8. The Sparagmite Series and the Vemdal Quartzite of the Hede Region, Härjedalen

By

Göran Stålhös

Contents

Introduction

The essential features of the geology of the region of Hede have been known so far from TÖRNEBOHM'S (28) excellent map to the scale of 1:800,000 published in 1896 in his paper "Grunddragen av det Centrala Skandinaviens Bergbyggnad". A. G. HÖGBOM, who worked contemporaneously with TÖRNEBOHM, in a paper of 1889 (14) dealt in great detail with a number of important localities, notably in Härjedalen. This paper was accompanied by a map to the scale of 1:500,000. Also HÖGBOM's descriptions of the province of Jämtland of 1894 and 1920 are supplemented by maps to the scales of 1:500,000 and 1:800,000, respectively. As far as the region of Hede is concerned the old map published by TÖRNEBOHM has proved to be best in agreement with the picture obtained by the new mapping of the region to the scale 1:20,000 carried out by the author. Among other geologists who have worked on the bedrock of the Hede region FR. SVENONIUS (27), O. E. SCHIÖTZ (23), G. FRÖDIN (7), and N. ZENZÉN (31) should be mentioned.

On the initiative of Dr. N. MARKLUND the author in 1950 started the mapping of the region of Hede, together with the geologists A. STRÖMBERG, B. AHRENWALL, and F. PIPPING. A great part of the material collected on this occasion has been put at the disposal of the writer, together with some sketch maps made by MARKLUND in 1951 and a written report by the latter. The material collected by STRÖMBERG has been accounted for in a paper of 1952, "Om Hedekalken", and one of 1955, "Zum Gebirgsbau der Skanden im mittleren Härjedalen". Both these papers are referred to in the following.

The region in Härjedalen mapped by the author coincides with the southeastern part on STRÖMBERG's map of 1955. The elaboration of the two maps has been carried out side by side and independently from each other. The author has worked to the scale of 1:20,000 while STRÖMBERG's mapping has been mainly of a more general character. The principal geological units of the map, Pl. I, are the crystalline Archean basement rocks, and an overlying sedimentary complex. The crystalline bedrocks consist of a western parautochthonous and an eastern autochthonous complex. Of these the latter is only scantily represented within the area of the map near Vikarsjön (Pl. I). The sedimentary complex consists of a Sparagmite series and an Eocambrian Quartzite formation.

The rocks of the Sparagmite series appear along the marginal zones of the Caledonian geosyncline with very variable development and thicknesses, and are supposed to have been deposited in a belt of local basins within a region with strongly accentuated relief.

The younger Eocambrian Quartzite formation is more uniform both with regard to development and thickness. With regard to their tectonics we have to distinguish between (1) authochthonous quartzites, and (2) allochthonous quartzites.

1) Throughout their occurrence along the Caledonides the autochthonous quartzites rest either upon Archean rocks or upon sparagmite. Areas where autochthonous quartzites are supposed to appear are e.g.: Nes and Furnes in the middle Mjøsen district (S. SKJESET, 24) and Engerdalen in Norway (O. HOLTEDAHL, 13), the region along the eastern margin of the Archean anticline in northern Jämtland including the classical section on the river Sjougden, and beneath, the autochthonous Middle Cambrian beds along the Tåsjö valley of Ångermanland (B. ASKLUND and P. THORSLUND, 2 a), the area around Laisvall

(N. MARKLUND, 19) in Lapland, and several others. The overlying Cambro-Silurian deposits have on the whole the same extension as the Eocambrian Quartzites with the exception only that at this time the transgressions extended still farther eastward over the Baltic shield.

2) The allochthonous quartzites occur, with interruptions, in a rather broad belt from the region W. of Mjøsen in Norway and up to central Lapland. In Norway they form the so-called "kvartsandsteins-dekket", in Härjedalen and southern Jämtland the "Vemdal quartzite nappe", and in northern Jämtland–Ångermanland–Lapland the "Ström quartzite nappe". The latter corresponds in part to the Blaik nappe in Västerbotten which has been distinguished by KULLING (18). The tectonic discordance of the quartzites with regard to their foundation bears evidence of their allochthonous nature. Thus quartzites are frequently met which rest for miles and miles in direct contact upon the younger, strongly kneeded Cambro-Silurian shales. Of less frequent occurrence are larger or smaller torn-along masses of granite at the base of the quartzites. Regarding the northern part of Jämtland GRIP (8, p. 382) has suggested that the nappes of quartzite may have their origin along the eastern margin of the great granitic anticline which extends from Sjougdälven in the north to Hotagen in the south. ASKLUND (3, Fig. 7) on the other hand holds that the allochthonous quartzites had been deposited in an area much farther to the west. From the petrographical point of view great similarities exist between the autochthonous and the allochthonous quartzites as demonstrated by DU RIETZ (5).

In Härjedalen the quartzites are obviously allochthonous and can be proved to rest in several places upon Cambro-Silurian. These conditions are clearly demonstrated in ASKLUND's paper on "Vemdalskvartsitens ålder". The main aim of the following study has been to obtain a reliable picture of the sequence of the strata of the Sparagmite series in Härjedalen by means of a systematic petrographical investigation of the rocks. A comparison between the rocks of the Sparagmite formations and the Vemdal quartzite has also been carried out and the mutual tectonic relations between the crystalline bedrock, the Sparagmite series, and the Vemdal quartzite have been dealt with in detail.

Methods

The planimetric rock analyses which form the base of the descriptive petrographical sections of this paper, have been carried out by means of an ordinary mechanical stage, only slightly modified. This mechanical stage which has been described by DAHLLÖF (4, p. 385) is provided with an arresting device with a spring-loaded ball. By this arrangement the slide can easily be shifted in two perpendicular directions, arrested at fixed intervals without the necessity of every time taking a reading of the stage scale. In the case in question the distance between two successive intervals is 0.5 mm. A note is made of the mineral which at each of these points is found exactly in the cross-wire. When a series of observations has been made in this way the slide is shifted 0.5 mm in transverse direction whereupon another series of observations is made etc., exactly as when working with an integrating stage.

On account of unequal grain-size, fine grain or for other reasons some analyses have been considered less reliable. In these cases the respective value in the table is preceded by an asterisk. The inhomogeneity of the porphyritic varieties of the granites involves considerable inaccuracies in the analyses of these rocks.

The values obtained by the measurements have been entered directly into the tables with retention of decimals. In the case of the minerals which occur in greater abundance and where the error of determination can be expected to exceed a whole number of percents no importance can, of course, be attributed to the decimals.

The tables contain furthermore a special column with the most common grain-size for each thin-section as well as observations about the degree of roundness according to PETTIJOHN (22, p. 52), about crushing, and crystallinity. A special column contains also the maximal grain-size, by which the largest diameter of a grain in the respective slide is meant. The following abbreviations have been used:

A = angular	WR = well rounded
SA = subangular	C = crushed
SR = subrounded	SC = strongly crushed
R = rounded	Cryst. = crystalline

The analyses have been numbered consecutively, and are referred to in the text by these numbers within brackets.

The classification proposed in 1922 by WENTWORTH for sedimentary rocks has been used as scale for the grain-size.

The sedimentary rocks have been named mainly on account of their mineralogical composition according to the principles elaborated by KRYNINE (17, p. 137) and PETTIJOHN (22, p. 227). As, however, also other properties of the rocks have to be taken into account, the classificatory principles of the authors mentioned have been applied with a certain modification. Thus the limit between arkoses and feldspatic sandstones has been drawn at a feldspar content of 30% instead of 25% and 20% as given by PETTIJOHN and KRYNINE, respectively. This has been done since the rocks dealt with in this paper, with a percentage of feldspar between 25 and 30%, seem to be genetically connected—partly on account of their uniform grain-size—with the class of sandstones poorer in feldspar rather than with the arkoses which are often not sorted and richer in feldspar.

The Archean Bedrock and its Tectonics

About one fourth of the mapped region around Hede consists almost exclusively of granites and gneiss-granites. A triangular area in the SW., including the mountains Stavsåsen, Tällberget, and Gethögen, is entirely separated from a northern area stretching in W.–E. direction.

From the last-named area three wedge-shaped portions project towards the south, viz. one in the neighbourhood of Vinberget, one E. of Torrberget, and one near Hammarbergen. In addition a few smaller isolated masses of granite occur at Ulvberget and Gammelvallsberget, and in a region SE. of Fallkojan along the middle course of Kvarnån.

All these areas consist of gneiss-granites of indubitable Rätan type, preponderantly of red salic to intermediate varieties with often finely porphyritic texture. Within the area mapped, the granite mountains often form heights of 600–700 m (see Pl. I). They differ thereby markedly from the autochthonous granites which appear towards the east (STRÖMBERG, 25, p. 202). These attain rarely a height of more than 450–500 metres. In the area of Vemdalen about 10 km E. of Hedeviken they exhibit a well peneplaned surface which can be followed for many miles in the direction S.–SE. with differences in level of some tens of metres (FRÖDIN, 7, p. 28). The autochthonous granites are often coarsely porphyritic with large reflecting crystals of feldspar; they are very resistent to percussion and differ thereby from the granites of the mapped area which, when being worked, split along a great number of fissures in spite of their fresh appearance.

It is obvious that the granites of the mapped region have been lifted up in relation to the eastern crystalline rocks. This has probably been due to the tangentially directed pressure which can be supposed to have been exerted by the compressed central part of the Caledonian geosyncline in the west. The strong pressure has split the granite areas into a great number of slices with imbricate arrangement and separated them by granite mylonites of very varying order of size and properties. In this connection the granite has, in part, assumed a gneissous character with well developed lineation. Observations of the dips show that the tectonic forces have been acting mainly from NNW.–N. towards SSE.–S. Also other directions of more local character are represented, e.g. one from NE. towards SW. Locally larger overthrusts give a sharp relief to the otherwise flat granite landscape. Examples of such are Hockla, Gethögen, and Tällberget in the south. Gethögen rises steeply about 150 m above the surrounding granite landscape. In the north similar areas are found near Vinberget, Näfjan, and Hammarbergen.

In the region of Hede the relief just mentioned has been produced by the forcing up of the granites, and thus also the sediments resting upon the granites have been lifted to higher levels. On this account the sediments were greatly exposed to the action of erosion and were soon removed. The large uncovered areas of granite within the mapped region are the result of these processes. Another contributing factor were the faults in the west along which the eastern regions have been elevated in relation to those in the west. In some places a primary contact has been preserved between the granite and the overlying sediments as at Torrberget and at Hockla where the Sparagmite series rests upon granite with a basal conglomerate (see pp. 303 and 314).

The western boundary of the granite window SW. of Hede is formed by a marked though rather gently dipping fault running from Tällberget in the south to the river of Ljusnan in the north. Thus the granite region with the overlying, now removed sediments has been raised in relation to the sparagmites around Vitåsen. The fault line can be studied at several localities, e.g. near Tällberget and Gethögen. In the latter place a zone of granite mylonite can be traced for several hundred metres in N.–S. direction along a small brook about 1 km WSW. of Gethögen. The edge of the eastern bank consists of red, comparatively fresh granites whereas the western bank consists of dark-violet mylonitized granites with a western dip of 45–60°.[1] In westerly direction and in direct continuation of the mylonite zone follow violet sparagmitic sandstones. The extension of the fault towards the north is clearly seen W. of Gethögen where a small tectonically conditioned valley exhibits sparagmitic rocks in its western part, while the eastern side consists of granites.

Also the northern granite region with the overlying sparagmites has been raised in relation to a western sparagmite area by a rather gently dipping fault trending NNW. This fault is indicated 500 m NNW. of V. Röstan by a dark-violet granite mylonite of the type just mentioned and with a dip of 60° W.; it is exposed on the eastern side of the road. On the western side of the road follow outcrops of violet sparagmitic sandstone. The distribution of the rocks on the map Pl. I also shows the continued course of the fault line.

The existence of a fracture zone running parallel with the Ljusnan and connecting the two above-mentioned N.–S. faults can be assumed, though no facts are available to prove it. Nothing definite can be said about the age of the faults, but they are probably of syntectonic origin.

In the region of Gammelvallen an overthrust of the Red sparagmite towards SE.–S. with a length of at least 2 km over the Vemdal quartzites in the east has been observed. A primary contact exists, however, at Torrberget (p. 314) between Red sparagmite and granite, and for this reason it is necessary to assume that the sparagmites in the area from Gammelvallen in the east to Vinberget in the west has been transported in one way or the other by the underlying granites without being completely separated from them. South of the Ljusnan the overthrust of the granites and sparagmites towards the east seems to be of considerably smaller extension.

From the above, the active part played by the Archean bedrock in the shaping of the region around Hede becomes evident. Wedges and sheets of granite seem to have carried the overlying sediments and to have effected their gradual transport. The length of these transports depended upon the depth at which the

[1] The granite mylonite consists of lenticularly elongated eyes of feldspar immersed in finely granulated, strongly regulated recrystallized quartz. A pronounced impregnation with hematite throughout the zone indicates a supply of solutions of iron.

Archean wedges separated from their base, and upon the dip of the thrust-plane. Unless flat tectonic fracture zones exist at very great depths, whereby transports of the sedimentary formations over tens of kilometres might easily be explained, we must assume the granites of the region around Hede as well as the formations of the Hede limestone and of the sparagmites to be parautochthonous. The investigations in the region of Hede have so far not yielded any indication for a long transport of the rocks of the Sparagmite series, except for the small areas in Vikarberget (cf. p. 323).

Description of Localities and Smaller Areas

Hockla, SW. of the church of Hede

At the eastern side of *Hockla* mountain a basal conglomerate rests upon granite. A continuous sequence through the lower formations of the Sparagmite series is exposed here in two parallel erosion valleys of about 20 m depth. Sections from this locality have been published earlier by TÖRNEBOHM (28, p. 47) and HÖGBOM (14, p. 141). The rocks have been preserved in the shelter of the strong upward-thrust towards south and east to which the granites in Hockla mountain has been subjected. The map, Fig. 1 and the section Fig. 2, show the structure of the region. Closest to the granite in the west the folding is most strongly developed with the beginning of isoclinal overturn whereas at a greater

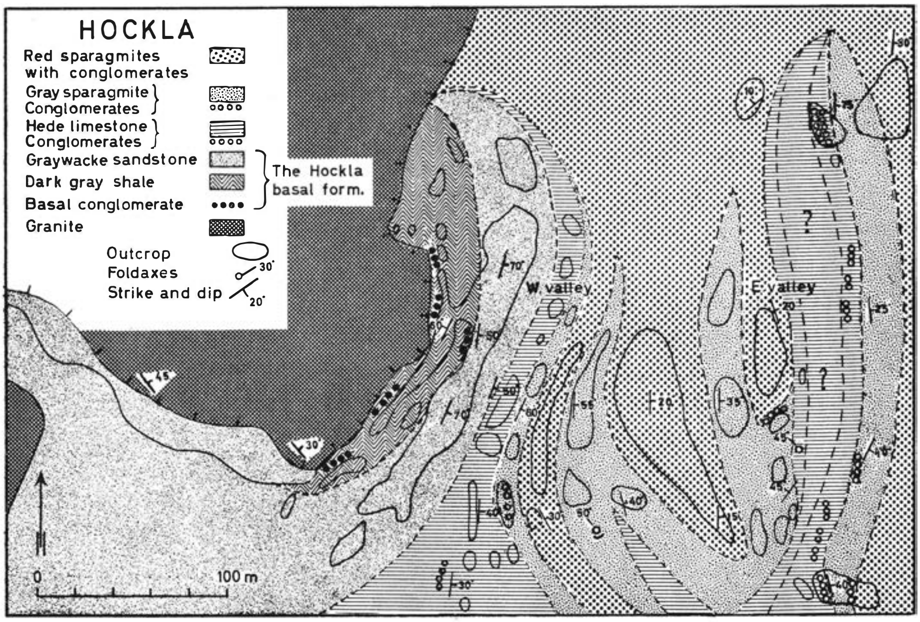


Fig. 1. Detailed map of the parautochthonous Sparagmite field at Hockla, 3 km SSW. of the church of Hede.

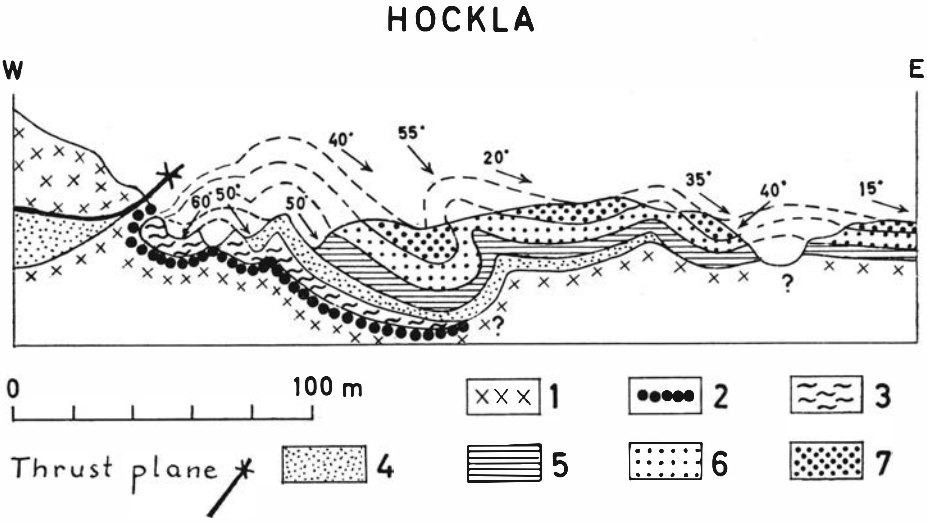


Fig. 2. Section through the Sparagmite series at Hockla SSW. of Hede church. Drawn to scale.

1. Granite.
2. Basal conglomerate.
3. Dark gray shale.
4. Graywacke sandstone.
5. Hede limestone.
6. Gray sparagmite.
7. Red sparagmite.

distance to the east folding with flat dips occurs. In the anticlinal zones the basal portions of the sedimentary series are exposed. Particularly in the vicinity of the bends of the folds a very strong crushing and subsequent recrystallization have taken place during the compression of the strata (see 33).

In the western valley the basal deposits upon the granite (1, 4) are 9–14 m thick and consist, from below upwards, of basal conglomerate, shale, and graywacke sandstone; these together constitute the Hockla basal formation. This is succeeded by the continuous sequence of the Hede limestone formation, about 12 m thick, composed of calcareous shales, calcareous sandstones, and conglomerate (cfr. detailed sections on p. 305). Then follow the Gray and the Red sparagmite formations. The entire sequence of strata, excluding the Red sparagmites, thins out towards the north. In the southern part of *Stavsåsen* the sequence below the Red sparagmite has been completely squeezed out as a result of the pushing up of the granite in eastern direction. In the south-western part of the detailed map (Fig. 1) a dark-green chloritic porphyritic granite has been pushed in a breadth of 200 m in south–southwestern direction over the graywacke sandstone of the Hockla basal formation. The shaly zone of the Hockla basal formation which is otherwise strongly folded and pressed all along the valley, as well as the basal conglomerate are both squeezed out in the same direction between the granite and the graywacke sandstone mentioned.

The basal conglomerate consists of rounded cobbles of granite together with an abundance of quartz pebbles and grains, cemented with a black matrix containing graphite (p. 329). Along a distance of 150 m, the basal conglomerate is

	Section measured in *the western valley*.			In the northern part of *the eastern valley*.		
top	12–14 m	Very coarse polymict conglomerate, reddish or spotted with red, and arkoses (39, 57).	The Red sparagmite formation.	> 10 m	Very coarse polymict conglomerate, reddish or spotted with red, and arkoses.	
	8–12 m	Gray coarse-grained arkoses (31, 32, 33, 34) interbedded with single beds of graywacke sandstones and siltstones (36, 43, 44, 45). Coarse polymict conglomerates.	The Gray sparagmite formation.	8–12 m	Gray coarse-grained arkoses. About 5 m covered.	Coarse polymict conglomerate occasionally intercalated in the south and middle parts of the valley.
		About 4 m covered.		3 m	Light gray fine-grained arkosite (11). About 2 m covered.	
	4 m	Gray medium-fine-grained calcareous sandstones (12, 13).	The Hede limestone formation.	4. 0.5 m	Coarse gray polymict calcareous conglomerate (see Table 6).	
				0.5 m	Light gray medium-grained calcareous arkose with silty layers (10).	
	8 m	Dark banded argillaceous limestones (19), calcareous sandstones (14, 15).		0.3 m	Dark gray banded sandy siltstone (17).	
				3. 0.1 m	Gray coarse polymict conglomerate (see Table 6).	
				0.1 m	Dark gray siltstone.	
		About 3 m covered.		2. 0.2 m	Grayish green coarse polymict calcareous conglomerate (see Table 6).	
				1.2 m	Dark gray calcareous siltstone.	
				1. > 1 m	Grayish green coarse polymict calcareous conglomerate (see Table 6).	
	0.5–1 m	Gray polymict calcareous conglomerate (in the southern part of the valley) (see Table 6). About 5 m covered.		> 1 m	Dark banded argillaceous limestones (in the southern part of the eastern valley).	
	5–7 m	Grayish green fine-grained graywacke sandstone (24, 25, 26).	The Hockla basal formation.		Covered.	
	3–5 m	Dark gray silty shale, strongly tectonized (29, 30).				
	1–2 m	Black graphitic basal conglomerate with granite cobbles and quartz pebbles.				
bottom						
		Granite.				

found in close connection with the granite, below which it has apparently been pressed. The conglomerate is furthermore visible in the core of a small anticlinal hump which is formed by the shale in the middle portion of the western valley (see Figs. 1 and 2).

On account of the flat position of the sediments the lower portions of the sequence are not visible *in the eastern valley*. The lower beds of the Hede limestone formation are exposed only in the southernmost part of the eastern valley in the shape of banded calcareous shales 1 m thick. The upper portions of the limestone formation are, on the other hand, much more clearly visible. They begin with an alternation of shales and conglomerates with a varying content of lime, and pass upwards into fine-grained light arkosites. The entire thickness amounts to about 7 metres. Then follows, without noticeable discordance, the Gray sparagmite formation characterized by increasing grain-size and increasing content of feldspar at the same time as calcite occurs more and more sporadically. Intraformational coarse conglomerates appear in the upper portions of the Hede limestone formation as well as in the Gray sparagmite.

The remarkable gradual transition between the Hede limestone and the Gray sparagmite can be studied also at other localities, e.g. in the region S. of *Husberget*. There the limestones pass gradually into 75–100 m of gray coarse arkoses and feldspathic quartzites which, occasionally, contain conglomerates. The Gray sparagmite seems to provide a transition from the Hede limestone, consisting mainly of finely clastic calcareous sediments, into the overlying Red sparagmite formation with its usually coarse, clastic sediments. The latter begins with a division, about 10 m thick, consisting of polymict purple-red porphyry conglomerates (p. 353) and arkoses. The conglomerates are widely distributed and are exposed at Hockla, Stavsåsen, Damm, and Husberget, and likewise along a line from Klockarberget to V. Röstan. At Hockla the conglomeratic division mentioned constitutes the highest member of the sequence. At Stavsåsen and Damm towards the north the conglomerate is overlain by additional members consisting of violet arkoses alternating with red siltstones.

Stavsåsen–Damm

The entire region NE. and E. of Hockla and as far as Damm–Fallkojan–Enbergskojan is occupied mainly by reddish violet conglomerates and arkoses with low variable dip. At western *Stavsåsen* an inconsiderable rest of the Hockla basal formation is exposed, consisting of a few metres of graywacke sandstone (28) in contact with a black ultramylonitic granite infiltrated with lime. A band of Gray sparagmite can also be followed, both in situ and in blocks, along a great arch from Stavåsen via Damm–Fallkojan to Furuberget. At Stavsåsen scaly tectonic structures are of frequent occurrence. Thus the following tectonic units have been observed in a NNE.–SSW. section of 300 m length from the central parts of the locality (see Pl. I).

Top. 15–20 m		Coarse dark-green arkoses with red spots, and purple arkoses.	The Red sparagmite formation.
	½ m	Dark purple calcareous sandstone with several beds of purple-red siltstones and shales.	
		Very coarse polymict red conglomerate.	
> 2 m		Graywacke sandstone. Granite mylonite.	The Hockla basal formation.
		Thrust-plane (covered)	
> 5 m		Very coarse polymict red conglomerate. Covered about 15 m.	The Red sp. form.
> 2 m		Banded calcareous siltstones and calcareous sandstones.	The Hede limestone formation.
		Thrust-plane	
> 3 m		Very coarse polymict red conglomerate. Covered about 15 m.	The Red sparagmite formation.
> 2 m		Banded calcareous siltstone.	The Hede limestone formation.
		Thrust-plane (covered)	
10 m		Very coarse polymict red conglomerate. Covered about 20 m.	The Red sparagmite formation.
		Thrust-plane (covered)	
Base.		Granite mylonite.	

Thus, there occur here not less than four scales of the same sequence resting on top of each other. The third thrust-plane from below is almost absolutely sharp. An example of the limited extension of the scales in lateral direction is provided by the second scale from below which after an extension of 100 m in W.–E. direction thins out towards both ends and disappears.

The sequence of strata is identical in the different scales and the thickness amounts to some tens of metres in each. The dips are northerly and vary between 5 and 30°. The Gray sparagmite formation is not exposed in any of the scales, but space is provided for it in the covered parts of the section. In the upper scale the Gray sparagmite has obviously been squeezed out together with the Hede limestone. This follows from the fact that here the red conglomerate rests upon the basal graywacke sandstones. The small thickness of the sediments together with the plasticity of the Hede calcareous shales have here been of importance for the behaviour of the granites. In connection with the major overthrusts, which have been mentioned earlier, these granites have also segregated a multitude of small wedges and sheets which penetrated into the basal portions of the Sparagmite series, and which have been piled one upon the other together with the attached sediments.

In eastern Stavsåsen only one scale with a north-western dip of 50–80° can be distinguished. It stretches in north-eastern direction for a distance of about 500 m along the foot of a series of small rocky hills. The sequence of strata is the following:

Top.

> 3 m	Coarse-grained dark green arkoses spotted with red.	The Red sparagmite formation.
1.7 m	Light green siltstone and shale.	
0.3 m	Dark purple shale.	
	Covered 5–10 m.	
> 2 m	Dark purple calcareous sandstone (68).	
	Covered 5–10 m.	
> 2 m	Very coarse, purple polymict conglomerate.	
> $1\frac{1}{2}$ m	Gray coarse-grained arkose.	The Gray sparagmite formation.
> $\frac{1}{2}$ m	Banded calcareous siltstone.	The Hede limestone formation.
> 1 m	Light gray conglomerate in calcareous sandstone. (Table 6.)	
	——— Thrust-plane (covered) ———	
> 20 m	Very coarse, purple polymict conglomerate and arkoses with interbedded purple siltstones and shales.	The Red sparagmite formation.

Base.

The four lowermost members in the scale above the thrust-plane have been measured in a continuous series whereas the figures for the thicknesses of the others have been obtained in different places along the series of rocky hills mentioned above. The sediments are well preserved almost without exception in spite of the strong pressure to which they have been subjected at Stavsåsen. The surrounding granites, however, which pierce the sediments, are almost always mylonitized. This indicates that they have been the active components in the development of the tectonic structure of the region (cf. ASKLUND, 2 b, p. 56).

The Gray sparagmite formation is here only 1.5 m thick and consists of a gray coarse calcareous arkose. The above sections show that the lower sedimentary formations are thinner in Stavsåsen than at Hockla. The Red sparagmite, on the other hand, is considerably thicker and contains red shales which are very characteristic from the stratigraphical point of view. These red shales have not been found at Hockla since the sequence of strata is incomplete there.

A continuation of the stratigraphical sequence at Stavsåsen is encountered along the Kvarnån at *Damm* in an exposure of 200 m length. A series of red conglomerates, violet sandstones and shales with a total thickness of about 7 m is folded in an anticline with the axis dipping 35° N. 10° W. At Damm the following section has been measured:

15 dm Light-purple, very coarse arkoses with grains of white quartz and red feldspar.
1 dm Dark-purple siltstone.
8 dm Light-purple coarse-grained arkose.
1.5 dm Purple siltstone and shale.
2 dm Fine-grained purple sandstone.
1 dm Dark-purple siltstone and shale.
1.7 dm Fine-grained purple sandstone.
1 dm Dark-purple shale.
5 dm Light- and dark-purple sandstones.
1.5 dm Dark-purple shale.
1.5 dm Fine-grained light-purple sandstone.
5 dm Interbedded layers of purple siltstone and shales with purple sandstones.

Fig. 3

Covered about 1 m.
10 dm Light-green sandy siltstone (81). Purple sandy siltstone (78) and silty shale (83).
10 dm Very coarse polymict dark purple conglomerate (see Fig. 4).

The Red sparagmite formation

Fig. 3. Interstratified beds of purple sandstones, siltstones and shales. The sequence rests on coarse red conglomerates. Damm, Kvarnån. Photo G. Stålhös.

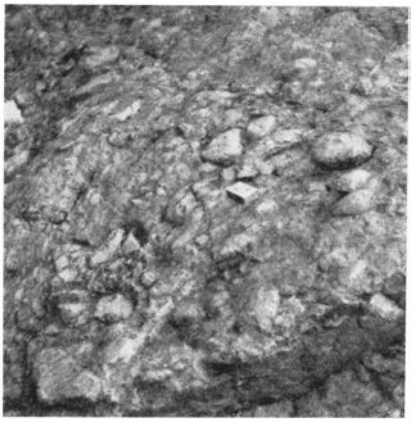


Fig. 4. Coarse polymict red sparagmite conglomerate at Damm, Kvarnån. Photo G. Stålhös.

A streak of Hede limestone with NW.–SE. extension occurs about 200 m NE. of the outcrops at Damm and at a level which is about 10 m lower. The limestone occurs in huge blocks which are partly covered by the soil and which lie side by side in a belt of about 500 m width and a length of at least 1 km along the Ljusnan. This belt has probably originated by the shattering of an earlier continuous limestone horizon. Since a similar streak of limestone blocks is found at the same level at Särvoset about 5 km farther towards NNW. it can be assumed that the extension of the Hede limestone formation follows on the whole the valley of the Ljusnan (see Pl. I).

The area around Kvarnån–Furuberget and the shieling of Gammalbodarna

A streak of Gray sparagmites can be followed in the middle of the area of the Red sparagmites from Fallkojan at the *Kvarnån* via Enbergskojan and to Furuberget. This streak usually consists of gray to grayish blue arkoses rich in feldspar, and of some coarse polymict conglomerates. North of Fallkojan the surrounding Red sparagmite is represented by violet coarse arkoses and porphyry conglomerates. The same development is found in the region of Furuberget. The streak of Gray sparagmite can be suspected of representing here the limits of an old anticline, now overturned towards the east, and from which the overlying Red sparagmites have been removed by erosion. About 600 m SE. of Fallkojan occurs a sheet of granite which is roughly 10 m thick, pressed upwards towards SE. This sheet probably indicates the existence of a thrust-plane which runs parallel with the overturned limb of the fold (Fig. 5).

The bottom of the anticline of the Gray sparagmite at *Furuberget* contains a 10–15 m thick siltstone which could possibly be considered as equivalent to the rocks of the Hede limestone formation. These are occasionally poor in lime or altogether without lime as it happens locally at Hockla and Ulvberget (see p. 305).

In the western part of the anticline of *Furuberget* the following sequence of strata has been noted. The dip is 25° to WNW.

35 m	Coarse- and fine-grained purple, light-purple (52), yellowish green (57), and gray (48) arkoses.	5.	The Red sparagmite formation.
1.5 m	Light grayish green thin-bedded shale.	4.	
7 m	Same as 5.	3.	
5 m	Gray, somewhat calcareous arkose.	2.	The Gray sparagmite formation.
10–15 m	Dark-gray thick-bedded siltstone.	1.	The Hede limestone formation.

Towards the east and as far as a line through Furubergstjärn the region consists of coarse clastic, intensely red arkoses with a few beds of violet siltstone. In the last named locality occur intercalations of very coarse arkoses with plenty of cobbles of red porphyry and of granite of about 5 cm diameter.

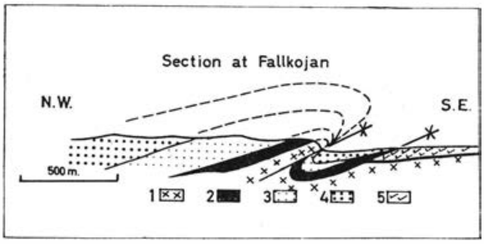


Fig. 5. Thrust fold at Fallkojan.
Parautochthonous: 1. Granite.
2. Hede limestone.
3. Gray sparagmite.
4. Red sparagmite.
Allochthonous: 5. Vemdal quartzite.

Farther to the east the arkoses become paler and pass into dirty-yellow to grayish feldspatic sandstones. The whole sequence of strata is folded along flat axis in the direction NNE.–SSW.

After some additional hundreds of metres in eastern direction over an area without outcrops, the rocks of the Vemdal quartzite formation appear. They have the same western dip as the sparagmites. Farthest in the west, the former formation consists of some 20 metres of coarse quartz conglomerate of the same type as in Vikarbergen (see p. 357 and Fig. 21) and in some other localities. It is followed by bluish gray to dark-blue coarse feldspathic quartzites with a thickness of at least 50 m, and finally, farthest in the east, in the region of the shieling of *Gammalbodarna*, green and gray variegated siltstones and shales with a thickness of several tens of metres. These latter are strongly pressed and exhibit very variable axis of folding indicating that they have been exposed to a deformation of much higher intensity than the parautochthonous sparagmites in the west. The quartzites constitute the westernmost spurs of the allochthonous Sonfjäll massif which is situated in the SE. and is built up exclusively of the rocks of the Vemdal quartzite formation. The siltstones and shales mentioned obviously lie in one of the many planes of movement which have been formed within the quartzites of the Sonfjället while they were thrust towards E. and SE.

The region of the shieling of Gammalbodarna exhibits no outcrops which would permit a more detailed study of the boundary between the sparagmites and the quartzites. This boundary is probably of a tectonic nature in analogy to the conditions along the corresponding boundary N. of the Ljusnan where the sparagmites are thrust with a sharp discordance over the Vemdal quartzites in the east. Along the boundary south of the Ljusnan the overthrust of the sparagmites is presumably quite insignificant or at all events of smaller extent than the mentioned overthrust north of the Ljusnan.

Tällberget

East of *Tällberget* runs a broad zone of closely packed large blocks of Hede limestone formed probably by the shattering of an earlier continuous limestone stratum as is the case at Särvoset and at Damm.

The limestone is represented mainly by coarser and more fine-grained pale-gray calcareous sandstones. West of the Hede limestone formation follows

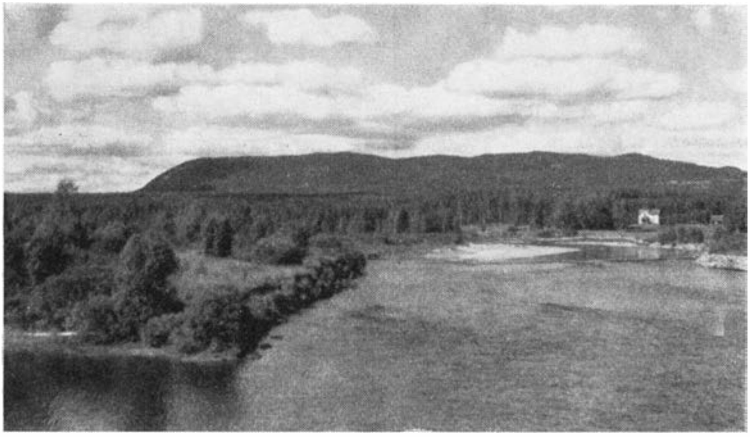


Fig. 6. The slope of Säterberget seen from SE. In the foreground the Hede limestone formation and Archean rocks. The mountain is composed of Gray and Red sparagmites. Photo G. Stålhös.

a tectonically altered grayish green granite which has been pressed over the former (STRÖMBERG, 26, p. 209).

The calcareous zone is a direct continuation of the limestone along the valley of the Ljusnan via Stavsåsen and Hockla, and probably continues beyond Tällberget at a lower level to crop out again 10 km farther to the south in the shape of a broad belt in *Råndalen* which runs parallel with the valley of the Ljusnan. If the limestone had not been moved up from a lower level in connection with the pushing up and forward of the underlying granites, it would not be at all exposed in the area from Stavsåsen to Tällberget.

Säterberget–Digerknätten–Vinberget

The Sparagmite complex of *Säterberget–Digerknätten* reaches its highest point about 300 m above the valley of the Ljusnan which is here occupied by Hede limestone (Fig. 6). The sediments of the region are strongly folded and large portions have been pushed up by the granitic fundament. Hede limestone, in close contact with granite, has thus been found NE. of V. Röstan in a position 100 m above the limestone belt in the valley. This is also the case at *Vinberget* where the graywacke sandstone of the Hockla basal formation (27) outcrops 640 m above sea-level. This sandstone is 5 m thick and is followed by some metres of gray calcareous arkose, and, on top of this, by a coarse arkose belonging to the Red sparagmite. Starting from a deep depression NE. of the farms of *Klockarberget* and proceeding some distance up the slope of Säterberget the following, partly very generalized section has been measured in north-westerly direction.

Top. > 100 m	Purple arkoses and feldspathic quartzites.	The Red sparagmite formation.
	Some tens of metres covered.	
5 m	Coarse purple and dark-green arkoses.	
0.20 m	Dark-purple fine-grained feldspathic quartzite.	
0.35 m	Dark-purple shale.	
0.8 m	Dark-purple fine-grained feldspathic quartzite.	
0.7 m	Dark-purple shale.	
0.5 m	Coarse dark-green arkose.	
	Some tens of metres covered.	
> 10 m	Coarse purple and dark-green arkoses. Very coarse purple polymict conglomerate.	
> 30 m	Various kinds of light arkoses and feldspathic sandstone.	The Gray sparagmite formation.
5 m	Light-gray calcareous arkoses and coarse conglomerates.	
2 m	Banded dark calcareous siltstone.	The Hede limestone formation.
	——— Thrust-plane (covered) ———	
	Covered about 5 m.	The Red sparagmite formation.
Base 5 m	Coarse green arkose, spotted with red.	
	——— Thrust-plane (covered) ———	

The tectonic discordances at the bottom of the sequence indicate the occurrence at this locality of the same kind of imbricate structure as in the region of Stavsåsen mentioned above. The section is also intended to demonstrate the similarity of the stratigraphical sequence at Klockarberget–Säterberget with that at Stavsåsen–Damm–Hockla. Its main elements are represented in the same order in all the localities mentioned, as follows:

Top.	4. Purple arkoses and sandstones interbedded with purple siltstones and shales.	The Red sparagmite formation.
	3. Very coarse purple polymict conglomerates.	
	2. Light-gray arkoses and sandstones with coarse conglomerates.	The Gray sparagmite formation.
	1. Banded dark calcareous siltstones and shales.	The Hede limestone formation.
Base.		

Owing to the very complicated folding of the sequence, the thickness of the Sparagmite formations in the Säterberget–Digerknätten region could not be determined. The Gray sparagmite formation has a folding axis with a low western dip and can be followed from Klockarberget about 1.5 km towards the west where it dives down and disappears. The division, which on a rough estimation has a thickness of some 50 m, consists of very varying members, as gray to dark-green arkoses (39), pale feldspathic quartzites (40, 74, 75), and dark siltstones (46) together with repeated layers of coarse polymict conglomerates. The Red sparagmite formation, at least 150 m thick, consists of red conglomerates, red shales (79, 80, 82), red arkoses (53), and feldspathic sandstones (60, 61, 69, 70, 72) which can be followed from Klockarberget in the east to V. Röstan in the west.

Vitåsen

At *Vitåsen*, west of the large N.–S. fault in the western part of the map, the sparagmites are usually in almost horizontal position or sligthly folded with varying directions of dip. Slightly tilted continuous plane sheets of sparagmite with sizes up to 50 × 100 m are of frequent occurrence. A folding axis observed in the field showed a dip of 30° SSW. The sparagmites consist of violet, pale-violet or light-gray rather equigranular feldspathic sandstones (63, 66, 73) with a visible thickness of about 200 m. In distinction from the north-eastern and eastern region neither coarse, clastic arkoses and conglomerates nor red shales have been found. This agrees with the conception that the regions W. of the fault-line have not been noticeably pushed up. On this account neither the deep-seated Gray sparagmites nor the lower parts of the Red sparagmite formation appear on the surface.

Torrberget

At the north part of Torrberget the basal conglomerate of the Red sparagmite formation rests upon granite. This is probably the conglomerate mentioned by TÖRNEBOHM (28, p. 48) from this region. It can be followed around the summit of the mountain and dips towards it. It is furthermore found about 750 m SW. of the first locality. The conglomerate is 15–20 m thick and is overlain by 10–15 m of violet sandstones. It consists almost exclusively of closely packed rounded boulders of red granite, rarely of quartz, mostly 20–30 cm, in a matrix of dark-violet feldspathic sandstone (62). The granite boulders are derived exclusively from the underlying granite. In the bottom of the conglomerate, the rounding of the boulders becomes less perfect. Finally they give way to irregular sharp-edged tightly packed blocks of the size of ½ metre. Thus the homogeneous granite merges gradually into the conglomerate. Both with regard to the size of the boulders and the character of the matrix the upper portion of the conglomerate resembles those described above at the base of the Red sparagmite formation e.g. at Stavsåsen–Damm. The above-mentioned basal conglomerate of the Red sparagmites which passes downwards into a weathering breccia has its counterpart within the sheet Søndre Femund in Norway (G. HOLMSEN, 10, pp. 19–20) where the Red sparagmite rests in a similar way upon the Archean, and via a weathering breccia passes upwards into a conglomerate.

Consequently rocks of the type which form part of the Hockla basal formation, the Hede limestone formation, and also the Gray sparagmites are missing to the north of Torrberget and have probably never been deposited here.

This seems also to be the case all along the northern boundary of the region of the Red sparagmite where no traces of the lower sedimentary complexes have been observed, but where the rocks in closest vicinity of the granites are coarse red arkoses including fragments of red granite of centimetre size.

The entire region from Vinberget in the west to the line Hammarbergen-Ulvberget in the east consists mainly of very uniform violet to pale-violet arkoses and feldspathic sandstones, as a rule of medium grain-size. The occurring coarser rocks consist of less well sorted greenish gray to bluish gray arkoses spotted with grains of red feldspar.

The thickness of the Red sparagmite formation has been estimated in different localities at the following figures:

Vitåsen	>200 m	Säterberget	>150 m	The northern part of Torrberget	>30 m
Nupdalåsen	>100 m	Gammelvallsberget	>180 m	Ulvberget	>75 m
Hammarbergen	> 50 m	Stavsåsen	> 15 m	Hockla	>10 m
Husberget	>200 m	Furuberget	> 50 m		

Farthest to the east within the area of the map the Vemdal quartzite formation extends in the shape of feldspathic quartzites, quartzites, quartz conglomerates, siltstones, and shales (see p. 356). Towards the sparagmites in the west it exhibits a sharp tectonic boundary exposed in several places from Ulvberget and towards NNE.

The tectonic boundary between the Sparagmite-granite complex and the Vemdal quartzite

A sharply marked tectonic boundary between different kinds of rocks can be traced from Ulvberget in the south via Näfjan and farther towards the NE. far beyond the area of our map. In the region N. of Hammarbergen, gneiss-granites are thrust in southern and southeastern direction over the Vemdal quartzites. At Orrhögberget, E. of Sör Vemån, STRÖMBERG (26, pp. 206–207) has shown that the gneiss-granites with an underlying mylonite zone rest directly upon the Vemdal quartzites. In the same region this author also noted the common occurrence of imbricate structure in front of the large thrust-line between gneiss and quartzite. The quartzite region in the SE. is separated from the north-western region, which consists alltogether of gneiss-granites, by a transitional zone formed of alternating sheets of gneiss and quartzite.

Also in the area S. of Hammarbergen an overthrust of granites towards the E., SE., and S. can be observed but here the Sparagmite series, which rest upon the granites, has been included in the thrusting. During this process the sparagmites have been separated from their granite foundation along large portions of the boundary, and have thus come to rest directly upon the Vemdal quartzites.

Considering the primary contact between granite and sparagmite at the north part of Torrberget (p. 314) a movement on a larger scale of the sparagmite in relation to the underlying granites is unlikely. This becomes obvious also at all localities where the granitic basement together with the sparagmites has been pushed over the quartzites in the east.

All over the bay formed by the quartzites between Hammarbergen and Gammelvallen the Red sparagmites, which here are developed as violet sandstones, rest upon yellowish green pure quartzites belonging to the Vemdal formation. These quartzites dip everywhere below the sparagmite.

Depending on the direction assumed for the movements of the sparagmites, the following minimum values for the relative movement between sparagmite and quartzite are obtained:

From	W.	towards	E.	results in about	2 km
,,	NW.	,,	SE.	,, ,, ,,	2 ,,
,,	NNW.	,,	SSE.	,, ,, ,,	3 ,,
,,	N.	,,	S.	,, ,, ,,	4 ,,
,,	NNE.	,,	SSW.	,, ,, ,,	7 ,,

Observations of the dips and of the direction of the axis of the folds show that the directions of movement of the sparagmites probably varied mainly within the sector NW. to N. to which the estimated distances of thrust between 2 and 4 km belong.

Below are given some observations of granite protruding between the sparagmites and the Vemdal quartzite.

About 800 m SSW. of Gammelvallen occurs a sheet of dark-red granite-mylonite, about 5 m thick, overlain by red feldspathic sandstones. It is thrust over Vemdal quartzites which are exposed for some tens of metres, and consist farthest down of light-gray, and then yellowish green quartzites.

The relations between the sparagmites and the Vemdal quartzites in the boundary region about 400 m V. of Gammelvallen are shown in the section, Fig. 7.

Sparagmite.	Purple feldspathic sandstone. Grayish-green feldspathic sandstone, spotted with red.	15 m.
	Dark-purple granite-mylonite.	2 dm.
	——— Thrust-plane ———	
Vemdal quartzite.	Grayish-green quartzite. White quartzite. Covered. Grayish-green quartzite.	
	——— Thrust-plane? ———	
Sparagmite.	Dark-purple feldspathic sandstone. Covered.	
	——— Thrust-plane ? ———	
	Covered. Vemdal quartzites.	

Sparagmite with an underlying sheet of granite is thrust over a strongly compressed sequence of Vemdal quartzites. These, in turn, rest upon red feldspathic sandstones, and finally Vemdal quartzite reappears in the lower portions of the slope. In spite of the fact that the conditions at this locality are not per-

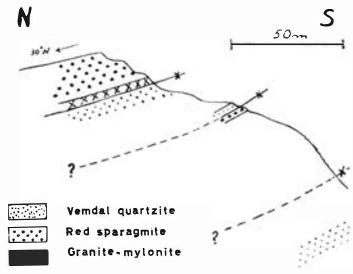


Fig. 7. Section of the NE. part of Gammelvallsberget, 3 km ENE. of Hede church.

fectly clear the assumption may be permissible that the slope consists of a series of scales piled one upon the other. This is in accordance with the "Schuppen tectonics" in the front of the large thrust-line between gneiss and quartzite mentioned by STRÖMBERG.

As far as the tectonics are concerned the granite in the region of Ulvberget occupies principally a similar position as the granites around Gammelvallen.

Ulvberget and the neighbouring regions

Ulvberget, situated about 4 km E. of Hede, forms the SE. boundary of the great sparagmite area N. of the Ljusnan. A. G. HÖGBOM (14, p. 138) writes that it "is of no mean interest, although the local conditions must still be regarded as unsettled" (author's translation). He adds a sketch-map of the mountain and its surroundings (14, p. 7), and mentions a number of interesting facts without, however, entering into any attempts towards the explanation of the tectonic structure of the region. Later HADDING (9, part III, pp. 160–163) has published some sections from the SE. part of Ulvberget (see p. 337).

A detailed map of Ulvberget has been prepared by the present author to the scale of 1:10,000 (see Fig. 8 and section Fig. 9).[1] The granite forms two separate sheets, a lower one of about 80, and an upper one of about 40 m thickness (Fig. 9). The upper sheet dips 45° NW. It has been thrust about 10 m over the lower sheet and forms the roof of the so called Getgrottan, a cave of about 75 m length (see Figs. 9 and 10). The extension of the granites in the region of Ulvberget is otherwise seen in the map (Fig. 8). In the north, the Vitån runs for a distance of about 200 m along a zone of granite mylonites which dip 55° SW. These gradually wedge out, but an isolated sheet of granite mylonite, about 10 cm thick, is found between red sparagmite sandstone and white Vemdal quartzite in the extreme north (see Fig. 8).

Originally, the granite of Ulvberget has probably formed a hill which rose above the surrounding Archean under the covering sedimentary layers (p. 321). Later, in connection with the obliquely and upwardly directed overthrust, this

[1] A preliminary geological sketch map of parts of Ulvberget and a written explanatory report has been kindly put at the author's disposal by Dr. N. MARKLUND who had visited the locality on several occasions in 1950–1951.

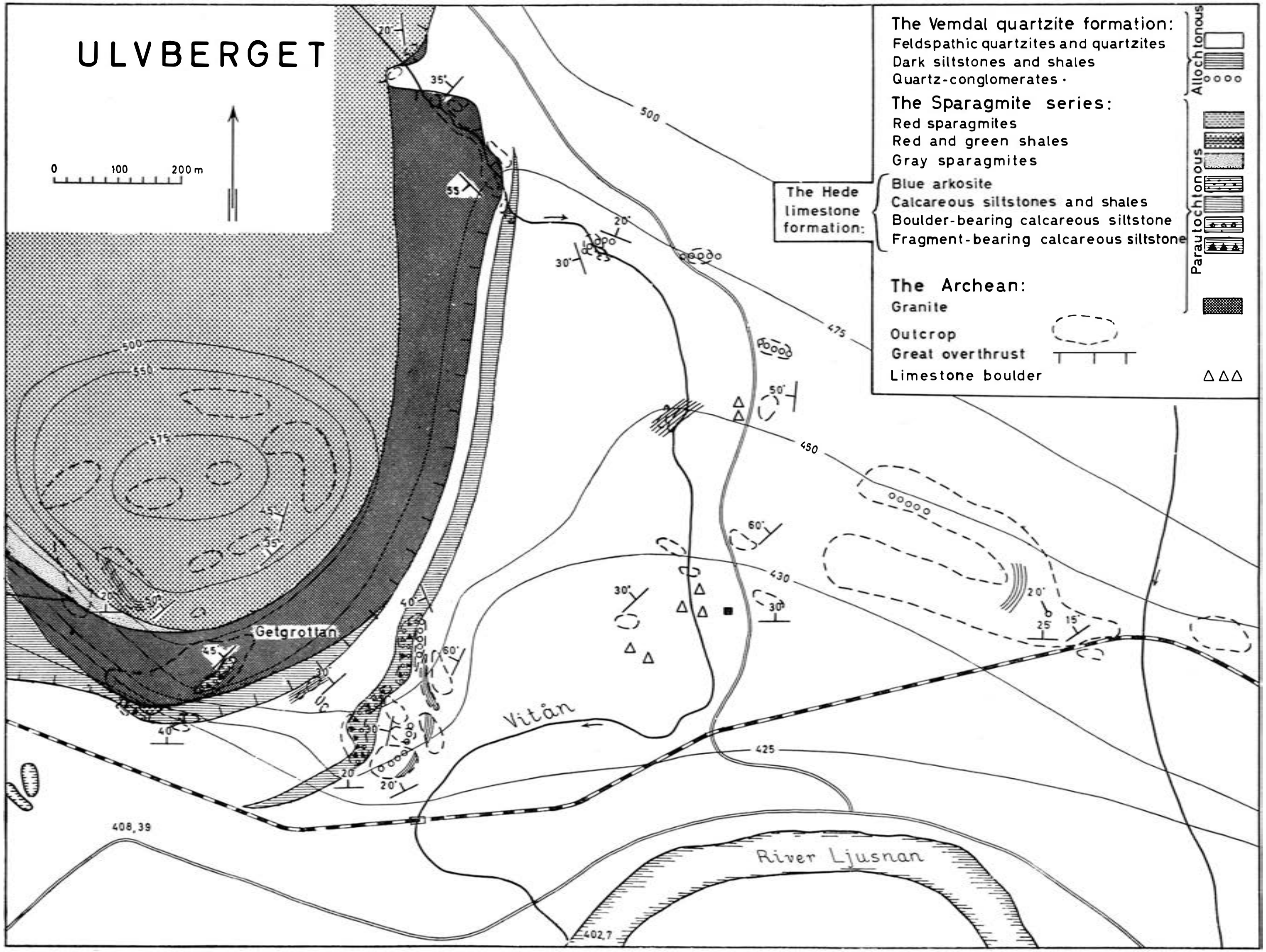


Fig. 8. Ulvberget, 4 km east of Hede church. The overthrust front between the Sparagmite series and the Vemdal quartzite.

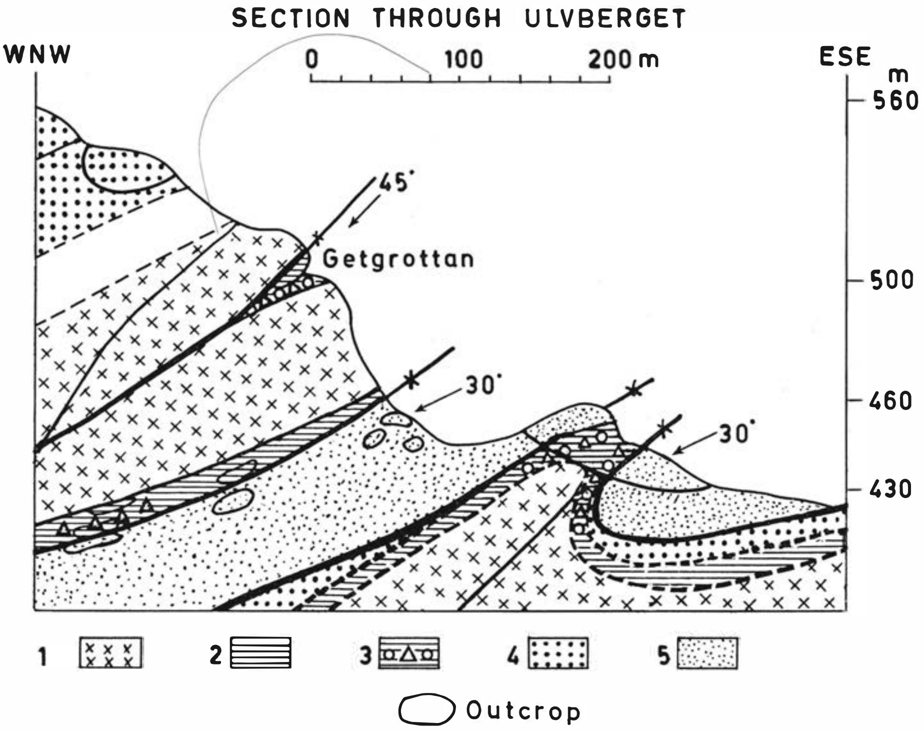


Fig. 9. Section through the overthrust front in Fig. 8.
Parautochthonous:

1. Granite.
2. Calcareous siltstones and shales. } The Hede limestone formation.
3. Calcareous siltstones and shales with boulders and fragments of granite. } The Hede limestone formation.
4. Sparagmites. (Above Getgrottan gray and red sparagmites occur. Below the cave conditions are unknown.)

Allochthonous:

5. The Vemdal quartzite formation.

hill has penetrated the whole sequence of overlying sediments and, thus, become still more conspicuous.

The tectonic sequence of events at Ulvberget was probably the following. During a first phase the Vemdal quartzites of our area, which are connected with the Sonfjäll massif and with the other clearly allochthonous quartzite massifs in the east, have on the whole taken up their present position. During a second phase, the Ulvberget granite being an essential part of the granite region which moved towards SE. and S., has penetrated the sequence of rocks of the overlying Sparagmite series. In this connection the whole stratigraphical sequence has been inverted all along the thrust-zone. During this process the sparagmites have been completely squeezed out, and thus the Hede limestone now is found at the base of the advanced granite nappe resting with a sharp tectonic discordance upon the compressed Vemdal quartzites. On a minor scale this entire

Fig. 10. Ulvberget. View from SE. The thrust-plane between the upper and lower granite sheets is seen. Boulder-bearing Hede limestone is squeezed between the granite sheets in the cave called "Getgrottan". Photo G. Stålhös.

sequence of tectonic events is repeated in the small rise of the foundation which lies immediately SE. of the front of the large overthrust (Fig. 9). The last-named small upthrust can be looked upon as the embryonic stage of a "Schuppe" in the front of the large overthrust as mentioned earlier (pp. 315 and 316).

In the middle part of Ulvberget remains of the basal Hede limestone formation have been preserved in the so-called Getgrottan where they are wedged in between the two granite sheets mentioned above, and also in several other places along the very steep southern slope of the mountain where they almost give the impression of being stuck to the support. The upward vaulting of the sedimentary series resembling an anticline which obviously has taken place at Ulvberget, and which has been followed by the inversion of a southern limb, has its direct continuation westward to the region around the Lunån where the anticline wedges out. The thrust-plane below the limestone in Ulvberget continues presumably in westerly direction. At the place where the railway and the road cross near Östbacken, the southern limb of the fold is found to contain first Gray and, farther towards the NW., Red sparagmites. Thus the squeezing out of the sparagmites which is complete at Ulvberget ceases towards the west. Consequently the plane of overthrust cuts obliquely through the sequence of the Sparagmite series and reappears farthest in the west below the Red sparagmite. This is represented by a marked streak of blocks consisting of coarse violet polymict conglomerates extending to the western part of Husberget where identical conglomerates have been found in situ. The core of the anticline which consists of Hede limestone, and which reaches from Ulvberget to the western part of Husberget, contains in several places folded-in masses of Gray sparagmite with conglomerate (p. 324). Also a very pronounced imbricate structure occurs there, exhibiting numerous sheets of granite mylonite wedged into the basal portions of the limestone. These sheets which can reach a length of some tens

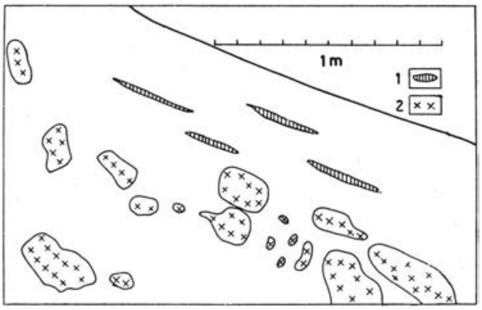


Fig. 11. Hede limestone of boulder clay type, 1 km to the west of Ulvberget. 1. Dark calcareous siltstone with sandy layers. 2. Granite.

of metres and a thickness of a metre (cf. also p. 324) indicate that (1) the granite support is found immediately below the limestone and very close to the surface of the ground, and that (2) the granite support has taken an active part in the development of the anticline and therefore exhibits great similarities with the granite of Ulvberget from the tectonic point of view.

Through the compression and folding of the Hede limestone by the advancing granite support, considerable heights have been formed where it is tempting to overestimate the thickness of the limestone. The thickness of the limestone has been given by A. G. HÖGBOM (14) as 75–80 m, but does probably not exceed about 30 metres.

The primary contact between Hede limestone and granite in the southern slope of Ulvberget (p. 320) also suggests that the Hede limestone rests directly upon granite in the above-mentioned anticlinal area. The different conditions in the west, at Hockla–Stavsåsen and Vinberget, have already been dealt with.

The Hede formation which in its lower parts consists preponderantly of dark, more or less clearly banded calcareous shales contains, however, occasionally also abundant granite boulders of varying diameters. About 1 km WNW. of Ulvberget and quite close to a smaller sheet of granite mylonite which is wedged into the limestone, occurs a zone of dark Hede limestone with sparse rounded granite boulders between 10 and 50 cm diameter. This zone is about 3 m long and 1.5 m broad (Fig. 11). Such boulders are also found in abundance in Getgrottan (Fig. 12), and in the long and narrow limestone anticline in the south-eastern part of Ulvberget. If the great similarities between this development of the Hede limestone with a boulder clay could be ascribed any genetic significance, a glaciation might perhaps be assumed for this time (p. 336).

Apart from these relatively well rounded boulders of granite the limestone of all localities at Ulvberget exhibits a strong admixture of angular fragments of the same granite which also forms the boulders. The very local occurrence of these angular fragments just around the Ulvberg granite can be explained by the assumption, referred to already (p. 317), that, at the time of deposition of the Hede limestone, this granite formed a height which dominated over the surroundings and from which an extensive local transport of granite material was

Fig. 12. Granite boulders in dark siltstone belonging to the Hede limestone formation. Getgrottan, Ulvberget. Photo G. Stålhös.

taking place. The sedimentary breccia which, in this way, was formed became crushed in connection with the tectonic movements, and in places a certain parallel arrangement of the fragments was produced. In Getgrottan, it can thus be observed that boulders of granite have been completely or partly crushed in certain places, and that the angular fragments of granite resulting from this process have moved into the surrounding ground-mass.

At the same place another less common development of the Hede limestone is to be seen, viz. a blue black arkosite (16), 3–5 m thick, wedged in just below the overthrust granite. An exactly similar arkosite is found 75 m below this level at the foot of the mountain (see Fig. 8) where it is wedged in below the lower sheet of granite.

It has already been mentioned that the contacts of the Hede limestone formation with the Vemdal formation are clearly of tectonic nature. The following observations of direct contacts between the formations have been made in the immediate vicinity of Ulvberget: (1) At the foot of Ulvberget, farthest to the west: black banded calcareous siltstone with boulders and fragments of granite upon grayish white feldspathic quartzite. (2) In the easternmost limestone streak farthest in the south: grayish green feldspathic sandstone (100) rests for a long distance upon siltstone with boulders and fragments of granite. (3) 200 m NE. of locality 2: calcareous siltstone with boulders of granite upon bluish gray feldspathic quartzite (87). (4) The crossing of the limestone streak by Vitån: grayish blue feldspathic quartzite upon black feebly calcareous siltstone.

A narrow zone of the Gray sparagmite formation runs between the Red sparagmite and the Hede limestone from Säterberget via Husberget as far as Ulvberget (see Pl. I). This is formed, in the western part of Husberget, by gray to grayish green to whitish gray medium-grained arkoses (37) and feldspathic quartzites (41) at least 40 m thick, with a single coarse polymict conglomerate in the upper parts. The sequence of strata dips 30° NE. Other outcrops are found 2 km to SE. They exhibit a series of medium- to coarse-grained light-gray to gray or grayish green arkoses and feldspathic quartzites with a total thickness of 75–100 metres. The series dips 60° NE. and contains, in its upper part, a polymict grayish green conglomerate 3 m thick. TÖRNEBOHM in one of his papers (28, Fig. 24) has designated this sequence of strata as Vemdal quartzite creating thereby considerable confusion in the interpretation of the relative age of sparagmite and Vemdal quartzite. Conditions in the field as well as the lithology of the rocks, indicate that we have here Gray sparagmite. At the west part of Ulvberget, finally, some 50 m of Gray sparagmite rest with an intervening granite mylonite zone upon granite. The Hede limestone has obviously been squeezed out here. The Gray sparagmite consists entirely of grayish green to gray arkoses and feldspathic quartzites. There is no sharp boundary towards the Red sparagmite but the arkoses contain a gradually increasing amount of grains of red feldspar. At the same time the weathering crust assumes the pink colour which is typical for the Red sparagmite. The only marked interruption in the otherwise rather monotonous sequence are red and light-green shales met with in the Red sparagmite in some places. As some parts of the sequence are not accessible to observation some unknown conglomeratic layers might exist. In Ulvberget the Red sparagmite reaches a maximum thickness of 75 m and consists almost exclusively of violet feldspathic sandstones which become paler downwards.

A considerable part of the Vemdal quartzites round Ulvberget and in the boundary zone towards NNE. is strongly crushed (see Table 11). In the north the zone of contact with the sparagmites contains exclusively pure quartzites whereas in Ulvberget only feldspathic quartzites and feldspathic sandstones are represented. This demonstrates that throughout its length the overthrust has cut obliquely across the sequence of the Vemdal quartzites of which the lower levels, richer in feldspar, are represented by the feldspathic quartzites of Ulvberget, while the higher levels with little feldspar are represented by the pure quartzites in the NNE. The feldspathic quartzites at Ulvberget with their inclusions of quartz conglomerate form, moreover, a direct continuation of corresponding formations in Vikarberget and Olberget (cf. FRÖDIN 7, p. 44). The orientation of the quartzites is very variable as can be seen from the numerous dip observations on the map. The northern part of the valley of the Vitån cuts a nicely vaulted anticline. This contains, at the base, bluish gray feldspathic quartzites with a coarse quartz conglomerate of the same type as in Vikarberget and Olberget (see p. 362). The often very thick conglomerates mentioned are obviously intraformational and appear mainly in the lower levels of the quartzites which consist essentially of feldspathic quartzites and feldspathic sandstones.

Typical Red sparagmite (64, 76) is exposed in Vikarberget in two places but its relation to the surrounding quartzites could not be observed. Both outcrops measure a few metres only. The northern outcrop exhibits a distinct dip of the strata of 40° N. Here the sparagmites are either parautochthonous, having reached their present position through some rise of the support, or they represent torn-off portions of the sparagmites found in the west, having been carried along at the bottom of the allochthonous Vemdal quartzites. The occurrence of allochthonous Red sparagmite at the base of the Vemdal quartzite nappes observed by ZENZÉN (31) in the Idre region, Darlecarlia, is in favour of the latter alternative. Here, Red sparagmite overlain by Vemdal quartzite is thrust over Cambro-Silurian beds. Further, the Moelvs-sparagmite in Norway, which is equivalent to the Red sparagmite in Härjedalen, has been included in the allochthonous "kvartssandsteins-dekket" by SKJESETH (24). A compilation of the stratigraphical sequence at Ulvberget gives the following result:

Red sparagmite	about 75 m
Gray sparagmite	about 50 m
The Hede limestone formation.	Bluish black fine-grained calcareous arkosite (16) about 3–5 m. Dark calcareous shale containing boulders and fragments (18, 22, 23) about 3–5 m.
	Granite (6, 9).

The area near the railway NW. of Östbacken

Within an area of about 0.5 sq.km situated about 2 km E. of Hede the bedrock exhibits numerous outcrops (Fig. 13).

The Gray sparagmite consists of gray arkoses and feldspathic sandstones in alternation with coarse polymict conglomerates. Petrographically it corresponds entirely to the Gray sparagmites, p. 322, which form a streak from Ulvberget in the E. along the southern slope of Husberget (Pl. I), and most likely it has been connected with them as suggested by remains of Gray sparagmite with coarse conglomerates of exactly the same appearance as found as in-foldings in the intervening calcareous area.

A bending down towards SW. of the Hede limestone and of the Gray sparagmite can be observed along a narrow belt of steeply inclined structures which can be traced from the railway crossing for about 500 m towards NW. with a mainly NW. strike. In the first calcareous zone from the west (Fig. 13), the limestone disappears with a SW. dip under the Gray sparagmite. In an outcrop immediately E. of the railway crossing a complete fold is exposed with the Hede limestone resting upon Gray sparagmite in an overturned anticline dipping 35° towards the N. 70° W.

The large thrust-plane below the limestone at Ulvberget can be followed in a westerly direction to the railway crossing. From this spot the Gray sparagmite forms the base of the thrust-plane (see p. 320).

The granite in the mapped area represents one of the numerous granitic "Schuppen" in the calcareous region W. of Ulvberget (p. 320). The strongly pressed shale which has been pushed up in front of the granite sheet resembles the shale which appears in the Hockla basal formation.

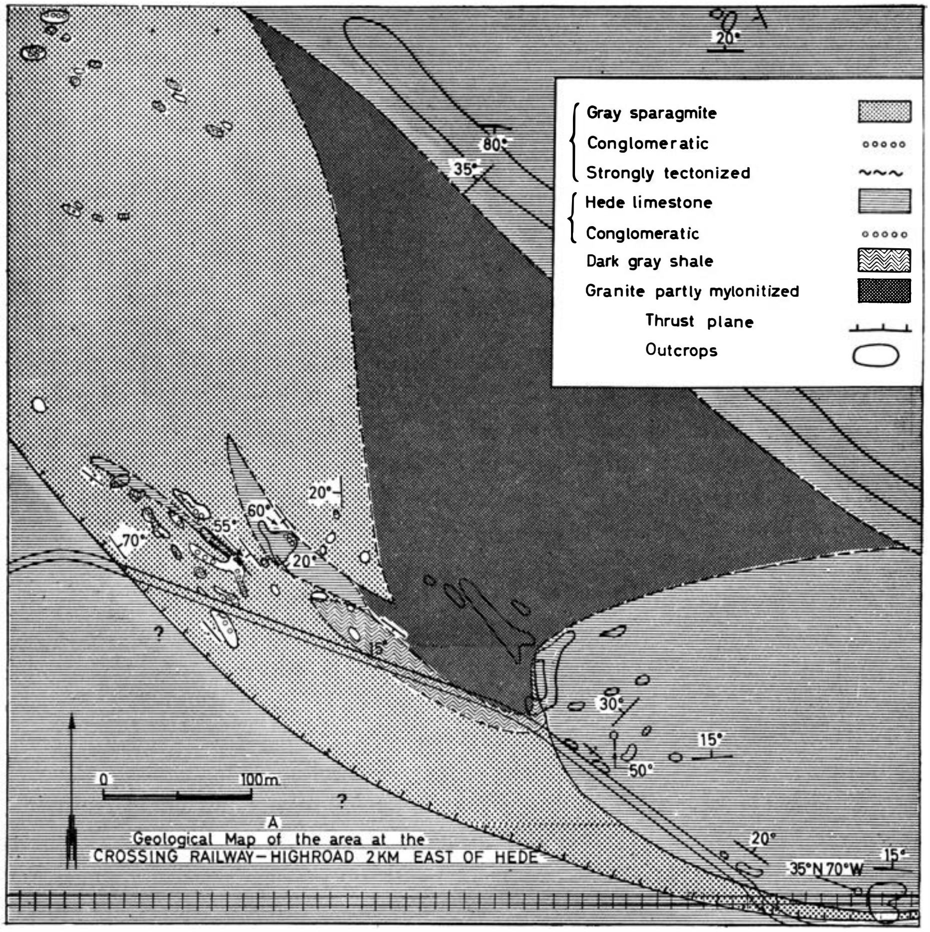


Fig. 13.

The second zone of limestone is a syncline of banded dark Hede limestone, 10 m thick, with NW.–SE. strike. At the base of the limestone a conglomerate is found with cobbles of grayish green granite and, more sparsely, of green porphyry. A similar conglomerate appears at the bottom of the westernmost streak of limestone. Tentatively it can be assumed that the limestone has been originally intimately connected with the sheet of granite in its neighbourhood, and that it has been thrust forward together with it.

Petrology of the rocks

The Archean bedrock

The Archean bedrock in the region of Hede consists almost exclusively of granites and gneiss-granites. These are represented to a large extent by porphyritic varieties, but also types with more uniform grain and fine-grained aplitic granite occur. The diameter of the "eyes" in the porphyritic granites is usually 0.5–1 cm, more rarely 2–3 cm. The colour varies according to the character of the feldspar. The "eyes" of potassium feldspar consist of large uniform porphyroblasts whereas the eyes of plagioclase consist, as a rule, of an accumulation of smaller crystals. The plagioclases which are almost without exception saussuritized and sericitized thus obtain a pale greenish to grayish green colour. In the coarser varieties the quartz is slightly bluish gray, and occasionally forms eyes of 2–4 mm. The principal dark minerals are epidote-clinozoisite, penninite, biotite, and hornblende, in order of frequency (see Table I). Sphene, in varying amount, is always present.

Within most of the zones where the granite has been exposed to stronger tectonic influence, its originally red colour changes into more subdued grayish green to green tints. Formation of chlorite has taken place at the expense of biotite and hornblende which confers to the strongly pressed bedrock a dark-green schistose appearance (5). Sericitization of the plagioclase and deposition of calcite in fissures and veinlets, particularly in the potassium feldspar, contributes to the toning down of the red colour of the rock. The granite cobbles found in the conglomerates are grayish green to green, with few exceptions (see the conglomerate from Torrberget, p. 314) and are often even more altered than the granites in the bedrock. Side by side with the chemical changes mentioned the granites have also been crushed mechanically. This crushing has given rise to a rich choice of granite mylonites ranging from those in which the mineral grains were only partly crushed to typical ultramylonites consisting of an extremely fine-grained isotropic ground-mass mixed with a few coarser mineral fragments. The crushed granites are sometimes recrystallized and then assume a vitreous, quartzitic appearance (6). The resulting colour is lighter or darker depending on the content of dark minerals. In some cases at Stavsåsen and N. of Vinberget black ultramylonites, reminding of mudstones are found. These rocks are soaked with calcite, chloritized, and crushed, and their dark colour is due to a coaly substance in a very disperse state.

The dark-red granite-mylonites from Vitåsen and V. Röstan mentioned on p. 302 and similar types at Gammelvallsberget are coloured by finely distributed hematite.

Common to all the granites of the region is the formation of porphyroblasts of microcline-perthite or microline at the expense of plagioclase. Thus, patches of microcline with uniform optical orientation are sometimes found included in the plagioclase. In other cases the plagioclase is included in the microcline in the form of uniformly orientated remains.

The content of anorthite in the *plagioclase* of the Archean rocks is shown in Table I. The determinations have been carried out in sections $\perp$ PM on the universal stage. The average content of anorthite varies between 6 and 14%.

The plagioclase occurs in rectilinear plate-like crystals twinned to the albite law. The most obvious type of alteration is saussuritization, but in same cases

Table 1

Volumetric analyses of the mineralogical composition in *Archean rocks.* Per cent by volume.

	Quartz	Microcline	Plagioclase Se = sericitic Sau = saussuritic	Chlorite	Biotite	Hornblende	Hematite	Sphene, Leucoxene (L)	Epidote-Clinozoizite	Zircon	Apatite	Tourmaline	Calcite	% An ⊥ MP
1 Greenish gray fine-grained granite, Hockla.	35.4	26.0	32.4 Se	5.0	+		1.0[1]	0.2L	+	+	+			8.0 2 determ.
2 Pale reddish medium to fine-grained granite, ½ km N. of Hockla.	35.0	19.0	34.0 Se + Sau	4.2	0.8		0.7	0.6	5.3	0.2	0.2	+		8.5 3 determ.
3 Pale-red medium-grained granite, somewhat porphyritic, ½ km N. of Hockla.	33.6	27.6	28.8 Se + Sau	3.2	1.0		0.3	0.7	4.5	+	0.3			6.0 2 determ.
4 Greenish gray aplitic granite, Hockla.	28.0	40.0	27.0 Se	3.0				1.2L	0.5	0.3	+	+		11.0 2 determ.
*5 Dark grayish green coarse porphyritic granite, strongly crushed, Hockla.	13.6	37.2	27.2 Se	12.0[2]				4.0		+	+		6.0	13.0 1 determ.
6 Grayish white medium-grained granite, crushed, Ulvberget.	44.4	32.4	18.0				+	+	+				5.2	8.5 2 determ.
7 Pale-red medium-grained granite, somewhat porphyritic, Torrbergstjärn.	28.5	37.2	25.5 Se + Sau	2.4			1.2	1.6	3.3	+	0.3			10.0 2 determ.
*8 Pale-red granite, somewhat porphyritic, the top of Gethögen.	20.5	9.4	45.5 Sau + Se	3.5	3.0	1.7	0.3[2]	1.4	14.0	+	0.7			14.0 3 determ.
*9 Grayish white coarse porphyritic granodiorite of part of Ulvberget.	14.5	1.2	51.0 Sau + Se	2.5	12.0	2.8	1.0[3]	2.5	11.5	+	1.0			9.5 2 determ.

[1] Oxidic ore other than hematite. [2] Including pyrite. [3] Pyrite only.

sericitization is quite dominant (see Table I). Often plagioclase enters more abundantly than potassium feldspar, e.g. in the grayish white porphyritic granodiorites from Ulvberget (9).

Potash feldspar enters abundantly partly in the form of microcline-perthite, partly as quadrille structured microcline. It forms large perfectly transparent porphyroblasts at the expense of the plagioclase and is, thus, a mineral of late formation.

In the case of the *quartz* at least two generations can be distinguished, one earlier with crystals enclosing microliths and one later without microliths. The later generation of quartz is restricted to small areas with rectilinear outlines which are bordered by idiomorphic crystals of plagioclase. To this generation belong probably also small drop-shaped inclusions and fillings of fissures of quartz in the porphyroblasts of potassium feldspar. The quartz exhibits undulosity to a large extent.

Biotite is sparse in the granite from Gethögen, but is rather common in Ulvberget. In the other granites examined it occurs only sporadically. 2V is near 0°. It is strongly birefringent and pleochroic; at Gethögen: α colourless–γ olive-brown; Ulvberget: α colourless–γ yellowish brown; Hockla: α light yellow–γ yellowish green. It is usually more or less extensively altered into penninite. The biotite often also includes epidote-clinozoisite together with idiomorphic sphene and crystals of apatite.

Hornblende usually more or less epidotized, is found in small quantities only in a few granites. Hornblende from the granite of Gethögen has the following data: $N_\gamma - N_\alpha = 0.018$ determined $\perp \beta$, $2V_\alpha = 68°$, $c/_\gamma \perp \beta = 15°$. Pleochroism α feebly yellowish green–γ bluish green. For the hornblende from the granodiorite of Ulvberget has been determined: $c/_\gamma \perp \beta = 21°$, $N_\gamma - N_\alpha = 0.019$ and pleochroism yellowish green–green. According to WINCHELL (30, p. 250) the optical data point towards a common hornblende.

Epidote-clinozoisite is found in abundance in Ulvberget and Gethögen (8, 9) (se Table I) forming relatively large crystals in part obviously secondary after hornblende. In this case the pleochroism is colourless–light green and the birefringence $N_\gamma - N_\alpha = 0.028 \perp \beta$, corresponding to an ordinary epidote (WINCHELL, p. 313). It is of late formation and appears as filling between rectilinear flakes of biotite which are transformed into penninite, and also frequently as filling of cracks which cross the other minerals. The saussuritized plagioclase is often entirely filled with fine needles of clinozoisite mixed with sericite. In this case both clinozoisite and sericite have been included with the plagioclase in the planimetric analyses (see Table I).

Sphene is particularly well represented in the porphyritic varieties, often as crystals several millimetres in size; it sometimes includes idiomorphic crystals of apatite.

Other accessories of importance are *pyrite*, *zircon*, and *hematite*. For the qualitative distribution in the granites of the accessory minerals see Fig. 17.

At Hockla a light gray to greenish gray aplitic granite (1, 4) forms the immediate foundation of the basal conglomerate. The same granite enters also abundantly as cobbles both in the conglomerate mentioned and in the conglomerates in the Hede limestone (see Table 10). The texture is xenomorphic and equigranular with grain-sizes 0.25–0.50 and sometimes up to 1 mm ⌀. The quartz occurs generally as drop-shaped inclusions in the microcline. The plagioclase is relatively feebly altered, and then usually sericitized. Otherwise the rock has been subjected to similar alteration as the granites mentioned above.

The petrography of the granites in the region of Hede classifies them as granites of the Rätan type as defined by HÖGBOM 1920 (16, p. 33). A more detailed description of the granites from Rätan and their different varieties is given by VON ECKERMANN (6, pp. 251–264) in the Loos-Hamra region. The modal mineral composition as calculated from numerous chemical analyses agrees very closely with the granites from the Hede region both with regard to the varieties poorer in quartz, intermediate granites and granite aplites. VON ECKERMANN places the formation of the Rätan granite some time between late Svionian and Jotnian and before that of the Rapakivi granite.

Below Getgrottan at Ulvberget a swarm of *dolerite* dykes with a supposed strike towards N. or NE. is found in the granite. The dolerites are dark green and medium- to fine-grained with well preserved ophitic texture. A pidgeonitic pyroxene with low birefringence ($2V_\gamma = 46°$, $c/_\gamma = 40°$) constitutes a matrix between laths of plagioclase of about 1 mm in length. Plenty of reddish brown biotite and ore in rod-like aggregates complete the picture of the rock.

The Hockla basal formation

At Hockla (see p. 329 and Figs. 1 and 2) the basal formation is initiated by a basal conglomerate of several metres thickness. This is characterized by its intensely black colour caused by a considerable amount of graphitic substance distributed partly in very dispersed state in the matrix, and partly in irregular loops and spots. An average sample of the matrix of the conglomerate, analyzed by J. Lukins gave 1.36 % by weight of C $\simeq$ 1.63 % by volume.

Planimetric analyses of the matrix are given in Table 2, only the fraction <3 mm being included.

Table 2

	% by volume					
	Quartz	Feldspar	Fine-grained matrix of chlorite, sericite, and quartz	Graphitic substance	Porphyry fragments	Σ
Hockla	60.0	14.6	16.0	9.0	0.0	99.5
,,	58.0	23.0	12.0	6.5	0.0	99.5
,,	38.0	17.0	43.0	0.5	1.0	99.5

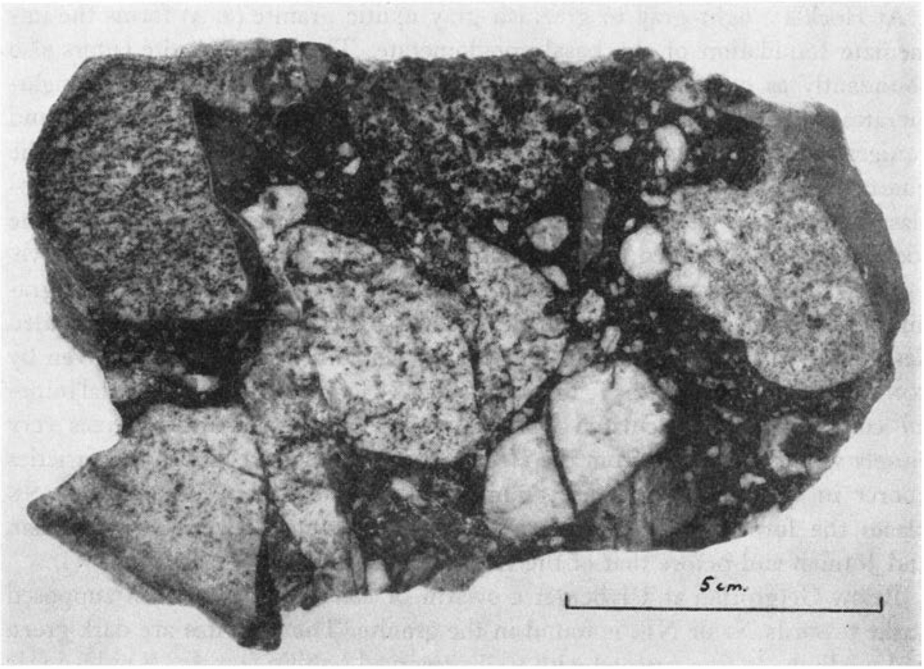


Fig. 14. Basal conglomerate with granite boulders and quartz pebbles from Hockla. Polished surface. Photo N. Hjorth.

Quartz is abundantly represented, partly as larger grains, and partly as cementing medium together with chlorite and sericite. The poor agreement between the chemical and the planimetrical determination of the carbonaceous matter is probably due to the intimate mixing of the coaly substance with fine-grained chlorite-sericite matrix which thereby has become opaque. Minor amounts of titanite, zircon, epidote, and tourmaline have to be added to the values in Table 2.

Amongst the cobbles and pebbles of the conglomerate granite and quartz greatly predominate. Most conspicuous is the quartz with its milky white, small, closely packed and often well rounded pebbles which rarely exceed a diameter of 2.0 cm. In other parts again the quartz grains are altogether angular. The cobbles of granite are well rounded and may attain a size of 10 cm (see Table 3 and Fig. 14). All of them consist of the same types of granites as in the foundation but are usually more altered than the latter (see p. 326).

The next division of the Hockla basal formation (Fig. 1) consists of strongly pressed dark gray silty shale of 3–5 m thickness. The same pressed shales with similar thickness are found also in a zone along the granite sheet at the railway crossing east of Hede (Fig. 13). The shale consists of angular grains of quartz and feldspar <0.06 mm $\varnothing$ in an abundant fine-grained sericitic to chloritic matrix (29, 30). In both localities the shale is pressed and folded by the neigh-

Table 3

Diameter in cm	Number and kind of cobbles and pebbles of the basal conglomerate in different size intervals		
	Granite	Quartz	Porphyry
0.5–1.0	11	17	1
1.0–2.0	13	16	3
2.0–5.0	12	4	1
5.0–10.0	5	0	0
	41	37	5

bouring granite, and disintegrates along numerous fissures and cracks when struck with a hammer. The fissures are cemented by penninite or quartz. The dark colour of the shale is due to a certain content of graphitic substance which has been determined at 0.11 % by weight $\simeq$ 0.13 % by volume.

The shales are overlain by fine-grained grayish green graywacke sandstone, the uppermost member of the Hockla basal formation. This has been noticed at *Hockla* (5–7 m), at *Stavsåsen* (2 m), and at *Vinberget* (5 m). Appearance as well as composition (24, 25, 26, 27, 28) are practically identical in all three localities. Angular, tightly packed grains of quartz and feldspar of 0.1–0.2 mm size are held together by a sericitic-chloritic matrix. Occasionally calcite occurs in amounts of 0–5 %. TÖRNEBOHM (28, Fig. 23) has, in a misleading way, applied two designations to the graywacke sandstone at Hockla terming it partly gray quartzite, and partly gray fine-grained sparagmite. HÖGBOM (14, Fig. 12) on the other hand classified the whole graywacke sandstone including the underlying shale as gray quartzite, and believed the same formation to occur also in the eastern valley in Hockla.

The Hede limestone formation

The Hede limestone formation has been studied previously by A. G. HÖGBOM (14–16), SCHIÖTZ (23), A. E. TÖRNEBOHM (28), G. FRÖDIN (7), A. HADDING (9), and A. STRÖMBERG (25–26). The two last-named authors have given the most detailed petrographic and stratigraphic description. HADDING (9, pp. 158–169) has published a number of sections of the Hede limestone in the region of Hede, in Rråndalen, and at Sörvallen about 4 km SW. of Råndalen, with a petrographic description of the most important members of the formation. STRÖMBERG'S paper (25, pp. 309–316) contains a chemical analysis and a detailed petrographical study of the Hede limestone at Hede.

The tectonic development of the Hede limestone is very variable. In the region of Hockla it is rather moderately folded (p. 303) whereas Stavsåsen exhibits a very pronounced imbrication structure (p. 307). The region of Ulvberget exhibits isoclinal folding as well as imbricate structure.

Below, a compilation of the estimated thickness of the Hede limestone formation at different localities is given.

Vinberget > 2 m	Klockarberget > 2 m
Särvoset > 15 m	W. Husberget > 15 m
Damm > 15 m	Railway–road crossing > 12 m
Stavsåsen > 2 m	The area WNW. of Ulvberget > 30 m
E. Hockla > 7 m	Ulvberget 6–10 m
W. Hockla > 13 m	Furuberget > 10 m

The triangular window of granite in the SW. part of the map has probably been entirely or partly covered by the rocks of the Hockla basal formation and the Hede limestone formation (p. 301). It is possible that the Hede limestone in Råndalen, 10 km S. of the area of the map, may have been directly connected with the same formation in the valley of the Ljusnan in the Hede region. With a length of about 15 km and a breadth of 5–10 km the demonstrable extension of the basin in the Hede area, has, in any case, been considerable.

In the western part of the basin, from Hockla in the S. via Stavsåsen to Vinberget in the N., the sedimentation has been initiated by the deposition of the Hockla basal formation, from the basal conglomerate up to and including the graywacke sandstone. At Ulvberget, however, and at some other neighbouring places, the Hockla basal formation seems to be absent and the Hede limestone has been deposited directly upon the granitic basement. Here, boulders of granite are embedded in the lower part of the limestone formation. Towards the supposedly peripheral region of the limestone basin, as at E. Hockla, Stavsåsen, Vinberget, and Ulvberget, the sediments exhibit decreasing thicknesses. In these localities a certain tendency towards a decreasing content of lime in the sediments can be noticed at the same time as the facial changes between fine-grained and coarse-grained clastic members are more pronounced. At E. Hockla, for instance, calcareous shales and shales free of lime alternate with beds of coarse conglomerate (p. 305).

This lacuna in the series increases still more further to the north and thus, at Torrberget, not only the Hockla basal formation and the Hede limestone formation are lacking, but also the Gray sparagmite formation, and the Red sparagmite rests here directly upon strongly weathered granitic rocks.

As shown by the analyses of Table 4, the rocks of the Hede limestone formation exhibit considerable differences in their mineralogical composition. The content of calcite varies between the extreme values of 0 and 95 %. Of 14 analyses 3 gave values of > 50% calcite, 3 between 30 and 50%, 3 between 10 and 30%, and 5 less than 10%. Pure limestones, according to the nomenclature of PETTIJOHN (22, p. 290), are rare. Silty and clayey limestones and calcareous sandstones dominate.

When the calcite disappears its place is taken by finely distributed pelitic substance of varying sericitic and chloritic composition. In certain cases the fine-grained calcareous and pelitic substance is suppressed and rocks of the size grades of sandstones consisting mainly of quartz and feldspar develop.

The restricted extension of the different members of the formation laterally, and their rapid changes in vertical direction make it hardly possible to establish an univocal stratigraphy. The following stratigraphical main elements can nevertheless be traced:

Top. Light gray arkoses transitional to the Gray sparagmites. Light gray fine-grained calcareous sandstones. Dark gray limestones, argillaceous limestones, calcareous silststones and shales, occasionally with a distinct banding; these rocks are interbedded with layers of calcareous sandstones. Bottom.	Sometimes including intraformational conglomerates.

The lower dark division is the thickest and the most characteristic for the Hede limestone. It occurs in all localities mentioned with the exception of Tällberget and Vinberget. In the last place a calcareous sandstone rests upon the graywacke sandstone of the Hockla basal formation. The banding in the limestone is produced by an alternation between lighter, very fine-grained layers of calcareous sandstone with thicknesses between a millimetre and a centimetre, and layers of darker clayey and calcareous siltstones which are richly intermingled with graphitic substance. (Cf. Hadding, 9, Fig. 71, and Strömberg, 25, Figs. 1–3.)

At the surface of the layers of light calcareous sandstone the calcareous matrix has often been removed by solution, leaving behind a mass of unconsolidated sand. When, later on, this is carried away grooves are formed parallel to these layers which make the banding appear very distinctly upon the weathered surface of the rock.

Apart from the banded members the main mass of the lower calcareous division consists of dark argillaceous limestones and calcareous siltstones. The slightly sandy components in the rocks mentioned above are usually of the size grade 0.06–0.2 mm. In the siltstones the size grade 0.02–0.06 mm is dominating, while the grain-size of the clayey limestones (17, 18, 19, 20, 21) is less than 0.02 mm. Apart from the mentioned members, intercalations of both light and dark calcareous sandstones are found here and there in the shape of beds of some tens of centimetres, and of rapidly thickening lenses. In these the grain-size usually falls between 0.1 and 0.3 mm (12, 13, 14). Secondary growth of the quartz grains makes it difficult to determine the rounding of the grains (Table 4). A few more or less well rounded grains are occasionally to be seen. In one case (15) the rounded material is clearly dominant. The rock in question is poorer in lime and has a larger grain-size than the other calcareous sandstones.

The calcareous sandstones of the upper division are in general light-coloured and sometimes somewhat coarser than those mentioned. Upwards, they pass

Table 4

Volumetric analyses of the mineralogical composition in the rocks from the *Hede limestone formation* and the *Hockla basal formation*. Per cent by volume.

	Quartz	Microcline	Plagioclase	Sericitic substance[1]	Chloritic substance [1]	Biotite	Muscovite	Calcite	Graphitic substance	Pyrite	Oxidic iron	Zircon	Tourmaline	Apatite	Epidote	Porphyry grains	Rutile	Sphene	Predominant grain-size in mm Roundness Crystallinity	Max. grain-size
Arkoses, calcareous sandstones, argillaceous limestones, siltstones.																				
10 Light-gray, medium-grained calcareous arkose with silty layers, Hockla, N. part of the E. valley.	36.8	26.0	17.6	4.8		0.4	+	11.2		0.4				+	+	2.8			0.2–0.5 SA–SR[2]	1.0
11 Light-gray fine-grained arkosite, Hockla, E. valley.	48.6	36.4	6.0	3.8			+	3.2			0.6	+	+	0.4		1.0		+	0.15–25 SA–R(C)	3.0
12 Gray fine-grained calcareous sandstone, Hockla, W. valley.	29.0	17.2	0.8	1.8				48.2		2.6		+	+	0.2	+	+		0.2	0.1–0.2 A–SA	0.5
13 Dark-gray medium-grained calcareous sandstone, Hockla, W. valley.	30.0	18.8	1.2					47.6		1.2		+	+	+		1.2			0.2–0.3 SA–SR	0.5
14 Light-gray fine-grained calcareous sandstone, Hockla, S. part of the W. valley.	33.2	22.8	0.8	3.2				38.4		1.5		+	+	+				+	0.1–0.2 A–SA	0.3
15 Dark-gray medium-grained calcareous sandstone, Hockla, S. part of the W. valley.	32.0	11.2	7.6		21.6			21.2		2.4		+	+			4.0			0.2–0.5 R–WR	1.0
16 Bluish black fine-grained arkosite, Getgrottan, Ulvberget.	48.0	25.5	10.5		4.1			5.0	6.0			0.2		+		+	0.2	0.5	cryst. (SC)	
*17 Dark-gray banded sandy siltstone, Hockla, N. part of the E. valley.	18.0	32.4	1.6	43.0		+				4.6		0.4	+	+			+	+	0.06–0.12 <0.06 A	0.5
*18 Dark-gray banded sandy calcareous siltstone. The base of Ulvberget.	23.0	9.0	2.0	41.0				19.0	6.0			+	+	+			+	+	0.06–0.2 <0.06 A(C)	0.3

19 Dark-gray argillaceous limestone, Hockla, W. valley.	10.2	3.6		29.4		52.0		+	4.8	+					+	+	> 0.02 A(C)	0.15
*20 Dark-gray banded argillaceous limestone, 400 m NNW. of rail-way-road crossing. 2 km E. of Hede church.	12.0	3.0	2.0	22.0		57.0	4.0			+						+	0.06–0.12 < 0.06 A	0.2
21 Dark-gray limestone, Hockla, E. valley.	2.0					95.0	+	3.0		+							< 0.02 A(C	0.3
*22 Grayish black siltstone contain-ing granite fragments. The SE. spur of Ulvberget.	26.0	21.5	9.5	38.0		+		+		+	+	+	+	5.0	+	+	– A(SC)	
*23 Grayish black siltstone contain-ing granite fragments. The SE. spur of Ulvberget.	21.0	28.4	8.0	25.9		2.0			+	+	+	+		4.7		+	– A(SC)	
The Hockla basal formation.																		
Graywacke sandstones and shales.																		
24 Greenish gray fine-grained gray-wacke sandstone, Hockla, W. valley.	45.6	25.8	4.5	20.1	+	3.0			0.2	0.6				+		0.2	0.1–0.2 SA(C)	0.7
25 Grayish green fine-grained gray-wacke sandstone, Hockla, W. valley.	44.4	21.3	3.9	27.7	2.0				0.2	+			+	0.2	+	0.3	0.1–0.2 SA	1.4
26 Greenish gray fine-grained gray-wacke sandstone, Hockla, W. valley.	48.4	27.9	4.1	17.7	0.5	1.0			+	0.2		+		+		0.2	0.1–0.2 SA	0.7
27 Grayish green fine-grained gray-wacke sandstone, Vinberget.	45.0	22.5	4.5	21.5	+	5.0			0.5	0.5						0.5	0.1–0.2 A(C)	0.5
28 Grayish green fine-grained gray-wacke sandstone, W. part of Stavsåsen.	51.5	21.5	6.0	19.0	0.5	0.5			+	0.2			+			0.8	0.1–0.3 A(SC)	1.0
*29 Dark-gray silty shale, Hockla, W. valley.	21.0	6.0	1.0	70 8			+		0.5		+		+		+	0.7	0.02–0.1 < 0.02A(SC)	0.15
*30 Dark-gray silty shale, Hockla, W. valley.	24.0	6.0		67.4			+		0.3	+			1.3			1.0	0.02–0.06 < 0.02A(SC)	0.2

[1] Intimately mixed up with fine-grained quartz.

[2] C = Crushed, SC = Strongly Crushed. A = Angular, SA = Subangular, SR = Subrounded, R = Rounded, WR = Well Rounded.

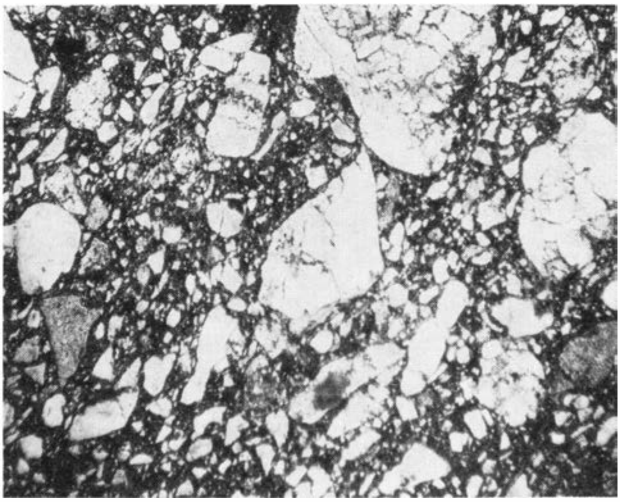


Fig. 15. A sedimentary breccia in the Hede limestone formation at Ulvberget (23). Angular granitic fragments in a sericitic matrix. || nic., 25 ×. Photo N. Hjorth.

into rocks gradually richer in feldspar and poorer in lime, and become finally indistinguishable from the overlying Gray sparagmite formation (10, 11).

An unusual development of the Hede limestone is the bluish black arkosite (16) which appears at two places in Ulvberget (p. 322). It has a quartzitic appearance and contains more than 80% of quartz and feldspar, the clayey substance and the lime amounting together to less than 10%. The dark colour is due to a very high content of graphitic substance arranged in compact loops along the limits of the grains.

At Ulvberget, the basal part of the Hede limestone formation, which here contains boulders of granite and much granitic detritus, is poor in lime but rich in argillaceous material, with the ordinary appearance of boulder clays. But only one kilometre to the west (Fig. 11) the formation is altogether free from such detritus and the sediment, in which the boulders are embedded, is very rich in lime. The usually sharply angular fragments in the siltstone at Ulvberget consist up to about 90% of granite, the remainder consisting mainly of porphyries (Fig. 15).

The partly banded marly sediments with blocks and boulders of granite exhibit many features suggestive of a boulder clay of glacial origin; other mode of formation is, however, not excluded.

It is of interest in this connection that Chr. Oftedahl (20, p. 285) has presented evidences suggestive of a stage of glaciation preceding the deposition of the Biri limestone in Central Norway, the Biri limestone being, most probably, equivalent to the Hede limestone. Thus, two stages of Late Precambrian glaciation may be represented within the Sparagmite series of Central Norway, viz. one earlier and closely connected with the Biri conglomerate, and one later which is the classical Moelv tillite of the Mjösen region. No trace of the latter has been found in the Hede area.

According to STRÖMBERG (25, pp. 310–312) a chemical analysis of an average sample of the Hede limestone gave a ratio between $CaCO_3$ and $MgCO_3$ of 2.6:1, the limestone thus proving to be dolomitic. Magnesium is particularly abundant in the tectonic fissures of some millimetres breadth, filled with white carbonate, which usually vein the rock. Here a supply of magnesium in connection with the latest tectonic activities is supposed. The chemical analysis gave furthermore a content of carbon (C) of 0.86 % by weight. This low figure is the result of the circumstance that also material from the light calcareous sandstones free of carbon had been included. STRÖMBERG (25, p. 311) determined by extraction the content of bitumous oil in the Hede limestone and obtained 0.01 % by weight (Cf. also HÖGBOM, 16, p. 61). The distribution of accessory minerals in the Hede limestone formation is shown in Fig. 17. As only a few planimetric analyses have been carried out on the dominating dark calcareous shales but numerous analyses have been made of the light calcareous sandstones the diagram, Fig. 17, is not quite representative with regard to coaly substance and pyrite which are both extremely common in the dark shales.

The primarily deposited organic substance which is now found in the shape of coaly substance and hydrocarbons together with the obviously secondarily crystallized pyrite, point to a deposition of the dark Hede limestone in stagnant water poor in oxygen. This is in agreement with HADDING's opinion (9, p. 166) that the Hede limestone should have been deposited in lacustrine basins or in cut-off bays of the sea. Simultaneously with an abundant chemical precipitation of lime a very diversified sedimentation of fine clastic, coarse clastic, and conglomeratic members has taken place. As structures suggestive of slumping are of frequent occurrence in the limestone, it can be supposed that the latter was often deposited upon an inclined surface. (Cf. STRÖMBERG, 25.)

It should be mentioned in this connection that the sequence of strata in the section described by A. HADDING from south-eastern Ulvberget (9, p. 160) is Vemdal quartzite–Hede limestone (developed as boulder clay)–Red sparagmite and not Hede limestone–Gray sparagmite–Red sparagmite. Thus Fig. 73 in his paper represents a typical "blue-quartz" like feldspathic, graphite-bearing quartzite of Vemdal type (90), and not a variety of the Hede limestone.

As the coarse conglomerates in the Hede limestone formation and those in the Gray sparagmite formation are very similar, they are being described here together.

Material of cobbles and pebbles: Green porphyries > granites > pale-red porphyries > > quartz > quartzite.

(Locally grayish green granites can be more abundantly represented than green porphyries).

Colour: Light gray to gray to dark gray to greenish gray.

Cement: 1) Clay ≷ calcite (sometimes missing).
2) Quartz.

Rounding: Fairly good, particularly in grains of quartz and larger balls. Poor rounding locally dominant.

Other data: Pyrite almost always present.

The most important localities for conglomerates in the Hede limestone are those at Hockla (p. 305) and Stavsåsen (p. 308).

Gray sparagmite conglomerates occur in several places along the front of Husberget and Säterberget at the crossing between railway and road E. of Hede (p. 37), and at Hockla.

An examination of the material of the balls in hand specimens of the Gray sparagmite conglomerate (about $\frac{2}{3}$ of the material) and conglomerate in the Hede limestone gave the following result, calculated from 50 balls with diameters above 3 cm (see Table 5).

Table 5

Pale grayish green, green, dark green porphyries	Gray, pale red porphyry	Gray, pale green granites	Quartz	Quartzite
60 %	10 %	16 %	8 %	6 %

As appears from Table 5, the rock material consists preponderantly of grayish green porphyries together with smaller amounts of granites, reddish porphyries, quartz, and quartzite. The usual diameter of the balls is 3–6 cm, more rarely 10–25 cm. The largest ones are found mainly in the Gray sparagmite conglomerates which occasionally reach a thickness of several metres. The cobbles and pebbles are usually well rounded and tightly packed with small amount of matrix. The sandy element of the latter is variously, but often well rounded. The approximate composition of the matrix of the conglomerate in the Hede limestone, as far as particles <3 mm are concerned, can be seen in Table 6. In addition to the figures noted the following accessory minerals occur in varying amounts: zircon, titanite, apatite, tourmaline, and rutile.

Table 6

	Quartz	Microcline	Plagioclase	Porphyry fragments	Calcite	Clay	Pyrite	% by volume
Hockla								
Conglomerate 4. E. valley (see p. 305)	45	22	6	10	0.5	15	0.5	99
Conglomerate 3. E. valley (see p. 305)	41	19	6	17	0	15	0.5	98.5
Conglomerate 2. E. valley (see p. 305)	39	15	5	20	10	6	3	99.0
Conglomerate 1. E. valley (see p. 305)	43	14	11	3	18	10	0.5	99.5
Conglomerate. W. valley (se. p. 305)	41	18	2	6	18	12	1	98.0
Stavsåsen								
Conglomerate (see p. 308)	39	27	6	8	15	3	1	99.0

The mineral grains exhibit secondary growth at the edges due to crystallization of quartz in the same way as in the calcareous sandstones. The calcite in the matrix is corrosive with regard to the surrounding minerals, in particular to the plagioclase which usually appears corroded and penetrated by veins of calcite.

The pyrite has crystallized secondarily in idiomorphic cubes. A crystallization of the larger cubes of pyrite by combination of smaller cubes can be observed. The cubes of pyrite are often entirely or partly hydrated and produce dark red reflexes in reflected light due to oxides and hydroxides of iron which thus appear pseudomorphous after pyrite.

The Gray and Red sparagmite formations

The distribution of the Gray sparagmite formation is shown on the map Pl. I. The thickness varies from about 10 m at Hockla to 50–100 m in the long streak which extends from Ulvberget in the east to V. Röstan in the west (see pp. 306 and 322). The formation is not clearly delimited from the subjacent calcareous sandstones but is distinguished from them by gradually decreasing content of lime, increasing content of feldspar, and an increase in grain-size. (Cf. p. 306.) The Hede limestone covers on the whole the same area as the Gray sparagmite formation. In the region W. of Ulvberget, where the limestone is thickest, also the Gray sparagmite reaches its greatest thickness, and in places where the limestone is absent, also the Gray sparagmite is missing.

The appearance of intraformational coarse polymict conglomerates at several levels of the Gray sparagmites have been described in the preceding chapter in connection with the closely allied conglomerates in the Hede limestone.

Upwards the sedimentation becomes increasingly coarser clastic and conglomeratic, and reaches its maximum with the beginning deposition of the Red sparagmite. This starts with a porphyry conglomerate of about 10 m thickness, followed immediately by an alternation of red arkoses and shales. In the places where no Hede limestone and no Gray sparagmites have been deposited, the red conglomerate rests directly upon granite (cf. p. 314). The conglomerate can be traced over a wide area from Hockla via Stavsåsen–Damm–Husberget to Säterberget (see p. 306) and still farther towards NE. to Torrberget. Already prior to the deposition of the red conglomerates a gradual change had taken place in the appearance of the Gray sparagmites.

Thus, locally solitary grains of red feldspar make their appearance in the otherwise grayish green rock which gradually becomes coated with a pink weathering crust about a millimetre thick, and thereby the rock assumes an appearance resembling the Red sparagmite formation. A comparison of the quantitative and qualitative composition and of other features which characterize the Gray sparagmites with those of the Red sparagmites, does not point towards any essential difference in the conditions of sedimentation or in the supply of material of the two formations. The content of feldspar, the ratio between microcline

Table 7 a

Volumetric analyses of the mineralogical composition in rocks from the Sparagmite formations. *Gray Sparagmite formation.* Per cent by volume.

	Quartz	Microcline	Plagioclase (Sericitic)	Sericitic substance	Chloritic substance	Biotite	Muscovite	Hematite	Oxidic ore other than hematite	Pyrite	Calcite	Porphyry grains	Quartzitic grains	Zircon	Sphene	Tourmaline	Epidote	Apatite	Predominant grain-size in mm Roundess Crystallinity	Max. grain-size
Arkoses–arkosites																				
31 Grayish green coarse-grained arkose, Hockla.	36.7	42.9	7.8		8.7					+	1.2	2.7							(SC)	
32 Gray coarse-grained arkose, Hockla, 3.5 km SW. of Hede church.	33.0	38.3	11.6		8.2		0.5		1.4	+	+	6.8		+	0.2	+			0.5–1.0 SR	1.5
33 Light-gray coarse-grained arkosite, Hockla.	50.2	40.6	5.6		0.6				+			2.8			0.2				cryst (SC)	
34 Light-gray coarse-grained arkosite, Hockla.	42.8	31.4	8.8		2.8			+			+	13.0	1.2						0.5–1.0 SR–R	1.7
35 Dark-gray coarse-grained arkose, N. part of Stavsåsen.	39.6	29.2	9.6		4.4	0.4		2.8[1]				14.0		+	+	+			0.5–1.0 R–WR	3.0
36 Dark grayish green fine-grained arkose, Hockla.	42.8	27.4	9.0		18.0		+	+		+		2.4		0.4					0.15–.03 SA–SR	0.4
37 Gray medium-grained arkose, Husberget, 2 km NE. of Hede church.	55.0	31.0	5.0		4.9		+			0.6	2.3	1.0	0.2	+	+	+	+	+	unsort. (C) R–WR	2.5
38 Gray coarse-grained arkosite, 400 m WNW. of railway-road crossing, E. of Hede.	57.0	25.2	8.5		4.0	0.2	0.2			0.2	0.5	2.5		+	1.7				cryst (SC)	
39 Grayish green coarse-grained calcareous arkose, 500 m WNW. of Klockarberget.	54.4	27.6	4.0		6.6				+		5.4	2.0		+				+	0.5–1.0 SR–R	1.5

	Feldspathic quartzites and feldspathic sandstones.																		
40	Gray medium to coarse-grained calcareous sandstone, 800 m WNW. of the habitation of Klockarberget.	56.0	20.0	2.0	+					16.6	3.0	1.8						0.4–0.8 R–WR	2.0
41	Gray medium-grained feldspathic quartzite, 1.6 km WNW. of Ulvberget.	72.0	11.2	3.8	9.2				1.0	2.2	0.6		+		+		+	0.3–0.5 WR(C)	0.7
	Graywacke sandstones, siltstones and shales.																		
*42	Grayish green, very fine-grained graywacke sandstone, W. part of Ulvberget.	41.0	31.0	6.5	19.5		+	0.5					+	1.5	+		+	0.06–0.12 A–SA(C)	0.25
*43	Dark-gray fine-grained graywacke sandstone, Hockla.	36.0	26.8	6.4	24.8	1.2	+	4.8	+				+	+	+	+	+	0.1–0.2 A(C)	0.3
*44	Dark-gray silty, very fine-grained graywacke sandstone, Hockla.	27.6	24.0	6.0	35.6	5.6		1.2					+	+	+	+	+	0.06–0.12 <0.06A(C)	0.3
*45	Dark grayish green, very fine-grained sandy siltstone, Hockla.	21.0	11.0	3.0	49.0	9.0	+	4.0			+		+	2.0	+	1.0	+	0.06–0.15 <0.06A(C)	0.3
*46	Dark gray sandy siltstone, 800 m WNW. of the habitation of Klockarberget.	25.6	21.0	1.2	50.0	+	+	0.6					0.2	1.2			0.2	0.06–0.12 <0.06 A	0.2

[1] Graphitic substance.

Table 7 b

Volumetric analyses of the mineralogical composition in rocks from the Sparagmite formations. *Red Sparagmite formation.* Per cent by volume.

	Quartz	Microcline	Plagioclase (Sericitic)	Sericitic substance	Chloritic substance	Biotite	Muscovite	Hematite	Oxidic ore other than hematite	Pyrite	Calcite	Porphyry grains	Quartzitic grains	Zircon	Sphene	Tourmaline	Epidote	Apatite	Predominant grain-size in mm Roundness Crystallinity	Max. grain-size
Arkoses–arkosites.																				
47 Greenish-gray coarse-grained arkosite spotted with red, 600 m NW. of V. Röstan.	38.0	39.0	16.0		4.0			+		0.3		2.0		+	0.2		0.5		0.5–1.0 SR(C)	2.0
48 Greenish gray very coarse-grained arkose, W. part of Furuberget.	31.5	25.5	25.5		8.5					1.0	1.5	5.5		+	0.8	0.2		+	unsort.	5.0
49 Dark greenish gray coarse-grained arkose spotted with red, Hockla.	37.3	32.3	12.2		8.7			1.2				7.3	1.0	+	+				0.7–1.3 SA–SR(C)	3.0
50 Purple medium-grained arkosite, Hockla.	47.8	28.8	11.4		7.2		+	0.2			1.4	3.0	+	+	0.2			+	0.3–0.5 SR–R	1.0
51 Pale-purple arkosite, Damm at Kvarnån, 1.2 km SE. of Hede church.	44.2	29.2	7.0	4.4				12.0				0.8		0.4	+		2.0	+	cryst (C)	
52 Grayish green medium-grained arkose spotted with red, W. part of Furuberget, 8 km SSW. of Hede church.	54.0	24.0	10.5	1.0				+	+			10.5		+		+		+	0.3–0.5 SR–R	1.0
53 Bluish gray coarse-grained arkosite spotted with red, 1.2 km NW. of Klockarberget.	58.6	31.6	3.6		3.4			0.4				2.0	0.2	0.2					0.5–1.0 R–WR	2.5
54 Purple very fine-grained arkose, 1.2 km N. of Vitån railway crossing NNE. of Ulvberget.	52.6	34.0	1.0	10.2			+	1.4						0.4	0.4	+		+	0.06–0.15 A–SA(C)	0.3
*55 Purple unsorted, very coarse-grained arkose, 2.5 km NNE. of Ulvberget.	58.4	26.4	7.0	4.4				2.0				1.6		0.2	+				unsort. R–WR	7.0

*56 Purple coarse-grained arkosite, pebbly, Särvoset, 4 km WNW. of Hede church on the river Ljusnan.	63.2	29.6	3.0		1.2			0.4			2.6		+	+			+	0.5–1.0 SR–R	
57 Yellowish-green arkose, W. part of Furuberget.	57.0	21.5	10.5	5.0		+	+		+		6.0		+		+		+	0.4–0.6 SA–SR	0.8
Feldspathic quartzites and feldspathic sandstones.																			
58 Pale purple medium-grained feldspathic sandstone, 1 km SW. of Vågbäckstjärn.	63.0	27.4	1.4	7.2				0.6					+	0.4		+	+	0.2–0.4 SR–R(SC)	1.0
59 Grayish purple fine-grained feldspathic sandstone, 400 m W. of Gammelvallen.	62.2	25.4	2.4		7.0						1.0	0.2	+	1.8		+		0.2–0.3 SA–SR(C)	0.7
60 Dark-purple medium-grained feldspathic quartzite, 1 km NW. of Klockarberget.	60.0	22.2	4.8	3.0			+	8.0		0.4	1.6						+	0.2–0.4 WR	0.7
61 Purple fine-grained feldspathic quartzite, 500 m SE. of V. Röstan.	70.2	23.4	3.6	0.4		+	+	1.2			1.0	0.2	+	+				0.2–0.3 WR	1.0
62 Dark purple medium-fine grained feldspathic sandstone, Torrberget, 6 km NNE. of Hede church.	66.2	21.0	4.5		6.5			0.6					0.4	+	+	0.8		0.2–0.3 WR	
63 Light-gray to pale-purple feldspathic quartzite, the middle part of Vitåsen.	74.0	23.4	1.6		1.0			+			+		+	+				0.3–0.6 WR(SC)	1.0
64 Bluish gray medium-grained feldspathic quartzite spotted with red, 1.7 km NW. of Hedeviken.	73.2	22.6	2.2	0.8			+	0.4			0.2	0.6	+					0.3–0.5 R–WR	3.0
65 Pale-purple medium-grained feldspathic quartzite, Torrberget, 5.5 km NNE. of Hede church.	72.6	23.2	0.4	3.2				0.2			0.2		+	0.2	+			0.3–0.5 SR–R(C)	2.0
66 Purple medium-grained feldspathic quartzite, the top of Vitåsen.	74.0	16.0	7.6		1.6			+			0.6		+		0.2			0.3–0.5 WR	0.8

Table 7 b (continued)

	Quartz	Microcline	Plagioclase (sericitic)	Sericitic substance	Chloritic substance	Biotite	Muscovite	Hematite	Oxidic ore other than hematite	Pyrite	Calcite	Porphyry grains	Quartzitic grains	Zircon	Sphene	Tourmaline	Epidote	Apatite	Predominant grain-size in mm Roundness Crystallinity	Max. grain-size
67 Grayish purple medium-grained feldspathic sandstone, 500 m W. of Gammelvallen.	56.8	21.2	1.0	18.8					1.0			0.2	+	0.3	0.7				0.2–0.3 SR–R(SC)	2.0
68 Dark-purple fine-grained calcareous feldspathic sandstone, Stavsåsen, 2 km SSW. of Hede church.	39.6	18.0	4.0		6.6			5.5	+		23.0	2.0		0.3	0.3	+		0.7	0.1–0.2 SA–SR–R	0.4
69 Greenish gray fine-grained feldspathic sandstone, 1 km ESE. of V. Röstan.	70.0	17.2	4.4		6.7	+			0.8	+		0.5			0.2			+	0.2–0.4 R–WR	0.5
70 *Dark-purple silty fine-grained feldspathic sandstone, 1 km ESE. of V. Röstan.	56.0	19.6	2.0	5.2				16.2	+			0.4				+	+	+	0.2–0.3 R–WR <0.06 A	0.8
71 Reddish purple medium-grained feldspathic quartzite. The top of Husberget, 3 km ENE. of Hede church.	73.6	18.2	3.2		4.0			+				0.8		+	0.2		+	+	0.2–0.4 SR–R(C)	1.0
72 Bluish gray medium-grained feldspathic quartzite spotted with red, 700 m NNW. of Klockarberget.	71.0	16.8	4.0		6.4			1.0				0.6		+	0.2	+	+	+	0.2–0.4 R–WR	1.5
73 Purple medium-grained feldspathic quartzite, NE. part of Vitåsen, 7 km W. of Hede church.	78.1	15.5	4.5		1.5			0.2				0.2		+	+			+	0.3–0.5 WR–(C)	1.0

74	Light-gray to white medium-grained feldspathic quartzite, 600 m WNW. of Klockarberget.	78.4	15.8	4.0	0.4				+		1.2		+	0.2	+			0.2–0.4 R–WR	0.7
75	Gray fine-grained feldspathic quartzite, 500 m WNW. of Klockarberget.	69.8	16.2	3.0	10.0			+	0.2	0.4	0.4		+	+		+	+	0.2–0.3 R–WR(C)	0.5
76	Bluish gray medium-grained feldspathic quartzite spotted with red, 2 km NW. of Hedeviken.	77.2	15.6	1.4	4.6	+	+	0.2			0.4	0.6	+				+	0.3–0.5 R–WR(C)	2.0
77	Very pale grayish purple feldspathic quartzite, 2.5 km NNE. of Ulvberget.	83.2	9.6	2.8	4.0			+					+	0.4		+		0.3–0.5 WR(C)	
	Graywacke sandstones, siltstones and shales.																		
*78	Dark-purple sandy siltstone, Damm at Kvarnån, 1.2 km SE. of Hede church.	23.6	32.0	6.8	15.3	+	+	20.5	+		1.6		0.2		+		+	0.06–0.2 <0.06 A	0.5
*79	Dark-purple silty very fine-grained graywacke sandstone, 500 m SE. of V. Röstan.	24.4	28.4	5.2	25.6	+	+	15.2			0.4		+	0.4			0.4	0.06–0.15 <0.06 A	0.3
*80	Dark-purple siltstone, 500 m WNW. of Klockarberget.	34.0	14.0	1.0	29.0	2.0	+	20.0					+					0.02–0.06 A	0.3
*81	Light-green, very fine-grained sandy siltstone, Damm at Kvarnån.	28.0	21.6	5.6	42.4	+			1.2		0.8		0.4				+	0.06–0.12 <0.06 A	0.4
*82	Dark reddish gray siltstone, 800 m WNW. of the habitation of Klockarberget.	27.0	17.0	1.0	51.0	1.0	+	+	1.0				1.0	1.0	+		+	<0.06 A	0.2
*83	Purple silty shale. Damm at Kvarnån.	14.6	21.0	1.0	60.0			2.0					0.2	1.2			+	0.02–0.06 <0.02 A(C)	0.2

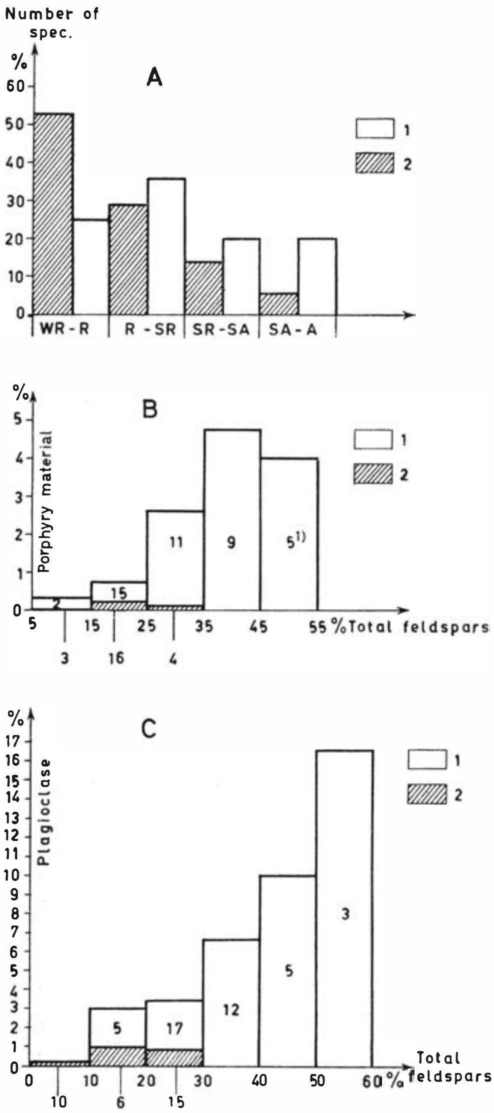


Fig. 16.

1. The Gray and Red sparagmite formations.
2. The Vemdal quartzite formation.

A. A comparison between the most common types of grain-roundness in psammites from 1 and 2. See PETTIJOHN (22) p. 49. The values are taken from Tables 7 and 11. A = Angular, SA = Subangular, SR = Subrounded, R = Rounded, WR = Well rounded.

B. Content of porphyry material plotted against total feldspars in rock-specimens from 1 and 2.

C. Plagioclase plotted against total feldspars in rock-specimens from 1 (42 sp.) and 2 (31 sp.)

[1] Number of rock-specimens included in every interval.

and plagioclase, and the other characters are very similar. (Cf. e.g. 32, 49 and 50). Table 7 shows that the gray coloured varities of arkoses are in general richest in feldspar, irrespective of whether they are referred to the Gray or to the Red sparagmite formation, and that they have at the same time a high content of porphyry fragments. This contradicts the opinion expressed by some authors that the Gray sparagmites should be more strongly weathered than the Red sparagmites, resulting particularly in a low content of the more easily weathered plagioclase feldspar in the Gray sparagmite.

In the sparagmites microcline is the dominating feldspar throughout but in one case plagioclase and microcline occur in equal amounts, viz. in (48) with 25.5 % of each. The histogram, Fig. 16C, shows the ratio between the content of plagioclase and total feldspar in the rocks of the Sparagmite formations (Table 7) as compared with the corresponding rocks of the Vemdal quartzite formation (Table 11). In the Red sparagmite the fragments of porphyry and the grains of feldspar are, as a rule, reddish violet and red, respectively, while in the Gray sparagmites the corresponding colours are more subdued grayish green to gray.

If, on the other hand, the material of the cobbles in the coarse conglomerates in the respective formations is taken into consideration, a comparison of Table 5 with Table 9 shows considerable divergences. In the Red sparagmite conglomerate cobbles and pebbles of red and violet porphyry greatly predominate whereas the conglomerates of the Hede limestone and of the Gray sparagmites contain mainly gray to grayish green porphyries, grayish green granites, and reddish porphyries, in this order. This suggests a certain difference in the composition of the material in the two formations.

The basal parts of the Sparagmite series, including the Gray sparagmites, have probably been formed to a large extent of local detrital products resulting from the weathering of granite hills which rose in the basin of sedimentation. The granitic gravel was then mixed with varying quantities of porphyry material derived from a more distant source region. With the filling up of the basin of sedimentation the supply of local granitic gravel decreased and the share of distal porphyry material augmented.

The differences in appearance of the extreme types of the Red and the Gray sparagmites could also be due to secondary colour phenomena developed in connection with the metamorphosis of the rocks (cf. KULLING, 18, pp. 74–77). The dominant factor which determines the colour in the Red sparagmites is always hematite in one form or another. It occurs either in the form of a finely distributed material exclusively in the feldspars and in the fragments of porphyry as in the red coloured types of arkoses (47, 49, 52, 64, 72, 76), or likewise in the matrix as e.g. in the entirely pink to violet arkoses and feldspathic sandstones in the upper parts of the Red sparagmites (65, 66, etc.). If the hematite appears in the matrix in greater abundance or accumulates into compact loops along the limits of the grains, dark violet varieties can be formed (60, 68, 70).

Out of 53 sparagmites from the Hede region which have been examined planimetrically, 20 can be classified as *arkoses–arkosites* with a content of feldspar $> 30\%$ according to the principles of classification mentioned above (p. 300). A great part of the Gray sparagmites and the lower portions of the Red sparagmites belong to this group. Here coarse-grained rocks are most common with diameters of the grains of 0.5–1.0 mm. Varieties like (36) and (54) occur, however, which approach the graywackes because of abundant matrix, the fine grain, the angularity of the grains etc. The rounding of the grains in arkoses usually falls within the interval SR–R (see Table 7). The quartz often occurs in isometric well rounded grains while both shape and roundness of the feldspar are very variable. This condition is general for rocks both poor and rich in quartz within the sparagmites as well as within the Vemdal quartzites. Fig. 16 A represents the distribution (in %) of psammitic rocks from the Sparagmite formations and the Vemdal quartzite formation within the four grades of roundness of the grains. Within the Vemdal quartzites the rounding is evidently somewhat better than in the sparagmites but the differences are not sufficiently great to permit any definite conclusions, particularly if it is kept in mind how difficult is the choice of a representative material.

Certain arkoses have been subjected to heavy pressure resulting in the crushing of the grains, bent lamellae in the plagioclases, and strong undulosity of the quartz. By recrystallization these rocks have then been transformed into arkosites with quartzitic habitus (33, 51, 38).

In all sparagmites quadrille structured microcline and microcline-perthite enter in about similar amount. The perthite is of varied appearance with dominance of the coarser types. Authigenous potash feldspar is quite frequently filling fissures and veinlets in the sparagmites.

The plagioclase is always more or less extensively sericitized. The high content of plagioclase (cf. p. 346 and Fig. 16 C) of the sparagmites as compared to the Vemdal quartzites is one of the most distinctive characters and suggests a more intense chemical weathering during the time of the deposition of the Vemdal quartzites than earlier. Another conspicuous petrographical difference between the sparagmites and the Vemdal quartzites is the abundance of porphyry material in the former and its scarceness in the latter (Fig. 16 B) due, probably, to different source regions.

The matrix of the gray arkoses consists essentially of a light green chlorite or a mixture of fine-grained quartz and chlorite-sericite in varying proportions (see Table 7). In all the various types of sparagmites chlorite is the predominant mineral in the matrix, whereas sericite dominates in the Vemdal quartzites. Calcite enters occasionally particularly in the matrix of the gray arkoses adjoining the Hede limestone formation.

Fig. 17 shows the distribution of the accessory minerals in the sparagmites and the Vemdal quartzites. Minerals which are practically always missing in the Vemdal quartzites are apatite, epidote, and hematite, whereas titanite and tourmaline are found occasionally. All these minerals are very common in the sparagmites. Zircon, pyrite, and magnetite, on the other hand, occur both in the sparagmites and in the Vemdal quartzites. Graphitic substance is frequently found in the Vemdal quartzites but has been observed in one single instance only in a dark arkose belonging to the sparagmites from Stavsåsen (35). A comparison of Tables 7 and 11 shows that the accessory minerals occur much more abundantly, from the purely quantitative point of view, in the sparagmites than in the Vemdal quartzites. Biotite and muscovite appear very rarely in the sparagmites with the grain-size of sandstones. One kind of biotite exhibits pleoch-

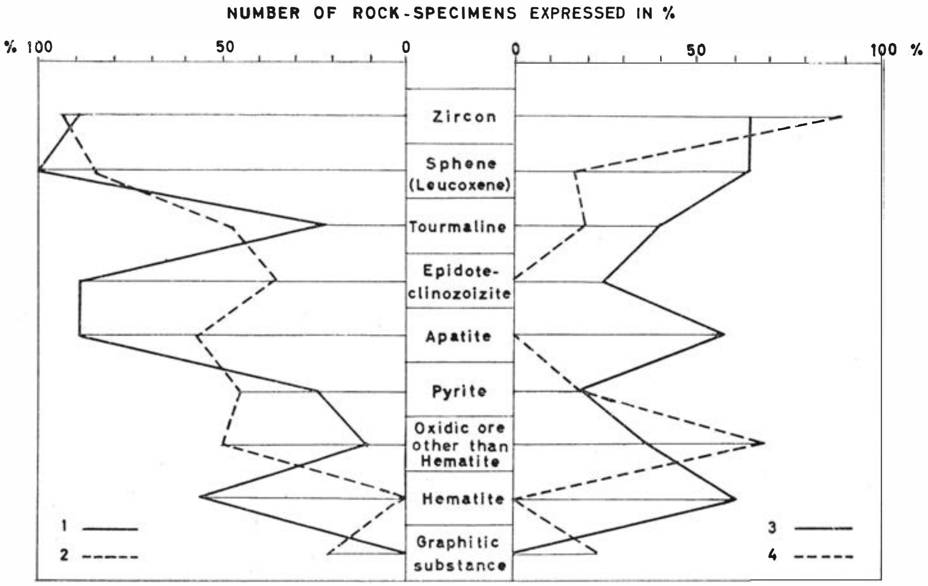


Fig. 17.

1. Archean rocks (9 spec.).
2. The Hede limestone formation (21 spec.).
3. The Gray and Red sparagmite formations (53 spec.).
4. The Vemdal quartzite formation (36 spec.).

These diagrams show the "qualitative" distribution of accessory minerals in rock formations 1, 2, 3 and 4.

roism in light yellow to reddish brown, another in light yellow to yellowish green. These two biotites probably originate from the subjacent granites where similar varieties are encountered. Otherwise the biotite exhibits the same transformation into green penninite in both sparagmites and granites (p. 328).

Out of 53 examined sparagmites 22 fall within the systematic interval *feldspathic sandstones–feldspathic quartzites*. These rocks form the main mass of the Red sparagmite formation in the Hede region and occur in all shades from intensely dark violet to an exceedingly pale grayish violet tint. Occasionally the violet colour element is altogether absent as e.g. in certain light gray to white feldspathic quartzites from the region of Klockarberget and elsewhere (74, 75). Medium-grained rocks with grain-sizes of 0.2–0.4 and 0.3–0.5 mm dominate. Occasionally also fine-grained sandstones can appear (Table 7). The rounding of the grains is usually one step better than in the arkoses, and lies in the interval R–WR. This is, however, subject to several exceptions particularly in the more fine-grained varieties as can be seen in Table 7. Both the well sorted violet feldspathic quartzites (60) and (61) exhibit extremely good rounding of the quartz as well as of the feldspar (Fig. 18). It is thus not possible to consider the sparagmites in general as formed by the rapid accumulation of detrital gravel by running water as has occasionally been asserted. It must on the contrary be

Fig. 18. Well rounded dark purple medium-grained feldspathic quartzite (60) (Red sparagmite). The grains are cemented by quartz and surrounded by a border of hematite. ‖ nic. Photo N. Hjorth.

assumed that prior to deposition an elaborate process of sorting and comminution has taken place.

Apart from the higher content of quartz and the lower content of feldspar in comparison with the arkoses previously mentioned, it is particularly the abundantly occurring hematite which gives its distinguishing character to the group of rocks in question. The hematite is concentrated specially in the matrix of the most fine-grained varieties, e.g. in the dark violet fine-grained feldspathic sandstone (70) with 16 % hematite. A very moderate content of hematite < 1 % is, however, often sufficient to induce the pink violet colouring characteristic of nearly all feldspathic sandstones in Table 7. With regard to the composition of the feldspar, the content of fragments of porphyry, and the accessory minerals, the conditions mentioned above for the arkoses apply also here.

Isolated pebbles of different porphyries and other rocks with diameters up to several centimetres are, however, occasionally encountered particularly among the coarser rocks in the lower parts of the Red sparagmites (56). Such pebbles occur occasionally in great abundance and give then origin to beds of a conglomeratic appearance.

In addition to these pebbles of porphyry the Red sparagmite often contains fragments of green, red, and gray shales varying is size from some millimetres up to ten centimetres. This material has probably been derived from shattered horizons in the shaly levels, partly in the Gray sparagmites (see p. 305), and partly in the lowermost parts of the Red sparagmite, by the erosive action of shifting streams.

Current bedding has been observed in the sparagmites only in a few outcrops as e.g. in the SW. slope of Säterberget where coarse light red arkose with current bedding is intercalated in a sorted dark violet sandstone.

Calcite occurs rarely in the red varieties of sparagmite; it is, thus, found so far only in a fine-grained dark violet calcareous feldspathic sandstone at Stavsåsen (68), occurring together with red shales in a sequence of strata closely above the red conglomerates (see p. 307). In the Gray sparagmites, on the other hand, a cer-

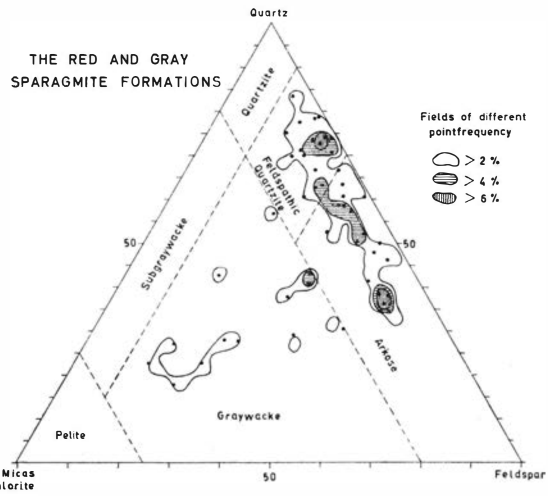


Fig. 19. A somewhat modified classification of rocks based upon mineral composition according to KRYNINE (17) and PETTIJOHN (22) (see p. 300) is shown in this triangular diagram. Fifty volumetric analyses from the Gray and Red sparagmite formations in Table 7 are inserted as points in the diagram. The distribution of the points is easily seen from the fields of different point frequency. No pure quartzites could be established among the rocks of the sparagmite formations although in choosing the analysed material for the above diagram the sparagmitic rocks with expected low content of feldspar have been over- rather than under-represented.

tain content of lime is of common occurrence in the arkoses (see p. 339) as well as in the feldspathic quartzites (41). In the upper parts of the Gray sparagmite at Klockarberget a gray medium- to coarse-grained calcareous sandstone is found (40). The rock consists of well rounded grains of 0.4–0.8 mm ∅ with a matrix of calcite, bordering on either side on fine-grained siltstone.

No pure *quartzites* (< 10 % feldspar) have been found in the Sparagmite series of the Hede region (see Fig. 19) although specially looked for. A great number of sparagmites with quartzite-like appearance has been planimetrically examined. The lowest content of feldspar noted is 12.4 % in a pale grayish violet feldspathic quartzite from Ulvberget (77). Light feldspathic quartzites which very much resemble pure quartzites are found occasionally in the Gray sparagmite formation (41), and in the middle portions of the Red sparagmite (69, 74, 75). Two levels poorer in feldspar have been distinguished also by O. KULLING (18, p. 109) in the Sparagmite series of Västerbotten, one in the lower parts corresponding to the Gray sparagmites, and the other in the middle portions of the sparagmites. From the last named level, KULLING mentions also some pure quartzites which have, however, no counterpart in the sparagmites of the Hede region.

The remaining 11 of the 53 sparagmite rocks examined consist of fine-grained *graywacke sandstones*, *siltstones*, and *shales*, intercalated mainly in the Gray sparagmites and in the lower levels of the Red sparagmites. The thickness of these sediments varies from some centimetres to 4–5 metres. Only dark gray

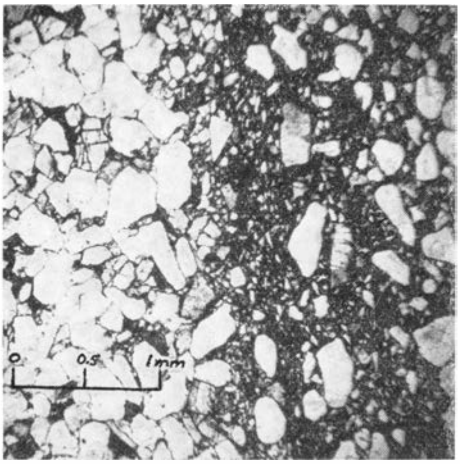


Fig. 20. Sharp contact between hematite-rich and hematite-free sandy siltstone. NW. of Klockarberget. ‖ nic. Photo N. Hjorth.

shales are found in the Gray sparagmites (42, 43, 44, 45, 46), while red shales dominate, with certain exceptions, in the Red sparagmite formation (78, 79, 80, 81, 82, 83).

As a rule, the shales consist of a sandy fraction of 0.06–0.25 mm ⌀ with a variable amount of silty and clayey material (see Table 7). The sand grains are sharply angular throughout. The content of feldspar is usually very high; a considerable part of it consists of plagioclase, as is also the case in the more coarse-grained sparagmites. The clayey material consists of a fine-grained mixture of sericite and chlorite in varying proportions. Biotite enters as flakes some millimetres in size, parallel to the bedding plane. Various degrees of alteration are indicated by the change of the pleochroism: (1) Light yellow–brown, 2) yellowish green–dark brown, 3) colourless–light green. Biotite of similar types is found in the granites of the foundation (p. 328).

Accessory minerals are much more frequent in the fine-grained sediments than in the coarser sparagmites (Table 7). Hematite enters abundantly in the red siltstones and shales and has probably been introduced in the form of iron hydrates during the deposition of the sediment since absolutely sharp contacts exist between red siltstone rich in hematite and light green siltstone free of hematite (Fig. 20). The shaly zones within the sparagmites are well preserved throughout. Only a feeble plastic folding is sometimes to be seen.

In the diagram Fig. 19, the data of Table 7 on the mineral composition of the sparagmites are reproduced graphically. When the amount of accessories is <3 % vol., it has been included with the micaceous minerals; when >3 % it has been deducted from the sum of quartz + feldspar + mica, and the rest recalculated to 100 %. The diagram exhibits two maxima, one for the composition of arkoses (38 % quartz, 53 % feldspar, 9 % mica), the other corresponding to feldspathic sandstones with 73 % quartz, 23 % feldspar, and 4 % mica. The composition of the sparagmites varies within wide limits but none can be classified as quartzites although when selecting rocks for analysis, such with apparently low content of feldspars may have been over-represented rather than under-represented.

Conglomerates associated with the Red sparagmites

The conglomerates in the Red sparagmites are very conspicuous and characteristic on account of their frequently red to violet colours and the polymict nature of their balls. The occurrences at Stavsåsen, Husberget, and Damm at Kvarnån were known to HÖGBOM (14, pp. 140–142). Later HADDING (9, p. 66) gave a detailed description of the conglomerate at Husberget. The distribution of the conglomerate appears from the map Pl. I.

Material of the cobbles and pebbles: Red and violet porphyry > green porphyry > granites > quartz.

Colour: Violet to red or dark green with fragments of violet porphyry and red feldspar, etc.

Cement: 1) Quartz.
2) Clay ≫ calcite.

Rounding: Larger pebbles and cobbles are well rounded. Finer material subangular to subrounded.

Other data: Relatively poor in quartz. Ore minerals mainly hematite.

The elements in the conglomerate are, as a rule, rather large and well rounded with diameters of 5–10 cm, more rarely 10–20 cm. Their distribution is more scattered than in the types of conglomerate mentioned earlier. Most of them consist of violet, light red, and green porphyries together with a smaller number of red granite and quartz. Quartzites of different kinds, arkoses, greenstone, dark brown porphyry, and others constitute less than 1 % of the balls. The numerous red to violet cobbles and pebbles and the intense impregnation with hematite result locally in a vivid red or violet colour of the conglomerate. When the balls are more sparsely distributed and the hematite becomes less abundant, the matrix is dark green with interspersed grains of violet porphyries, red feldspars, granite, etc. The composition of the matrix of the conglomerate, as far as particles <3 mm are concerned, is shown in Table 8.

Table 8

	Quartz	Microcline	Plagioclase	Porphyry fragments	Clay	Calcite	Hematite	% by volume
Dark purple conglomerate, Stavsåsen	31	27	7	20	9	2	3	99
Purple conglomerate Husberget, 1.5 km NNE. of Hede church	35.5	31.0	2.0	21.0	8.5	0.5	1.0	99.5

To the above-mentioned minerals then come minor quantities of zircon, titanite, epidote, etc.

The most marked difference in the composition of the matrix of the above conglomerate compared to the conglomerate of the Hede limestone (p. 338) is the occurrence of hematite instead of pyrite, and the low content of calcite in the former.

Table 9 shows the character of the cobbles and pebbles in the Red sparagmite conglomerate at Stavsåsen and at Damm. At Stavsåsen 100 balls larger than 4 cm have been counted per sq.m, as against 50 at Damm.

Table 9

	Kind of balls (>4 cm) in the Red sparagmite conglomerates Number in %				
	Quartz	Red granites	Light grayish red to red porphyries	Purple to dark purple porphyries	Grayish green, green, dark green porphyries
Stavsåsen (100 balls)	5	30	38	7	20
Damm (50 balls)	4	12	24	42	18

A brief description is given below of the various types of rocks represented in the basal conglomerate and in the Gray and Red sparagmite conglomerates.

Cobbles and pebbles of porphyry

The matrix of the porphyries can be classified into three groups.

1. Microgranitic matrix with grain-size . . . . $>$0.05 mm
2. Fine-grained matrix with grain-size . . . . 0.05–0.01 mm
3. Very fine-grained matrix with grain-size . . . . $<$0.01 mm

Porphyries with fine-grained matrix dominate. Potassium feldspar, plagioclase, and quartz appear usually as phenocrysts.

1. From Gray sparagmite conglomerate, Hockla: *Green porphyry* with very fine-grained felsitic matrix pigmented by sericite. Phenocrysts: microcline-perthite, quartz, and sericitized plagioclase, 1–2 mm, occasionally 3–4 mm ⌀. The quartz occurs in perfectly clear grains with uniform extinction. Certain grains have re-entrant angles, others are of rounded idiomorphic hexangular shape.

Planimetric analysis: quartz 14.4%, microcline 15.2 %, plagioclase (An_4–An_8) 3.2 %, matrix + accessory minerals 65.2 %.

2. *Green porphyry* with fine-grained matrix impregnated with calcite. The phenocrysts, 1–2 mm large, consists almost entirely of microcline-perthite occasionally with patches of albite (An_8) included in or bordering on the phenocryst.

3. Red sparagmite conglomerate, Säterberget: *Light red porphyry* with fine-grained felsitic matrix impregnated with chlorite and hematite. Phenocrysts (usually 1.5–3 mm, occasionally 5 mm ⌀) of microcline-perthite, plagioclase (An_4), and quartz, the latter in the shape of crystals with re-entrant angles.

Planimetric analysis: quartz 9.4%, microcline 17.4%, plagioclase 13.2%, matrix + accessory minerals 60%.

Cobbles and pebbles of granite, quartzite, and arkose

1. *Grayish green aplitic granite* from the basal conglomerate at Hockla (Table 10). Exactly of the same type as the granites of the foundation (cf. 1 and 4, Table 1).

2. *Red coarse-grained granite* from Damm (Table 10), consisting exclusively of quartz, microcline often twinned to the Carlsbad law, and plagioclase. The quartz is bluish gray, markedly banded with undulous extinction; it usually occurs, like the feldspar, as "eyes" a cm in size, consisting of an aggregate of smaller grains. The microcline as well as the plagioclase are coloured pale red by hematitic dust. The plagioclase is common as small patches in the potassium feldspar. This granite much resembles the Swedish Sub-Jotnian granites.

From the Red sparagmite conglomerate in Säterberget the following 3 pebbles are derived (Table 10).

3. *Dark gray fine-grained crystalline quartzite* containing 84% quartz, microcline, and chlorite together with needles probably of sillimanite 0.1 mm long. The quartzite is entirely crystalline with only insignificant loops of chlorite at the boundaries of the grains.

4. *Dark violet fine-grained muscovite-quartzite.* The rock is entirely crystalline with hematite in thin tracks in the boundaries between the grains. Muscovite occurs in abundance (12%) in localized aggregates from which dark red semi-opaque needles of hematite radiate in all directions.

5. *Dark gray medium-grained arkose.* This rock is rather interesting because the arkos contains small pebbles of porphyry with phenocrysts of both microcline-perthite and plagioclase. There exist varieties with either fine-grained or micro-granitic matrix. The mineral grains in the arkose are rounded and well separated from each other by abundant chloritic matrix. The plagioclase is a sericitized albite (An_8).

6. One cobble, a flat disk 14 cm ⌀, was collected in the Red sparagmite conglomerate at Stavsåsen. It is an *ore quartzite* with 36.4% hematite; the quartz grains are well rounded.

Porphyries and quartzites resembling those described above occur e.g. in the Late Pre-Cambrian of the Loos–Hamra region in Hälsingland and also in the Sub-Jotnian series of Dalecarlia. The latter series extends also for some distance across the Norwegian frontier (cf. the sheet Engerdalen, Liter. 13). The source areas of the sparagmite in the Hede region may thus have been situated in the southwest as well as in the south and southeast.

Table 10

Cobbles and pebbles of granite, quartzite, and arkose.

	% by volume					
	1	2	3	4	5	6
Quartz	22.8	55.0	84.0	84.6	51.9	63.0
Microcline	44.0	34.0	4.0	1.0	24.0	0.4
Plagioclase	22.8 (A_{12})	11.0 (An_{15})	–	–	3.3	–
Muscovite	–	–	–	12.0	0.4	–
Sillimanite	–	–	1.2 ?	–	–	–
Chlorite	8.8 + (sericite)	+	9.3	0.9	15.6	0.2
Hematite, Magnetite*	–	+	1.5*	1.2	–	36.4
Sphene	0.8	–	–	–	–	–
Zircon	0.4	–	+	0.3	0.3	–
Tourmaline	–	–	+	+	+	–
Apatite	0.4	–	+	–	+	+
Porphyry fragments	–	–	–	–	4.5	–
Predominant grain-size in mm	–	–	0.2 – 0.3	0.2 – 0.3	0.3 – 0.5	–
Max. grain-size	–	–	0.5	0.5	1.5	–

Summary of the stratigraphy of the Sparagmite series

Red sparagmite formation.	Red arkoses and feldspathic sandstones. Light feldspathic sandstones. Division of arkoses and shales. Red coarse polymict conglomerates (resting in the N. upon granite).	Red and green siltstones and shales.	about 15–200 m
Gray sparagmite formation.	Arkoses and light feldspathic quartzites.	Dark gray to gray siltstones.	about 0–100 m
Hede limestone formation.	Light calcareous sandstones. Dark blue arkosites. Banded calcareous siltstones and shales. Boulder clay (resting in the E. upon granite).	Intraformational conglomerates.	about 0–30 m
Hockla basal formation.	Graywacke sandstone. Dark gray shale. Basal conglomerate (resting in the W. upon granite).		about 0–15 m

The Vemdal quartzite formation

In the form of a huge nappe the rocks of the Vemdal quartzite formation occupy the entire eastern part of the map around Hede (Pl. I). In Vikarberget the thickness of the entire series of strata is roughly estimated at 200–300 m. The composition is as follows:

Uppermost Different light quartzites of various colours. Light gray to light green feldspathic quartzites.	Intercalations of thin beds of sub-graywacke sandstones.
Dark blue to bluish gray feldspathic quartzites and feldspathic sandstones. Dark blue to grayish green quartz conglomerates.	Intercalations of beds of graywacke sandstones, siltstones, and shales.

Feldspathic sandstones – feldspathic quartzites

Out of 36 rocks examined 21 fall within the interval *feldspathic sandstones–feldspathic quartzites.*

Colour: Dark blue, grayish blue, gray, light gray, greenish gray.

Grain-size: Medium-grained 0.2–0.5 mm > coarse-grained 0.5–1.0 mm ⌀.

Rounding: Very variable. SR–R > SA–SR > R–WR.

Cement: Quartz with plenty of sericite.

Other data: Rock often dotted with white spots of weathered feldspar. Pale biotite is common.

The content of feldspar varies from 11 to 28% (see Table 11), plagioclase seldom exceeding 2% (see Fig. 16C). Twinned microcline is somewhat more common than microcline-perthite. The matrix consists mainly of a colourless to dirty yellow sericite and some chlorite. In several cases a pale inhomogenous biotite occurs with $\alpha =$ colourless to dirty light yellow and $\gamma =$ feebly olive brown to brown.

In thin sections it is easily seen how the small bent flakes of biotite have been formed by co-crystallization of the fine-grained sericitic matrix.

The qualitative distribution in the Vemdal quartzite formation of the accessory minerals is seen in Fig. 17 (see also p. 348). In the dark blue feldspathic quartzite graphite occurs abundantly in the joints between the grains (see 84, 89, 90, 91, 104, and others). A chemical analysis of an average sample of these rocks gave 0.31% by weight C $\simeq$ 0.37% by volume C. Fragments of porphyry occur sporadically only, contrasting in this respect to the sparagmites (see Fig. 16B). A grayish white medium-grained feldspathic quartzite from the south-eastern part of Ulvberget contains an unusually great amount of calcite (4.5%). Otherwise calcite is no essential constituent in the Vemdal quartzite formation. Medium-grained and coarse-grained rocks dominate, in this order. The rounding of the grains is very variable, and usually hard to distinguish because of secondary growth.

In a belt from Olberget via Vikarberget to Ulvberget conglomeratic members alternate with coarse, partly gravel-conglomeratic feldspathic sandstones and feldspathic quartzites (84, 94), with an aggregate thickness of several tens of metres. In the region around Ulvberget and SE. of it, conglomerates have been

Table 11

Volumetric analyses of the mineralogical composition of the rocks from the *Vemdal quartzite formation*. Per cent by volyme.

		Quartz	Microcline	Plagioclase	Sericitic substance[1]	Chloritic substance [1]	Pale biotite	Muscovite	Pyrite	Graphitic substance	Oxidic iron	Calcite	Zircon	Tourmaline	Sphene	Quartzitic grains	Porphyry grains	Predominant grain-size in mm Roundness Crystallinity	Max. grain-size
	Feldspathic quartzites and feldspathic sandstones.																		
84	Bluish gray coarse-grained feldspathic quartzite, 1 km N. of Hedeviken, Vikarberget.	62.2	27.6	0.2	5.5		4.0			0.5	+		+			+		0.5–1.0 SR–R[2]	5.0
85	Gray medium-grained feldspathic quartzite. SE. part of Ulvberget.	60.6	25.6	2.2	11.0			+				0.4	+				0.2	0.2–0.4 SR–R	0.8
86	Bluish gray fine-grained feldspathic quartzite, 1 km N. of Olberget.	62.2	24.4	0.6	12.6			0.2					+					0.1–0.3 A–*SA*	0.5
*87	Bluish gray coarse-grained feldspathic quartzite, SE. part of Ulvberget.	68.5	23.0	2.0		6.0			0.5				+					unsort. SA(SC)	
88	Light-gray coarse-grained feldspathic quartzite, 1 km N. of Hedeviken.	71.8	22.8	0.4	4.8		+	0.2			+		+					0.5 –1.0 SR	1.0
89	Dark-blue medium-grained feldspathic sandstone, SE. part of Ulvberget.	62.8	21.6	1.2	12.2		1.0	0.8		0.4			+		+		+	0.2–0.5 *SA*–SR	1.5
90	Dark-blue feldspathic quartzite, 150 m N. of Vitån railway crossing, Ulvberget.	72.6	20.0	2.4		1.6		0.4		3.0								cryst (SC)	
91	Dark bluish gray medium-grained feldspathic quartzite, 3 km NNW. of Hedeviken.	70.8	21.4	0.6	4.4					2.8			+				+	0.4–0.6 R–WR(SC)	3.0

92	Brownish green medium-grained feldspathic sandstone, 2 km NNW. of Hedeviken.	61.6	21.6	0.2	14.2		+	+			0.4		+			1.6	0.4	0.3–0.5 R–WR	2.0
93	Dark grayish blue medium-grained feldspathic quartzite, 2.5 km N. of Hedeviken.	63.0	21.0	+		10.3	2.5	0.4	+	2.6	+						0.2	0.4–0.6 SR–R	3.0
94	Bluish gray coarse-grained feldspathic sandstone, 1.5 km N. of Hedeviken.	63.0	20.6	+	12.4		0.6	+		2.2	+		+		+	+	1.2	0.5–1.0 0.2–0.5 SA–SR	4.0
95	Grayish green medium-grained feldspathic sandstone, Olberget.	64.6	20.2	0.2		13.4	0.5	0.5			0.4		+				0.2	0.2–0.5 A–SA(SC)	2.5
96	Grayish green medium-grained feldspathic sandstone, 2.5 km N. of Hedeviken.	69.4	17.8	2.4	8.2		0.2	0.2			0.2	0.6	+			0.6	0.4	0.3–0.5 SA–SR	1.0
97	Grayish green coarse-grained feldspathic sandstone, 1.5 km E. of Ulvberget.	69.7	20.0	0.2		8.1		+			1.2		+			0.4	0.4	0.6–0.8 SR–R	2.0
98	Dark grayish blue medium-grained feldspathic quartzite, 1 km N. of Olberget.	67.8	19.4	0.6	6.2		0.4	+		2.0		1.8	0.2			1.6	+	0.2–0.5 cryst(C)	2.0
99	Light gray medium-grained feldspathic quartzite, 2.5 km N. of Hedeviken.	72.5	18.0	0.3		7.2		0.3			0.5	1.2	+				+	0.2–0.5 *SR*–R	2.0
*100	Gray medium-grained feldspathic sandstone, SE. part of Ulvberget.	73.0	14.5	2.0	8.0				0.3			1.5	0.2				0.5	0.2–0.4 *SA*–SR	1.2
101	Grayish green medium-grained feldspathic sandstone, 1.5 km N. of Hedeviken.	62.4	15.6	0.2		21.6	+	+			+		+	+			0.2	0.2–0.3 0.5–1.0 SR–R	0.5 1.5
*102	Grayish white medium-grained feldspathic quartzite, SE. part of Ulvberget.	73.5	13.0	2.0		6.5		+	0.5			4.5	+				+	0.2–0.4 SA	1.5

[1] Intimately mixed up with fine-grained quartz.

[2] C = Crushed, SC = Strongly Crushed, A = Angular, SA = Subangular, SR = Subrounded, R = Rounded, WR = Well Rounded.

Table 11 (continued)

	Quartz	Microcline	Plagioclase	Sericitic substance	Chloritic substance	Pale biotite	Muscovite	Pyrite	Graphitic substance	Oxidic iron	Calcite	Zircon	Tourmaline	Sphene	Quartzitic grains	Porphyry grains	Predominant grain-size in mm Roundness Crystallinity	Max. grain-size
*103 Grayish white feldspathic quartzite, 1.2 km N. of Vitån railway crossing, NNE. of Ulvberget.	85.8	12.4	1.2							+	+	0.2		0.2			cryst (SC)	
*104 Grayish blue coarse-grained feldspathic quartzite SE. part of Ulvberget.	85.4	11.0			1.5				3.0			+					cryst (C)	
Quartzites.																		
105 White quartzite, 2.5 km N. of Hedeviken.	91.0	4.2		3.2						1.6		+					cryst (C)	
106 Bluish gray medium-grained quartzite, 2.5 km N. of Hedeviken.	88.4	3.8		7.6						0.2		+					cryst (C)	
107 Bluish gray medium-grained quartzite, 3 km NNW. of Hedeviken.	90.0	0.2			9.8					+		+					0.2–0.3 cryst WR	1.0
108 Greenish yellow quartzite, 1 km SW. of Vågbäckstjärn.	88.4				10.4		+			1.2		+		+			cryst (SC)	
*109 Grayish white quartzite, 400 m W. of Gammelvallen.	89.2				10.4					+		+		0.4			0.1–0.3 cryst (C)	3.0

*110	Pale orange quartzite, 1 km SW. of Vågbäckstjärn.	96.0					4.0					+						cryst (SC)	
111	Greenish white medium-grained quartzite, 3 km NNW. of Hedeviken.	98.4					1.6						+	+				0.3–0.5 cryst WR (C)	1.0
*112	Light-gray medium-grained quartzite, 1 km SSW. of Gammelvallen.	98.0					1.5			0.5				+				0.3–0.5 cryst WR (C)	
*113	Pale-orange quartzite, 3 km NNW. of Hedeviken.	99.5										0.3	0.2					cryst (SC)	
114	Faintly reddish white quartzite, 400 m NW. of Gammelvallen.	99.8					0.2					+	+					cryst (SC)	
	Subgraywacke–graywacke sandstones, shales.																		
*115	Grayish green fine-grained graywacke sandstone, Olberget.	48.0	16.0	2.4		31.6		+	+			1.2	0.4				0.4	0.1–0.2 A(C)	0.5
*116	Gray very fine-grained subgraywacke sandstone, 3 km NNW. of Hedeviken.	50.8	7.6			31.0			6.6			3.0	0.8	0.2		+		0.06–0.01 A(C) 0.2–0.5 R–WR	1.0
*117	Dark-gray very fine-grained subgraywacke sandstone, 3.5 km N. of Hedeviken.	60.0	4.8	0.4			32.8	+	+			1.2	0.8	+				0.06–0.1 A(C)	0.2
*811	Yellowish green medium fine-grained subgraywacke sandstone, 4 km NNW. of Hedeviken.	71.2	2.0	+		26.0		+	0.4	0.7		+	+	+		+		0.3–0.5 Sr–R 0.1–0.3 A–SA	1.0
*119	Dark-gray silty shale, 4 km NNW. of Hedeviken.	12.4	1.6		84.6				+		0.3	0.7	0.2	+	0.2			<0.06 A(SC)	0.1

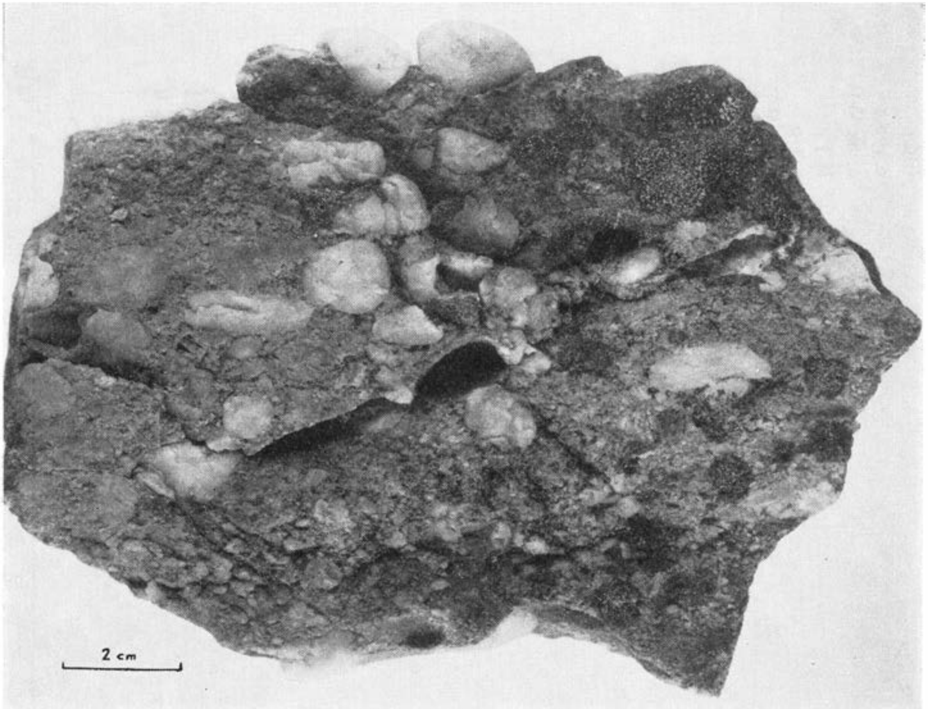


Fig. 21. Quartz conglomerate from the lower part of the Vemdal quartzite formation. Vikarberget, 1 km N. of Hedeviken. Photo N. Hjorth.

described by A. HADDING (9, p. 67). The pebbles consist mainly of milky white quartz; they are well rounded and oval, and usually 1–3 cm ⌀, occasionally as much as 8 cm (Fig. 21). About 15% of the pebbles consist of feldspar and granite of poorer rounding, and in addition a few pebbles of quartzite, shale, and porphyry occur. The conglomerate is variously bluish gray to greenish gray, its matrix being of the same type as in the surrounding feldspathic sandstones. Locally, the mineral grains in the conglomerate are strongly pressed as e.g. at *Olberget* where the sequence of strata is bent into a syncline with a dip of the axis of 50° towards N. 20° W. Along certain streaks the quartz has been flattened out here into longish grains with strong undulosity; the width: length ratio of these grains is 1:10. These conglomerates seem to have been formed along the shores of the wide rather shallow basin in which the Eocambrian quartzites are supposed to have been deposited.

Quartzites

Higher in the formation the feldspathic quartzites gradually pass into *quartzites*. According to PETTIJOHN's nomenclature, the boundary between these two types of rocks has been placed at 10% of feldspar. Out of 36 rocks examined in the Vemdal quartzite formation 10 are quartzites.

Colour: White, grayish blue, yellowish green, and pale pink.

Texture: Crystalline with well rounded grains.

Cement: Quartz with some chlorite.

Other data: Strong tectonic alteration. Thin pure quartz conglomerates of subordinate occurrence.

The quartzites are characterized by a conspicuous siliceous cementation visible macroscopically by the vitreous appearance of the rock. The matrix of fine-grained sericite, which occurs rather abundantly in the feldspathic quartzites, is replaced in the quartzites by thin loops of light green chlorite. Compared with the feldspathic quartzites the grain-size is about the same, whereas the sorting and the rounding of the grains are better. Occasionally, however, certain gravel conglomeratic horizons are encountered with well rounded pebbles of quartz and quartzite up to 1 cm ⌀. These rocks contain no feldspar whatsoever, and differ thereby from the conglomerates in the feldspathic quartzites mentioned above (cf. also HADDING, 9, p. 91).

The feldspathic quartzites as well as the quartzites exhibit signs of a very intense tectonic activity resulting in crushing of the individual mineral grains within certain zones and a subsequent recrystallization. Less vigorous tectonic action has created only thin fissures in the rocks which have been filled later by newly crystallized quartz. In the pure quartzites the tectonic deformations are more conspicuous than in the feldspathic quartzites which usually contain a considerable amount of clayey substance. This latter has given the rock a certain plasticity preventing to some extent the crushing of the harder quartz and feldspar components in the rock.

The most fine-grained members of the Vemdal quartzite formation are represented by *subgraywacke sandstones*, *graywacke sandstones* and *shales*. These rocks appear in repeated banks, intercalated in the more coarse-grained members. The graywacke sandstones (115) and the shales (119) are associated mainly with those members of the Quartzite formation which are richer in feldspar while the subgraywacke sandstones are encountered mainly as thin horizons intercalated in the pure quartzites. The shale zones indicated in the map (Pl. I) consist essentially of shales (119) and graywacke sandstones (115) with thicknesses of 5–10 metres.

The graywacke sandstones are characterized by a relatively high content of feldspar while that of the subgraywacke sandstones does not surpass 10%. For comparison may be mentioned that the fine-grained sediments within the sparagmites rarely contain less than 30% feldspar (see Table 7).

In addition to the chlorite-mica-matrix the subgraywacke sandstones (116) and (118) contain a fraction of coarser grains of 0.2–0.5 mm ⌀ with good rounding, and a finer fraction with altogether angular grains. Both in their external appearance and in thin sections the subgraywacke sandstones reveal themselves as a facies somehow intermediate between psammitic rocks and shales.

The planimetric analyses of the rocks of the Vemdal quartzite formation have

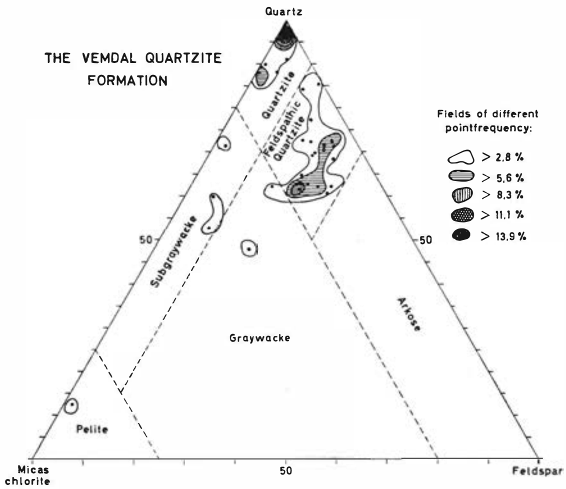


Fig. 22. Analogous to Fig. 19, 36 volumetric mineral analyses in Table 11 from the Vemdal quartzite formation have been inserted as points in a tringular diagram. The distribution of the points is easily seen from the fields of different point frequency. With the definite intention to demonstrate, if possible, the occurrence of varieties rich in feldspar among the rocks of the Vemdal quartzite formation these have in a certain way been over-represented in the choice of the material. No arkoses according to the definition used here could, however, be detected. The above-mentioned procedure in the choice of the analysed material (cf. expl. of Fig. 19) affords, on comparison of Figs. 19 and 22, a good idea of the smallest difference imaginable in the mineral composition between the rocks of the Sparagmite formations and the Vemdal quartzite formation, respectively.

been entered into a triangular diagram (Fig. 22) with quartz, feldspar, and mica in the corners according to the principles which have been applied to the sparagmites above (cf. p. 352). The mineralogical composition differs from that of the sparagmites as can be seen from a comparison of Figs. 19 and 22. The diagram exhibits two maxima, one for the composition of quartzites (90% quartz, 5% feldspar, 5% mica), the other corresponding to feldspathic quartzite with 62% quartz, 22% feldspar, and 16% mica. Thus no arkoses according to the definition used here have been encountered within the Vemdal quartzites, although when selecting rocks for analysis, such with apparently high content of feldspars may have been over-represented rather than under-represented. The Ström quartzites of Jämtland which are equivalent to the Vemdal quartzites contain coarse arkoses rich in feldspar in their basal portions, locally in primary contact with their granitic fundament. The absence of basal arkose in the Vemdal quartzite nappe in the Hede region may be due to the thrusting. The thick zones of shales and graywacke sandstones are all strongly influenced tectonically, especially so the soft shales. They are usually completely crushed and, when struck with the hammer, fall to pieces along concoidal fractures. Within the Sparagmite series, only the basal shales at Hockla, and at one or two other places (p. 324) have been tectonized in a similar manner. Here, the upward and forward movement of the adjacent granite has caused the strong compression of the shales. But such tectonics are not applicable to the Vemdal quartzite. The considerable difference in the intensity of the deformation of rocks in the Sparagmite series and in the Vemdal quartzite formation, particularly the siltstones and shales, suggests that the Vemdal quartzites represent a tectonic unit independent of the Sparagmites, belonging to the allochthonous Vemdal quartzite in the SE. and in the E. represented by the region of Sonfjället and Vemdalen.

In the Ström quartzite nappe in northern Jämtland, which rests discordantly upon Cambro-Silurian sediments for tens of kilometres (cf. B. Asklund and P. Thorslund, 2 a), shaly zones are found of exactly similar development and with the same kind of deformation as has affected the shales of the Vemdal quartzites.

The tectonics at Ulvberget and at the boundary between quartzite and sparagmite in north-north-eastern direction up to Hammarberget suggest the following development of the whole region.

1. The quartzite nappe was thrust over a complex of rocks consisting of granites, porphyries, Cambro-Silurian rocks, etc.

2. The forces which thrust the quartzite nappe did not cease to act with the termination of step 1; in the more deep-seated parts of the sparagmite and the granite foundation they were still active. A great number of gently inclined wedges of the granitic fundament gradually carried the rocks of the overlying Sparagmite series forwards and upwards. These we now find thrust over the allochthonous quartzites in the E. The faulting, shown in the map (Pl. I), is supposed to have taken place in connection with this process or perhaps somewhat later. Thus, the principal features of the present distribution of the rocks in the region were established.

Comparison between the Development of the Sparagmite Series in Härjedalen and in Southern Norway

The general stratigraphic development of the Sparagmite Series in Härjedalen agrees in many respects with that of the classical sections in the Mjösa region in eastern middle Norway, as is apparent by the comparison below.

As reference horizon may be taken the Biri limestone formation the correlation of which with the Hede limestone can hardly be doubted, although the former attains much greater thickness. Both exhibit remarkable lithological analogies such as rhythmical banding and local boulder clay facies. The basin in which the Hede limestone was deposited seems not to have constituted a direct easternly extension of the Biri basin, but to have formed a more or less confined local basin which, however, must have been of considerable size.

A conspicuous feature of the Hockla basal formation underlying the Hede limestone is the appearence of carbonaceous matter abundantly in the matrix of the basal conglomerate, a remarkable fact considering the sparseness of this

Table 12

	Mjösa region		Hede region		
Eocambrian Quartzite formation	Ringsaker quartzite. Vardal sparagmite.	500 m	Allochthonous Vemdal quartzite nappe.	Quartzite. Feldspathic quartzite.	300 m
Sparagmite series	Ekre shale.	40 m	Not observed.		
	Moelv tillite.	20 m?	Not observed.		
	Moelv sparagmite.	300 m?	Red sparagmite. Gray sparagmite.		300 m
	Biri limestone, partly developed as boulder clay.	100 m?	Hede limestone, partly developed as boulder clay.		30 m
	Biri conglomerate. Bröttum sparagmite.	75 m 500 m?	Hockla basal formation.		15 m

element higher in the Sparagmite series. A similar enrichment of coal is found also in the dark Bröttum sparagmite which appears below the Biri limestone formation in the Mjösa region.

The enrichment of coal in the Hockla basal formation in the Hede region combined with a similar stratigraphical position, are weighty arguments in favour of a correlation of the latter formation as more or less homotaxial with the Bröttum sparagmite. Its inconsiderable development in the Hede region, mainly in conglomeratic facies resting upon the Archean fundament, is evidence of the rather diversified topography prevailing at that time. The magnitude of the relief is further demonstrated in the more northerly parts of the region where also the Hede limestone is absent and the Red sparagmite rests upon deeply weathered granitic rocks (p. 314). Similar conditions have been recorded in the region of Femunden by G. HOLMSEN (10). This demonstrates in a convincing way the limited extension of the formations which occur below the Red sparagmite formation.

Transitional between the Hede limestone and the Red sparagmite appears in the Hede region the rather thick Gray sparagmite. No corresponding member has been distinguished in eastern Norway. The Red sparagmite of the Hede region can be traced with only minor interruptions from our region into eastern Norway and thus its correlation with the red Moelv sparagmite is firmly established.

The Red sparagmite constitutes the uppermost preserved member of the parautochthonous sequence in our region. Thus, the tillite-bearing beds which follow the Red sparagmites in eastern Norway and in northern Jämtland, have not been found in any of the sections studied in Härjedalen, probably because of the higher parts of the sequence being removed by denudation.

The Eocambrian Vemdal quartzite nappe, which is thrust over the parautochthonous series, represents the uppermost part of the sedimentary sequence in the Caledonian sparagmite basin in the west. In this nappe we have distinguished a lower division of quartzite rich in feldspar, and an upper one of pure quartzite in which feldspars are sparse. These may correspond to the Vardal sparagmite and the Ringsaker quartzite respectively of the Mjösa region. (Cf. T. VOGT, 29, pp. 314–316.)

Acknowledgements

The field work in the Hede district has been financed by contributions from the funds for field research of the Faculty of Natural Sciences of Upsala and, during parts of the summer of 1954, by a grant from the Geological Survey of Sweden. For the latter I beg to express my obligation particularly to the Director General, Professor N. H. MAGNUSSON, and Govt. Geologist Dr. B. ASKLUND.

The examination of the collected material has been carried out at the Institute of Mineralogy and Geology of Upsala, and I take great pleasure to express my sincerest thanks to its head, Professor ERIK NORIN, for the valuable assistance by advice and references during the progress of the work, and to Professor NORIN and Professor P. THORSLUND for the final examination of the manuscript.

I also wish to thank DR. N. MARKLUND and DR. A. STRÖMBERG for their contributions, partly in the form of material placed at my disposal, and partly in the form of stimulating discussions.

The translation of the manuscript is by Professor O. ZDANSKY. Preparator O. WALLNER has prepared the thin sections, amounting to over two hundred, which were needed for the work. Mr. N. HJORTH has prepared some of the illustrations. To all of them I express my sincerest thanks.

References

Abbreviations:

G.F.F. = Geologiska Föreningens Förhandlingar, Stockholm.
S.G.U. = Sveriges Geologiska Undersökning, Stockholm.
N.G.T. = Norsk Geologisk Tidsskrift, Oslo.
N.G.U. = Norges Geologiska Undersökelse, Oslo.

1. ASKLUND, B., 1933: Vemdalskvartsitens ålder. *S.G.U.* Ser. C, no. 377.

2 a. ASKLUND, B. and THORSLUND, P., 1935 a: Fjällkedjerandens bergbyggnad i norra Jämtland och Ångermanland. *S.G.U.* Ser. C, No. 382.

2 b. ASKLUND, B., 1935 b: Stratigrafien inom södra Lapplands kvartsit-sparagmitbildningar. *S.G.U.* Ser. C, No. 387.

3. —— 1954: Review. Nyare tektonisk-stratigrafiska studier inom den centrala fjällkedjan. *G.F.F.*, Vol. 76.

4. DAHLLÖF, T., 1952: En enkel förbättring av korsbordet. *G.F.F.*, Vol. 74.

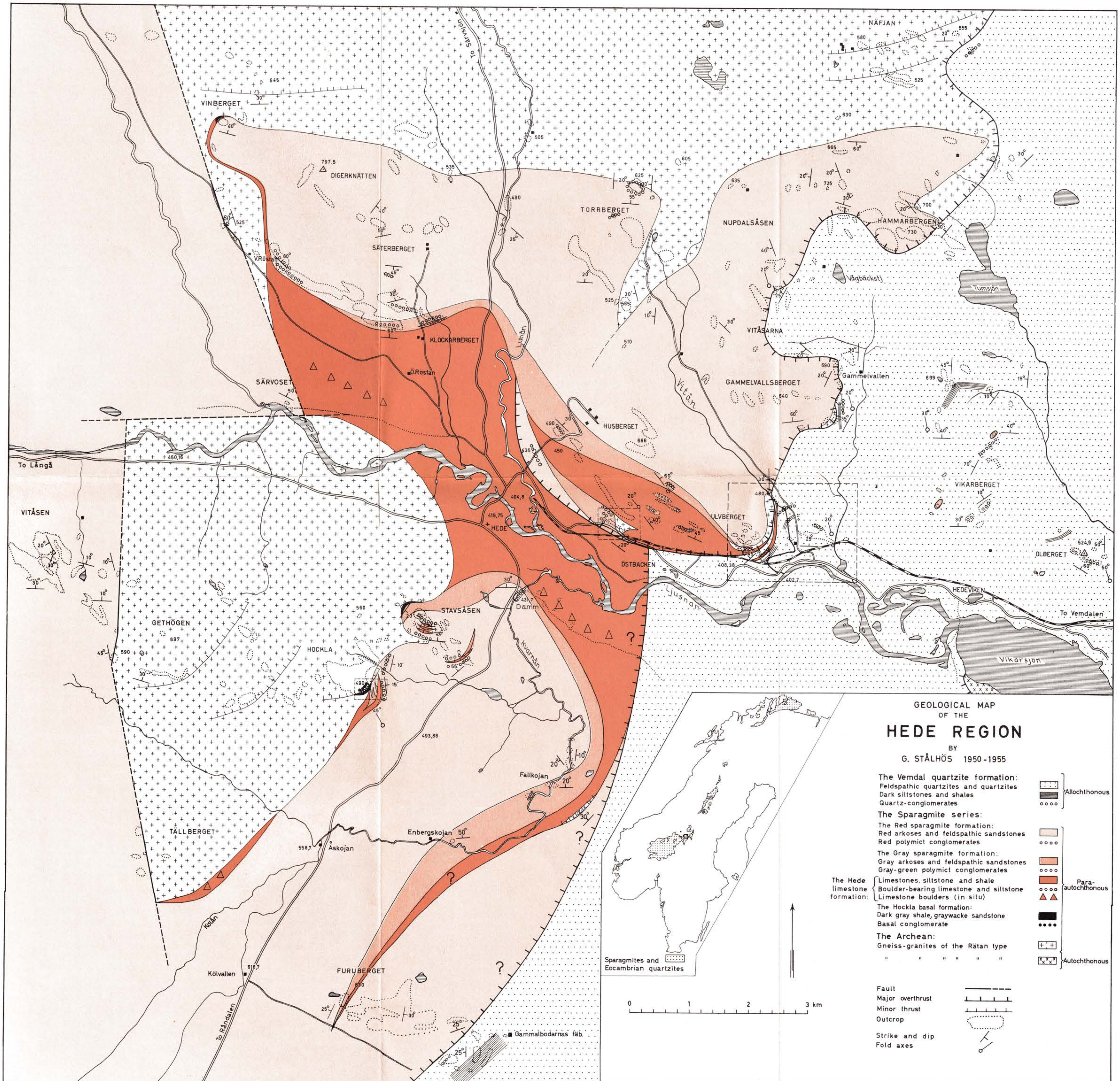
5. DU RIETZ, T., 1943: Kvartsitskollorna i Ormsjö-Tåsjötrakten. *S.G.U.* Ser. C, No. 448.

6. VON ECKERMANN, H., 1936: The Loos-Hamra region. *Med. fr. Sthlms Hög. Miner. Inst.*, No. 58.

7. FRÖDIN, G., 1920: Om de s.k. prekambriska kvartsit-sparagmitformationerna i Sveriges sydliga fjälltrakter. *S.G.U.* Ser. C, No. 299.

8. GRIP, E., 1941: Der Strömsquarzit im nördlichen Jämtland und seine Tektonik. *G.F.F.*, Vol. 63.

9. HADDING, A., 1927: The pre-Quaternary sedimentary rocks of Sweden, part I (pp. 66–71, 90–92), part III (pp. 151–171, 260–274). *Medd. fr. Lunds Geol.-miner. inst.*
10. HOLMSEN, G., 1937: Søndre Femund, beskrivelse til det geologiske rektangelkart. *N.G.U.*, No. 148 (pp. 8–24).
11. HOLMSEN, P., 1943: Geologiske og petrografiske undersøkelser i området Tynset-Femunden. *N.G.U.*, No. 158.
12. —— 1954: Review. Om morenekonglomeratet i sparagmittformasjonen i det sydlige Norge. *G.F.F.*, Vol. 76.
13. HOLTEDAHL, O., 1921: Engerdalen, fjeldbygningen inden rektangelkartet Engerdalens omraade. *N.G.U.*, No. 89.
14. HÖGBOM, A. G., 1889: Om kvartsit-sparagmitområdet mellan Storsjön i Jämtland och Riksgränsen söder om Rogen. *G.F.F.*, Vol. 11, pp. 123–170.
15. —— 1891: Om kvartsit-sparagmitområdet i Sveriges sydliga fjälltrakter. *G.F.F.*, Vol. 13.
16. —— 1894 and 1920: Geologisk beskrivning över Jämtlands län. *S.G.U.* Ser. C, No. 140. 1st and 2nd edition 1894 and 1920.
17. KRYNINE, P. D., 1948: The megascopic study and field classification of sedimentary rocks. *Journ. of Geol.*, Vol. 56.
18. KULLING, O., 1942: Grunddragen av fjällkedjerandens bergbyggnad inom Västerbottens län. *S.G.U.* Ser. C, No. 445.
19. MARKLUND, N., 1954: Review: "Sparagmitformationen" i södra Norrbotten. *G.F.F.*, Vol. 76, p. 124.
20. OFTEDAHL, CHR., 1945: Om tillitene i det central-norske sparagmiteområde. *N.G.T.*, Vol. 25, pp. 285–293.
21. —— 1948: Skyvedekker i det centrale Norges sparagmittformasjon. *N.G.T.*, Vol. 27.
22. PETTIJOHN, F. J., 1949: Sedimentary Rocks.
23. SCHIÖTZ, O. E., 1882: Sparagmit-kvarts-fjeldet i den östlige del af Hamar Stift. *Nyt Mag. for Naturvidenskaberne*, Vol. 27, Oslo.
24. SKJESETH, S., 1954: Review. Forholdet mellom Oslofeltets Kambro-silur og Sparagmittformasjonen (Kvartssandsteins-dekket og Sparagmitt-dekket). *G.F.F.*, Vol. 76, pp. 145–153.
25. STRÖMBERG, A., 1952: Om Hedekalken. *G.F.F.*, Vol. 74.
26. —— 1955: Zum Gebirgsbau der Skanden im mittleren Härjedalen. *Bull. of the Geol. Instit. of Upsala*, Vol. 35.
27. SVENONIUS, FR., 1881: Till frågan om förhållandet mellan "Wemdalsqvartsiten" och den siluriska formationen inom södra delen av Jemtlands län. *Öfversigt af Kongl. Vet. Ak. Förhandl.*, No. 10, Stockholm.
28. TÖRNEBOM, A. E., 1896: Grunddragen av det centrala Skandinaviens bergbyggnad. *Kongl. Sv. Vet. Ak. Handl.*, Vol. 28, No. 5, Stockholm.
29. VOGT, T., 1924: Forholdet mellem sparagmitsystemet og det marine underkambrium ved Mjøsen. *N.G.T.*, Vol. 7.
30. WINCHELL, A., 1947: Elements of Optical Mineralogy. Third edition.
31. ZENZÉN, N., 1932: Nya geologiska notiser från Idre. *G.F.F.*, Vol. 54, pp. 533–534.



Drawn by E.T.Marinello & B. Tuçan 1956