Contributions to the geology of Hardangervidda (West-Norway) [1]

I. An explosion-breccia occurrence in Hjølmodalen.

By *Sverre Svinndal* and *Henri Barkey.*

Abstract.

An occurrence of a breccia, which is thought to have been formed by a fluidization process, is described. The breccia is supposed to be genetically related to similar breccias encountered in other parts of the Precambrian of southern Norway. A short comparison is made with the previously described Gardnos breccia.

The occurrence of the breccia is situated in Hjølmodalen, about 2 km to the south of the village Øvre Eidfjord (see Fig. 1 for the location).

The breccia is outcropping over a distance of about 110 m along a fresh road-cut of a road under construction, leading from the valley up to the mountain plateau of SW Norway (Hardangervidda).

The dimensions of the outcrop are estimated to be about 130 m x 50 m, with the elongated direction along a major fault system. The border contacts of the breccia are very irregular and many minor offshoots radiate into the country rocks, which are mainly gneisses and granite-gneisses of Precambrian age. Some minor amphibolitic bands occur.

A geological section of the breccia along the road is given in Fig. 1. From this section and Figs. 2 and 3, it is clearly seen that blocks and fragments are in all stages of detachment from the walls and from each other. The separating medium consists of veins of "intrusive tuff" which also have perforated and dissected the blocks and fragments themselves.

H. Cloos (1941) proposed the term *tuffisite* for this kind of "intrusive tuff",

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[1]) The authors are engaged in engineering geological work in the NW part of Hardangervidda in connection with a designed hydro-electric power project by the Norwegian state hydroelectric power organisation. (NVE. STATSKRAFTVERKENE). The engineering geological investigations started in 1962 and the technical results are presented in a series of internal reports to NVE. Statskraftverkene, for whom the investigations were carried out. In a series of short papers the authors intend now to present and describe some geological features which might contribute to a better knowledge of the geology of this part of Hardangervidda.

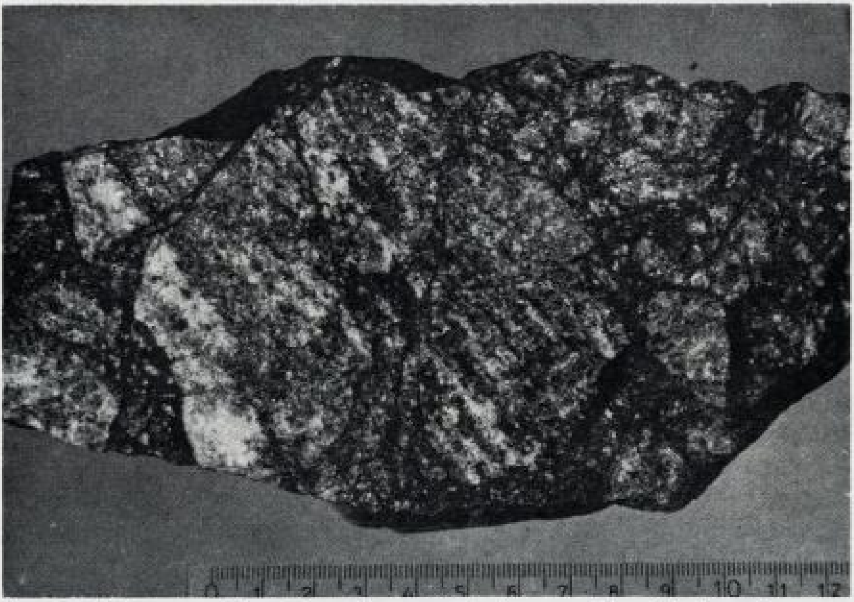


Fig. 2. Rock fragments in an incomplete stage of detacment. Note the larger fragments with preserved orientation of the foliation.

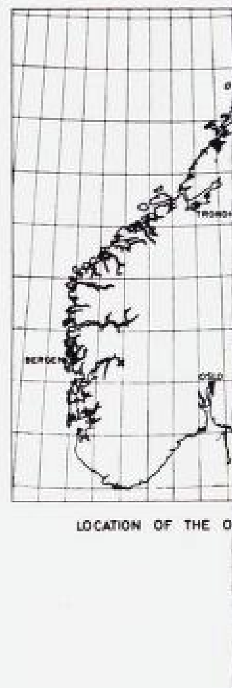
formed from the country rocks to distinguish it from the tuffs normally deposited over the surface as volcanic ash. According to Cloos's extensive description of the Tertiary tuff pipes of Swabia, the tuffisite consists of al lkinds of country rock debris down to dust size and in addition solidified droplets (lapilli) of lava.

No detectable volcanic material has been observed by the authors in the breccia described here.

The most typical feature of the breccia is the cataclastic texture (Fig. 4). Cognate crystals and fragments of the country rock are embedded in a submicroscopic granulated groundmass, in which epidote minerals and a brownish biotite are quite abundant, in part, these minerals are newly crystallized. In addition, patches of opaque ore minerals and some scattered graphitic material occur. Often, these minerals occur even along the finest fissures and cracks.

Quartz, feldspar (both plagioclase and microline), biotite with sagenitic inclusions, muscovite, carbonate, chlorite, sericite, saussurite and accessory minerals (zircon, apatite, ilmenite with leucoxene rims) are minerals which are also characteristic of the gneissose country rock.

Most of the cognate crystals and fragments of the country rock are angular



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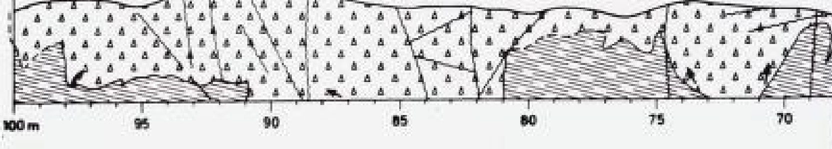

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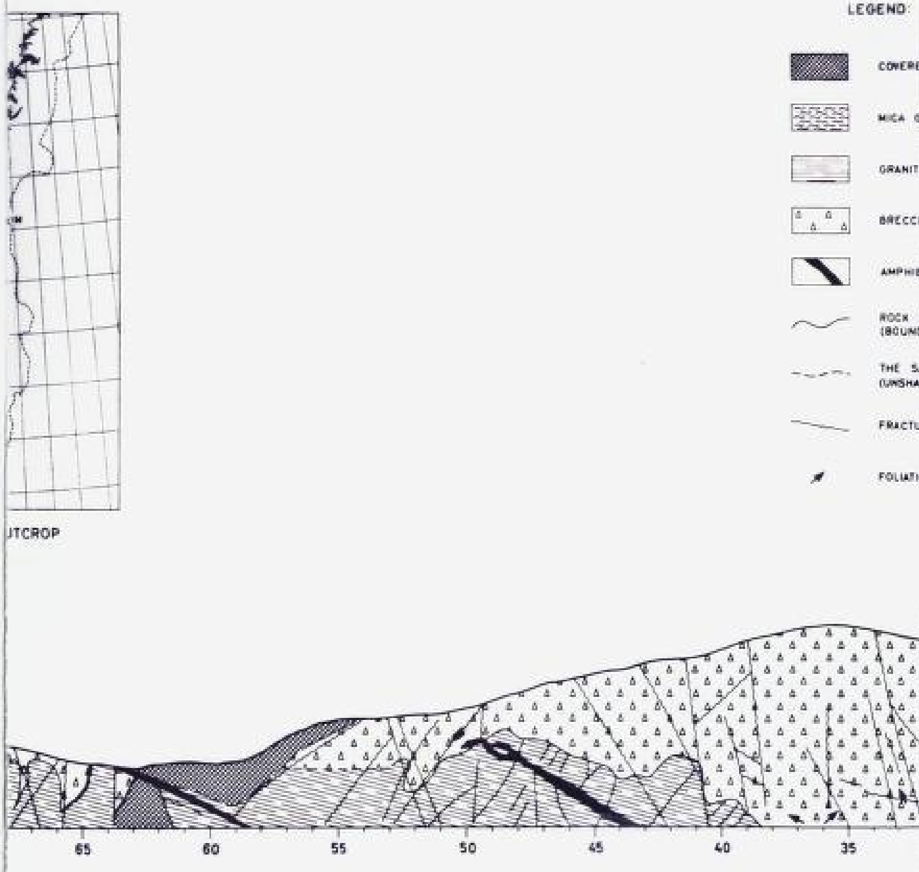
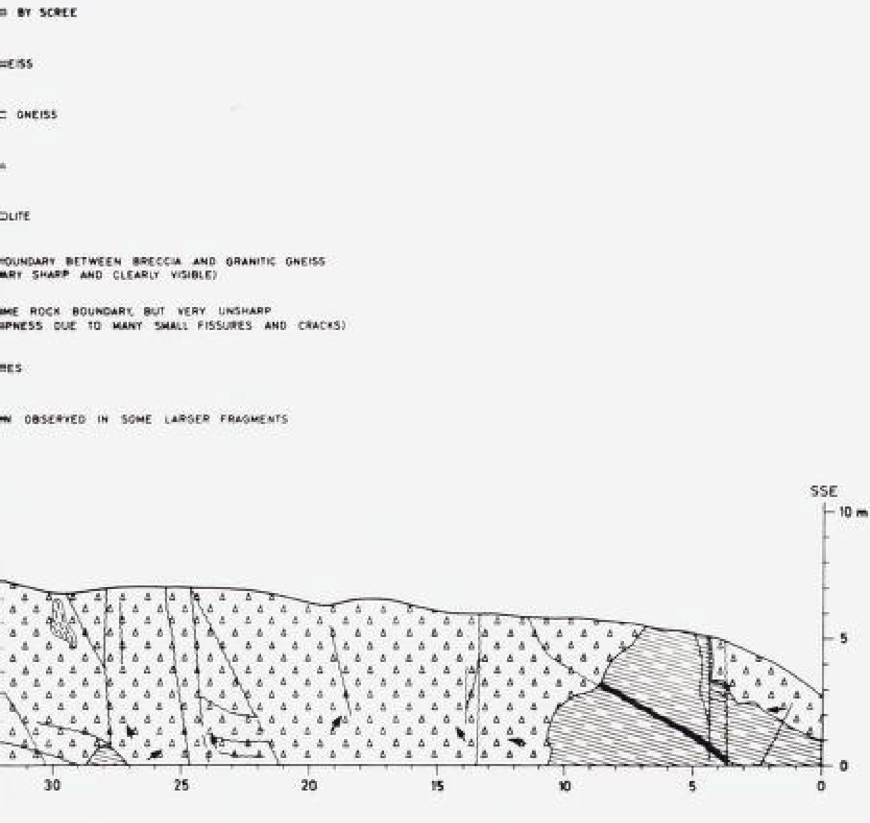


IED SECTION ALONG THE EXPLOSION-BRECCIA IN HJØLMODALEN, HARDANGERVIDD



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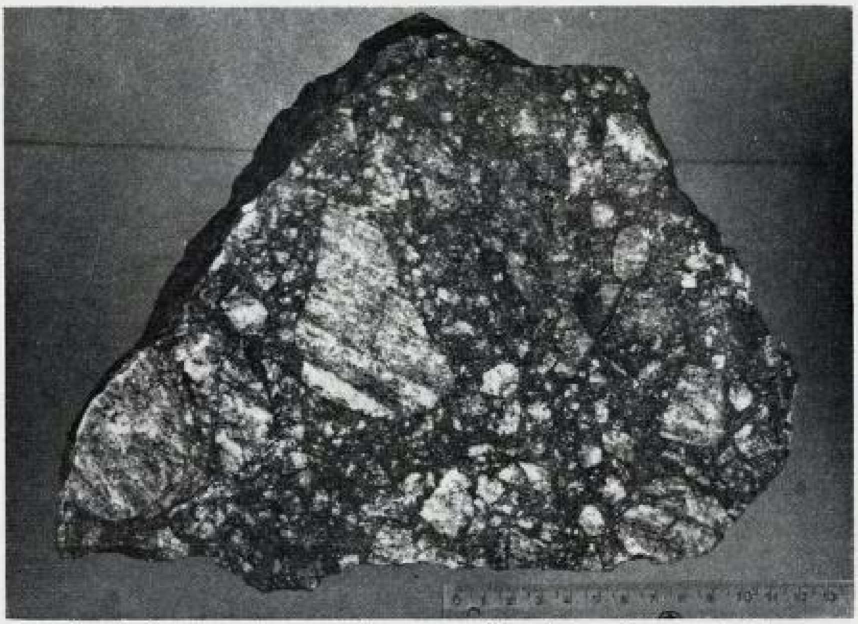

Fig. 3. Fragments in a complete stage of detachment from each other.

to sub-angular, sometimes with pronounced abrasion borders. Rounded to sub-rounded forms occur, but are not abundant.

Sometimes rounded microscopic inclusions of quartzitic rocks (Fig. 5) are encountered, while in the cross-section some larger fragments of mica-schists are present. These rock types are not found in the immediate vicinity of the breccia outcrop, but they are not uncommon in the gneissose rock series of this part of Hardangervidda.

Some foliation measurements on fragments and blocks indicate that transition from parallel (to the foliation of the country rock) to completely random orientations exist. No vertical grading of the fragments is observed. Fragments of country rock appear even in very small fissures.

The rocks adjacent to the breccia are not visibly tectonized, most often the contacts being conspicuously clean and sharp (Fig. 6). Only where the ramifying veins in the surrounding gneissose rocks become abundant does a kind of "transition" exist. The observed foliation in some rock fragments and blocks, being parallel to the foliation of the country rock, is in striking contrast to the chaotic jumble that would have resulted from the explosive process usually envisaged. Volcanic explosions and their effects are familiar enough, but here we are dealing with phenomena that cannot be so easily explained.

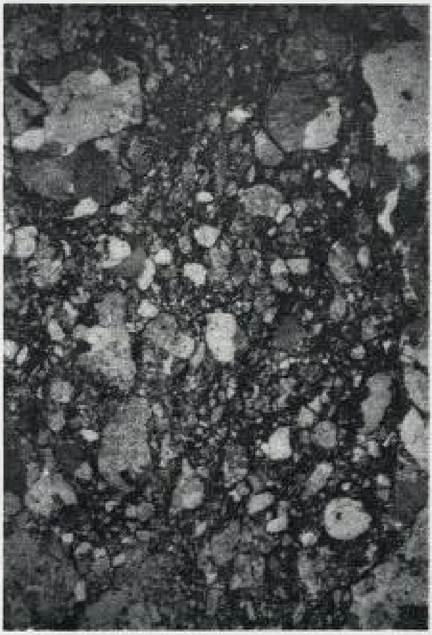

Fig. 4. Cataclastic texture in the tuff-isite. Crossed nicols. x 10 magnification.

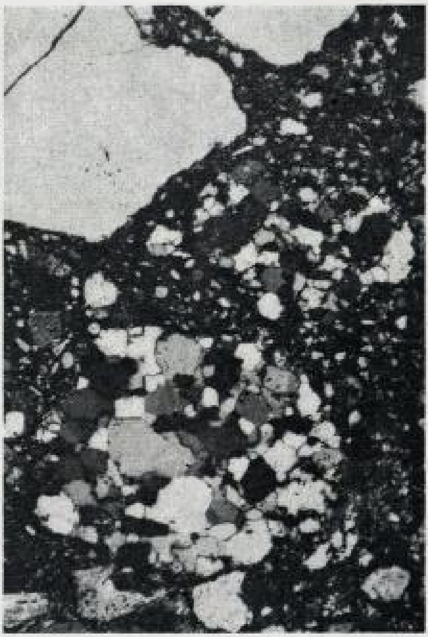

Fig. 5. Microscopic inclusions of rounded quartzitic rocks. Crossed nicols. x 40 magnification.

In the authors' opinion, fluidization or a gas-solid streaming process, such as that envisaged by Cloos (1941) and Reynolds (1954), could adequately explain all the intrusion and comminution phenomena encountered in the breccia outcrop in Hjølmodalen.

In a discussion after a paper presented by Coe (1966), Dr. Doris Reynolds pointed out that in several recent papers the term "explosion-breccia" had been used as though explosion and fluidization were one and the same process.

With the term "explosion-breccia" the authors just want to stress that an explosion must have been the generating force that resulted in "opening" the rocks for the fluidizing process. Any explosive energy that may have been liberated at great depths will be unable to bring about the swift outburst of fragments that one observes in quarry blasting. It will, however, give rise to blast waves, which will shatter the adjoining rocks, and to heat, which will increase both the pressure and the temperature of the gas present. As soon as cracks have been generated (or old fractures sufficiently re-opened), rising streams of high-pressure expanding gas will force their way to the surface

Fig. 6. Sharp contact between the tuffisite and the adjacent gneissose rocks. Roadcut Hjølmodalen.

through passage ways which they can widen by abrasion: the streams of gas are thus arming themselves with dust and fragments that will add to their erosive capabilities. Once a crack is wide enough, the dust-laden gas that streams through it will quickly increase the size of the opening by liberating bigger fragments. Thus all fragments, large and small, will be constantly worn down by abrasion.

Such a process would account for the lack of pyrometamorphism along the margins of the fragments and blocks. The degree of metasomatic alteration of the fragments is strongly dependant upon the gas temperature and chemical composition.

Nowadays, fluidization is a commonly accepted process to explain the peculiar features observed in kimberlites and kimberlitic rocks. This explains perhaps the close genetic relationship between kimberlites and the present type of autoclastic breccia, as observed by so many authors.

For similar breccias encountered in other parts of the Precambrian of southern Norway, Ramberg and Barth (1966) assume a genetic relationship to the Fen volcanism. According to isotope-ratio determinations they postulate an Eocambrian age for this regional volcanic activity. In this connection the authors want to stress Davidson's (1964) conclusion, that it is not necessary to assume that the kimberlitic composition of kimberlites was introduced in a molten state. Consequently, radiometric age determinations on minerals from the kimberlitic fragments do not necessarily represent the real age of the kimberlite emplacement.

The autoclastic breccia in Hjølmodalen is very similar in appearance to some parts of the previously described Gardnos breccia (Broch 1945).

The junior author has had the opportunity to study a detailed section of the Gardnos breccia in a water supply tunnel (Nes hydro-electric power plant), which had been driven through the breccia pipe. A report on these investigations will appear in a separate paper. Peculiar to the Gardnos breccia is the rather high content — as compared to the breccia in Hjølmodalen — of graphitic material which gives the tuffisite its black colour. Some chemical analyses of carbon content for both the Gardnos breccia and the breccia in Hjølmodalen are given below. The sample from Hjølmodalen represents a very fine-grained dark tuffisite, sample G3 from the Gardnos breccia represents a very fine-grained black tuffisite taken in the central part of the breccia pipe and sample G2 is a fine-grained black tuffisite taken closer to the wall contact.

The analyses were carried out by A. Flårønning at the chemical department of NGU.

Sample no.		C %
558 A	E30 tuffisite	
Hjølmodalen, explosition-breccia		0.12 %
J 21	G3 tuffisite	
Gardnos breccia, (tverrslag T2 venstre)		1.52 %
J 21	G2 tuffisite	
Gardnos breccia, (tverrslag T2 høyre)		1.02 %

Fairly pronounced metasomatic alteration phenomena along fissures and the margins of fragments were observed in the Gardnos breccia, especially in the central part of the pipe, whereas such features are not perceptible in the breccia of Hjølmodalen. The alteration phenomena and the graphite-content of the tuffisite in the Gardnos breccia seems to diminish towards the contact with the adjacent rocks (mainly gneissose Precambrian rocks). Especially close to the wall contact, the Gardnos breccia is difficult to distinguish from the breccia in Hjølmodalen. A genetic relationship between these two breccia occurrences seems to be very likely. In the authors opinion, a systematic mapping of the Precambrian area in this part of Norway will certainly reveal more of these peculiar breccias.

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