

PART I  
GENERAL GEOLOGY

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**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), BIERHER (1941), FRÄNKEL (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 (Westphalien- Stephanien/ Pennsylvanian)	Domkirken series	continental	red arcose
	Lebachia series	limnic esturine	sandstones with plant remains and Palaeoniscids *)
	Blyklippen series	limnic fluviatile	multicoloured sandstones  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, 1954). 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 estuarine. 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 terrigenous to a sedimentation with brackish water intercalations.

#### Domkirken series.

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

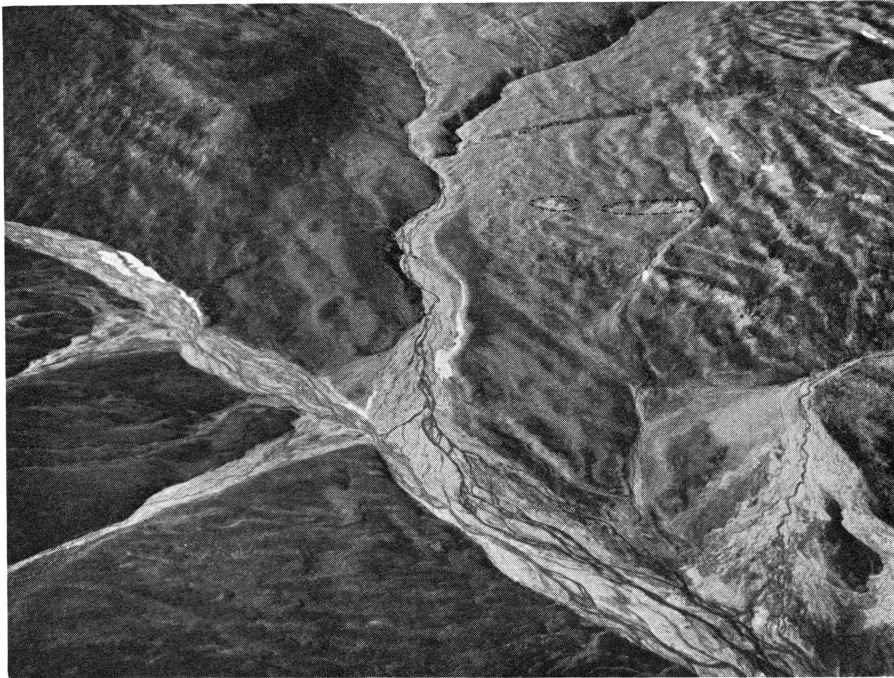


Fig. 3. Aerial view of Blyklippen, before exploration started. The vein outcrops have been encircled.

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  $10^{\circ}$ .

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., *Posidonomya* and *Spiriferidae*<sup>1</sup>). 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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<sup>1</sup>) 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 Antarectics 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 similar succession of lavabeds occur.

### Tectonics.

According to BIERTHER (1941), the tectonic pattern of the north-eastern part of Scoresby Land is that of a rather simple germano-type 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 studied 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 palæozoic and mesozoic. Sediments of devonian to cretaceous age have been deposited in longitudinal basins.

At Blyklippen the offset of the faults is 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 abrasives 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 arcose 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 ob-

servations 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 montmorillonite. (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 Hestekoen, also in a higher stratigraphical level than the Blyklippen occurrence. The gangue of the Hestekoen 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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