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Tittel

Primary volcanogenic structures of precambrian age in the Alta Kvënangen window.

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Sammendrag

Et mindre omrade vest i Alta - Kvënangen vinduet er studert pga. fine blotninger av prekambriske vulkanske-strukturer. Minst seks lavalag er pavist, alle skilt av tuff- eller tuffitt-lag. Putelavaer, spesielle sprekkemonster ('columnar jointing') og 'pipe vesicles~ er studert og skildra. Sedimentaere strukturer i tuffene er ogsa beskrevet. Finnmark.

PRIMARY VOLCANOGENIC STRUCTURES OF PRECAMBRIAN AGE IN THE ALTA-KVÆNANGEN TECTONIC WINDOW, NORTHERN NORWAY.

Per Bøe & André M. Gautier.

Bøe, P. & Gautier, A.M. 1975: Primary volcanogenic structures of Precambrian age in the Alta-Kvænangen tectonic window, northern Norway.

A small area in the western part of the Alta-Kvænangen window provides a unique opportunity for studying primary volcanogenic features of high age. A local mapping has revealed the presence of at least six lava layers separated by tuff/tuffite beds. The lavas have well-preserved volcanogenic structures including lava-pillows, columnar jointing and pipe vesicles. Massive lava lacking any specific structures is also present. The tuff/tuffite beds exhibits sedimentary bedding, graded bedding and cross bedding. The close association of the different volcanogenic structures to water-deposited sediments indicates a subaquatic "mise en place" for all the volcanic rocks of Middavarre, including columnar jointed and massive lava. The rocks are only weakly metamorphosed and the tectonic deformation is insignificant with the layers lying right way up.

Per Bøe
Geologisk Institutt
N-7034 Trondheim - N.T.H.

André M. Gautier
Dpt. de Minéralogie de l'Université
13 rue des Maraichers
CH-1211 Geneve 4.

Introduction.

The volcanic and volcanogenic structures in question have been studied in some detail in the Middavarre area in Burfjord on the northern side of the Kvænangen fjord in the county of Troms, Northern Norway. The Middavarre itself is a small, partly forest-covered mountain situated at a distance of about 5 km from highway 6, and is easily accessible by car through Burfjord Valley. From the crossing of Storelva (Fig.1) a cart road leads up to Søndre Middavarre.

Regional geology.

Middavarre is situated in the Western part of the Alta-Kvænangen tectonic window of Precambrian rocks (Reitan 1960, Zwaan et.al. 1973). This window is almost continuous with the Altenes window (Roberts & Fareth, 1974) and the Komagfjord window (Reitan 1963b) lying to the northeast in Finnmark. The rocks of all three windows belong to the Raipas Group, and are divided into two divisions (Reitan 1960).

Upper Raipas : Mostly sandstone.

Lower Raipas : Diabase, lava streams and pillow lavas with basaltic composition - sometimes spilitic; these rocks being associated with tuff, tuffites and tuffogenic sediments, along with some pelitic and carbonate layers.

The rocks of Middavarre belong to the Lower Raipas Group and have been metamorphosed to greenschist facies. K^{40}/Ar^{40} and Rb/Sr radiometric dating on rocks from the Alta-Kvænangen window is in progress at the Dept. of Mineralogy, University of Geneva, preliminary results giving ages up to 1400 million years. These ages are probably too low, and at present a Karelian age of about 1800 million years seems possible for the Lower Raipas rocks.

The Raipas Group is uncomformably overlain by the Late Precambrian autoøchthonous Bossekop Group which is dominated by white and pinkish quartzite (Holtedahl 1918, Føyn 1964). Locally the contact between the Raipas Group and the Bossekop Group may be tectonically disturbed (Føyn 1964, Roberts & Fareth 1974).

Geology of Middavarre.

A geological map of the Middavarre area is presented in Fig.1 with a profile in Fig.2. The dip is 40 to 50 degrees towards east and northeast, except for the area along the northwest course of Gammeelva where the layering is horizontal. The layers do not exhibit small scale folding. The volcanic/ volcanogenic rocks of Middavarre are bordered to the north by the Bossekop quartzite which close to the contact is mostly white, occasionally reddish. The Middavarre area appears to be one where the contact between the Raipas rocks and the rocks belonging to the Bossekop Group is tectonically disturbed. The effects of this, probably local, disturbance is noticable as a schistosity of the volcanic rocks a few metres away from the contact. Furthermore, lenses of volcanic rocks occur in the quartzite close to the contact. A fault along Storelva has downfaulted the rocks to the north relative to the Middavarre area.

The western part of the Alta-Kvænangen window, including Middavarre, was mapped in small scale by Nils Zenzen (1915). On this map there is an elongated northwest to southeast trending metagabbro zone along the southern slope of Middavarre. For the remaining part of Middavarre the rock symbol "Meta-basalt (Pillow lava)" is used.

Many small iron ore and copper ore mineralizations on Middavarre have attracted the attention of prospectors through the years. The three largest known occurrences are Malmkula, Storskjæringa and Søndre Middavarre which periodically have been worked as mines. The location of these three mines (Fig.1) gives the approximate extension and direction of the roughly 300 metres broad, mineralized zone on Middavarre. In written reports (NGU archives) the country rock is always called meta-gabbro or diorite.

Volcanogenic structures.

Several kinds of volcanic and volcanogenic structures are nicely displayed in the Middavarre area. The excellent preservation of some of these structures which are described below appears to be remarkable when taking into consideration the relatively high age of the rocks.

Pillow-lava structures.

It is now generally recognized that pillow-lavas have been formed beneath water or at least in swampy or water-saturated ground. The criteria for the identification of pillow-lavas and their distinction from pahoehoe are quite well defined

(Vuagnat 1946, Vuagnat & Pustaszeri 1965, Moore et al. 1971, Macdonald 1972, Rittmann 1958, 1973).

In the present area, pillow-lavas were observed and mapped already by Zenzen (1915). This lavatype occurs as closepacked piles of pillows (Fig.3) with restricted lateral regional extension for each layer of pillows in the Middavarre area. The pillows are well preserved allowing a safe determination of the facing of the piles.

The individual pillows often have the shape of elongated "sausages" having circular to flattened forms, with bean and balloon sections and with one or several stems. (Fig.4). Cross sections range from about 15 cm to 1.5 m in diameter. Lengthwise, the sausage-shaped pillows may be tortuous showing sometimes a bulbous growth. Occasionally the pillows fork into two parts, thus showing the direction of the stream (Vuagnat & Pustaszeri 1965). It is even possible to find pillows whose crust has been pierced (probably due to internal lava pressure) and thereby formed new pillows as indicated in Fig.5 (Tepley & Moore 1975). Connected pillows are commonly observed.

The individual pillows in the pillow-lava streams are generally well-jointed and separated from each other by what is the former glassy crust about 1 to 2 cm thick. The crust consists now mostly of chlorite along with a little epidote. Calcite or chert is occasionally present in the interstices between three pillows. The crust separating the pillows crumbles rather easily by chemical action, causing the pillows to weather out almost unbroken in some instances (Fig.5). At the base of escarpments along Gammeelva small screes of pillows have accumulated in this way in post-glacial times.

On a cut and polished surface the internal structure of a pillow is clearly visible, starting with an outer dark chlorite crust which has been a glass matrix. This is followed inwards by a thin and lighter-coloured variolitic zone which is in contact with an amygdule zone about one centimeter from the pillow border. The amygdules are filled with dark chlorite, and are often coated with epidote. Close to the Storskjæringa mine pillows were found in which some amygdules were partly pyritized. The amygdules ranges in size up to 3-4 mm. From the amygdule zone to the centre of the pillow there is a fine grained matrix. With a handlense it is sometimes possible to detect a very fine ophitic to intersertal divergent texture. Under the microscope it is evident that metamorphic transformations have to some degree altered the original texture which is now defined by an intimate mineral intergrowth involving actinolite, epidote, albite and sphene/leucoxene.

The pillows are usually cracked in a somewhat irregular, radial manner. It happens that pillows with an empty central space are found, this space perhaps now being filled with calcite. The weathered surface of the pillow-lava is greyish-brown to russet, while bleached sections of pillows are light-green. In the latter case the amygdules and the "glassy" crust appear whitish and have a positive relief on the surface. It happens too that the chlorite filling of amygdules has disappeared leaving empty vesicles.

Pillow breccia.

In a description of volcanic rocks and their associates from British Columbia, Carisle (1963) distinguishes between two types of pillow breccia, viz.1. Isolated pillow breccia, consiting of irregularly shaped, but unbroken pillows with more than 10 per cent matrix, and 2. Broken pillow breccia, consisting largely of dissaggregated fragments of pillows set in a matrix. Rocks being mixtures of the two types of breccias are called pillow breccia by Carisle.

Fragmental volcanic rocks have been found on the top plateau of Middavarre and exposed on flatlying surface close to the Söndre Middavarre mine. Boulders of similar rock were encountered in the northern screes of Middavarre, above Storelva. In all probability these boulders originate from the uppermost parts of the mountain. The breccias of Middavarre have unsorted fragments of sveral types. A tracing of part of the best exposure found is shown in Fig. 6. One seemingly whole, unbroken pillow can be seen here (fragment A, Fig. 6). However, it could not be excluded that this is a fractured pillow of similar type as fragment B. Pillow fragments are easily recognized by their crust and amygdule zone like fragment C. Fragments lacking any specific characteristics are abundant (illustrated by fragment D of Fig. 6). These are usually of a smaller size than other types of fragments. The general appearance of these fragments is the same as for the inner parts of fractures pillows and pillow fragments. Many fragments lacking crust and amygdule zone are very likely interior parts of diaggregated pillows.

The fragments are enclosed in a finegrained metahyaloclastic matrix without bedding or sorting. When seen through the microscope the matrix appears to be very rich in epidote. In places there are radial aggregates of redbrown tourmaline (tourmaline suns). The thickness of these breccias cannot be estimated as they have been partly eroded on the top of the mountain.

Columnar jointing.

In some instances the cooling of lava streams, and also of intrusive dykes, may cause a special jointing resulting in multisided columns. The number of column sides ranges usually from four to eight with six-sided columns perhaps being the most common. The columns are orientated at roughly right angles to the cooling surfaces, e.g. the upper and lower surface of lave streams or the walls of a dyke (Macdonald 1967, 1972).

Famous examples of columnar jointing in lavas are provided by the Giants Causeway in northern Ireland and the Devils Postpile in the Sierra Nevada, California. Columnar jointing is also commonly found in Iceland in Tertiary and recent lavas. Sigvaldason (1968), in a study of subaquatic volcanics in Iceland, describes supposed underwater lavas without pillow structures. According to this writer the subglacial Palagonite formation of Iceland often contains lavas with columnar jointing in the lower parts of lavastreams, whereas the upper parts have irregular jointing.

Joints in lavas are formed during cooling and accompanying shrinkage of the lava in the course of solidification (Macdonald 1967). The cooling rate is probably one important factor for the development of characteristic joints in lava flows. Very likely this condition and eventual other requisites for the shaping of columnar joints are present in subaquatic lavaflows as well as in subaerial flows.

A characteristic feature of Middavarre is a steep irregular jointing which can readily be observed close to the chart road in the open mining pits of Storskjæringa. On flatlying or moderately inclined surfaces the jointing is seen to form irregular networks. In some outcrops a distinct polygonal pattern is clearly visible. Well-developed jointing on nearly horizontal surfaces causing multisided polygons are exposed inside and close to the Søndre Middavarre mine (Fig.7).

Along the nortwest escarpment of the Middavarre plateau a three-dimensional view of the jointing is afforded (Fig.8). It is seen here that the steep jointing actually is a columnar jointing of the type often exhibited in Tertiary and Recent basalts. The columns, which at this locality are seen to terminate abruptly downwards against a tuff/tuffite layer, are 15-20 cm across. The columns are somewhat bent in all directions, this being a primary feature.

The best and most regular columns were found in a big boulder lying close to Gammeelva. The five or six sided columns are here 30-40 cm across extending without curvature for at least two meters. A five-sided columnar fragment is shown in Fig.9 broken by a saucer-shaped crossjoint with a flat lip between the edge of the column and the edge of the saucer. This is probably a "ball-and-socket" joint (Preston, 1930) which is quite common in columnar basalts of younger ages.

The columnar jointing is approximately at right angles to the tuff/tuffite layering. The rocks affected by this type of jointing are otherwise massive, fine- to medium-grained. The relatively coarse grain of the rock, often visible to the naked eye, have misled prospectors and others to identify the rocks as metagabbro or diorite. The steep jointing described above is not seen in pillow lavas or in tuff/tuffites.

Massive greenstone.

Within the Lower Raipas Group massive greenstones are frequently found lacking pillow structures and columnar jointing. The massive grennstones are in concordant positions and have widespread lateral extensions. In places there seems to be a transition to pillow lava. The texture is often blasto-ophitic, fine- to medium-grained, individual grains being often visible to the naked eye.

In the Middavarre area there occur within the massive greenstone bodies of a massive coarse-grained rock with an easily recognized ophitic texture. The plagioclase laths are up to one centimetre long set in a matrix of uralitic hornblende. The border against massive greenstone seems to be transitional and the lateral extent of the coarse-grained rock is clearly restricted in every case. In an ore prospect located between Malmkula and Storskjæringa this coarse-grained rock-type has a somewhat crude, but distinct columnar jointing.

We presume that the massive greenstones, including the coarse grained varities, are submarine flows that did not develop pillow structures or columnar jointing. The coarse grained rocks may represent inner, central portions of lava streams with different cooling history.

The probability of the massive greenstones being sills is excluded as no indications of intrusive contacts have been observed.

Pipe vesicles.

On the northeast corner of the top plateau of Middavarre, about 500 m from Søndre Middavarre, the surface of the lava outcrop is perforated by elongated vesicles. The average diameter is 2-5 mm, in some places holes attain a diameter of 1 cm. In sections at right angles to this lava surface one observes the pipe vesicles along their length, the longest vesicle measured being 4 cm (Fig.10).

The pipe vesicles are chiefly filled with calcite and dark chlorite together with a little epidote. Postglacial weathering has removed some of the secondary vesicle fillings, leaving partly empty holes on weathered surfaces.

The overall feature of these structures seems to conform with the definition of pipe vesicles in the sense of Shrock (1948). When a lava stream flows over a wet substratum the steam formed rise into the lava flow with a considerable force forming "pipes". Two adjacent channels might meet each other, forming an inverted Y. This is assumed to be a facing figure (Shrock 1948). On Middavarre and also in the surrounding areas this facing criterion indicates that the layering sequence is right way up.

Rocks with sedimentary strutures.

Closely associated with lavas of different structural types there occur layers exhibiting sedimentary features, such as cross bedding, graded bedding and sedimentary layering. The sedimentary layers appear to be fine-grained and massive in some localities, whereas in other places microbreccias lacking any form for sorting, and with rock fragments up to 1 cm long, are seen. Spherical fragments resembling mudballs (Shrock 1948, p.334) were also discovered.

The sedimentary rocks might be considered mostly as tuffs and tuffites, using the Blokhina et al. (1959) classification for ancient clastic rocks. However, it is possible that these rocks in some places grade into tuffogenic sedimentary rocks with the amount of pyroclastic material being less than 50%. Some layers just outside the present map contain considerably abundance of calcite.

A mottled chert layer, with colours alternating from red to blue is interbedded in the lowermost tuff/tuffite layer of Fig.2. The observed sedimentary facing as seen from cross bedding and graded bedding corresponds perfectly well with all observations made on pillow lavas.

Discussion.

The layered sequence of volcanic rocks and their derivatives constitute a stratigraphic pile of layers which can be seen to be some 400 m thick along the profile shown in Fig.2. By means of the tuff/tuffite layers it is possible to separate a minimum of six individual lava-flows. The number of flows may, hoewever, exceed this figure since some flows probably are not separated by any marker horizon and therefore difficult to delineate. Preliminary results of chemical examination of the volcanic rocks indicate a tholeiitic composition with a rather high specific weight (2,86 - 2,94).

The close association of the pillow lavas of Middavarre with water-formed sediments exhibiting structures like sedimentary bedding, graded bedding and small scale cross bedding confirms the assumption that the pillow lavas are subaquatic. In this connection the occurrence of chert is significant.

The exceptional feature concerning Middavarre is a close proximity of columnar jointing to these subaquatic structures. The intimate interlayering of columnar jointed layers with pillow lavas and subaquatic sediments strongly indicates a subaquatic formation also for the columnar jointed layers. It should be stressed that columnar jointing with various grades of perfection is the most common structure seen in the Middavarre area. There is little evidence to suggest that columnar jointed layers on Middavarre represent sills. The regular trend of all layers seems to be in contradiction to the idea of several rather thick and closely spaced sills. It would also appear that the columnar jointed layers are too thick to develop a regular jointed pattern when regarded as sills (Macdonald, 1967).

In the Middavarre area proper the individual pillow lavas have restricted lateral extension. It is evident from field examination of the second lava layer to the northeast of Gammeelva Fig.2, that more than one structure is present in the same layer, viz. lava pillows, columnar jointing and massive lava. It appears highly possible that the different lavaflows have in general given rise to several types of structures in a single stream. A multistructural lavastream may have formed by the development of pillows in the advancing lobes of the lavastream with simultaneous formation of columnar jointing and massive lava behind and within. Our observations from the Middavarre area appears to some extent to be in accordance with experience from Iceland, reported by Sigvaldason (1968), where Cenozoic volcanic formations display a multitude of structures in subaquatic lava flows. The physical and environmental factors giving rise to closely associated lava structures of several kinds could, according to Sigvaldason (op.cit.) be special combinations of lava viscosity, rate of lava production and bottom slope gradient.

Conclusion.

The Middavarre area constitutes only a small segment of the Alta-Kvænangen tectonic window. It is known that well-preserved primary structures of different kinds are present all over the window. In the course of future regional scale mapping in the region, a thorough search for all types of primary structures certainly will be of great importance, not only as an aid to the correct identification of lithologies, but also as a means of deciphering the regional tectonic deformation of the rock units.

Finally it should be added that an comprehensive understanding of the ore genesis of Middavarre and probably elsewhere within the window is dependent upon a correct interpretation of the volcanic - volcanogenic lithologies and structures. For example the "substitution" of the "Middavarre metagabbro" by the layered subaqueous volcanic sequence demonstrated in this paper, puts the Middavarre mineralizations in an entirely new geological setting and suggests a new interpretation of the genesis. Work is proceeding to elucidate the ore genetical features of the area and will be reported on in a future publication.

Acknowledgement.

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Figure captions.

Fig.1 Geology of Middavarre.

Fig.2 Profile across the southwestern slope of Middavarre. For exact location see Fig.1. Arrow indicate layers along the profile where the facing has been determined. Note that the bedding is about horizontal along Gammeelva.

Fig.3 Close up picture of lava pillows showing a normal facing. Length of ruler 32 cm. Gammeelva.

Fig.4 Elongated sausage-shaped pillow (to the left of the compass). Riverbank of Gammeelva.

Fig.5 Orientated lava pillow with pierced crust. The pillow is seen from above, the arrow points to the east. Length of pillow 30 cm. SW slope of Middavarre.

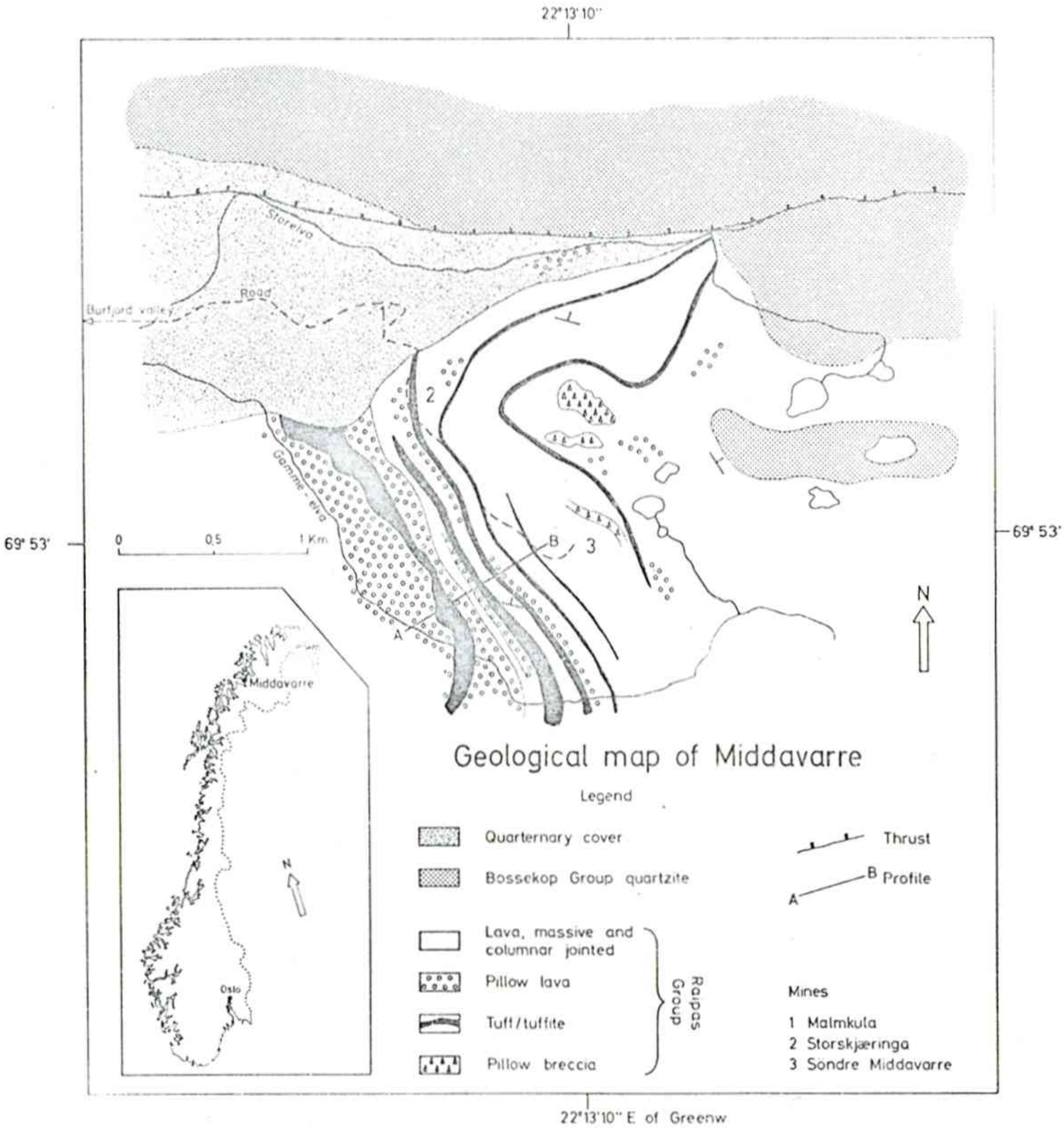
Fig.6 Pillow breccia with different types of fragments. A: Possibly unbroken pillow. B: Partly broken pillow. C: Pillow fragment with amygdule zone. D: Fragment without amygdule zone. Traced directly from outcrop. Søndre Middavarre mine.

Fig.7 Columnar jointing exhibiting a polygonal joint pattern on a horizontal surface. Length of ruler 32 cm. Søndre Middavarre area.

Fig.8 Basalt columns starting abruptly above a tuff/tuffite layer. NW escarpment of the Middavarre top plateau.

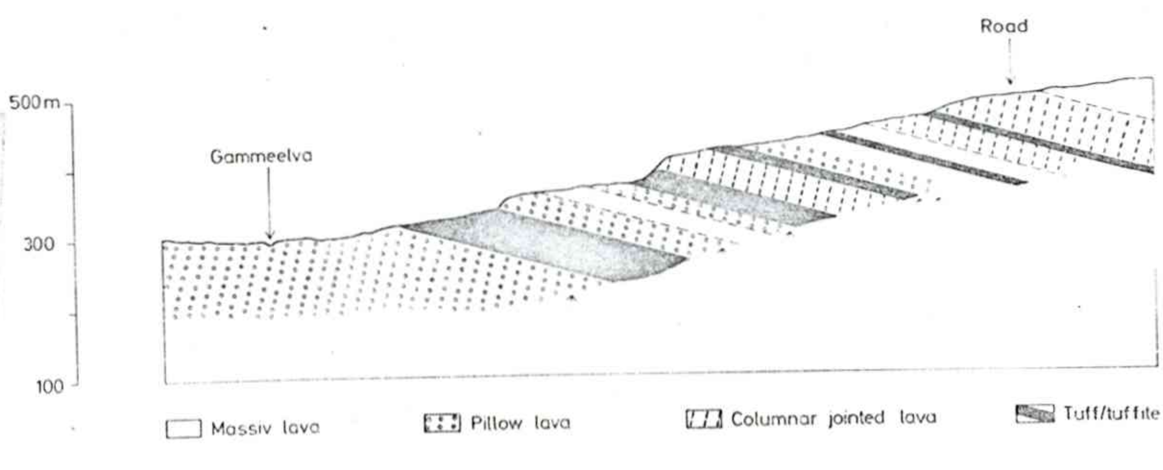
Fig.9 Fragment of a regular five-sided basalt column with "ball-and-socket" crossjoint.

Fig.10 Curved pipe vesicles. The vesicles have been coloured. Søndre Middavarre area. Scale bar 2 cm.



22°13'10"
Storelva
Road
Burfjord valley
Gamme-elva
2
3
B
A
0
0,5
1 Km
69° 53'
69° 53'
N
Middavarre
Oslo
N
Geological map of Middavarre
Legend
Quarternary cover
Bossekop Group quartzite
Lava, massive and columnar jointed
Pillow lava
Tuff/tuffite
Pillow breccia
Raipas Group
Thrust
Profile
Mines
1 Malmkula
2 Storskjæringa
3 Söndre Middavarre
22°13'10" E of Greenw

Fig. 1



Road
500 m
Gammeelva
300
100
Massiv lava
Pillow lava
Columnar jointed lava
Tuff/tuffite

Fig. 2

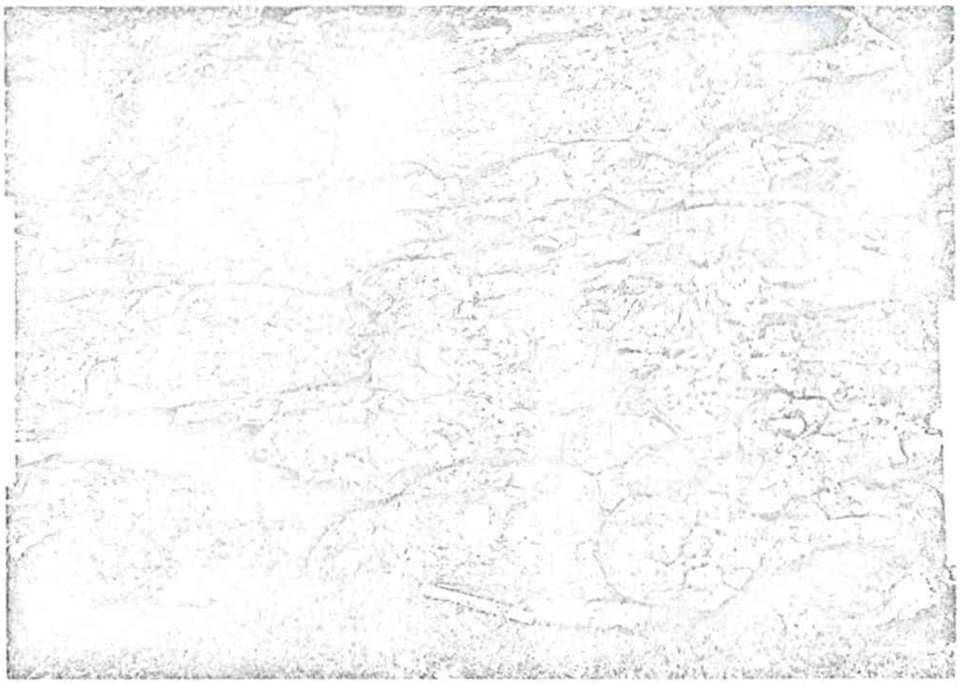


Fig. 3

Fig. 4

Fig. 5

Fig. 6

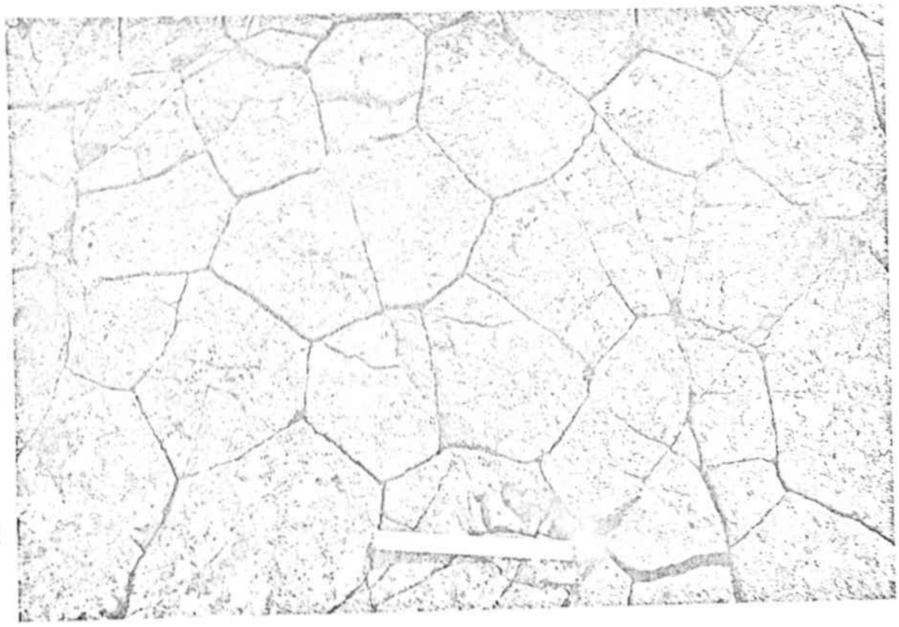


Fig. 7

Fig. 8

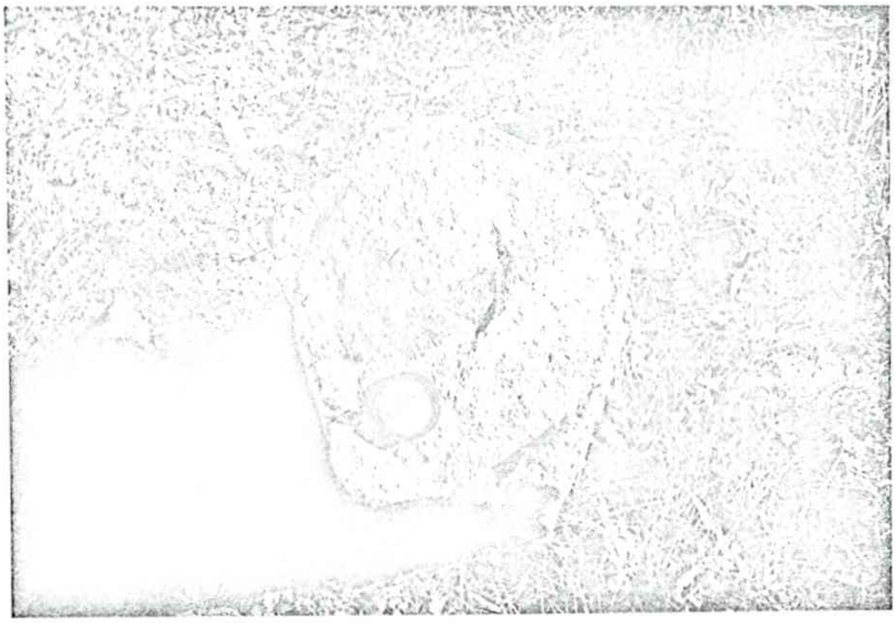


Fig. 9

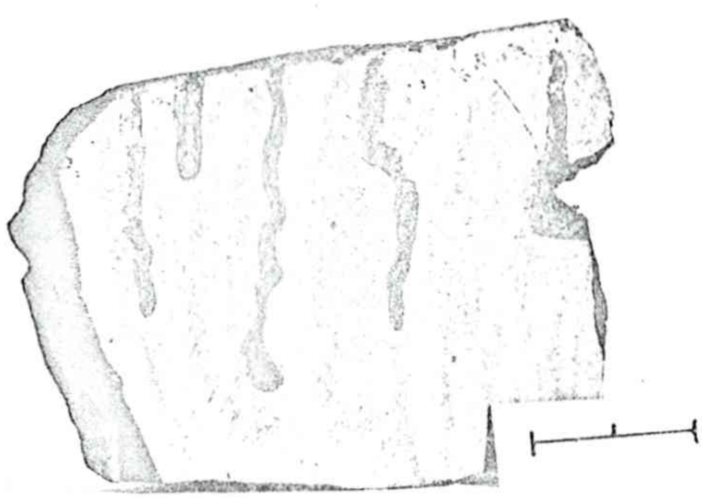


Fig. 10