THE NAUTESUND BRECCIA IN SAUHERAD, EAST TELEMARK, SOUTHERN NORWAY

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The Nautesund breccia contains fragments of leptite, quartzites, amphibolites, biotite gneiss, and, to a lesser extent, greenish black and dark red schists. The matrix consists mainly of quartz, but sericite, chlorite, potassium-feldspar, epidote, pyrite, and crushed rock occur in minor amounts. It is suggested that the breccia was formed by gas coring through a vent either accompanied or followed by hydrothermal activity. The schist fragments are foreign to the environment and their origin is discussed. Although the breccia is younger than Precambrian supracrustal rocks, its precise age remains a subject of speculation.

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Introduction

Nautesund is the name of a narrow sound connecting the lakes Heddalsvann and Bråfjorden in the Sauherad district of Telemark. It is situated about 12 km south of Notodden, some 95 km WSW of Oslo (Fig. 1).

The breccia, which is well exposed in a relatively new road-cut along the main road (Highway 360) from Notodden to Skien about 1.3 km SSW of the Nautesund bridge, was pointed out to the author by Head Curator J. A. Dons in connection with the mapping of an area in East Telemark for a cand.real. thesis (Myrland 1968). The lithology was re-examined in May 1969. This breccia was first mentioned by Ramberg & Barth (1966) in their description of Eocambrian volcanism in Southern Norway. In this paper, quartz was erroneously omitted as a constituent of the matrix.

The breccia and its environment

The breccia is situated within an area of Precambrian supracrustal rocks, mostly quartzites and leptites, about 3 km NW of the main border of the Oslo Region Permian province. A smaller area of Permian biotite granite and akerite is located some 3 km south of the Nautesund breccia. The quartzites, which contain later amphibolite sills of restricted exent, are believed to belong to the Seljord Group and the leptites to the younger

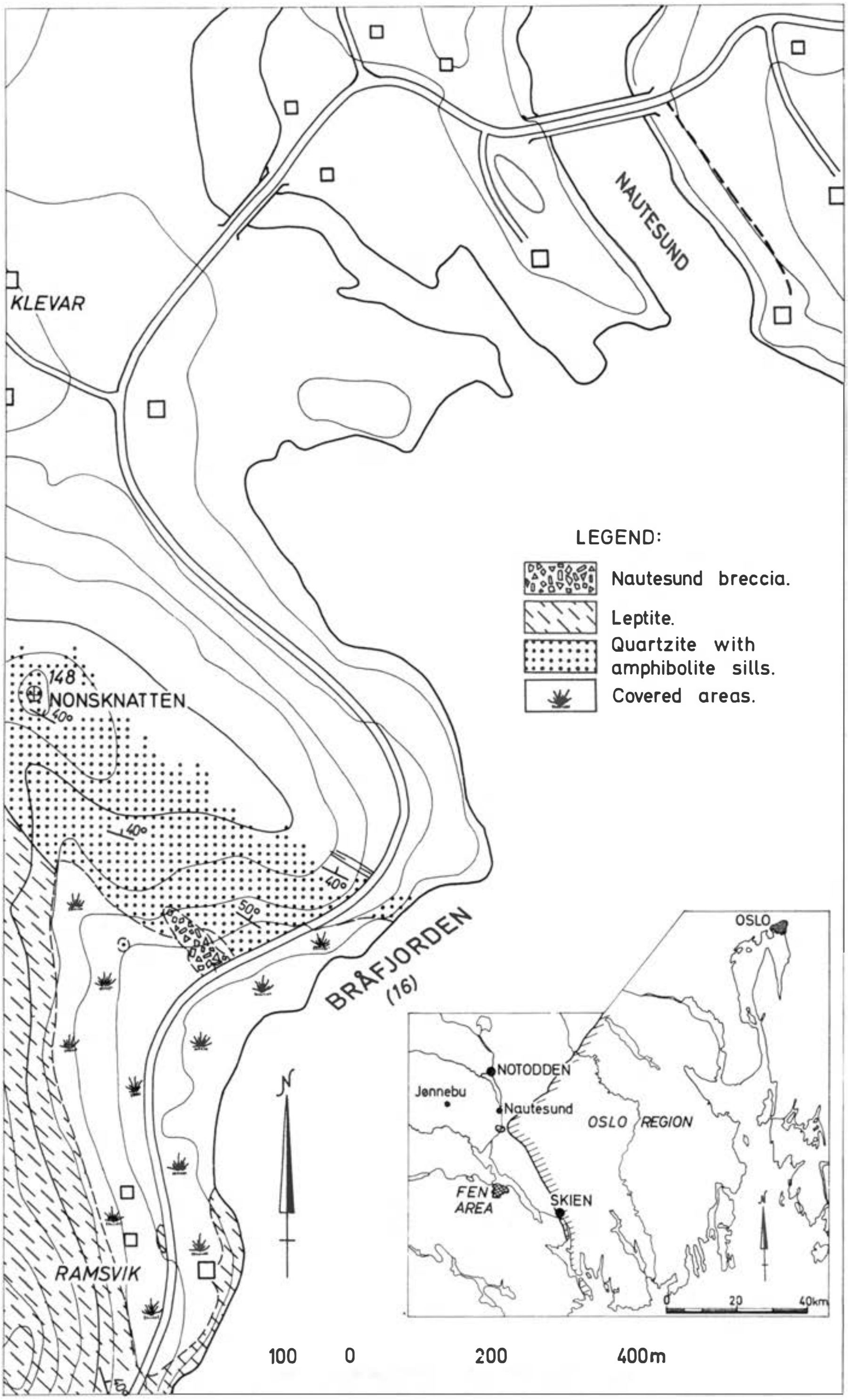


Fig. 1. Location and geological position of the Nautesund breccia; the western border of Oslo Region Permian province is shown on the inset map.

Bandak Group (Dons et al. 1960, Myrland 1968). All supracrustal rocks in the area are strongly deformed in tight, overturned folds along NNW-SSE axes; these folds are the earliest representatives of at least two phases of folding.

On the surface the breccia has an elongate form parallel to the strike of the foliation (bedding) in the surrounding quartzite and has a minimum length of 125 m. Its borders are covered in the south and south-west (Fig. 1). In a vertical section the breccia cuts the foliation at a low angle and is seen to be ca. 50 m in thickness. The breccia itself is not folded, nor has it any visible folds. Fragments of leptite in an amphibolite 3 km to the north are strongly deformed and elongated parallel to the local fold axes. Although marked linear structures have been observed elsewhere in the region, a similar deformation is not seen in the Nautesund breccia.

Over its exposed length the breccia is situated entirely within the quartzite. This is normally a feldspathic quartzite, but is sometimes of orthoquartzitic composition. A specimen from Nonsknatten contained 92% quartz with feldspar and muscovite in minor amounts.

Leptite is present tectonically below the quartzite some 150 m west of the breccia. About 200 m east of the breccia, and within the quartzite, a 5 m thick leptite layer is exposed in a road-cut. The leptite is a grey or faintly pink fine-grained rock of granitic composition; a modal analysis of a specimen from Ramsvik showing 33% quartz, 40% potassium feldspar, 8% plagioclase (An_{25}), 10% biotite, and 8% hornblende. Diabase dykes

Fig. 2. The central part of the breccia as seen in the road-cut. The field of view measures 10 m × 6 m.

and a meta-leucodiabase transect the leptite in the road-cuts towards Ramsvik. These dykes are thought to be of Permian age, principally because they are found in increasing numbers towards the Oslo Region (Dons 1965, Myrland 1968).

The best overall impression of the breccia can be gained at the new road mentioned previously and illustrated in Fig. 2. The breccia is exposed throughout this 30 m × 7 m road-cut and crops out farther north-west at several localities.

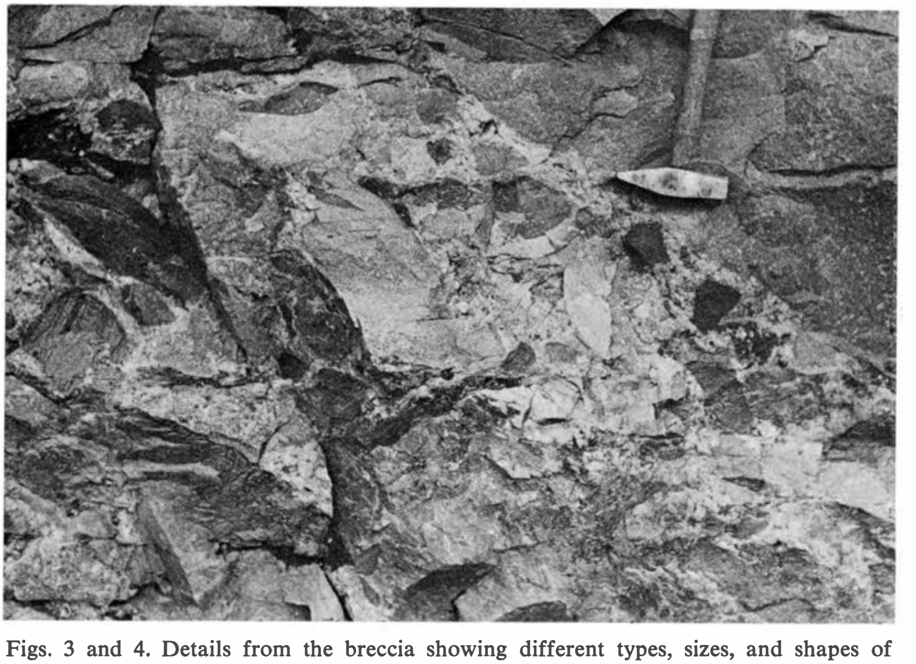
Blocks and fragments in the breccia consist mostly of leptite, quartzites, and amphibolite, i.e. all the neighbouring rock-types. To a lesser extent, fragments of a biotite-rich gneiss are present which have possibly been brought up from a biotite gneiss horizon occurring above the Telemark gneiss granite border (Myrland 1968). A few fragments of greenish black and dark red schists have also been found. These contain chlorite and some sericite, while the dark reddish colour is due to the presence of haematite. Siggerud (in Dons et al. 1960) reports red and black xenoclasts of schist in a breccia at Jønnebu on Lifjell about 16 km WNW of the Nautesund locality (see Fig. 1).

In terms of size, the randomly orientated fragments range from 1 cm to 1 m across, though generally they are between 10 cm and 30 cm. Fragments smaller than 1 cm occur in the groundmass. No part of the breccia seems to contain any one particular size or size-range of fragments. The fragments are angular, although there is a tendency for the corners to be rounded off. Figs. 3 and 4 illustrate different types and sizes of fragments.

Though varying somewhat throughout the breccia, the matrix constitutes on average about 10% of the lithology and consists mainly of quartz, in part as 1 cm crystals in cavity-fillings. Crushed rock fragments, sericite, chlorite, potassium feldspar, epidote, and pyrite occur in minor amounts. Veining of fragments by the matrix has not been observed, but sometimes there is a reaction rim around the dark (amphibolitic) fragments along their contacts with the matrix. Near the border of the breccia, the adjacent quartzites are dissected by quartz veins and the quartzite layers are often fragmented and disorientated. A few metres from the breccia, quartz-veins cut through the quartzite without disturbing the layering. There is, thus, a diffuse transitional zone from breccia into undisturbed country rock.

Discussion and conclusions

Major fissures in the area have the general strikes NNW-SSE and NE-SW and along some of these, breccias of two different types may be present, namely quartz-breccias and mylonites. These are best exposed in the marked valleys E and SE of lake Heddalsvann. The Nautesund breccia differs clearly from the friction breccias and an explosive mode of formation is envisaged.



Figs. 3 and 4. Details from the breccia showing different types, sizes, and shapes of fragments.

When compared with other breccias in the Precambrian southern part of Norway (Ramberg & Barth 1966, Svinndal & Barkey 1967) the Nautesund breccia is unique in having a quartz-rich matrix with no igneous or tuffaceous material. This matrix owes its derivation to low-temperature hydrothermal solutions which either accompanied or succeeded the brecciation.

The breccia is best designated as an alloclastic breccia (Wright & Bowes 1963, p.81), i.e. a rock formed by the fragmentation of pre-existing rocks by volcanic processes beneath the surface, and the absence of tuffaceous material in the matrix suggests a deep-seated origin. The fact that the fragments are mostly angular indicates that there has been little movement of the brecciated blocks. Movements of blocks by a rising stream of gas can give rise to a breccia wherein the blocks have been rounded (Wright & Bowes 1963).

The occurrence of the exotic schist fragments in the breccia is difficult to explain. Schists of this type are absent from the Nautesund-Jønneby area and from the point of view of metamorphism they are of lower grade than the surrounding country rocks, which were metamorphosed up to low-medium amphibolite facies. It is possible, however, that they could have been derived from the upper part of the Seljord Group (Dons pers. comm.).

Another possibility is that the schist fragments may have been introduced into the breccia from above. Schists do occur within the Eocambrian Sparagmite Group, but as it is supposed that the Telemark area was dry land during the sedimentation in the Sparagmite basins (Skjeseth 1963), an Eocambrian age for the schist fragments is rejected. If the fragments are not of Eocambrian age they must have been brought into the breccia from a level above the sub-Cambrian peneplain, calculated to have been situated about 700 m above the breccia (contoured map in Holtedahl et al. 1960, p. 171). The nearest occurrences of Cambrian-Silurian rocks are situated within the Oslo Region 13 km to the SE and 12 km to the ENE.

Downward-directed movements in an ascending gas stream have been postulated by Cloos (1941), Coe (1966), and Dons (1952) but, in the case of the Nautesund breccia schist fragments, this mechanism is not favoured as it would have had to involve descents greater than 700 m. The low degree of rounding of the fragments is also a factor which argues against any great circulatory movements within the gas stream.

For these reasons it seems more likely, in the author's opinion, that there was a simple explosion which reached a level of occurrence of younger schists, with at least some of the material, including a few schist fragments, falling back into the explosion pipe. With such a mechanism the fragments would still be expected to be mostly angular. Werenskiold (1920) showed that fragments can fall 1000 m down into a relatively narrow pipe, while Broch (1945), in his description from the Gardnos breccia, noted that a schist pendant had fallen back into the breccia pipe 3-400 m below the sub-Cambrian peneplain. In discussing the age of the Nautesund breccia, the origin of the schist fragments has to be taken into account. Ramberg & Barth (1966) connect the explosive activity in southern Norway with the formation of the Fen explosion pipe, giving ages between 565 and 603 million years (Broch 1964), i.e. Eocambrian. If future investigations can show that the schists are younger than the formation of the sub-Cambrian peneplain, then the Nautesund breccia must also be younger than the Fen explosive activity. Quite possibly the Fen explosion pipe represents an early, Eocambrian phase of igneous activity which continued throughout the Caledonian orogeny, reaching its maximum in Permian time (Ramberg & Barth 1966, Dons 1965). The emplacement of the Nautesund breccia may, therefore, conceivably have occurred at any time between the Eocambrian and Permian epochs.

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