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THE GEOLOGY OF THE SVARTVATNET AREA,
LØKKEN, NORWAY.

DAVID H. BLAKE.

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THE GEOLOGY OF THE SVARTVATNET AREA.

David Blake,
Imperial College, London.
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Svartvatnet.

Looking northwards, with Svartvatnet Farm and the ridge of Svartvassaasen N in the middle distance.
Høidal Hill in the left background.

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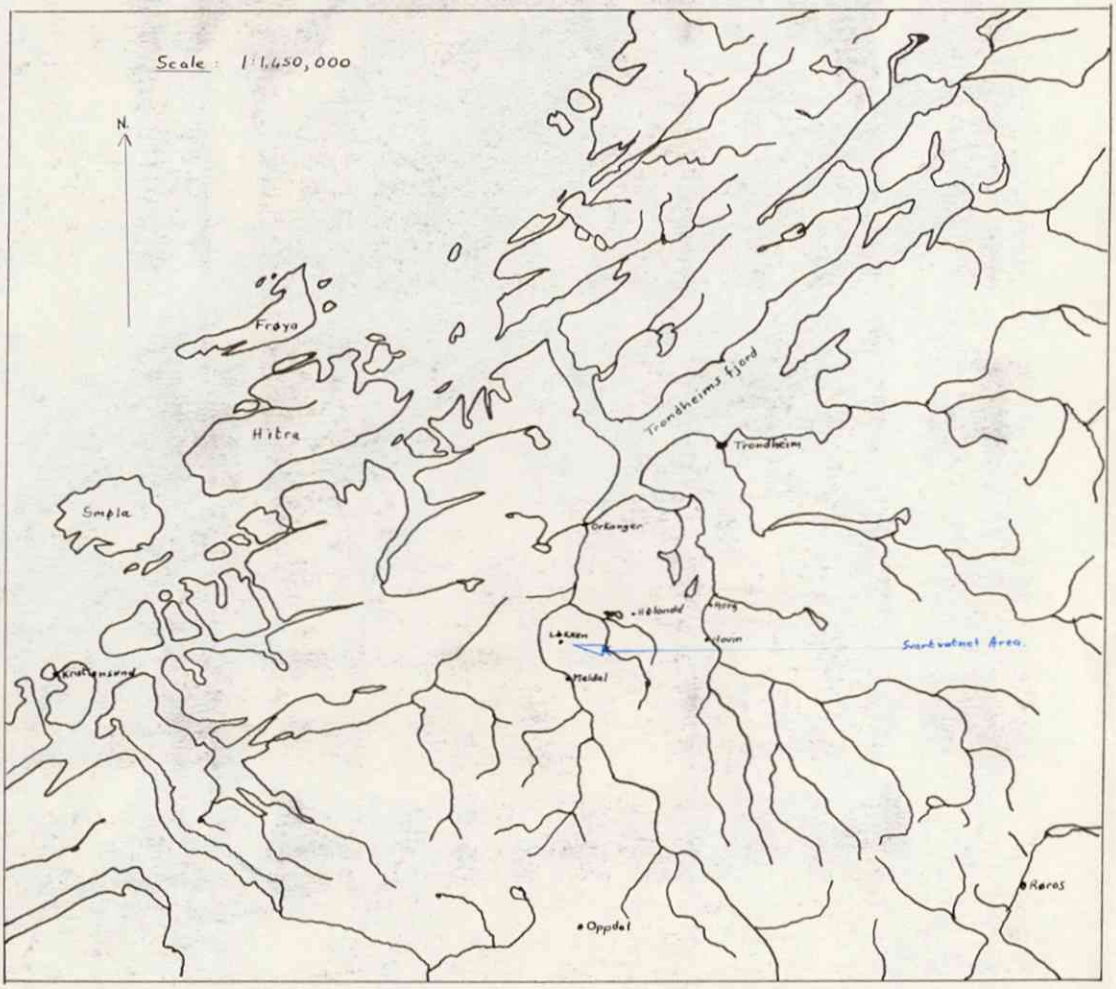


Sketch Map showing the relative position of the Svartvatnet Area.

INTRODUCTION

The area mapped during the summer of 1960 lies 8K E.S.E. of the Mining Town of Løkken, Løkken being 51K S.W. of Trondheim, in the central part of Norway. In the centre of this area is the Lake Svartvatnet and the region covered by the accompanying geological map is here called the Svartvatnet Area.

The purpose of the mapping was to work out the detailed structure and stratigraphy of the Hovin Series, a predominently sedimentary group of rocks which here form a westward-pointing V-shaped outcrop bounded on the north and south by the Støren Series. To the north of the northern Støren outcrop is another Hovin outcrop which forms a narrow east-west trough of sediments again bounded by the Støren Series. This trough has been mapped by Brian Chadwick. Previously to this summer the Hovin Series in this area was practically unknown geologically, and it was hoped that we would be able to link it up with the Hølonda-Horg district by T.Vogt, whose results were published in 1945 (Norsk geologisk Tidsskrift 25, pp. 449-527). Seven weeks were spent in the field during which time some 25 square Kilometres were mapped.

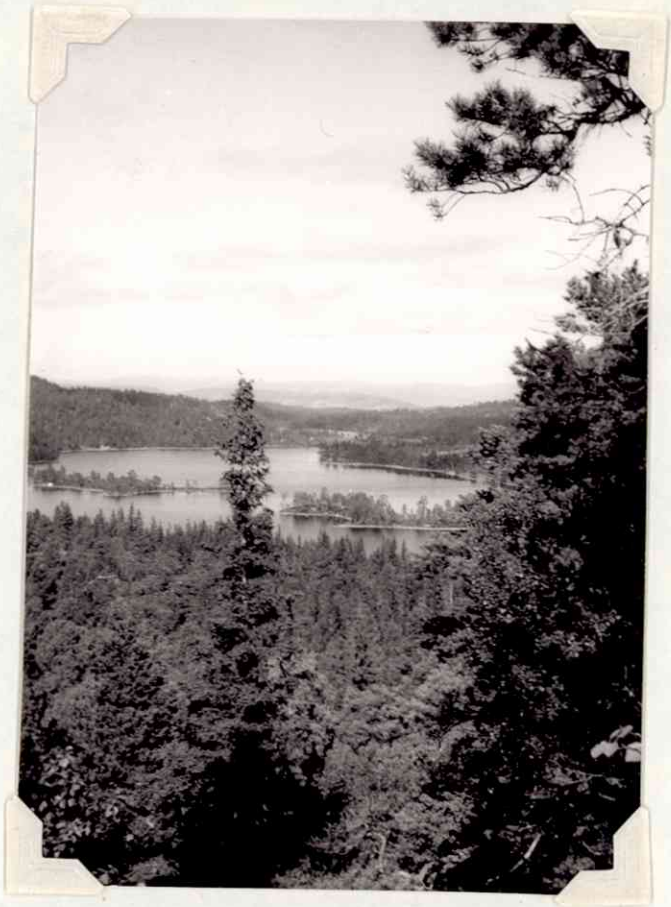
In the field the mapping was carried out on a scale of 1:10,000 approx. No official maps of this scale exist for this area, and so a map had to be drawn from a mosaic of aerial photographs of this scale very kindly provided by the Orkla Grube Mining Company of Løkken. The resulting map was somewhat inaccurate because of the distortion within the aerial photographs and the lack of any strict ground control; also the position of True North on the map was not constant. The magnetic variation in the area is apparently unknown, so all the dip and strike measurements are measured in respect to magnetic north only. The geological map accompanying this report has been largely re-drawn, still using the aerial photographs but using as a base the map "Kart Over Statsskofer Til Svorka-Trivja Fra Gravrok Til Grutseter", a copy of which was again kindly provided by the Mining Company at Løkken. With the improved ground control the final map should be rather more accurate.

Brian Chadwick and myself stayed at the farm at Fieldheim whilst in the field thanks to the kind hospitality of Mr. C. Smith and the Skjevdal family. I also wish to take this opportunity of thanking Mr. Per. Sandvick, of the Orkla Grube Mining Company, who gave us every possible assistance during our stay in Norway. Further help and hospitality was given us by Mr. Thams, of Storbuan, and Mr. E. Sagvold, the geologist at the Løkken Mine.

Within the general Svartvatnet Area there are a number of small farms, some of which are now deserted. These provide the only sites of settlement except for around the banks of Frilsjøen, where recently many houses have been built as week-end retreats. Hay is the chief crop on the farms, whilst lumber is the chief natural resource of the area.

The weather whilst in the field was surprisingly good, with plenty of hot sunshine as well as the more normal damper weather. Wet weather did not hold up the mapping because staying at the farm meant that clothes could be dried over-night. Flies were a nuisance during the month of July, but the onset of cooler nights saw a much reduced activity on their part. Numerous adders were seen whilst in the field providing considerable excitement at times. No elks were seen, unfortunately, though various signs indicated their presence in the area.

The relief within the area varies from less than 300m. above sea level, west of Frilsjøen, to over 700m. on Grefstadfjeldet south-east of Frilsjøen. The general topography suggests a "grooved peneplain", with interrupted east-west ridges rising up to 100m. above lowland troughs. The troughs form the sites of the various lakes in the area. These include Prestøbuvatnet, Storbuvatnet, Svartvatnet, Frilsjøen and Rauaatj. The main rivers of the area flow northwards, cutting across the east-west grain of the country, the Bogo and the Rauaaa Rivers flowing northwards into Prestøbuvatnet, which itself drains eastwards, via Storbuvatnet,



Prestbuvatnet.
Looking eastwards.

into the River Trivja, which forms part of the eastern boundary of the area mapped. Frilsjøen drains to the west and is served by streams flowing northwards of the greenstone hills of Grefstadfjeldet and Graahammeren to the south.

The hills are forested, except on the higher ground, as on Grefstadfjeldet, whilst much of the lower area, other than those occupied by lakes, are covered by marshes and peat bogs. Because of the vegetation cover the percentage outcrop is generally as low as 1%, the outcrops that do exist usually covering only small areas. However a sufficient number of small outcrops exist throughout the area to enable one to get a general picture of the geology, even if the relationships of the different rock types are often obscured. On wooded hills fallen trees provide many good exposures, under their roots, and near-vertical slopes are usually only moss-covered. Outcrops can be found on the tops of most of the hills, and the numerous streams and rivers frequently provide some good exposures. Even many of the peat bogs are not devoid of outcrop, as many small moss-covered rock mounds occur within the peat.

Typical Peat Bog.
N. of Blomli

Heath - Land.
N. of Blomli

SYNOPSIS OF GEOLOGY

A great variety of rock types were found in the area. The correlation of these rock types provides a major problem, because of the observed existence of numerous faults and the probability of many others not visible, and also, of course, the lack of extensive exposures.

The whole region has been affected by the Caledonian Orogeny, though here the rocks show few signs of metamorphism, contrasting strongly with areas further west. Structurally the area mapped appears to be a down-faulted trough, with numerous "minor" faults crossing this trough. The dip and strike of the bedding and cleavage within the trough are generally remarkably constant, and various evidence suggests that the strata are at least partly inverted. This basically simple structure has, however, become much more complicated because of the later faulting.

The oldest rocks shown on the map are those of the Støren Series (the "Bymark Group" of Kiaer). This Series consists very largely of effusive greenstones - spilitic lavas - with a few thin associated sediments, probably tuffs originally, now schistose, and also jasper. An intrusion of gabbro was seen within the Støren succession. The Støren Series was considered to be Skiddavian (Lower Ordovician) in age by Vogt.

The Hovin Series is known to be younger than the Støren Series, and was considered by Vogt to be not older than Llanvirnian in age. The present work suggests, however that here the Hovins are, in part, Middle Skiddavian in age (Phyllograptus densus zone) and possibly, in part, even older. This further suggests that the Støren Series here may be rather old than was previously supposed. These new ages have been suggested by the finding of a graptolitic shale within the succession, of Middle Skiddavian age. This is a particularly important discovery, resulting in several new fossil localities being found which can all be accurately dated. A full description of the great variety of graptolites found will be added to this report at a later date.

Rock types within the Hovin succession include, besides the graptolitic shale, various other shales, siltstones, sandstones, grits, limestones, a possible radiolarian quartzite, and various conglomerates, agglomerates and breccias. Fossils were found in some of the limestones but it is doubtful if they are determinable. No horizons could be matched with those mapped by Vogt in the Hølonda-Horg area.

Besides these sedimentary rocks the Hovin Series also includes possibly two types of intrusive igneous rocks, and considerable igneous activity in the area during this time is shown by the highly tuffaceous nature of many of the sedimentary rocks.

The only younger rocks in the area are the Pleistocene deposits. These consist mainly of gravels, a north-south belt of which occur between Prestubuvatnet and Storbuvatnet. Otherwise the main effect of the Pleistocene Glaciation was of erosion, and it is undoubtedly very largely responsible for the present topography of the area.

River Trivja, looking northward; in the middle distance, on the west bank of the river, a 'porphyrite' bluff can be seen.

Gravels (glacial?) on the north side of the new Storbuan road, just E. of Prestbuvatnet.

THE STØREN SERIES

The Støren Series was so named by Kjerulf in 1875 after the type locality at Støren to the East of the area mapped. The Series is generally considered to be of Lower Ordovician age. The rocks of this Series are principally volcanic, consisting of thick effusive greenstones, with some associated tuffs. It is thought that these rocks are contemporaneous with similar volcanic rocks of Lower Ordovician age in Great Britain, such as the Ballantrae Volcanics of Southern Scotland. However, if the Hovin Series is younger than the Støren Series, the latter are possibly at least as old as earliest Skiddavian.

In this area the Støren Series form the Northern and South Western borders of the Westward pointing triangular prolongation of the Hovin Series. On both sides the Støren-Hovin contact appears to be a fault, the Støren Series forming a fault scarp feature. This is particularly prominent North of Frilsjøen where they are vertical cliffs up to 70m. high, with scree slopes at their bases. This feature must have been accentuated by Pleistocene ice action.

The Støren greenstones are basaltic lavas of spilitic type, with pillow lavas very common, indicating submarine extrusion. In the area mapped these pillow lavas, although recognisable, are considerably squashed and deformed, and cannot be used as "way-up" criteria. Here they can be best seen near the Gabbro intrusion South East of Frilsjøen. Easily recognisable pillows can also be seen along the new road-cutting West of Storbuan. In most of the greenstone out-crops, in fact, there are indications of pillow structures. Undeformed and very extensive pillow lavas can, however, be seen to the South of the area mapped, on Grefstadfjeldet, and here can be used for "way-up". They also give a bedding-plain measurement, the lavas dipping 75° North, striking 096°, and are right way up. The pillows here vary considerably in size, as can be seen in the accompanying photograph though are generally less than 1m. in diameter.

The greenstone lavas are typical spilites, according to Vogt, with abundant calcite, and with chlorite, albite, quartz and sphene, with or without epidote: actinolite or green hornblende may also occur. In this area epidote is very common, expecially as veins; veins of chlorite, calcite and quartz are also common. Brian Chadwick has done some thin-section work on some of the greenstones, getting results similar to those of Vogt.

In appearance the greenstones vary very considerably, even within the same outcrop. The pillows, when identifiable, may or may not show vesicular interiors; their outer margins are invariably very rich in chlorite, often with a yellowish epidote zone just inside. All these features can be seen in exposures West of Storbuan. Smaller "pillows" also occur, only 10cm. or so in diameter, dark green in colour, due to chlorite, and crossed by numerous thin, yellowish epidote veins. These small pillows give the exposures a conglomeratic appearance, as in the greenstone escarpment North East of Frilsjoen.

Pillow - lavas

on Grefstadfjeldet, looking westward. The pillow-lavas here can be seen to be right-way up, with their Vs pointing southward. The lavas dip 75° towards 006°N.

In other parts the greenstones are more massive, and may be an almost uniform dark green in colour, or, more commonly, pale green with dark to very dark green chloritic specks, up to 2mm. in diameter, giving the rock a porphyritic appearance. In this case the pale green ground-mass is extremely fine-grained, almost glassy. Mottled pale, dark green and grey-green greenstones are also common. In all cases the greenstones are much veined and jointed, these being very irregular. Generally the greenstones are very fine-grained, the individual mineral grains being indistinguishable under a hand lens, although coarser varieties, doleritic, also occur, as near the Gabbro intrusion South East of Frilsjoen.

Beside the greenstone lavas there are also some intercalated sedimentary "tuffs" which are now represented by phyllites. The best exposures of these are on the western shore of Frilsjoen, where the phyllites are dark green, grey green or blue-green in colour and also reddish purple, presumably due to hematite. Again these phyllites are much veined. Where the phyllites are reddish in colour the greenstone lavas in the vicinity are often also tinged with red. The phyllites appear to grade into the massive greenstones by gradually loosing their schistosity.

Beds of jasper are said to be quite common within the Stören Succession, but only one locality of jasper in situ was found; this was in the greenstone ridge North of Frilsjoen, where a large mass of jasper is exposed. The jasper here is much veined with epidote, giving the rock a brecciated appearance, and also contained pyrite cubes up to 5mm. in diameter.

In the Løkken district the greenstones have been intruded by numerous masses of Gabbro. One of these lies to the South-East of Frilsjoen with part of its Northern boundary just coming within the area mapped. In the few exposures seen the Gabbro shows signs of having suffered considerably alteration, though its texture is still preserved. The Gabbro here is coarse-grained, with slender well shaped crystals, up to 1cm. in length, of feldspar and a ferro-magnesium mineral(s), with no preferred orientation. Its actual contact with the greenstone country-rock was not found as the greenstones here appear to grade into the Gabbro, the Gabbro becoming finer-grained and the greenstone coarser-grained in the vicinity of the actual contact.

As has already been stated, the Stören Series is faulted against the Hovin Series. The vertical displacements of these faults must be in the order of several hundred feet. No where in the field could the actual contacts be seen, but the evidence for the faults seems conclusive as :-

1. The greenstones near the "fault" are much brecciated and veined, with many slicken-sided joint surfaces, suggesting the possible action of dislocation metamorphism. These features can be seen in the gr enstone cliffs North of Frilsjoen.

2. The greenstone outcrops cut across the strike of the Hovin Series and show an overlapping relationship to the younger rocks.

3. At the base of the greenstone fault scarps there are invariably narrow shallow depressions, grass covered and often a stream site. This can be interpretted as a zone of weakness produced along the trace of the fault.

The Støren Series can be seen to be older than the Hovin Series in spite of the faulted contacts, as pebbles of greenstones and jasper are quite common in many of the Hovin conglomerates. The greater degree of metamorphism suffered by the Støren Series could also be said to suggest this, although the greenstones are likely to be more unstable under surface conditions then the normal sedimentary rocks.

THE HOVIN SERIES

In contrast with the older Støren Series the rocks of this series are predominently sedimentary, although volcanic material forms a very important constituent of most of these sediments. The very varied rock assemblage within this series shows that the sedimentary environment must have been rather odd! For exapme classical graptolitic shales occur within a succession of massive, highly tuffaceous, boulder conglomerates and agglomerates, with grits and thin bedded sandstones and shales. Thin bands or lenses of a pure crystalline marble also occur within the tuffaceous succession. "Odd" outcrops of an impure fossiliferous limestone, dark blue calcareous mudstone and a black graphitic quartzite, possible with radiolaria, also occur. Later intrusions of igneous rocks add to the variety of the rock types found.

Correlation within this Series is rendered very difficult by lack of adequate exposures and the presence of numerous faults. Therefore it has been decided here to divide the Hovin outcrop into three parts:-

A. West of the Bogo River.

B. Between the Bogo and Rauaaa Rivers.

C. Between the Rauaaa and Trivja Rivers.

An attempt will be made later to correlate these areas. In each the strata dip northwards at a steep angle, generally about 70^{0}, striking between 100^{0} North and 110^{0} North (magnetic).

A. WEST OF THE BOGO RIVER

In this area thick conglomerates and grits become fine grained southwards and eventually pass into grey shales. Graded-bedded tuffs show that some of the beds (all?) young to the South and are inverted. It is hoped that this can be proved palaeontologically, with the graptolitic shale.

The general succession here, from South to North is:-

9. Grey Shales with pyrrhotite specks.

8. Banded Grits and Shales with more massive grits at base.

7. Massive Conglomerates and Agglomeratic Grits.

6. Graptolitic Shale.

5. Thin Impure Limestones, Scaly Mudstones and a "Shaly Breccia".

4. Agglomeratic Grits.

3. Pale Grey Marble.

2. Blue-black Pyritous Slate.

1. Massive Conglomerates with marble fragments.

Because of faulting this succession is probably not in correct stratigraphical order.

1. Massive Conglomerate - This division is only exposed near the mouth of the River Bogo, being cut out by the greenstone fault further westward. One outcrop occupies a hill just to the South of the greenstone escarpment, while smaller outcrops occur a few metres East of the Bogo, on westward facing slopes.

The fragments making up the conglomerate are sub-angular and vary in size up to one foot in diameter. Some layers are very rich in limestone fragments, which, on exposed surfaces, show solution weathering. This limestone is finely crystalline and is a distinctive pale grey in colour, with irregular pale blue markings. In places the limestone or marble appears conglomeratic. Limestones of this type occur at various localities within the area mapped, and at different stratgraphical levels. Other rock fragments could not be identified because of the weathered nature of the exposures. The general matrix appeared feldspatic.

The most southern of the outcrops to the east of the Bogo River is of different rock type. Here is a dark brownish, massive rock, fine grained, with tabular feldspar phenocrysts; this is probably a lava. On the top of this outcrop is a badly weathered dark grey shale, non-pyritous, which is largely hidden. The contact between the two rock types is obscured by vegetation. This "lava" appears practically identical to that seen in outcrops further to the South East, to be described later.

2. Blue-Black Pyritous Slate - This is the lowest rock actually exposed in the bed of the Bogo River. Further outcrops occur sporadically westward, along the general strike, but are not found to the east. No contacts with other sediments were seen, so the thickness of this division can only be roughly guessed at; it would appear that the slate is less than 50m. thick.

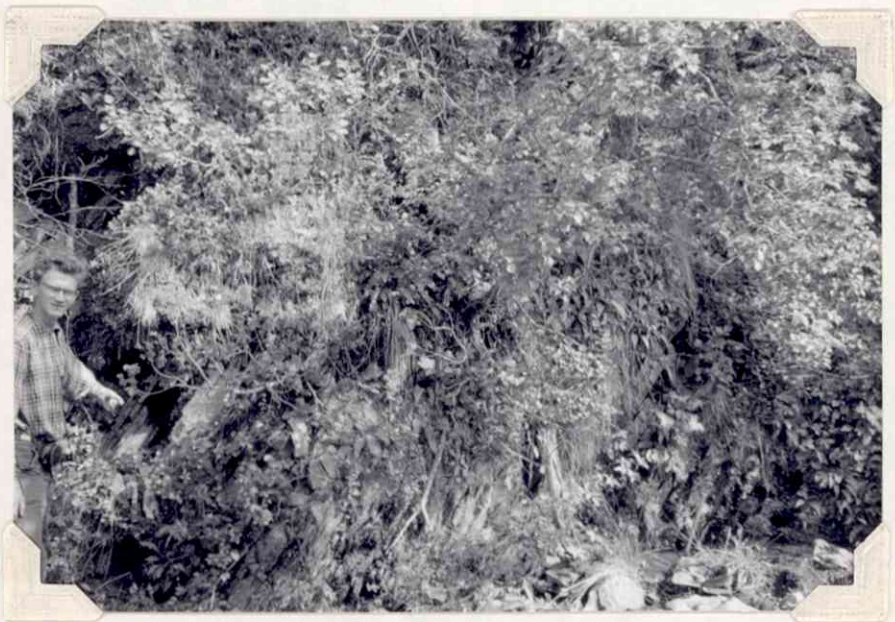
The slate is blue-black in colour and contains much pyrite. It is harder and more flinty than the graptolitic shale to the South and seems "baked". When dropped the slate gives a ringing sound and "clatters", similar to the Welsh slates. The slate is very fine-grained and possesses a good slaty cleavage. There are no signs of possible bedding, though it seems quite probable that the cleavage and bedding plains are almost identical, comparing the cleavage orientation with that of the bedding in the graptolitic shales just to the South. Some cleavage plains are covered with a very thin film of pyrite and joint surfaces are usually filled with this mineral, which also forms veins. This gives the weathered exposures a rusty appearance.

No fossils were found in the slates, in spite of hopes to the contrary, probably because of the slaty nature of the rock. Only two definite further exposures were found, just a few metres to the West, along the strike.

3. Pale Grey Marble - A single issolated exposure of a very pale, bluish grey marble was found just to the West of the Bogo River and to the South of the Pyritous Slate outcrop. A small sunken stream crosses this marble and forms a narrow shallow crevice, with solution hollows, almost hidden by vegetation. This marble or limestone is identical to that forming the limestone fragments in the conglomerates to the North. No fossils were found here.

4. Agglomeratic Grit - This division is based on two outcrops one of which forms a small hummock just to the South of the marble outcrop. The rock here is a grey-green massive grit, with small angular white feldspar crystals visible in the matrix. The other outcrop, of similar rock type, is on the Bogo River, where it is in contact (probably faulted against), with the following division. These last two divisions have a total thickness, along the Bogo River, of about 40m.

5. Varied Group of Impure Limestones, etc - This rock group was seen at only one locality, where it overlies the northern-most outcrop of graptolitic shale exposed in the Bogo River; here it helps form a bluff some 7m. high. These rocks appear to be faulted up against the graptolitic shales to the South, and occupy a fault zone, about 2m. thick, to the North of which the agglomeratic grit just described is visible. Included in the zone are impersistent bands of impure dark blue-grey limestone, finely conglomeratic; also bands of dark grey mudstone, some gritty bands and bands of a dark, slightly greenish-grey rock, possibly basaltic, with small phenobrysts possibly of feldspar about 2m. in diameter. This last rock has an irregular parting, apparently parrallel to the fault plains which here dip northwards at about 60°. The most distinctive rock, however, is a black,



h41. Brian Chadwick and the Graptolitic Shale exposure on the E. bank of the Bogo River, below the rapids N. of the Bogo Bridge. The first discovery of graptolites in the Svartvatnet Area. A very varied fauna includes species of Isograptus, Didymograptus, Tetragraptus, Dichograptus, Glassograptus and Glyptograptus, as well as various inarticulate brachiopods and crustacea remains

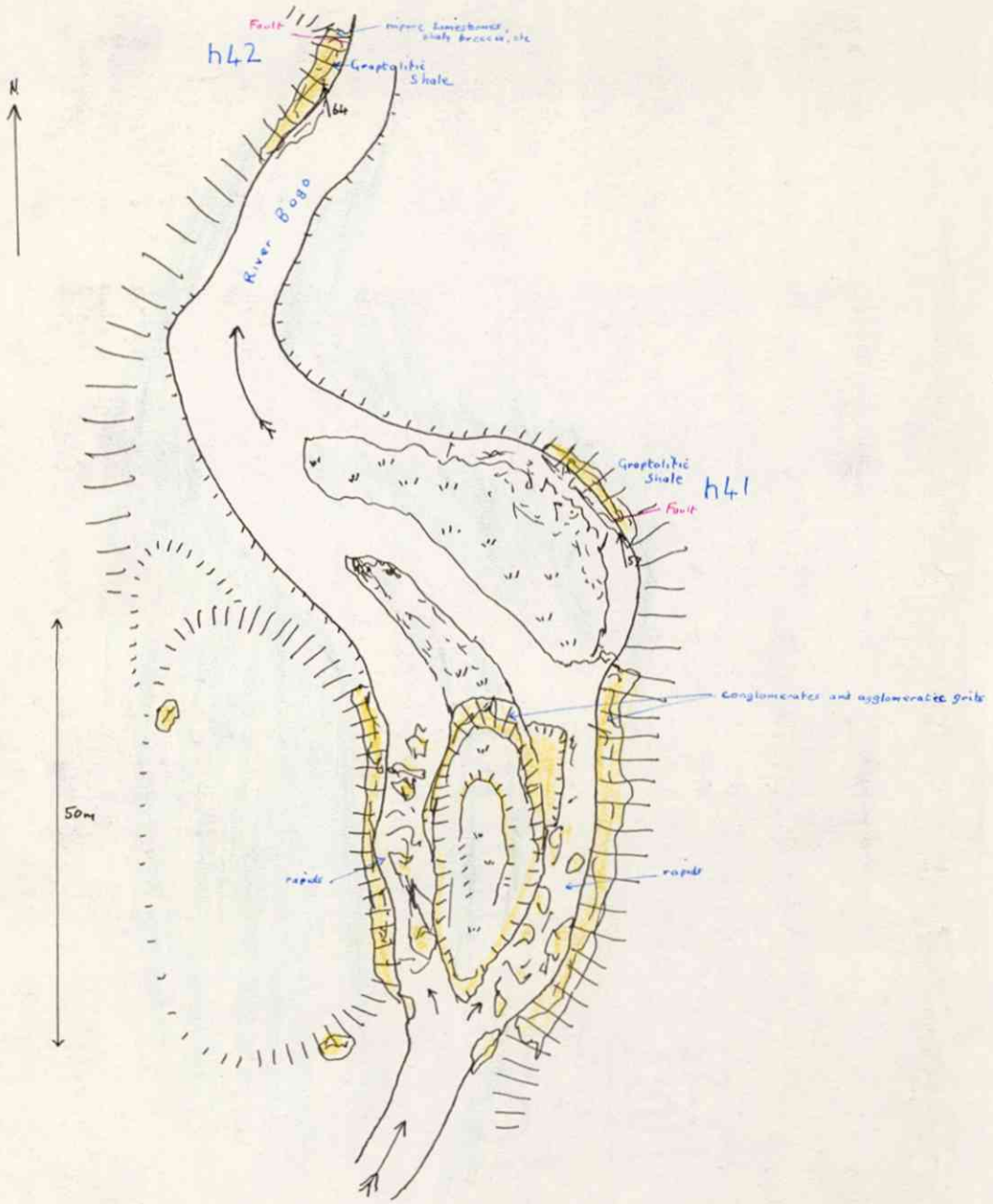
shaly rock with abundant light-coloured, sharply angular fragments up to 2cm. in diameter in a black shaly matrix. These fragments making up to 50% of the total rock. The larger fragments consist mainly of pale, blue-grey "grits" and an almost white rhyolitic rock. This "shaly breccia" occurs as thin, impersistent bands and lenses; it is possibly a fault breccia. Within these rocks a cast of strophomenoid brachiopod was found.

6. Graptolitic Shale - Rather unexpectedly, several fossil localities were found in the area mapped, none having previously been recorded. Most of these resulted from the discovery of this shale. The best exposures of the shale were found along the Bogo River (i) On the East bank of the Bogo River (ii) Forty yards down stream, on the West bank, both outcrops occurring just below the rapids to the North of the Bogo bridge. A further outcrop occurs in a stream bed about 150 m. up a tributary which flows eastward into the Bogo joining it just to the North of the other two outcrops. Graptolites were found at two other outcrops besides these three, while similar shales probably of the same age, outcrop in a few other localities, though no graptolites were found in them. East of the River Bogo the only graptolitic shales found were in a single outcrop on the West bank of the Trivja River. The shales are dark grey or black in colour and exposures are usually rusty because of the presence of pyrite, as veins, occasionaly, but more normally as coating joint surfaces; also as fossil impressions on some bedding plains. The pyrite is not irregularly distributed throughout the shales. A brief description only of each outcrop will be given here, as a more detailed report, with descriptions of fossils found, will be given later.

The outcrop studied in most detail is that on the east bank of the Bogo River just below the r apids. Here the shales are separated from the grits forming the rapids by a grass bank 10m. wide: the northern boundary is also grass covered. As in the other outcrops, the shales here dip northwards at about 65°. The lowest best exposed show two bands of an impure dark blue, finely conglomeratic limestone, possibly with shelly fragments, each 12cm. thick, seperated by a black, unfossiliferous shale less than 1cm. thick. On top of these limestone bands some 5m. of dark grey, slightly pyritous shales are exposed, partly repeated by a vertical fault. Some bands of the shales are highly fossiliferous with an abundant and varied assemblage of well preserved graptolites. Inarticulate braciopods are also quite common, as are fragments of crustacea. No trilobites were found.

Generally the shales have a well developed shaly cleavage, which is distorted in places, presumably by faulting. Some thin, dark blue, silty bands and thin, grey, gritty layers occur within the shaly succession, giving sedimentary banding. These bands are generally less fossiliferous, with the grits appearing tuffaceous. The true thickness of the shales is difficult to estimate because of the small exposure and the faulting.

The graptolites in the shales include species of Dichograptus, Isograptus, Didymograptus (extensus type), Tetragraptus, Phyllograptus and the diplograptids, Glossograptus and Glyptograptus. This assemblage suggests a Middle Skiddavian



h41 & h42. Sketch Map of the Graptolitic Shale outcrops on the Bogo River, just below the rapids formed of conglomerates and grits. 600m. N. of the Bogo Bridge.

age - Phyllograptus densus zone.

Forty metres downstream on the West bank of the Bogo, there is another outcrop of similar shales, the northern contact of which having been already described.

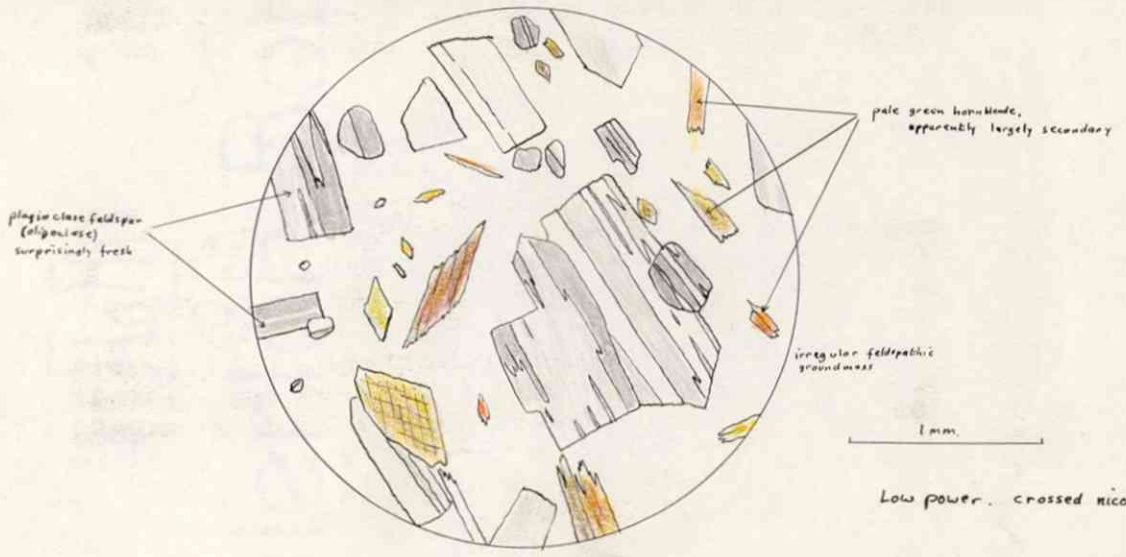
SOme 7m. thickness of shale is exposed here within which are a few thin bands of a more silty shale and also of a blue-grey calcareous mudstone. The shales are not highly pyritus, they differ from those of the last outcrop in possessing some bands which have very regular paper-thin cleavages. The graptolites are generally not so well preserved, being more flattened and preserved in barbonaceous matter instead of pyrite.

Graptolites are particularly abundant in the top 4m., where they are associated with crustacean remains. The assemblage differs from that of the last outcrop in a few respects and diplograptids, especially Glyptograptus are more common. Horizontal didymograptids are again common, as are species of Isograptus and Glossograptus; no specimens of Phyllograptus or Tetragraptus were found here, ~~nor any brachiopods~~.

The only other locality at which more than one graptolite was found lies 150m. eastward of the last outcrop, in the bed of a small, northward flowing tributary of the Bogo. The lowest bed found was a dark blue, finely conglomeratic, limestone, on tope of which were dark blue-grey shales, richer in pyrite than before and more "slaty". After much chipping two fossiliferous bands were found, with graptolites, well preserved, in pyrite. Large extensiform didymograptids some diplograptids (Glyptograptus?) and a Phyllograptus species were found here. About 70m. eastwards along the strike, another small outcrop of dark blue-grey shale was found in another stream bed, but no graptolites were found here. However it seems reasonable to include the shales here within this division.

In none of the outcrops so far described has the southern boundary of the shales been seen. About 500m. downstream, the river which flows westward out from Frilsjoen is joined by a small tributary from the North, 60m. up which is an outcrop of dark grey shale, in the stream bed. This shale can be seen resting on a pale, bluish-green, badly weathered and broken grit, which belongs to the next division. The contact between the two rocks is very sharp but is conformable: there does not appear to be a fault plane here. This contact can be explained if the beds here are inverted, as they are further south, with the grit representing a sudden change in sedimentary conditions, such as an outburst of volcanic activity. Near this contact the shales are not pyritous, but become so a few metres upstream. A thickness of 25m. of shale is exposed. The northern contact is covered by vegetation forming the north bank of the stream which here flows from the East before suddenly flowing southward to join its parent river. Above this North bank is an East-West ridge of tuffy grits, possibly representing a fault scarp. In the shale a single graptolite was found, a diplograptid, poorly preserved in pyrite.

One Km. to the North-North-East a similar exposure occurs in a stream flowing southward from the greenstone escarpment.



K54. Thin-section of a typical tuff.
W. of Frilsjoen

012. Thin section of a feldspathic agglomeratic grit
800m. W.N.W. of Boge Bridge.

10m. downstream from the outcrop of Støren greenstone a dark grey shale appears in the stream bed, 5m. thick, below which is a thin band of badly weathered, pale "grit". As before, the contact, though very sharp, appears conformable, though the basal few centimetres appear somewhat broken up. The shale is slightly pyritous and very similar in all respects to the graptolitic shales already described, except that no graptolites were found here. Between the greenstone outcrop and the shale outcrop the stream is strewn with greenstone boulders, hiding the position of the greenstone fault.

South-West 250m. a small outcrop of dark blue-grey shales, puritous in parts, occurs in a southward-facing bank. The exposure is very scrappy and badly weathered. The shales appear slightly baked and slaty. One small poorly preserved diplograptid was found here. Just to the north, on the opposite bank, there are some small exposures also of dark, blue-grey pyritous shale, with some silty bands. This shale can be seen in contact with an intrusive gabbroic igneous rock, the shale being baked at the contact. No graptolites were found here, nor in similar exposures on a ridge just to the West. One further small outcrop of blue-grey shales was found, about 200m. to the South West again in a stream bed, no fossils found.

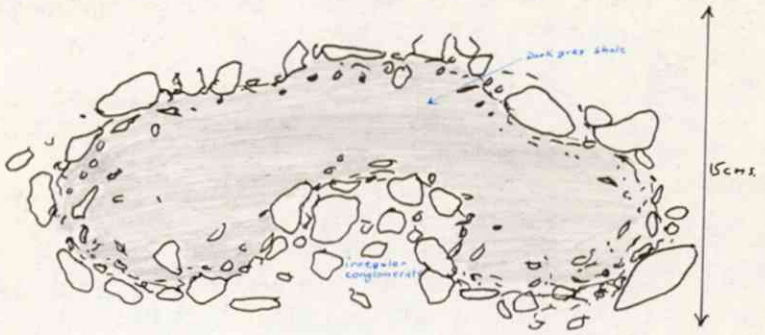
Although all these occurances of graptolitic, and possibly graptolitic shales have similar dips and strikes, they do not occur along a constant strike position on the map. Their relative displacement to one another must be due to faulting.

7. Tuffaceous Conglomerates and Agglomeratic Grits - This division succeeds the Graptolitic Shale with a marked change in rock type. It passes southward into the succeeding division of Banded Grits and Shales, the boundary between which being taken where the banded rocks form more than 50% of the rock total. Numerous large and small outcrops of the conglomeratic division occur along, and to the West of, the River Bogo, and also just to the East of the Bogo River, North of the Bogo bridge.

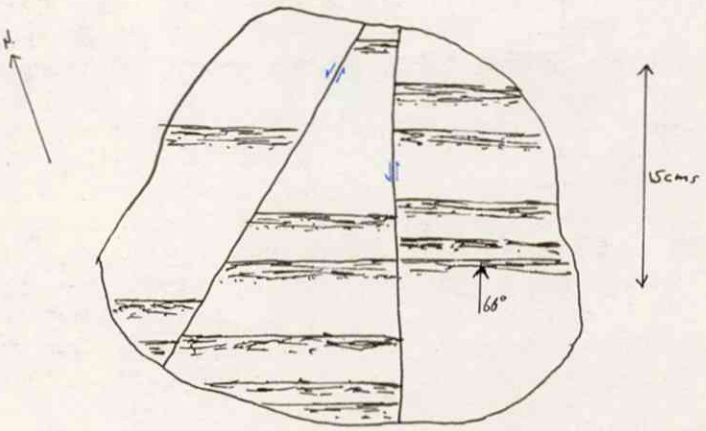
Only along the Bogo River in the East and at the western end of Frilsjoen can a reasonable estimate be made of the thickness of this division: along the Bogo River it is about 150m. thick, and in the extreme West 80m. thick. This does not take into account the probability of a repetitive succession due to strike faulting.

As well as along the Bogo River good outcrops occur on the tops and sides of hills and ridges and on many small mounds along the general strike.

The rocks includedhere are all highly tuffaceous, and they vary considerably from place to place. In colour the grits are various shades of green and blue, usually fairly pale. Weathered surfaces show a large percentage (greater than 50%) of white feldspar grains, usually angular, in both the grits and in the g ritty matrix and included pebbles of the conglomerates. This indicated in the field, what was seen later in thin-sections, the richly feldspathic nature of these rocks.



038. Dark shaly patch in irregular conglomerate, with many sub-angular fragments around its edge. Possibly an 'armoured mud-ball'. Transition of 'shaly agglomerate' and 'massive conglomerate'. 700m N of Frilsjøen.



f18. Small faults cutting banded grits and shales, which show inverted graded-bedding. 70m NNE. of the Bogo Bridge.

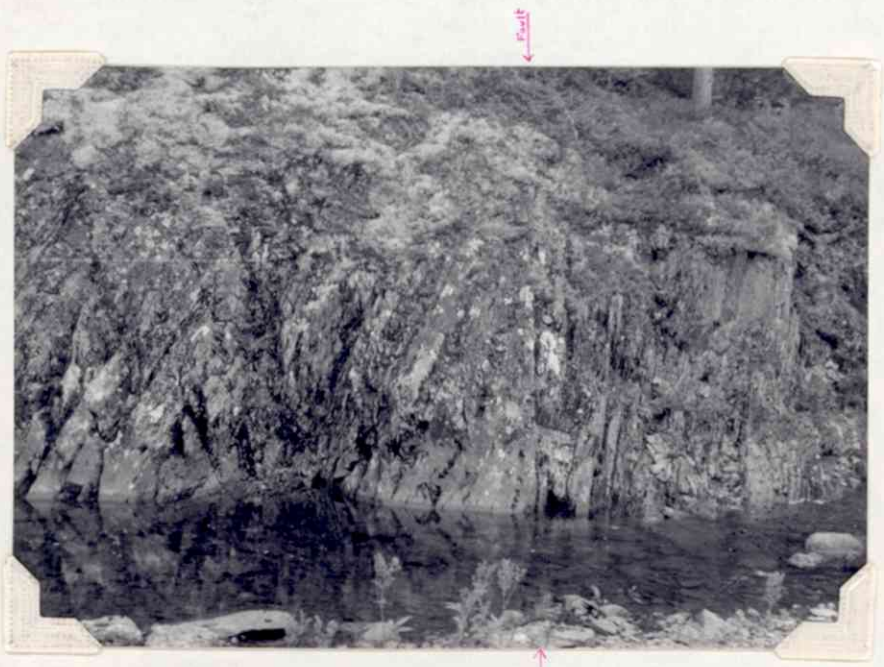
A thin section of a representative grit showed that the rock is made up approximately of 50% albite crystals almost unaltered, showing albite twinning. These crystals are variable in size and shape and have angular and sub-angular outlines. Skeletal crystals of colourless amphibole (tremolite?), subangular zireons and subangular leucoxene were also seen. The ground mass is quite fine grained, though again variable in size and consists largely of feldspar, with pyroxene and amphibole. This highly tuffaceous grit is here called an "agglomeratic grit", to distinguish it from other tuffs and grits.

The grits here occur as separate bands as well as making up the matrix of the conglomerates. In places, as at one locality in the extreme West, the "grit" is even more obviously tuffaceous, with hornblende laths, up to 5mm. long, visible, as well as feldspar crystals. A slide of this rock showed that albite crystals are again dominant, but also important are brownish green laths of hornblende, showing secondary growth, and, possibly, hypersthene remnants. The ground mass is again feldspathic.

The conglomerates consist dominantly of angular, subangular and rounded rock fragments, poorly sorted, ranging in size up to 30 cm. in diameter. These fragments are tuffaceous and richly feldspathic, as is the gritty matrix. The larger the fragments, generally, the better rounded they are. On surfaces cleared of vegetation the fragments making up the conglomerate are whiterthan the matrix, suggesting that they are even richer in feldspar. A very fine exposure of this conglomerate 400m. due north of the Bogo bridge, on the east side of a hill, shows most of the features described. Here the sedimentary "packing" and the graded-bedding of the gritty matrix suggests that these beds are inverted, younging to the South, and this is also indicated in other outcrops in this area. Also in the outcrop just mentioned a few foreign pebbles can be seen, including small fragments of greenstone and jasper. The conglomerate is sometimes fine-grained, with pebbles sometimes less than 1cm. in diameter, though it is commonly much coarser. Although the conglomerate occurs in bands, no identical bands could be definitely traced from outcrop to outcrop along the strike, as seen in the same outcrop the conglomerate bands could be seen to vary considerably in thickness. Also small faults about 19cm. displacement or less could be seen in some outcrops, causing a variable displacement of the bands.

A different type of conglomerate occurs about 1Km. No the North of the eastern end of Frilsjoen. Here the conglomerate forms a low southward facing slope just south of the greenstone escarpment. It consists typically of angular fragments in a dark matrix. The matrix is a dark bluish grey in colour and appears shaly. About 50% of the rock is composed of angular fragments which show very little sign of any rounding. The rock shows more characteristics of a breccia than a conglomerate. At the South West corner of the locality of this breccia it can be seen apparently grading into the more normal conglomerate. Here there is a poorly sorted tuffaceous conglomerate, with large irregular shaly patches, up to 15cm. long, with small subangular fragments around their edges. A thin section of this "breccia" showed that most of the fragments do show very slight signs of "rounding". The matrix is sandy, with much opaque material, probably either iron oride or graphite, giving it its dark grey colour. The grains making up the matrix are irregular and much altered. They were, quite possibly, feldspathic originally.

h32. Fault 150 metres N of the Bogo Bridge, cutting banded grits and shales. Apparently downthrown to the south.



f20. Fault cutting steeply dipping banded grits and shales, on the E. bank of the Bogo River, 100 m. upstream from the Bogo Bridge. The fault in apparently downthrown to the N, bringing thick grit bands alongside thin-banded s to the south.

This unusual rock type may possibly represent a submarine breccia, or scree, with the angular fragments settling in a silty sludge; a volcanic explosion could cause a similar effect, and this rock may represent an explosion breccia. Although it is considered here, it is not all that certain that this is its correct position, as it all depends upon the interpretation of the faulting in the area.

8. Banded Grits and Shales - This division grades up from the conglomerates, the boundary between the two being where the banded grits and shales comprise more than 50% of the rock total. The conglomerates included within this division are finer-grained on the whole, and become less important to the South. In the West this division is about 100m. thick whilst in the East it is at least four times as thick as this, probably because of faulting. It occurs to the South of the previous division and to the North of Frilsjoen - Bogo Bridge road.

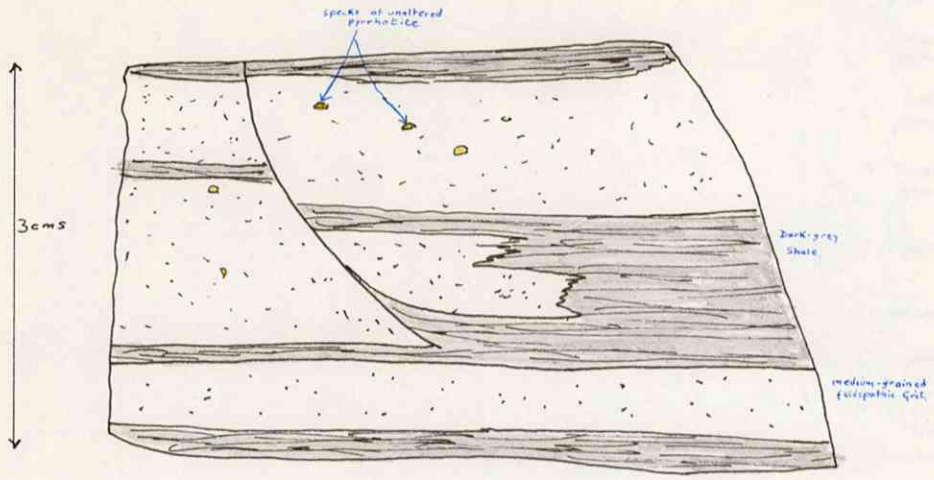
The grits are pale green and pale greenish-grey in colour, the finer-grained sands and siltstones being darker and more bluish, with the shales being a very dark blue-grey in colour. Often within each band there is a complete gradation from green grit to dark sandstone. The bands vary considerably in thickness. Near the Bogo Bridge they are often less than 1cm. thick and the exposure consists of numerous similar bands, on top of one another, rather similar to varved-clay deposits. A vertical fault, with a throw of at least 3m. can be seen here. Also, here and elsewhere, grit bands over 30cm. thick occur. On weathered surfaces the highly feldspathic nature of the coarser constituents is shown by the predominance of white grains. Graded bedding is very common and, when seen, always showed that the bands young to the South, and, as they dip northwards, they must be overturned. Graded bedding can be very well seen in the Bogo River by the Bogo Bridge, just to the East of the bridge on either side of the road, and on the North side of the road just West of the bridge. Many other outcrops occur further West, and, in fact, almost every outcrop within this division shows or suggests graded-bedding younging to the South.

In an exposure along the Bogo river, 150m. downstream from the Bogo Bridge the banding is more irregular due to sedimentation rather than tectonics. Here the shales occur as lenses and discontinuous layers within the grits; this is also shown further westwards. At this outcrop another prominent fault can be seen, with a throw of some metres, probably downthrown to the South.

The most southerly outcrop of the division along the Bogo River is 50m. upstream from the Bogo Bridge. The last outcrop here is of a coarse conglomeratic grit with fragments up to 3cm. in diameter, subangular and highly feldspathic.

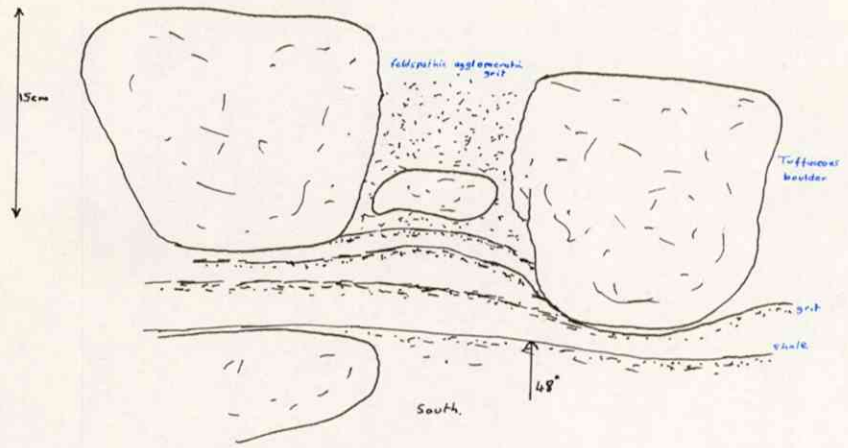
A thin section of a banded grit from an outcrop further East showed that the feldspar grains make up most of the grit though they are usually much altered. This will be described in more detail later.

9. Grey Shales - Although there is no proof that this is so, it, seems likely that these grey shales grade up from the preceding division. A few outcrops occur along the Bogo



h32. Irregular bedding in banded grits and shales, due to slumping
150 m. N. of the Bogo Bridge, W. bank of Bogo River

North



h54. Graded bedding and sedimentary 'packing' seen here in plan view show that the beds are inverted.
400 metres N. of the Bogo Bridge.

River South of the bridge, but they can best be considered when dealing with the area East of the Bogo River. A few outcrops occur just West of the Bogo River, the most westerley outcrop being found midway along the North shore of Frilsjoen. The shale here is grey in colour, with small brown specks, probably after pyrrhotite. The shale is very fine-grained though more silty bands do occur, giving the bedding-plane orientation which, in the last outcrop, is parallel to the cleavage. This is not usually the case, however, further to the South-West.

B. BOGO RIVER TO RAUAAA RIVER

The rocks exposed in this area are similar to those of the last three divisions found West of the River Bogo, with the important addition of a white marble. The Grey Shales are better developed and include conglomeratic patches. No outcrops were found between Prestbuvatnet and the Storbuan road. The exposures in the Rausaa River, near the road bridge, will be described under Area C.

The succession here, as elsewhere, dips northward, and graded-bedding in the banded beds shows that these are again inverted. The Svartnatnet Depression, 50m. or more wide, from just South of Blomli in the East to 800m. West of the Bogo Bridge, including Svartvatnet, forms a zone with no outcrops. East of the Bogo River and West of Rauatj the shaly division is found only to the South of this depression, with the other divisions only being found to the North.

The succession in this area is:-

4. Grey Shales and Arenaceous Shales.

3. Banded Grits and Shales.

2. Tuffaceous Conglomerates and Agglomerate Grits.

1. Pale Grey Marble

1. Pale Grey Marble - Two localities of this rock type were found in the area, both along the northward-facing rock cliff, South of the Storbuan road and opposite Prestbuvatnet. A very small exposure was found at the Eastern end of this cliff, while the other locality was found 900m. westward, 80m. south of the road. This limestone or marble is a very pale grey, almost white, in colour, and finely crystalline. It is identical to the marble found just North of the graptolitic shales to the West of the Bogo River. No fossils or signs of any fossils were found. The limestone can be seen in contact with the tuffaceous conglomerates to the South in the more western outcrop. Near the contact the marble becomes increasingly conglomeratic, while the tuffaceous conglomerates near the contact contain many limestone fragments of all sizes, even feet in diameter. The contact itself is very irregular in outline, as are the conglomeratic patches within the marble.

2. Tuffaceous Conglomerate and Agglomerate Grits - This division is practically identical, in most respects, to that West of the Bogo River. Outcrops occur South of the Storbuan road, forming the steep slope and cliff face here. The thickness of the division is estimated at 200m., although faulting has probably obscured the true thickness. These rocks do differ near the marble outcrops, where limestone fragments are important, and also in the occurrence of a dark brown "basaltic" rock, possibly a lava, 300m. from the eastern end of the ridge. This last rock is similar to that found just to the South East of the mouth of the Bogo River. Otherwise, as before, this division consists of highly tuffaceous and richly feldspathic conglomerate and agglomeratic grits.

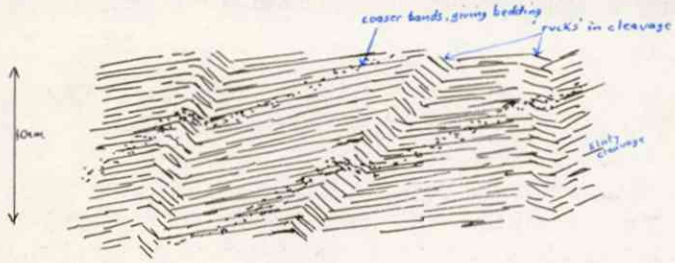
3. Banded Grits and Shales - Banded grits and shales are exposed to the North East of the Storbuan - Svartvatnet road junction, where they can be seen to be very similar to the banded rocks on the Bogo River North of the Bogo Bridge. The banding in these rocks is generally slightly wrinkled, and is frequently displaced along numerous minor faults, of 1cm. of so throw, roughly perpendicular to the bedding planes. The bands show rather poorly developed graded-bedding which suggests that, as elsewhere, these beds young to the South, although they dip northwards. A few similar outcrops occur further East, just to the South of the Tuffaceous Conglomerate outcrop.

South of the outcrops just considered there is a belt, 200m. or so wide, stretching from the Rauaaa River in the East to the Storbuan-Svartvatnet road junction in the West, with almost no exposures. South of this belt there are the porphyry ridges of Svartvassaasen and Prestseterasen. The porphyry here, as will be fully described later, intrudes the banded grits and shales. These beds are particularly well exposed on the South side of Svartvassa sen.

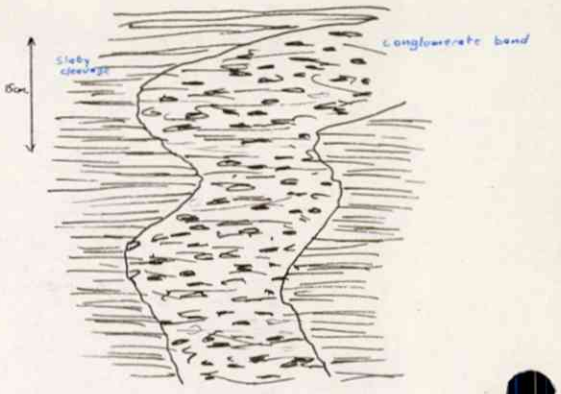
The banded grits and shales in these southern outcrops show all the features of the similar division further West, with very well developed graded-bedding, and also sedimentary slump structures in a few places. The shales are bluish-grey in colour, with the grits a pale bluish-green, so the bands, which have an average thickness of 1cm. show colour as well as grain-size gradations. A thin-section of a graded-bedded grit band occurring here showed an abundance of much altered feldspar, with some quartz and quartzite grains. The grains, up to 1mm. in size, are poorly sorted and subangular; calcite is very abundant with the grits, though whether of secondary or primary origin could not be ascertained. The southern-most outcrops seem to be rather finer-grained. The grits show no signs of any metamorphism other than compaction.

A very fine exposure of these banded rocks occurs on the North side of the Svartvatnet road, parallel to Svartvatnet itself. Probab-ly the best exposure, however, is on the South side of the road, at the North Western end of Svartvatnet, where recent quarrying shows these beds to perfection. Here a conglomerate band 2m. thick, can be seen with the banded beds on either side. It contains irregular, subangular fragments, very variable in size, up to 10cm. in diameter, in a blue-grey, finely-banded sandy matrix which shows contorted turbulent depositional structures. The fragments comprise less than 25% of the rock whole, and, unlike the conglomerates previously described, are not tuffaceous, consisting of a varied group of rocks, including greenstones and plutonic igneous rocks.

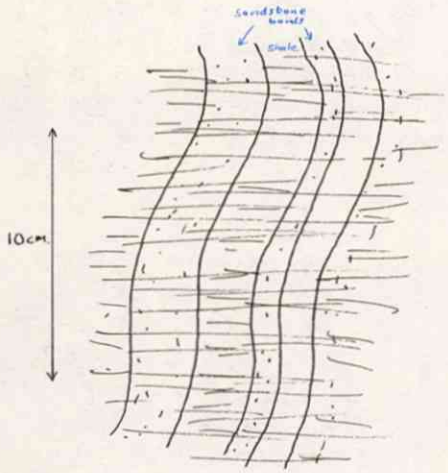
This very distinctive conglomerate can be traced eastwards on the North side of the road, from where it can be followed along the North side of the Porphyry intrusion of Svartvassaasen. In places it contains white marble fragments identical to the marble found 350m. to the North. However, it could not be traced East of Svartvassaasen, and no exposures of any sort were found North of Prestseterasen for a distance of 800m. On the South side of the porphyry intrusion of Prestseterasen, and in contact with it, more banded grits and shales can be seen. They appear finer-grained here, and more shaly, the shales having a pale, reddish-brown weathered appearance: graded-bedding is not so well developed. A definite cleavage can be seen to differ very slightly from the bedding planes. No similar beds were found east of Prestseterasen.



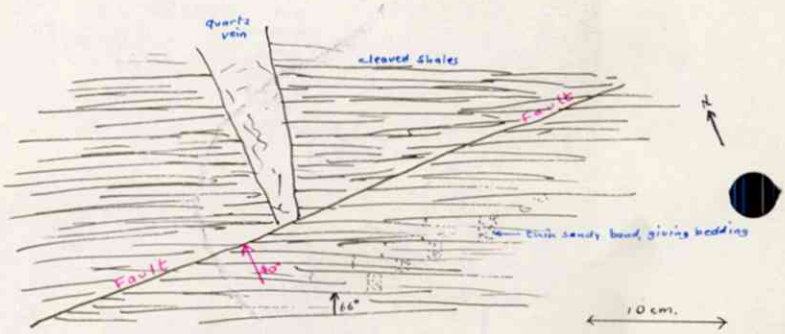
r36 Arenaceous shales, with some coarser bands, with a prominent cleavage, showing rucks. 1300m S.S.E. of Svartvatnet



912 Conglomerate band, folded, with pebbles flattened in the plane of the cleavage. 90m NE. of Ravvatj



r34 Folded shale and sandstone bands, cut by the cleavage 1300m. S.S.E. of Svartvatnet.



89 Plan view of an outcrop showing a major fault cutting cleaved sandstones and shales, the bedding of which has been displaced along certain cleavage planes. 500 m. S.E. of Svartvatnet.

4. Grey Shales - The rocks within this division include fine and coarse conglomerates, tuffaceous grits and banded feldspathic sandstones, as well as grey shales and shaly sandstones. The shaly cleavage of these rocks, more often than not, is different from the bedding plane orientation. This cleavage commonly shows small "rucks", indicating a movement after the production of the cleavage. The general dip and strike of the cleavage is similar to that of the bedding further North, dipping at about 70° North striking between 100° and 120°.

The area covered by the Grey Shales is much larger than that covered by any other division. As has been already mentioned, it occurs West of the River Bogo and extends eastward of Rauaatj and the Rauaaa River. A North-South line through the Bogo bridge passes across a horizontal thickness of 800m. until the greenstone fault in the South is reached. In the East the most northerly outcrop lies 100m. North of Rauaatj and Southward from here, to the greenstone ridge, there is a horizontal thickness of 1.3Km. Faulting and tight folding within this belt, and the presence of the slaty cleavage, shows that this cannot be a true thickness. The Grey Shales are in marked contrast to the divisions to the North, which show practically no signs of any tight folding. It might well be that this belt represents the core of a syncline, the inverted limb of which outcrops to the North whilst the right-way-up limb has been cut out by the greenstone fault.

Many small outcrops occur between the River Rauaaa and the River Bogo, even in boggy areas, where they are found as low moss-covered mounds. No outcrops were found onthe Northward facing slope, overlooking the Svartvatnet Valley, all the outcrops being found South of here. There is another large area of no exposure in the marshy ground at Holstad, where the Rauaaa River and its tributaries flow northwards, off the greenstone hills of Grashammeren.

Outcrops of Grey Shale occur at various places along the Bogo River, South of the Bogo Bridge, and North of the greenstone hills. The rocks exposed here are grey and blue-grey shales, usually with small elongate brown specks, 2mm. or so in length, on their cleavage planes. These specks, when fresh, were seen to be formed of pyrrhotite. Pale silty bands occur within the shales and give the bedding plane orientation. In some places this differs from the cleavage, whilst at others it appears coincident. A few gritty bands, greenish grey to pale blue in colour and uncleaved, also occur within the shale succession, sometimes being crossed by quartz veins.

In outcrops to the East of the Bogo River, the shales appear to become coarser-grained, with their cleavage often differing greatly from their bedding. Greenish-grey micaceous siltstones and blue-grey shaly sandstones are more common than the true grey shales. These rocks weather to a characteristic reddish-brown colour, and on close inspection can be seen to be richly feldspathic and highly tuffaceous. Coarse grit bands are also quite common, b eing found at numerous outcrops East of the Bogo River. Usually these bands are quite thin, sometimes less than 2cm. thick. A thin-section of a typical band was made, taken from the Bogo River due south of Svartvatnet. In this the coarse grit band is in sharp

contact with a normal grey, specked shale, the contact being strongly oblique to the cleavage of the shale, and the grit grains being flattened parallel to the cleavage planes. The grains of this grit, up to 3mm. in diameter, were all much altered, and showed varying degrees of angularity. Some of the grains showed badly altered feldspar crystals, whilst other suggested, by their "ghost" texture a porphyritic lava origin. Secondary colourless amphibole, probably tremolite, occurs as quite large crystals, cutting across the original texture, and calcite, quite coarsely-crystalline, is very common between grains and also as grains. No quartz grains were seen, and their absence suggests a volcanic origin for the grains. In some of the outcrops minor and major faults can be seen.

A much coarser conglomerate is found in the South West, close to the greenstone fault and North and East of the Bogo River. The most easterly of these outcrops forms a prominent hillock, with other outcrops forming discontinuous ridges to the West-North-West, as far as the Bogo River. Grey Shales and shaly sandstones occur both to the North and South of this conglomerate, and grade into it. The conglomerate is dark green in colour and is massive with few signs of any bedding. The included rock fragments are very variable in colour and composition and they range in size from coarse grits to boulder conglomerates, all richly feldspathic. The rock fragments show varying degrees of angularity, many being well rounded. They vary considerably in composition, vein quartz pebbles being common, with pebbles of quartzite, various igneous rocks, including greenstones, jasper and very irregular pale grey marble fragments. The latter show typical solution weathering identical to that of the marble already described. In places pyrite cubes, up to 0.5cm. in diameter occur in the gritty bands, which, in places, do show bedding. This conglomerate does not show any cleavage.

C. RAUAAA RIVER TO TRIVJA RIVER

This area is complicated by various phorphyry intrusions, which stand out as ridges and, as before, numerous faults. The succession in the southern half of this area can be worked out reasonably well, but, in the North, various isolated exposures of different rock types cannot be fitted in any succession. That faulting is again very important can be seen in the only three outcrops found on the West bank of the Trivja River. In these, four prominent faults were found, and the rock types exposed, working upstream, were, firstly, an intrusive porphyry and a graptolitic shale; secondly, an intrusive prophyry a grey shale and a porphyry again; and, in the third outcrop, a massive limestone and a black quartzite. Of these, only the porphyry and the grey shales were found in other outcrops West of this River.

Graded-bedding in thinly-bedded sandstones in the sourthern part of the area again show younging to the South and there is no evidence to suggest that this is not so to the North. However, because of the faults, it cannot be assumed that the rocks in the North are older than those in the South.

Because of these complications this area cannot be treated in the same way as the two previous ones. North of an East-West line, 700m. South of Storbuvartnet, each rock type will be considered by itself, without trying to put it in the succession, although its relationships with the other rocks will be discussed. South of this line a succession can be worked out, and the rocks here will be described in stratagriphical order.

The northern part of the area will be dealt with first. The rock types found here included a purple-banded shale, a grey tuffy shale and a graptolitic shale; a blue-grey fossiliferous limestone, a dark blue muddy limestone and a pale greenish-grey massive limestone; a black graphitic quartzite and a group of tuffaceous rocks.

Limestones - The most interesting of the limestones is the one that is fossiliferous. A single outcrop of this limestone occurs near the eastern end of the steep northward-facing slope of the Granin Ridge, overlooking Storbuvatnet. There is another exposure 200m. to the West, on the shore of Storbuvatnet, though here it is possibly a slumped block. This rock is an impure, blue-grey limestone, with a definite parting plane and many irregular calcite veins. Though there are many signs of fossils, none could be properly identified, as they are largely fragmentary, and also that limestone has been recrystallised. No similar limestones have been found at any other locality, and its relative age and position is uncertain.

Immediately above the limestone, on the shore of Strobuvatnet, there is a single exposure of a dark blue limestone. This limestone is massive, granular, with no signs of any fossils, and is crossed by thin calcite veins. A very small outcrop, 250m. eastwards along the ridge, shows a rather similar rock type.

It is possible that the two limestones just described represent different facies of the Pale Grey Marble found

further West, though it seems more probable that they represent a different limestone altogether.

The other limestone to be described here was found in a single outcrop on the West bank of the Trivja River, opposite a small island 900m. North-North-West of Blomli. Here a small bluff shows the limestone is pale greenish-grey in colour, massive, with vague indications of fossils; again its relative age and position is unknown. It is very different from the other limestones in the area.

Shales - Along the Granin Ridge South of Storbuvatnet there are numerous exposures of a porphyry intrusion. This porphyry contains many irregular shaly patches, and other shales occur both on the North and South side of the porphyry. The shales enclosed in the porphyry are dark grey in colour, and apparently slightly baked, though still retaining some of their shaly cleavage. Just to the south of the intrusion the shale are paler in colour, containing dark brown specks, after pyrrhotite, on their cleavage planes. No signs of bedding, however, were found. These latter shales appear tuffaceous, especially on weathered surfaces, which are pale milky-grey or reddish-brown in colour. They are best exposed at the eastern end of the ridge, where, in some of the outcrops, slight "rucking" of the cleavage can be seen. Here the isolated outcrops occur among isolated porphyry outcrops.

On the North side of the Granin Ridge a dark grey shale was found. This shale has thin, irregular, deep purple bands, distinguishing it from the other shales found. It would appear to underlie the limestones found here.

On the South side of the old Storbuan Road, 150m. from the western end of the Granin Ridge, an outcrop of another shale was found, though it could not definitely be decided if it is here in situ. This shale is blue-grey in colour and includes paler sandstone bands, which show graded bedding. This rock has a prominent parting which cuts the bedding.

At the eastern end of the Granin Ridge, on the Trivja River, yet another shale was found, apparently faulted up against the porphyry to the North, the sides of the porphyry showing slickensides and the shale being very much broken up near the contact. This shale is dark grey in colour, with pyrrhotite specks on some of the cleavage planes, which may also sho manganese staining. Most of the joint planes are slightly rusty. No fossils were found here whilst in the field, but recently, on further examination of the shale some graptolite fragments made their appearance, including part of a diplograptid and parts of slender uniserial stripes of leptograptid type. As yet this shale cannot be proved to be of the same horizon as the graptolitic shale on the Bogo River, West of the Bogo Bridge, though it seems most likely that this is so.

Graphitic Quartzite - A single outcrop of this unusual rock was found on the West bank of the Trivja River, 300m. upstream from the shale with graptolites. Here a small bluff shows it to be faulted up against the pale greenish-grey limestone, already described, to the North. At the fault the parting planes within the quartzite are contorted and

d1. Outcrop of Purple Agglomerate, to the west of the Trivja River. Looking westward. The bedding can be seen to dip steeply northwards, dipping 85° N. to 030° N.

there are irregular quartz veins and slickensided surfaces here also. This evidence, plus the evidence of any gradation between the two very different rock types, proves the existence of this fault, even though the actual fault plane is covered with vegetation and loose rock fragments. This quartzite is black in colour and quite soft. A thin-section showed it to consist of fine-grained, granular quartz crystals with about 10% or less disseminated graphite, giving the rock its black colour and its softness in the hand specimen. Small spherical aggregates of quartz crystals 0.5mm. or less in diameter, often with a minute regular graphitic mesh in the centre, are very abundant throughout the thin-section and these spherical bodies may possibly represent radiolaria.

Purple Agglomerate - A rock answering this description was found in a single outcrop, apparently in situ, 80m. South West of the outcrop of the shale with graptolites. This rock consists of reddish-purple bands, up to 10cm. thick, of sandstones, grits and agglomerates dipping 85° North and striking 120°. The bands are badly sorted, with angular fragments of various colours and rock types, up to 2cm. in diameter. A few fragments of grænstones could be recognised. This rock is unique in this area though it seems similar to the Gaustadbakk Breccia of Vogt, which occurs just above the basal conglomerate of the Hovins in the Hólonda area further East.

Tuffaceous Group - South of the eastern part of the Granin Ridge, some 400m. south of Storbuvatnet, occurs a ridge made up largely of tuffaceous rocks. The North side of this ridge consists of a vertical bare rock face, up to 9m. high, running in an East-West direction, whilst the southern side consists of a much lower rock cliff, with a narrow, shallow trough separating it from another porphyry ridge to the South. The tuffaceous rocks here include shales, grits and agglomerates, pale grey and greenish-grey in colour, massive grits and agglomerates being the most common. Only on weathered surfaces, however, can the rock be seen to be agglomeratic, with angular fragments visible, themselves tuffaceous and up to 3cm. in diameter. Fresh surfaces appear apparently structureless. Feldspar is very abundant and hornblende laths are very common in parts. The South Eastern part of this ridge is formed of porphyry which can be seen in contact with grey tuffaceous shales of the Tuffaceous Group. This contact is very irregular. West of this ridge, on a lower continuation of it, a few isolated exposures were found of a grey and bluish-grey tuffaceous shale on the southward facing slope. These shales appear identical to the shales within the tuffaceous group. The whole group is very similar to that found just South of the Frilsjoen-Storbusn Road South of the eastern part of Prestbuvatnet.

The rocks in the Southern part of this Eastern sector, unlike those further North, can be correlated reasonably well, and contacts between the various rock types are at least exposed in part. Even here, though, correlation is not easy as, for instance, banded sandstones occur only in the western part and limestone conglomerates seem to occur quite haphazardly throughout the area. The succession here is:-

2. Grey Shales (and Shaly Sandstones?)

← d8 Irregular feldspathic and highly tuffaceous conglomerate
800m N.N.E. of Blomli

S11 Another photograph of a very typical tuffaceous conglomerate. Identical conglomerates occur also west of the Ravana River and also west of the Bogo River. The white colour is due to the weathering of feldspar, reflecting the highly feldspathic nature of the rock.
450m. N.N.W. of Blomli →

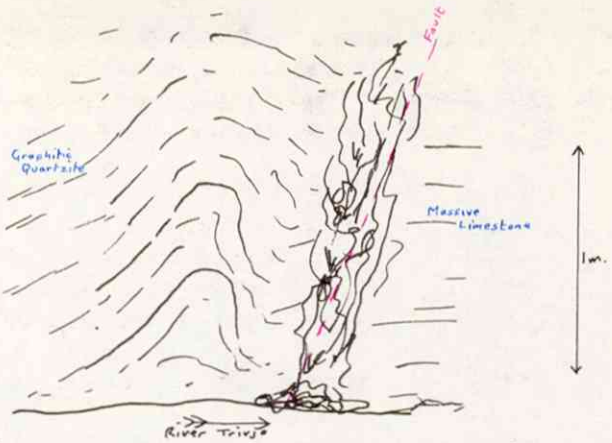
← d13. Exposure of tuffaceous conglomerate, showing varying degrees of angularity of the pebbles, and their irregular size, well brought out by weathering.
550m. N.E. of Blomli

S15. Exposure of Massive Conglomerate revealed under the roots of a fallen tree. The irregular nature of the conglomerate can be seen. Rock fragments of jasper and greenstone are included, as well as those of tuffaceous material
400m. N.N.E. of Blomli →

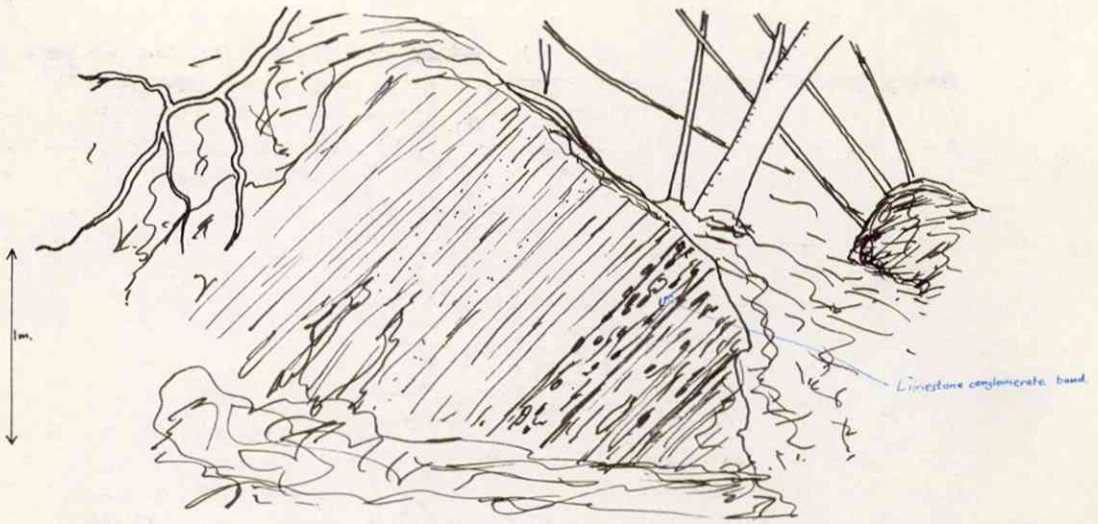
1. Massive Conglomerate - This conglomerate is highly tuffaceous and very similar to the tuffaceous conglomerates and grits of the western areas. Many outcrops of this conglomerate occur in the area, particularly just west of the Trivja River, North of Blomli, where is has horizontal thickness perpendicular to the strike of some 600m. No outcrops of this conglomerate were found along the Rausaa River, though some were found in the scrubland 130m. East of the river, due East of Prestseterasaen, and at various localities further West. The conglomerate is very variable, being coarse-grained in places, with boulders 30 cm. in diameter, whilst elsewhere it might be quite fine-grained, with fragments less than 2mm. in diameter. There is not, generally, so much gritty matrix present as further West and non-tuffaceous pebbles are more common, though the typiceal tuffaceous conglomerate still predominates. The matrix is, as before, irregular and agglomeratic. The fragments show all degrees of angularity from sharply angular to well rounded, even in the same exposure. Greenstones and other volcanic rocks are often quite common in the conglomerates, as is jasper, as well as the typical tuffaceous rock fragments. Limestone fragments, particularly the distinctive pale grey marble, with its irregular weathering, are very common in parts, as in outcrops 650m. North-North-East of the Rausaa bridge, where certain bands, 1m. or so thick, of pale blue-grey limestone comglomerate outcrop. The finer-grained conglomerates are dark green in colour when fresh, with well rounded fragments of jasper, pale quartzite, greenstone, as well as other unrecognisable rocks. These finer-grained conglomerates frequently show banding, as 500m. North-North-West of Blomi, showing that the conglomerates dip steeply northward. The gritty matrix of the coarse tuffaceous conglomerates is also sometimes banded, giving a similar bedding-plane orientation.

The top of a southward facing slope, 200m. North East of Blomli, shows a typical tuffaceous conglomerate, fine-grained, parts of which are banded, with the bands having been displaced along numerous small irregular faults of about 1cm. throw. Half-way down this bank the conglomerate becomes finer grained and includes a thin shaly layer near its southern boundary. A few metres further West, along the strike, large boulders 15cm. or so in diameter, can be seen within the conglomerate. Here also it becomes finer-grained to the South, and the base of the conglomerate can be seen near the bottom of the bank, where it grades into a limestone conglomerate, pale grey in colour, grystalline in part, about 2m. thick, which passes southward into grey shales, these being found at the very base of the slope. Crinoid ossicles and some possible Nautiloid cross-sections were found in the limestone conglomerate.

Banded sandstones occur, apparently within the conglomerate. They are finer-grained than the banded sandstones and grits under the Bogo Bridge, and do not appear so feldspathic. They have a restricted distribution, only being found East of the Rausaa River and West of the north-south valley due North of Blomli. Good exposures occur 120m. due North of Blomli and for 250m. West of here along the strike. The sandstones occur here in bands, 2cm. or so thick: they are generally fine-grained, though gritty and agglomeratic bands also occur. In colour they are brownish or greyish-green and show graded-bedding younging to the South showing that they are inverted.



d7 Faulted contact of massive limestone and graphitic quartzite, the letter showing a contorted 'parting' near the fault. W. bank Trivja River, N. of Blumli



e10. Sketch of an outcrop of gritty sandstones and grey shales, with a limestone conglomerate band near the base. The sandstone bands show inverted graded-bedding. 450m N.E. of the Ravana Bridge. Looking eastwards

On a southward-facing hillside, 250m. North of the old Blomli Road West of Blomli, the sandstone bands are thicker and less obviously banded. Here the sandstones are grey in colour and again show graded-bedding youging to the South. Grey shaly bands and limestone conglomerate bands occur amongst the sandstone, as well as more gritty bands. The limestone conglomerates here are unfossiliferous and occur as bands about 30cm. thick; they are again pale grey in colour and similar to limestone conglomerate bands found further South and East. These banded sandstones are all, presumably, within the massive conglomerate succession.

Between the hilltop to the North and the old Blomli Road to the Souther there is a marshy belt 150m. wide, with no outcrops. Just South of this belt an isolated exposure of a pale grey crystalline limestone was found. This limestone or marble is identical to the marbles found further West, in most respects, and also has conglomeratic layers. But here there are, in addition, vague suggestions of fossils and in fact this limestone is also quite similar to that found on the South bank of Storbuvatnet. Just to the South of this outcrop are outcrops of pale grey limestone conglomerates, further outcrops occurring along the strike, both to the East and West, just North of the old Blomli Road from the River Rauaaa to Blomli itself. To the South the limestone conglomerates pass conformably into the succeeding Grey Shales.

2. Grey Shales - These shales occur to the South of the limestone conglomerates, which apparently form the top of the massive conglomerate division. They are found continuously from the Trivja River in the East to the Rauaaa River in the West in a belt some 150m. wide, to the South of which is the Svartvatnet Depression. The shales are very well exposed in the Rauaaa River, which has cut a shallow gorge through the shales. Here they are bluish-grey or grey in colour, with abundant brown specks after pyrrhotite on their bedding planes. That the parting is true bedding is shown by silty bands, and also by the occurrence of thin pale grey limestone conglomerate bands. No fossils were found in the shales.

South of the Svartvatnet Depression grey sandy arenaceous shales appear. They are identical to the shaly sandstones West of the Rauaaa River, with rucked cleavage planes, not parallel to the bedding, and with conglomerate and gritty bands. Good exposures occur around Rauaatj. Further exposures were examined, just East of the Rauaaa River and although the mapping was not continued further eastwards than this, the shaly sandstones appear to extend at least as far eastward as the northward flowing tributary stream which joins the Trivja River 230m. South East of Blomli. In outcrops near the greenstone hills in the South to the East of the Rauaaa River, banded tuffaceous grits and sandstones occur within the division. These are quite tightly folded with a good cleavage, and with many small faults displacing the bands. These bands are very similar to the banded sandstones found below the Bogo Bridge.

This group of grey arrenaceous shales could not be shown to pass downwards into the grey shales of the North and they may, possibly, have been brought together by a fault, the plane of which follows the Svartvatnet Depression.

INTRUSIVE IGNEOUS ROCKS

Igneous rocks of possibly two varieties have been intruded into the sediments of the Hovin Series in the Svartvatnet Area, forming a number of dyke-like intrusions. One variety appears "doleritic", the other "andesitic" in the hand specimen. However, under the microscope, the groundmass minerals in both cases, as well as the feldspar phenocrysts, have been completely altered, and it cannot be shown what was the original composition of these intrusions, or even whether or not the two "varieties" are of similar rock type. Differences in the hand specimen may well be due to a different state of metamorphism and weathering suffered by the intrusions, although I personally think that the two varieties really are different. The "doleritic" variety was only found west of the Bogo River and north of the Graptolitic Shale. Only isolated exposures were found and it could not be seen whether the "dolerite" occurs as a single sheet-like intrusion, or as a series of such intrusions. The "andesitic" igneous rocks, on the other hand, form a number of intrusions only to the east of the Bogo River. This latter variety is characteristically porphyritic and probably corresponds to the Hølonda Porphyrites mapped by T.Vogt in the Hølonda-Horg area.

"DOLERITE"

This rock was identified in the field as a gabbro because of its dark colour and coarse even-grained texture in the land specimen. However, as the rock occurs as a dyke-like intrusion (or intrusions), it may be better described as a dolerite.

A thin-section showed that this rock has suffered considerable alteration, though it still retains its original texture. Well-shaped crystals of feldspar and augite, occur in a sparse fine-grained chloritic and epidotic "groundmass". The feldspar crystals about 5mm. in length and less than half as wide, although very largely saussuritised, still show albite-twinning. The feldspar remnants are now albitic in compositions, though the original feldspar was probably much more basic. The augite occurs as almost colourless well-shaped crystals, less abundant than those of feldspar, which, under crossed-nicols, show slight zoning. These phenocrysts are usually twinned and have a moderate birefringence, with a 2V of 50° and an extinction angle Z^C of 39°. These values were obtained using a universal-stage microscope. Pale green amphibole - actinolite? - occurs as an alteration product after the augite, forming alteration rims around the augite crystals. Leucoxene, after ilmenite, occurs and secondary epidote and chlorite are very abundant. Small amounts of interstitial quartz, probably primary in origin, suggest that the rock may originally have been a quartz-dolerite. No ophitic texture was seen.

The "dolerite" can be seen to be intrusive at two localities, one just west of the Bogo River, the other 600m. north of the eastern part of Friljøen. At the first of these localities the southern boundary of the "dolerite" is in contact with blue-black slates, the slate appearing somewhat "baked" and the "dolerite" finer-grained at the contact. At the other locality the dolerite is in contact with a similar slaty rock, which here apparently belongs to the Graptolitic Shale Division. The slate again appears baked at the contact, with its shaly parting somewhat contorted. The contact cuts the cleavage of the slate having a similar general strike but dipping at a shallower angle. Only the northern boundary of the dolerite was seen here.

"PORPHYRITE"

At least eight "porphyrite" intrusions occur east of the Bogo River and west of the River Trivja where they form prominent east-west ridges. The largest of these intrusions forms the Granin Ridge south of Storbuvatnet. 300m. south of this ridge is another intrusion, whilst between the two, on the Trivja River, is another smaller intrusion (intrusions). To the south further "porphyrite" intrusions occur, one

626. 'Porphyrite' exposure revealed by fallen tree on N. face of the Granin Ridge, overlooking Storbuvatnet.

628. Irregular contact of 'porphyrite' and brownish-grey shales, apparently 'baked'. N face of the Granin Ridge, overlooking Storbuvatnet.

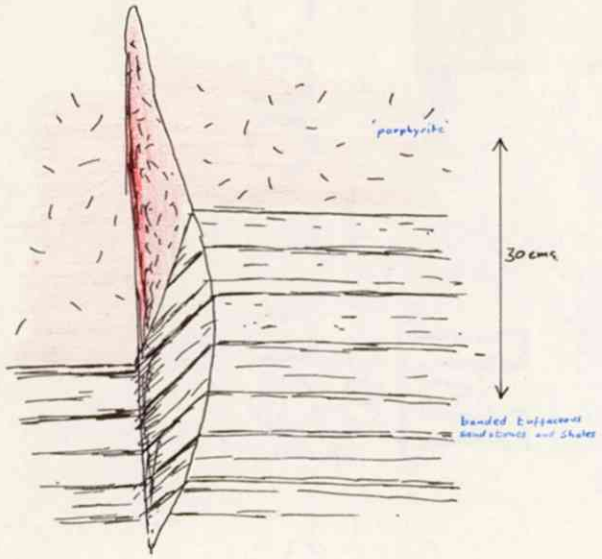
200m. north of Blomli, another just to the west of this intrusion, whilst still further west, just north of the Svartvatnet Depression, and three other intrusions, two forming the ridges of Prestseteraasen and Svartvassaasen, and the other a low ridge just west of Svartvatnet. These intrusions appear to have almost vertical sides, forming dyke-like bodies, though whether they were intruded as dykes after the folding of the sediments or as sills before the folding took place is not known. All these separate intrusions appear to be formed of the same general rock type, which is characteristically strikingly porphyritic, with well-shaped phenocrysts up to 8mm. in length of feldspar and pyroxene in a dark greenish or brownish fine-grained groundmass. On weathered surfaces the feldspar phenocrysts stand out as white laths on a dark background. The phenocrysts may be very abundant, forming up to 50% of the rock total, or may be entirely absent. When abundant they sometimes show suggestions of flow structures, as in outcrops on the north side of the Granin Ridge. In parts of the intrusions, particularly Prestseteraasen, the whole rock is coarse-grained and has a granitic texture. Besides the massive porphyritic and non-porphyritic rocks occurring in the intrusions, there are also shaly patches which appear to grade into the more normal phorphyry. These shaly patches are dark grey in colour and very irregular in form, with their shaly parting usually being sub-parallel to the margins of the intrusions. They possibly represent inclusions of country rock with the "porphyrite".

Near the fault-contacts of the "porphyrite" on the west bank of the River Trivja the rock is more green in colour with bright-green altered feldspar phenocrysts. This greater alteration is probably due to a dislocation metamorphism produced by the faults here.

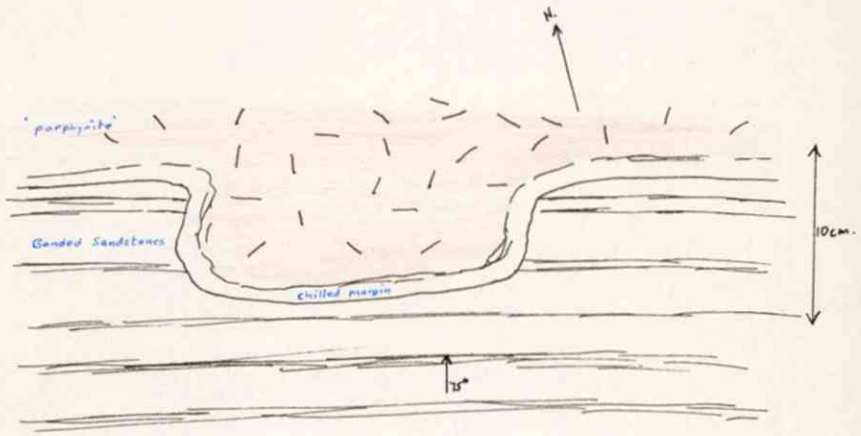
A thin-section of the "porphyrite" taken from the intrusion north-west of Blomli showed that it has been much altered, although the original texture is preserved. The tabular feldspar phenocrysts, up to 5mm. long, are almost completely saussuritised, though they still show "ghosts" of albite twin lamellae. They make up to 50% of the rock as seen in the thin-section. The less abundant pyroxene phenocrysts are also well-shaped and of similar size to those of the feldspar. In ordinary light the pyroxene is almost colourless. It shows bright interference colours under cross nicols, with a 2V of 46° and an extinction angle Z^C of 40°, showing that it is an augite. The phenocrysts are usually twinned, sometimes showing lamellar-type twinning. In the centres of the phenocrysts the augite is surprisingly fresh, though around the margins it has been altered to green chlorite or pale green amphibole, forming alteration rims. Veins of chlorite and epidote commonly traverse the crystals. Small crystals of leucoxene after ilmenite also occur. The groundmass is very much altered, now being an aggregate largely consisting of epidote, chlorite and sericite. None of the phenocrysts show any signs of zoning. The relative abundance of feldspar suggests that the rock may originally have been andesitic in composition.

In the two thin-sections examined, the "porphyrite" and "dolerite" differ apparently only in the proportion of fine-grained groundmass and the slight differences in the optical properties of the pyroxenes.

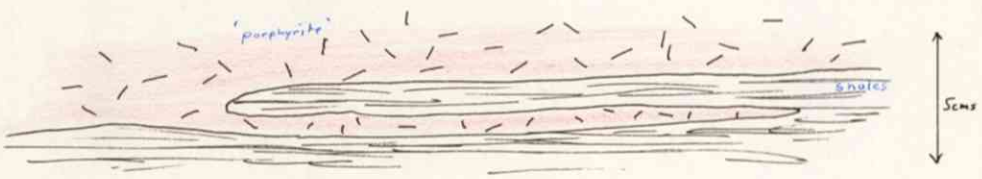
Epidote veins and quartz and calcite veins can usually be seen crossing the porphyrite exposures and at two localities thicker veins were found containing slender prismatic crystals, 2cm. or so in length, of a pale brown mineral in a quartzose matrix. This mineral was found to be clinozoisite. One of these veins was found at the western end of Prestseteraasen whilst the other occurs at the western end of the intrusion north of Blomi, where a thin vein of porphyry 10cm. thick cuts the country rock.



← 940. 'Porphyrite' intrusion cutting banded sandstones and shales which young to the S. though they dip to the North.
S.E. side of Svartvassaasen.



E14. Irregular southern contact of the 'porphyrite' with banded sandstones. The 'porphyrite' has a chilled margin, about 1cm. wide, which is glassy in places. N.W. of Bloml.



934. Veinlet of 'porphyrite' penetrating tuffaceous shales. Southern contact of the Svartvassen intrusion, N. of Svartvatnet.

The contacts of the "porphyrite", when exposed, were seen to be chilled, sometimes having a glassy margin 5mm. wide, as seen north of Blomi. Near the contact the "porphyrite" is usually non-porphyritic for a few centimetres, while the country rocks appear "baked" for a centimetre or so. The boundaries of the intrusions are not concordant with the bedding of the country rocks, and at numerous localities could be seen to be definitely intrusive, not only cutting the bedding but also giving off small veinlets penetrating the country rock for a short distance.

Only the northern boundary of the Granin "Porphyrite" is exposed, where it is in contact with grey shales, the contact being very irregular. In the other intrusions only the southern contact is usually well exposed. The intrusive nature of the porphyrite can be seen north of the Svartvatnet Depression where it is in contact with banded sandstones and shales. These banded rocks, which are inverted, younging to the south, have their bedding cut by the southern boundary of the porphyrite. This could be seen in numerous exposures, and examples are shown in the accompanying sketches. The northern contacts of the Svartvassaasen and Prestseteraasen intrusions are exposed at a few localities. In both cases the "porphyrite" is in contact with baked grey shale.

Steep N face of Prestseteraasen, 'porphyrite'-shale contact.

Just to the N. forest cut down. No outcrops here.

Looking westwards, with the Ravaan valley in the middle-distance.

STRUCTURE

The Svartvatnet Area is bounded on the north and south by the Greenstone Faults, as already described, the Hovin Series being down-faulted in between. In both the north and south outcrops, as far as could be determined, the Storen greenstones dip northwards at about 70° and the Hovin sediments generally have a similar dip.

North of the Svartvatnet Depression the Hovin Series dips northwards at between 45° and 80°, and strikes 070° to 120°, a variation of 50° apparently due to a slight "wrinkling" of the bedding. The evidence of graded-bedding shows that most of the beds, if not all, are inverted, younging to the south and to the north of this Depression the beds appear to form part of inverted limb of a large fold. Just to the north and east of Friljóen tight minor-folds can be seen in the Banded Grits and Shales Division exposed here with a well developed cleavage, apparently parallel to the general bedding. Also in this area the rocks are crossed by innumerable irregular quartz veins, suggesting a more intensive tectonic activity here. The very local development of these minor folds suggests faulting as a possible cause, though no direct evidence of any faulting was found here.

Numerous faults were found crossing the Hovin outcrops. The major faults appear to be strike-faults, with associated minor dip-faults. Some of the faults which have already been described, could be seen in the field, three being seen along the Trivja River and three others along the Bogo River. Other faults have been drawn on the accompanying geological map which, although not actually visible in the field, have their presence indicated by other evidence, such as the displacement of beds along normal to their strikes. Undoubtedly numerous other faults also exist, and only the apparently more obvious were put on the map. The broken lines of the faults on the map shows that the positions of these faults could not be accurately determined.

A major fault follows the Svartvatnet Depression, as indicated by the differences between the characters of the rock types on either side of the Depression and also the Depression itself. North of this fault the beds show almost no evidence of minor folding, while to the south minor folds and "rucked" cleavages abound, though the rock types themselves are not dissimilar.

West of the River Bogo most of the faults shown effect the Graptolitic Shale Division, as this Division provides a good marker horizon. To the east this horizon was not found and faults are not so obvious, most of those drawn here having little evidence for their existence other than the lack of any other evidence to suggest a reason for the present distribution of the rock types. Thus a fault is placed between the Massive Conglomerate Division and the Grahitic Quartzite on the Trivja River. Dip-faults east of the Bogo River, as to the west, explain the relative displacement of the rock types normal to their strikes, although again no direct evidence for their existence was found. A number of low-lying north-south belts occur in the area, and it seems likely that some of the faults have been partly responsible for these.

Crossing the Bogo River sough of the Bogo Bridge fault has been drawn which again follows a line of marshy ground. This is a major dip-fault which has resulted in the rocks to the east being shifted northwards relative to those in the west. In none of the faults shown however, could the actual displacements of the beds be determined.

South of the Svartvatnet Depression the beds possess a slaty cleavage which is not normally parallel to the bedding. In many outcrops the bedding could be seen to be strongly oblique to the cleavage, which dips from 60° to 80° north and strikes 095° to 120°, very similar to the bedding orientation of the beds to the north. Conglomeratic patches in the southern part of the area give bedding-plane measurements very similar to those of the cleavage. This cleavage shows slight "rucking", indicating a "brittle" movement later than that joining the cleavage. The readings of the cleavage and bedding obtained were plotted on a stereogram, but insufficient data made any conclusions from the resulting distribution impossible.

It is suggested here that these cleaved beds may represent the centre of a syncline the inverted limb of which lies to the north, the right-way-up limb being cut-out by the southern Greenstone Fault. The position of the possible axis of this fold could not be determined.

CORRELATION OF BEDS WITHIN THE SVARTVATNET AREA

AREA WEST OF THE BOGO RIVER	AREA BETWEEN THE BOGO AND RAUAAA RIVERS	AREA BETWEEN THE RAUAAA AND TRIVJA RIVERS
?	?	?
	4. Grey Shales and Arenaceous Shales.	4. Shaly Sandstones
8. Grey Shales, with pyrrhotite specks.		3. Grey Shales
7. Banded Grits and Shales	3. Banded Grits and Shales.	Banded Sandstones
6. Massive Conglomerates and Agglomeratic Grits.	2. Tuffaceous Conglomerates and Agglomeratic Grits.	2. Massive Conglomerates.
5. Graptolitic Shale.	1. Pale Grey Marble.	?
4. Impure Limestones, Mudstones and Shaly Breccia.	?	
3. Agglomeratic Grits. (Pale Grey Marble).		Graphitic Quartzite.
2. Blue-black Pyritous Slate.		Green-grey Limestone.
1. Massive Conglomerate.		Tuffaceous Series.
?		Purple-agglomerate.
		Purple-banded Shales
		Graptolitic Shale.
		Fossiliferous Limestone.
Break	Break	Break
Støren Greenstones	Støren Greenstones	Støren Greenstones.

STRATIGRAPHICAL CORRELATIONS

1. Within the Svartvatnet Area

As has already been mentioned, a major difficulty within the Svartvatnet area is the working out of the relationships between the rock types within the Hovin Series. This is due mainly to the lack of exposures and the presence of faults. Also the general absence of fossils means that the correlation has to be based largely on lithology. The accompanying table, which outlines the conclusions reached, is based on the assumptions that the beds are all inverted and that the succession is in correct stratigraphical order, from north to south. It is by no means certain that these two assumptions are valid, as strike-faulting, which has definitely taken place, may have resulted in the repetition of rock types, and possibly isoclinal folding may have caused a similar effect. The banded beds all show graded-bedding, suggesting younging to the south, though this may not be true throughout the area.

In the table the numbered beds are those that occur throughout the area concerned, whilst those underlined can be used for correlation purposes. The rocks of the Støren Series are sufficiently distinctive not to be mistaken for the Hovin Series. The rocks within the Hovin Series, however, cannot easily be correlated.

West of the Bogo River the lowest Hovin rock exposed is apparently the Massive Conglomerate. This is very similar to the conglomeratic division higher up the succession, and may, in fact, be a repetition of this higher division produced by faulting. The succeeding slate may also represent a more metamorphosed equivalent of the graptolitic shale similarly repeated and the intervening agglomeratic grits are identical to those on top of the graptolitic shale. The thin division of a variety of rock types north of the graptolitic shale on the Bogo River was only found at one outcrop, where it appears to occupy a fault zone. The Graptolitic Shale is very useful for correlation west of the River Bogo, but the only possible equivalent further east is a single outcrop on the west bank of the Trivja River.

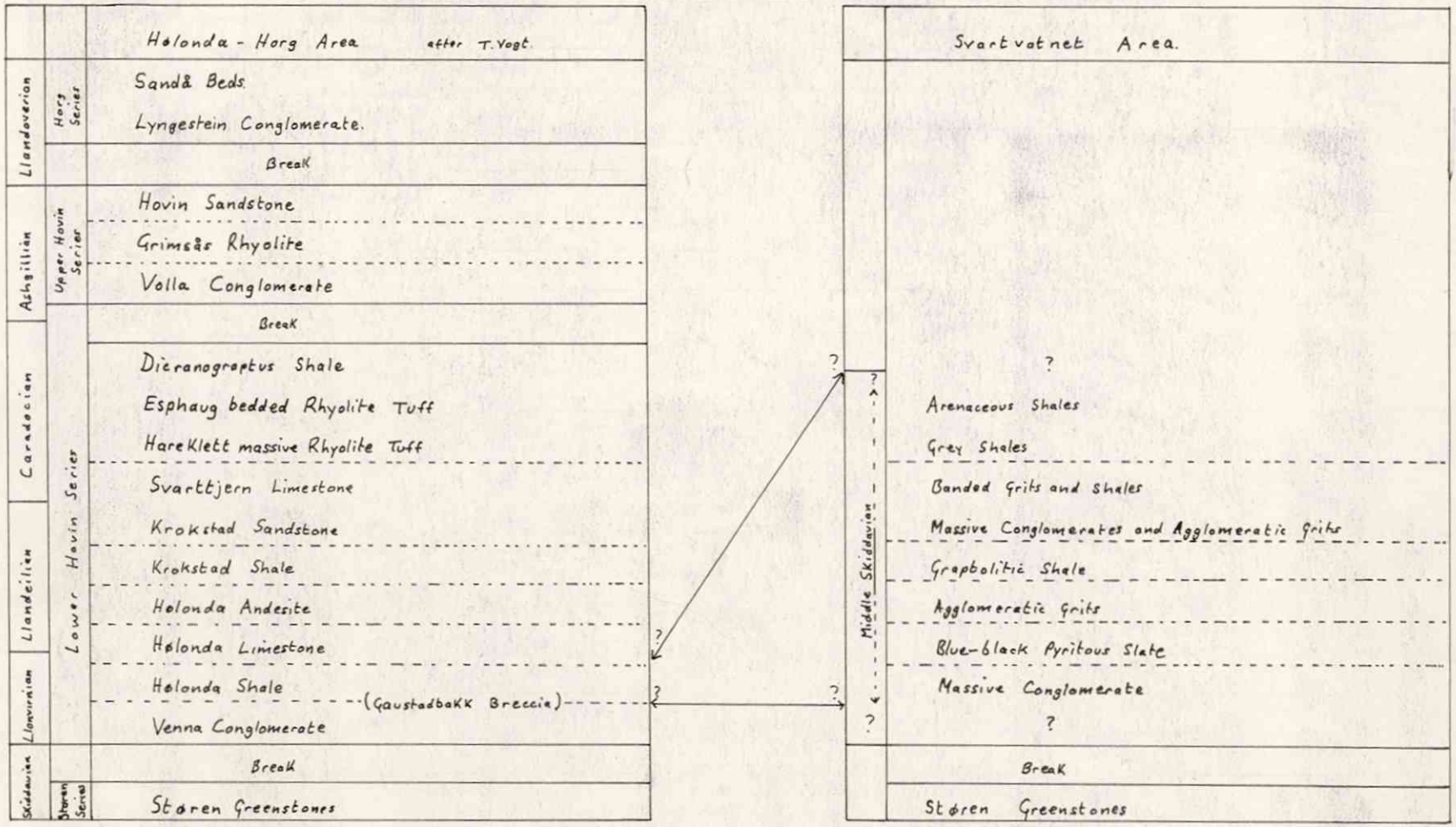
The Massive Conglomerate and Agglomerate Grits above the Graptolitic Shale is the only division that can definitely be found throughout the Svartvatnet Area. The succeeding Banded Grits and Shales are found east of the Bogo River but not east of the Rauaas River, though here they may be represented by the Banded Sandstones. However along the Trivja River no Banded Sandstone Division occurs. The grey Shale here succeeds conformably the Massive Conglomerates, with a thin limestone conglomerate band between the two. Identical limestone conglomerates appear within the Banded Sandstones which are found west of the Trivja River and also occur as bands within the Grey Shale Division.

The Grey Shales of the eastern area were not definitely found west of the Rauaaa River. The highest division, of Arenaceous Shales, however, was found in both the two eastern areas, this division being readily recognisable by possessing a cleavage which is not normally parallel to the bedding. The southern-eastern exposures of these beds may possibly be the folded counter-parts of the Banded Sandstone Division to the north-west. No limestone conglomerate bands occur within the Arenaceous Shales.

The Pale Grey Marble which occurs in all three divisions cannot be used for correlation purposes as it occurs as restricted lenses at different stratigraphical levels.

East of the Rauaaa River and north of the Massive Conglomerate Division various distinctive rock types occur which cannot be related with each other or with any other rocks within the Svartvatnet Area, though the graptolitic shale here may well correspond to the Graptolitic Shale on the Bogo River and it is possible that the fossiliferous limestone is a

Attempted Correlation between the Hølonda-Horg and Svartvatnet Areas



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different facies of the limestone conglomerate found to the south. However, none of these rock types can be put in any definite stratigraphical order.

2. Outside the Svartvatnet Area

The value of the map work carried out would obviously have been increased if the rock types found could be correlated with known rock types outside the Svartvatnet Area. However this has not been proved possible.

The rocks of the Støren Series are the only rocks mapped that can definitely be correlated with similar rocks in other areas, they can be traced throughout the Trondjeim region providing a marker-horizon at the base of the younger Ordorvician rocks of the Hovin Series, in which Series the sediments of the Svartvatnet Area are considered to belong. This Series has been mapped by T.Vogt in the Hølonda-Horg area some 10 Km. to the east. The succession in this area is given in the accompanying table, with the succession in the Svartvatnet Area alongside for comparison. As can be seen the Svartvatnet sediments cannot be fitted into Vogt's succession. In an area just north of Fieldheim, Brian Chadwick mapped a series of sediments lying on top of the Støren Greenstones, presumably belonging to the Hovin Series. The sediments here consist of greenish sandstones and shales, with conglomerates, resting on a massive boulder-conglomerate consisting almost entirely of greenstone and jasper fragments, of all degrees of angularity, resting on the Støren Series. The contact between the Støvens and the Hovins here is a sedimentary one, not a structural one. These sediments presumably form the basal beds of the Hovin Series in this area, with the massive boulder-conglomerate being the lateral equivalent of the Venna Conglomerate in the Horg area and the Stokkvola Conglomerate found elsewhere in the Trondheim region. The Hovins mapped by Chadwick could not be matched with any of the sediments of the Svartvatnet Area and presumably the Hovins north of Fieldheim are older in age than those to the south.

The lowest reliable fossiliferous horizon found by Vogt in the Horg Area was the Hølonda Limestone which he considers to be of Upper Llanvirnian and Lower Llandeilian age, whilst higher up in his succession the Dicranograptus Shale is of Caradocian age. In the Svartvatnet Area the graptolitic Shale Division is of Middle Skiddavian age, and so is older than the Hølonda Limestone, yet must be younger than the Vennan Conglomerate. The whole of the Svartvatnet sediments must presumably fit in somewhere between the Hølonda Limestone and the Vennan Conglomerate. Further work is needed in the area to fix the position accurately.

The Middle Skiddavian age of the Svartvatnet Graptolitic Shale suggests that the Vennan Conglomerate is at least as old as early Skiddavian, placing the Støren Greenstones as earliest Skiddavian or even Tremadocian in age. This is a somewhat older age than has previously been suggested for the Støren Series.

The porphyrite intrusions of the Svartvatnet Area probably correspond to those of the Hølonda-Horg area, where they are considered by Vogt to be of similar age to the Hølonda Limestone. This supports the suggestion that the Svartvatnet sediments are older than the Hølonda Limestone, as the porphry intrusions are definitely younger than the Banded Grits and Shales Division.

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BRIEF SUMMARY OF THE GEOLOGICAL HISTORY OF THE AREA

The oldest rocks exposed in the area belong to the Støren Series. These rocks include spilitic pillow lavas, with associated jasper and tuffs, suggesting a submarine formation.

In other areas the Støren Series is followed unconformably by the Hovin Series, the basal bed of which is usually a massive conglomerate composed very largely of greenstone fragments, obviously locally derived. This suggests that before the Hovin Series was deposited the region was uplifted and subjected to sub-areal denudation.

In the Svartvatnet Area the varied rock types, all probably marine, indicate a varying sedimentary environment. Quiet tranquil conditions, with slow sedimentation, are represented by the pyritous slates and graptolitic shales, whilst, in contrast, the massive conglomerates suggest very rapid deposition. The highly tuffaceous nature of these conglomerates indicates the close proximity of volcanic eruptions, which were possibly sub-areal. The banded tuffaceous grits and shales may represent repeated eruptions, or, possibly, successive turbidity currents. The other Hovin rocks in the area, the various limestones and shales, are all apparently marine, and there is no evidence of any break in deposition.

After the Hovin sediments exposed in the area were deposited, the next event to take place was probably the intrusion of the igneous porphyries. Later in time, during the Caledonian Orogeny, the area was subjected to folding, with the development of a cleavage in certain beds. The "rucks" in the cleavages were obviously formed at a slightly later date. Most of the faulting in the area is definitely later than the folding, though how much later cannot be determined.

The Pleistocene Glaciation is the only other geological event which can be recognised at present in the area, and is very largely responsible for the present topography of the area, though this has been modified by subsequent denudation.

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REFERENCES

Carstens, C.W., 1952 Geologisk Kart over Løkken-Feltet.

Holtedahl, O., 1960 Geology of Norway, N.G.U. 208.

Kiaer, J., 1932 The Hovin group in the Trondheim area. With palaeontological contributions by O.A. Høeg, A. Hadding, F.R.C. Reed, A.F. Foerste, T. Strand, L. Størmer and the author. Vid. Akad. Skr. 1932,No.4.

Monsen, A., 1937 Die Graptolithenfauna im uniteren Didymograptusschiefer Norwegens. N.G.T. 16, p.57.

Vogt, Th., 1945 The geology of part of the Hølonda-Horg district. N.G.T. 25, p.449.

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Also to Misses Sylvia and Sheila Blake, who very kindly and patiently typed this report.

27th January 1961

THE GEOLOGY of the FJELDHEIM AREA

Scale

200 100 0 500 1000 m

NORTH

URVATNET

TRIVJA

LOKTJ

Hematitic Shale

BRATHUSTJ

MJOVATNET

LERTJ

FJELDHEIM

PRESTBUVATNET

STORBUAN

STORBUVATNET

GRANIN

Purple Agglomerate

Graphitic Quartzite

R. TRIVJA

R. BOGO

BOGO BRIDGE

RRAUÅA

FRILSJØEN

SVARTVASSÅSEN

PRESTSETERÅSEN

SVARTVATNET

BLOMLI

RAUÅ BRIDGE

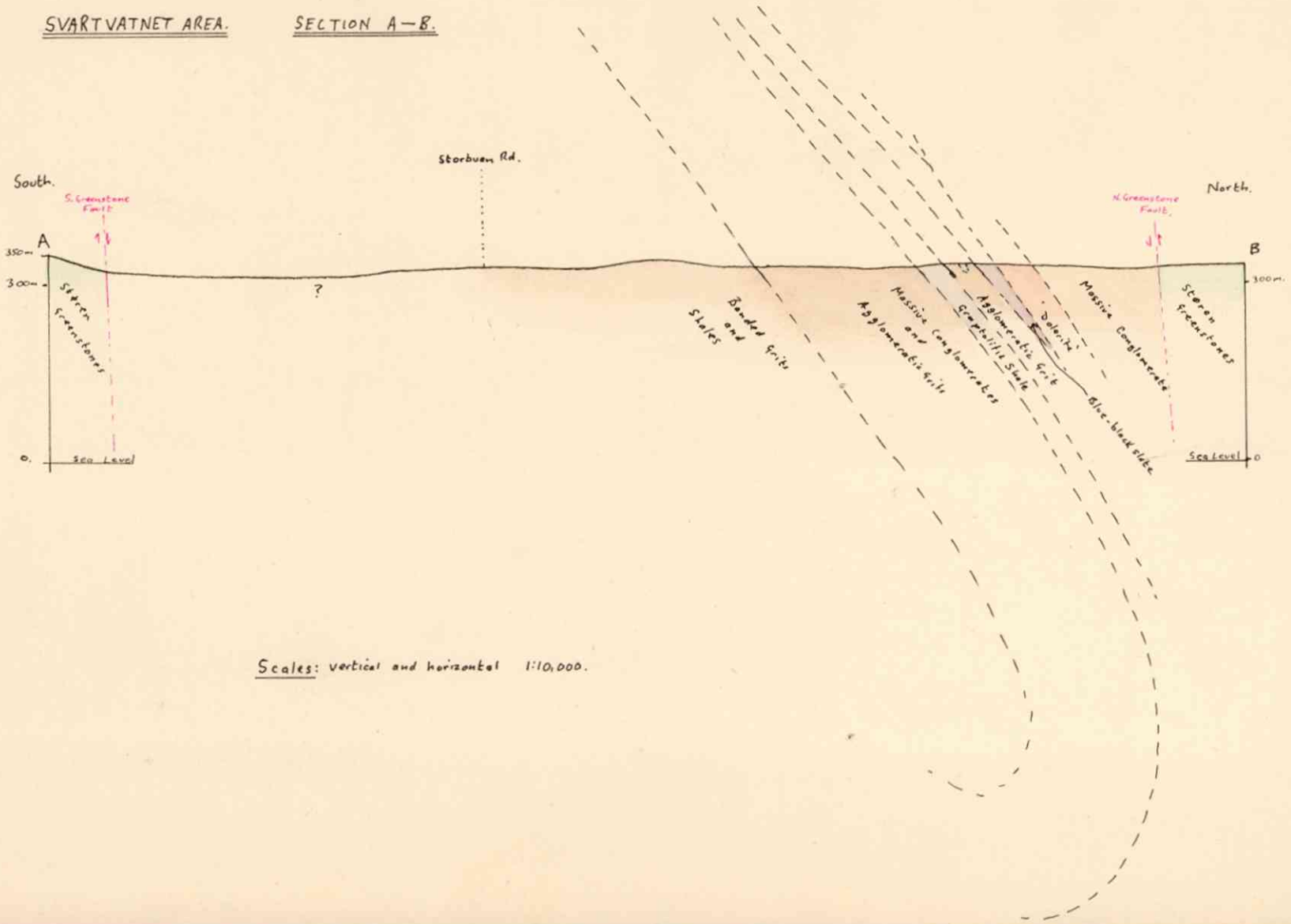
RAUÅTJ

LEGEND

- Massive Conglomerate & Agglomeratic Grits
- Graptolitic Shales
- Agglomeratic Grits
- Blue-black Slate
- Massive Conglomerate
- Grits, Sandstones, & Banded Shales
- Basal Conglomerate
- The Støren Series
- Purple Banded Shales
- Limestone
- Tuffaceous Group
- Arenaceous Shales
- Grey Shales
- Limestone Conglomerate
- Banded Sandstones
- Banded Grits & Shales
- Recent
- "Porphyrite"
- "Dolerite"
- Dykes
- Gabbro
- Faults
- Angle of Dip
- Cleavage

D.H.BLAKE & B.CHADWICK MAY 1961

SVARTVATNET AREA. SECTION A—B.



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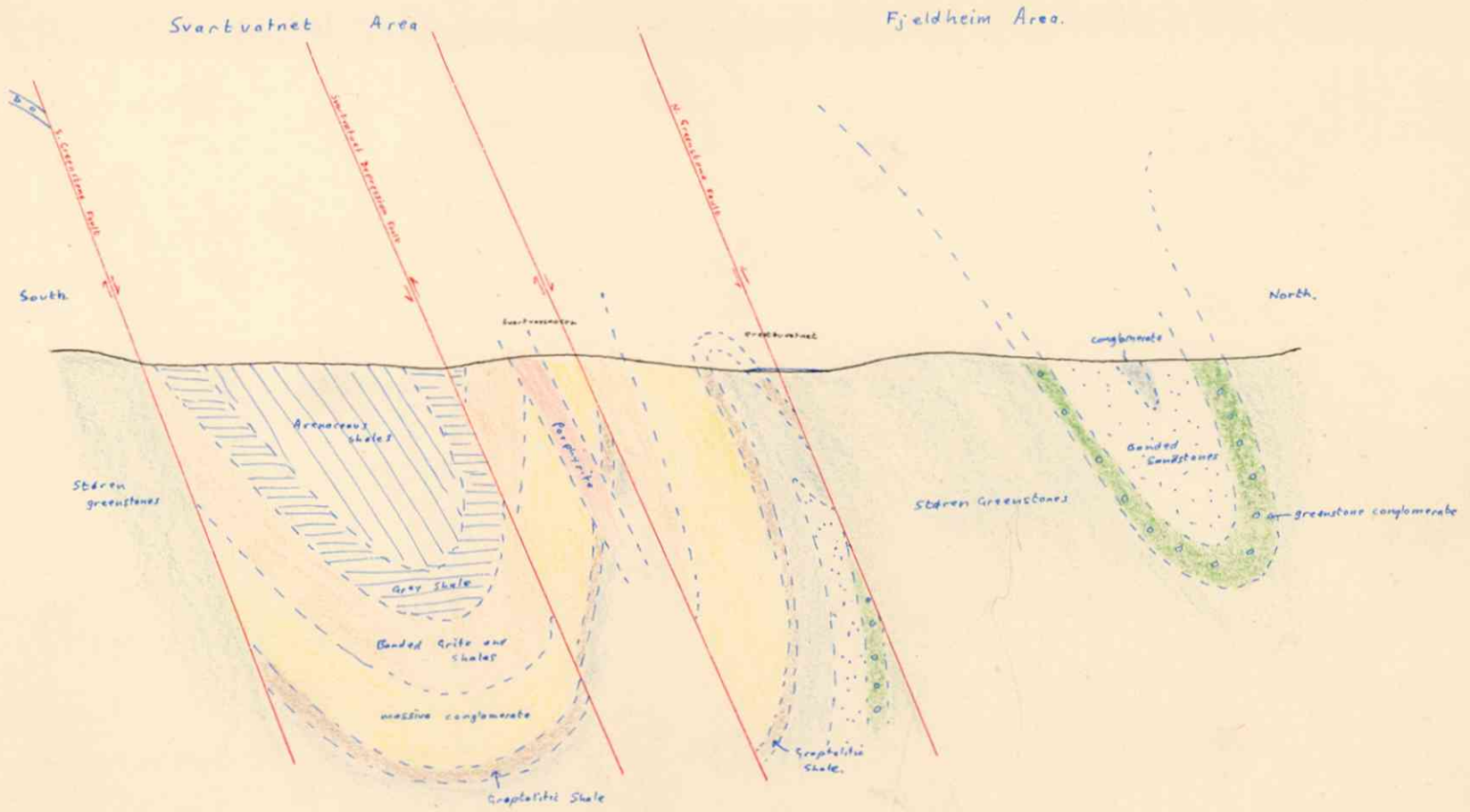

Hypothetical section across the Svartvatnet and Fjeldheim Areas

Sketch-Section drawn along a N-S. line a few metres east of the Bogo Bridge
Length of section about 8. Kilometres.

D.H.B.