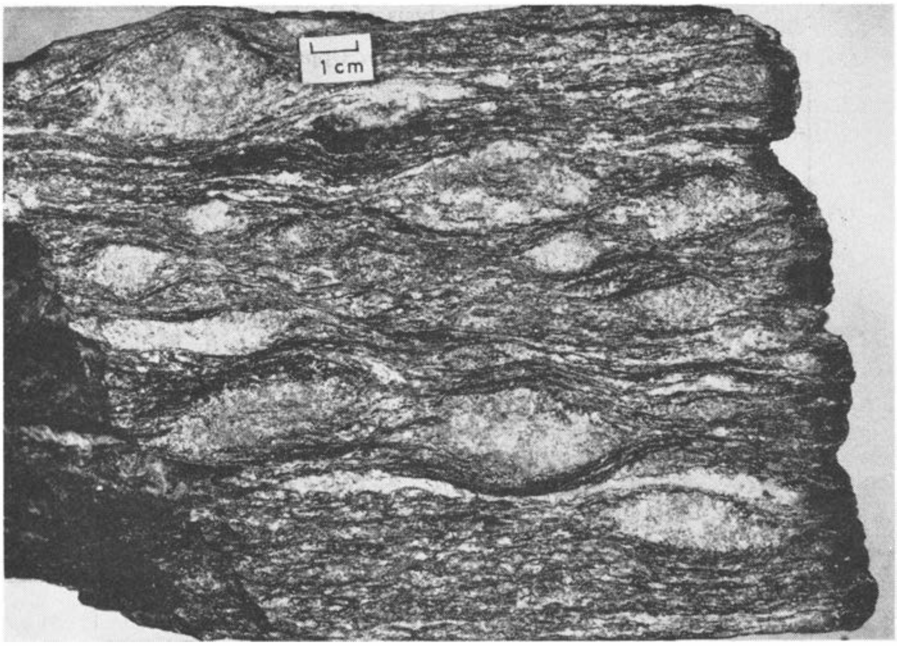

Fig. 5. Fresh surface of the middle part of the "conglomeratic" schist (Spec. 1565).

with the analyses of lamprophyres and ultrabasic rocks given by NIGGLI (1923) our chlorite-schist exhibits a considerable similarity with a lamprophyric diabase porphyry from Remigiusberg described by LEPPLA (1882). The modal composition of the chlorite-schist, as calculated from the chemical analysis, is given in Table 1, Col. 6.

Spec. 1566. — The lower part of the "conglomeratic" schist (20 cm) consists of ovoid accumulations of dolomite packed *en echelon* parallel to the schistosity, and diffusely delimited against a surrounding shell of chlorite (Fig. 6) which also forms a kind of matrix. The pebbles reach a size of up to ca. 15 mm. Apart from the chlorite, the matrix consists of fine-grained quartz and plagioclase with granoblastic development, elongated parallel to s. The basis (001) of the chlorite is orientated parallel with the s-surface, forming thin layers with thicknesses up to 0.75 mm. The micas exhibit quer-stellung, but are in addition grouped radially around a centre. Chlorite and biotite are occasionally intimately intergrown. Together with them crystals of titanite and scattered crystals of apatite occur.

The pebbles contain not only dolomite, but also greater or smaller amounts of the minerals of the matrix. The dolomite includes numerous small grains of quartz. Its refractive index: $n_\omega = 1.669$, $n_\varepsilon = 1.489$, $n_\omega - n_\varepsilon = 0.180$.

Spec. 1565. — The middle part of the "conglomeratic" schist (Figs. 3 and 5) has a maximum thickness of 30 cm. The pebbles have a core of homogeneous

Table 2. Chemical analysis of Spec. 1565.

Analyst: Centrala Analyslab., Uppsala.

Oxides	Weight, %	Mol. prop.			
SiO_2	36.83				
TiO_2	0.12				
Al_2O_3	1.99	$(0.0195)-(0.0073)^2 = (0.0122)^1$			
Fe_2O_3	<0.05				
FeO	4.12	0.0574		0.0574	
MnO	0.20	0.0028		0.0028	0.6241
MgO	10.33	0.2562		0.2562	
CaO	17.94	0.3199 [1]		0.3077	
Na_2O	0.084	(0.0013)	(0.0073) [2]		
K_2O	0.56	(0.0060)			
CO_2	27.45	0.6239			0.6239
P_2O_5	0.024				
$H_2O^{+105°}$	0.12				
S	0.001				
Cr	+				
	99.819				

[1] 0.0122 of CaO is placed in the anorthite. Rest = 0.3077.
[2] 0.0073 is placed in alkalifeldspars.

dolomite with clean joints between the grains. The grains of carbonate include numerous grains of quartz. As in Spec. 1566, the ovoids are surrounded by a shell of chlorite. At the tapering ends of the pebbles, accumulation of equigranular quartz and plagioclase is generally to be seen. Refractive index of the dolomite: $n_\omega = 1.672$, $n_\varepsilon = 1.503$, $n_\omega - n_\varepsilon = 0.169$.

Occasionally the pebbles of dolomite are more or less speckled with green spots, and are sometimes traversed by streaks of chlorite (Fig. 5). The green colour is conditioned by Cr-mica (fuchsite) containing 1.02% Cr_2O_3. (Analysis by Centrala Analyslaboratoriet, Uppsala.) The optical data of the fuchsite are: $2V_\alpha = 42°$, $r > v$, $n_\beta = 1.595$, $n_\gamma = 1.599$. The chemical analysis of a homogeneous portion of a pebble shows that the carbonate component is dolomitic with a considerable admixture of carbonate of Fe^{2+} and Mn^{2+} (Table 2). The low content of Fe^{3+} is remarkable.

Spec. 1564. — The upper part of the "conglomeratic" schist (20 cm) is distinctly schistose, the chlorite being orientated along the s-surface. Dolomite occurs abundantly, and encloses small grains of quartz in a poikiloblastic manner. The grains of dolomite are usually scattered, but here and there pebbles of larger size with a shell of chlorite are observed. The surrounding matrix consists of angular grains of quartz and plagioclase. Q u e r - g l i m m e r are fairly abundant.

Table 3. The mineralogical composition of Spec. 1568, 1567 B, A, 1563, 1562 and 1583.

Components	1568		1567 B		1567 A		1563		1562		1583	
	I Vol. %	II Weight %	I Vol. %	II Weight %	I Vol. %	II Weight %	I Vol. %	II Weight %	I Vol. %	II Weight %	I Vol. %	II Weight %
Quartz	} 31.2	28.5 [1]	} 49.0	19.8 [1]	} 49.6	26.5 [1]	} 34.0	24.7 [1]	} 37.5	30.9 [1]	} 27.9	14.9 [1]
Plagioclase		1.2		26.2		20.4		7.5		4.8		11.4
Biotite	13.7	14.9	12.7	13.5	3.3	3.6	5.9	6.4	9.9	10.7	5.1	5.5
Chlorite	—	—	34.5	35.3	41.1	42.5	38.0	39.2	—	—	39.0	40.1
Talc	51.9	51.0	0.5	0.5	—	—	—	—	48.3	47.4	1.2	1.2
Fuchsite	—	—	—	—	2.3	2.3	2.4	2.4	—	—	—	—
Dolomite	—	—	—	—	1.8	1.7	18.2	17.5	—	—	25.1	24.2
Ore	1.7	2.7	2.0	3.2					2.6	4.3		
Accessories and undetermined minerals	1.5	1.7	1.3	1.5	1.9	3.0	1.5	2.4	1.7	1.9	1.7	2.7
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1] Chemically determined. Analyst: B. Almqvist.

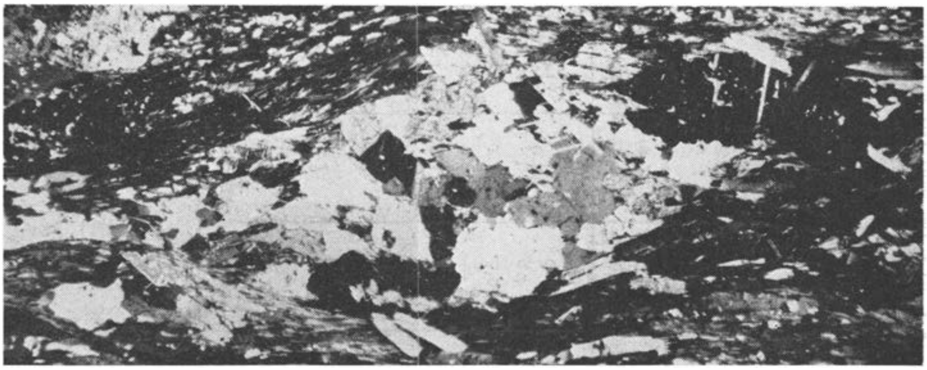

Fig. 6. Pebble of dolomite with the surrounding mass of chlorite. (Spec. 1566). Nicols crossed. 50×.

Spec. 1563. — Chlorite-schist rich in dolomite (Table 3). The biotite is pleochroic with n_β colourless and n_γ pale yellowish-brown. It is concentrated to certain layers, and is intimately intergrown with chlorite originating from the former.

Spec. 1562. — The rocks overlying the section are talc-schists indentical with those below it. The mineral composition of the talc-schist is given in Table 3, Spec. 1562.

The author has arrived at the conclusion that the mother rock of this so-called dolomite "conglomerate" may have been a rock of peridotitic character. None of the original minerals have, however, survived. The altered rock is situated in an environment with, according to HESS (1933), is apt to result in a complete transformation of ultrabasic eruptive rocks by hydrothermal solutions. The schistose peridotite at Stråttekjaure (DU RIETZ, 1935), mentioned above, exhibits a different mineral association. Here the peridotite has been in part very intensely altered, while other portions have retained even the original olivine. As secondary minerals appear tremolite, carbonates (partly breunnerite, partly ankerite), chlorite (penninite), talc, and serpentine. The ankerite occurs in the most intensely transformed portions, the breunnerite in the less affected. The environment is here, however, of a different character, the rocks enclosing the peridotite being zoisite-amphibolites.

As can be seen from Table 3, several of these minerals, which are typical for transformed peridotites, are missing in the Dalovardo schist. There the chlorite is rich in Al, and does not exhibit the anomalous interference colours of the penninite. If the "conglomerate" has been derived from an olivine rock, the latter must have been considerably altered by the addition of Al and SiO_2. The content of Cr^{3+} admittedly speaks for an ultrabasic origin, but being rather mobile, the presence of Cr^{3+} cannot be regarded as a definite proof.

It might also be imagined that the dolomite "conglomerate" has originated from an impure carbonatic horizon which has become boudinaged in the course of the subsequent metamorphosis, and has acquired conglomeratic structure.

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References

Du Rietz, T., 1935. Peridotites, serpentines, and soapstones of Northern Sweden. *Geol. Fören. Förhandl.*, Bd. 57, pp. 134–260.

Hess, H. H., 1933. The problem of serpentinization and the origin of certain chrysotile asbestos, talc and soapstone deposits. *Econ. Geol.*, 1933, P. 634.

Hirsch, H. & Dawihl, W., 1932. Die Einwirkung von Phosphorsäure auf keramische Rohstoffe sowie gebrannte Erzeugnisse und ein neues Verfahren der rationellen Analyse von Tonen. *Ber. d. D. Keram. Ges.*, Bd. 13, S. 54–60. Bonn.

Kahma, A. & Mikkola, T., 1946. A statistical method for the quantitative refractive index analysis of minerals in rocks. *Bull. de la Com. géol. de Finlande,* N.o 138.

Leppla, A., 1882. Der Remigiusberg bei Cusel. *Neues Jahrb. f. Miner.*, Bd. 2, S. 124.

Niggli, P., 1923. Gesteins- und Mineralprovinzen. Bd. 1.

Marklund, N., 1956. Essmitjåkko-Dalovardoområdet. Unpublished report to Bolidens Gruv AB, Boliden.

Marklund, N., 1957. Om fältarbetena i norra delarna av Västerbottenfjällen. Unpublished report to Bolidens Gruv AB, Boliden.

Tsuboi, S., 1923. A dispersion method of determining plagioclases in cleavageflakes. *Miner. Mag.*, Vol. 20, P. 108.

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