Deep-seated Volcanism along the Major Precambrian Breccia in South Norway II. Svarten at Ny Hellesund

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Barth, T. F. W.: Deep-seated volcanism along the major Precambrian breccia in South Norway. II Svarten at Ny Hellesund. *Norsk Geologisk Tidsskrift*, Vol. 50, pp. 253–256. Oslo 1970.

Svarten, a small sea rock, and the neighboring shore of Nordre Hellersöy in the Hellesund archipelago, 12 km SW of Kristiansand, are situated on the great breccia zone and are parts of a serpentinized ultramafic body. The original petrography of this body corresponds to a harzburgite.

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The great breccia zone reaches the sea at Kristiansand and dissolves in a network of secondary tectonic lines extending far westward. Svarten is a small black sea rock 12 km SW of Kristiansand and situated on the extension of the main breccia line in the Ny Hellesund archipelago. See map, Fig. 1.

The rock is an altered peridotite made up of large crystals (1–10 mm) of serpentinized olivine with $2V \approx 90°$ corresponding to about 10 Fa. The primary olivine was richer in iron, for it is now completely shot through by black opaque dust particles, probably magnetite, v.i.

Anthophyllite is conspicuously present in large leaves up to several centimeters long. It is colorless to faintly brown or green in thinsection, $2V \approx 90°$. The identity was verified by X-rays.

Common hornblende is unevenly distributed in large corroded crystals with weak pleochroism, γ = pale green, β = pale brown, $2V \approx 90°$, c: $\gamma \approx 20°$. The X-ray powder pattern corresponds to that of actinolite.

Mica is present in small colorless flakes with absorption $\gamma < \alpha$; uniaxial or nearly so, but does not give good X-ray patterns.

Apatites are of two types, one red-orange in color, one colorless.

Zircon of brown color is present.

Chemical analysis, norm and mode are listed in Table 1. The similarity to the Degernes periodite (described by Touret in the previous article) is obvious. The catanorm approaches the mineral content as it would have been

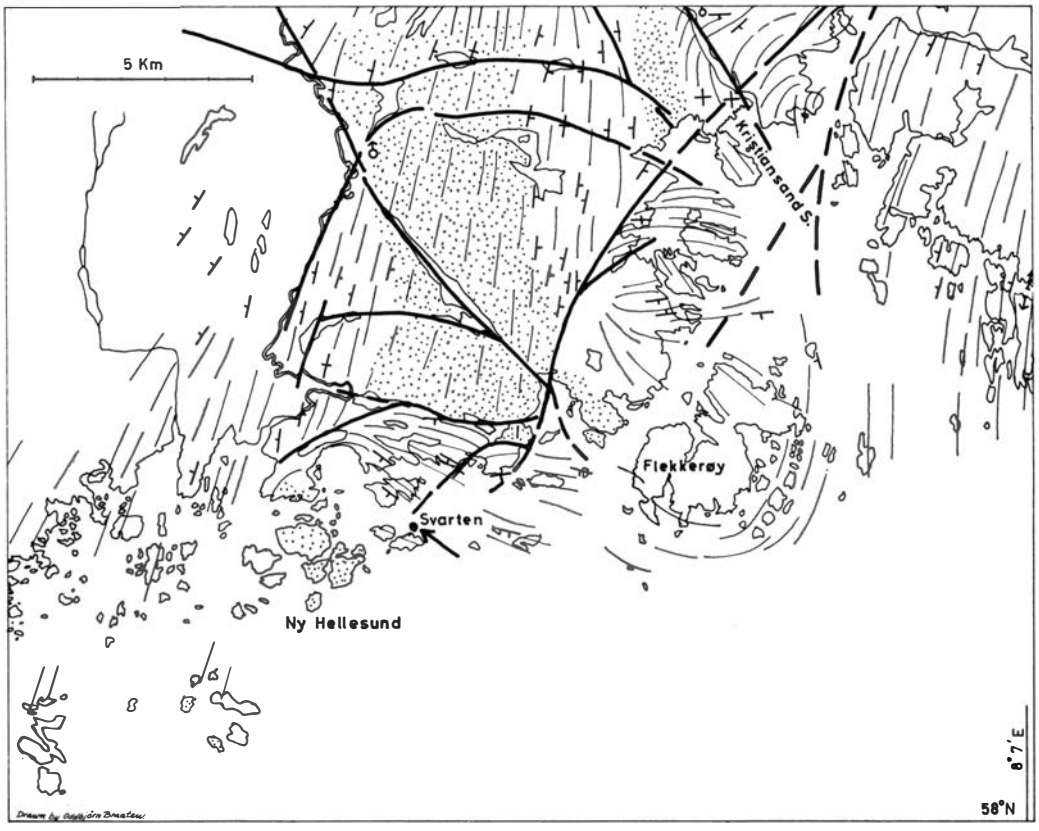

Fig. 1. Geological map of the Precambrian coastal area SW of Kristiansand. – Lined areas = mixed gneisses and migmatites; strikes and dips are indicated. – Dotted areas = gneissic granites. – Heavy lines = friction breccias and other tectonic lines.

in a pristine igneous rock; the greatest discrepancy comes from the fact that during the secondary alteration, iron in olivine was oxidized to magnetite. The relation is:

$$18\ \mathrm{Ol}\ (+\ \mathrm{O_2}) = 6\ \mathrm{Mt} + 12\ \mathrm{Hy} \qquad (1)$$

If we assume that six of the 7.2 Mt of the catanorm are secondary, the pristine mineral association is reconstructed by letting 6 Mt react back to olivine according to equation (1).

Thus the pristine norm becomes as listed in Table 2, column 1.

This is the norm of the commonest type of periodite, so called harzburgite, which forms a facies of nearly every important body of olivine rocks (New Zealand; the Great Dyke of Rhodesia; the Serpentine Belt of New South Wales; the Ural Mountains; the Bushveld Complex). It is reasonable to assume, therefore, that the Svarten rock was formed by serpentinization of a common harzburgite.

Much discussion has arisen around the phenomenon of serpentinization (see e. g. Turner & Verhoogen 1960, Thayer 1966). By using cation per-

Table 1. Chemical analysis of the Svarten rock

	weight %	cation %	catanorm		
SiO_2	42.21	39.7	Or	5.5	
TiO_2	.37	.3	Ab	7.5	
Al_2O_2	6.59	7.3	An	11.5	
Fe_2O_3	6.86	4.8	Sal		24.5
FeO	6.97	5.5			
			Ol	35.7	
MgO	27.00	36.3	Hy	.6	
CaO	3.09	3.1	Il	.6	
Na_2O	.83	1.5	Mt	7.2	
K_2O	.95	1.1	Ap	1.3	
P_2O_5	.66	.5	Fem		75.4
H_2O	6.56				

Table 2. Mineral composition of Svarten and its parent rock

Norm of Pristine Harzburgite		Calculated Minerals of Serpentinized Harzburgite		Mode of Svarten	
Or	5.5	Or	5.5	6	mica
Ab	7.5	Ab	2.5	4	plag. (An_{35})
An	11.5	An	1.5		
Ol	53.7	Ol	14.7	40	oliv. and erp.
Hy	18.6	Hy	.6		
		Serp.	20.0		
		Ant.	30.0	24	anthoph.
		Ho	16.0	17	hornbl.
Mt	1.2	Mt	7.2		
Il	.5	Il	.5		
Ap	1.3	Ap	1.3		

centages and one-cation mineral formulas as advocated by Barth (1948) and Eskola (1954) the survey of the problem becomes easier.

The simple serpentinization of Mg-olivine and of orthorhombic pyroxene is a process of hydratization:

$$9\text{Ol} + \text{Q}\,(+\text{H}_2\text{O}) \rightarrow 10\ \text{Serp} \qquad (2)$$

$$6\text{Hy}\,(+2\text{H}_2\text{O}) \rightarrow 5\ \text{Serp} + \text{Q} \qquad (3)$$

But concomitantly, the iron component in natural olivine oxidizes to magnetite according to equation (1). Consequently, the serpentinization of the Svarten rock requires in the first place both hydratization and oxidation. In addition a series of complicated reactions takes place attendant upon the simultaneous formation of new minerals, viz. anthophyllite, common hornblende, as well as magnetite and serpentine.

The chemical relations of this complicated alteration are summarized by equation (4).

$$39\ Ol + 18\ Hy + 5\ Ab + 10\ An\ (+ 11\ H_2O + O_2) = 30\ Ant + 16\ Ho + 20\ Serp + 6\ Mt \qquad (4)$$

(The following theoretical formulas have been used:

$15\ Ant = Mg_6Al_2Si_7O_{22}(OH)_2$; $16\ Ho = Ca_2NaMg_5AlSi_7O_{22}(OH)_2$;
$5\ Serp = Mg_3Si_2O_5(OH)_4$, in which Fe partly substitutes for Mg.)

If the normative minerals of the pristine harzburgite react according to equation (4), the result will be a serpentinized harzburgite represented by the minerals listed in column 2 of Table 2. A comparison with the mode listed in column 3 shows the great similarity to the actual minerals of the Svarten rock.

8 September 1969

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