MEDDELELSER OM GRØNLAND
UDGIVNE AF
KOMMISSIONEN FOR VIDENSKABELIGE UNDERSØGELSER I GRØNLAND
Bd. 135 · Nr. 7

THE GEOLOGY AND MINERALISATION OF THE MESTERS VIG AREA, EAST GREENLAND

Part I
GENERAL GEOLOGY

BY
J. BONDAM

WITH 3 FIGURES IN THE TEXT

Part II
BLYKLIPPEN OCCURRENCE, STRUCTURE AND ITS INFLUENCE ON ORE DEPOSITION

BY
H. BROWN

WITH 11 FIGURES IN THE TEXT

KØBENHAVN
C. A. REITZELS FORLAG
BIANCO LUNOS BOGTRYKKERI A/S
1955

PART I

GENERAL GEOLOGY

BY

J. BONDAM

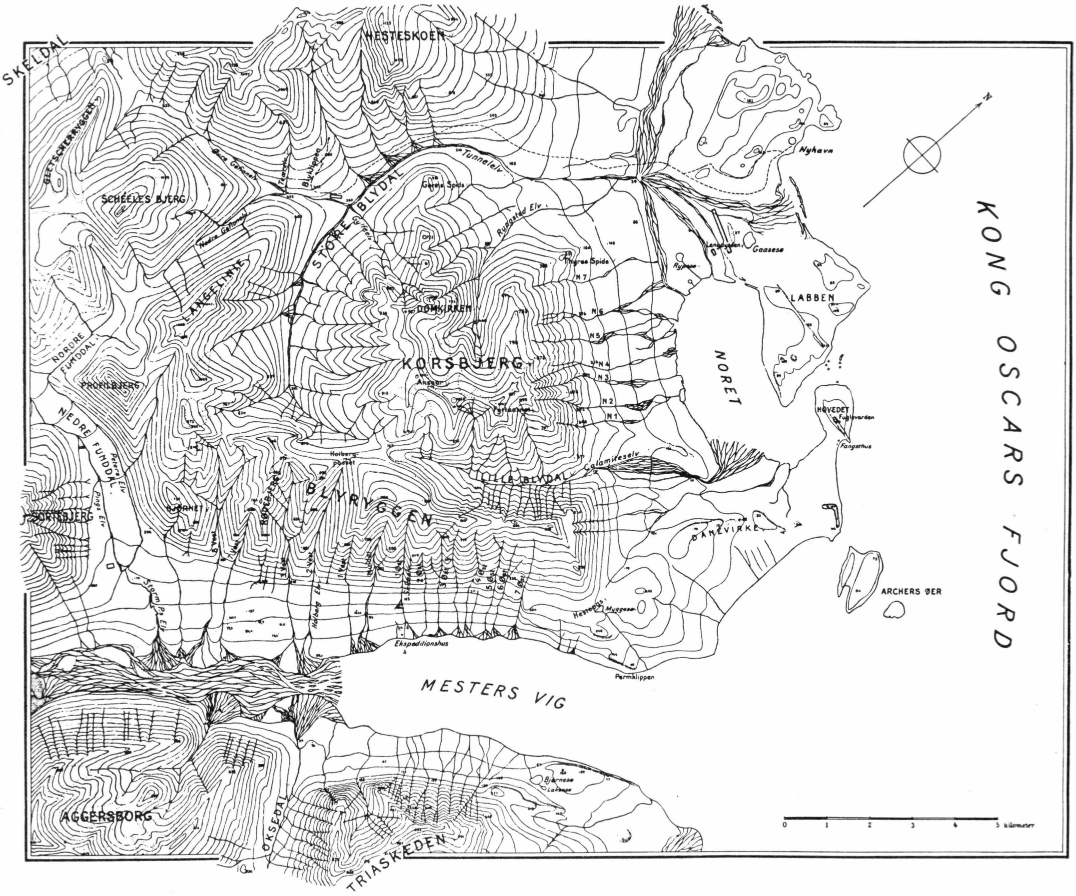

Fig. 1. Topographical map of the Mesters Vig Area, East Greenland. Courtesy Northern Mining Company, Copenhagen.

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ACKNOWLEDGEMENTS

This publication has been made possible through the courtesy of the Northern Mining Company in Copenhagen.

We wish particularly to express our thanks to Mr. V. Brinch, Director of the Company, and to the Technical Committee for their readiness and cooperation in this matter. Our best thanks are also due to Miss R. Hansen, and to Mr. V. Kristensen, who prepared the drawings.

Copenhagen, November 1954.

H. Brown
J. Bondam.

PREFACE

An account of The Geology and Mineralisation of the Mesters Vig area will be best expressed by dividing the descriptions into three different parts.

Part I includes the general geology of the Mesters Vig area. It has been prepared by J. BONDAM, Geological Survey of Greenland, Copenhagen. The description is a brief summary of the stratigraphy within the area, as it has been established by E. WITZIG, Switzerland, former geologist of the Northern Mining Company[1]).

To this summary new field and laboratory observations have been added.

The geological map has been published through the courtesy of the Northern Mining Company, Copenhagen.

Part II deals with the structural relations of the Blyklippen veins, and their influence on ore deposition. The study has been accomplished by H. BROWN, Northern Mining Company, during the years 1953 and 1954.

Part III will be published later in connection with these two papers. This part will deal with the paragenesis of the ore depositions at Blyklippen.

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[1]) A more detailed account, accompanied by the geological map of the area, by E. WITZIG, is in press (M.o.G. 72. II–5).

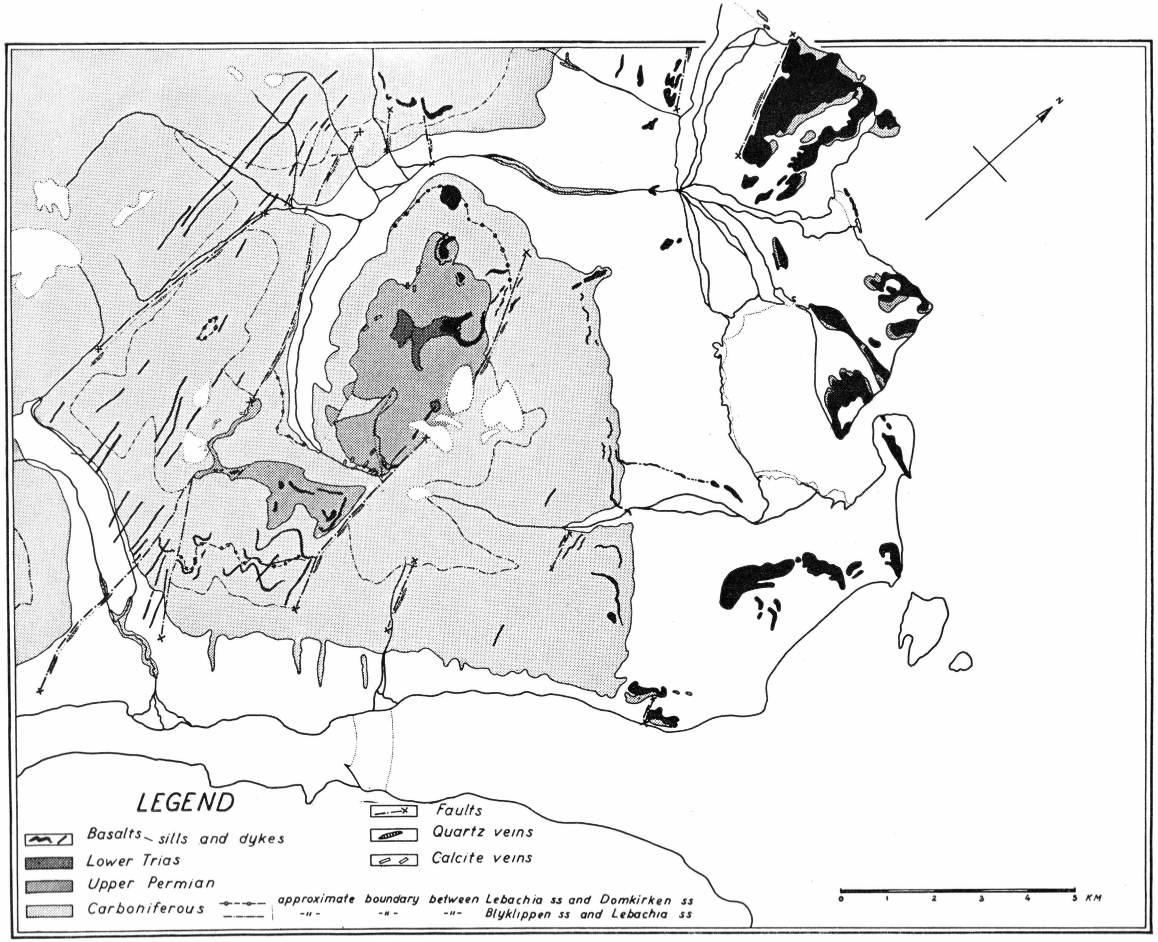

Fig. 2. Geological Sketchmap of the Mesters Vig Area, East Greenland. Modified after E. Witzig. Courtesy Northern Mining Company, Copenhagen.

PART I

GENERAL GEOLOGY

Introduction.

The Mesters Vig area is situated in the NE corner of Scoresby Land, East Greenland, at 72°15′ latitude and 24° longitude. It is bordered to the north and the west by Skeldal, to the east by Kong Oscars fjord, and to the south by Mesters Vig (map Fig. 1).

It is part of a post-devonian "graben", in the sense of Vischer (1943). Faulting and gliding of the Caledonian basement, covered by Devonian and possibly lower Carboniferous sediments towards the east has produced a succession of troughs in which partly marine, partly continental deposits were accumulated during the younger Palaeozoic and Mesozoic times.

In the Mesters Vig area the sediments range from Westphalien (U. Pennsylvanian), to U. Permian/Eo-trias. In several places the sediments are covered by Tertiary basalts, by some, referred to as Eocene (RAVN, 1933, a. o.).

The sediments are separated from the Caledonian range by the post-devonian mainfault (VISCHER, 1943), which runs through Skeldal. North and west of this valley a series of folded dolomites and quartzites, with intrusive granites, the Staunings Alper complex, has been observed and described by FRÄNKEL (1953). The metamorphic series belongs to the upper part of the Eleonore Bay formation.

The faulting in the Mesters Vig area has first been preliminarily described by BIERTHER (1941). BIERTHER distinguished two systems, one which runs parallel with the postdevonian mainfault, and is northerly in direction; the other system runs parallel with the Kong Oscars Fjord Shore, in a northwestern direction. The system of basalt dikes, which intersects the country rock, mainly in the western part of the area, has a northern direction too, but, in general, different from the primary faulting, just mentioned (see p. 16).

E. WITZIG (1954) observed a broad anticline in the eastern Blyryggen range.

Topographically, the country is accentuated by deep-cut glacier valleys, surrounded by steep hills. Towards Kong Oscars Fjord glaciers and melt-water streams have produced an extensive delta of gravel deposits through which only resistant sandstone remnants and basalt flows protrude.

The country is typical for the subarctic tundra, where permafrost has its influence. (For a description of the East Greenlandic tundra, see POSER, 1932).

The permafrost belt continues to a depth of approximately 100 metres from the surface. The lower limit has been observed in a raise at an elevation of 340—345 metres. Lenses of hard, airfree ice are to be seen in cavities and cracks in the rock. The portal at 335 metres is situated below the permafrost.

The talik-layer is from 0.6—1.5 metre thick, depending on the cover. The streams in the area supply enough water the whole year round to allow exploration to be carried on. This water causes considerable icing on roads and installations.

The main ore-occurrence is situated at Blyklippen. Exploration by drilling and tunnelling has been going on here since 1950, while drilling only has been accomplished on the occurrence at Sortebjerg (map, fig. 1).

Previous investigations.

In 1948 members of an expedition, conducted by Dr. LAUGE KOCH, discovered galena-bearing float at several places in the area. During the summer of 1949 most of the now-known mineralized veins were localized, and estimates made as to their economic value gave support to a claim for further investigations (EKLUND, Unpublished Report). During the subsequent seasons of 1950 and 1951, these were concentrated around the Blyklippen occurrence, which, from the start, was considered the best one and the one most easily accessible. Diamond drilling and workings were started in 1951 in the upper parts of the deposit. The promising results justified the execution of still more exploration work (THOMPSON, Unpublished Report). During 1952 a geological map of the area was prepared by WITZIG. Heavy material supply and the construction of an airstrip secured the possibility for year-round operations at Blyklippen.

The studies described in this paper were carried out mainly during 1953. The want of detailed knowledge has made it necessary to concentrate on the known resources, first of all the deposits at Blyklippen.

Outline of the stratigraphy in the Mesters Vig area.

In the following mention will only be made of the stratigraphical units within the area proper. For descriptions of the geology of Scoresby Land and Jameson Land, references are made to the papers of STAUBER (1940), BIERTHER (1941), FRÄNKL (1953) and WITZIG (1951).

The general stratigraphy of the area, accompanied by the geological map, has been worked out by Emil Witzig, who has proposed the subdivision in the stratigraphical scheme for local use. This division is only very preliminary. Further references are made to the forth-coming publication by E. Witzig (MoG 72. II-5).

Formations.

Tertiary (Eocene)		effusives	sills and dykes
Lower Trias (Eotrias/Ophiceras beds)		marine	sandy and marly shale
	+++++++++	+++++++++	basal conglomerate
Upper Permian (Zechstein)		marine	sandy and limy shale
	+++++++++	+++++++++	basal conglomerate
Upper Carboniferous	Domkirken series	continental	red arcose
(Westphalien-Stephanien/Pennsylvanian)	Lebachia series	limnic esturine	sandstones with plant remains and Palaeoniscids *)
			multicoloured sandstones
	Blyklippen series	limnic fluviatile	grey sandstones with plant remains

*) Added by the author.

Upper Carboniferous.

Blyklippen series.

The oldest unit in the area is a series of sandstones, presumably of Westphalien (Lower Pennsylvanian) age, here referred to as Blyklippen series.

Lithologically the series consists of a lower succession of grey-green, fine- to medium-grained sandstones, with intercalations of thin bituminous shales, conglomerates, and arcose beds, which obtain a thickness of about 5 metres. The pebbles of the conglomerates are mainly white quartzites from the Caledonian range. Crossbedding is very common, it suggests a limnic sedimentation. The series is thus of continental, fluviatile type. In the upper part of this unit multicoloured layers are found. The colour ranges, sometimes gradually, from green to violet, or to red. The upper beds alternate with shales and conglomerates, as in the lower parts. The conditions of sedimentation have been the same as for the lower beds. The upper series have therefore been included in the same unit. Some plant-remains have been found, Lepidodendron sp., Calamites sp., and though not typical, they suggest a Westphalian age (WITZIG, 1951). They are possibly slightly younger than the U. Carboniferous continental deposits as described from, for example, Passagehøje (SÄVE-SÖDERBERGH, 1937) and Kongeborgen on Traill Ø (HALLE, 1931).

Lebachia series.

The sedimentation of sandstones continues through the whole Upper Carboniferous, though conditions change slightly. Above the Blyklippen series follows a limic sedimentation of rather coarsegrained grey sandstone, with thin black sandy and limy shales, beds of conglomerate and arcose-beds, the Lebachia series. Some sandy shales contain remains of Lebachia parvifolia and Calamites gigas, the limy shales carry very good specimens of Palaeoniscids. BIERTHER mentions that these have been found together with brackish water molluscae (p. 7). The profile (1) described by BIERTHER (1941) covers probably only the upper part of the Upper Carboniferous in this area. Here it is impossible to make any subdivision in the lower Carboniferous sequences. BIERTHER's collections, which contain several remains of Palaeoniscids (described by J. A. MOY-THOMAS, Annals and Magazine of Natural History, Ser. 11, vol. XI, pp. 737—759, 1942. "Carboniferous Palaeoniscids from East Greenland"), are now at the Geological Institute of the University of Copenhagen.

The black limy shales might have a great lateral extent, their thickness, however, varies greatly, which suggests that they have been deposited in shallow depressions in flat water. Otherwise, conditions have been very nearly the same as during the sedimentation of the Blyklippen series, though probably more esturine. Cross-bedding is rather common in the lower part of the sequence, just above the Blyklippen series.

As a whole the distinction between the Blyklippen series and the Lebachia series is very difficult to observe, if not impossible, in many cases. There has not been any break in sedimentation, only the mode of sedimentation has gradually changed from purely freshwater or terrigene to a sedimentation with brackish water intercalations.

Domkirken series.

The uppermost Carboniferous in the area consists of a purely terristic arcose sandstone, the Domkirken series. The colour is usually dark red. The sequence is built up of coarsegrained abbrasive material without any trace of fossils. The intercalated conglomerate beds carry

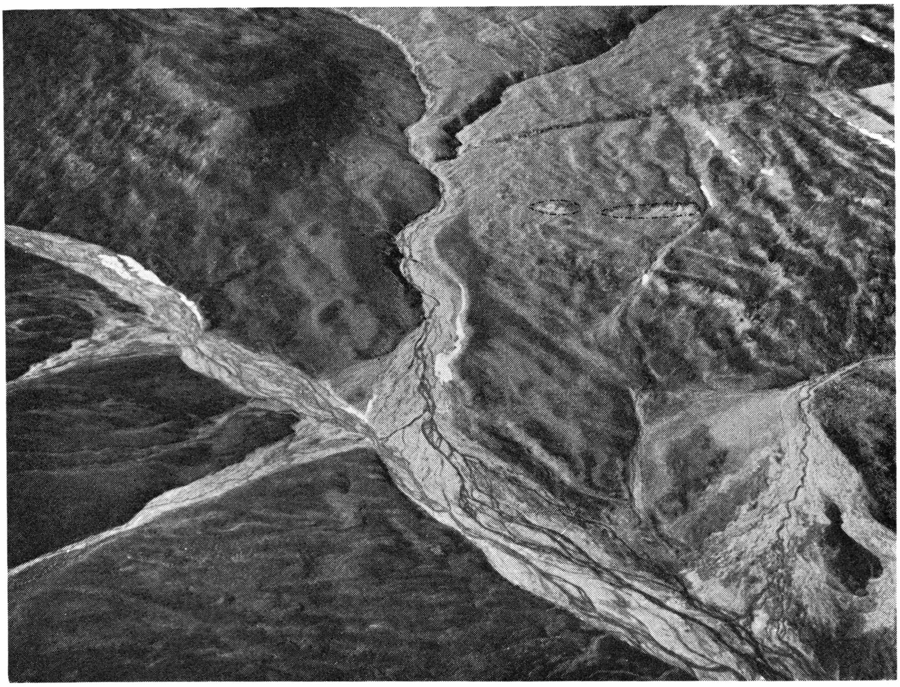

Fig. 3. Aeriel view of Blyklippen, before exploration started. The vein outcrops have been encircled.

components from the Caledonian range, as in the lower parts of the Upper Carboniferous, together with oldpaleozoic boulders.

The character of some of the coarse-grained red beds of the upper Blyklippen series is very much like the Domkirken arcose. The intermixing of shale beds, however, is decisive whether the beds belong to the Domkirken series.

Stress has been placed upon this fact because the red sandstone on the hanging wall side of the Blyklippen fault has previously been mistaken for Domkirken sandstone. Later workings and diamond drillings, however, revealed that the red sandstones did not in general show the characteristics of the Domkirken arcose. Thin bitumuous shalebands, bands of red siltlike material and alternation with grey and green beds have been decisive in placing the so-called Domkirken sandstone in the same stratigraphical level as the Blyklippen series.

Upper Permian.

The Upper Carboniferous is discordantly overlaid by marine Upper Permian. The angle of discordance varies slightly around 10°.

The formation is dominantly shales, which can be divided conveniently into a lower limy facies and an upper sandy-marly facies. The former begins with a basal conglomerate from 10—20 metres thick, consisting of rather small debris from the Caledonides, embedded in a yellow-brown to reddish matrix. The lower base of the Upper Permian in this area is found at an altitude of about 650 metres. In the Domkirken complex the shales contain very fossiliferous lenses of limestone, containing Martinia sp., Productus sp., Posidonomyae and Spiriferidae¹). The series therefore may be classified as Upper Permian.

Its stratigraphical position is in full accordance with other occurrences in East Greenland (L. Koch, 1929, Rosenkrantz, 1929 og 1930, Frebold, 1931 and Maync, 1942). The upper beds gradually become more sandy, thin marl beds and shales alternate with sandy light-brown lime-shales.

At several places, for instance in the upper parts of Store Blydal, a triple succession of the Permian basal conglomerate has been observed. Measurements of strike and dip in the strata revealed that slumping must be the cause. The beds strike parallel to the punctured lines in fig. 2, which are supposed to represent the gliding planes. The dip of these planes could not be determined exactly, but corresponds to the general slope of the hills.

The effect of slumping is wellknown from several localities in Greenland.

Trias.

Between the Permian and early Triassic beds a slight discordance has been observed, not exceeding 5°.

The Triassic series starts with a modest basal conglomerate and continues upwards with yellow-brown shales, sandy marls and some thin sandstone-beds. Black limestone concretions occur very commonly in the lower part of the series. Trias is only found on the highest peaks, the lowest border lies at the 950 metres altitude. The Triassic beds belong, presumably, to the lower scythian period (Nielsen, 1935, Spath, 1935). Triassic sediments are more common in the area just south of Mesters Vig. A description of a Permo-triassic profile is again given by Bierther (1941, profile 3).

Discussion.

The stratigraphical division, as outlined above, is rather schematic. The lower parts of the sedimentogene sequence, the Upper Carboniferous, is completely devoid of stratigraphically inconvertible remains. The plant remains could belong as well to the Westphalien/Stephanien period

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¹) No detailed study of the Permian fauna has so far been made. A more detailed description of the Permian in this area has been given by Bierther (1941, profile 2).

(Pennsylvanian) as to the lowermost Permian (Autunian) (Witzig, 1951). The possibility that the Lebachia series might be of lower Permian age involves that the Domkirken series can be compared with the Permian red series of Lower New Red—Saxonian type.

Effusives.

Manifestations of younger volcanic activity are numerous within the Mesters Vig area. In the western part a large number of dykes intersect the sediments; sills are found in the Carboniferous, Permian and Triassic strata. Thick basaltic sills are common in the lowlands bordering Kong Oscars Fjord.

Undoubtedly the basalts belong to the huge arctic province of Tertiary age. Descriptions of these Tertiary volcanics have been given by Wager (1939), Backlund and Malmqvist (1932), Krokström (1944), and Rittmann (1940).

Associated with the volcanics are possibly the syenitic intrusives at Traill Ø, at Kap Simpson and Kap Parry, by Schaub (1938) referred to as postcretaceous. Presumably related with these intrusive complexes are minor intrusives near Kap Syenit and Antarctics Havn, southeast of the Mesters Vig area. They have been mentioned by Bierther and by him referred to as post-jurassic. Finally a large complex of syenitic rocks has been recognised just south of Mesters Vig. This complex, Werner Bjerge, has been mapped preliminarily by Bierther, and it partly appears on the map edited by Stauber (1950).

The dyke-swarm which appears in the western part of the Mesters Vig area has a northerly trend. The strike is usually different from that of the strike-slip faults, which run parallel to the post-devonian mainfault system, striking N 20-40 W. This fact suggests that the directions of internal tension have been slightly different from each other during the faulting at one side and during the intrusions of the dykes on the other. We do not want to emphasise this fact more than it stands for, as it is not proof of a difference in age between the faulting and the intrusions. Moreover dykes do occur in zones where the tension is at its maximum, while faults occur in zones of minimum tension and maximum shearing. A kersantitic dyke of unknown parentage has been observed in the Blyklippen fault zone. (Bondam and Graff-Petersen, 1954).

The basalt-complex near Nyhavn, though presumably sills, bears the characters of a flood-basalt. The cover consists of olivine basalt, overlying carboniferous sandstones. The lower contact of the complex is undulating, with the relief of the sandstone surface. Its western boundary, however, is a fault. The contact here lies persistently at an altitude of about 50-60 metres. A strip of exposed sandstones along this fault contains faintly mineralized quartz-stringers. It seems to be the only rather certain evidence that the faulting, and with it, the mineralization, is of Tertiary age. As a matter of fact it must be assumed that faulting in this area has been repeated several times, the faulting having been rejuvenated since the beginning of and during the general heaving of the East-Greenlandic basin (KOCH 1929). Most probably the western block along the fault at Nyhavn has been heaved in comparison with the eastern block. After the basalt-cover was eroded, the erosion of the underlying sandstones continued more rapidly than in the case of the eastern block, the now exposed basalt complex. The altitudes of the two blocks are at the moment reversed, the western being about 100 metres lower than the eastern. Typical of the basalt complex at Nyhavn are the secondary calcite fillings in cavities and cracks. They have not been observed in the sills at higher altitudes. Possibly these calcite exhalations might be connected with the occurrence of calcite veins in the Permian strata. It will be more fully discussed on page 20. Remnants of the basalt cover, if not sills, of the lowlands are further observed south of Noret and on the northern slope of Mesters Vig at Permklippen. On top of the Eo-Triassic strata of Domkirken Mt. and on Gorms Spids a similiar succession of lavabeds occur.

Tectonics.

According to BIERTHER (1941), the tectonic pattern of the northeastern part of Scoresby Land is that of a rather simple germanotype block faulting. Two systems have been recognised by him, the one parallel with the postdevonian mainfault, running through Skeldalen in a NE direction, the other system, having a more westerly direction, runs parallel with Kong Oscars fiord.

The block faulting of the East Greenland postcaledonian "graben" has been thoroughly stùdied by VISCHER (1943). The results of his studies show that the eastgreenlandic "graben" is built up of a succession of blocks, bordered by steep, easterly dipping, transcurrent faults. The faults have been partly reactivated several times during the young palaeozoic and mesozoic. Sediments of devonian to cretaceous age have been deposited in longitudinal basins.

At Blyklippen the offset of the faults in generally very moderate. From observations made on a series of inclined diamond drill holes from the 335 m level of the Blyklippen workings, it could be deduced that the offset of the Blyklippen mainfault (longitudinal fault—see page 29) does not exceed 100 metres.

The importance of the structural relations in connection with the mineralisation of the area will be dealt with in part II.

An older fold structure has been reported by Witzig in the eastern Blyryggen range. (Witzig, 1954).

Special descriptions.

In the following some special descriptions will be given, relating to a few aspects of the general geology of the Mesters Vig area, which are of interest for the occurrence at Blyklippen, and for the problem of mineralization in general. The paragenesis of the Blyklippen deposit will be more fully discussed in Part III of this paper, by H. Brown.

These descriptions will be given in the following order:

(1) The sandstones of the Blyklippen occurrence
  a. the grey series
  b. the multicoloured series
  c. the faultzone.
(2) The veins
(3) Calcite fillings.

1) The Sandstones of the Blyklippen occurrence.

(1a) The grey series (Blyklippen sandstone).

On the footwall side of the vein a succession of sandstone beds, of grey to grey-green colour, is seen. The grain-size varies greatly, but in general, it can be said that the size of the quartzite-grains of the grey series is slightly less than that of the multicoloured series, which will be discussed in the following. The colour-variation of the lower part of the Blyklippen series is slight. Grey beds, in which the matrix consists mainly of sericite, alternate with beds containing more chloritic material in the cement. Thin layers of very mica-rich abbrasives occur occasionally in the beds. The mica is much corroded and mostly sericitized. It is therefore thinkable that the matrix in the common sandstone type has been originally micaceous material. Although the amount of ferrous oxides is usually negligible, they give the colour of the sediments a more brownish tone.

Black, bituminous shale bands are regularly intercalated in the sandstones. The same counts for conglomerate layers.

The sandstones are characterized by a simple composition. No other elements than badly sorted quartz, gained from quartzitic rocks and a far smaller amount of feldspars, in which both plagioclases and corroded alkali feldspars have been found. The cement ranges from sericite to chloritic material, with small streaks or insula of calcite. In so far as it has been possible to observe, the grey Byklippen sandstone has been the host-rock for the vein-solutions. All the samples of silicified sandstone breccia examined show the characteristics of the grey series; it might be possible that secondary mineralization has occurred in the multicoloured series, close to the hanging wall. The bleaching effect of the hydrothermal solutions on the multicoloured sandstones near the vein makes it hard to distinguish it from grey Blyklippen sandstone.

(1b) The multicoloured series.

This sequence usually consists of rather coarse-grained sandstone, situated at the hanging wall side of the Blyklippen mainfault. The regional dip of the beds near the Blyklippen occurrence is 15—25° S to SW. Towards the mainfault the dip increases and the strike changes more to the N.

The series has possibly an equivalent in the multicoloured beds which outcrop at the junction of Øvre Gefionelv and Tværelv. It is assumed that this sequence occurs in connection with the Blyklippen series, on a slightly higher level.

Grey-green chloritic sandstones alternate with dominantly red to red-brown stained beds. Thin layers of red silt, black shales and conglomerates are incorporated in the series. As already mentioned (p. 13) the coloured series has previously been mistaken for Domkirken sandstone. Unmistakably the multicoloured series bears elements of arcosic origin, especially in the red beds. The occurrence of shales, however, has been decisive in not regarding the multicoloured series as an equivalent of the continental Domkirken series.

Macroscopically the coloured series are characterized by badly sorted quartzitic material. The grain size varies greatly and single pebbles are not uncommon in those beds which otherwise consists of finer abrasives. The sandstones sometimes carry garnet, with small kelyphitic rims.

The quartz grains are embedded in a matrix of sericite and chlorite, as in the case of the grey series, while there is often found calcite in the cement. The plagioclases, which are found in very subordinate amounts, are oligoclase-andesine. The alkali feldspars are usually much corroded; they occur only occasionally. In many beds, biotite can be seen macroscopically. It is often chloritized. Besides, traces of epidote have been observed.

The amount of staining with ironoxides will commonly determine the colour of the beds, as does the amount of chlorite. Which mineral will be formed depends partly on the conditions under which the sediments have been deposited.

(1c) The faultzone.

The faultzone of the Blyklippen occurrence will be the subject of a closer study by H. Brown, in this paper. A few incidental observations of general interest, not within the scope of the particular field of that study will be mentioned.

The shale bands, included as well in the grey series as in the multicoloured series, occupy a special position.

The shales may act as incompetent layers in the process of faulting. They keep their character of beds in a disorientated faultgouge. The shearing of the shale layers has resulted in a rupture of the beds, so that they remain as streaks or bands in the faultgouge. In other instances the shales have been brecciated.

A sample of a shaly band (more correctly graywacke) taken in the faultzone at N 5140 E 4660 335 m level, shows quartzflour with a rather uniform grain size (about 0.04 mm) in a sericite-chlorite cement. The sample contains thin bituminous stringers, folded in the non-bituminous matrix. The chlorites have a tendency to be orientated in connection with these stringers. Calcite is found between and around them.

A special study has also been made of a dark, kersantitic dyke, intruding the footwall fault over a distance of about 100 metres.

The dykematerial, mainly consisting of plagioclase and biotite, has been completely altered by hydrothermal action, within the footwall zone. The alteration products showed to be a mixture of illite and montmorrilonite. (Bondam & Graff-Petersen, 1954).

2) The veins.

Bierther, again, first mentioned the occurrence of mineralised veins: (p. 15) "Zu erwähnen sind noch selten auftretende, an Störungen gebundene quartzgange, der auch Kalkspat und Kupferkies führen", though without locating them further on his sketch map.

The vein system in the Mesters Vig area generally strikes N 20-30 W; the dip varies, but is usually steep to the NE.

They are open fissure veins; the gangue is normally quartz. The width of the veins varies greatly, varying from a silicification of over 50 metres to a narrow zone, not more than 1-2 metres wide. As far as is known yet, mineralisation is confined to the veins or vein-pockets of moderate width, close to the footwall of the fault zone. (See Part 2). The extension of silicification, often beyond the footwall, can be very wide. A zone thus silicified contains numerous small, thin, quartz veinlets in the faintly quartzitic sandstone. They seem to be joint filling in a system of fiederspalten, accompanying the faulting. Sometimes they contain small single ore crystals.

Brecciation of the slab is considered to be a condition for ore-formation, together with the impermeability of the incompetent shales and structural relations (see part II).

All the mineralised veins discovered so far occur in the lower Upper Carboniferous sandstone series. The higher the stratigraphical level the fainter mineralisation seems to be. The most promising occurrences appear to be confined to the lower Blyklippen series, this counts for the Blyklippen as well for the Sortebjerg, and Nuldal deposits. The higher sandstone levels usually show silicification in a broad belt with only traces of ores in the quartz veinlets. The veins at the SE bank of Gefionelven show an example of this type of veins. The sequence contains a shale with remains of Palaeoniscids within the silicified zone.

Another type of mineralisation is found at the occurrence on Hesteskoen, also in a higher stratigraphical level than the Blyklippen occurrence. The gangue of the Hesteskoen vein consists mainly of barytes; quartz is present only in amount subordinate to that of barytes. The mineralisation is confined to stringers of both sphalerite and galena. No other ores have been observed. The showing is situated just adjacent to a minor fault, dipping steeply to the NE. A hard, faintly silicified shale with a polished schlickenside face is found immediately to the footwall.

3) Calcite fillings.

In the Permian strata a number of calcite veins have been observed, which seem to be connected with minor faults.

These veins do not seem to have any relation to the mineralised quartz veins, they rather form isolated fillings of restricted fractures in the strata. The relation between quartz veins and calcite veins could be considered from the point of view that hydrothermal fluids had dissolved and precipitated calcite drawn from the Permian strata. The dissolving power of groundwater, however, is sufficient to bring about these reactions. Association of calcite fillings and thin skeleton stringers of chalcedony might be found, but it is no proof for the hydrothermal origin of these fillings. In no place a direct continuation between quartz veins and calcite veins has been observed. Calcite fillings are well known from the basalts near Nyhavn, where the mode of occurrence in minor fractures and cavities, reminds one of that in the Permian strata.

It is the author's opinion that these calcite fillings must be considered in relation to secondary volcanic processes rather than with the formation of quartz veins. The observed calcite veins sometimes carry faint traces of chalcopyrite, never of other sulfides. Chalcopyrite is known to occur with the basalts too, and has been found as a thin coat in a minor crack in basalt.

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Part II

BLYKLIPPEN OCCURRENCE, STRUCTURE AND ITS INFLUENCE ON ORE DEPOSITION

BY

H. BROWN

CONTENTS

PART II

BLYKLIPPEN OCCURRENCE, STRUCTURE AND ITS INFLUENCE ON ORE DEPOSITION

Introduction.

An essential preliminary to serious and extensive field exploration in a new field is an understanding of the geological occurrence of known deposits. It must be determined whether other similar deposits are likely to occur in the area, and which localities are the most favourable for investigation. Geological work is being directed towards these ends, at Blyklippen (fig. 4). In particular, the following subjects are under investigation:—

(1) The determination of the structural factors which have controlled the ore solutions and the deposition of the ore, in order that these may be recognised in further exploration and their significance understood.

(2) A study of the mineral distribution and its relationship to the structural controls, to determine whether the distribution is a consequence of depth (temperature) or is due to structural influences. Hence, whether the termination of mineralisation at a certain level represents the bottom of the ore horizon of the district, or whether further ore may be expected at a greater depth, on repetition of similar, favourable structural conditions.

(3) The determination of the temperature of formation of the ores and the paragenesis. These give an indication as to the probable source of the ores and their place relative to metallogenetic zoning.

This part of the paper forms an introduction to the geological occurrence of the Blyklippen deposit and deals, in a brief and elementary manner, with the chief influences which have controlled ore deposition, and with the distribution of the ore minerals. The mineralogy will be discussed, with further structural details, in a further paper.

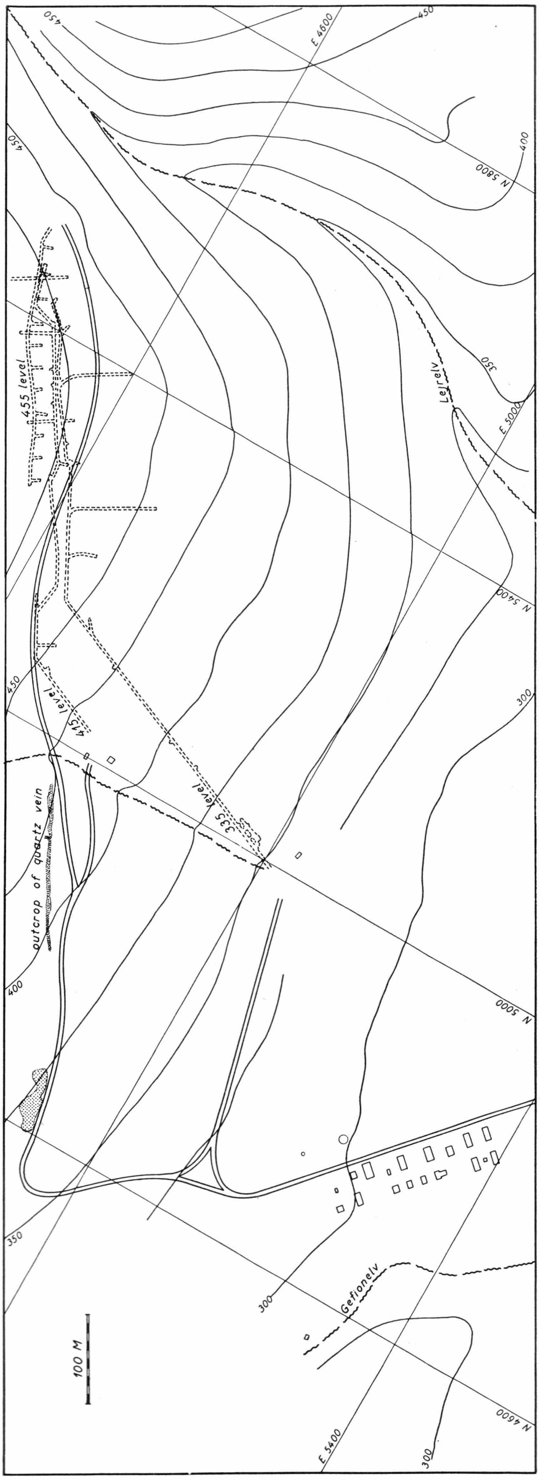

Fig. 4. Situation map of the Blyklippen Prospect, Mesters Vig, East Greenland.

1. Description of the Structural Features.

(1) Longitudinal Faults and Fractures. Faults and fractures which strike approximately 20° to 30° west of north are described as longitudinal. Their dip varies from about 40° easterly to vertical, with an average value of about 70°. The main longitudinal fault forms the hanging wall of the ore zone. As shown by the drawing, figure 5, this fault branches or splits at the northern end of the deposit. The vertical, transverse section shows that the fault becomes less steep with increase of depth, so that the faulted zone has a similar pattern in plan as in transverse section. The fault zone contains sandstone and shale which have been compressed and dragged down and along the fault. These materials are in a plastic or clayey form. The rock in the vicinity of the fault is brecciated, and subsidiary slips and fractures, parallel to the fault, in strike and in dip, extend into the sandstones, the interval between the fractures increasing with distance from the fault. In the brecciated and fractured sandstones have been deposited quartz, the ore and other minerals. The quartz zone is delimited definitely to the east by the main longitudinal fault, but its western limit is less definite, and depends upon the local extent and intensity of the fracturing. In agreement with the longitudinal fault, the longitudinal fractures change direction at the northern part of the deposit, swinging easterly.

In the areas of the constrictions, which will be described in the next section, similar fracturing is traversed by later fractures, striking more to the east and dipping westerly. These latter fractures contain quartz and barytes, and, in many cases, contain small cavities, lined with crystals of these minerals.

Fractures having the same attitude as those last described, but containing no minerals, cut across all other structures and mineralisation. These occur in and near to the constricted areas, and cause considerable brecciation of the vein material.

(2) The Constrictions. The width of the quartz zone is variable; this may be illustrated by reference to the longitudinal section, fig. 5. On this section have been plotted horizontal widths of the quartz zone. The plan indicates that a gradual narrowing of the zone takes place from south to north, to a section of minimum width, followed by a gradual widening of the zone to the north. The trace of the narrow zone, say 5 metres or less in width, in longitudinal section, plunges to the south and is horizontal, alternately. Fig. 6 is a plan of a part of the 415 level, showing the longitudinal fault and slips and the constricted section. As shown in the figure, between the points (6) and (7), the fault F 1 (2) undergoes a rapid change in strike direction.

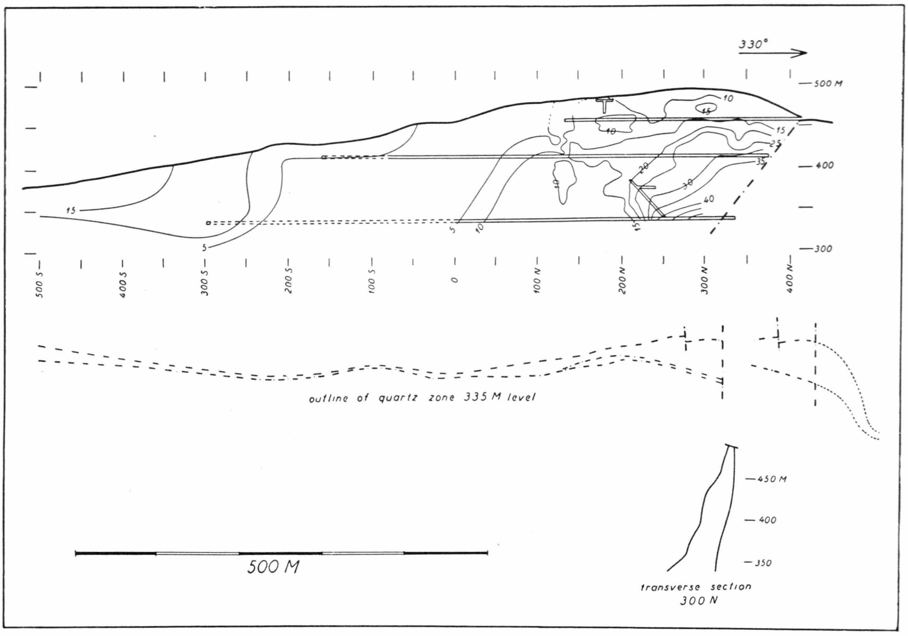

Fig. 5. Quartz Zone Widths, longitudinal Section, Blyklippen vein.

In a distance of about 15 metres in the general strike direction the displacement in the dip direction is 14 metres. The hanging wall fault, F 1 (1), makes a similar, but less marked, change. Fig. 6 (2) shows this feature on a larger scale.

The chief observed structural features between the points (11) and (12), fig. 6, are also shown on the larger scale in fig. 6 (5). It may be seen that a fault, F 1 (4), cuts the longitudinal fault, F 1 (3). On the west side of the drift, between point (11) and the fault F 1 (4), the longitudinal fractures parallel to the fault F 1 (3) terminate abruptly against the south side of the fault F 1 (4). Some of the quartz stringers are bent towards the east, against the fault. On the east side of the fault F 1 (3) the predominant fracturing and quartz stringers change in strike through a curved path, from a direction parallel to that fault, to a north-easterly direction, and back to their original direction, south of point (12). The fault, F 1 (2), indicates, in part, the path followed. On the north side of the fault F 1 (4), the dominant fracturing is parallel to the fault.

A comparison of the two features described above shows similarities in the directions of strike during the changes and in the displacement of the longitudinal system to the east. They are considered to be structures of the same type and formed in the same way. The fault F 1 (4) is interpreted as a further development in the formation of the structures, as described in paragraph 3.

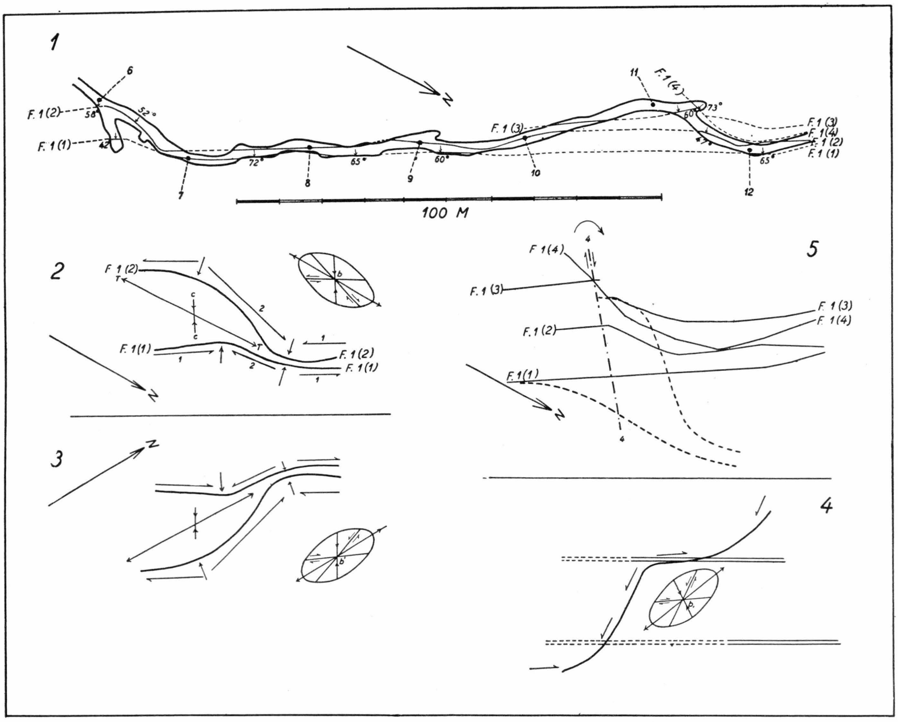

Fig. 6. Structural relations on the 415 m-level (detail).

(3) The Transverse Fault. This fault cuts and displaces the longitudinal fault and fracture systems, and the orebody. The fault is exposed in the 335 metre level, and it has been intersected by a drill hole from the surface to about the 445 metre horizon, and by drill holes U50 and U51 drilled from the 415 metre level. The fault dips at about 50° in a direction of about 10° east of south. A section of the fault is given in fig. (2) 4, and notes are below. Parallel in strike and dip are joints, best observed at the north end of the 335 level. These joints cut through, but do not displace, all other structures and minerals, and they themselves contain no minerals.

2. Formation of the Structures.

An understanding of the kind of forces which operated, and the manner in which the structural features were formed, may be obtained from an examination of the constrictions on the 415 metre level. Referring to fig. 6 (1), with the change in strike, there is a rapid convergence of the faults F 1 (1) and F 1 (2). This squeezing points to the operation of compressive forces acting normal to the local direction of strike.

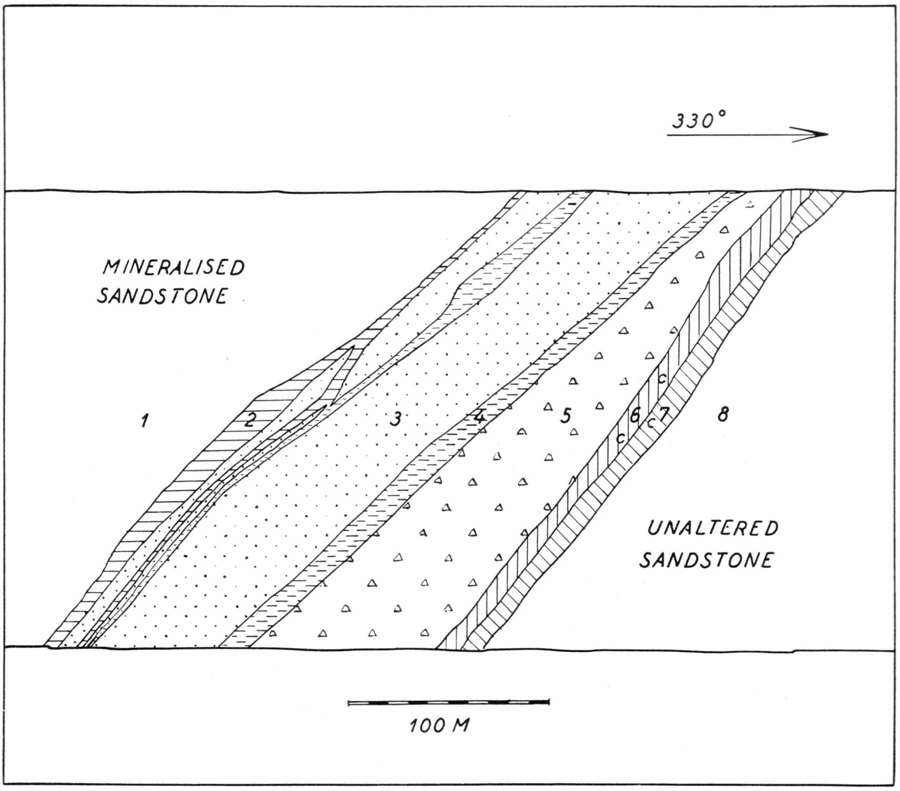

Fig. 7. Detail of transverse fault, 335 m-level.

Section of the 335 transverse fault.

1.	Grey sandstone, fractured and mineralised.	
2.	Black shale	20 cm.
	White, altered sandstone, iron stained	16 cm.
	Fault gouge—compressed sandstone and shale	3 cm.
	White altered sandstone	2 cm.
	Fault gouge	3 cm.
3.	White, altered sandstone. Crushed and compressed sandstone. Plastic consistency	70 cm.
4.	Fault gouge—sandstone and shale, etc.	15 cm.
5.	Brecciated quartz	57 cm.
6.	Quartz and fine-grained galena	15 cm.
7.	Quartz and normal galena and sphalerite	10 cm.
8.	Sandstone, unaltered.	

The fact that displacement to the east of the whole of the longitudinal system has occurred shows that the forces have not been entirely compressive. If that had been the case there would have been a constriction, but no lateral displacement. The effects observed may be explained by shearing forces. The diagram in fig. 6 (2) shows, approximately, the direction in which such forces would have acted. It is supposed that the forces (1) caused the longitudinal fracturing and faulting (F 1). In opposition to these forces, the reaction forces (2) were induced. Elongation occurred in the direction T-T, and compression approximately as C-C. The force (2), parallel to F 1 (2), was greater than that parallel to F 1 (1), so that clockwise rotation occurred, resulting in a gradually increasing convergence from south to north, until the latter force equalled the former, and equilibrium was restored. The orientation of the strain ellipsoid is indicated in the diagram, with the major axis plunging to the south, and the 'b' axis to the east.

Reference has been made to the alternate southerly plunge and the horizontal attitude of the constricted zone in longitudinal section. Orientation of the ellipsoid to obtain this pattern is indicated in fig. 6 (4), and it is seen to correspond to that in figure 6 (2). By projecting the plan, fig. 6 (2), on to the same vertical plane as the longitudinal section, as shown in the lower diagram, fig. 6 (3), it may be seen that both are part of the same structural pattern and have been formed by the same forces.

The second feature on the 415 metre level, to which reference has been made, and which is shown in fig. 6 (5), is regarded as having been formed in the same manner as the constriction described above. In this case, it is thought that the constriction had not fully developed before shearing occurred along the line 4-4 towards the eastern side of the zone. A further development of this structure is assumed, as indicated by the broken lines on the same figure. With clockwise rotation of the reaction, continued deflection of the longitudinal fractures, and of the shear plane 4-4, would occur to the east, resulting in the formation of a constriction at the northern end of the structure. Failure would naturally be expected to begin at the western side of the zone, as shown in the figure, where the rocks would be in tension.

The plan of the 335 metre level, fig. 5, shows the pronounced deflection towards the east of the longitudinal fracturing at the northern end of the level. The degree of the deflection increases from the western side of the zone. This structure is interpreted as being a part of a constriction-type structure, such as has been described above, and to have been formed by the same forces. A reconstruction of the pattern of the structure to the north of the transverse fault, before faulting occurred, is given in the diagram 5 (1).

The stage of development of the structure is more advanced than that of either of the two other structures, and the origin and development of the transverse faulting is indicated in fig. 8. The age of the final development, i. e. the displacement, of the transverse fault seems to be definitely established by the following:—

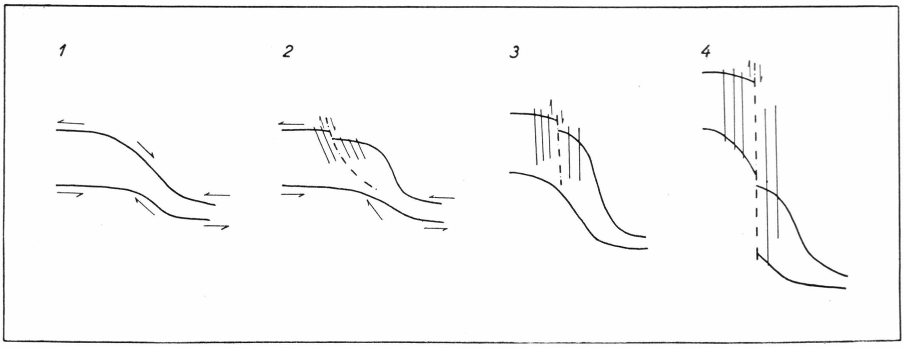

Fig. 8. Stages of development of transverse faulting.

(1) Strong and persistent fractures, seen on the 335 level, which are parallel to the transverse fault, and which were probably induced by the same forces which caused the faulting. These fractures contain no quartz or ore minerals, and are evidently later than any primary ore mineralisation.

(2) The transverse fault contains re-crystallised galena and brecciated normal galena and sphalerite, previously deposited minerals, rearranged by the shearing and its effects. The normal galena and the sphalerite occur in a breccia consisting of shale, cemented with quartz. The galena and sphalerite in this breccia appear to be broken pieces and grains from larger masses and to have been brought into their present position by the flow of „secondary" quartz formed as a result of the movements. The normal galena occurs on the extreme limit of the faulted zone and is farthest from the planes on which shearing was most intense. It has suffered little deformation, therefore, and was further protected from the effects of shearing, including deformation and orientation, by the fluid quartz. The galena which was in close contact with the planes on which movement occurred was transformed to the fine-grained variety.

3. The Influence of Structure on Ore Deposition.

(1) *Impermeable Fault Gouge and Shales.* During the production of the longitudinal faulting, the sandstone and shale beds close to the fault were compressed to a plastic state and drawn down into the planes of movement. This plastic material on the hanging wall, or eastern side, of the zone acted as an impermeable barrier to the solutions, so that deposition occurred within the fractured zone, and escape of solutions was prevented. Very little silicification, and no ore is found beyond the hanging wall fault.

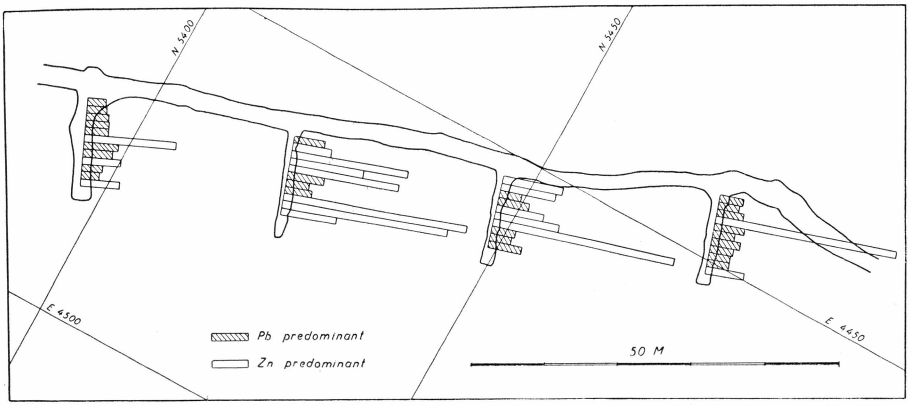

Fig. 9. Lateral distribution of the ore minerals; 455 m-level.

(2) The Longitudinal Fracturing. The effects of the longitudinal fracturing on lateral and on longitudinal mineral distribution are considered in brief in the following:—

(a) Lateral Distribution. As an example of the lateral distribution of the ore minerals, the results of the channel sampling at the 455 metre level may be examined. From the mean assay results, the ratios Pb + Zn/Pb have been plotted in fig. 9. The graphs show the abrupt changes in mineralogy transversely, lead and zinc predominating alternately across the zone. A similar arrangement is seen in practically all other cross cuts and in diamond drill holes which cross the zone. The explanation of these abrupt, lateral changes is that the ore minerals occur in fractures, parallel to the longitudinal faulting. The lateral control over the movement of the solutions was fairly rigid, due to their confinement between the longitudinal fault and slips and between the walls of the fractures. Variation of structural conditions, including the strike and dip and the size of opening, of the fractures, together with variation in the composition of the solutions in individual fractures, would determine whether lead-rich or zinc-rich ore would be precipitated at any particular section.

(b) Longitudinal Distribution. The longitudinal distribution of the ore minerals may be illustrated by reference to the 415 metre level. In fig. 10, two bodies of high grade lead ore, A-B and C-D, are shown. These bodies occur between the main constriction and the transverse fault. As the result of the reaction forces, a constriction occurred at "B", see figures 10 and 6. Ore solutions became confined between B and the neck A of the main constriction, and deposition of galena-rich ore occurred between A and B.

Passage of solutions through the constriction at B was controlled under high pressure, a gradual reduction in which took place northwards

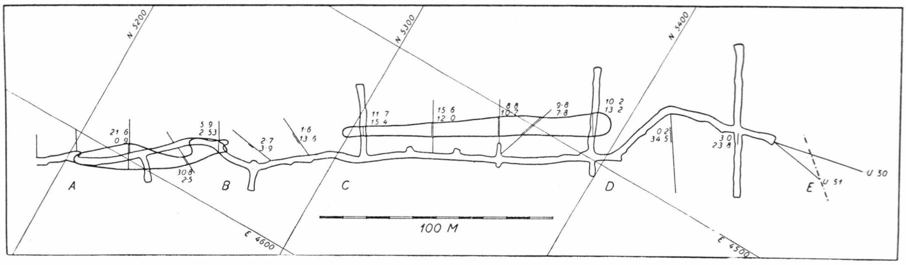

Fig. 10. Longitudinal distribution of the ore minerals; 415 m-level.

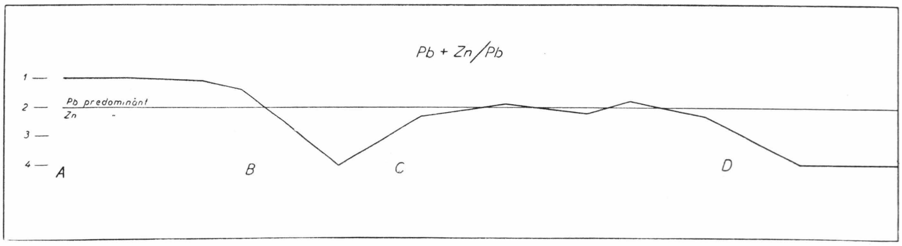

Fig. 11. Depositional variations longitudinally with changes in structural conditions, illustrated by the ratios of Pb + Zn/Pb; 415 m-level (compare fig. 10).

A. Neck of constriction. Passage of solutions blocked.
Solutions trapped between "A" and the constriction "B". Predominant lead precipitation.

B. Constriction formed initially, before development of the fault, F. 1 (4). Rapidly changing attitude of fractures. Passage of solutions controlled under high pressure. Gradual reduction of pressure, with widening of fractured zone and more consistent attitude of the fractures. First, zinc deposition predominant.

C. Second; with further reduction, pressures favourable to lead as well as to zinc deposition.

D. Pressure reduced to the point where lead deposition virtually ceased, but a marked increase of zinc mineralisation.
Fractured zone continues to widen and deflection to the east occurs.

from this section, with widening of the fractured zone and more consistent attitude of the fractures. Predominant zinc deposition occurred first. From C to D conditions of pressure were favourable for both lead and zinc, in about equal proportions, until, at D, with increasing width of the zone, and the resulting reduction of pressure on the solutions, galena deposition practically ceased, and zinc became strongly dominant. In fig. 11 have been plotted the ratios of lead plus zinc to lead, to illustrate the depositional variations longitudinally with changes in structural conditions.

In the section between A and B, there appear to have been two local influences on ore deposition.

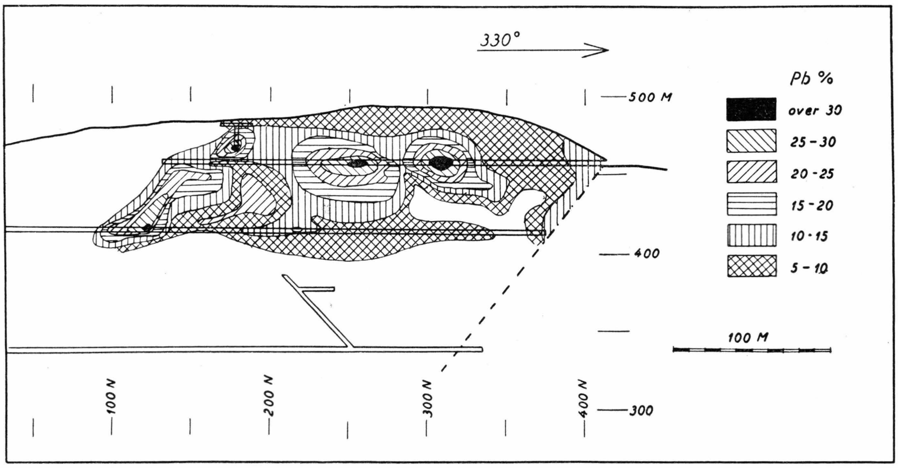

Fig. 12. Pb-distribution in longitudinal Section, Blyklippen vein.

(1) Due to the constriction at B, causing reduction in the volume of flow of the solutions, with a pressure gradient decreasing from the contraction southwards. Precipitation of galena would take place at sections where the pressure would be most suitable to promote reaction of the solutions with the wall rock. The more southerly part of this ore lens is attributed to this mode of formation.

(2) Due to the partial damming effect of the fault 4-4, which was formed during the ore formation period, by further development of the forces which caused the constriction at B. The concentration of galena just south of this fault is ascribed to this cause.

(3) The Constrictions. A comparison of the vertical, longitudinal sections of lead and of zinc values and of zone widths, figs. 5, 12 and 13, indicates that a definite relationship exists between ore deposition and the vein structure. The higher lead values occur where the zone width is moderate, between about 5 and 20 metres. Zinc is predominant in the zones of greater width. Where the zone is very wide, the tendency is for little or no deposition to occur. The most favourable position for the richest ore would appear to be, then, within the fractured zone of moderate width. There is a small occurrence of ore above the constriction, between sections 100 and 300 South. This may be explained by deposition resulting on the release of pressure on the solutions after passing through the constriction. To the north, the ore appears to occur beneath the narrowest part of the zone. If the interpretation of the development of the transverse fault is correct, and a constriction was formed, before faulting occurred, north of the present fault, then the Blyklippen orebody occupies the zone between two parallel constrictions.

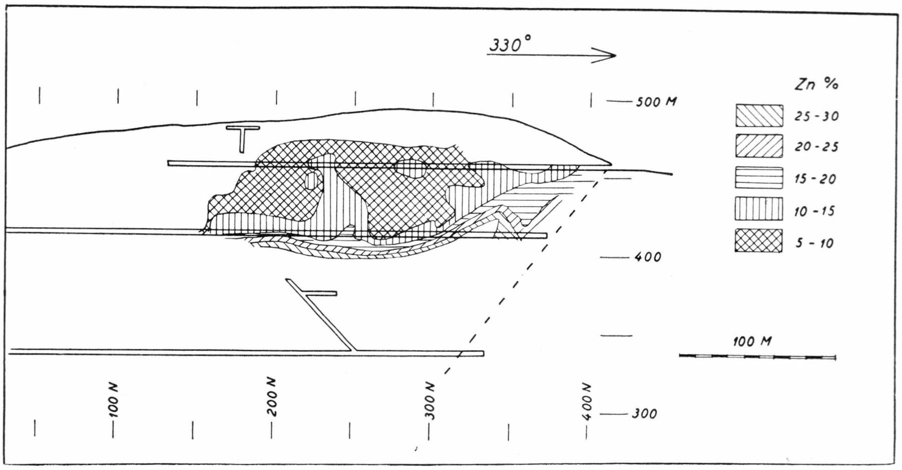

Fig. 13. Zn-distribution in longitudinal section, Blyklippen vein.

The longitudinal and vertical movements of the ore solutions were thus controlled by these constrictions.

The relative proportions of lead and zinc are shown in fig. 14. From this, two things are evident,

(1) Variations in the relative amounts of these two metals occur horizontally. The reason for this has been discussed above. It indicates that the lead-rich lenses shown in the figure have a zonal arrangement, with an increasing proportion of zinc outwards.

(2) Horizontally, from south to north, and vertically, with depth, there is an increase in the relative and actual amounts of zinc in the ore.

The fact that zinc increases longitudinally, as well as with depth, indicates that the zonal arrangement is not a result of temperature changes with depth, and that depth is not the determining factor in the mineral distribution. It is significant that the zinc/lead ratio lines are parallel to the southerly plunge of the constriction in the southern part of the deposit. The evidence is strongly in favour of a zonal arrangement due to the controlling influences of the constrictions.

4. Form of the Orebodies.

The structural controls discussed above have influenced the form of the orebodies. Bodies of ore which are greater in length than in height and in width are found. This is due to the rigid lateral control exercised by the walls of the longitudinal fractures and by the impermeable materials which lie parallel to these fractures, and to the less rigid

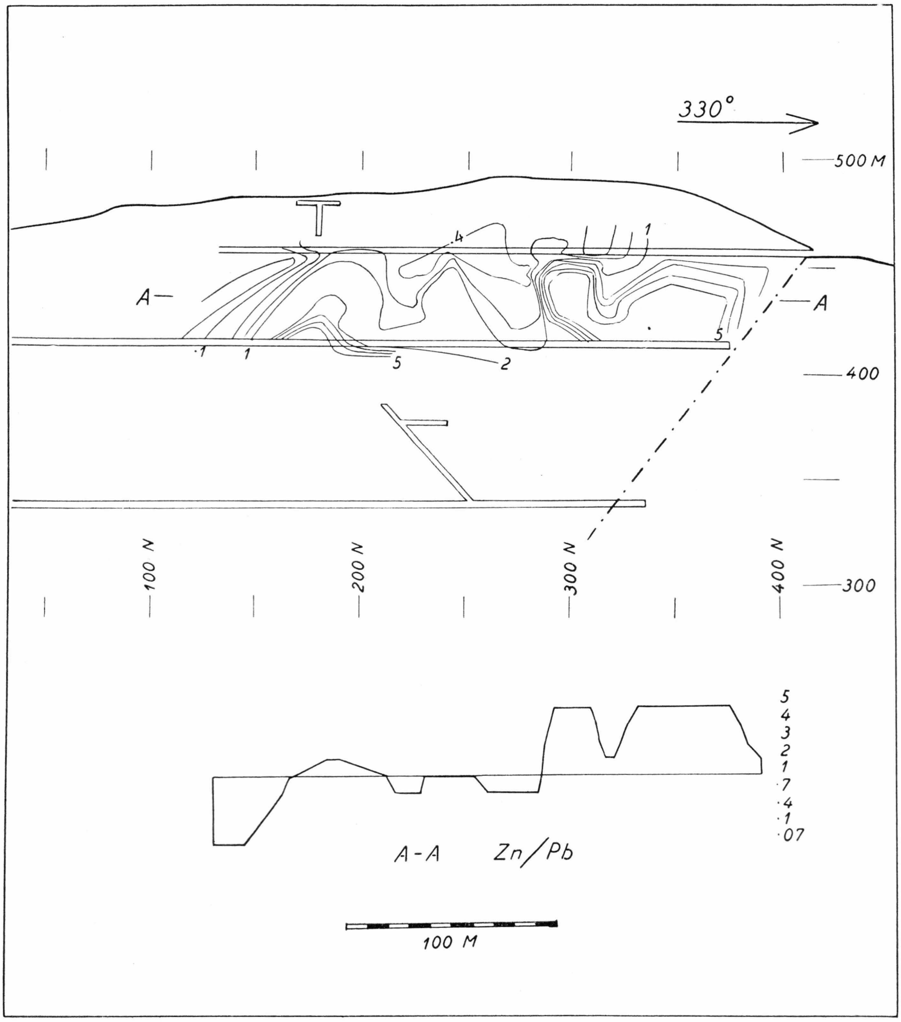

Fig. 14. Zn/Pb ratio in longitudinal section, Blyklippen vein.

control longitudinally, on account of the fractures being continuous, although variable in size and in attitude, in that direction.

The lenticular shape of the bodies may be seen in the longitudinal section, fig. 12. Two of these lenses of high grade material occur with their long axes nearly horizontal, i. e. parallel to the horizontal constriction, now eroded, under which deposition took place. The long axis, of another such lens, in the southern part of the orebody, also lies parallel to the constriction axis, the plunge being to the south.

The body to the north, lying against the transverse fault, by comparison with the others, appears to be part of a lens, the missing part of which has been displaced by the fault.

5. Sequence of Events.

The following summarises the chief events which occurred in the formation of the structures and the ore formation:—

1. Longitudinal Shearing, resulting in the longitudinal faulting, with the formation of fault gouges and plastic shales; brecciation near to the fault planes; longitudinal fractures, decreasing in intensity with distance from the fault. Introduction of quartz.

2. Reaction to the Longitudinal Faulting, causing brecciation of previously deposited quartz. The constrictions began to form and the ore minerals to be deposited.

3. Continued Reaction, with clockwise rotation, with formation of tension fractures and entry of quartz and barytes along them to seal brecciated ore and quartz.

4. Transverse Faulting and Fracturing, as a final development of the reaction forces. All mineralisation ceased before this stage.

6. Application to Further Exploration.

The structural features discussed in the foregoing form a part of the structural pattern in the Mesters Vig area, so that the results of work done at Blyklippen may be applied to further exploration in the faulted zones of that area.

The association of ore deposition with directional changes and with constrictions of the longitudinal fracturing constitutes a guide for conducting field exploration. The points where changes in direction of the longitudinal faults occur in the Mesters Vig area indicate localities for attention.

The possible development of the transverse faulting from the constriction feature also indicates that attention should be given to such faults, or, more correctly, the areas immediately to the south and north of them.

In regard to exploration in depth at Blyklippen, the conclusion reached, in paragraph 3, that mineral zoning is due, not to depth, but to structural causes, indicates that the Blyklippen deposit does not necessarily lie at the bottom of the ore zone, and that ore might be expected to occur associated with repetition of similar structural conditions at depth.

Færdig fra trykkeriet den 3. september 1955.