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Isotopic age determinations in South Norway: I. The Skår volcanic breccia, Greipstad, Vestagder

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Abstract

Two samples of the fine-grained acidic matrix of the Skår volcanic breccia about 16 km WNW of Kristiansand in Vest Agder, southwestern Norway were investigated by whole-rock K-Ar. The breccia is situated on the intersection of a WNW and a NNE trending tectonic line, associated with the NE trending 'Great Breccia', a major tectonic feature of southern Norway. The samples yielded Late Permian ages of 248 ± 15 Ma and 233 ± 15 Ma. This indicates that the explosive Skår volcanism was related to the period of epeirogenesis that in southern Norway gave rise to the formation of the Oslo-graben and Hardangerfjord-graben. Possibly there is a genetic connection between the acid volcanism at Skår and periodic alkaline mafic magmatism in the whole of northern Europe and parts of northern North America during the late Palaeozoic and the Mesozoic. The alkaline magmatism in the South Scandinavian Shield during this prolonged period might be an expression of a fundamental, mainly tensional 'Basin and Range-like' tectonic regime which prevailed in the northern hemisphere after the Caledonian orogeny and which lead to the opening of the Atlantic Ocean. The acid volcanic breccia erupted at Skår could be a product of contact-anatexis of crustal material generated by intruding alkaline basic magma.

Introduction

In 1924 K.O. Bjørlykke reported the discovery by one of his students of a volcanic breccia near Skår in the Greipstad parish, Vest Agder, southern Norway (Fig. 1). The breccia occurs in the bed of the stream that connects the Bredland lake with the Birkeland lake about 16 km WNW of Kristiansand. The area forms part of the polyorogenic Gothian-Sveconorwegian 'Southwestern Gneiss Region' (Verschure, 1985). The breccia occurs at the intersection of tectonic lines that are inferred from WNW and NNE directed topographic expressions. The NNE direction is similar to that of the southern extremity of the mainly NE trending 'Great Breccia', or 'Kristiansand-Bang Shear Zone', (e.g. Hageskov, 1980) that forms a major tectonic phenomenon in southern Scandinavia. The breccia measures about 50 m across and consists of fragments of quartzite and gneiss in a fine-grained, brownish-red felsitic groundmass. The groundmass contains quartz and feldspar phenocrysts and irregular shaped vugs often filled with calcite. Barite occurs in fissures.

The age of this breccia was fully uncertain, Bjørlykke (1924) hypothetized that it could be an ex-

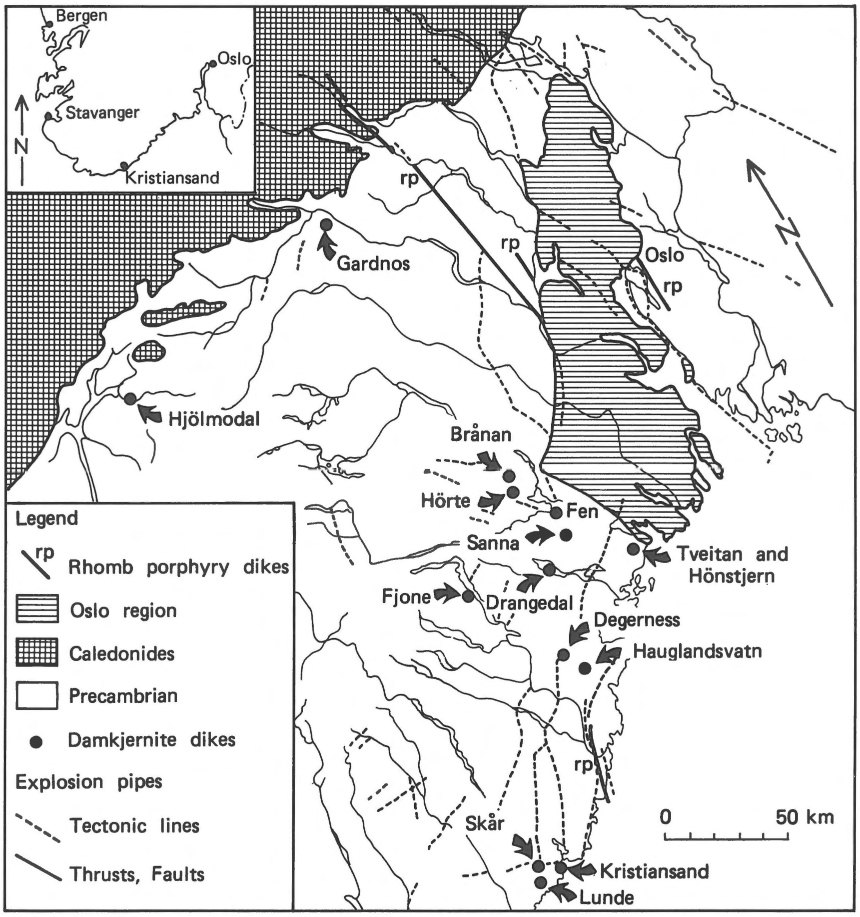

Fig. 1. Geological sketchmap of Southern Norway showing the explosion breccias in Telemark and Agder (After Ramberg & Barth 1966; Verschure et al. 1983).

pression of, either, (1) the Precambrian acid volcanism of the Telemark Supracrustal Suite, (2) the Eocambrian magmatism of the Fen area, (3) the Permian volcanism of the Oslo Graben area or, (4) the Tertiary volcanism that gave rise to the ash deposit found in the 'Moler', an Eocene clay in Jutland, North Denmark (e.g., Bøggild, 1918, Norin, 1940). Ramberg & Barth (1966) emphasized that volcanic breccias and vents in southern Norway are associated with widespread systems of fissures, shatter zones and friction breccias. The tectonic alignments in southern Norway strike generally NE and NNW. Most of the explosion breccias in southern Norway are located on or near intersections of these alignments. The explosive volcanism in southern Norway belongs, according to Verschure et al. (1983), to two major magmatic events of respectively 600 Ma and 300 Ma ago reflecting Eocambrian and Permian tectono-magmatic precursor phases of the Caledonian orogeny and the Oslo-Graben epeirogeny.

K-Ar age-determinations on mafic alkaline dikes (Halvorsen 1970, Færseth et al., 1976) that are associated with NE and NNW trending tectonic zones in the Precambrian basement of southwestern Norway and the Caledonides disclosed that these zones must have remained active for a prolonged period. The dikes tend to be clustered in areas where NE directed fractures, which belong to the NE trending graben that form the Hardangerfjord (Goldschmidt, 1912), are transsected by NNW oriented fractures. Færseth et al. (1976) argued that the normal faulting and the alkaline phases of igneous activity within the Scandinavian landmass are manifestations of a fundamental tectono-magmatic event associated with the North Sea rift system (e.g., Gibb & Kanaris-Sotiriou, 1976, Ramberg & Spjeldnæs, 1978, Dixon et al., 1981, Fall et al., 1982). Close to the southwestern edge of the Baltic shield, large vertical movements along the NE trending fractures have been found. The contact between Precambrian basement and its Caledonian cover subsided at places more than 2000 m. Whole-rock Rb-Sr dating shows that the rocks that are associated with the NE-directed fault zones were sheared 400 ± 15 Ma ago, i.e. early Devonian-late Silurian (Andresen et al., 1974). According to Færseth et al. (1976) the NNW fractures are younger than the NE fractures. The NNW fractures have a westerly throw and at places the Lower Palaeozoic rocks have been brought in contact with the Precambrian basement. Movements in excess of 500 m could be demonstrated. The major fractures in the Sunnhordland region are occasionally filled with calcite-cemented breccias (Kolderup, 1934). Færseth et al. (1976) determined K-Ar whole-rock ages ranging between about 280 Ma and 160 Ma for the NNW directed mafic alkaline dikes in the Sunnhordland region. Episodic alkaline igneous activity apparently lasted from the Late Carboniferous-Early Permian to the Late Jurassic-Early Cretaceous and exhibits a magmatic trend towards increasing alkalinity and progressive enrichment in rare earth content.

Scope of the investigation

To determine the age of explosive volcanism that perforates the Precambrian basement in southernmost Norway (e.g., Verschure et al., 1983) a suite of rocks of the Skår breccia were collected during the summer of 1983.

Sample description

The material selected for age determination was an extremely fine-grained, light-brown, compact rock, which supposedly formed the magmatic component of the breccia. Macroscopically the selected material is free from country rock xenoliths and carbonate. However, microscopical observation revealed that it was not purely magmatic but composed of several components:

1. A groundmass of mainly fine-grained cloudy quartz, fine-grained sericite and minute particles of opaque ore material. In the groundmass magmatic flow textures can be discerned, indicated by bands differing in opaque material content.
2. Mylonitized granitic rock fragments showing a high degree of alteration. The minerals of these fragments are: undulose quartz with criss-crossing trails of crystalline and fluid inclusions, unaltered orthoclase, completely sericitized and saussuritized plagioclase and biotite (?) pseudomorphs indicated by very fine-grained opaque ore material.
3. Xenocryst of country rocks mainly made of quartz, biotite (?) pseudomorphs made of very fine-grained opaque ore material and some apatite.
4. Veins and patches made of clear quartz crystals.
5. Veins, patches and impregnations of carbonate.
6. Rounded fragments of a breccia similar to the containing breccia and consisting of a groundmass, granitic xenoliths, xenocrysts, quartz and carbonate material.

Results and discussion

From the measured data of both samples (83 Bam 28 and 30) ages of respectively 248 ± 15 Ma and 233 ± 15 Ma were calculated (Table 1). The concordancy of the calculated ages is rather poor and is probably the result of the differing amounts of foreign components in these samples that have not been completely degassed during the explosive volcanism. This result indicates nevertheless that the explosive Skår volcanism took place in Late Permian times. The volcanism is associated with the epeirogeny in southern Norway (e.g., Verschure et al., 1983) that resulted in the formation of e.g., the Oslo-graben, the Hardangerfjord-graben and the North Sea grabens and throughs. Periodical alkaline magmatism during the Palaeozoic and the

Table 1. K-Ar data and calculated ages.

Sample nr.	UTM Coordinates	Rock-type	Material	K (% Wt)	Radiogenic ^{40}Ar (ppm Wt)	Calculated age (Ma)
83 Bam 28	$^{4}256–^{64}517$	fine-grained felsite	whole-rock	1.82	0.0336	248 ± 15
83 Bam 30	$^{4}256–^{64}517$	fine-grained felsite	whole-rock	1.93	0.0333	233 ± 15

Mesozoic has been demonstrated in northern North America and western Europe (e.g., Doig, 1970, Færseth et al., 1976, Fall et al., 1982). It might be an expression of a fundamental, 'Basin and Range-like' (Minster & Thomas, 1987) tensional tectonic regime leading to the formation of the Atlantic Ocean. The acid volcanic breccia erupted at Skår might be a product of contact anatexis of crustal material generated by intruding hot alkaline basic magma. The 'breccia-in-breccia structure' proves that the Skår volcanic breccia was the result of a multiple explosive event.

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