Meddelelser om Grønland

The mineral occurrences of central East Greenland

Ole Harpøth, John L. Pedersen, Hans Kristian Schønwandt and Bjørn Thomassen

Geoscience
17 · 1986

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Accepted 24-06-1986
ISSN 0106-1046
ISBN 87-17-05418-4
Printed in Denmark by AiO Print Ltd., Odense

Preface

This monograph gives an up-to-date description of the known mineral occurrences of central East Greenland. The data presented are mainly the result of 30 years of field activity by the Northern Mining Company but include also observations reported by the Lauge Koch expeditions and more recent investigations made by the Geological Survey of Greenland.

The monograph is the most comprehensive and detailed regional description of mineral occurrences anywhere in Greenland. The ice-free part of the concession area is bigger than Denmark, and the geological environment spans from Archaean crust to Tertiary intrusions. Processes of mineralization occurred throughout all stages of the geological history. The monograph contains a detailed inventory of all known mineral occurrences. The book is however more than just an evaluation of the mineral potential of this big area. It places the hundreds of mineral occurrences in a modern geological context, both in a detailed, regional, and plate tectonic scale. It illustrates that ore formation is an integrated part of the geological processes. In central East Greenland, however, investigations have only led to the operation of one mine, so far.

This monograph is an important contribution to the understanding of the geology of East Greenland and the North Atlantic region, and serves at the same time as a guide for the future search for mineral resources in East Greenland. Mineral exploration in this beautiful but inhospitable part of the world is arduous and expensive. It is therefore important that the results of more than 200 man seasons in the area are made known to as wide a public as possible, so that future exploration can be planned so as to attain optimum efficiency.

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Harpøth, O., Pedersen, J.L., Schønwandt, H.K. & Thomassen, B. The mineral occurrences of central East Greenland. Meddr Grønland, Geosci. 17: 139 pp. Copenhagen 1986-12-31.

The present monograph on the mineral occurrences of central East Greenland is the result of an agreement between Nordisk Mineselskab A/S and the Mineral Resources Administration of Greenland (Råstofforvaltningen for Grønland) on compilation of the mineral-exploration activity carried out in central East Greenland by Nordisk Mineselskab A/S during the period 1952–1984. The main aim is to present geological descriptions of all known mineral occurrences and to compile most of the existing geochemical data in a manner applicable to future exploration in the area. More than 200 individual mineral occurrences are described and many in great detail. Geochemical data are presented for scheelite and for 16 elements relevant to the evaluation of the mineral potential of the area. The data are presented as single-element anomaly maps for both rock samples and panned heavy-mineral concentrates and include data from a file consisting of more than 10 000 rock samples and close to 4000 panned heavy-mineral samples.

Mineralization in central East Greenland occurs in rocks of Archaean to Oligocene age and has tentatively been grouped into several periods when mineralization took place.

Mineralization hosted in Archaean-Lower Proterozoic rocks includes magnetite and chromite accumulations and iron-sulphide segregations associated with ultramafic and mafic igneous assemblages, volcanogenic massive-sulphide occurrences, titaniferous magnetite and ilmenite occurrences associated with original plutonic anorthositic massifs, banded iron-formations, gold-bearing quartz veins, a complex copper-skarn occurrence, and uranium and gold-uranium occurrences of unknown origin.

Mineralization hosted in Middle and Upper Proterozoic rocks is restricted to lead-zinc and tungsten skarns and stratiform copper occurrences.

Mineralization hosted in Lower Palaeozoic rocks is in general believed to be associated with Caledonian orogenic activity. It comprises tungsten skarn occurrences mainly associated with granodiorite intrusions, base-metal and tungsten mineralization associated with late-kinematic probably calc-alkaline granite, tin-tungsten-arsenic quartz veins associated with late-kinematic probably mildly alkaline granites, gold-bearing quartz veins associated with late-kinematic granite, uraniferous veins in probably Devonian alkaline granite, tungsten-antimony-gold and silver-bearing base-metal veins in low-grade metamorphic sediments, uranium-fluorite veins in Devonian felsic volcanic rocks and strata-bound uranium occurrences hosted in Devonian clastic rocks.

Mineralization hosted in Upper Palaeozoic sediments (Carboniferous – Permian) includes base-metal quartz-baryte veins locally enriched in precious metals, gold-bearing quartz veins, uraniferous veins, carbonate-hosted strata-bound baryte base-metal occurrences, carbonate-hosted strata-bound celestite occurrences, stratiform base-metal showings of Kupferschiefer type and strata-bound red-bed copper occurrences.

Mineralization hosted in Mesozoic sediments is represented by Triassic stratiform and strata-bound base-metal occurrences of red-bed type and Jurassic placers rich in zirconium and rare-earth elements.

Tertiary mineralization includes a major porphyry-molybdenum occurrence, granite roof-zone molybdenum mineralization, niobium mineralization associated with alkaline intrusive rocks, lead-zinc skarn occurrences, a minor magnetite-skarn showing, lead-zinc-bearing quartz veins and precious-metal, base-metal, molybdenum and fluorite mineralization associated with fumarolic volcanic activity.

The location of all mineral occurrences is shown on a separate map: Mineral Occurrences in Central East Greenland.

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The main aim of the present monograph on mineralization in central East Greenland is to present descriptions of all known mineral occurrences and present most of the existing geochemical data applicable to future exploration in the area.

The background for this compilation is to be found in the change of concession for Nordisk Mineselskab A/S (Nordmine) which came into force on the 6th of December 1984. In 1952, Nordisk Mineselskab A/S obtained by law (No. 431 – December 17th 1952) a 50-years exclusive exploration and exploitation concession for all metals, coal, oil and minerals except cryolite and radioactive minerals in an area of central East Greenland located between 70°N and 74°30'N latitude and from 30°W longitude eastwards to the sea (Fig. 1). In 1984, the original concession was relinquished and replaced by six exclusive hard-mineral concessions and one exclusive hydrocarbon concession lasting for the period 1985–1997 in the general area. As a part of this change of concession Nordisk Mineselskab A/S agreed to present a compilation of the mineral-exploration activity carried out in the 1952-concession area during this 33-years period. Moreover, in order to present as complete a picture as possible, information from other sources on mineralization in central East Greenland has been included in the present work.

Although the mineral exploration history of central East Greenland is relatively short, several authors have at different times compiled existing data on mineral occurrences and presented their evaluation of the mineral potential. The first systematic compilation and evaluation of the mineral potential was done by Eklund (1944). A more recent evaluation of the mineral potential was presented by Petrascheck (1971). In both evaluations only the Tertiary intrusive complexes are attributed a good potential, mainly for molybdenum and base metals. Nielsen (1973), in his summary of mineral occurrences in Greenland, included selected examples from central East Greenland, and the same data are presented in the monographs "Geology of Greenland" (Nielsen 1976) and "Mineral Deposits of Europe" (Sørensen et al. 1978). A more comprehensive review, which however only incorporates the mineralization hosted in parts of the pre-Caledonian sediments, has recently been published (Stendal & Ghisler 1984). Internally, Nordmine has prepared an inventory of the mineral potential twice (Hintsteiner 1972 and Geyti et al. 1979).

The 1952-concession area (Fig. 1) comprises a land area of *c.* 118 000 km² of which *c.* 55 000 km² is covered by inland ice and glaciers and *c.* 63 000 km² is ice-free. Actually, it is one of the largest ice-free regions in Greenland – 500 km long and up to 300 km wide.

The physiography of the area is dominated by inland ice to the west and by mountainous terrain, varying from glacier-dissected Alpine regions (Fig. 2) with peaks nearing 3000 m, to less rugged plateau mountains (Fig. 3) cut by deep U-shaped valleys, to relatively flat low-lying areas of sedimentary rocks to the east. Numerous long and deep fjords and valleys dissect the entire area. In general the glacially eroded land surface is very well exposed, but low-lying areas may exhibit extensive Arctic vegetation cover.

The climate is high Arctic with a mean annual temperature varying from −7.5°C in the south (Scoresbysund), over −9.8°C in the central part (Mesters Vig – Fig. 4) to −10.4°C in the north (Daneborg). The mean annual precipitation varies from *c.* 460 mm in the south to only 220 mm in the north.

A Greenlandic population of about 500 people is divided between the settlements Scoresbysund (Ittoqqortoormiit), Kap Hope (Ittaaijeme – *c.* 15 km west of Scoresbysund) and Kap Tobin (Uunartoq – *c.* 7 km south of Scoresbysund), all in the southeastern part of the area (Fig. 1). Other permanent housing with a few people exists at Constable Pynt, Mesters Vig and Daneborg, which is the headquarters of the military sledge-patrol "Sirius". Two gravel air strips are located at Constable Pynt (1000 m runway) and at Mesters Vig (1800 m runway) respectively and provide the only access to the area except for a 1–2 month period when the fjords are navigable for ice-strengthened ships. The northern part of the area forms part of the North Greenland National Park established in 1974.

All East Greenland place names in the text and illustrations are those authorized. Most can be found on the 1: 250 000 topographical maps of the area. A few place names, which have not yet been approved officially, are shown in quotation marks.

Exploration

History

The search for mineral occurrences in central East Greenland goes as far back as the discovery history of the area (Jameson 1823, Bay 1896 and Nordenskjöld 1907). The most interesting find of the early period (1822–1900) was by Nordenskjöld (1907) on the Amdrup expedition to Kong Oscar Fjord, where he reported calcareous quartzites with thin veinlets of chalcocite, cuprite and malachite in Pingel Dal, Fleming Fjord. The early history of discovery is outlined in detail by Rosenkrantz (1970) and Haller (1971), and the earliest findings are summarized by Bøggild (1905, 1953).

Since this early period, the knowledge of mineral occurrences in central East Greenland has continuously increased and the hope of finding commercial deposits has been the most important reason for the geological research performed and still going on. The exploration-related activity is summarized in Table 1.

The first systematic mineral exploration work was carried out in connection with the "Danske Treårsekspedition til Østgrønland" from 1930 to 1934 (Eklund

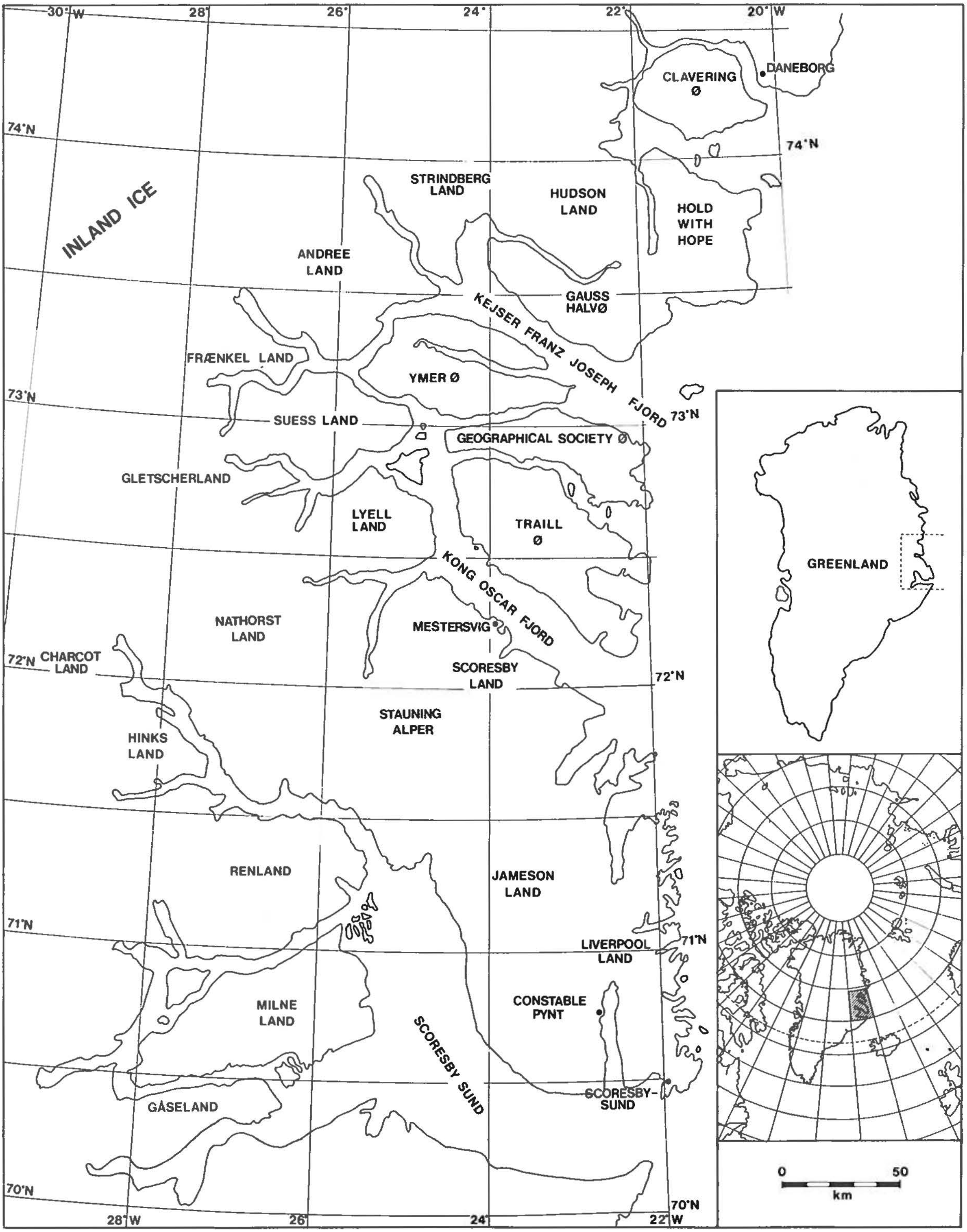


Fig. 1. Location map, central East Greenland.

Fig. 2. Alpine terrain. Bersærkerbræ, Stauning Alper.

1944, Koch 1955). The major exploration activity was directed towards gold-bearing pyrite veins on Clavering Ø (Fig. 5), but other finds from this period include copper in Charcot Land, gold-arsenic at Drømmebugten on Traill Ø, and gold-copper and copper-lead-silver mineralization on Wegener Halvø.

After the Second World War, the expeditions to East Greenland were continued from 1947 to 1958 under the leadership of Lauge Koch (Koch 1963, Haller 1971). As a spin-off from geological mapping two significant finds were made. In 1948 lead-zinc-bearing quartz veins were found in the Mesters Vig area (Witzig 1954), and in 1954 molybdenite mineralization was found at Malmbjerg (Bearth 1959). Other, but minor, finds include galena-bearing quartz veins in Alpefjord (Fränkl 1951), lead-zinc-bearing quartz veins in Noa Dal on Ymer Ø (Eha 1953), base-metal mineralization west of Schuchert Dal (Kempter 1961) and fluorite base-metal mineralization at Kap Franklin (Graeter 1957).

The lead-zinc mineralization in the Mesters Vig area was investigated from 1949 to 1951 by the Lauge Koch expeditions, and from 1952 the investigations were taken over by the Danish mining company Nordisk Mineselskab A/S (Nordmine) (Kampmann 1953, Brinch 1969). The company was established with the aim of investigating and if possible mining the Blyklippen lead-zinc deposit, and it was granted an exclusive exploitation concession in East Greenland from 70°N to 74°30'N

Fig. 3. Plateau mountains. Revdal, Karstryggen, in the foreground and northern Jameson Land in the background.

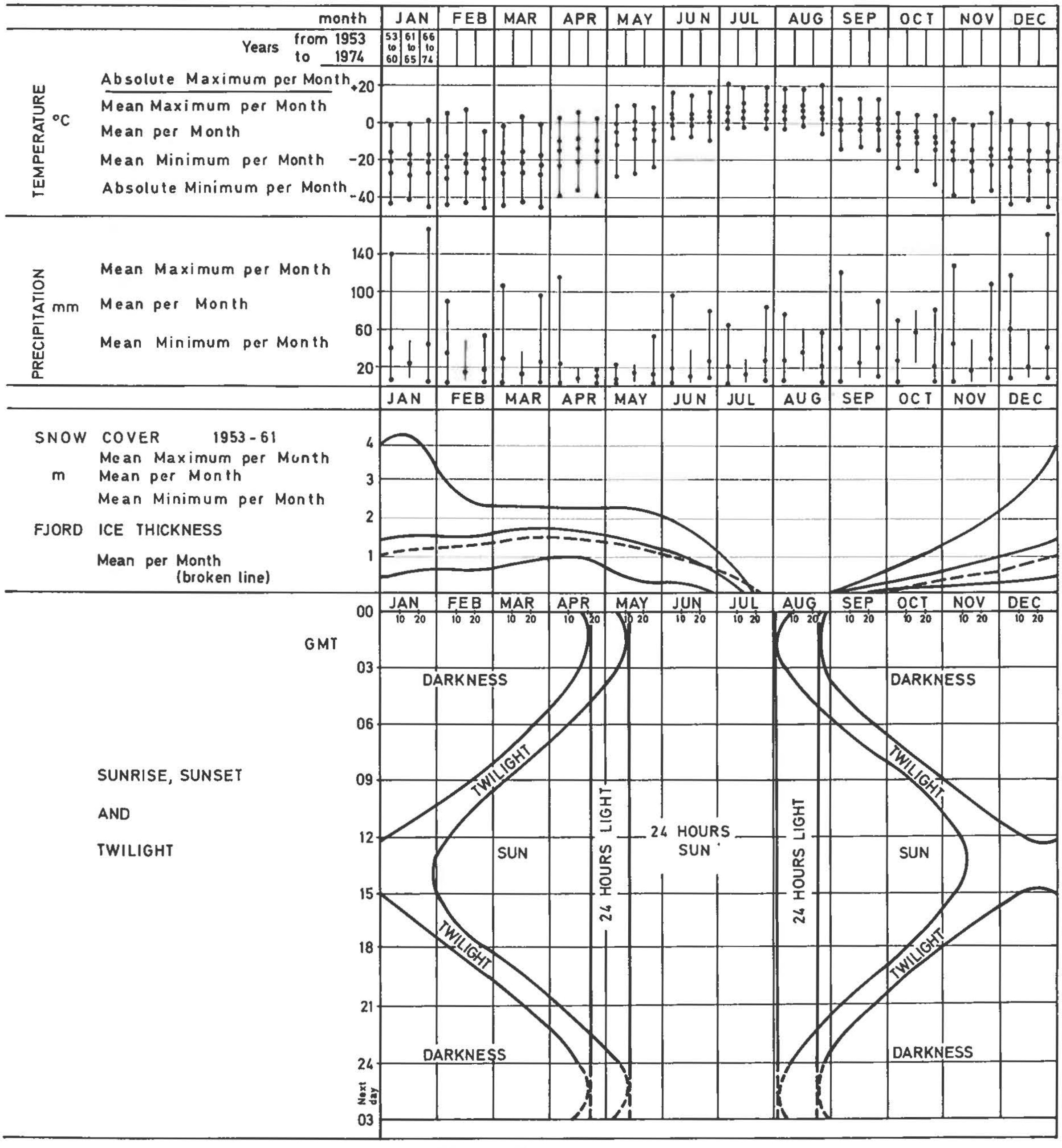


Fig. 4. Summary of climatic data for Mesters Vig, 72°15′N, 23°54′W.

for a period of 50 years. From 1952–1954 deposit investigations were made, and mining was initiated in 1956 and lasted until 1962. A total of 545 000 tons of ore with 9.3% Pb and 9.9% Zn was mined (Nordmine annual reports 1956–1962). At the same time as mining, exploration was continued by Nordmine and in particular concentrated on similar lead-zinc-bearing veins in the Mesters Vig and Schuchert Dal areas, which however failed to demonstrate mineable tonnages. Major drilling programmes were performed on the east slope of Sortebjerg and in Pingo Dal. A limited and more regional exploration programme in the northern part of the concession area (72°–74°30′N) was also unsuccessful. After the finding of the Malmbjerg molybdenum occurrence, the activities were gradually concentrated there and from 1958 to 1962 major deposit investigations were made at first by Nordmine, and from 1961 by Arktisk Minekompagni A/S, which was owned equally by Nordisk Mineselskab A/S and AMAX Inc., New York (Brinch 1969). Ultimately an ore body of 150 million tons with 0.23%

Fig. 5. Exploration in the thirties using ponies for transportation of geophysical equipment on Clavering Ø. From Koch (1955).

Table 1. Summary of mineral exploration related activities in central East Greenland. The cost estimate (1985-Dkr) is calculated on basis of actual cost using the consumer price index.

Period	Organization	Activity	Estimated cost of mineral exploration (million 1985 D.kr.)
1823–1907	The early expeditions	Scattered observations	–
1927–1938	Lauge Koch expeditions	Scattered observations. Detailed exploration – Clavering Ø	5
1947–1958	Lauge Koch expeditions	Scattered observations. Deposit investigation at Blyklippen	30
1952–1954	Nordisk Mineselskab A/S	Deposit investigations at Blyklippen and Sortebjerg	125
1956–1962	Nordisk Mineselskab A/S	Reconnaissance exploration	15
1956–1975	Nordisk Mineselskab A/S Arktisk Minekompagni A/S	Exploration and deposit investigation at Malmbjerg	90
1968–1972	The Geological Survey of Greenland	Mapping. Aeromagnetics. Scattered observations	5
1963–1984	Nordisk Mineselskab A/S	Exploration (mainly for base metals)	90
1971–1977	The Geological Survey of Greenland	Uranium exploration	15
1979–1984	Nordisk Mineselskab A/S Commission of the European Communities	Tungsten-antimony exploration	15
1978–1983	EGMO	Drilling at Malmbjerg	10
1974–1975	IGCP project University of Copenhagen	Reconnaissance	1
1979–1986	The Technical University of Denmark Commission of the European Communities The Geological Survey of Greenland	Remote sensing projects	4
1979–1982	The Technical University of Denmark Commission of the European Communities	Geochemical project	1
1983–1986	University of Aarhus Commission of the European Communities	Investigation of molybdenum porphyries	1

Fig. 6. Preparation for diamond drilling in north Margeries Dal, Ymer Ø.

MoS_2 was outlined. The deposit is subeconomic and has not yet been put into production. A new mineralization model for the Malmbjerg deposit was tested in 1979 by a 1000 m deep drill hole (Fig. 9) below the known ore body by the EGMO joint venture between Nordisk Mineselskab A/S and AMAX Inc. Only low-grade molybdenum mineralization was intersected.

In the mid-sixties it was recognized by Nordmine that the likelihood of bringing the Malmbjerg molybdenum occurrence into production was decreasing, and it was decided to continue the general exploration within the concession area. On a discontinuous basis this exploration has been going on since 1968. From 1968 to 1972 the exploration was concentrated in the southern part of the concession area (70°N to 72°N) where it led to the finding of fossil zirconium and rare-earth element placers on Milne Land, vein-type uranium in west Schuchert Dal, strata-bound baryte and base-metal mineralization at Bredehorn, strata-bound base-metal mineralization on Wegener Halvø, vein-type base-metal mineralization on east Traill Ø and vein-type niobium and rare-earth-element mineralization on Traill Ø and in Werner Bjerge.

The next period with major field activity lasted from 1974 to 1976. It led to the finding of strata-bound copper-silver-lead mineralization in east Jameson Land, strata-bound copper-antimony-silver mineralization on Strindberg Land, disseminated uranium and skarn-type copper mineralization in the northern part of the Central Metamorphic Complex and vein-type tungsten-arsenic mineralization at Randenæs.

The last period with major exploration activity lasted from 1979 to 1983 and led to the finding of strata-bound celestite and base-metal mineralization at Karstryggen, strata-bound baryte in Oksedal, red-bed type copper-silver mineralization on Traill Ø, vein- and skarn-type tungsten and/or tin mineralization in Kalkdal, Milne Land, North Stauning Alper, Blokadedal and Rendalen, vein-type fluorite and base-metal mineralization on Canning Land, vein-type precious- and base-metal mineralization at Sernander Bjerg, vein-type tungsten-antimony mineralization in Margeries Dal (Fig. 6), vein-type antimony-gold mineralization in Noa Dal and vein-type gold-bismuth mineralization at Luciagletscher.

Simultaneously with the exploration activity of Nordmine, government institutions and scientific research groups have also been working in the area.

From 1968 to 1972, The Geological Survey of Greenland (GGU) mapped the area between 70°N and 72°N and several mineral occurrences were reported in connection with this activity. The findings include massive iron-sulphide horizons in Charcot Land, gold-uranium mineralization in Flyverfjord, massive chromite-magnetite lenses in Hinks Land and stratiform copper mineralization on Canning Land (Caby 1972).

In continuation of an aeroradiometric survey carried out jointly by Nordmine and the research establishment RISØ in 1970, GGU conducted an open-spaced aeroradiometric reconnaissance programme in central East Greenland in 1971 (Nielsen 1972 and Løvborg & Nielsen 1973). A more comprehensive flight programme was carried out in 1973 (Nielsen & Larsen 1974), and the results from both years are summarized by Nielsen & Løvborg (1976). In continuation of the flight programme, GGU conducted from 1973 to 1977 a uranium exploration programme in the area betweeen 73° and 76°N. The findings include uranium-lead-zinc mineralization associated with Devonian volcanics in Giesecke Bjerge and Ritomsø (Secher et al. 1976, Steenfelt 1976, Steenfelt & Nielsen 1978).

During and after the aeroradiometric programme, aeromagnetic measurements were carried out by GGU in 1973 and 1974 (Nielsen & Larsen 1974, Larsen 1975 and 1977). Strong magnetic anomalies were identified in Gletscherland and at Schackleton Bjerg.

As part of an IGCP project (International Geological Correlation Programme), the University of Copenhagen investigated the pre-Caledonian sedimentary sequence between 72°N and 74°N in 1974 and 1975. Tungsten-arsenic mineralization was located in the Alpefjord area and additional strata-bound copper mineralization was found north of 72°N (Ghisler et al. 1980a and b).

The investigations on tungsten mineralization by Nordmine received support from the Commission of the European Communities (CEC) from 1979 to 1984. Similarly, the CEC has been supporting other research groups also working in central East Greenland. The activities include geochemistry and remote sensing projects at the Technical University of Denmark (Conradsen et al. 1982, Clausen & Harpøth 1983, Conradsen & Harpøth 1984), a remote sensing project at GGU (Thyrsted & Friedman 1982, Favard et al. 1982) and a molybdenum project at the University of Århus. None of these projects has so far led to the finding of new mineral occurrences, mainly due to lack of follow-up.

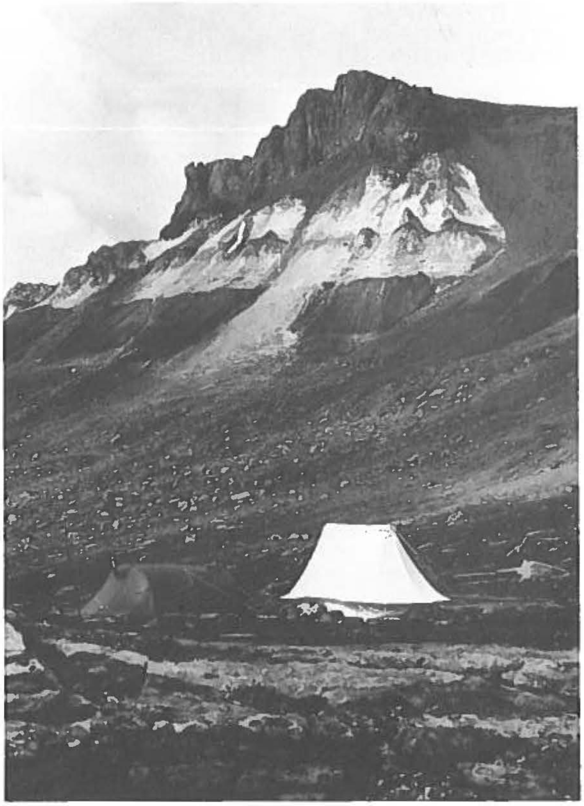


Fig. 7. Traditional light-weight two-men tent camp suitable for summer exploration.

Methods and results

As extensive snow cover exists except in July, August and part of September, geological field work is mainly restricted to those months. However, steep fjord walls, which are common in the western part of the area, often remain snow-free. Such areas can be examined in September-October or, preferably, in April-May, when the fjord ice is fit for travelling on by snow scooters.

A wide range of mineral exploration methods have been applied in central East Greenland. The oldest and most widely used method is reconnaissance in the terrain with identification of alteration phenomena, structural features favourable for mineralization, mineralized boulders and outcrops. The method only requires a minimum of equipment (Polegeg 1971, Thomassen 1971). Special portable equipment which has been in use includes portable X-ray spectrometer for direct analysis in the field (Kunzendorf et al. 1971), scintillometer for identification of radioactive minerals and ultraviolet lamps for identification of fluorescent minerals (scheelite, hydrozincite, secondary uranium minerals) (Hintsteiner 1977). Most mineral occurrences in central East Greenland including Malmbjerg and Blyklippen have been found in this way. Today, the method is mostly used in connection with follow-up of geochemical and/or geophysical anomalies.

The most basic exploration method applied – visual reconnaissance by foot traversing – is unfortunately restricted to smaller areas (Figs 7 and 8). However, the effectiveness can be increased considerably by using boats in the fjords during summer time, dog sledges and snow scooter on the ice-covered fjords during spring, and fixed-wing airplane or helicopterr during summer time when the mountains are free of snow. The first two methods were systematically employed by the Lauge Koch expeditions and later by Nordmine, and for example the uranium-gold mineralization in Flyverfjord and copper mineralization in central Kejser Franz Joseph Fjord were found in this way. Systematic air reconnaissance has only been performed in limited areas, but this, in connection with observations during interior land transport, has led to the finding of several mineral occurrences such as baryte at Bredehorn (10 m thick white horizon), lead in eastern Schuchert Dal (white quartz vein) and copper-lead mineralization at Quensel Bjerg (green malachite staining).

Visual interpretation of existing air photos covering nearly the whole of central East Greenland (scale 1:50000) has not yet given any direct clues to mineral occurrences, but serves as an indispensable background for detailed field work. Visual interpretation of computer enhanced, false-colour, multispectral scanner images both from aircraft (Favard et al. 1982, Thyrsted & Friedman 1982) and from satellite (Conradsen et al. 1982, Conradsen & Harpøth 1984) is very efficient in

Fig. 8. Modern two-men helicopter-moveable field camp.

delineating rust colour anomalies. Conradsen & Harpøth (1984) identified 38 major rust-colour anomalies (larger than 0.5 km^2) within the Central Metamorphic Complex in central East Greenland. Most of these still await ground follow-up.

Another widely used exploration tool is the application of geochemical methods which has been instrumental in finding tungsten, tin, uranium, base metals, precious metals, niobium and rare-earth element occurrences. Various sample types have been collected, including stream-sediment samples from the drainage system (Nielsen & Steenfelt 1975, Steenfelt et al. 1976, Kunzendorf et al. 1978, Steenfelt & Kunzendorf 1979, Stendal 1979a, b), heavy-mineral concentrates (pan samples) from the drainage system, from moraine and from scree cones (Hintsteiner 1977, Stendal 1980b, Hallenstein et al. 1981), water samples (Asmund 1974, Nielsen & Steenfelt 1975, Asmund & Steenfelt 1976), moraine and scree fines, soil samples (Reece & Mather 1961, Lehnert-Thiel & Vohryzka 1968, Cooke 1976), rock samples (Stendal & Hock 1981, Steenfelt 1982, Thomassen et al. 1982) and vegetation (Brooks et al. 1980). In regional exploration the most frequently applied methods are stream-sediment and heavy-mineral

Fig. 9. Diamond drilling of a 1000 m deep hole at Malmbjerg in 1979.

Fig. 10. Diamond drilling in 1983 in south Margeries Dal.

concentrate sampling from the drainage systems. Stendal (1982a) has compared the two methods, and he concludes, that they supplement each other. The entire central East Greenland is covered with relatively systematically collected heavy-mineral concentrates. All positional, descriptive and analytical data on these samples are stored in a data base (for additional information, see the chapter on geochemistry). Hudson Land and Gauss Halvø are covered by systematically collected stream-sediment samples (Steenfelt & Kunzendorf 1979). The different sample types have been analysed for a wide range of elements by different analytical methods. Advanced statistical methods have been put into use in order to interpret the anomaly pattern (Conradsen et al. 1976, Clausen & Harpøth 1983).

Geophysical exploration methods have also been used in central East Greenland. The most commonly used method has been aeroradiometric measurements (Nielsen 1972, Nielsen & Løvborg 1976, Nielsen & Steenfelt 1977). Several uranium-mineralized localities were found in this way. Aeromagnetic measurements have also been obtained from large areas of central East Greenland (Larsen 1975 and 1977). They are a very open-spaced line measurements, and only large features can be recognized. On the ground, magnetic, EM, IP and VLF methods have been in use during investigations of specific mineral occurrences, for example the pyrite veins on Clavering Ø (Fig. 5) (Koch 1955) and the lead-zinc-bearing veins in the Mesters Vig area.

More detailed prospect investigations have comprised geological mapping, chip sampling, trenching, systematic sampling by percussion drilling and diamond drilling. Shallow diamond drilling has been carried out at Milne Land, Nedre Arkosedal, Brogetdal, Devondal, Bredehorn, Oksedal and Panoramafjeld, and major diamond drilling programmes have been performed at Sortebjerg, Blyklippen, east Schuchert Dal, Malmbjerg (Fig. 9) and south and north Margeries Dal (Figs 6, 10).

Exploration adits have been driven on Clavering Ø (Fig. 49) (Koch 1955) and at Malmbjerg (Hintsteiner 1964), but Blyklippen is the only place where actual mining has taken place (Astlind & Fahlström 1957, Fischer et al. 1958).

Geological evolution and mineralization – an overview

The complex geological history of central East Greenland has been summarized in three monographs (Koch 1929, Haller 1971, Escher & Watt 1976) and in a series of review papers (Maync 1942, Stauber 1942, Cowie & Adams 1957, Donovan 1957, Bütler 1959, Haller 1970, Surlyk et al. 1973, Perch-Nielsen et al. 1974, Birkelund & Perch-Nielsen 1976, Henriksen & Higgins 1976, Higgins 1976, Noe-Nygaard 1976, Surlyk 1977, Higgins & Phillips 1979, Clemmensen 1980, Surlyk et al. 1981, Friend et al. 1983, Surlyk et al. 1984, Bengaard 1985, Henriksen 1985).

Basically, the geology of central East Greenland is dominated by the East Greenland Caledonian fold belt, with younger sedimentary basins of Lower Carboniferous to Tertiary age, including important Tertiary volcanic and plutonic rocks. However, the geological evolution of the Caledonian fold belt in central East Greenland seems to be more complex than in the classic model proposed by Haller (1971); he had assumed the different infracrustal and supracrustal rock units and associated structures to have all been formed during the Caledonian orogeny. More recent investigations point towards a polyorogenic nature of the fold belt, including large areas of pre-Caledonian basement rocks which were only partly reworked during the Caledonian orogeny (Henriksen & Higgins 1976, Steiger et al. 1979, Higgins et al. 1981, Bengaard 1985, Henriksen 1985). The geological evolution is summarized in Fig. 11 and a simplified geological map of central East Greenland is presented in Fig. 12.

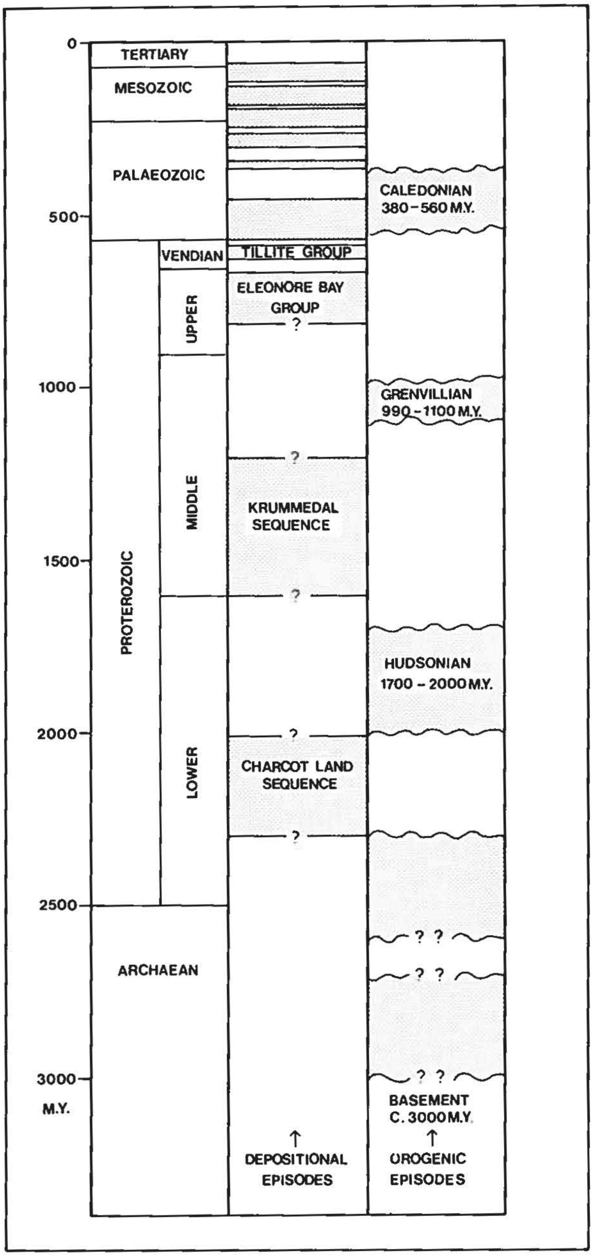


Fig. 11. General chronological scheme of the geological evolution in central East Greenland. Modified after Henriksen & Higgins (1976) and Henriksen (1985).

Archaean – Lower Proterozoic

Archaean – Lower Proterozoic ages have been obtained from various units of the crystalline basement in the so-called gneiss and schist zone (Henriksen 1985). The oldest recognized unit is the Flyverfjord infracrustal complex (Henriksen & Higgins 1969) which occurs between 70°–72°N. This complex comprises banded biotite-hornblende gneisses of granitic to quartz-dioritic composition. Inclusions of amphibolitic and ultramafic composition are common in the gneisses and several generations of amphibolite dykes also occur. Recognizable metasedimentary sequences are extremely rare. The complex is intensely folded with several superimposed phases of folding. The amphibolite dykes post-date at least two phases of deformation, but are themselves affected by a younger (possibly *c.* 2500 Ma) phase. A Rb-Sr isochron age of *c.* 3000 Ma on a biotite gneiss (Rex & Gledhill 1974) indicates that the main development of the complex extends well back into the Archaean. Gneisses and migmatites of the Flyverfjord infracrustal complex can be traced northwards into the so-called Gletscherland migmatite complex (Haller 1955 and 1971), where they have yielded a Rb-Sr whole rock age of *c.* 2450 Ma (Rex & Gledhill 1981). Here they were subsequently reworked during a Lower Proterozoic (Hudsonian) orogeny. Other Archaean – Lower Proterozoic infracrustal basement units may occur within the so-called Niggli Spids migmatite dome and Hagar migmatite sheet (Haller 1955 and 1971), and in central and southern Liverpool Land. At least two orogenic cycles occurred before the deposition of the first recognizable sedimentary sequence (Fig. 11).

The Lower Proterozoic (Hudsonian) orogenic phase (*c.* 2000–1700 Ma) is marked by deposition of sediments, volcanic rocks and the intrusion of mafic and felsic rocks. The best known metasedimentary and volcanic sequence (greenstone) occurs in the Charcot Land window and is known as the Charcot Land supracrustal sequence (Henriksen & Higgins 1969). The sequence is more than 2000 m thick, with a lower part consisting of marble and amphibolite units, overlain by semi-pelitic and quartzitic units with a pronounced lateral facies variation (Steck 1971). In addition, there are thick units of mafic extrusives which locally exhibit pillow structures. The supracrustals are cut by two post-kinematic granodiorite and granitic intrusions, which were emplaced *c.* 1840 Ma ago (Hansen et al. 1981). Lithologically similar supracrustal sequences of probable Lower Proterozoic age are known from Gletscherland and southern Liverpool Land (Bengaard 1985).

The Hudsonian orogeny affected the basement and the Lower Proterozoic supracrustal sequences, which were folded, metamorphosed and intruded by plutonic rocks. The fold pattern of the Charcot Land window and of the Gletscherland migmatite complex with E-W to SE-NW structures suggests that north-south compression occurred during the orogeny. The metamorphic grade decreases southwards in the Charcot Land window, suggesting that the southwestern boundary of the Hudsonian fold belt may be situated here. A minimum age of *c.* 1840 Ma for the deformation in Charcot Land has been suggested (Hansen et al. 1981). In southern Liverpool Land a southwards thrust episode and metamorphism of up to granulite facies grade are attributed to the Hudsonian orogeny (Bengaard 1985).

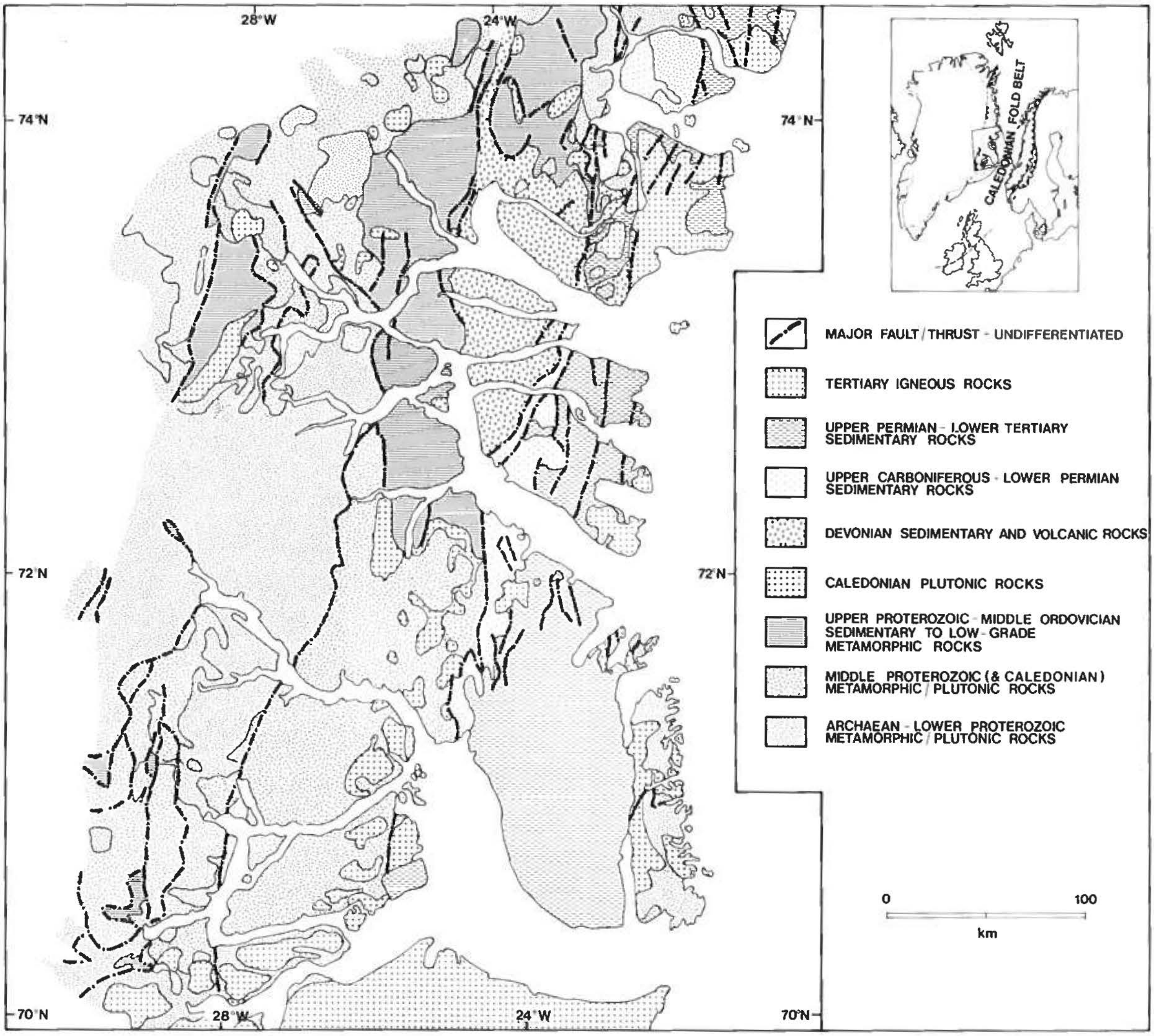


Fig. 12. Simplified geological map of central East Greenland. Modified after Bengaard (1985). Inset shows the North Atlantic in a pre-drift configuration.

However, the connection with the western areas are unknown. In other parts of central East Greenland the Hudsonian orogeny is represented by radiometric ages of 1975–1705 Ma. Whether these ages represent a single or several orogenic episodes is not known. In summary, it is believed that the Hudsonian orogeny is represented in East Greenland by a north-south collision with extensive east-west folding, southwards thrusting, metamorphism and plutonism.

Known mineralization hosted in Archaean – Lower Proterozoic rocks in central East Greenland is relatively sparse and partly confined to the greenstone belt, part of which is exposed from Charcot Land to Gletscherland, and partly confined to crystalline basement units of unknown origin. Minor occurrences associated with mafic and ultramafic igneous assemblages include accumulations of magnetite and chromite (no. 7) and iron-sulphide segregations with minor chalcopyrite, pentlandite and sporadic enrichment in platinum-group elements (PGE) and/or gold (nos 1–3). Mineralization of volcanogenic affiliation is represented by minor massive-sulphide occurrences (nos 8 and 9). Other observed mineralization is titaniferous magnetite and ilmenite occurrences probably associated with original plutonic anorthosite massifs (no. 10), banded iron-formation (no. 11), a gold-uranium occurrence of unknown origin (no. 5), gold-bearing quartz veins (nos 2 and 6), a complex copper skarn occurrence (no. 12) and uranium occurrences of unknown origin (nos 13 and 14). In general, the exposed part of the greenstone belt is characterized by sulphide facies to the south (Charcot Land) and oxide facies to the north (Gletscherland).

The observed Archaean – Lower Proterozoic mineralization pattern is in good accordance with that of basement areas in West Greenland (banded iron-formations (Appel 1978), chromium in layered anorthosite (Ghisler 1976), gold-quartz veins in greenstones (Appel & Secher 1984)) and Norway (banded iron-formations (Bugge 1978)).

Middle Proterozoic.

Middle Proterozoic metasedimentary sequences are widespread in the gneiss and schist zone, where they overlie the Archaean – Lower Proterozoic basement gneisses. The sedimentation is one element of the Middle Proterozoic (Grenvillian) orogenic phase (*c.* 1100–990 Ma) (Fig. 11). In the migmatite and granite zone of the Scoresby Sund region (Henriksen 1985) similar sequences are highly migmatized, but are believed to have the same origin. An informal term – the Krummedal supracrustal sequence – has been applied to the Middle Proterozoic supracrustal rocks in the Scoresby Sund region (Higgins 1974). The sequence mainly consists of pelitic, semipelitic and psammitic schists and gneisses, which resemble flysch sediments (Bengaard 1985). The contact to the underlying older rock units is often tightly folded, and generally modified by shearing; occasionally, a nearly undisturbed sedimentary contact may occur, for example in parts of Andrée Land (Higgins et al. 1981).

At about the same time as the deposition of the Krummedal supracrustal sequence and comparable sequences south of 76°N, extensive extrusion of tholeitic plateau basalts was taking place further north in eastern North Greenland. The plateau basalts have been linked with the continental break-up which resulted in a Grenvillian ocean (Bengaard 1985). The Grenvillian fold belt in East Greenland is oriented NNE-SSW and the ocean is assumed to have had the same trend. The orogeny seems to have been relatively short, occurring during the period 1100–990 Ma ago (Fig. 11), and westwards thrusting occurred at least in the southern part (Bengaard 1985). Much of the extensive migmatization and amphibolite facies metamorphism exhibited by the Krummedal supracrustal sequence and similar sequences, probably took place during the Grenvillian orogeny (Steiger et al. 1979). Plutonic activity is mainly expressed as migmatization. It has been suggested that the Grenvillian orogeny in East Greenland represents an east-west collision with extensive westwards thrusting and associated folding, metamorphism and migmatization.

Mineralization hosted in Middle Proterozoic rocks in central East Greenland is sparse and restricted to small lead-zinc- and tungsten skarn occurrences (nos 16–18 and 21) and low-grade stratiform copper occurrences (nos 19 and 20).

In the neighbouring areas, mineralization of that age also seems to be relatively sparse, but large strata-bound copper deposits in clastic sediments (for example Zaire-Zambian copperbelt and many deposits in North America) characterize the Middle Proterozoic world-wide (Meyer 1981).

Upper Proterozoic – Middle Ordovician

The Upper Proterozoic – Middle Ordovician sedimentary sequences are well exposed in East Greenland, and were deformed and metamorphosed during the Caledonian orogeny (560–380 Ma) (Fig. 11). The sediments were deposited in a large north-south-trending basin (Haller 1971) (Fig. 12). The lower part of the sequence – the Eleonore Bay Group (EBG) – comprises a more than 12000 m thick (composite) succession of shallow-water sediments. It consists of a lower unit (the Lower EBG) up to 9000 m thick of dominantly quartzites and shales laid down on a wide subsiding and fluctuating deltaic shelf. It is overlain by an upper unit (the Upper EBG) up to 4000 m thick, comprising three main divisions: the Quartzite Series, the Multicoloured Series and the Limestone-Dolomite Series. The main rock types are sandstones (mainly quartzites), siltstones, mudstones, carbonates (often stromatolitic) and locally evaporites (originally gypsiferous deposits). The age of the lower part of the sequence is somewhat uncertain, but the top is thought to be of Upper Riphean age (*c.* 800–650 Ma) (Vidal 1976).

After a considerable hiatus the Tillite Group was deposited probably during the mid-Vendian period (*c.* 600 Ma) (Vidal 1979) (Fig. 11). It is a 500–800 m thick sequence including two distinct tillite levels of regional extent, which rests with slight angular unconformity on EBG sediments. Two tillite occurrences in the Gåseland and Charcot Land windows (Phillips & Friderichsen 1981, Henriksen 1981) are possibly of similar age.

After another break in sedimentation, up to 3000 m of shallow marine carbonates were deposited during the Lower Cambrian to Middle Ordovician period (Cowie & Adams 1957). Local occurrences of marble and chlorite schist in the Gåseland tectonic window have been interpreted as metamorphosed Cambrian-Ordovician sediments (Phillips et al. 1973) (Fig. 12).

Mineralization hosted in Upper Proterozoic to Middle Ordovician rocks in central East Greenland comprises large but low-grade stratiform and strata-bound copper occurrences (nos 22–43). Pan-sample anomalies (see section on geochemical maps) also indicate the existence of strata-bound barium and lead-zinc occurrences in the Upper Proterozoic – Middle Ordovician sedimentary sequence.

In formerly neighbouring areas, stratiform and strata-bound copper, lead-zinc and barium mineralization of similar age is widespread. Examples are barium and lead-zinc occurrences in the Dalradian sequence of Scotland (Coats et al. 1980) and Ireland (Williams &

McArdle 1978), lead-zinc deposits in the Upper Proterozoic – Lower Cambrian along the Caledonian front of Scandinavia (Bjørlykke & Sangster 1981) and copper occurrences in the Raipas windows of northern Norway (Bugge 1978).

Caledonian 'period'

The Caledonian orogeny in central East Greenland is associated with a Cordilleran type of mountain building; however only the zone underlain by continental crust is exposed (Henriksen 1985). Subduction below the Greenland continental plate occurred somewhere east of the present coast line and resulted in extensive calc-alkaline plutonism and north-south folding. The main phase of the Caledonian orogeny (*c.* Upper Ordovician) affects both the Precambrian crystalline complexes and the overlying Upper Riphean – Middle Ordovician sedimentary sequence. The partly reactivated basement and the overlying sediments are separated by a probable decollement zone. Gentle N-S folding of the sediments indicates a limited lateral shortening of only 5–15 per cent in the central part of the area. The intrusive activity culminated during the Middle Silurian, but otherwise show a big spread in time from 560–380 Ma (Henriksen 1985). Between 72°–74°N the granites were mainly intruded in the boundary zone between the EBG sediments and the adjacent metamorphic complexes (Haller 1971), whereas further south intrusions are widespread within the crystalline complexes (Fig. 12). In general the granites show a calc-alkaline trend (Bengaard 1985). However, the Devonian granites may be alkaline (Steenfelt 1982). During the Middle Silurian, low-grade metamorphism affected the sediments whereas amphibolite facies/lower granulite facies metamorphism occurred in the eastern part of the granite and migmatite zone. During the Upper Silurian – Lower Devonian the main Caledonian thrusting (at least 50 km westwards) occurred and was locally associated with retrograde metamorphism (greenschist facies).

After the main phase of the Caledonian orogeny an up to 7000 m thick sequence of continental clastic sediments was deposited during the Lower Devonian – lowermost Carboniferous in several intramontane basins (Fig. 12) as a result of late-Caledonian tectonic activity. Various phases of molasse sedimentation, tectonic activity and volcanism have been distinguished (Friend et al. 1983). The sediments mainly comprise continental conglomerate and sandstone with subordinate shale. The volcanics include rhyolite, rhyodacite, latite, basalt and pyroclastic rocks. Sedimentation terminated during the Lower Carboniferous and was followed by widespread deformation of the Devonian sequence resulting in north-south open folding and westwards thrusting (Haller 1971). This last tectonic phase brings an end to a long period of compressional tectonics and marks the end of the late-Caledonian orogenic period.

Mineralization in central East Greenland hosted in Lower Palaeozoic rocks and in general believed to be associated with Caledonian orogenic activity is widespread. Three types are distinguished: 1) granite-related mineralization, 2) structure-controlled mineralization, and 3) strata-bound mineralization. The granite-related mineralization is represented by tungsten skarn occurrences mainly associated with granodiorite intrusions (nos 44, 45, 63 and 71), base-metal and tungsten mineralization associated with late-kinematic granite (no. 46), tin-tungsten-arsenic quartz veins associated with late-kinematic probably mildly alkaline granites (nos 59, 61, 62, 64, 65 and 84), gold-bearing quartz veins associated with late-kinematic granites (nos 66 and 72) and uraniferous veins in probable Devonian alkaline granite (no. 80). The structure-controlled mineralization seems to be related to deep-seated oblique strike-slip movements in the basement from E-W compression during the late-Caledonian period (Pedersen & Olesen 1984). It is represented by tungsten-antimony-gold veins (nos 67–71 and 73–76) and silver-bearing base-metal veins in sediments/Devonian felsic volcanic rocks (nos 47–56, 60 and 83) and uranium-fluorite veins in Devonian felsic volcanic rocks (nos 77–79, 81 and 82). Finally, strata-bound uranium occurrences are hosted in Devonian clastic rocks (nos 57 and 58).

Granite-related and structure-controlled mineralization are also well known from neighbouring areas of the Caledonian fold belt. In the Scottish Caledonides, Plant et al. (1983) suggest that metalliferous granite intrusions are mineralized only where they are emplaced into cool crust (low-grade metamorphic rocks) or where granites are associated temporally with major faulting that continued after their intrusion. Mineralization thus depends on the interaction between metalliferous magma and epizonal water. In Ireland and Norway small, but often high-grade, mineralizations are also related to Caledonian granite intrusions (Williams & McArdle 1978, Bugge 1978). Structure-controlled mineralization of clearly Caledonian age seems to be relatively sparse, but the tungsten veins of Carrock Fell in England and various gold-quartz veins of Wales seem to be of that age. In northern Scotland strata-bound uranium occurrences are known from the Devonian Old Red Sandstone (Dunham et al. 1978).

Carboniferous – Permian

During the Upper Carboniferous the regional stress field changed from the dominating compressional regime of the Caledonian period to mainly east-west tension throughout the remaining cratogenic geological history of central East Greenland (Surlyk et al. in press). Post-Caledonian sedimentation took place in various NNE-SSW-oriented basins (Fig. 12) mainly as a result of rifting, eustatic sea-level changes and basin subsidence. Sedimentation occurred during the Upper Carboniferous – Lower Permian in southwards-propagating continental rift basins, which seem to have been filled with fluviatile sediments (2–5 km) deposited by northwards flowing rivers (Surlyk et al. 1984). The syn-rift sediments were deposited in a system of westwards-tilted half-grabens bounded to the west by faults of the Post-Devonian Main Fault System (Fig. 12). The whole syn-rift sequence was further tilted, uplifted and subjected to peneplanation before the Upper Permian transgression.

The marine Upper Permian section (up to 400 m) was deposited unconformably mainly on an extremely flat Carboniferous – Lower Permian peneplain. The sequence comprises a basal, fluviomarine, sandy conglomerate unit, a marginal marine carbonate and evaporite unit, a more open marine carbonate unit, a black basinal shale unit and finally a progradational shale and sandstone unit (Surlyk et al. in press). The latest Permian marks a phase of regression and probably renewed tectonic activity along the boundary faults.

Mineralization hosted in Carboniferous – Permian rocks in the area is typically of vein and strata-bound nature and associated with a tensional regime as opposed to the late-Caledonian compressional regime. The major fractures (for example the Post-Devonian Main Fault System) probably opened to a deep level of the crust and provided excess heat for the ore-forming processes. Pan-sample anomalies of niobium, rare-earth elements, uranium, thorium and zirconium (see section on geochemical maps) along the Post-Devonian Main Fault System indicate that an alkaline geochemical trend is related to the tensional regime. Known mineralization includes base-metal quartz-baryte veins (nos 85, 86, 88–92, 96–101 and 125–127) locally enriched in precious metals (nos 93 and 94), gold-bearing quartz veins (no. 95), uraniferous veins (no. 87), carbonate-hosted strata-bound baryte base-metal occurrences (nos 102, 103, 107–124 and 127), carbonate-hosted strata-bound celestite occurrences (nos 104–106), stratiform base-metal occurrences of Kupferschiefer type (nos 117 and 118) and strata-bound red-bed copper occurrences (nos 128 and 129). As noted in the following section, some of the veins and the strata-bound occurrences might be of early Mesozoic or Tertiary age. Similar vein deposits are in particular well known from the British Isles, where important districts occur in Ireland, Northern Ireland, Wales, central and northern England and Scotland (Dunham et al. 1978). According to Dunning (1984), major periods of vein emplacement in England occurred during the Upper Carboniferous and the Upper Permian–Lower Triassic. The important strata-bound Irish base-metal deposits occurring in Lower Carboniferous carbonates show many similarities with the large occurrences in the Upper Permian carbonates of central East Greenland. In particular, a striking similarity exists between the strata-bound mineralization at Quensel Bjerg (nos 117 and 118) and the Tynagh deposits in Ireland (Boast et al. 1981). The strata-bound celestite occurrences, stratiform base-metal mineralization and red-bed copper occurrences are comparable with minor occurrences in England and the important stratiform and strata-bound copper deposits in Germany and Poland.

Mesozoic

The area was again transgressed during the Lower Triassic and for a relatively short period the basin was the site of a shallow marine embayment (Clemmensen 1980). Up to 500 m of sandstone and mudstone make up this marine sequence. Continental deposition was resumed already in Late Scythian time, when another phase of rifting occurred and was responsible for locally more than 500 m of coarse arkosic sediments. An almost continuous continental depositional environment was preserved during the remaining part of the Triassic when 300–800 m of alluvial fan, braided river, aeolian desert, flood plain, saline playa lake and freshwater shallow lake sediments were laid down (Clemmensen 1978a).

At the Triassic-Jurassic boundary a pronounced climatic shift from arid to humid conditions occurred, and the depositional environment changed from continental to marine (Surlyk et al. 1981). During the Jurassic, the rift opened from the south by progressive downfaulting of blocks resulting in a stepwise basin extension and submergence of the rifted basin (Surlyk et al. 1981). The depositional environments changed from a tidal bay over a shallow siliciclastic shelf sea to a wide muddy shelf. About 1–2 km of marine sand, silt and mud was deposited during the Jurassic. At the Jurassic-Cretaceous boundary important rifting, mainly characterized by antithetic block faulting, occurred and submarine fan sediments were laid down. During the remaining part of the Cretaceous and the lower part of the Paleocene 1–2 km of mainly outer shelf mudstones were deposited during several periods interrupted by phases of block faulting.

Mineralization hosted in Mesozoic rocks are restricted to stratiform and strata-bound occurrences in the Triassic sequence of eastern Jameson Land (nos 130–158) and to Jurassic fossil placers (no. 159). The Triassic mineralization, which is of red-bed type and is due to diagenetic processes, includes stratiform copper-lead-zinc occurrences in black mudstones, stratiform copper mineralization in sandstones with mud flasers and strata-bound copper-silver, copper-arsenic and lead occurrences in sandstones and conglomerates. The Jurassic placers are local and are rich in zirconium and rare-earth elements. The strata-bound Mechernich-Maubach lead deposits of West Germany (Bjørlykke & Sangster 1981) resemble some of the Lower Triassic occurrences in central East Greenland.

Tertiary

The Upper Palaeozoic and Mesozoic rifting never led to active plate separation by sea-floor spreading in central East Greenland. However, during the Tertiary the final break-up of the North Atlantic occurred. During the Paleocene extensive sheets of tholeiitic plateau basalts were extruded in various parts of the area (Fig. 12). The thickness of the lava sequence is locally more than 1 km. Post-basaltic tectonism is expressed as reactivation of the former Mesozoic faults and as numerous basalt dykes and sills in the otherwise basalt-free basinal area between Scoresby Sund and Kejser Franz Joseph Fjord. The Upper Paleocene effusive volcanism was followed by a period of intrusion of plutonic and subvolcanic rocks during the Oligocene. A prominent NE-SW-trending line of plutonic centres is traceable for approximately 100 km from northern Scoresby Land to eastern Traill Ø (Haller 1971, Noe-Nygaard 1976) (Fig. 12). Geophysical investigations off East Greenland (Larsen 1984) indicate that the line of plutonic centres continues for an additional 150 km towards the northeast, and does not move towards NNE to link up with the Kap Broer Ruys complex as proposed by Haller (1971) and Noe-Nygaard (1976). The magnetic lineament forms a natural continuation of the initial North Atlantic spreading ridge north of Kong Oscar Fjord and probably represents a continuation of an oceanic spreading ridge into the East Greenland continental crust. The plutonic and subvolcanic rocks have a distinct alkaline to peralkaline trend and comprise a variation from gabbro to alkali granite with important nepheline syenite complexes. Locally, indications of effusive activity are expressed as pyroclastic rocks and fumarolic activity. The final phase of the Tertiary is marked by differential vertical movements of the continental margin area which started during the Oligocene – Miocene. The coastal area was uplifted 1.5–2 km to its present position, while subsidence in the order of 3–6 km occurred offshore (Surlyk et al. 1981).

Tertiary mineralization in central East Greenland is important and related to the final break-up of the North Atlantic. Active rifting and sea-floor spreading with melting in the lower crust governed mineralization mainly related to alkaline – peralkaline plutonism, effusive volcanism and tensional faulting. Mineralization includes a major porphyry-molybdenum occurrence (no. 160), granite roof-zone molybdenum mineralization (no. 161), niobium mineralization associated with alkaline intrusive rocks (no. 167), lead-zinc skarn occurrences (no. 162), a minor magnetite-skarn showing (no. 163), lead-zinc-bearing quartz veins (nos 162 and 166) and precious-metal, base metal, molybdenum and fluorite mineralization associated with fumarolic volcanic activity (nos 164(?) and 165). Porphyry-molybdenum mineralization and base-precious metal veins are also known further south in East Greenland (Geyti & Thomassen 1984) in the same Tertiary alkaline magmatic province.

In general the Phanerozoic mineralization in central East Greenland is comparable with world-wide ore-forming processes during this period. The Mississippi Valley type lead-zinc deposits, hydrothermal tin-tungsten deposits and porphyry-molybdenum ores are characteristic examples from this period.

Inventory of mineral occurrences

This section presents geological and mineralogical descriptions of all known mineral occurrences in central East Greenland. Numbers in brackets in the headings and in the text refer to the location of these as shown in the attached map – Mineral Occurrences in Central East Greenland. The chemical elements noted on this map only include those of particular interest for a given mineral occurrence.

The various occurrences are related to the geological evolution of the area and placed in the most probable of seven major geological periods when mineralization took place. The seven periods are:

Tertiary
Mesozoic
Upper Palaeozoic
Lower Palaeozoic (mainly Caledonian)
Upper Proterozoic
Middle Proterozoic
Archaean – Lower Proterozoic

For each period, occurrence descriptions are presented grossly from south to north and reflect the degree of investigation rather than the size or economic potential of the mineralization. The big spread in the number of mineral occurrences of the different periods is of course a result of varying mineralization intensity, but also reflects the unevenness in exploration due to the remoteness and inaccessibility of some areas in central East Greenland.

The age grouping of the various mineral occurrences is of course a tentative one. It is to a high degree based on host-rock age and for that reason in most cases expresses maximum ages.

The analyses presented most frequently represent semi-quantitative multi-element emission spectrography data. However, other methods applied include atomic absorption spectrography for base metals, X-ray fluorescence spectroscopy for determination of tungsten, antimony, arsenic, barium and rare-earth elements, neutron activation for determination of uranium, thorium, gold, tungsten and antimony and fire-assay for the determination of gold and silver.

Concerning tonnage-grade estimates in non-drilled occurrences, these are primarily based on calculations of observed dimensions combined with chip sample results and the general geological information avaliable.

Archaean–Lower Proterozoic

Although Archaean–Lower Proterozoic (3000–1600 Ma) metamorphic complexes make up a very large area in the western and southwestern part of central East Greenland (Fig. 12) only nine areas with mineralization are known. The main reason for this is probably that the Precambrian terrain in general is quite remote and inaccessible and thus only limited mineral exploration has been carried out.

The observed mineralization comprises:

- Nickel-copper and gold in Vestfjord
- Nickel in central Liverpool Land
- Gold-uranium in Flyverfjord
- Quartz-calcite veins in Nordvestfjord
- Chromium in Hinks Land
- Massive iron sulphides in Charcot Land
- Iron-titanium in Gletscherland
- Copper in Dickson Fjord
- Uranium in Frænkel Land

Nickel-copper and gold in Vestfjord (1–3)

Mineralization in the Vestfjord area was first reported by Backlund in 1934 (Eklund 1944). He mentions the occurrence of a 2 million tons semi-massive pyrrhotite mineralization within ultramafic rocks at "Kap Carita" (Renodde). Geological mapping and prospecting was carried out later by Nordmine in 1960, 1968 and 1969 (Dahlkamp et al. 1960, Frisch & Thum 1969, Köck & Pogöschnik 1970). However, the occurrence reported by Backlund was never found.

The area consists of two structural units (Fig. 13). In inner Vestfjord, autochthonous Archaean gneisses overlain by late Proterozoic or Lower Palaeozoic marble and Eocambrian(?) tillite occur below a major, slightly east-dipping thrust plane. Above the thrust plane are reworked Archaean gneisses (the Flyverfjord infracrustal complex) and Middle Proterozoic metasediments (the Krummedal supracrustal sequence) (Wenk 1961, Phillips et al. 1973). Both the autochthonous and the allochthonous gneisses contain a minor percentage of mafic and ultramafic rocks which locally are cut by pegmatite and aplite veins. Small amounts of disseminated pyrrhotite mineralization with minor chalcopyrite and pentlandite and trace amounts of platinum group elements (PGE) and gold are widespread in the mafic and ultramafic rocks (Fig. 13).

At Kobberpynt (1) (Locality A, Fig. 13) scattered small (<10 m^2) titanomagnetite and pyrrhotite accumulations occur in mafic to ultramafic rocks, which are also locally cut by up to 0.2 m thick asbestos veins. Analyses of selected samples yielded up to 0.4% Ni, 0.4% Cu, 0.45% Cr, 500 ppm Co, 0.77 ppm PGE and 0.16 ppm Au. At Renodde (Locality B, Fig. 13) similar scattered occurrences exist. Analyses of selected samples show contents of up to 0.05% Ni, 0.03% Cu, 0.3% Cr, 0.01 ppm Pt and 0.02 ppm Au. At locality C (2) (Fig. 13) mineralization occurs in weakly altered amphibolite and hornblendite which are cut by aplite dykes. In particular, mineralization is concentrated where the mafic rocks occur in the core of a WNW-plunging fold. The size of individual occurrences is comparable with that of Kobberpynt. Magnetite, ilmenite and chalcopyrite are the most abundant ore minerals. An analysis of a selected sample revealed 1.25% Cu, 0.1% Ni, 2.2 ppm Au and 6 ppm Ag. At Døde Bræ (3) (Locality D, Fig. 13) pyrrhotite mineralization with subordinate chalcopyrite, pyrite and sphalerite is associated with the contact zone between a quartz-feldspar pegmatite vein and an amphibolite dyke. The occurrence is also of small size (10 m^2). An analysis of a selected sample gave 0.5% Ni, 0.18% Co and 700 ppm Cu.

In addition to small pyrrhotite occurrences, copper-gold mineralization is also associated with a NNW fault at locality E (2) (Fig. 13). The fault can be traced for at least 4 km over a height of 1000 m and in an up to 8 m wide zone. Widespread malachite staining occurs in the fault zone and is in particular concentrated where the fault cuts an amphibolite band. Chalcopyrite, pyrite and subordinate pyrrhotite occur in amphibolite and in aplitic veins. No systematic sampling of the fault zone has been performed, but analyses of selected samples show contents of up to 1.1% Cu and 3.7 ppm Au.

In the general area neither gold nor platinum minerals have been identified in any of the known occurrences. However, native gold occurs in a pan sample collected 10 km southwest of localities C and E (Fig. 13).

The observed element association is typical for sulphide segregations in mafic and ultramafic rocks. The fault-associated mineralization probably represents mobilization of the primary disseminated occurrences.

Nickel in central Liverpool Land (4)

The area was investigated for its tungsten potential in 1979 (Karup-Møller 1979) and 1980 (Pedersen 1980a), and in connection with this activity nickel-copper-bearing sulphide lenses were found in west Kalkdal.

The area comprises probable Archaean – Lower Proterozoic hornblende gneiss, garnet-biotite gneiss, biotite gneiss and marble intruded by granodiorite of unknown age and Caledonian granite (Coe & Cheeney 1972, Coe 1975). Disseminations and small accumulations of pyrrhotite and pyrite are frequent constituents of quartz-rich gneisses in contact with marble. A massive pyrrhotite lens up to half a metre thick and 30–40 m long occurs along a fault plane intersecting garnet-bio-

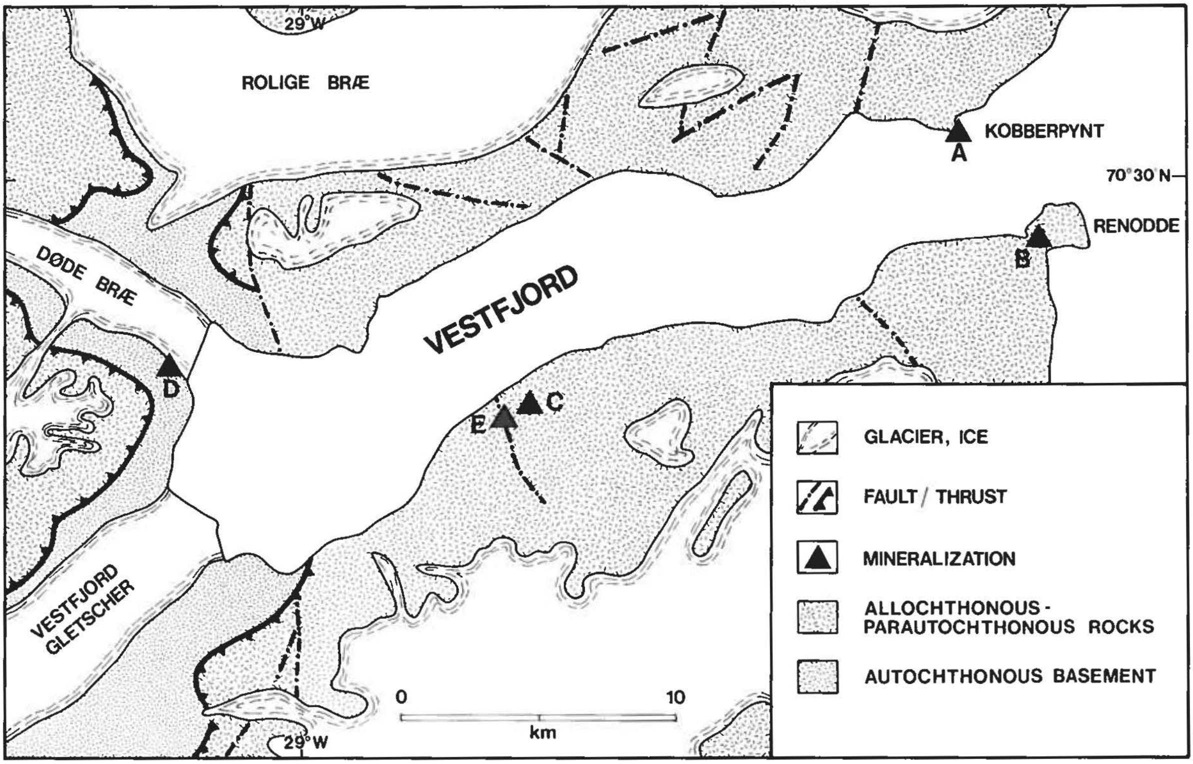


Fig. 13. Simplified geological map of the Vestfjord area with indicated mineralization.

tite gneiss on the north side of west Kalkdal (Fig. 20). In addition to pyrrhotite, the lens contains minor chalcopyrite and pentlandite.

Selected samples of semi-massive pyrrhotite contain 0.3–0.7% Ni, up to 1.5% Cu, *c.* 0.1% Co and up to 0.16 ppm Au.

A boulder of similar composition has been found in Skarndal 50 km north of Kalkdal.

In Tværdalen, just west of Scoresbysund, Smith & Cheeney (1981) have noted chromite-garnet lherzolite lenses in gneiss of probable Archaean to Lower Proterozoic age.

The semi-massive sulphide lens probably represents mobilized sulphides from the gneisses. It is noteworthy that the chemical composition is similar to nickel-copper-bearing massive sulphides associated with mafic and ultramafic rocks, although such rock types are only known as small lenses in gneisses in the Kalkdal area.

Gold-uranium in Flyverfjord (5)

The mineralized locality is situated on the south coast of Flyverfjord in inner Scoresby Sund. It was found by GGU as a radioactive anomaly in 1968 and briefly visited by Nordmine in 1970 and 1983 (Thomassen 1983).

The country rock is amphibolite-bearing gneiss of the Archaean Flyverfjord infracrustal complex (Henriksen & Higgins 1969, Higgins 1982).

The mineralization is hosted in two southerly dipping rust zones situated 1.5 km apart in the steep coastal cliffs of Flyverfjord. The zones have only been visited near sea-level. They are several tens of metres thick and continue laterally for more than 500 m. The rust zones consist of whitish, sericite-biotite-bearing siliceous gneiss containing up to 20 cm thick, green fuchsite-rich bands and up to 10 cm thick, conformable quartz lenses or veins.

In general, the zones contain less than one per cent sulphides (pyrrhotite and subordinate chalcopyrite) as scattered blebs and disseminations. The sulphides and biotite account for the rusty weathering of the rocks. However, a 1 m thick massive, siliceous horizon with up to 10% disseminated pyrrhotite, pyrite and chalcopyrite occurs in both rust zones. Analyses of ten grab samples from this horizon average 4.4% Fe, 3.1% S, 337 ppm Cu, 113 ppm Zn, 78 ppm Pb, 111 ppm Th, 75 ppm U, 59 ppm Co, 40 ppm Ni, 2 ppm As, 0.6 ppm Ag, 0.34 ppm Au and 0.01 ppm Pt. Gold seems to correlate with uranium-thorium, but no discrete gold or uranium-thorium minerals have been observed.

The origin of the mineralization is unknown. However, it could represent either a metamorphosed equivalent of a quartz-pebble conglomerate type of gold-uranium occurrence or a sulphide accumulation associated with hydrothermally altered acid volcanic rocks.

Quartz-calcite veins in Nordvestfjord (6)

A vein system discovered by GGU north of T-sø in south Nathorst Land was briefly investigated by Nordmine in 1969 and 1983 (Thomassen 1983).

The plateau between Nordvestfjord and Frederiksdal is underlain by Archaean gneisses separated from Middle Proterozoic supracrustals further east by a NNE-trending, east-dipping thrust of presumed Caledonian age (Henriksen et al. 1980). Some 6 km west of this thrust a major NNE-SSW-orientated, sub-vertical vein structure has been observed in the gneisses for a distance of *c.* 10 km across the plateau. The vein is hosted in a fault of unknown age. It is a 10–15 m thick, quartz-calcite cemented fault breccia with traces of pyrite and chalcopyrite. Selected samples contain up to 0.2% Cu and 0.038 ppm Au.

Galena-bearing veins have been reported from the area by Henriksen et al. (1980).

All of the veins are of unknown origin.

Chromium in Hinks Land (7)

Chromite-magnetite-mineralized localities occur in Hinks Land on the southeast side of Daugaard-Jensen Gletscher (Fig. 14). They were found by GGU in 1968 and studied by Nordmine in 1969 (Frisch et al. 1970).

The area is divided into two separate units by a NNE-SSW-trending, east-dipping thrust plane of Caledonian age. The Lower Proterozoic Charcot Land sequence occurs below the thrust plane and the Archaean Flyverfjord infracrustal complex and the Middle Proterozoic Krummedal supracrustal sequence both occur above (Henriksen & Higgins 1969, Higgins 1982).

The chromite mineralization is hosted in ultramafic plugs of hornblenditic, dunitic or peridotitic composition, which intrude the Flyverfjord gneisses just east of the thrust plane (Fig. 14). Two major plugs have been mapped in the area, the largest one covering 0.5 km^2. Pods of chromite are up to 0.8 m in diameter and thin massive layers up to a few cm thick can be traced over several metres. However, the overall mineralization intensity is very low.

Massive chromite and magnetite-bearing samples contain 10–15% Cr, 15–20% Fe, max. 0.35% zinc, max. 0.2% nickel and max. 700 ppm cobalt. Microscopically, the aggregates are made up of medium-grained, rounded, intensely jointed chromite and magnetite grains and subordinate sheared zones with very fine-grained chromite and magnetite.

Ultramafic plugs have also been mapped in the area between Hinks Land and Gåseland, and a few scattered observations of associated mineralization exist. Ultramafic plugs on the south-side of Martin Carlsen Dal contain magnetite lenses (N. Henriksen, pers. comm. 1985), and a selected sample from a cluster of plugs a few kilometres north of Rolige Bræ contains one per cent pyrrhotite with minor amounts of chalcopyrite and pentlandite.

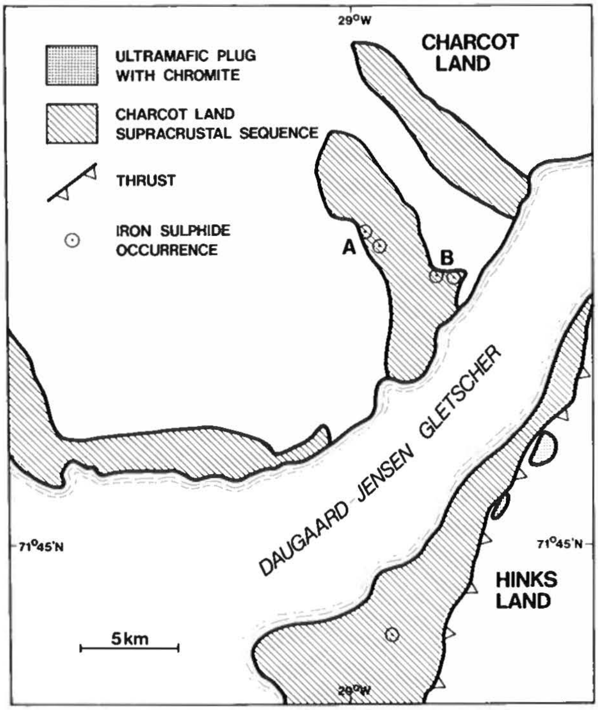


Fig. 14. Location of mineral occurrences in the vicinity of Daugaard-Jensen Gletscher.

Massive iron sulphides in Charcot Land (8,9)

Copper mineralization was reported by Backlund and Wenk on Charcot Land (Eklund 1944). In 1968 widespread occurrences of iron-sulphide horizons were discovered by GGU in connection with geological mapping. These findings were investigated by Nordmine the following year (Frisch et al. 1970).

Massive iron-sulphide horizons are hosted in the Lower Proterozoic supracrustal Charcot Land sequence which crops out on both sides of Daugaard-Jensen Gletscher (Fig. 14). The sequence consists of marble, mica schist, quartzite, greenstone and amphibolite and is intruded by Early Proterozoic diorite and granite (Steck 1971, Higgins 1982).

Iron-sulphide mineralization is widespread and massive pyrite-pyrrhotite beds with trace amounts of chalcopyrite occur concordantly in the marbles at several stratigraphical levels. The largest occurrence described (9) (Loc. A, Fig. 14) comprises a one to four m thick horizon which outcrops over a length of 50 m. The lithology from bottom to top is: marble, a few metres of intensely altered felsic rock, massive pyrite-pyrrhotite and on top of that marble with a few thin layers of felsic rocks. Although massive sulphides in marble predominate, other types have been described as well. At locality B (8) (Fig. 14) an up to 2 m thick pyrite-pyrrhotite horizon occurs concordantly in magnetite-bearing garnet-hornblende skarn and garnet skarn intersected by aplite. Frisch et al. (1970) propose that the skarn development is the result of the intrusion of nearby diorite.

The pyrite-pyrrhotite lenses contain up to 0.1% nickel, up to 600 ppm copper, up to 20 ppm silver, up to 200 ppm tin and up to 100 ppm molybdenum. The zinc and lead contents are <200 ppm and the gold content is <10 ppb.

Genetically, the iron-sulphide formations may have the same origin as the well-known massive sulphide deposits in Proterozoic volcano-sedimentary rocks.

Iron-titanium in Gletscherland (10,11)

Significant magnetic anomalies (up to 2000 gamma) were detected in the Gletscherland area during an aeromagnetic survey carried out by GGU in 1974 (Larsen 1975 and 1977). Scattered ground observations were made during reconnaissance in the same area by Nordmine in 1975–1976 (Hallenstein 1977) and by GGU (Larsen 1977).

Gletscherland is part of the Central Metamorphic Complex (Haller 1955). It consists of different types of gneisses folded together with amphibolites, granites, mica schists, marble bands and ultramafic lenses and is of Archaean to Lower Proterozoic age (Higgins et al. 1981).

The E-W-trending magnetic anomalies form several hundred metres wide, 5–20 km long zones parallel with the major fold axes of the area (Larsen 1977). Massive, one metre thick magnetite beds have been observed as up to 300 m long horizons in synorogenic granite/gneiss in Dickson Fjord (11) and as several km long bands in migmatite in Røhss Fjord (10). Samples collected by GGU comprise massive intergrown hematite-ilmenite and semi-massive magnetite with minor quartz and feldspar. The former type contains 52% Fe, 11% Ti, 0.8% P_2O_5 and 0.15% V and the latter type contains 53% Fe, 0.8% Ti and is low in phosphorus and vanadium (Larsen 1977).

The chemical composition implies that the origin of the former type is best explained as titanomagnetite associated with a basic magma. The latter type may be an iron-formation.

Copper in Dickson Fjord (12)

During reconnaissance in the spring of 1976, Hallenstein (1977) discovered skarn-type mineralization at the north side of Dickson Fjord southwest of Røde Støvhorn.

The area belongs to the Gletscherland migmatite complex (Haller 1955) and comprises mixed Lower Proterozoic gneisses and supracrustals intruded by synorogenic leucocratic granites, most probably of Lower or Middle Proterozoic age. A 10–30 m thick leucocratic granite sill intrudes an up to 100 m thick impure marble bed, which is part of a supracrustal sequence also including amphibolite, mica schist and quartzite (Fig. 15). The marble is partly skarnified with development of pyroxene-amphibole-garnet assemblages of more than 10 m thickness.

Irregular mineralization comprising massive lenses and disseminations of magnetite, pyrrhotite, pyrite, chalcopyrite, sphalerite, molybdenite and allanite is widespread. The skarn sequence has been traced for more than 500 m. The complex copper mineralization, which has an average thickness of more than 10 m, shows a copper content of up to 0.1%. In addition the following maximum values have been recorded – 800 ppm molybdenum, 12% rare-earth elements, 70 ppm silver, 0.5% zinc, 0.4% thorium, 200 ppm tungsten, 200 ppm cobalt, 0.1% chromium, 160 ppm uranium, 100 ppm beryllium, 0.1% niobium, 200 ppm nickel, 25% iron, 0.85% manganese, 500 ppm vanadium, 50 ppm tin and 300 ppm lead.

Similar mineralization is known from Skræntdal (Hallenstein 1977).

The occurrence represents a contact mineralization to a granite intrusion.

Uranium in Frænkel Land (13,14)

Uranium-bearing boulders were found by surveys made with a portable scintillometer in two areas in Frænkel Land by Nordmine in 1975–76 (Hallenstein 1977).

The mineralized areas belong to the probable Lower Proterozoic Hagar migmatite sheet of the Central Metamorphic Complex. The sheet consists of a variety of gneisses, amphibolites and granites as well as subordinate mica schists and discordant amphibolite dykes (Haller 1955, Higgins et al. 1981).

The radioactive mineralization of the Hagar Sheet has been observed in local boulders and outcrops of migmatitic gneisses in Haredal (14), and in numerous local moraine boulders of Lystergletscher (13), which drains into Knækdalen. The typical mineralized rock is a fine- to medium-grained, two-mica leucogranite with fine-grained pitchblende. Mineralized pegmatitic and aplitic rocks were also observed, and one aplitic rock sample contains blebs of uraninite. The uranium content of mineralized samples from the Hagar Sheet is from 100 to 500 ppm with a single value of 0.5% U.

In addition to uranium, the gneisses in the Knækdalen area contain minor disseminated pyrite, pyrrhotite and chalcopyrite, and quartz-calcite-ankerite veinlets with occassional galena and chalcopyrite. A selected sample from a malachite-stained, calcareous amphibolitic band returned 600 ppm Cu and 0.19 ppm Au.

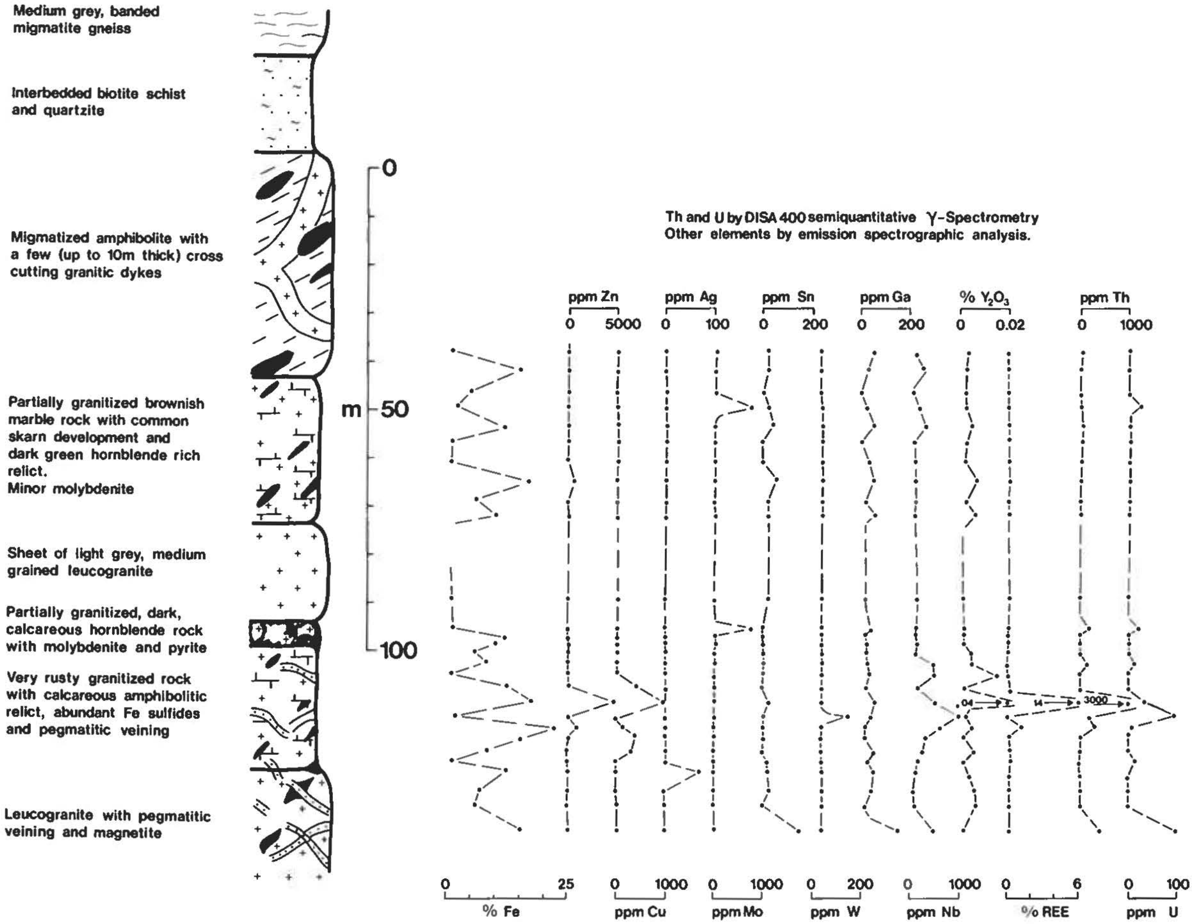


Fig. 15. Geological and geochemical section through skarn mineralization in Dickson Fjord. Modified after Hallenstein (1977). Each dot represents a rock sample.

Middle Proterozoic

Middle Proterozoic (1600–900 Ma) metamorphic complexes comprise a large part of central East Greenland of which the largest coherent area is the Gåseland-Stauning Alper migmatite and granite zone (Henriksen & Higgins 1976). Only six areas with mineralization are known.

The observed mineralization comprises:

- Uranium in Hinks Land
- Tungsten at Roslin Gletscher, Stauning Alper
- Zinc-lead at Damslottet, Nathorst Land
- Lead-zinc-silver in Schaffhauserdalen, Nathorst Land
- Copper in northern Suess Land and southern Andrée Land
- Tungsten in Gemmedal, Andrée Land

Uranium in Hinks Land (15)

A parautochthonous sheet of biotite granite occurs in the Archaean basement of central Hinks Land. The granite is believed to have formed by anatexis of the adjacent gneisses during the 1100 Ma orogenesis (Henriksen et al. 1980). However, an Archaean – Lower Proterozoic age is also possible (Bengaard 1985). The central part of the sheet hosts a coarse-grained, pegmatitic phase *c.* 100 m thick and 10 km long.

The pegmatite was briefly inspected by Nordmine in 1969. It was found to contain rusty parts with high scintillometer readings and up to 595 ppm U and 60 ppm Th in selected samples. Furthermore, scattered, up to 5 cm large blebs of magnetite were observed in the pegmatite (Frisch et al. 1970).

Tungsten at Roslin Gletscher, Stauning Alper (16)

Scheelite-mineralized boulders were found in the end moraine of Roslin Gletscher in 1976. Heavy-mineral prospecting in 1979 led to the identification of a scheelite anomaly on the north side of the glacier 10 km from the glacier front (Karup-Møller 1979), and subsequent follow-up in 1980 led to the finding of many mineralized skarn boulders within a restricted area (Pedersen 1981).

The area comprises Middle Proterozoic granitic migmatites with remnants of marble and amphibolite horizons (Henriksen & Higgins 1970, Henriksen at al. 1980). Intrusive bodies, varying in composition from granodiorite to syenite and in age from Proterozoic to Caledonian, make up 20% of the south Stauning Alper. The nearest intrusive to the Roslin Gletscher scheelite occurrence is a granodiorite 10 km to the south.

White to yellow-fluorescent scheelite is found in dark green, massive skarn, which occurs as 5–30 cm thin bands in forsterite-bearing marble. The skarn is composed of diopside, plagioclase, scapolite and accessory scheelite (up to 2% W), sphene and apatite (Hallenstein & Pedersen 1982 and 1983).

It is assumed that the scheelite mineralization represents minor skarn development at the margins of marble horizons probably formed during Middle Proterozoic migmatization.

Zinc-lead at Damslottet, Nathorst Land (17)

The first report on lead-zinc mineralization at Damslottet in inner Alpefjord was made by Fränkl (Haller 1958). In connection with follow-up of scheelite anomalies, Nordmine investigated the zinc-lead occurrence (Fig. 23), which is associated with calc-silicate rocks (Stendal 1980c).

The geology comprises intensely migmatized quartzite, biotite schist, gneiss and calc-silicate rocks of Middle Proterozoic age. The calc-silicate rocks consist of garnet, hornblende, diopside, plagioclase and quartz with subordinate sphene, pyrrhotite, scheelite and lead-zinc sulphides. Scheelite is found as widely disseminated grains. The richest zinc-lead mineralization observed is confined to a 1x5 m calc-silicate lens. In addition to disseminated galena and sphalerite a small semi-massive sulphide lump with 10–20% sulphides occurs enclosed in the lens. Galena and sphalerite predominates with subordinate chalcopyrite and pyrrhotite. A selected sample contains 7.2% Zn, 1.5% Pb, 0.1% Cu, 18 ppm Ag, 0.03 ppm Au, 60 ppm Bi, 70 ppm Sn and 16 ppm Sb.

The lithologies, the age and the chemical composition could indicate the existence of lead-zinc-(precious metal) massive sulphide mineralization in the general area. In a similar geological setting at Roslin Gletscher, lead and zinc anomalies are also abundant (Karup-Møller 1979).

Lead-zinc-silver in Schaffhauserdalen, Nathorst Land (18)

Lead-zinc mineralization associated with calc-silicate rocks in the Alpefjord region was first noted by GGU (Caby 1976a and c) and later investigated in detail (mapping and chip sampling) by Nordmine (Rasmussen 1980 and 1982). The mineralization is located on the NE slope of Schaffhauserdalen 10 km upstream from the delta in Alpefjord (Fig. 23).

The geological setting of the area comprises Middle Proterozoic metasediments (quartzite, biotite schist, biotite-muscovite schist, garnet-biotite schist, pyrrhotite-bearing quartzite and garnet-amphibole calc-silicate lenses) of upper amphibolite facies intruded by syn- to late-kinematic granite and bordered by low-grade metamorphic EBG sediments. During the Caledonian orogeny, another suite of granite intrusions was emplaced and locally caused incipient retrograde metamorphism of the Middle Proterozoic metasediments.

Lead-zinc-silver mineralization is associated with garnet-amphibole calc-silicate lenses in a vertical E-W fault zone in the Middle Proterozoic metasediments. The mineralized area covers approximately 100x75 m The mineralizing solutions have altered and partly replaced the calc-silicate lenses and precipitated galena and sphalerite with subordinate arsenopyrite, chalcopyrite, cubanite, pyrite, pyrrhotite and marcasite and the silver-bearing sulphosalts pyrargyrite and freibergite. Analcime, natrolite, chlorite, epidote and zoisite are associated with the sulphides and show a zonation around millimetre-thick veinlets with epidote, zoisite, analcime and sulphides surrounding a central zone with analcime, natrolite, chlorite and sulphides.

Analyses of 83 chip samples show the following maximum values: Pb 3.6%, Zn 1.5%, Ag 270 ppm, Sb 170 ppm, B 500 ppm, Mn 0.7%, Li 300 ppm, Cu 140 ppm and Ba 0.3%. The average grade is 1.1% Pb, 0.4% Zn and 40 ppm Ag. The largest lens covers a surface area of approximately 100x40 m.

Lead-isotope studies indicate that the mineralization is of Late Proterozoic age (900 Ma) (Rasmussen 1982). This is further supported by structural evidence because the mineralized fault zone does not continue into the Caledonian granite. The mesothermal nature of the mineralization is indicated from stability investigations of analcime and microprobe investigations of sphalerite in equilibrium with pyrrhotite and pyrite. These show that the temperature of mineralization was 225°–265° C and the maximum pressure 4.25 Kbar (Rasmussen 1982).

Copper in northern Suess Land and southern Andrée Land (19,20)

During Nordmine reconnaissance exploration in the spring of 1976 apparently strata-bound copper mineralization was found on the south and north coast of cen-

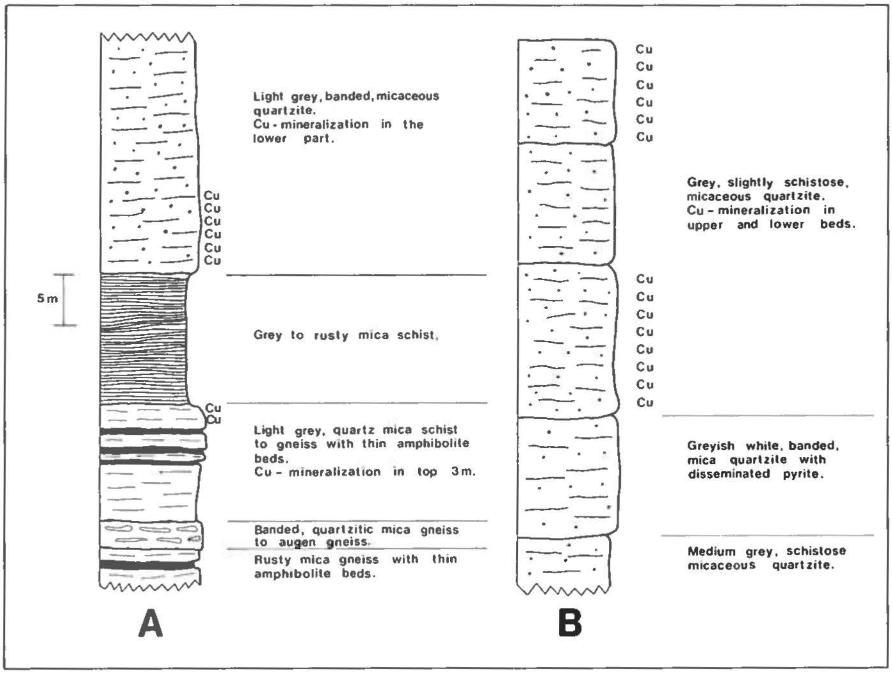


Fig. 16. Copper-mineralized quartzitic sections from northern Suess Land (A) and southern Andrée Land (B). Modified after Hallenstein (1977).

tral Kejser Franz Joseph Fjord (Hallenstein 1977). The occurrence in Suess Land is located in the coastal cliffs *c.* 3 km west of Sonklargletscher (19) and the occurrence in Andrée Land is located *c.* 1 km west of Junctiondal (20) (Fig. 31).

The geological setting of the area comprises Middle Proterozoic metasedimentary sequences which overlay and are interfolded with the infracrustal Niggli Spids migmatite dome of presumed Lower Proterozoic age (Haller 1953, Higgins et al. 1981). The metasediments comprise a calcareous sequence overlain by garnet-mica schists and quartzites. Primary bedding is often recognizable in the metasediments.

Apparently strata-bound copper mineralization occurs in bedded quartz-mica schists and micaceous quartzites (Fig. 16). Mineralization has been observed over a composite thickness of 15–20 m with an unmineralized interval of *c.* 10 m between two malachite stained horizons (Fig. 16). The lateral extension is unknown, but mineralization occurs for at least several hundred metres. The metasediments are rather weathered, and apart from malachite, only subordinate chalcopyrite is seen. Analyses of selected samples yielded up to 0.4% Cu and 3 ppm Ag, however the overall grade based on section sampling is as low as 300–500 ppm Cu. In addition, zinc values of up to 500 ppm occur.

The strata-bound nature probably indicates that the primary copper mineralization took place shortly after the deposition of the sediments during the Middle Proterozoic.

Tungsten in Gemmedal, Andrée Land (21)

A pronounced scheelite anomaly in pan samples was identified in Gemmedal in 1979 (Karup-Møller 1979). Follow-up the next year led to the finding of a skarn-type scheelite mineralization at the southwest and southeast side of a nunatak 8 km NW of Spejderhatten at an altitude of 1400 m (Lind 1981a).

The area comprises Middle Proterozoic metasediments (Higgins et al. 1981), and it is possible to distinguish two structural units separated by a NE-dipping shear zone. The area north of the shear zone comprises folded migmatitic garnet-biotite schist, biotite gneiss and garnet-bearing, two-mica granite. The area south of the shear zone comprises intensely folded biotite-muscovite schist with sporadic garnet aggregates and quartz sweats and subordinate calc-silicate and marble horizons and lenses. The meta-sediments are intersected by garnet-tourmaline-bearing, two-mica granite veins which locally are rotated and sheared. Deformation is presumed to be contemporaneous with the overthrusting.

Scheelite mineralization is restricted to the calc-silicate/marble lenses which show a wide compositional variation. It is possible to recognize diopside-clinozoisite, diopside-idocrase and garnet-clinozoisite-diopside assemblages. Quartz is always a major constituent and plagioclase is locally abundant. Calcite, sphene, scheelite and apatite constitute accessory minerals. Characteristically, scheelite occurs as inclusions in garnet and quartz.

Analyses of a few selected samples show the following maximum values: 3.4% tungsten, 400 ppm tin, 200 ppm bismuth and 0.5% titanium. Due to the irregular distribution of scheelite and the scattered occurrence of calc-silicate lenses the overall tungsten content is low.

The scheelite mineralization does not represent a typical contact skarn. It may represent metamorphically mobilized tungsten which has reacted with marble.

Upper Proterozoic

Upper Proterozoic (900–600 Ma) copper mineralization is widespread in the Eleonore Bay Group (EBG). Although the mineralization is known at several stratigraphical levels, a general description is given in the following section.

Copper in the Eleonore Bay Group basin (22–43)

Stratiform and strata-bound copper mineralization was found both in the Lower and Upper Eleonore Bay Group at Canning Land by GGU in 1971 (Caby 1972). These finds led to continued investigations throughout the EBG basin located between 72°N and 74°N. In the mid-seventies parallel investigations were carried out by a group from the University of Copenhagen (Stendal 1979a and b, 1980b, Ghisler et al. 1980a and b, Stendal & Hock 1981, Stendal 1982a, Stendal & Ghisler 1984) and by Nordmine (Appel 1974, Moeri 1975, Gruner & Probst 1976). Nordmine later investigated occurrences on Ymer Ø (Hallenstein 1982) and on Canning Land (Harpøth 1982). A detailed description is given by Ghisler et al. (1980b), from which most of the following descriptions are adapted.

The EBG sequence shows a largely similar lithological development in a region 450 km from south to north and 200 km from east to west (Haller 1971), but has only been investigated for its mineral potential in some detail in the central fjord region between 72°N and 74°N.

Stratiform and strata-bound mineralization has been observed within a 3000 m thick stratigraphical pile comprising the uppermost part of the Argillaceous-Arenaceous Series of the Lower Eleonore Bay Group and the Quartzite and Multicoloured Series of the Upper Eleonore Bay Group.

The Upper Argillaceous-Arenaceous Series is dominated by thin-bedded quartzites and shales. The Quartzite Series is divided into six numbered beds (1–6) and consists of well-sorted sandstones (mainly quartzites), sandy shales and shales. The Multicoloured Series is divided into seven numbered beds (7–13) comprising shales, mudstones, arenaceous dolomites, limestones, dolomitic shales, sandstones and sandy shales occurring in a characteristic sequence of alternating beds of variable colours. The described sequence represents very shallow water sedimentation. Eight different levels in the stratigraphical columm exhibit stratiform or strata-bound copper mineralization (Fig. 17). The approximate area distribution of the individual mineralized stratigraphical levels south of 74°N is shown in Fig. 18. A description of the various mineralized horizons is given below.

Argillaceous-Arenaceous Series

Two strata-bound copper-mineralized levels occur within the uppermost part of the Series: a lower level some 150 m below the top and an upper level at the transition to the Quartzite Series.

The lower level is mineralized at several localities, is up to 5 m thick, but has a poor lateral persistency. The pyrrhotite-pyrite-chalcopyrite-mineralized quartzite beds in general contain less than 0.1% copper.

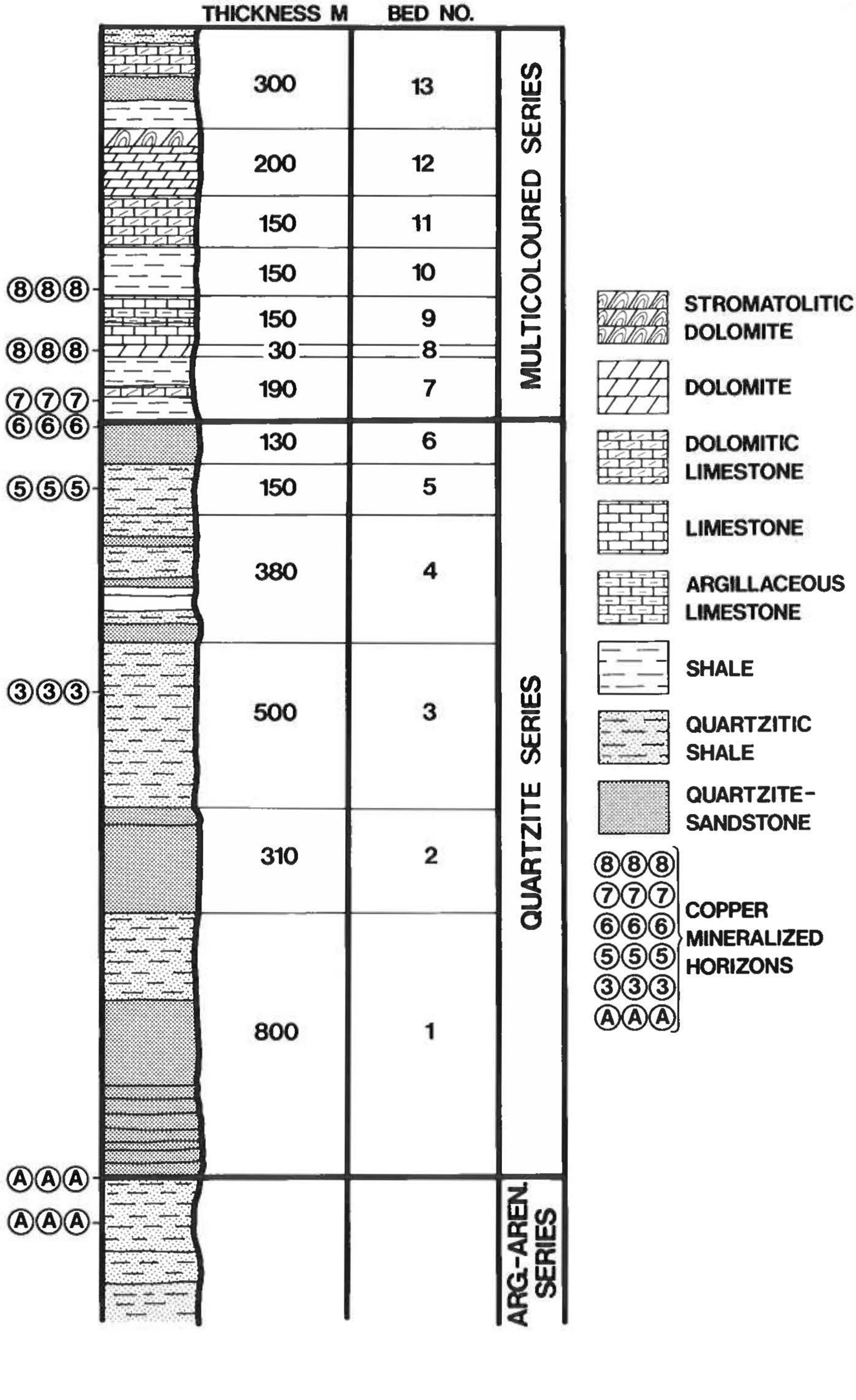
The upper and most distinctive copper-bearing horizon is situated immediately above a rusty-weathered bed which according to Katz (1952) defines the top of the Lower Eleonore Bay Group. This pyrrhotite-pyrite-bearing quartzite bed is recognizable throughout the region, but copper mineralization is only found in Andrée Land (Fig. 18), where it has been followed laterally for more than 10 km in a region where the sediments have been metamorphosed. Malachite staining makes the 0.2–1.5 m (max 5 m) thick horizon easily recognizable. Microscopically, the quartzite rock contains minor amounts of biotite, chlorite, muscovite, pyrrhotite, pyrite, chalcopyrite, galena, sphalerite, cobaltite, molybdenite, rutile, ilmenite and graphite and the secondary minerals malachite, covellite and goethite. Graphite is always associated with the sulphides. The copper content of selected samples varies from 0.25 to 2.5%. The average grade is estimated to be below 0.1% copper.

Quartzite Series – bed 3

Widespread copper mineralization (Fig. 18) occurs in 0.5–2 m thick horizons in the upper part of bed 3 which is dominated by dark green quartzitic shales interbedded with thin quartzites. According to lithology and sulphide mineralogy three types of mineralization are distinguishable:

- The first type of mineralization occurs in finely laminated shales-siltstones with characteristic graded bedding. The stratiform copper mineralization is strictly associated with the more coarse-grained units which contain chalcopyrite. Pyrite is the only sulphide in the fine-grained laminae, whereas rutile/anatase and organic matter/graphite occur in both lithologies.
- The second type of mineralization concerns disseminated framboids of pyrite associated with subordinate galena, sphalerite and chalcopyrite in shale. The pyrite is always associated with organic matter or graphite.
- The third type occurs in coarse-grained quartzites

Fig. 17. Stratigraphical section of the uppermost part of the Argillaceous-Arenaceous Series (Lower Eleonore Bay Group) and the Quartzite Series and Multicoloured Series (Upper Eleonore Bay Group). Copper-mineralized levels are indicated and are also shown in Fig. 18. Modified after Ghisler et al. (1980b).



with a chlorite matrix and cemented by quartz and minor chalcopyrite and pyrite. The quartzites typically have a spotted appearance.

The average copper grade of all the mineralized beds is estimated to be below 0.1%.

Quartzite Series – bed 5

Widespread copper mineralization (Fig. 18) occurs in 0.2–2 m thick intercalations of white quartzites and green quartzitic shales in a sequence dominated by dark red quartzitic shales. Chalcopyrite and subordinate bor-

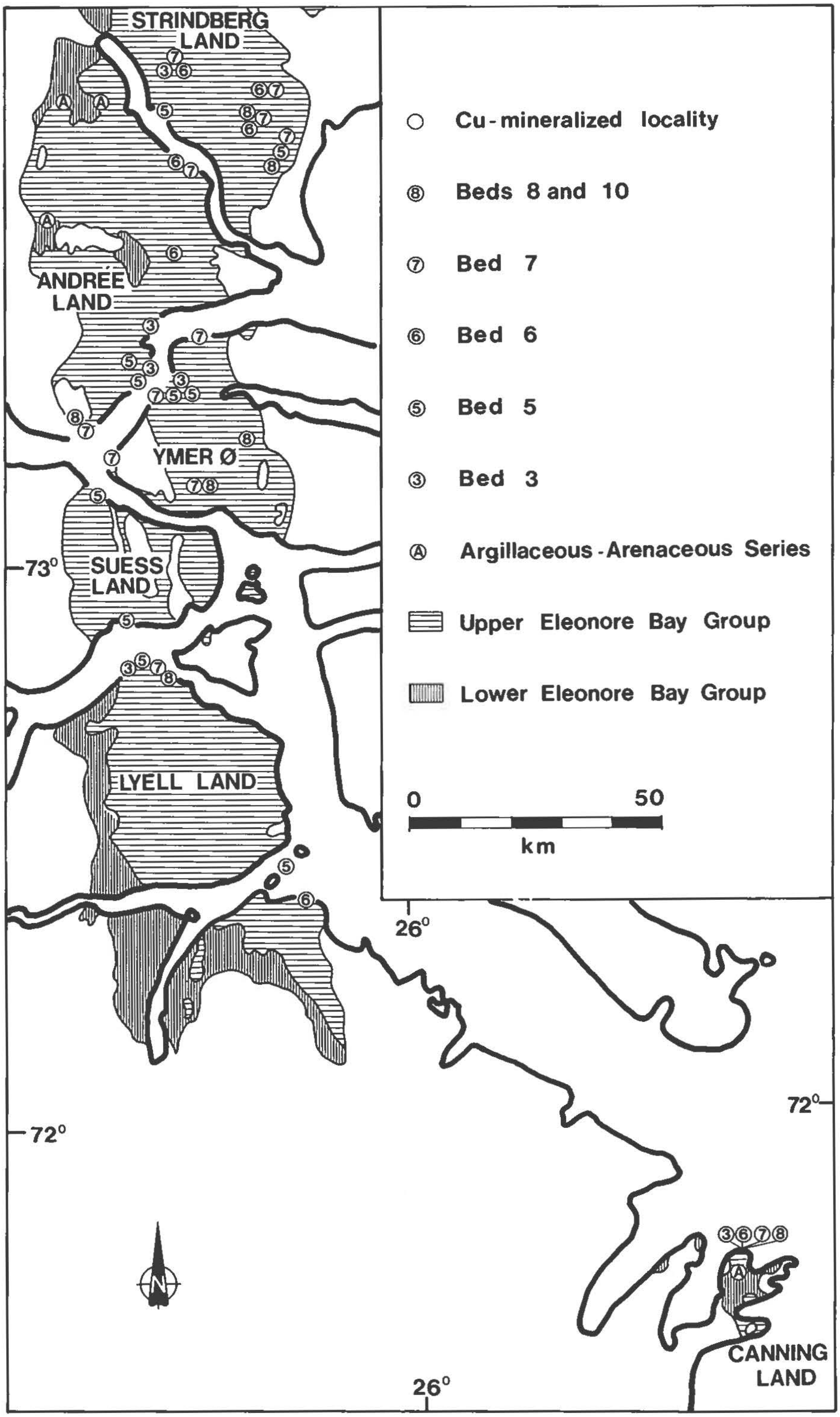


Fig. 18. Distribution of major copper-mineralized outcrops in the Eleonore Bay Group south of 74°N. Numbers refer to Fig. 17 as well. Modified after Ghisler et al. (1980b).

nite, chalcocite and pyrite occur partly in detrital quartz grains (Ghisler et al. 1980b) and partly as cementing phases associated with the more coarse-grained laminae in the quartzitic shales.

Analyses of selected grab samples range from 0.1 to 1.25% Cu. The average grade is estimated to be below 0.1% Cu.

Quartzite Series – bed 6

Widespread but non-persistent copper mineralization occurs in 0.2–1 m thick quartzite beds in the uppermost part of this unit (Fig. 18). Disseminated euhedral pyrite and chalcopyrite occur interstitially to coarse-grained quartz. The average copper grade is low.

In Brogetdal epigenetic copper-antimony mineralization occurs in the top of bed 6 (see section on copper-antimony in Brogetdal, Strindberg Land).

Multicoloured Series – bed 7

This stratiform copper mineralization is the most widespread and persistent one in the EBG with an observed distribution of 275 km from south (Canning Land) to north (Strindberg Land) (Fig. 18). The host rock is a monotonous red shale displaying mm- scale graded bedding. The shales are calcareous and dolomitic with an increasing carbonate content from 5% in the lower part to some 50% near the top (Katz 1952). Mineralization occurs in green intercalations of carbonaceous shale ranging in thickness from a few cm to a few m. Two distinct mineralized horizons occur, one 10–15 m and the other 60–70 m above the top of the white quartzite bed 6. In addition, traces of copper sulphides are found locally at higher levels in bed 7.

The copper sulphides generally occur as very fine-grained disseminations of chalcocite and/or chalcopyrite, but locally discrete sulphide blebs (up to 5 cm large) elongated parallel to bedding plane fissility dominate. The blebs are characteristically rimmed by graphite/organic matter and predominantly consist of chalcocite with subordinate bornite and chalcopyrite.

The average copper content of the mineralized green shales is estimated to be 200–1000 ppm over a thickness of 1–2 m. In local areas (for example Strindberg Land), average grades of 0.1–0.5% occur. Selected samples yield up to 6% copper. The average silver content is low (a Cu/Ag ratio of 1000–1500).

Multicoloured Series – bed 8

Thin (10–25 cm) stratiform copper-mineralized beds occur scattered but widespread (Fig. 18). Disseminated chalcocite occurs in dolomite or dolomitic shale. The copper content is low.

Multicoloured Series – bed 10

Thin (10–15 cm) stratiform copper-mineralized beds are scattered but widespread (Fig. 18). Disseminated chalcocite with subordinate bornite, chalcopyrite and pyrite occur in dolomitic shale and dolomitic siltstone. The grade is estimated to be 0.1% Cu over a thickness of 10–25 cm.

Genetically, the mineralized beds in the Eleonore Bay Group are interpreted as being of synsedimentary-early diagenetic origin. This is strongly indicated by the cementing nature of the copper sulphides, by the selective precipitation in the more coarse-grained laminae, and by the occurrence of copper-mineralized boulders of identical type in the overlying tillites. Organic matter acted as the reducing agent for sulphide precipitation.

Lower Palaeozoic (mainly Caledonian)

Lower Palaeozoic (600–345 Ma) mineralization is very widespread and in particular associated with late Caledonian granitic activity, with Devonian intrusive and extrusive events and with late Caledonian–Upper Devonian faulting. Until quite recently the Caledonian granites were believed to be more or less sterile with respect to mineralization, but investigations during the past decade have shown that the granites are often associated with mineralization like in other parts of the Caledonides.

The observed mineralization comprises:

- Tungsten in Milne Land
- Tungsten in Kalkdal, Liverpool Land
- Base metals and tungsten at Kap Allen, Canning Land
- Base-metal veins on Wegener Halvø and Canning Land
- Uranium on Wegener Halvø
- Tin at Bersærkerbræ, north Stauning Alper
- Copper at Bersærkerbræ, north Stauning Alper
- Tungsten in north Stauning Alper
- Tungsten at Trekantgletscher, Nathorst Land
- Tungsten-arsenic in Alpefjord
- Tungsten-tin at Randenæs, Forsblad Fjord
- Gold in Forsblad Fjord
- Copper-tungsten on Jägmästarens Ø, Segelsällskapets Fjord
- Tungsten-antimony in Margeries Dal, Ymer Ø
- Antimony-gold in Noa Dal, Ymer Ø
- Tungsten at Knivbjerg, Andrée Land
- Gold at Luciagletscher, Andrée Land
- Tungsten at Panoramafjeld, Andrée Land
- Copper-antimony in Brogetdal, Strindberg Land
- Fluorite at Kap Franklin, Gauss Halvø
- Uranium in Randbøldalen, Gauss Halvø
- Uranium in Foldaelv, Gauss Halvø

Fluorite and uranium in Moskusokselandet
Base metals and silver at west Sernander Bjerg, Hudson Land
Tin-tungsten in Blokadedal, Hudson Land

Tungsten in Milne Land (44)

Heavy-mineral samples collected along the coast of east Milne Land in 1969 and 1972 contain some scheelite. On the basis of these samples and an assumed favourable geological setting for scheelite-skarn mineralization a detailed heavy-mineral sampling program was carried out in 1980 (Pedersen 1980a). Two scheelite-anomalous areas were delineated at the northern and southern contacts of a major granodiorite body. Subsequent UV traversing at the northern and most pronounced anomaly identified *in situ* scheelite-bearing skarn type mineralization (Fig. 19) (Hallenstein 1981, Hallenstein & Pedersen 1982 and 1983).

East Milne Land is separated from the rest of Milne Land by a prominent NNE-trending fault. The area east of the fault comprises Middle Proterozoic metasediments intruded by a variety of post-kinematic granitoids (Henriksen & Higgins 1971). The first intrusive phase comprises a 120 km^2 large granodiorite body in the central part of east Milne Land. The radiometric Rb-Sr whole-rock age is 453 Ma (Hansen & Tembusch 1979). At the northern border, the granodiorite is in contact with a 100–200 m thick marble horizon, which in turn is overlain by mica schist. The contact, which is concordant with the foliation, strikes E-W and dips 80° N. A few granodiorite veins which are parallel with the contact occur in the marble up to 50 m from the contact. Skarn formation has taken place up to 50 m from the contact, either at the contact between granodiorite (both main body and veins) and marble or in joints in the marble.

Skarn, with or without scheelite, has been traced along the contact zone for 2 km. In the eastern part skarn is found as lenses, both at granodiorite-marble contacts and enclosed in marble. Individual lenses can be up to 2 m thick and 10 m long. In the western part skarn is found only at the contact between granodiorite and marble. It occurs as a 150 m long, continuous, 0.4 m thick horizon with scheelite in the 20 cm closest to the marble.

Skarn types without scheelite comprise diopside-muscovite skarn and epidote skarn rich in sphene and apatite. Both rock types also contain 10–20% calcite. The scheelite-bearing skarn is a tremolite skarn. It consists of tremolite, quartz, idocrase, calcite and scheelite with minor biotite, diopside, chlorite and native bismuth. Scheelite was one of the first minerals to be formed, and scheelite grains are either enveloped by aggregates of prismatic tremolite, or together with diopside enclosed in large euhedral idocrase grains. Late-formed quartz and calcite enclose tremolite and idocrase and fill out interstitial space. Selected samples of scheelite-bearing skarns contain up to 3% W, 0.5% Bi and 0.6 ppm Au. Systematic sampling in the eastern area across the skarn lenses indicates an average tungsten content of 500 ppm.

The scheelite skarn is the result of late stage hydrothermal activity associated with the granitic intrusives.

Tungsten in Kalkdal, Liverpool Land (45)

Heavy-mineral samples from Kalkdal collected in 1970 and 1976 revealed high contents of scheelite. Additional

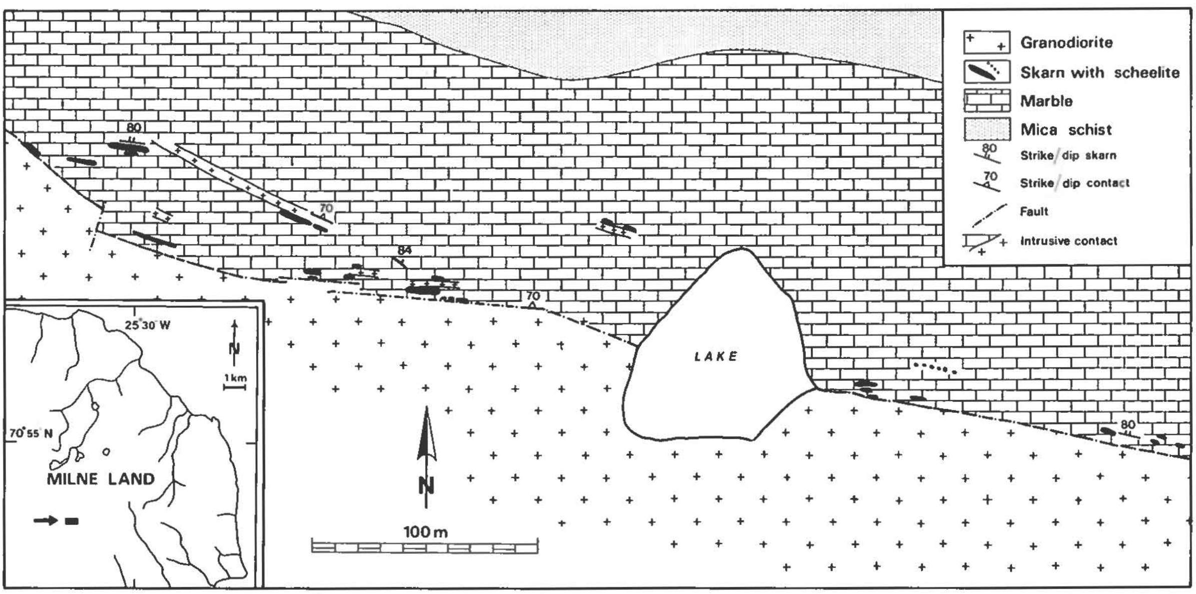


Fig. 19. Geological map of scheelite-mineralized area in Milne Land. Modified after Hallenstein (1981).

sampling during 1979 defined several anomalies and subsequent follow-up with UV-lamp traverses in 1979 and 1: 10 000 scale mapping in 1980 led to the discovery of *in situ* tungsten skarn mineralization at various localities (Karup-Møller 1979, Pedersen 1980a and b, Lind 1980 and 1981b, Hallenstein 1979, Hallenstein & Pedersen 1982 and 1983).

The area comprises a belt of metasediments bounded to the west by granite (The Hurry Inlet Granite) and to the east by foliated Caledonian granodiorite (Fig. 20) (Coe & Cheeney 1972, Coe 1975).

The metasediments are provisionally divided into dolomite marble, biotite-hornblende schist, biotite-garnet gneiss and amphibolite. The K-Ar age of hornblende from a gneiss is 1183 Ma (Hansen et al. 1973). The metasediments in general have an ESE strike and a moderate dip to the south. Small-scale folding is widespread, but it has not been possible to delineate any larger fold structures. Most of the metasediments are made up of biotite-hornblende schist alternating with biotite-garnet gneiss. Major units of marble occur at the base of the metasedimentary belt in contact with granodiorite in a large area of east Kalkdal, and at the top of the metasediments in contact with the Hurry Inlet Granite in west Kalkdal. Furthermore, an up to 30 m thick marble horizon enclosed in biotite-hornblende schist can be traced from west Kalkdal to Bodal (Fig. 20).

The granodiorite is a grey, foliated, medium- to coarse-grained rock composed of quartz, plagioclase, alkali feldspar, chlorite and accessory sphene, clinozoisite and muscovite. It is in contact with both marble and schist and intense interfingering between marble and granodiorite is frequent. At such contacts formation of various calc-silicate skarns is abundant.

The Hurry Inlet Granite is a biotite granite, locally with feldspar megacrysts. In west Kalkdal a slightly different variety is developed with abundant pink feldspar, a lower quartz content and with biotite altered to chlorite. Radiometric dating of the granite has indicated an age of 434 Ma (Hansen & Steiger 1971). The contact between the granite and the metasediments is irregular, with xenoliths of marble, schist and gneiss floating in the granite and granite veins penetrating the metasediments. The marble xenoliths have undergone intense deformation and partial melting, but there is no rim of mineralogical reaction (Coe 1975).

A few major faults are found in the area and some have been intruded by pegmatites. A large, up to 200 m wide fault zone striking 160° intersects the contact area between the Hurry Inlet Granite and the metasediments (Fig. 20). The block west of the fault zone is downthrown.

Tungsten mineralization is found in three different settings.

The first is associated with skarn formation which occurs where granodiorite is in contact with marble. The width of the skarn horizons varies from a few centimetres to several metres. Different types can be recognized in this setting and some contain scheelite.

- Diopside skarn is a medium-grained rock. It is formed from forsterite-rich marble, and is characterized by its high proportion of diopside and its plagioclase and/or scapolite content. Scheelite is never found in this rock type.
- Actinolite skarn is formed from diopside skarn. It is a dark green, medium- to coarse-grained rock. It contains prismatic actinolite grains which replace diopside. Scheelite can be an accessory component and has a white to pale-yellow fluorescent colour indicative of a minor molybdenum content. Selected samples contain up to 1% W, but the overall content is low.
- Epidote skarn is a grass-green, medium-grained rock. It alternates with diopside and actinolite skarns. It is composed of plagioclase and/or scapolite, equal amounts of epidote, actinolite and diopside and minor amounts of quartz and calcite. Scheelite is not found in this rock type.
- Garnet skarn is a reddish-green, medium-grained rock. It is only a subordinate skarn type and is irregularly distributed. Garnet skarn is characterized by its content of garnet, epidote and augite, the absence of actinolite, a high content of quartz, and in some samples the occurrence of humite and fluorite. Scheelite is virtually always disseminated. The fluorescent colour is yellow, which indicates a high content of molybdenum in the scheelite. Pyrrhotite and chalcopyrite are minor constituents. Selected samples contain up to 0.1% W.

A second type of scheelite mineralization is associated with skarn formation in the up to 30 m thick marble horizon which can be followed from west Kalkdal to Bodal (Fig. 20). Most skarn is developed where faults intersect the marble horizon and is seen as diopside skarn or actinolite skarn with cross-cutting veinlets of plagioclase and/or scapolite. Blue-fluorescent molybdenum-free scheelite occurs as parallel aggregates disseminated in the plagioclase/scapolite-veined actinolite skarn. It is characteristic that plagioclase and scapolite are intensely altered to sericite in scheelite-rich samples. Large boulders with 1–2% W have been observed, but the overall tungsten content is low, estimated at less than 0.05%. The actinolite skarn is also enriched in beryllium (max. 100 ppm).

Pegmatites and quartz veins with scheelite represent the third type of tungsten mineralization. The main occurrence is 2–3 km north of the lake in central Kalkdal. The pegmatites are up to half a metre thick, can be traced over several tens of metres and show no preferred orientation. They are composed of pale red, coarse-grained alkali feldspar, quartz and accessory chlorite, calcite, clinozoisite and muscovite. Scheelite, powellite and molybdenite are found as scattered large blebs. The

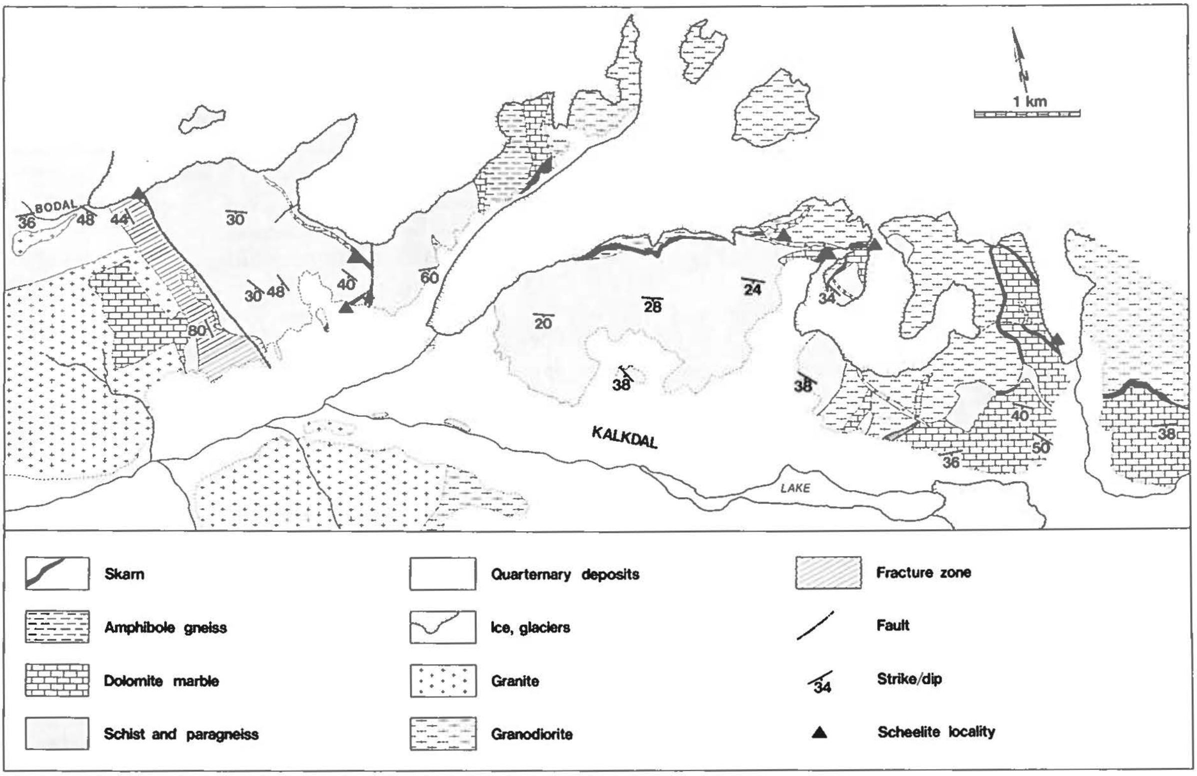


Fig. 20. Geological map of scheelite-mineralized area in Kalkdal. Modified after Hallenstein & Pedersen (1983). Star indicates location of massive pyrrhotite lens (no. 4).

quartz veins occur in the same area as the pegmatites and in some places intersect them. The width of the quartz veins varies from <1 cm to 10 cm. They consist of quartz and locally contain pyrite, scheelite, bismuthinite and molybdenite. Selected samples show the following maximum values: 0.5% W, 0.6% Mo, 0.5% Bi, 300 ppm Pb and 30 ppm Be. Systematic sampling from a limited area indicates a tungsten content of 100 ppm and a molybdenum content of <10 ppm.

The tungsten skarn and vein mineralization is viewed as contact mineralization to the granodiorite intrusion in east Kalkdal.

Base metals and tungsten at Kap Allen, Canning Land (46)

During reconnaissance exploration in 1980 and 1981 widespread fluorite-base metal, arsenopyrite-gold and scheelite mineralization was located in the altered roof zone of the Kap Wardlaw granite 1–2 km west of Kap Allen (Fig. 21) (Thomassen & Schønwandt 1981, Harpøth 1982).

Northeast Canning Land displays a more than 4500 m thick sedimentary sequence composed of parts of the late Precambrian Eleonore Bay Group intruded by the late-Caledonian (*c.* 410 Ma, Bengaard 1985) Kap Wardlaw granite. The roof zone of the granite intrusion exhibits irregular convex lobes and apophyses. A pronounced contact-metamorphic aureole (up to 400 m wide) surrounds the granite (Caby 1972).

Three types of mineralization have been observed:

- Lead-zinc mineralization occurs in a more than 100 m wide and more than 10 m thick zone in the altered granite roof. Inferred dimensions, mainly based on scree-sediment anomalies, could be as much as 200x1000x100 m. Fluorite with minor galena, sphalerite, chalcopyrite and pyrite is found in cm-dm thick veinlets and cavities. Analysis of a selected sample revealed 2.5% Pb, 0.3% Zn, 200 ppm Cu, 50 ppm Bi and 7 ppm Ag. Analysis of a pure galena-bearing sample shows 2400 ppm As, 500 ppm Zn, 450 ppm Ag, 440 ppm Cu, 140 ppm Bi and 20 ppm Sb. The overall grade is however relatively low with an estimated 1% combined lead and zinc.
- Arsenic-(copper-bismuth-gold) mineralization occurs as small (typically *c.* 100 m^2) scattered rust zones in the granite. No connection between mineralization and fracture pattern could be established, but some of the mineralized bodies exhibit extensive jointing. Arsenopyrite, pyrite, chalcopyrite, sphalerite, pyrrhotite, native bismuth, bismuthinite and loellingite occur disseminated and/or in veinlets associated with greisen type alteration. Analyses of selected samples

reveal the following maximum values: 17.5% As, 0.6% Cu, 0.1% Bi, 500 ppm Sn, 500 ppm Zn, 400 ppm Pb, 400 ppm Co, 300 ppm Ni, 300 ppm Nb, 30 ppm Mo, 5 ppm Ag and 0.58 ppm Au. However, the overall grade of the mineralized occurrences is much lower.

- Scheelite mineralization is indicated from mineralized boulders and from panned heavy-mineral concentrates in an area of more than 6 km^2 around Kap Allen and southwest of Kap Wardlaw. Most of the mineralized boulders represent granite/granodiorite with millimetre-thick joint coatings with quartz, scheelite and pyrite. Microscopically, chalcopyrite, pyrrhotite, marcasite, rutile and muscovite were also identified. Hydrothermal alteration in the form of bleaching and kaolinization occurs in mm-cm scale around the fractures. Furthermore, a few boulders with coarse-grained scheelite in quartz veinlets in granite were located. A single boulder of scheelite-mineralized spotted slate indicates that tungsten mineralization also occurs in the sediments. Analyses of two selected granitic samples reveal the following maximum values: 0.15% W, 0.35% B, 0.2% Ba, 0.15% Pb, 300 ppm Cu, 100 ppm Bi, 60 ppm Sn, 50 ppm Mo and 3 ppm Ag.

In summary, the observed mineralization pattern of the granite roof west of Kap Allen combined with a pronounced pan-sample anomaly pattern (B-F-As-Mo-Sn-W-Bi-REE and Cu-Pb-Zn-Ag-Au-Ba) is typical of a granite intruded in a shale sequence. The Lower EBG shales acted as an impermeable seal for the metal-bearing gases and fluids during the granite emplacement in Upper Silurian time.

Base-metal veins on Wegener Halvø and Canning Land (47–56)

Vein-type mineralization is fairly common in the pre-Permian rocks of the two peninsulas Wegener Halvø and Canning Land (Fig. 21). As early as the thirties a gold-bearing boulder was found at the mouth of Tvekegledal and a silver-bearing "blue vein" was investigated at Calamiteselv (Eklund 1944). Subsequent investigations by Nordmine were carried out mainly during the period 1979–1981 (Thomassen 1980 and 1982, Thomassen & Schønwandt 1981, Harpøth 1982).

The two peninsulas comprise a complex mosaic of fault blocks. Due to different elevations of these blocks a surprisingly comprehensive stratigraphical record is exposed within this relatively small area. Sediments of Upper Proterozoic (EBG), Cambrian, Devonian, Carboniferous, Permian and Triassic ages as well as Caledonian granite and Devonian volcanics are exposed (Noe-Nygaard 1934, 1937, Bütler 1948, Grasmück & Trümpy 1969, Caby 1972 and 1976b, Perch-Nielsen et al. 1972, Alexander-Marrack & Friend 1976).

Mineralized veins that are clearly structurally controlled by N-S to NW-SE oriented faults are hosted in Upper Proterozoic and Cambrian clastic and carbonate rocks, in Devonian clastic sediments and intermediate to felsic volcanics, and in Caledonian granite. The veins may be massive and up to 6 m thick, but frequently they form up to 100 m wide zones with abundant en echelon mm to cm veinlets. Such zones are often accompanied by silicification and argillization of the host rock. The gangue consists of quartz, baryte, fluorite and calcite. Drusy quartz with hematite coating is common. In general, the sulphide content of the veins is less than one per cent. Chalcopyrite, bornite, sphalerite, galena, pyrite and hematite are the common ore minerals, with subordinate chalcocite, tetrahedrite-tennantite, wittichenite, clausthalite and gold. A large scale zonation occurs with a predominance of calcite, copper minerals and gold on Wegener Halvø as compared with higher contents of fluorite, galena and sphalerite on Canning Land. Geochemically the veins are characterized by scattered high contents of copper, lead and zinc (1–20% in selected samples). Other analytical results include up to 0.35% Bi, up to 660 ppm As, up to 300 ppm Sb, up to 350 ppm Ag and up to 3.6 ppm Au.

Genetically, the veins are related to a set of conjugate shear faults (sinistral 165°–180° and dextral 120°) resulting from approximately NW-SE maximum compression. As seen in Fig. 21, most of the veins have been emplaced along the 165°–180°-striking sinistral shear faults and occur as en echelon vein segments in areas of maximum tension and dilation. As the veins cut Middle Devonian rocks but not Carboniferous or younger rocks, they are probably of Upper Devonian age.

Some of the more prominent vein systems are described below.

Kap Brown (55, 56)

Two major vein systems are associated with the eastern margin of the central graben of Wegener Halvø (Fig. 21). The easternmost system comprises quartz-calcite veins with traces of chalcopyrite and bornite emplaced in Devonian sediments. The 170°/80° W (subordinate 130°/subvertical) oriented veins occur intermittently due to snow cover over *c.* 1000 m laterally and *c.* 125 m vertically. The observed maximum vein thickness is 6 m. The other vein system associated with the eastern fault of the central graben of Wegener Halvø (Fig. 21) is the so-called "blue vein" described by Eklund (1944). This 160° oriented vein system occurs in the Devonian sediments along the ridge east of Calamiteselv across the whole width of the peninsula i.e. *c.* 2.5 km, and is exposed 350 m vertically. The system consists of several en echelon vein segments, each consisting of a number of maximum 1 m thick, steeply westward-dipping veins. The gangue is quartz with minor baryte and calcite. Scattered blebs of chalcopyrite and hematite with subordinate bornite and galena occur. The maximum gold

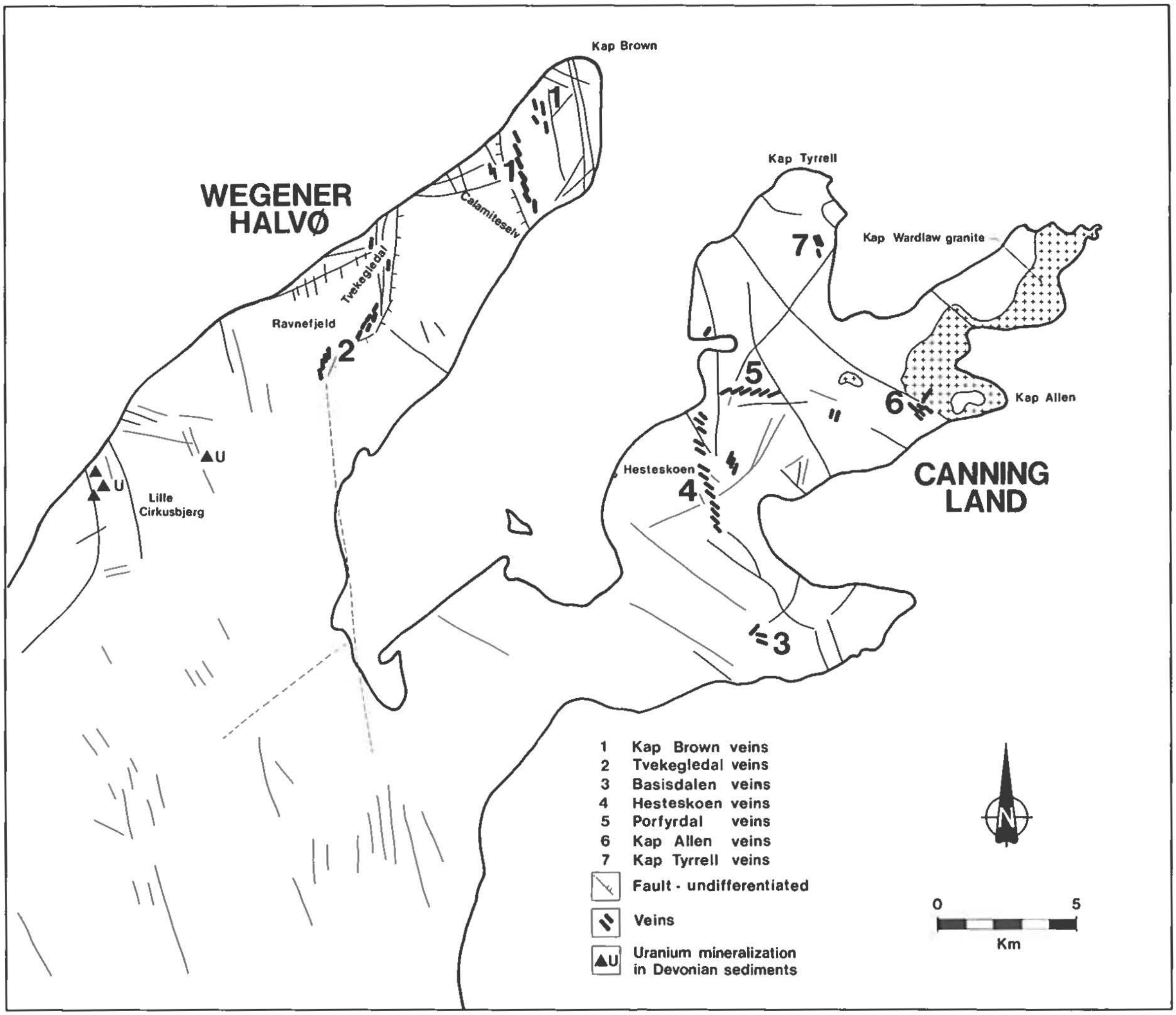


Fig. 21. Fault pattern and location of selected mineral occurrences in pre-Carboniferous rocks of Wegener Halvø and Canning Land.

content of a few selected samples is 0.27 ppm. Eklund (1944) reported maximum contents of 60 ppm Ag and 0.3 ppm Au from the southern part.

Tvekegledal (52, 53)

Along the western fault of the central graben of Wegener Halvø a vein system occurs intermittently in Devonian sediments for a length of approximately 6 km in a general NNE-SSW direction and for 300 m vertically (Fig. 21). The quartz veins (10°–30°/70°–80°E) occur in an en echelon pattern typically with zones of cm-dm thick veins. They contain minor bornite, chalcopyrite, galena and sphalerite. The maximum gold content of selected samples is 1.4 ppm.

Near the mouth of Tvekegledal, mineralization is also known from numerous scree boulders along the steep northeastern slopes of Ravnefjeld (54) (Fig. 21). These boulders belong to the Devonian Kap Fletscher Formation and consist of brownish to greenish feldspar porphyries of rhyodacite-latite composition. Large, yellowish-weathering zones of hydrothermal alteration (argillization, silicification, pyritization) occur. The gold-bearing porphyry boulder described by Eklund (1944) (5% copper and 5.7 ppm gold) originates from this area (A. Noe-Nygaard, pers. comm. 1981). Microscopy of this sample reveals several up to 0.2 mm large inclusions of intergrown gold-clausthalite aggregates in chalcopyrite. A check analysis returns 4% Cu, 21 ppm Ag and 3.7 ppm Au. A number of other mineralized scree boulders from this area were examined. They contain a network of mm-dm drusy quartz veins with scattered blebs of chalcopyrite and pyrite, but only traces of gold (max. 0.1 ppm) were detected.

Basisdalen (47)

A 1 m thick, 40°-striking vein of massive baryte with an estimated 5% combined sphalerite and galena is exposed for some 200 m in Devonian volcanics (Fig. 21). The sulphides (sphalerite and galena with minor chalcopyrite, pyrite, marcasite and fahlore) occur as 1–2 cm bands with comb-structure or as tiny linings around rock fragments. Selected samples rich in zinc and lead contain up to 27 ppm Ag and 0.55 ppm Au.

Hesteskoen (48)

Along the eastern slope of Hesteskoen, a vein zone occurs for some 4 km laterally and 300 m vertically (Fig. 21). The veins, which generally strike 110°, occur along a 170°-striking fault separating Eleonore Bay Group shales from Devonian volcanics. The veins are mainly hosted in the volcanics and are up to 1 m thick. They consist of drusy quartz, fluorite and baryte with minor chalcopyrite and pyrite. The gold content of selected samples is below 0.06 ppm.

Porfyrdal (50)

In the southern slopes of Porfyrdal, a 3 km long E-W-trending zone contains extensive fluorite-quartz veining hosted in EBG shales for *c.* 300 m vertically (Fig. 21). Individual veins (80°/subvertical) are of dm-m thickness and contain traces of sphalerite, chalcopyrite, galena and pyrite. The gold content of selected samples is low (max. 0.02 ppm).

Kap Allen (49)

West of Kap Allen (Fig. 21), a NW-SE-oriented fault zone separates Caledonian granite from EBG shales. Five major veins occur along the fault in the sediments and the granite. Early 75°-striking and late *c.* 120°-striking subvertical veins can be distinguished. The mean thickness is 1–2 m and horizontal and vertical dimensions of up to 1000 m and 300 m respectively are exposed (Fig. 22). The veins consist of quartz, fluorite and baryte with approximately 2% sulphides, mainly galena and chalcopyrite. The silver content may reach 350 ppm in galena-rich samples whereas the gold content is negligible.

Kap Tyrrell (51)

Just south of Kap Tyrrell (Fig. 21) several *c.* 155°-striking veins are exposed for a few tens of metres in EBG quartzites. The thickness is 1–2 m and they consist of quartz and baryte with 2% galena, mainly as cm-large crystals concentrated in the central part of the vein. The gold content is negligible.

Fig. 22. Quartz-fluorite-baryte vein in Eleonore Bay Group hornfelses, Kap Allen.

Uranium on Wegener Halvø (57, 58)

Uranium mineralization was found by Nordmine in the Devonian red beds of southern Wegener Halvø in 1975–76 during follow-up of uranium anomalies in pan samples (Hallenstein 1976, 1977).

The mineralization is hosted in the Upper Devonian Quensel Bjerg Formation, which consists of fluviatile sandstones and conglomerates (Alexander-Marrack & Friend 1976).

Mineralization has been observed north of Lille Cirkusbjerg (58) in local scree boulders and four km to the west (57) in three outcrops (Fig. 21). The intervening Devonian sediments do not outcrop due to post Devonian cover. Uranium is always directly associated with either scattered brick-red, mm to dm sized phosphatic clasts in conglomerates and coarse sandstones, or with brick-red medium-grained, dm-thick phosphatic sandstone beds within thickly bedded conglomerates. It is assumed that several thin horizons are mineralized, but the detailed stratigraphy has not been studied. Analyses of six selected samples gave 210–860 ppm U and 9–33% P_2O_5.

The presence of phosphorite in the fluviatile Quensel

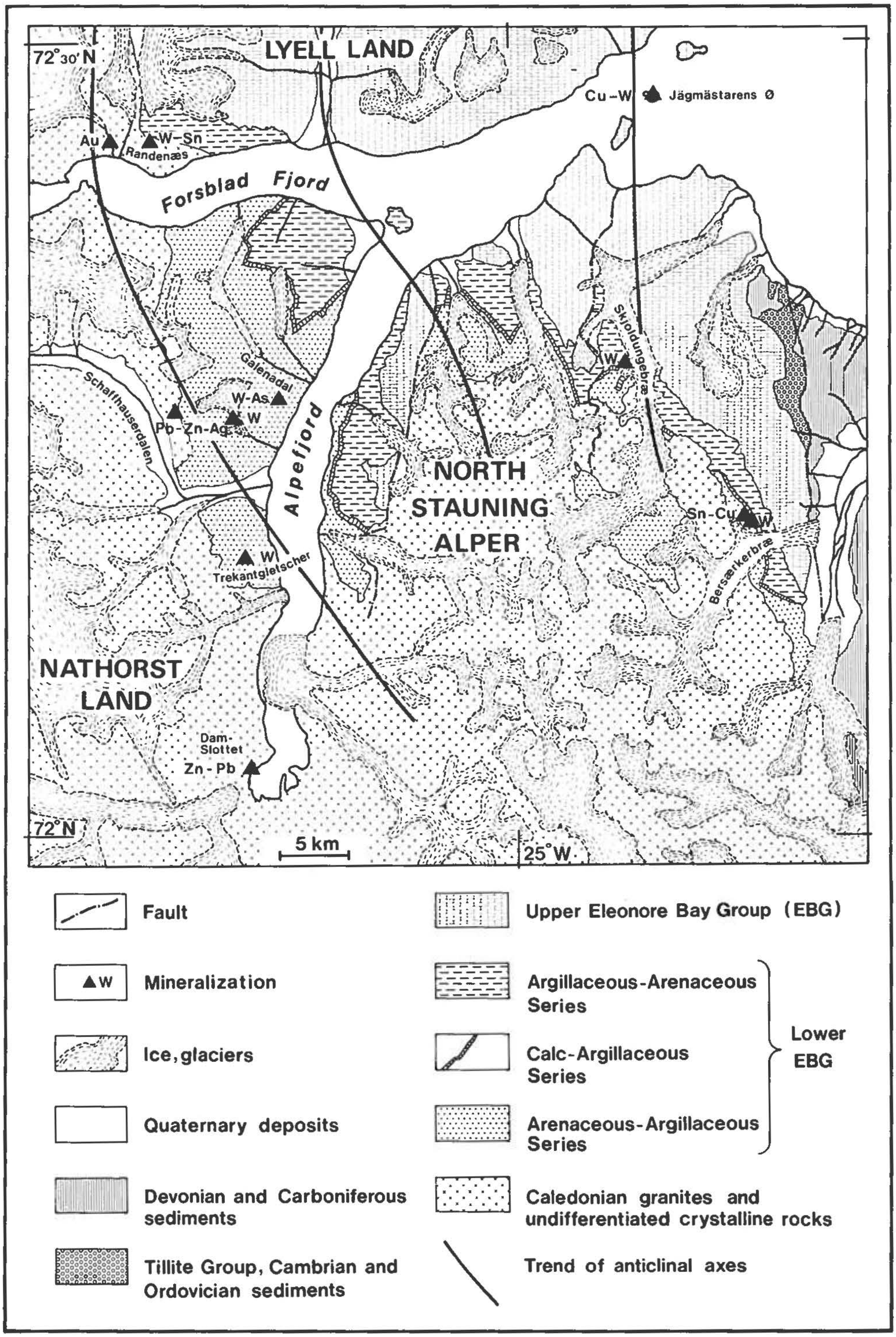


Fig. 23. Geological map of north Stauning Alper area with location of selected mineral occurrences. Modified after Hallenstein & Pedersen (1982).

Bjerg Formation is rather enigmatic, as most phosphorites are marine. The origin of the mineralization has possibly involved diagenetic mobilization and concentration of both uranium and phosphate.

North Stauning Alper (59–62)

Several types of mineralization including tin, copper and tungsten are described from this area (Fig. 23). The area comprises late Precambrian sediments (Lower Eleonore Bay Group) intruded by late Caledonian granites (Fränkl 1953b, Haller 1958). The lower Eleonore Bay Group is divided into: a) Lower Arenaceous-Argillaceous Series, b) Calc-Argillaceous Series and c) Upper Argillaceous-Arenaceous Series. The intrusive granite-sediment contact is situated in the upper part of the Lower Arenaceous-Argillaceous Series. Tectonically, the north Stauning Alper is divided into several major structural units (Fränkl 1953b) which are dominated by large-scale folding and N-S and NW-SE faulting and thrust faulting.

Tin at Bersærkerbræ (59)

Pronounced tin anomalies in panned heavy mineral concentrates led to the finding of two types of tin-mineralized quartz veins in the sediments two km northeast of Harlech Fjeld, Bersærkerbræ (Fig. 23) (Pedersen 1980b and 1981). These were later investigated in detail by Harpøth (1982).

Within the Lower Arenaceous-Argillaceous Series along a 2–3 km NW-SE-striking belt more than 20 persistent quartz veins have been observed 200–500 m vertically above a granite/sediment contact. It is noteworthy that no veins occur within the 200 m directly above the contact. The strike of the quartz veins is similar to that of the bedding of the host sediments (about 150°), whereas the dip of the quartz veins (10° – 90°) is much more variable than that of the sediments (60° – 70°). Some of the major veins could be traced in outcrop for more than 1000 m and observed in the cliff for an additional 2000 m. Individual veins are normally several tens of metres apart, but a section of 75–100 m contains 10–15 quartz veins. The thickness of the veins varies from 1–60 cm with an average of 15 cm (Fig. 24). The quartz veins contain varying amounts of alkali feldspar, coarse-grained cassiterite and chalcocite/bornite, and exhibit minor marginal greisenization (muscovite + cassiterite) (Fig. 25). Some of the mineralized veins exhibit strong late hydrothermal alteration and brecciation possibly resulting in redistribution of cassiterite and chalcocite/bornite. Microscopically, the primary ore mineral phases are cassiterite (with various inclusions of ilmenite, columbite(?) and possibly other oxides), chalcocite, bornite, hematite and minor native bismuth, pyrite and chalcopyrite. It is characteristic that single cassiterite crystals have many oxide inclusions in the early precipitated parts of the veins (closest to the margin) and no inclusions in the late precipitated parts of the vein (closest to the centre). The average grade of the veins, based on chip samples, is estimated to be 0.2% Sn (range of 22 analyses is 0.001–1.3%) with minor copper and silver. Most of the tin is hosted in the greisen margins, which on an average contain 0.6% Sn.

The other type of quartz veins comprises irregular, vertical NE-SW-striking veins, which occur in the partly inaccesible cliffs formed by the Calc-Argillaceous Series. The ore mineral paragenesis comprises cassiterite, stannite, galena, chalcopyrite and sphalerite. The stannite is a high-temperature precipitate because it contains numerous minute sphalerite inclusions and some galena inclusions as well (Ramdohr 1980). Microprobe analyses give the following molecular compositional ranges of stannite (S. Karup-Møller, pers.comm. 1984): $Cu_{1.63\text{-}1.90}Fe_{0.63\text{-}0.77}Zn_{0.17\text{-}0.70}Sn_{0.88\text{-}0.95}S_4$. Galena is also a high-temperature modification with very high bismuth and silver contents. Microprobe analyses give the following molecular compositional ranges (S. Karup-Møller, pers. comm. 1984): $Pb_{0.76\text{-}0.85}Bi_{0.09\text{-}0.11}Ag_{0.08\text{-}0.11}S$. This equals up to 9.46% Bi and 5.1% Ag in galena.

Genetically, there is no connection between the veins and the directly underlying granite, because a thrust

Fig. 24. Tin-mineralized quartz vein at Bersærkerbræ.

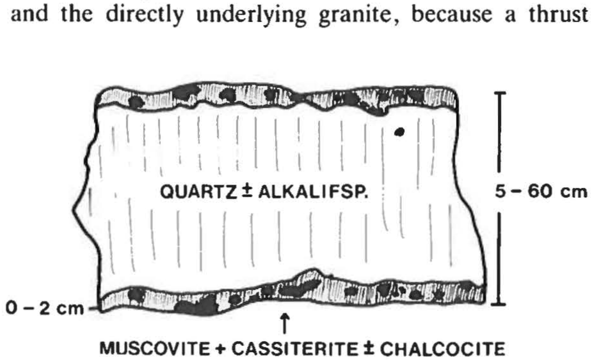


Fig. 25. Idealized sketch of tin-copper-mineralized quartz vein.

fault occurs in between. The assumed source granite for the vein mineralization is expected to be situated to the northeast as the general thrust fault movement of the area is towards SW.

Copper at Bersærkerbræ (60)

A copper-mineralized vein was found two km northeast of Harlech Fjeld, Bersærkerbræ (Fig. 23) in connection with tin exploration (Harpøth 1982). The mineralization is located just 200 m below the tin-bearing quartz veins described in the previous section.

The mineralized vein is located within contact metamorphosed sediments of the Lower Arenaceous-Argillaceous Series close to an intrusive contact to a late Caledonian granite. It is a vertical, N-S-striking baryte-fluorite vein exposed for 20 m laterally, but copper-mineralized scree boulders indicate a minimum length of 200 m.

The vein zone has a central part consisting of coarse-grained violet fluorite (10–20 cm) rimmed by massive baryte (20 cm). Next to the baryte is a brecciated and fractured zone (>1 m on either side of the vein) with chalcocite and bornite in up to 5 mm thick veinlets in the hornfelsic rock. Chalcocite contains numerous small inclusions of galena.

Analyses of selected samples gave the following results: copper 8.5–35.5%, silver 150–540 ppm, molybdenum up to 150 ppm, lead up to 400 ppm and gold up to 0.1 ppm. A very preliminary tonnage-grade estimate is 100 000 tons with 2–3% Cu and 50 ppm Ag.

The vein was emplaced along a N-S-striking fault with pronounced shear movement possibly succeeding the granite intrusion.

Tungsten (61, 62)

Nearly all the end-moraines of the glaciers in north Stauning Alper are scheelite-anomalous. Follow-up work at Skjoldungebræ and Bersærkerbræ in 1979 and 1980 show that scheeelite is found in veins and veinlets at both localities (Fig. 23) (Pedersen 1980b and 1981). A description of the mineralization has been presented by Hallenstein & Pedersen (1982 and 1983).

At Skjoldungebræ (62), scheelite has been located in outcrops within the Calc-Argillaceous Series (Fig. 23). It is found in thin folded veins up to 2 cm thick and a few metres long and on joint planes adjacent to the veins. The frequency of veins is low. The veins are composed of quartz, muscovite, fluorite and minor scheelite. Furthermore, thicker veins up to 1 m composed of quartz, fluorite and carbonates are abundant in the area. Analysis of pure scheelite shows a zinc content of 500 ppm.

In the side-moraines, quartzitic boulders with scheelite in quartz veins have been observed. The source of this mineralization has not been found.

At Bersærkerbræ (61), several types of scheelite mineralization have been found within and below the Calc-Argillaceous Series (Fig. 23). They comprise:

- A few widely scattered, folded veins in limestone beds of the Calc-Argillaceous Series. Individual veins are 0.5–5 cm thick and can be traced for a few metres. They consist of muscovite and quartz with accessory fluorite, apatite and scheelite. Scheelite invariably occurs in the vein margins and the tungsten content may be as much as 1%.
- Discordant 1 to 5 cm thick quartz veins in the shaly parts of the Calc-Argillaceous Series. In addition to quartz the veins also contain scheelite, arsenopyrite and pyrrhotite.
- Joints in shale with small, scattered scheelite grains.
- Calc-silicate rocks with disseminated scheelite. This type is only known from scree boulders.

Tungsten at Trekantgletscher, Nathorst Land (63)

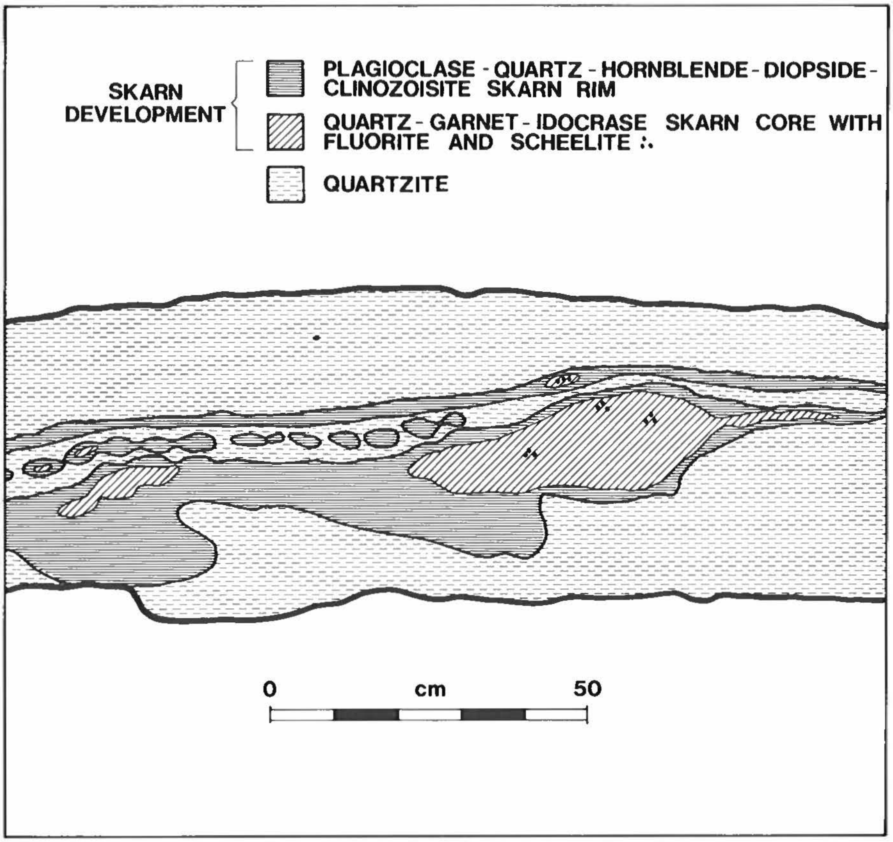
UV-light traversing by Nordmine along the coast between Schauffhauserdalen and Trekantgletscher in Alpefjord led to the finding of scheelite-mineralized skarn boulders in 1975. Follow-up panning in 1979 led to the discovery of *in situ* scheelite mineralization *c.* 2 km north of Trekantgletscher (Fig. 23) (Hallenstein 1979, Stendal 1980a). The mineralization is described in detail by Hallenstein & Pedersen (1982 and 1983).

The area comprises the lowest preserved beds of the Arenaceous-Argillaceous Series (Fränkl 1951). The rocks comprise metre-bedded, fine-grained, grey quartzite and quartzitic shale and subordinate calcareous quartzite which is found in thin (30 cm) beds and as concordant lenses up to 1 m thick and a few metres long. Intrusive Caledonian granite occurs 0.1–1 km west of the area. Xenoliths of the sediments occur in the granite and discordant granite veins of up to a few metres in thickness can be found for up to several km in the sediments. Both the granite stock and the granite veins are leucocratic two-mica granite. Feldspar-muscovite pegmatites with subordinate green mica, beryl and fluorite as well as pyrrhotite-bearing quartz veins are typically concentrated in areas with granite veining. Contact metamorphism has transformed the quartzitic shales into biotite schist and the calcareous quartzites into a calc-silicate assemblage, a so-called skarnoid rock.

Scheelite mineralization is associated with the skarnoid rock. The calc-silicate minerals and the associated mineralization in the lenses often reveal a characteristic zonal pattern (Fig. 26). Selected samples contain up to 0.8% W. A chip sample across a representative mineralized skarnoid lens yields only 100 ppm W. Other results include: Be max. 300 ppm, Bi max. 150 ppm, Sn max. 200 ppm, Cu max. 150 ppm and Pb max. 200 ppm.

Similar scheelite mineralization associated with skarnoid rocks has been indicated from boulders found in north Stauning Alper (Skjoldungebræ and Bersærkerbræ) and on the south coast of Forsblad Fjord. Genetically, the zoned skarnoid assemblages are interpre-

Fig. 26. Sketch of tungsten-skarn mineralization in Eleonore Bay Group quartzite. Drawn from photo. White areas are scree-covered.



ted as having been formed by a combination of metamorphism and metasomatism. The calcareous core assemblage has later reacted with hydrothermal fluids, and idocrase, scapolite, fluorite and scheelite were formed. The timing of the mineralization is believed to have been controlled by the intrusion of the granites.

Tungsten-arsenic in Alpefjord (64)

Galena-bearing quartz veins on the west side of Alpefjord (Fig. 23) were first described by Fränkl (1951). Later investigations by the University of Copenhagen (Stendal 1979b, Ghisler et al. 1980a) and by Nordmine (Thum et al. 1971, Stendal 1980a and c, Lind 1980, Pedersen 1980b, 1981 and 1982) have revealed extensive scheelite and arsenopyrite mineralization. The results are summarized by Stendal (1982b), Hallenstein & Pedersen (1982 and 1983) and Stendal & Ghisler (1984).

The area mainly comprises the lowermost EBG sediments – the Arenaceous-Argillaceous Series which consists of interbedded quartzites and semipelitic quartzites, striking NW-SE and dipping 30°–40°NE (Fränkl 1951, Caby 1976c).

Jointing, quartz veining and associated scheelite and arsenopyrite mineralization is abundant within a 15 km^2 area (Fig. 27). The stratigraphic thickness of the sequence containing mineralization is 1500–2000 m, and from base to top three localities are described in detail.

The stratigraphically lowest occurrence is found at an altitude of 1300 m (Locality A, Fig. 27). Large concordant quartz veins fifty to several hundred metres apart are enclosed in the quartzites. Individual veins are up to 3 m thick and 500 m long. The contact between the veins and the quartzite is sheared and broken and sometimes rotated fragments of quartzite can make up 10–20% of the veins. In addition to coarse-grained quartz, the veins contain aggregates of biotite, flakes of ilmenite, minor coarse-grained arsenopyrite and rare scheelite as cm-large euhedral crystals. The ore minerals are concentrated near the margins of the veins. Scheelite is also found as scattered grains on joint planes close to the veins.

At a higher stratigraphical level intense scheelite mineralization occurs south of Galenadal (Locality B, Fig. 27). In general, this area contains 1–2% quartz veins, but three zones are characterized by 2–6 m wide E-W-striking quartz vein swarms with 15% veins. At the top of the scree cones, two quartz vein swarms, 100 m apart, more than 150 m long and 6 m and 3 m wide occur. The third occurrence is found just below the scree cones and it probably represents the continuation of one of the vein swarms located above. It is 2 m wide and rapidly

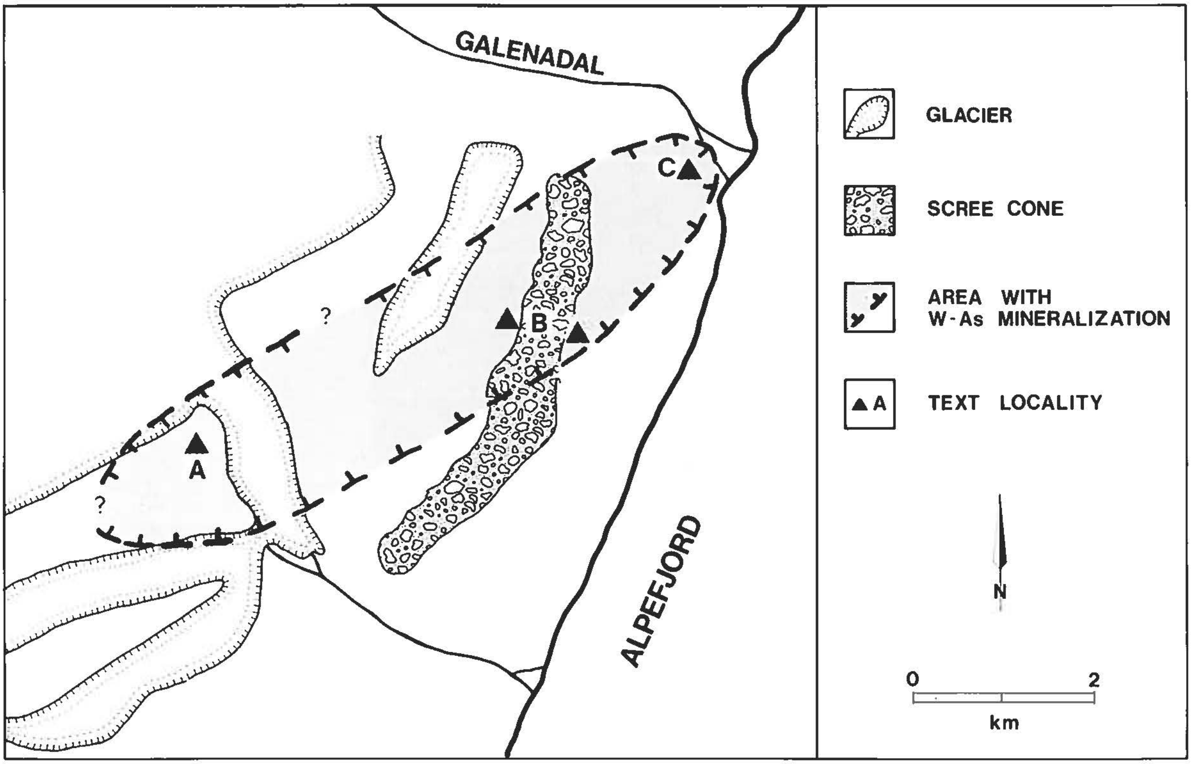


Fig. 27. Outline of area with scheelite-arsenopyrite quartz vein mineralization in Alpefjord.

fades away further east. The probable total length of these vein swarms is more than 1000 m. Several generations of veins exist (Fig. 28), each with its own ore-mineral assemblage. Four vein generations can be discriminated. These comprise (youngest first):

- Concordant quartz veins 0.1 to 1 m thick and several hundred metres long. They consist of quartz (90%), biotite, epidote, arsenopyrite and galena. Their contacts are sheared.
- Veins which strike 150° and are perpendicular to the bedding. Individual veins are 5–50 cm thick and up to 100 m long. They consist of quartz (>80%) and carbonates with minor pyrrhotite, arsenopyrite, chalcopyrite, bismuthinite, sphalerite and scheelite.
- East-west-striking veins perpendicular to the bedding. These predominate within the vein swarms. The thickness of individual veins is 0.5–5 cm. Splitting, merging and en echelon displacement of veins are frequent. In addition to quartz, the veins contain arsenopyrite, galena, bismuthinite and apatite. Analyses of 15 arsenopyrite-rich samples (H. Stendal, pers. comm. 1982) show a wide compositional variation with anomalous lead, bismuth and silver and enhanced antimony, copper, zinc and gold.
- Thin veins up to 2 cm which strike E-W, SW-NE and N-S and are perpendicular to the bedding. In addition to quartz, the veins contain scheelite and apatite. This vein generation contains most of the scheelite (Fig. 29). The veins have reacted with the wall rock. Where they intersect calcareous quartzites, the carbonate has been replaced by quartz and occasionally scheelite up to 2 cm from the vein. Selected samples contain up to 4% W.

Detailed sampling of the vein swarm at the top of the scree cones by percussion drilling indicates an overall content of 0.07% W, 0.2% As, 100 ppm Pb and 1–3 ppm Ag over a width of seven metres. The gold content is <0.1 ppm.

The highest stratigraphical level with mineralization occurs just south of the delta of Galenadal (Locality C, Fig. 27). In this area semipelitic quartzites are abundant and it is characteristic that whereas the quartzites contain 1–2% quartz veins, the semipelitic quartzites only display intense jointing with associated arsenopyritization of the wall rock. Other opaque minerals include pyrrhotite, ilmenite, rutile, sphene, magnetite, hematite, pyrite, galena, chalcopyrite, sphalerite and cobaltite. Scheelite does not occur.

Fluid inclusion studies on quartz vein material from Galenadal show a composition of moderately saline, carbon-dioxide-bearing water (Stendal & Ghisler 1984). The homogenization temperature was 225°–260° C. Sulphur isotope studies (Stendal 1982b) indicate that the sulphur most probably originates from sulphate-rich connate water.

Fig. 28. Complex quartz veining in Eleonore Bay Group quartzite in Alpefjord. Maximum vein thickness is half a metre.

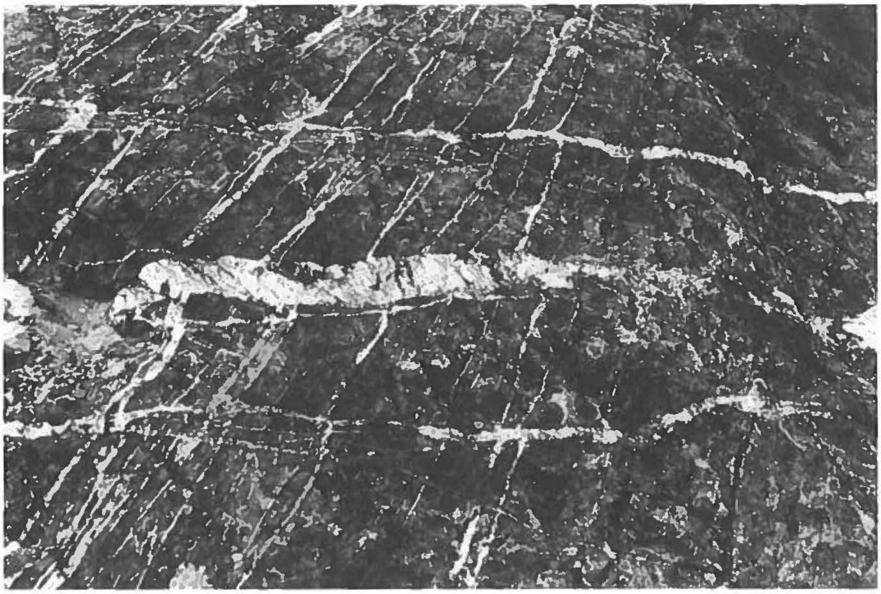
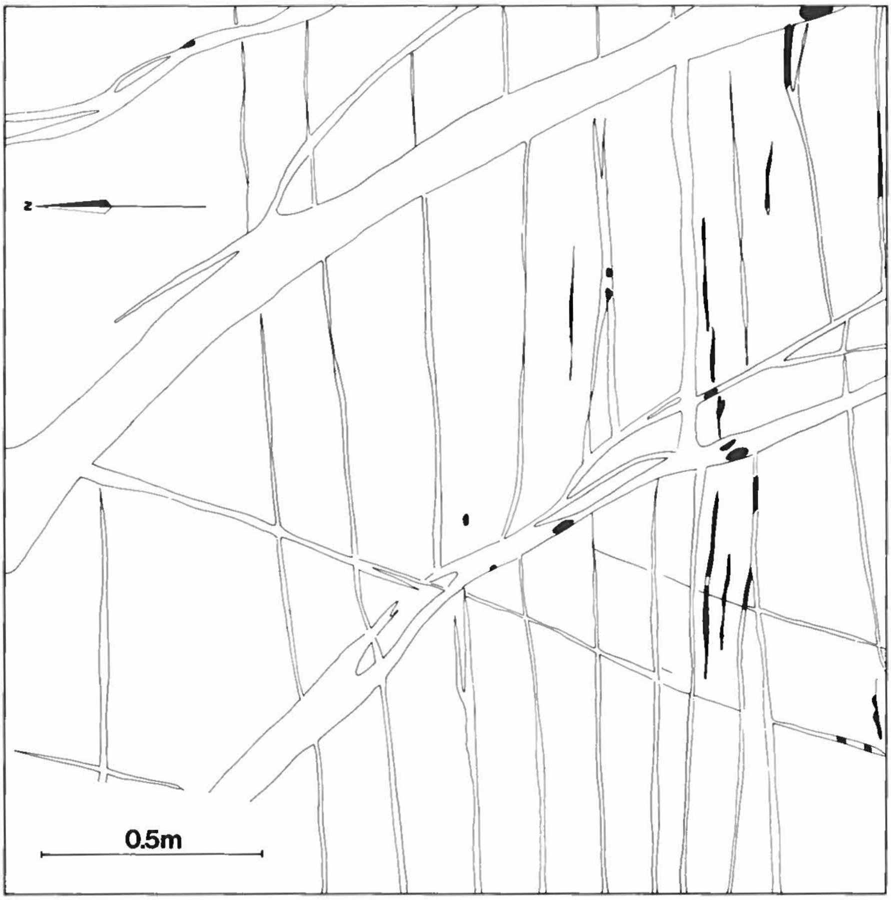


Fig. 29. Sketch of scheelite distribution in quartz veins hosted in EBG quartzites. Scheelite is shown in black. Alpefjord.



The veins and fractures are a result of folding and large-scale deformation of the sediments, which probably took place at the same time as the rise of the Caledonian granites. Quartz and ore minerals precipitated from a hydrothermal solution which may have been activated by the granites.

Tungsten-tin at Randenæs, Forsblad Fjord (65)

Outcropping scheelite and arsenopyrite vein mineralization was found at Randenæs in 1974 during follow-up on scheelite-rich pan samples (Hopfengärtner 1974). Further investigations including detailed panning and UV-traverses were carried out in 1979 (Lind 1980).

Randenæs is situated on the south coast of Lyell Land just east of the contact zone between Middle Proterozoic metasediments and Lower EBG (Fig. 23). The contact zone is intruded by Caledonian two-mica granites and by pegmatites. The oldest pegmatites are sub-concordant to the easterly dipping Lower EBG sediments, and are rimmed by mm-cm thick muscovite greisen whereas the younger pegmatites are sub-vertical without associated greisen. The metasediments comprise interbedded quartzite, biotite schist and garnet-biotite schist with small lenses of calc-silicate (skarnoid) rocks (Sommer 1957, Higgins et al. 1981).

Four types of mineralization have been observed:

- The most frequent type is associated with the greisen zones of the early generation of pegmatites. Fine-grained disseminated scheelite occurs together with sporadic coarse-grained cassiterite in the muscovite greisen. The contact between the greisen and the wall rock is locally mineralized with scattered decimetre-sized lenses of massive arsenopyrite with aggregates of tourmaline. Selected samples of the greisen contain up to 0.3% W, 800 ppm Sn, 200 ppm lithium and 50 ppm beryllium. Selected arsenopyrite-bearing samples contain up to 2 ppm Au.
- Joints near the mineralized pegmatites are locally coated with scheelite, muscovite, tourmaline, calcite, quartz and minor fluorite. The mineralized joints are subvertical and occur in three principal directions: 20°, 145° and 170°. Hydrothermal wall-rock alteration expressed as bleaching occurs. The overall grade and size is negligible.
- A third type of scheelite mineralization is found in some of the skarnoid lenses. They are often zoned with an outer rim rich in hornblende and a core rich in garnet. Quartz and in some cases plagioclase are the predominant minerals. Other minerals are diopside, clinozoisite, epidote, sphene, calcite and opaque minerals. Accessory amounts of scheelite and fluorite are disseminated and are often associated with sericitized plagioclase. The overall grade and size is negligible.
- Just east of Randenæs, sporadic, irregular, N-S-striking, subvertical quartz veins occur. The width of the veins is up to one metre and they contain blebs of arsenopyrite and galena. A galena-rich sample assays 175 ppm Ag; however the overall grade and size is negligible.

The observed mineralization is interpreted as contact vein mineralization associated with the intrusion of Caledonian granite.

Gold in Forsblad Fjord (66)

Gold-bearing boulders were found by Nordmine in the deltas of two small adjacent rivers on the north coast of Forsblad Fjord in 1975. This locality (Fig. 23) was briefly investigated in 1983 (Thomassen 1983).

The gold-anomalous area is situated in a north-south orientated décollement zone between Middle Proterozoic schists and migmatites of the Central Metamorphic Complex, and Upper Proterozoic sediments of the Eleonore Bay Group. The décollement is believed to represent an original basement-cover unconformity overprinted by Caledonain thrusting, metamorphism and granite emplacement (Higgins et al. 1981).

Outcropping mineralization occurs in a few cm thick quartz vein cutting a two-mica granite. The vein contains cm^2-dm^2 large arsenopyrite aggregates. Similar arsenopyrite-bearing boulders with occasional tourmaline are found in the nearby river bed, both above and below the outcrop. Microscopy reveals that small amounts of gold, bismuth, bismuthinite and chalcopyrite are intergrown with arsenopyrite. The gold may form up to 40 µ long, interstitial grains (Fig. 30). Microprobe analysis of

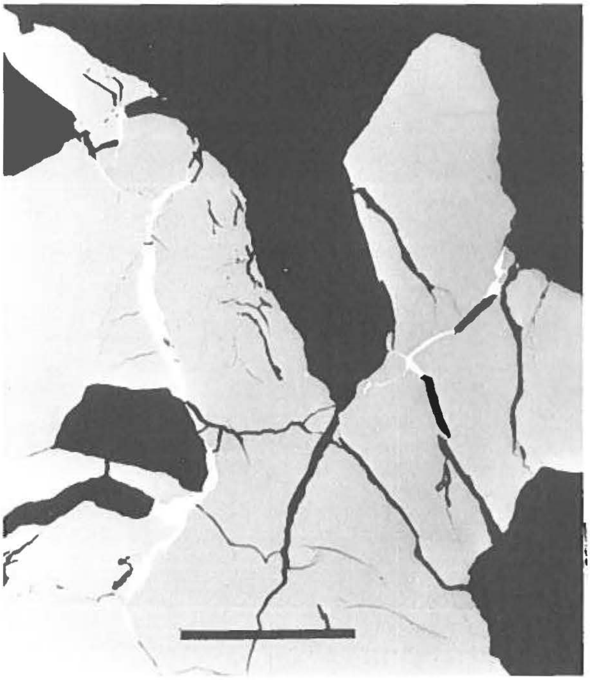


Fig. 30. Photomicrograph (reflected light) showing native gold filling cracks in arsenopyrite. Forsblad Fjord. Bar scale 50 microns.

the gold yields 94.4% Au and 3.7% Ag (S. Karup-Møller, pers. comm. 1983). The best mineralized sample contains 10% As, 0.5% Co, 0.07% Ni, 0.02% Bi, 26 ppm Au and 6.2 ppm Ag. Cobalt is supposed to substitute for iron in arsenopyrite.

Auriferous arsenopyrite is also known from a boulder in the neighbouring river a few hundred metres further east. Here the quartz-tourmaline-arsenopyrite vein is hosted in garnet quartzite.

It seems that the granites of the décollement zone between the Central Metamorphic Complex and the Eleonore Bay Group are critical for the location of this type of gold mineralization.

Copper-tungsten on Jägmästarens Ø, Segelsällskapets Fjord (67)

Investigations by Nordmine in 1975 (Hallenstein & Moeri 1975, Moeri 1975) at Jägmästarens Ø (Fig. 23) led to the finding of a copper-tungsten mineralization.

Jägmästarens Ø comprises folded quartzites of the upper Quartzite Series (Sommer 1957). A one metre thick green, argillaceous quartzite bed hosts copper mineralization of the type associated with Eleonore Bay Group sediments. However, in addition to the copper enrichment (up to 0.6%), selected samples also contain up to 0.1% tungsten, up to 50 ppm silver, up to 0.1% zinc and up to 150 ppm boron. A chip sample across the 1 m thick quartzite bed contains 0.15% Cu, 7 ppm Ag and <100 ppm W.

The Cu/Ag ratio of *c.* 200 and the relatively high tungsten and boron contents imply that the stratiform copper mineralization at this locality has been overprinted by hydrothermal mineralization of the type described for example in Noa Dal.

Tungsten-antimony in Margeries Dal, Ymer Ø (68,69)

Vein-type scheelite-stibnite mineralization was discovered in north Margeries Dal on Ymer Ø in 1979 during follow-up of scheelite-anomalous pan samples (Pedersen 1980b) (Fig. 31). The first report of scheelite in pan samples from Ymer Ø is due to Appel (1974). Follow-up in 1975 by Hallenstein (1976) was unsuccessful, but in 1980 he located the south Margeries Dal occurrence (Stendal 1980c, Hallenstein 1981). Subsequent prospect investigations in 1981 and 1983 include geological mapping, surface sampling, VLF survey and diamond drilling (total 2260 m) (Figs 6 and 10) (Hallenstein 1982, Swiatecki & Damtoft 1980, Pedersen 1981, 1982 and 1984). Detailed descriptions of the occurrences have been prepared by Hallenstein & Pedersen (1982 and 1983) and Pedersen & Olesen (1984).

The mineralization is hosted in the Multicoloured Series of the late Precambrian upper Eleonore Bay Group sediments. The Multicoloured Series is divided into 7 members (beds) (Eha 1953):

- Bed 7 is 190 to 200 m thick and comprises thick-bedded red dolomitic and quartzitic shales.
- Bed 8 is 40 m thick and is a light grey shaly dolomite which exhibits a characteristic yellow weathering colour.
- Bed 9 is 130 m thick and is a dark grey to black, massive, bituminous limestone with an intense network of calcite veins. It contains minor pyrite. Most of the scheelite- and stibnite-mineralized veins are hosted in this bed.
- Bed 10 is 145 m thick and consists of alternating, 5 to 15 cm thin beds of red shale and yellow dolomite. Near the base a 4 m thick, green shale unit, and a 9 m thick dolomite bed occur. Anhydrite/gypsum nodules replaced by quartz are common at certain levels. In fault zones a tectonic thinning is frequent.
- Bed 11 is 150 m thick and is a dark grey to black, massive to finely laminated, bituminous limestone. Calcite veining is frequent.
- Bed 12 is 130 m to 200 m thick and comprises white to light grey dolomite.
- Bed 13 is 250 m to 300 m thick and comprises red and green quartzites with rusty brown weathering colour.

Deformation in the area took place somewhere between the Ordovician and the Devonian and is expressed as large open folds with N-S axes. Contemporaneous with the folding, 1–2 km wide graben-like fault structures formed 10–15 km apart, perpendicular to the fold axes. The mineralization is associated with these faults (Fig. 31).

In south Margeries Dal (68) scheelite mineralization occurs in limestone breccia at two localities in the central part of a 1–2 km wide E-W-trending graben-like fault zone. The two occurrences are named the south Margeries Dal vein and the "Colinedal" vein (Fig. 32).

The south Margeries Dal vein comprises scheelite-mineralized, silicified breccia zones in the lowermost 60 m of the black limestone bed 9 and outcrops in a steep valley wall which is partly scree-covered. The limestones are oriented 163°/12° E. The breccia zones are oriented 52°/89° NW, and are thus perpendicular to the limestone. There is no apparent vertical displacement along the breccia zones. Two breccia zones, 5 m apart and both associated with scheelite mineralization, can be distinguished. The major northern one has a thickness of 1 to 3 m in outcrop, and 0.1 m some 200 m into the mountain, and extends from top to bottom of the limestone member. The smaller breccia zone is only up to 0.5 m thick and has a more restricted areal extent. The breccia consists of partly silicified fragments of limestone enclosed in a matrix of fine-grained quartz, dolomite, calcite and scheelite and coarse-grained calcite and scheelite. The breccia is more light grey than the enclosing limestone, and on weathering the dolomite gives the rock a yellow colouring. Scheelite is white. The breccia zone and the surrounding host lime-

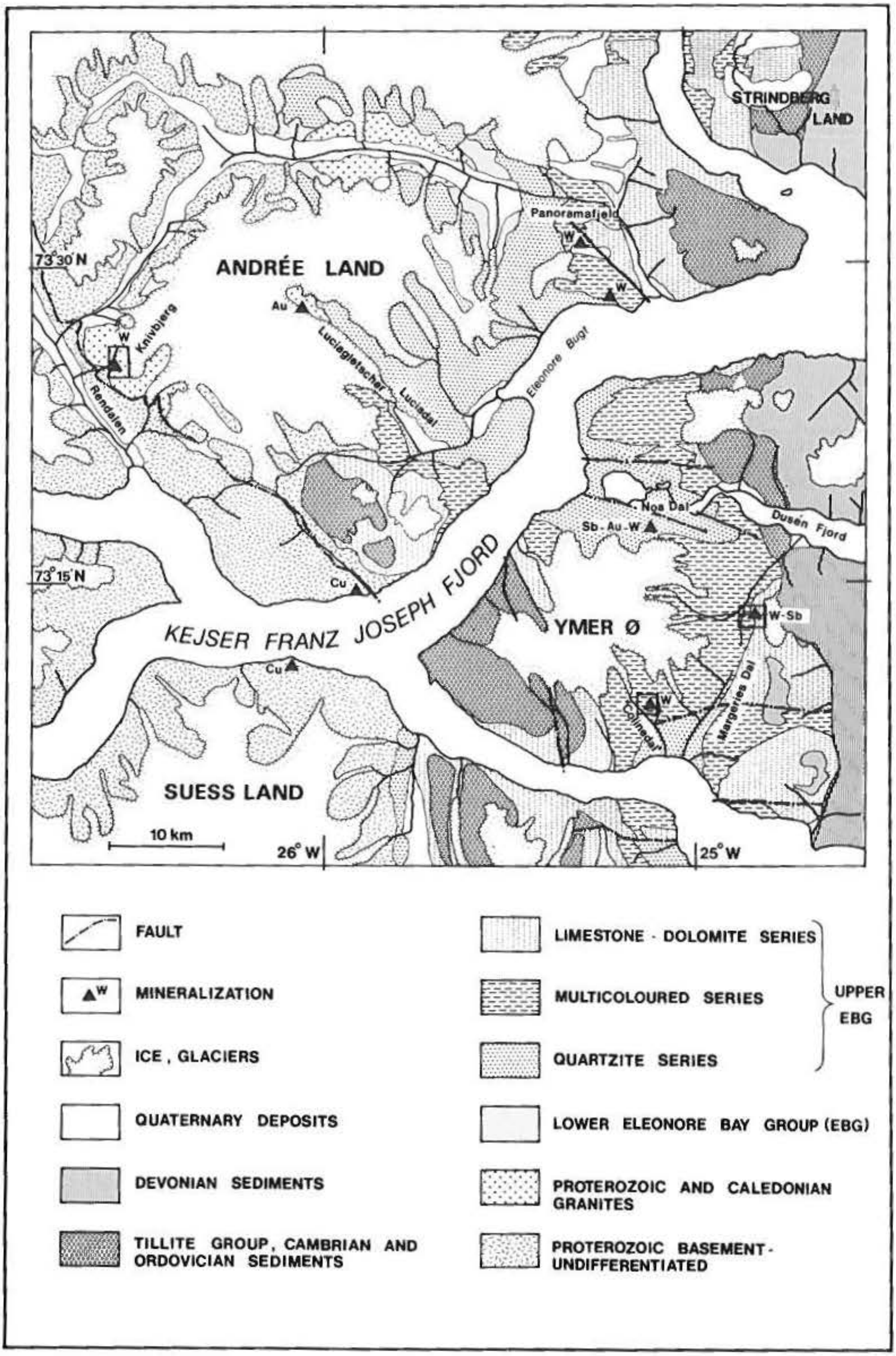


Fig. 31. Geological map of Ymer Ø – Andrée Land area with location of selected mineral occurrences. Framed areas shown in Figs 32, 33 and 37. Modified after Hallenstein & Pedersen (1982).

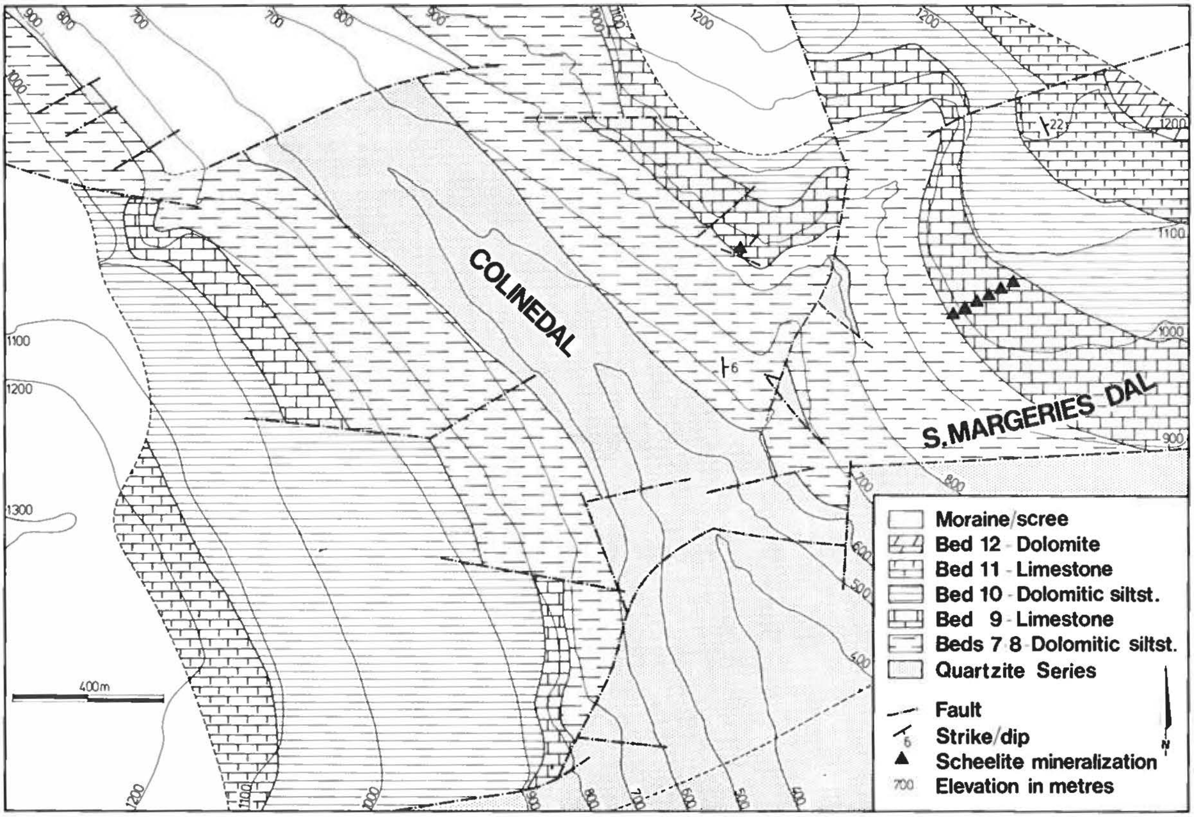


Fig. 32. Geological map of south Margeries Dal with scheelite-mineralized veins. Modified after Hallenstein & Pedersen (1982).

stone are intersected by a network of mm to cm thick calcite veins. The proportion of calcite veins varies from 1 to 15%.

High-grade scheelite mineralization is restricted to the thicker parts of the breccia zones. Individual half-metre sections contain up to 24% W in drill cores. Scattered scheelite is found in the thinner part of the breccia zone, 10–40 m away from high-grade mineralization, and in calcite veins in the limestone at a distance of up to 4 m from the breccia zones. The high-grade mineralization in the breccia zones seems to follow the base of bed 9, and thus plunges 10° NE. The continuation of the breccia zones into the underlying dolomite member – bed 8 – is not well investigated. However, from the outcrop it is known that scheelite mineralization disappears, exept for minor scattered scheelite found in veinlets together with quartz, at the very top of the underlying dolomite.

Chemically the mineralizing event is characterized by an increase in tungsten, silica, antimony and to a lesser degree also magnesium, and a decrease in calcium and carbon dioxide. Analyses show trace contents of antimony up to 140 ppm, but stibnite has not been identified.

Diamond drilling at the south Margeries Dal vein (Fig. 10) indicates a diluted tonnage of 82 000 tons with 2.3% W. However, the confidence limits for this estimate are wide (Pedersen & Olesen 1984).

The "Colinedal" vein occurs 500 m west of the south Margeries Dal vein (Fig. 32), and is similar. It is also found in a vertical breccia zone developed near the base of bed 9 limestone. The breccia zone strikes 55°. The mineralization has a height of 15 m and a width of up to 2 m. Chip samples indicate medium grade (*c.* 0.5% W) scheelite mineralization and the vein also contains minor stibnite. No drilling has been performed.

In north Margeries Dal (69) mineralization also occurs within a 1 to 2 km wide E-W-trending graben-like fault structure (Fig. 33). Mineralization has been located at the southern edge of the graben structure within a 800 m long, 150 m wide and 250 m high zone, which consists of two en echelon faults dipping 70° N (the northern and the southern fault). The en echelon shift, which is 40 m, is situated where the faults intersect beds 9, 10 and 11 (Figs 33 and 34). The vertical displacement along the faults is 200 to 300 m, and the occurrence of sub-horizontal slickensides in the fault planes indicates that horizontal displacement has also occured. The zone with the en echelon shift is characterized by flattening of the major fault planes, the occurrence of many antithetic faults and very intense splay faulting (Fig. 34).

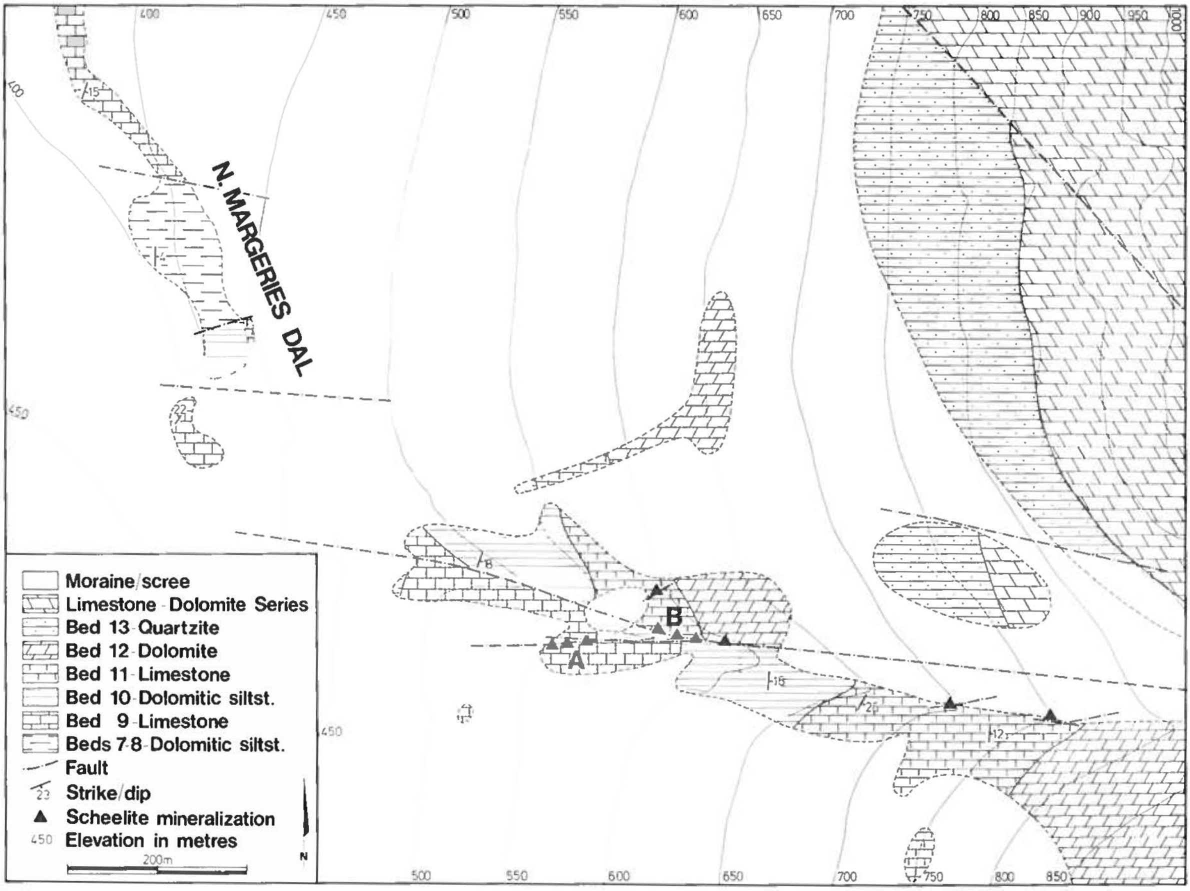


Fig. 33. Geological map of north Margeries Dal with scheelite and stibnite-mineralized veins. A and B indicate major ore lenses. Modified after Hallenstein & Pedersen (1983).

Scheelite mineralization occurs where the fault planes intersect the black limestones of beds 9 and 11 and breccia formation has taken place. The breccia zones are 0.1 to 4 m thick, silicified and rich in calcite veins. Dolomitization is less pronounced than in south Margeries Dal. Scheelite occurs only within or very close to the breccia zones, and only in limited areas, where the breccia zones show maximum curvature – areas where the fault planes change from steep to more flat lying. Within the mineralized area, this type of mineralization is developed in both black limestone members (beds 9 and 11). The size of individual lenses varies considerably. The largest scheelite-mineralized lens (Lens A, Figs 33 and 34) is a subhorizontal elongated lens 150 m long, and 20 to 40 m high. It is oriented 83°/76° N, and the thickness varies from 0.2 m to 3 m. Scheelite is very irregularly distributed and occurs both as fine-grained impregnation and as coarse-grained fissure fillings (Figs 35 and 36) with W contents in half-metre drill sections from traces to 11%. A characteristic feature is the light brown colour of the scheelite. Stibnite occurs sporadically with the highest content confined to areas close to the shale/dolomite – bed 10.

Stibnite mineralization occurs within the shale/dolomite, where intense fracturing, jointing and thin quartz veinlets are frequent. Stibnite occurs predominantly in massive to semi-massive veins 1–50 cm thick, and is associated with quartz. These veins are found along, below and above the faults up to a distance of 8 m from the fault planes, but only in areas where either the hanging wall, the foot wall or both consist of bed 10 shale or dolomite. The largest stibnite lens is found along the southern fault plane in continuation of the major scheelite lens (Lens A, Fig. 34). It is oriented 76°/63°N, is more than 150 m long, 50 m high and is up to 13 m thick. For a length of 60 m there is an overlap between the scheelite and the stibnite mineralization. Another stibnite lens (93°/38° N) occurs 40 m to the north along the northern major fault (Lens B, Fig. 34). Where the stibnite veins occur in shale or dolomite, there is no tungsten. Instead, trace amounts of arsenic (up to 100 ppm), bismuth (up to 30 ppm), mercury (up to 3 ppm) and gold (up to 0.1 ppm) occur.

In fractured limestone, fine-grained quartz, dolomite and scheelite have replaced calcite (Fig. 35). In dolo-

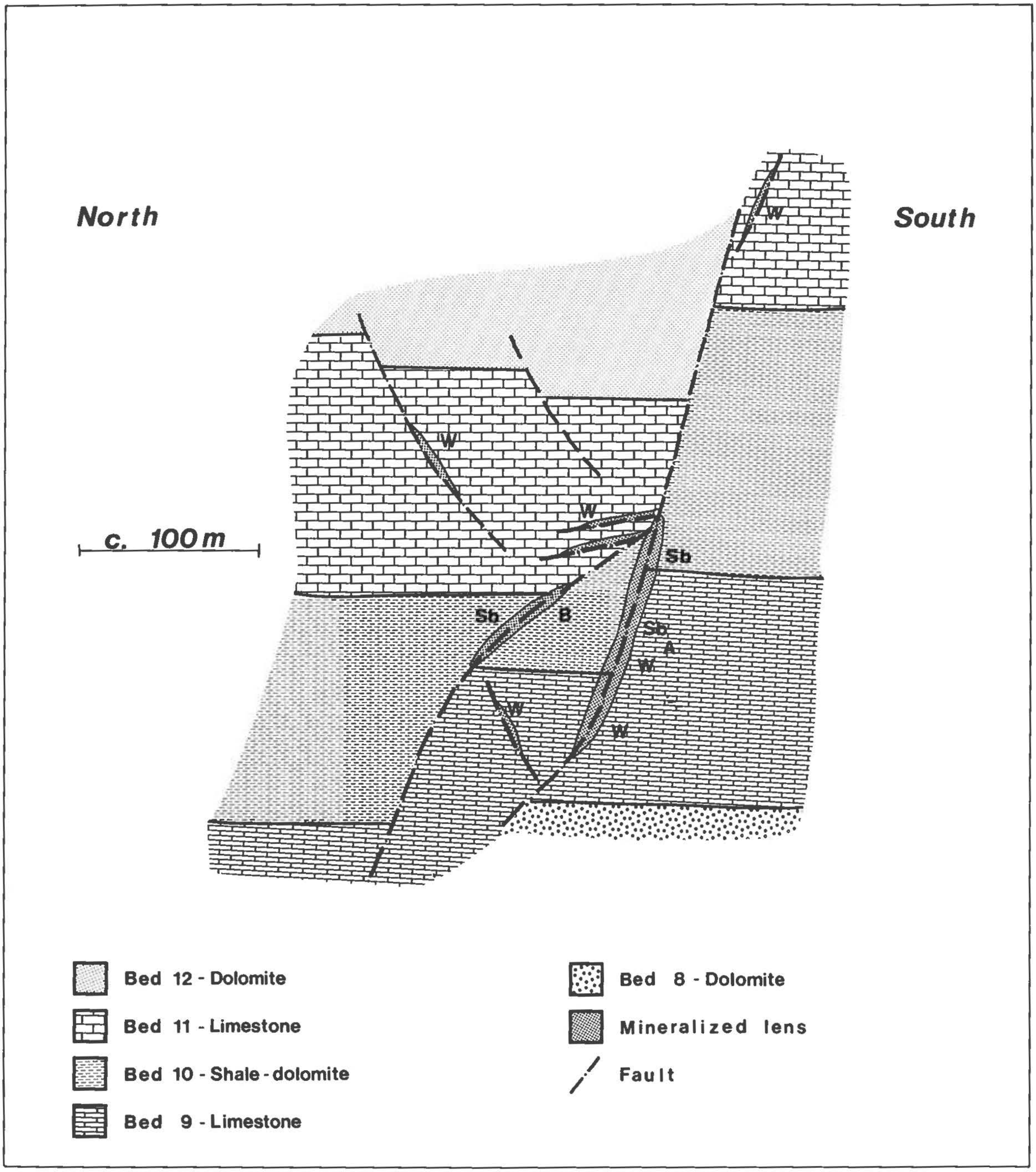


Fig. 34. Schematic profile of mineralized fault zone in north Margeries Dal. A and B indicate major ore lenses.

mitic shale and locally also limestone stibnite occurs instead of scheelite (Fig. 36).

Diamond drilling at the north Margeries Dal vein (Fig. 6) indicates diluted tonnages of 42 000 tons with 0.7% W and 108 000 tons with 3.5% Sb. As at south Margeries Dal the confidence limits for this estimate are wide (Pedersen & Olesen 1984).

Genetically, it is proposed that the tungsten-antimony mineralization is the result of precipitation from circulating hydrothermal solutions. The occurrence within the fault structures is due to the existence of proper channels. The close association between scheelite and black limestone, and stibnite and dolomitic shale respectively is supposed to reflect the fact that

Fig. 35. Photomicrograph (transmitted light) showing fine-grained silicified limestone with overgrowth of prismatic quartz and late-stage filling of scheelite (high relief). Bar scale 0.5 mm.

these rock types acted as chemical traps for the elements in question. The mineralizing event was contemporaneous with the formation of the fault systems.

Antimony-gold in Noa Dal, Ymer Ø (70)

Galena-bearing quartz veins were found in the EBG sequence in the Noa Dal area by Eha (1953). They were investigated in the mid-fifties by Nordmine and later described by Vohryzka & Vohryzka (1969). Pan samples collected in the area by Nordmine in 1981 and subsequent follow-up in 1983 (Pedersen 1982 and 1984) led to the finding of outcropping scheelite and gold mineralization as well as of stibnite-wolframite-gold-bearing boulders (Fig. 31).

The area comprises EBG sediments belonging to the Quartzite Series (Eha 1953). The Series comprises 1800–2000 m of red and white quartzites (beds 2 and 6), black and green quartzitic shales (beds 1, 3 and 5) and alternating layers of quartzite and quartzitic shales (bed 4). Structurally, the area is part of a major N-S-trending anticline dissected by E-W mainly normal faults. In general the bedding is dipping 10°–20° east.

At least four different types of mineralization occur in the Noa Dal area:

- Four major sulphide-bearing quartz veins occur in the quartzites of bed 3 within a limited area 2 km east of the delta in Noa Sø. The largest one is 0.1–2 m thick and 300 m long. It consists of quartz with subordinate feldspar, 1 to 2% galena and lesser amounts of chalcopyrite and sphalerite. Microscopically, pyrite, bournonite and arsenopyrite also have been detected. Analyses of selected samples yield in addition to high lead, copper and zinc values up to 400 ppm Sb, 200 ppm Bi, 150 ppm Ag and <10 ppb Au.
- A second type occurs at the base of bed 4 approximately 1 km south of the delta in Noa Sø. Scattered grains of scheelite occur on joint planes and in thin quartz veins in calcite-bearing quartzites close to a major E-W fault. The overall tungsten content is however very low.
- The third type of outcropping mineralization comprises brecciated quartzites impregnated with up to 20% pyrite, and locally with high gold contents (up to 5 ppm). This poorly investigated type is found in scattered lenses close to major E-W faults in the area 1–3 km east of the quartz veins described above, but at a considerably higher stratigraphic level (200–600 m).
- In addition, mineralized scree boulders from the

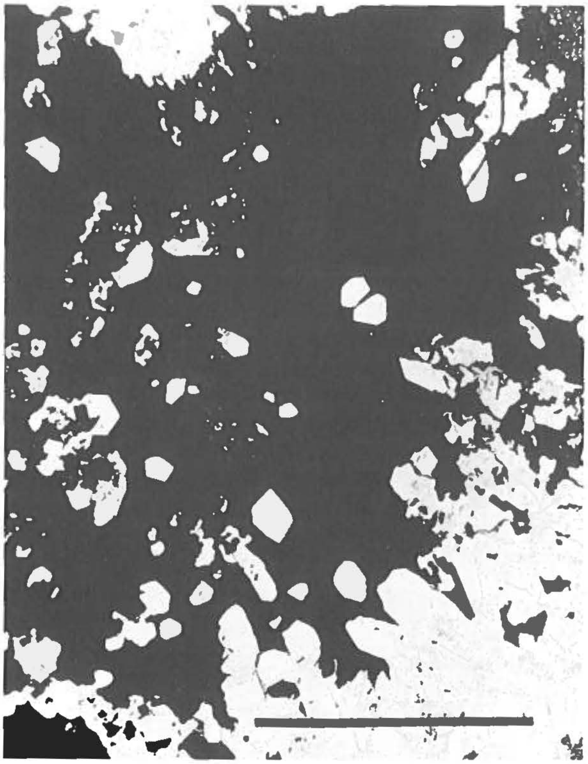


Fig. 36. Photomicrograph (transmitted light) showing euhedral quartz crystals and stibnite (black). Bar scale 0.5 mm.

south side of the valley indicate other types of mineralization. One type is stibnite-arsenopyrite-gold as impregnation and veinlets in brecciated dolomitic shale and in brecciated quartzite. Stibnite is paragenetically later than arsenopyrite. The host rocks probably originate in a level near the top of the Quartzite Series. Analyses of stibnite-mineralized scree boulders average 5–10% Sb, 0.5% As, 0.5–2 ppm Au and 2–5 ppm Ag. A second type comprises boulders of quartzite with wolframite-bearing fluorite-quartz veinlets and impregnated with arsenopyrite and gold. A few boulders contain up to 1% W, 2% As and 7 ppm Au.

The different types of mineralization are the result of hydrothermal activity which took place at the same time as the formation of the E-W-striking faults. On structural evidence this can be determined to have occurred somewhere between Ordovician and Devonian. The vertical zonation with silver-rich base-metal mineralization at the deepest level and antimony-tungsten mineralization at a more shallow level is probably due to decreasing temperature. The hydrothermal solution may have originated from deep-seated granites.

Minor galena-bearing quartz veins hosted in the EBG bed 4 quartzites occurring at Magdalena Sø, Strindberg Land (Moeri 1975) seem to be similar to the base-metal veins of Noa Dal.

Tungsten at Knivbjerg, Andrée Land (71)

A scheelite-anomalous pan sample was first collected by Nordmine in 1974 in the Rendalen delta. Later, detailed investigations during the years 1979–81 revealed widespread tungsten skarn mineralization just SE of Knivbjerg (Figs 31 and 37) (Hallenstein 1979, 1981 and 1982, Stendal 1980c). The mineralization is described in detail by Hallenstein & Pedersen (1982 and 1983).

The geology is dominated by a prominent SE-striking and easterly dipping late Caledonian thrust fault zone which occurs along the northeast side of Rendalen. The tectonic zone separates a Lower Proterozoic (1800–2000 Ma) basement in the southwest from a Middle Proterozoic (950–1250 Ma) metasedimentary sequence in the northeast (Higgins & Friderichsen 1979). The Middle Proterozoic unit is intruded by two generations of granites of Grenvillian and Caledonian ages, respectively (Higgins et al. 1981, Rex & Gledhill 1981). The Middle Proterozoic metasediments of the Knivbjerg area comprise a sequence of quartzites and a 100–200 m thick schist and marble unit. Granites have reached their highest intrusive level in the schist and marble beds which now partly occur in the granite as large lenses up to 1000 m long and 100 m thick and somewhat rotated in relation to the quartzite (Fig. 37). The schist consists of biotite, quartz, plagioclase as well as accessory sphene and apatite. To the north the schist is more calcareous and also contains diopside, tremolite and/or clinozoisite. Irregular sweats of quartz and plagioclase are abundant and occur concordant with the foliation. The marble is a medium-grained, blue-grey rock, which occasionally is recrystallized to a coarse-grained white marble. It consists of calcite, diopside and quartz. Skarn has been formed in the marble near the contact between marble and granite and along joints. Two distinct skarn types have been observed – a pale brown, coarse-grained, massive zoisite/clinozoisite skarn and a green, medium-grained, diopside skarn. Cross-cutting quartz-feldspar-biotite-muscovite-tourmaline-bearing pegmatites, aplites and quartz veins are frequent in the granite zone.

Scheelite mineralization has been observed at several localities within a 2x3 km area (Fig. 37). The most intense mineralization occurs in the eastern part of the area along a N-S-striking, 500 m long zone, where scheelite is found in both schist and in marble skarn. The control of the zone is unknown. In the western part of the area the scheelite occurrences are more scattered and confined to the schist.

In mineralized schist, fine-grained scheelite occurs in clinozoisite-rich layers, in cross-cutting shear zones, disseminated in biotite-rich layers parallel with the schistosity, and associated with quartz (-feldspar) sweats. The most intense mineralization is seen as several up to 10 cm thick bands in a 2 to 3 m section. In individual outcrops mineralization can be traced for 50 m before disappearing below scree cover. Analyses show that the overall tungsten content is less than 100 ppm. Selected samples contain up to 0.3% W. Enrichment in beryllium (max. 70 ppm) and tin (200 ppm) is ubiquitous.

The other scheelite-bearing rock type is the zoisite/clinozoisite skarn. It is composed of zoisite and clinozoisite with minor amounts of diopside, quartz, plagioclase, fluorite, calcite, apatite and scheelite. The zoisite skarn is developed together with diopside skarn, where it forms a 1–50 cm thick zone in contact with the marble. Scheelite is concentrated at the contact between marble and zoisite skarn, but only in small amounts. Zoisite skarn is also found as diffuse bands, up to 20 cm thick, enclosed in marble. This type has only been found in boulders in the N-S-striking zone in the eastern part of the area. Compared with the first type of zoisite skarn this type contains more scheelite, fluorite and quartz. These minerals tend to be laminated on mm-scale, and sometimes exhibit small-scale folding. Analyses show that the average tungsten content in a 0.2 m thick band is 1%. Selected samples contain up to 15% W, max. 700 ppm Li, max. 70 ppm Be, max. 400 ppm Sn, max. 50 ppm Bi and max. 200 ppm Cu.

Analyses of pan samples from the area also reveal distinct anomalies of tin, gold and bismuth. Tin mainly occurs in cassiterite which occasionally is intergrown with tourmaline, whereas gold is believed to be associated with bismuth minerals and/or arsenopyrite which has been identified in the concentrates.

The relationship between scheelite mineralization

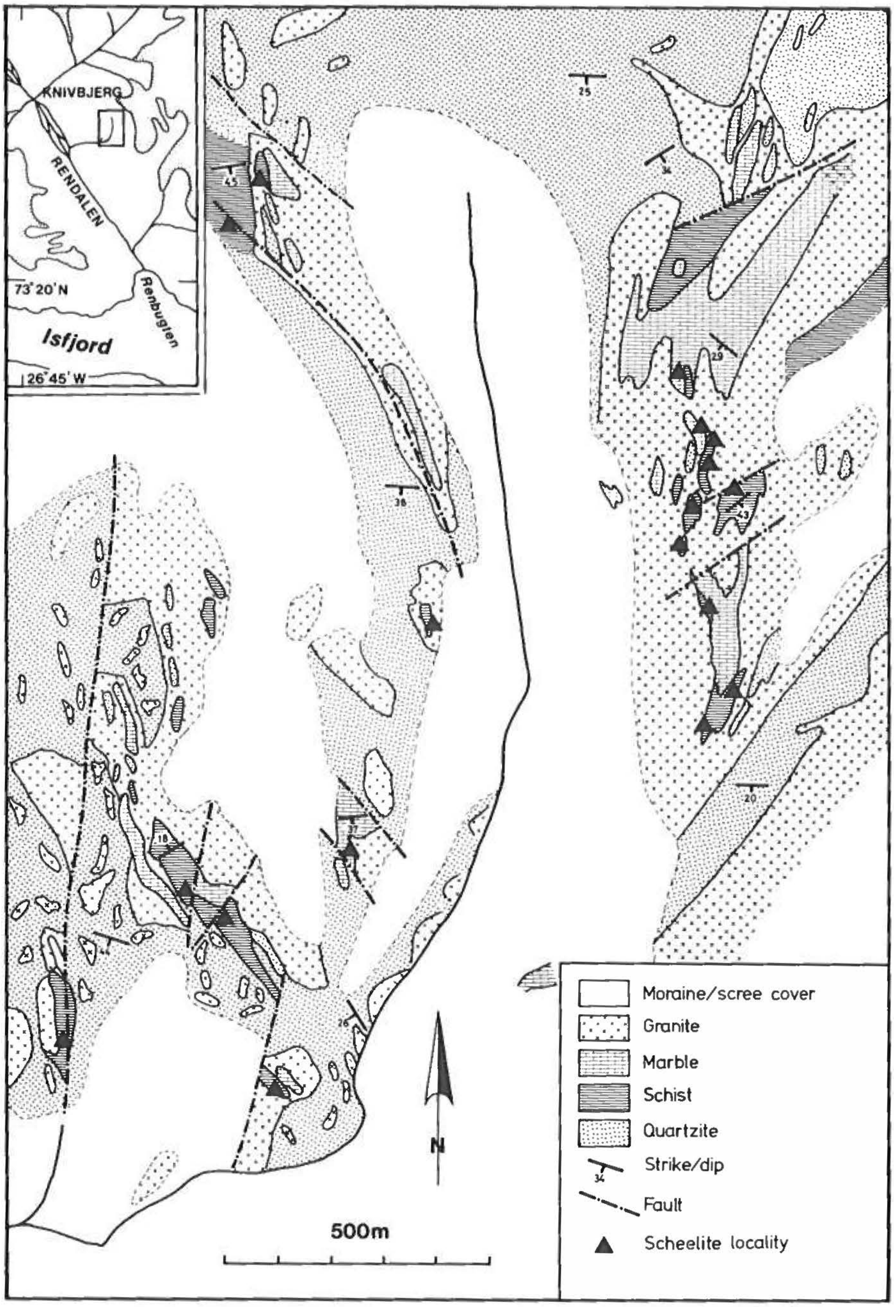


Fig. 37. Geological map of Knivbjerg area with scheelite-mineralized localities. Modified after Hallenstein & Pedersen (1983).

and granite intrusion is uncertain. No sign of scheelite-bearing skarn has been observed at the actual metasediment-granite contacts, and the granite intrusion of the area may postdate skarn formation and mineralization. However, remobilization of skarn mineralization by granite or pegmatite intrusion has not been observed either.

Gold at Luciagletscher, Andrée Land (72)

During 1983 and 1984 approximately 1500 pan samples from the NM-file were re-analysed for gold with a detection limit of 20 ppb (Thomassen 1984, Harpøth & Pedersen 1984). This led to the identification of a gold-anomalous drainage system including Benjamin Dal, Luciadal and Luciagletscher in the southeastern part of Andrée Land. Limited mineral exploration activity performed by Nordmine in the Luciadal-Luciagletscher area (Lind 1981b, Harpøth 1984) led to the findings of locally derived gold-bismuth-mineralized boulders (Fig. 31).

The area around Luciagletscher comprises a Middle Proterozoic metasedimentary sequence separated by faults from the late Proterozoic EBG and intruded by late Caledonian granites. The Middle Proterozoic metasediments comprise well-bedded sequences of quartzite, silicious gneiss, minor mica schist and occasional thin beds of calc-silicate rocks. The general metamorphic grade is amphibolite facies. Late Caledonian intrusive activity is reflected by aplites, pegmatites and large granite bodies. There is a marked increase in intensity in aplite/pegmatite veining towards the northwest where migmatitic rocks occur. Apart from the major N-S to NE-SW fault system which separates the two major rock units, a prominent NNW-SSE-trending anticlinal structure occurs in the upper Luciagletscher area (Fränkl 1953a, Haller 1953, Higgins et al. 1981).

Outcropping gold-bismuth mineralization has not yet been located, but is indicated from both microscopy of pan samples and from significant boulder finds. Gold-bismuth-mineralized, pyrrhotite-bearing quartz vein/pegmatite boulders are widespread in the northeastern side-moraine, whereas only few occur in the mid-moraines and in the southern side-moraine. The main source area is most probably located in the uppermost part of the glacier valley. The boulders exhibit a wide range of rock types from pegmatite and aplite to vein quartz, but characteristically they represent vein material occurring in both granitic and metasedimentary host rocks. The veins have observed dimensions of up to more than one metre in width. The ore minerals pyrrhotite and pyrite and subordinate chalcopyrite, galena, native bismuth, native gold and sphalerite have been identified. The gangue consists of quartz, alkali feldspar, tourmaline and muscovite with minor garnet and beryl. Microscpically, it is observed that there is an intimate relationship between galena, bismuth and gold (Fig. 38). Galena is optically slightly different from normal galena and is believed to have a high bismuth content. In general, galena, bismuth and in particular gold occur peripheral to large pyrrhotite aggregates. Native gold seems to be late in the paragenetic sequence, occurring as small (5–20 microns) individual grains or intergrown/associated with galena and bismuth in microfractures in quartz. Analyses of selected samples reveal the following maximum values: gold 8.3 ppm, bismuth 200 ppm, copper 0.1%, lead 200 ppm, and silver 2 ppm. Of ten samples analysed for gold, seven were anomalous and four had a gold content in the range of 1.4 ppm to 8.3 ppm.

Electrum and arsenopyrite with small (5 microns) inclusions of native gold have been identified by microscopy of pan samples which indicate that other types of gold mineralization occur as well.

More than one source area for gold occur in Luciagletscher, but the major part of the free gold contained in the northern side moraine is believed to originate in a limited area (0.5 km^2) in the uppermost part of the glacier valley. From helicopter reconnaissance a major network of quartz veins/ pegmatites/aplites has been located. Furthermore, a major fault zone/vein zone occurs within the same limited area. The vein network is assumed to be associated with the intrusion of late Caledonian granite. Concerning the fault zone, the orientation (60°–70°) is identical to mineralized Devonian faults of for example west Ymer Ø.

Tungsten at Panoramafjeld, Andrée Land (73,74)

Anomalous scheelite content in the river sediments south of Panoramafjeld was first noted by Stendal (1979b). Follow-up investigations including shallow drilling by Nordmine in 1980 and 1981 (Stendal 1980c, Pedersen 1981, Hallenstein 1981, Pedersen 1982) revealed the same type of scheelite mineralization as on Ymer Ø, i.e. scheelite in brecciated limestone.

The area consists of slightly folded limestones and shales of the Eleonore Bay Group (Beds 8–12). A major, SE-striking normal fault, along which the northeastern block is downthrown several hundred metres, intersects the area (Fränkl 1953a).

Outcropping scheelite mineralization has been located 1 km south of Panoramafjeld (74) just west of the

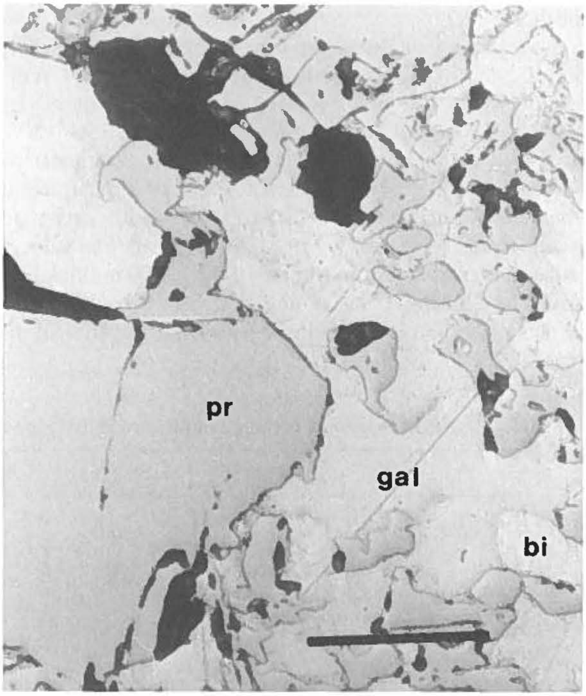


Fig. 38. Photomicrograph (reflected light) showing intergrown pyrrhotite (pr), galena (gal) and native bismuth (bi). From gold-bismuth-mineralized boulder at Luciagletscher. Bar scale 50 microns.

major fault (Fig. 31). Scattered grains and aggregates of scheelite occur in joints and in thin 60°–80°-striking veins which are restricted to the black limestones of bed 9. The mineralization can be traced discontinuously in outcrop for 200 m. Boulders from the same area contain semi-massive, light brown scheelite in up to 10 cm wide zones in dolomitized and silicified limestone.

A few km to the south of Panoramafjeld (73) scattered scheelite has been located in bed 8 outcropping on the cliff north of Eleonore Bugt (Lind 1981b) (Fig. 31). Mineralization occurs in sub-vertical 60°–80°-striking joints a few hundred metres east of a major SE-striking fault. Scheelite is found in thin veins and as coatings on joint planes. In addition a few dolomite boulders with semi-massive scheelite have been found.

The mineralization is believed to have a genesis similar to that of the mineralization observed on Ymer Ø.

Copper-antimony in Brogetdal, Strindberg Land (75, 76)

Copper-antimony mineralization was found at Holmesø in Brogetdal (75) during reconnaissance of the EBG sediments in 1974 (Appel 1974). Prospect investigations comprising geological mapping, geophysics and a single bore hole (21.1 m) were commenced the following year, but were never brought to a conclusion (Bruneau 1976, Gruner & Probst 1976). Similar mineralization was found at Laksesø (76), some 8 km further SE in Brogetdal, during reconnaissance for scheelite in 1981 (Harpøth 1982).

The geology of Brogetdal comprises Upper EBG, Tillite Group, Cambro-Ordovician and Devonian sediments which are block-faulted along abundant NNE-SSW to E-W faults. The core of an open, SSE-NNW anticline with intense faulting is situated southeast of Holmesø (Katz 1952). Near the core of the anticline malachite-azurite-stained outcrops of white quartzite occur inside a 500 x 1000 m area (Fig. 39). The mineralized outcrops occur in the top of the *c.* 100 m thick bed 6 of the Quartzite Series and is overlain by red, silty shales of bed 7 (Multicoloured Series). Geophysical investigations indicate a major fault which branches off in a more northerly direction at the mineralized outcrops, below the Quaternary cover.

Tetrahedrite-chalcopyrite mineralization occurs in the uppermost metres of the malachite-stained, white quartzite. The lateral extension in individual outcrop is up to 50 m. The ore minerals occur as fine-grained disseminations throughout the rock, as up to 5 mm large blebs and as fillings of abundant, criss-crossing, few mm thick veinlets and joints. Microprobe analyses give the following molecular compositional ranges of tetrahedrite (S. Karup-Møller, pers. comm. 1984):

$$(Cu_{9.82\text{-}10.21}Ag_{0.1})(Fe_{0.3\text{-}0.45}Zn_{1.5\text{-}1.58})(Sb_{3.62\text{-}3.89}As_{0.11\text{-}0.18})S_{13}.$$

Chalcopyrite with minor intergrown bornite replaces tetrahedrite. Analytical data are presented in Table 2.

Minor copper-antimony mineralization also occurs *c.* 1 km south of Laksesø (76) (Fig. 39) in bed 5 quartzite. The ore minerals comprise pyrite and chalcopyrite, and tetrahedrite with a grossly similar composition to that above. The mineralization occurs in hydrothermally altered, mm-cm wide breccias, veinlets and joints with a general orientation of 145°/80° W. This mineralization is associated with a nearby NE-SW fault zone.

The lack of lateral continuity, the geochemistry (high Sb) and the tectonic control (Upper Devonian faults) indicate an epigenetic origin comparable to that of the W-Sb veins of Ymer Ø.

Fluorite at Kap Franklin, Gauss Halvø (77,78)

Fluorite was first reported from the Kap Franklin area by Rosenkrantz in 1929 (Bøggild 1953). Geological mapping in 1950 revealed widespread fluorite mineralization in Devonian rocks (Graeter 1957), and the area was visited several times by Nordmine in the fifties and seventies (Kramers 1972, Hallenstein 1976). A systematic investigation of the Devonian felsic volcanic and subvolcanic rocks for uranium was carried out by a joint Nordmine/GGU party in 1975 (Ryan & Sandwall 1975) and a geochemical survey was carried out in

Table 2. Analytical results of various samples from the copper-antimony mineralization in Brogetdal, Strindberg Land.

Sample	Cu (%)	Sb (%)	As (%)	Zn (%)	Pb (%)	Ba (%)	Ag (ppm)
Drill core section (1.4 m) Holmesø	1.33	0.67	–	0.06	0.003	–	28
Bulk sample (35 kg) Holmesø	1.35	1.07	–	0.14	0.004	0.36	24
Tetrahedrite chips Holmesø	25	17.5	0.3	2.5	0.01	0.2	600
Selected sample Laksesø	1.3	0.5	0.1	0.3	0.04	–	8

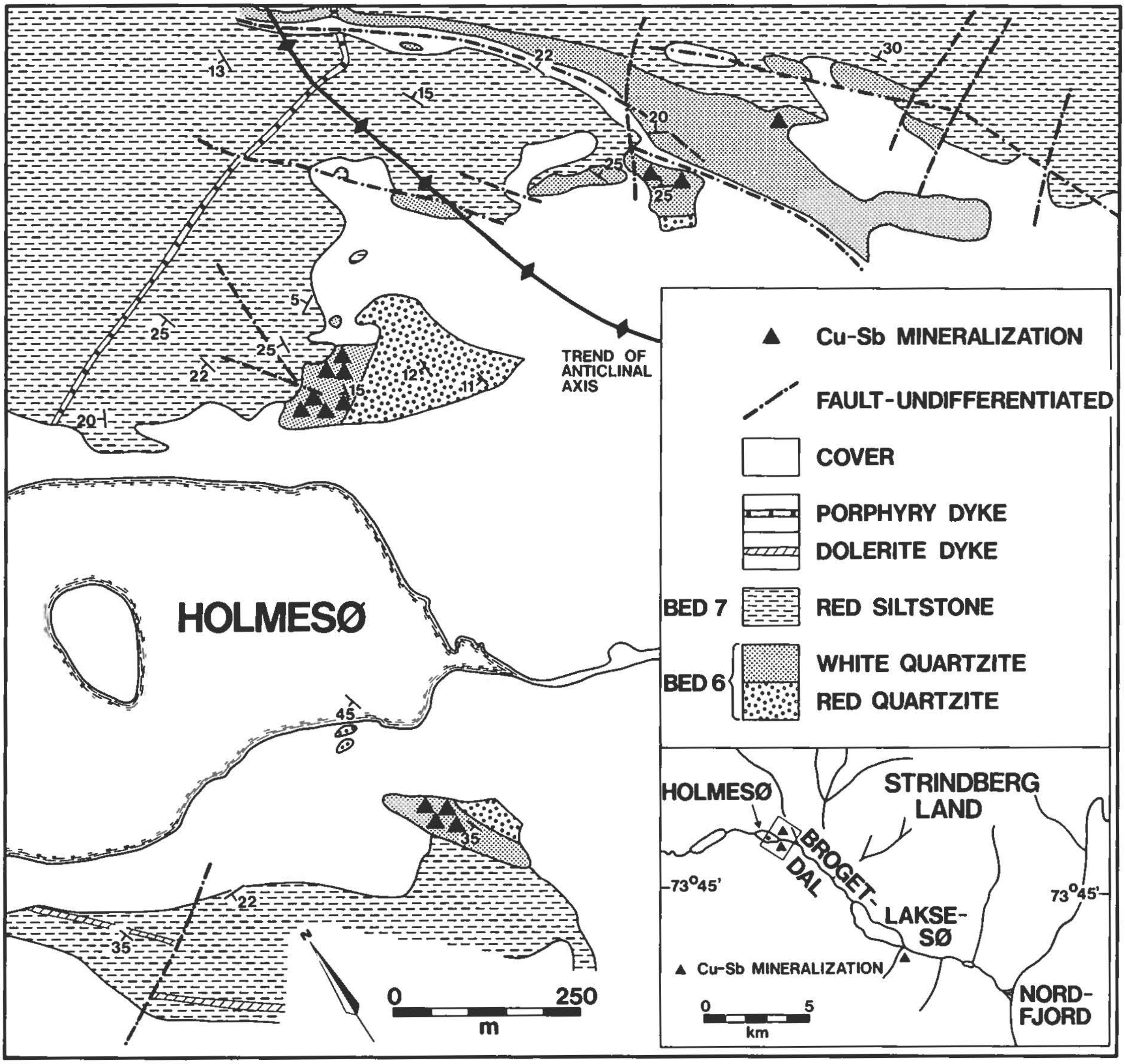


Fig. 39. Geological map of Holmesø area, Strindberg Land, with copper- and antimony-mineralized localities. Modified after Gruner & Probst (1976).

1974–76 by GGU/Risø geologists (Kunzendorf et al. 1978)

The area west of Kap Franklin comprises Middle (to Upper?) Devonian continental clastics with intercalated rhyolitic volcanics and intrusive shallow granite. These rocks are unconformably overlain by Permian and Mesozoic sediments and intruded by Tertiary dolerite sills and dykes. Hydrothermal alteration of the volcanic rocks is widespread (Graeter 1957, Alexander-Marrack & Friend 1976).

North-south-trending, subvertical hydrothermal veins are fairly common in the Devonian rocks along the coast for some 15 km west of Kap Franklin. They appear as massive veins or as fillings of fault breccias and are typically of cm-dm thickness. The dominant minerals are fluorite and quartz with minor baryte, strontianite, calcite, hematite and traces of galena, pyrite and chalcopyrite. Fluorite is mostly white to faint purple, but also green, yellow and black varieties exist. The largest known occurrence is an up to 1.8 m wide and 25 m long lens of massive fluorite occurring in a 2 m-wide, fluorite-cemented breccia zone. No significant contents of base or precious metals have been found.

The hydrothermal veins, which are similar to those occurring in the Devonian of Canning Land, intersect Middle-Upper Devonian rocks, but not Upper Permian or younger units. They are believed to be of Upper Devonian or Carboniferous age and to represent a late hydrothermal phase of the Devonian magmatism (Graeter 1957).

Uranium in Randbøldalen, Gauss Halvø (79)

During a 5-year regional uranium exploration programme conducted by GGU from 1971 to 1976, outcropping uranium mineralization associated with Devonian volcanics was located in Randbøldalen on Gauss Halvø (Nielsen & Steenfelt 1977). The occurrence in Randbøldalen is described by Secher et al. (1976) and Kunzendorf et al. (1978).

The area comprises Devonian porphyritic rhyolites locally overlain by pyroclastic rocks and Devonian molasse sediments. Small-scale faulting and shearing is widespread.

Intensely altered and limonite-stained radioactive mineralization is located within *c.* 1 km^2 of the rhyolites close to the boundary of the overlying pyroclastic rocks. Individual mineralized outcrops are concentrated along faults and shear zones, can rarely be traced for more than 20 m, and contain on the average 500–700 ppm uranium. Selected samples contain up to 0.2% U, whereas thorium contents are generally less than 50 ppm. Most of the uranium is hosted in uraniferous hydrocarbons (carburan) (Secher et al. 1976), which occur disseminated and in veinlets. Other identified uranium minerals are barian wölsendorfite (Beddoe-Stephens & Secher 1982). Associated with the carburan occur minor amounts of pyrite, pyrrhotite, chalcopyrite, covellite, galena and sphalerite. Limonite/goethite is very abundant as a secondary mineral and locally it contains uranium.

Steenfelt (1982) advocates a genetic model in which Devonian magmas enriched in uranium and fluorine reacted with circulating meteoric water. Precipitation occurred at a more shallow level controlled by carbonaceous matter and limonite (Secher et al. 1976).

Uranium at Foldaelv, Gauss Halvø (80)

During reconnaissance in 1981 minor vein mineralization was encountered at the mouth of the Foldaelv valley, Giesecke Bjerge (Thomassen 1982). The mineralization is located some 8 km NNE of the uranium mineralization in Randbøldalen. The veins are hosted in granite of probable Devonian age (Graeter 1957). The granite has a tectonic contact against Devonian clastics to the west and is unconformably overlain by Upper Permian-Mesozoic sediments and Tertiary basalts.

Near the southern bank of Foldaelv several up to 0.5 m thick veins with lateral extensions of a few tens of metres and directions of 040°–110° were observed in the granite. The gangue is predominantly quartz and fluorite, and the larger veins contain dm-sized pockets of massive pyrite. Other cm-thick veins display a zonation with quartz at the margin followed by fluorite and calcite in the centre. Minor disseminated chalcopyrite occurs throughout the veins. Grey mm-sized blebs of pitchblende, chalcopyrite intergrown with galena, tetrahedrite, and minor amounts of sphalerite, pyrite, marcasite and gold occur in calcite. Pitchblende is found partly as 0.5 mm large, rounded blebs with shrinkage cracks (occassionally filled with sulphides) (Fig. 40), and partly as larger aggregates. The gold occurs as up to 10 μ inclusions in chalcopyrite. A selected sample contains 0.23% Cu, 0.12% Pb, 320 ppm Zn, 100 ppm Bi, 45 ppm Ag, 0.5 ppm Au, 600 ppm U and 5 ppm Th, but in general the grade is much lower.

The veins are probably associated with the Devonian magmatic event.

Fluorite and uranium in Moskusokselandet (81, 82)

Widespread fluorite mineralization has been reported from the coastal areas of Moskusokselandet by Friedrich (1974) and Ryan & Sandwall (1975). In addition, minor uranium mineralization was discovered near Hochwacht in the hinterland during the GGU regional uranium exploration programme (Steenfelt 1976, Steenfelt & Nielsen 1978).

The area is underlain by Middle-Upper Devonian clastic sediments with scattered rhyolite and basalt bodies. Among the rhyolites, Ryan & Sandwall (1975) distinguish a 100–250 m thick unit of agglomerates, lavas and tuffs, and a unit of probably volcanic pipes. Brightly coloured alteration zones of inferred hydrothermal origin are common. The rhyolites locally contain disseminated pyrite and magnetite. Minor fluorite-quartz-baryte-calcite veins are common in the volcanic rocks and in the neighbouring sediments. The largest vein observed, which is situated 6 km from the coast (81), is a more than 100 m long and 1–2 m wide breccia zone in sandstone cemented with fluorite, quartz and baryte. The mainly purple fluorite forms up to 15 cm large, massive portions of the vein.

The uranium mineralization found near Hochwacht

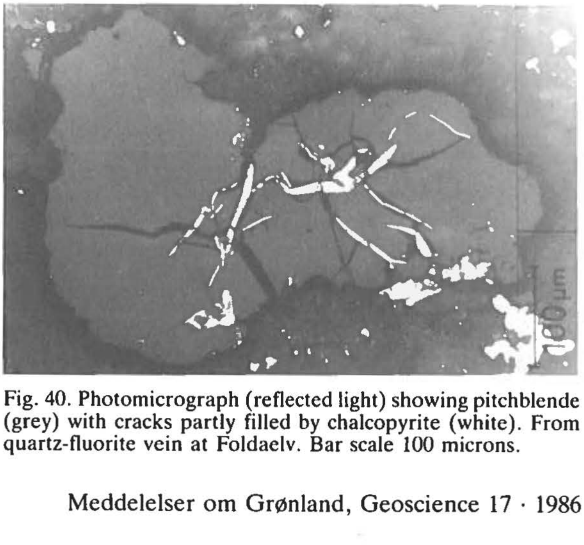
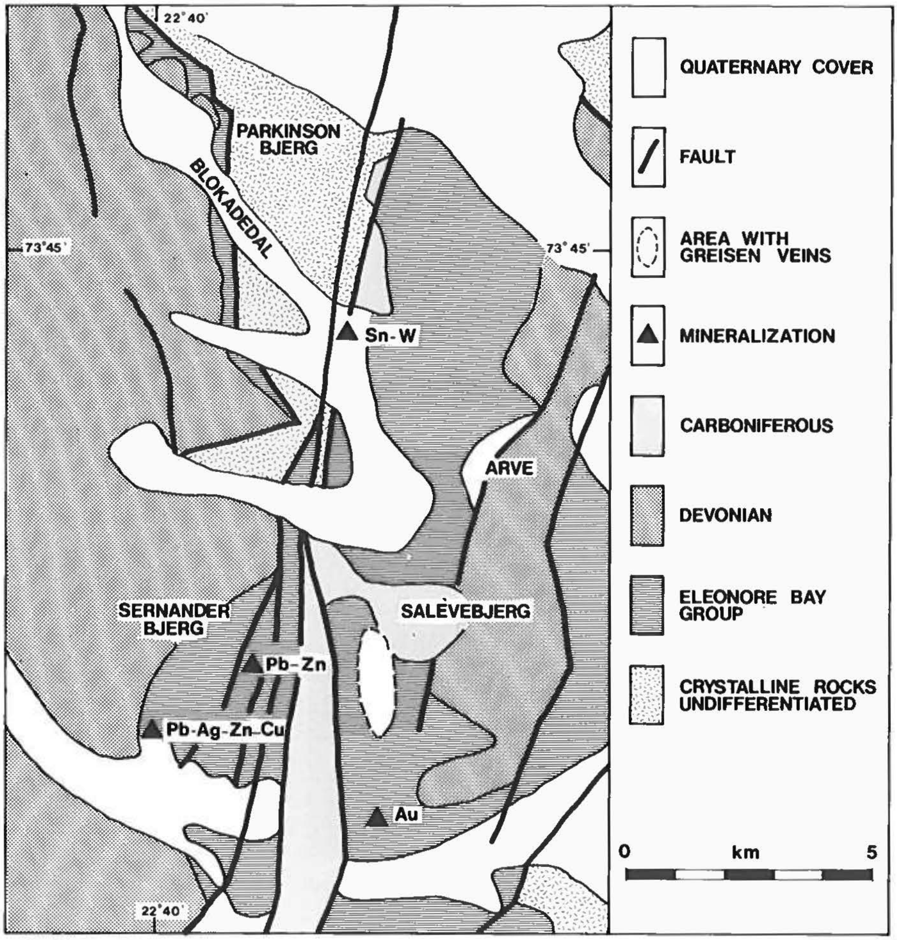


Fig. 40. Photomicrograph (reflected light) showing pitchblende (grey) with cracks partly filled by chalcopyrite (white). From quartz-fluorite vein at Foldaelv. Bar scale 100 microns.

Fig. 41. Geological sketch map of southeastern Hudson Land with location of selected mineral occurrences.



(82) is also associated with Devonian acid volcanics. Scattered pitchblende, carburan and beta-uranophane occur in veinlets and disseminated in the volcanics at several localities, but only in negligible amounts. Selected samples contain up to 1% U (Steenfelt 1982).

Steenfelt (1982) relates the mineralization to the Devonian acid magmas (suppliers of F, U and heat) and to the Post-Devonian Main Fault (structural control). She proposes an epigenetic model in which uranium was remobilized and introduced postmagmatically.

Base metals and silver at west Sernander Bjerg, Hudson Land (83)

Follow-up of Pb-Zn-As-Au-Ag-Cu-Ba-anomalous pan samples resulted in the discovery of a brecciated vein zone in EBG sediments (Harpøth 1984).

The geological setting of eastern Hudson Land is dominated by the pronounced NNE-striking Post-Devonian Main Fault System which brings old crystalline complexes and late Proterozoic sediments (EBG) in fault contact with Devonian and younger sediments (Figs 41 and 44). Late Caledonian granites intrude the area (Bütler 1957).

The west Sernander Bjerg vein is associated with an east-west-striking fault/shear zone in contact-metamorphosed Eleonore Bay Group sediments (Argillaceous-Arenaceous Series). The vein zone (90°/70°N) is exposed for a vertical distance of approximately 75 m (Figs 42 and 43). The length is uncertain, but the mineralized trace of the zone has been followed for 50 m laterally in the scree towards the west. The width of the vein zone is up to 20 m at the topmost part decreasing to less than one metre locally. Mineralized brecciated quartz veins attain thicknesses of up to 6 m with an estimated average thickness of 3.5 m for 75 m vertically. Mineralization is characterised by a complex mixture of galena, pyrite, sphalerite, chalcopyrite, arsenopyrite and fahlore. At least two phases of mineralization have occurred. An early phase comprises quartz, pyrite, arsenopyrite and chalcopyrite with subordinate galena, sphalerite (with abundant chalcopyrite exolutions) and

Fig. 42. The west Sernander Bjerg vein seen from east. Dashed lines indicate vein zone. Scale cf. Fig. 43.

a later phase comprises quartz, galena, sphalerite, pyrite, chalcopyrite and fahlore. Brecciation seems in particular to be related to the early mineralizing event.

Based on analyses of grab samples and chip samples the average estimated grade of the exposed part of the vein is 10.6% Pb, 285 ppm Ag, 1.5% Zn, 0.4% Cu and 0.2 ppm Au. It is noteworthy that a chip sample profile over 6 metres width from the thickest part of the vein averages 13.8% Pb, 400 ppm Ag, 2.1% Zn, 0.6% Cu and 0.25 ppm Au. Microprobe investigation showed that the average silver content in fahlore is 5.27% (average of 9 analyses) in one sample and 1.91% (average of 11 analyses) in another. The fahlore is an intermediate phase inbetween the end members tennantite – tetrahedrite. The calculated formulae for the two samples are:

$(Cu_{9.94}Ag_{0.28})\ (Zn_{1.66}Fe_{0.39})(Sb_{2.33}As_{1.23})S_{13}$
$(Cu_{9.03}Ag_{0.80})(Zn_{1.25}Fe_{0.81})\ (Sb_{2.50}As_{0.97})S_{13}$

Preliminary ore reserve calculations of the exposed vein, assuming the vein continues for 50–75 m into the mountain, indicate 50 000–80 000 tons with 12% combined base metals and 300 ppm silver.

Similar vein mineralization in other locations in Hudson Land is indicated from ore microscopy of pan samples, and all are believed to represent Upper Devonian hydrothermal mineralization.

Tin-tungsten in Blokadedal, Hudson Land (84)

Very pronounced tin anomalies in pan samples indicate an area around Arve and Blokadedal with granite associated Sn-W-Mo-Bi-Nb-Ta-REE-F mineralization (Fig. 41) (Lind 1981b, Harpøth 1984). Investigations by GGU also show that the late Caledonian (Devonian) granites of this area are characterized by a high content of incompatible lithophile elements including uranium (Steenfelt 1982).

The granite exposed at Parkinson Bjerg in Blokadedal is the only intrusion studied in some detail. The late Caledonian granite has intruded EBG shales which have been transformed into hornfels in a thick aureole around the intrusion. The granite is a medium- to coarse-grained, leucocratic, biotite-hornblende granite with local areas of feldspar-porphyritic phases containing abundant aplite fragments. Indications of hydrothermal activity are pronounced. First of all, the red

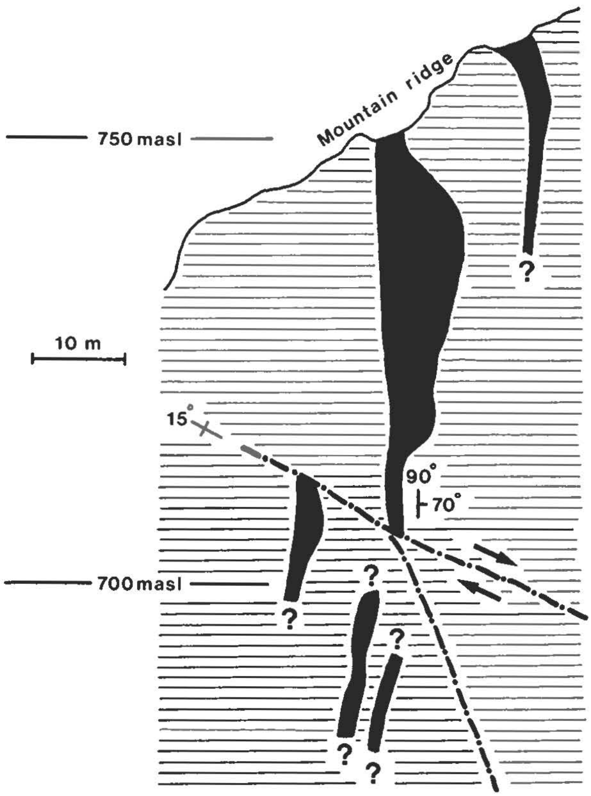


Fig. 43. Sketch of the exposed west Sernander Bjerg vein. Interpretation of Fig. 42. Mineralized lenses are outlined (black).

weathering colour is due to an overall hematization of the intrusion. Secondly, epidotization and argillization is widespread, in particular around minor faults and fractures. Hydrothermal activity is also reflected as widespread up to dm-thick quartz-fluorite veins and to a minor extent as silicified breccia zones. No macroscopic mineralization, except for the quartz-fluorite veins and very subordinate quartz-tourmaline veinlets, was observed. However, analyses of both altered (veined and epidotized) and unaltered (only hematization) granite confirm the high trace content of tin, which for unaltered granite averages 23 ppm. Furthermore, the analyses show enrichment in F-Rb-Li and depletion in Sr-Ba-Mg, indicating that the granite is an exellent tin granite (Harpøth 1984).

Laboratory investigations of pan samples from the scree cones of Parkinson Bjerg show that the concentrates contain abundant fresh black cassiterite grains (200–300 μ). Thus cassiterite is expected to occur disseminated throughout the intrusion without any significant enrichment.

Other evidence of granite-associated mineralization is found in the end moraines of the glacier in Blokadedal where scattered grey porphyritic granite boulders with up to dm-thick tin-tungsten-bearing tourmaline-quartz greisen veins occur (Fig. 41). The boulders are mainly confined to the central part of the end moraine and it is assumed that they originate in source areas of the uppermost glacier valley. Macroscopically, the greisen veins are composed of black fine-grained tourmaline and quartz with minor feldspar, red garnet, and scheelite. Microscopic investigations also reveal fine-grained (10–50 microns) cassiterite intergrown with tourmaline. Analyses of mineralized samples average 0.3% Sn (max. value 1.3%) and 0.2% W. Furthermore, sporadic high values of beryllium (max. 1.5%) occur.

Further evidence of granite-associated mineralization is seen at southwest Salévebjerg where abundant quartz-muscovite greisen veins hosted in contact-metamorphosed EBG shales and quartzites occur in an area of at least 2 km^2 (Fig. 41). The zone continues further to the north for another 3–4 km and is assumed to give rise to the tin anomalies observed just south of Arve. The mainly vertical quartz-muscovite greisen veins attain thicknesses of up to one metre, but on an average the estimated thickness is 0.2 m. The length of individual veins is at least several hundred metres. The distance between the veins varies considerably (10-100 m), but in general the veins occur with relatively wide spacing. They consist of quartz, minor muscovite (mainly at the margins) and very subordinate pyrite. Wall-rock alteration is observed as abundant weathering around the veins where they occur in shale. Analyses of six grab and chip samples reveal values of 30–40 ppm tin. One sample representing mainly weathered muscovite from the margins of a vein contains 250 ppm Sn and 30 ppm Be.

The source of the very strong geochemical anomalies of Mo, Bi, Nb, Ta and REE occurring in the area has not yet been identified, but the element combination fits with the described types of mineralization.

Genetically, the different mineralizations are related to the intrusion and late hydrothermal alteration of the late Caledonian granites.

Upper Palaeozoic

Even though Upper Palaeozoic (345–225 Ma) rocks occur in a limited area principally just east of the Post-Devonian Main Fault System, quite a number of mineral occurrences are known in these. Mineralization is either in veins associated with faulting or strata-bound and associated with the Upper Permian sequence.

The observed mineralization comprises:

Mineralization in the Post-Devonian Main Fault System
- Base metals in Gurreholm Dal area
- Uranium in Nedre Arkosedal
- Lead in west Schuchert Dal
- Lead-copper in east Schuchert Dal
- Lead at west Schuchert Gletscher
- Baryte in Skeldal
- Baryte at Rubjerg Knude, Traill Ø
- Copper-lead-silver in Gastisdal, Gauss Halvø
- Base and precious metals at Høgbom Bjerg, Hudson Land
- Gold at Salévebjerg, Hudson Land
- Base metals at east Sernander Bjerg, Hudson Land
- Copper in Nørlund Alper, Hudson Land
- Lead-zinc on Clavering Ø
- Lead-zinc in Karstryggen, Schuchert Dal
- Celestite in Karstryggen, Schuchert Dal
- Baryte-lead-zinc at Bredehorn, Scoresby Land
- Strata-bound base-metals on Wegener Halvø
- Lead-zinc at Mesters Vig, Scoresby Land.
- Copper on Traill Ø and in Giesecke Bjerge

Post-Devonian Main Fault System (85–101)

A very prominent NNE-SSW post-Devonian fault system occurs for at least 400 km from Scoresby Sund in the south to Grandjean Fjord in the north (Fig. 44). Vischer (1943) named the part of the system occurring north of Kong Oscar Fjord the Post-Devonian Main Fault ("Postdevonische Hauptverwerfung") and named the prominent fault which separates Stauning Alper and Jameson Land the Stauning Alper Fault ("Staunings Alper - Verwerfung"). Parts of the fault system had been described before by Säve-Söderbergh (1933, 1934) and Bütler (1935). Later, Bütler (1955, 1957 and 1959), Kempter (1961), Putallaz (1961), Stern (1964) and Haller (1970, 1971) investigated the fault system. According to Bütler (1957) the prominent faulting was initiated

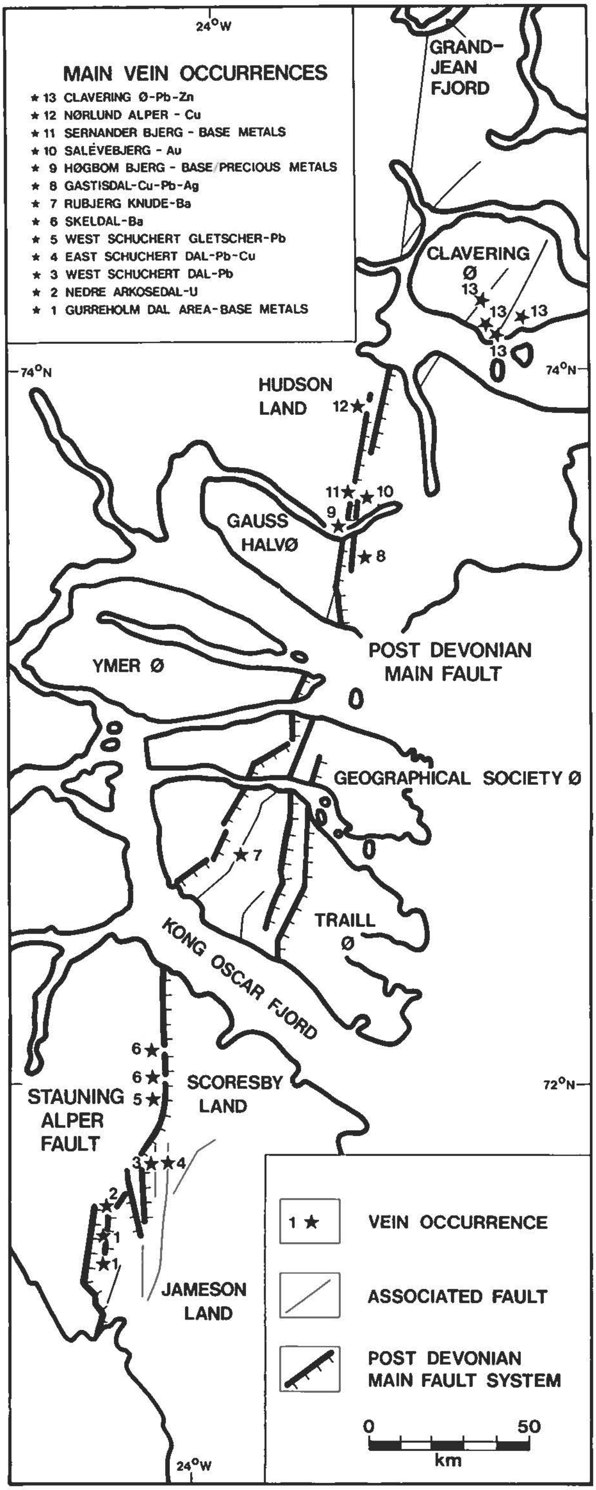


Fig. 44. The Post-Devonian Main Fault System with location of vein occurrences. Modified after Bütler (1957) and Haller (1971).

during the Lower Carboniferous and reactivated during the Mesozoic and Cenozoic. The fault zone is several kilometres wide and consists of subparallel, east-dipping normal faults locally with a throw of up to 3–4 km. A younger system of diagonal faults which branches off in a southwesterly direction near Kejser Franz Joseph Fjord, running through the eastern part of Ymer Ø, Geographical Society Ø and northwestern Traill Ø forms the connection between the two north-south running major fault zones – the Post-Devonian Main Fault to the north and the more westerly Stauning Alper Fault to the south (Bütler 1957) (Fig. 44).

Mineral prospecting was performed in the thirties and from the mid-fifties until the early eighties all along the fault zone from Scoresby Land to Clavering Ø. In particular, the Stauning Alper Fault has been investigated in detail. This exploration activity has revealed widespread vein mineralization associated with tensional regimes all along the zone. The veins, which may exhibit brecciation or appear as wide stringer zones, are arranged in an en echelon pattern indicative of a horizontal sinistral component and individual veins may be more than 1 km long and several metres wide. The quartz-fluorite-baryte veins contain varying amounts of base-metals, precious metals and locally uranium.

Genetically, all the veins are associated with tensional regimes related to the post-Devonian faulting. The more prominent veins (Fig. 44) are described in the following section.

Base metals in Gurreholm Dal area (85, 86)

Scattered base-metal-bearing veins were found between Nordostbugt and Bjørnbo Gletscher in Lower Permian sediments during geological mapping in 1956 (Kempter 1961). Reconnaissance was carried out by Nordmine mainly in 1980 (Jørgensen 1980, Harpøth 1981).

The veins are hosted in the Lower Permian Gurreholm Dal Formation (Kempter 1961) and, in one case, in a Caledonian two-mica granite. To the west, the Lower Permian is separated from the Caledonian crystalline basement by N-S-striking, normal faults, and to the east, it is unconformably overlain by Upper Permian sediments. A total thicknes of 600 to 2000 m has been estimated for the formation. It shows a facies variation with conglomerates near the main fault passing eastwards and downcurrent into arkoses and eventually into micaceous sandstones with a northerly palaeocurrent. Movements along the western boundary fault were probably the cause of the rapid uplift needed to supply the coarse sediments (Collinson 1972). The existence of blind mafic intrusions below the central part of the area is indicated by a pronounced aeromagnetic anomaly (H.C. Larsen, pers. comm. 1979).

About ten mineralized localities are known in the area. The more significant ones are located along a N-S-orientated zone of approximately 20 km from Øvre Arkosedal to Konglomeratelv. The zone is supposed to represent a branch of the Stauning Alper Fault (Jørgensen 1980). Mineralization appears in Lower Permian arkoses as widely spaced mm- to few cm-thick, sulphide-bearing, discordant veinlets surrounded by cm-dm-wide bleached zones with kaolinized feldspar. The sulphides are galena, sphalerite, chalcopyrite with minor chalcocite, bornite, pyrite and arsenopyrite in a gangue consisting of baryte, calcite and fluorite. Irregular intergrowths are common between the sulphides. Sphalerite is iron-poor and often developed as schalenblende (Fig. 45). Some sulphide impregnation occurs in the altered wall rock.

The best exposed mineralization occurs along Kuldedal (85). Here 160°–180°-striking and steeply dipping veinlets are frequent in pink arkoses inside a *c.* 100 m wide, 0°/65°E orientated fault zone. Some 4 km further north, in Øvre Arkosedal (86), mineralization mainly occurs in brecciated granite along the fault contact towards the sediments. This locality is situated 3 km south of the uranium mineralization of Nedre Arkosedal.

Mineralized samples may contain several per cent lead, zinc, copper and barium and up to 500 ppm silver and molybdenum. A high silver content is associated with chalcocite and in samples without this mineral the silver content does not exceed 80 ppm. Chip samples from a 15x25 m sized area in the fault zone of Øvre Arkosedal average 1.8% Ba, 0.8% Pb and 0.03% Cu.

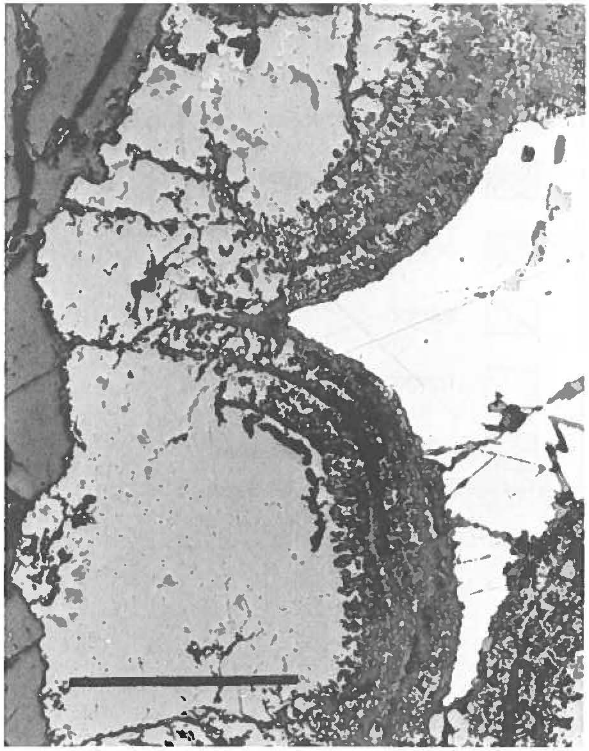


Fig. 45. Photomicrograph (reflected light) of sphalerite developed as schalenblende (light grey), and galena (white). From vein in Gurreholm Dal area. Bar scale 0.5 mm.

Uranium in Nedre Arkosedal (87)

A lead-zinc-bearing fluorite vein was observed in the western slopes of Nedre Arkosedal in 1956 during geological mapping carried out by the Lauge Koch Expeditions (Kempter 1961). Reinvestigations by Nordmine in 1970 revealed high uranium concentrations in the vein (Hintsteiner et al. 1970). Subsequent prospect investigations in 1971 and 1975 included geological and radiometric mapping, trenching, chip and channel sampling and the boring of a 9.1 m drill hole (Hallenstein 1976). Furthermore, detailed airborne radiometry was performed in the area by Nordmine in 1970 (Hintsteiner et al. 1970) and by GGU in 1971–75 (Nielsen & Løvborg 1976), but no significant new anomalies were detected.

The prospect is located within the Stauning Alper Fault zone, and the host rock is a post-tectonic Caledonian, red, two-mica microcline granite. Lower Permian clastic sediments occur just to the east and are in fault contact with the granite.

Uranium is found in a northern main vein and a southern smaller vein some 400 m further SW (Fig. 46). The veins are displayed as distinct yellow, limonitic zones visible from a distance. In both cases, the mineralization is restricted to brecciated and mylonitized granite, although some hydrothermal activity has affected the Permian sediments on the east side of the fault zone. The vein minerals are fluorite, baryte, pyrite, and traces of galena and sphalerite. Uranium occurs in the fluorite lattice and as fine-grained pitchblende. Secondary uranium minerals have also been observed.

The main mineralization is located at the intersection of two faults. The one fault (20°/65°E) is entirely within the granite, and the other (170°/70°E) marks the contact between the sediments and the granite. At the surface, the total strike length is about 200 m and it varies between 5 and 10 m in thickness. The vein consists of a breccia zone cemented by mm- to cm-thick veinlets of mainly purple fluorite. A *c.* one metre thick central zone contains semi-massive fluorite. Surface weathering is extensive, and a 4 m deep trench failed to expose fresh rock. 251 surface samples average 252 ppm U and 21 ppm Th with maximum values of 3427 ppm and 136 ppm respectively. The drill hole returned a 4.2 m intersection with 780 ppm U and less than 30 ppm Th.

The north-south-striking southern vein is *c.* 40 m long and it exhibits less superficial weathering. Chip samples representing 15 m accross the vein have been collected at a depth of 0.5 m. The best 2 m of this section average 3100 ppm U (range 1050–8710 ppm). Selected samples contain up to 2.25% U.

Lead in west Schuchert Dal (88)

A galena-bearing vein was discovered in 1956 on the western slope of Schuchert Dal between Roslin

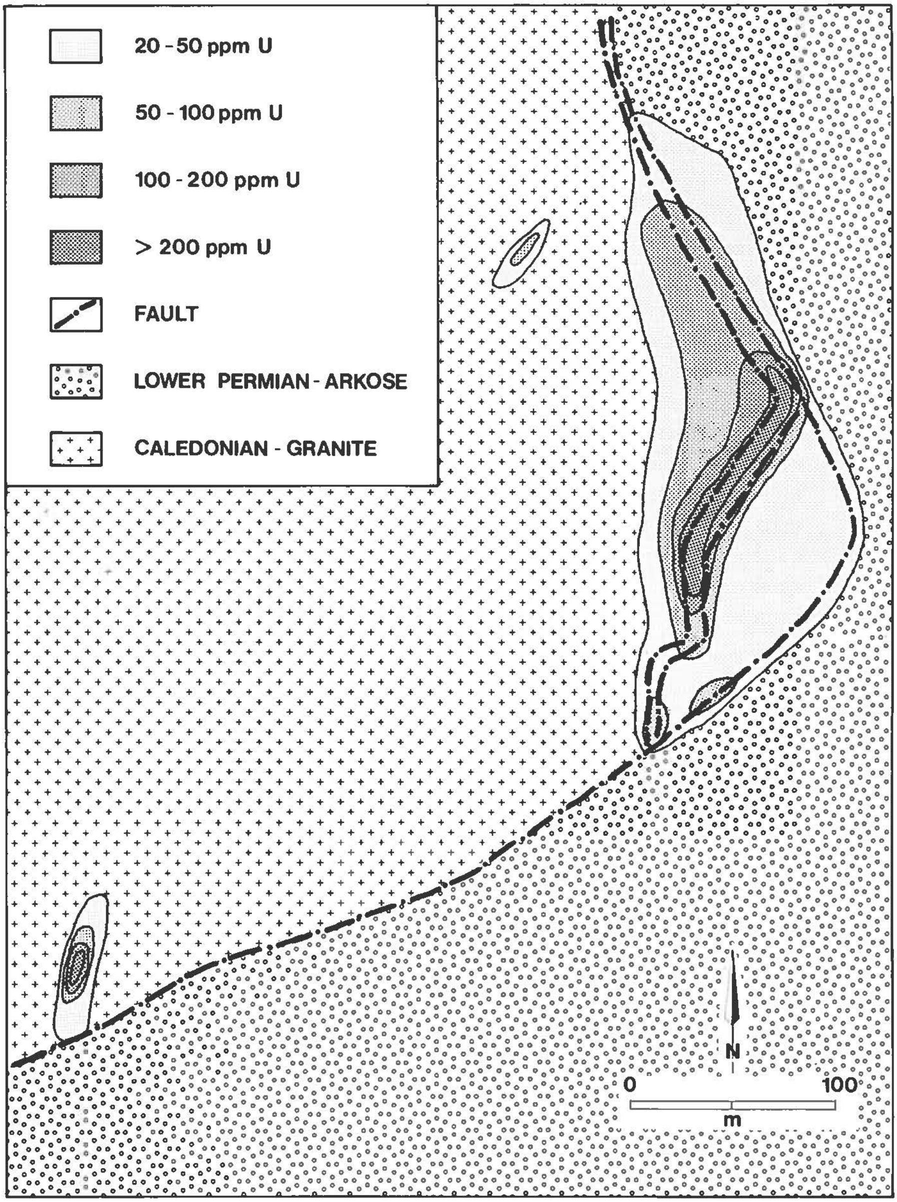


Fig. 46. Sketch map of uranium occurrence in Nedre Arkosedal. Uranium contours are based on field spectrometry. Modified after Hallenstein (1976).

Gletscher and Storgletscher (Lethbridge 1956). Detailed investigations the following year included mapping, geochemistry, geophysics, blasting and shallow drilling. The sampling programme was not completed (Reece 1957). The site was revisited in 1967 (Lehnert-Thiel et al. 1967).

The vein is hosted in Caledonian migmatites immediately west of the Stauning Alper Fault. It is intermittently exposed for more than 1 km laterally and 300 m vertically in a 30° direction. It dips 65° – 85° NW and is up to 6 m wide with an average width of 2 m. The wall rock is hydrothermally altered. The gangue is quartz and fluorite with minor baryte and iron carbonates. The main sulphide is galena, which occurs as scattered, up to 30x60 cm large, massive lenses. Furthermore, traces of pyrite and chalcopyrite occur. The richest parts of the vein contain an estimated 5% Pb. A sample rich in galena contains 28% Pb, 0.07% Cu and 10 ppm Ag.

Lead-copper in east Schuchert Dal (89)

Lead-copper-bearing quartz veins were observed in the eastern slopes of Schuchert Dal during aerial reconnaissance in 1955 (Pargeter 1955). Subsequent prospect investigations comprised detailed soil geochemistry (Reece & Mather 1961), trenching (Lethbridge 1956), geophysics (electromagnetic and self-potential techniques – Strangway 1957) and diamond drilling (4 holes, in total 358 drill metres – Reece 1957). A revisit was made to the area in 1980 (Thomassen & Schønwandt 1981).

The east side of Schuchert Dal consists of continental clastic sediments of Lower Permian age, unconformably overlain by Upper Permian and Triassic, mainly marine sediments (Henriksen et al. 1980). Tertiary alkaline intrusions occur in Werner Bjerge to the north, and mafic dykes and sills of the same age intersect the sediments. A N-S orientated, east-dipping normal fault with a throw of some hundred metres follows the valley slopes for *c.* 30 km.

Vein mineralization is known intermittently from the snout of Schuchert Gletscher and 15 km southwards. The prospect investigated in some detail is situated 2 km SW of Lomsøen, upper Pingo Dal. Here a number of galena-bearing quartz veins have been exposed after removing 2 m of overburden over a 100x200 m area at sites defined by soil geochemistry. Most of the veins strike 45°–60°, dip 75°SE and are of dm thickness. One 3 m thick 160°/90°-orientated vein has also been observed. In addition to dm-sized, massive pockets of galena, the veins contain a little sphalerite and chalcopyrite.The arkosic or shaly wall rock is bleached and silicified. A drill hole intersected a *c.* 5 m wide quartz vein mineralized in the hanging wall with galena over 0.5 m. A second 0.5 m wide, galena-rich zone in arkose with quartz stringers was intersected 5 m SE of this vein. Another bore hole in the continuation of the mineralized vein 60 m further SW intersected 9 m barren vein quartz. Two further drill holes did not reveal any sulphides. Only faint geophysical anomalies were outlined in this area.

The mineralized fault zone is exposed in a gully 2 km north of the trench site. Here the 80–100 m wide, 10°/70°E-orientated fault zone consists of silicified sandstone and shale breccia. In the centre it contains a swarm of quartz veinlets up to 30 cm wide for a distance of 10 m. These exhibit comb structures and contain pockets of chalcopyrite, with minor galena and late calcite.

The mineralized section of the fault also outcrops 1.5 km south of the trench site. Here it is 20 m wide and consists entirely of quartz-cemented breccia with a general orientation 0°–10°/45°E. Galena is the main ore mineral present in the form of irregular stringers up to 20 cm in thickness. Subordinate chalcopyrite occurs. The estimated galena content is about 5%. Further southwards, veining of quartz, baryte, minor calcite and hematite occur over some 8 km. At one locality, dm-thick quartz-baryte veins cut the Upper Permian Huledal Formation.

Microscopic investigations reveal galena and chalcopyrite as the main ore minerals with minor sphalerite,

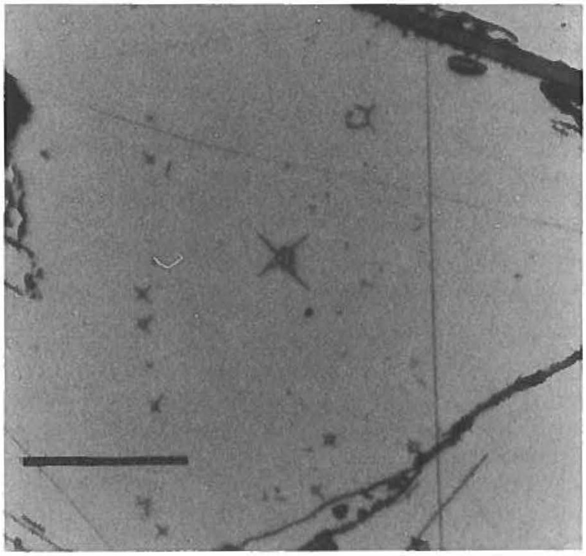


Fig. 47. Photomicrograph (reflected light) of chalcopyrite with sphalerite exsolution stars. From vein in east Schuchert Dal. Bar scale 100 microns.

pyrite, marcasite and tetrahedrite. Tetrahedrite occurs as relatively scarce inclusions in galena. Chalcopyrite may contain sphalerite exolution stars (Fig. 47) and well developed polysynthetic twins.

Some analytical results are presented in Table 3. It appears that in addition to base-metals the mineralization is enriched in silver and antimony.

Lead at west Schuchert Gletscher (90)

A large quartz vein was found west of the central part of Schuchert Gletscher in 1967 (Lehnert-Thiel et al. 1967). The vein is hosted in Caledonian migmatite and situated 4–5 km west of the Stauning Alper Fault. It is exposed intermittently for more than 3 km, is 10–30 m wide and has an orientation of 150°–170°/60°E. The wall rock is hydrothermally altered for a width of several metres. The vein consists of quartz and minor baryte. Pockets of galena with traces of pyrite, chalcopyrite and sphalerite occur near the foot wall. The estimated lead content is less than one per cent.

Baryte in Skeldal (91)

Lead-copper-bearing boulders were found west of Skelbræ during Nordmine reconnaissance in 1956 (Lethbridge 1956). Later, short visits to the area revealed vein-type mineralization between Skelbræ and Bersærkerbræ on the west side of Skeldal (Knup 1958, Friedrich 1975, Pedersen 1980b).

The N-S-orientated Stauning Alper Fault passes through the western slope of upper Skeldal and separ-

Table 3. Analytical results of selected samples, east Schuchert Dal.

Locality/sample description	Pb (%)	Zn (%)	Cu (%)	Ag (ppm)	Sb (%)	Ba (%)
2 km north of trench site	0.04	0.35	20.0	50	<0.01	<0.05
2 km north of trench site	4.0	0.08	0.04	30	<0.01	<0.05
Trench site	74.4	1.4	0.03	250	0.15	<0.05
0.5 m drill core. Vein quartz	11.7	0.8	–	36	–	–
0.5 m drill core. Arkose	46.7	0.65	–	142	–	–
1.5 km south of trench site	47.0	<0.05	0.03	211	0.09	<0.05
1.5 km south of trench site	0.7	<0.05	2.5	8	0.07	0.2
2.2 km south of trench site	0.003	<0.05	0.35	<2	0.15	<0.05
6 km south of trench site	0.003	20.1	0.002	<2	<0.01	14.5
7 km south of trench site	0.6	0.06	0.004	5	<0.01	12.5

ates EBG sediments to the west from Carboniferous–Lower Permian sediments to the east. The observed veins are up to 20 cm thick and hosted in crystalline rocks and in EBG sediments. They consist of baryte with minor galena and traces of chalcopyrite.

Baryte at Rubjerg Knude, Traill Ø (92)

Baryte veining associated with a prominent fault in the Upper Carboniferous was found by Nordmine in 1981 just west of Rubjerg Knude, central Traill Ø (Harpøth 1982).

The complex fault pattern of central Traill Ø as seen in Koch & Haller (1971) was studied in detail only west of Rubjerg Knude where a major NNE-SSW fault zone postulated by Putallaz (1961) to cut the Upper Permian was traversed for a strike length of 10 km. However, the Upper Permian has been eroded, and the fault is observed only in the Upper Carboniferous sediments.

Extensive but low-grade baryte mineralization occurs for a length of four km including 500 m with intense silicification at the northern end. Mineralization occurs in a 50–100 m wide zone where hydrothermal activity has caused extensive bleaching and baryte veining. Baryte veins range from mm to dm in thickness with an average in the cm-range. The spacing between the veins varies considerably, but the overall baryte grade is estimated to be 5–10%. The sulphide content of the exposed level of mineralization is very low with traces only of chalcopyrite.

Copper-lead-silver in Gastisdal, Gauss Halvø (93)

During reconnaissance of the Upper Permian in Giesecke Bjerge vein-type mineralization was observed in older rocks in the Gastisdal area (Thomassen 1982).

Gastisdal is a N-S-orientated valley occupying a *c.* 1 km wide graben structure associated with the Post-Devonian Main Fault. The graben continues north of Moskusoksefjord into Prospektdal. The Gastisdal graben hosts Carboniferous, coal-bearing clastic sediments downthrown against Devonian clastics and a wedge of gneiss and granite.

A number of quartz-fluorite-calcite veins sub-parallel to the main fault cut the Devonian sediments in the western slope of the valley. On the east side of the valley, irregular dm-sized lenses and veinlets with traces of galena and chalcopyrite occur in the granite. Furthermore, a *c.* 1 m thick vein has been followed for more than 500 m in outcrops and boulders in a 120° direction in Devonian sediments south of La Cours Bjerg. This vein consists of dense quartz with coatings of manganese oxides, hematite and minor malachite. It contains scattered mm-sized blebs of chalcopyrite, chalcocite and bornite with minor galena, sphalerite and pyrite. Selected samples return: copper max. 2.5%, lead max. 0.35%, silver max. 250 ppm, and bismuth max. 150 ppm.

Base and precious metals at Høgbom Bjerg, Hudson Land (94)

Base-metal-mineralized boulders were encountered in Prospektdal east of Høgbom Bjerg during Nordmine reconnaissance in 1955 (Lethbridge 1956), and outcropping mineralization was found in 1971. A crude radial pattern of mineralized veins and a possible mineral zonation was observed by a joint Nordmine-GGU team in 1975 (Ryan & Sandwall 1975). Subsequent investigations were carried out by GGU and Nordmine (Geyti 1982).

Høgbom Bjerg is underlain by Middle Devonian clastic sediments intruded by a 2x3 km laccolith-shaped subvolcanic complex comprising granites, aplites and rhyolites emplaced in several phases. The intrusive complex is cut by rhyolite dykes and unconformably overlain by Carboniferous clastic sediments. The N-S-striking Post-Devonian Main Fault intersects the area.

Mineralized veins of cm-dm thickness are scattered in both igneous and sedimentary rocks throughout the area. They may be concentrated in 5–10 m wide swarms. The veins consist of coarse-grained, vuggy quartz along with fluorite, calcite, baryte and epidote. Epidotization of the wall rock is common. Sulphide contents are generally below one per cent. The ore minerals are galena, bornite and chalcocite with minor sphalerite, chalcopyrite, pyrrhotite and arsenopyrite. A selected sample assays 3.5% Cu, 2.1% Pb, 0.7% Zn, 1.0% Fe, 460 ppm Ag and 1.3 ppm Au. Comparable precious-metal values occur in other veins of the area.

Gold at Salévebjerg, Hudson Land (95)

A gold-bearing breccia boulder was found at Salévebjerg by Nordmine in 1981 (Geyti 1982) and follow-up investigation were carried out in 1983 (Harpøth 1984).

Gold-bearing breccia boulders occur in a stream bed at the southern slope of Salévebjerg (Fig. 41). The boulders all represent quartz-fluorite-pyrite-(arsenopyrite)--gold-mineralized brecciated quartzite. Analyses of five samples revealed: gold 0.05–3.2 ppm, arsenic max. 5%, antimony max. 0.25%, silver max. 19 ppm, copper max. 200 ppm, and lead max. 200 ppm. The boulders could not be traced to any outcropping mineralization.

However, chip sampling of a 2 m wide outcropping N-S-striking pyrite-bearing breccia zone in EBG-hornfels approximately 500 m to the west of the boulder finds, but without any relation to these, returned 70 ppb gold, and thus indicates that the general area is gold anomalous. Microscopy of the various breccias did not reveal the occurrence of gold.

Base metals at east Sernander Bjerg, Hudson Land (96)

GGU discovered minor uranium-oxide mineralization associated with lead, zinc and copper in fractured Caledonian granite at Arve just north of east Sernander Bjerg (Stenfelt & Nielsen 1978, Stenfelt & Kunzendorf 1979, Stenfelt 1982). Lead-zinc veins were discovered at east Sernander Bjerg by Nordmine in 1981 (Fig. 41) (Geyti 1982) and similar fault-associated vein mineralization was indicated from reconnaissance investigations and pan-sample anomalies 2–5 km to the north (Lind 1981b, Harpøth 1984).

Both mineralized areas occur within the zone of the Post-Devonian Main Fault which strikes *c.* 20°. The fault zone is here characterized by extensive brecciation and mylonitization, epidotization and hematization, rhyolite and aplite dykes and widespread quartz-fluorite-calcite veining. Vein dimensions in general are small with cm-dm widths and m-sized lengths, but an up to 10 m thick massive calcite vein occurs in the steep cliffs of east Sernander Bjerg. No sulphides have been observed in the boulders from this vein.

Lead-zinc-mineralized vein-quartz scree boulders from east Sernander Bjerg (Fig. 41) contain abundant galena and sphalerite with minor pyrite. The gangue consists of quartz which typically contains breccia fragments of the host rock (metamorphosed EBG shales). Analyses of selected scree boulders revealed: lead max. 20.8%, zinc max. 5.9%, bismuth max. 150 ppm, and silver max. 20 ppm. The average grade is estimated to be a few per cent combined lead and zinc.

Copper in Nørlund Alper, Hudson Land (97)

A minor quartz vein occurs south of Toretinde in Nørlund Alper (Stendal 1980c). The area is underlain by Middle Proterozoic metasediments, Caledonian granites and Carboniferous clastics, and dissected by branches of the Post-Devonian Main Fault (Stern 1964).

The vein is hosted in quartzitic gneiss with lenses of amphibole-, diopside- and garnet skarns. It contains scattered, mm-cm sized blebs of chalcopyrite. A selected sample contains 0.35% Cu, 3.3 ppm Ag and 0.19 ppm Au.

Lead-zinc on Clavering Ø (98–101)

Several rust zones on south Clavering Ø (Fig. 48) were found and investigated in the period 1929–34 by the Lauge Koch expeditions (Backlund & Malmquist 1932, Koch 1955). Two localities, Rustplateau and Auspiciedalen, were more closely investigated. At Rustplateau, mapping, trenching and geophysics (Fig. 5) were carried out in 1932 by H.G. Backlund and D. Malmquist. Due to deep weathering and solifluction, no outcrops or boulders with "ore" were found, apart from boulders with pyrite and traces of chalcopyrite and galena. The electromagnetic results indicated the occurrence of massive mineralization at depth. In Auspiciedalen ("Gold Mine"), a pyrite vein was investigated in 1933 by surface trenches and a 20 m long test adit (Fig. 49) with a 4 m deep shaft (Eklund 1944). In 1957 part of south Clavering Ø was reconnoitered by Nordmine (Reece 1957), and a limited re-investigation of Rustplateau comprising mapping and geological sampling was accomplished in 1981 (Thomassen & Schønwandt 1981, Thomassen 1982).

The central part of Clavering Ø is underlain by a metamorphic complex consisting of Middle Proterozoic infracrustal migmatite gneiss and foliated granite, and supracrustal schist and biotite gneiss (Mittelholzer 1941, Higgins & Phillips 1979) (Fig. 48). These rocks are folded along SW-NE-trending axes and intruded by small bodies of Late Caledonian granite. The crystalline rocks are nonconformably overlain by Carboniferous continental clastics to the west, and by marine Upper Permian – Mesozoic sediments to the east. The highest peaks are capped by Tertiary basalts. The central part of the island is intersected by numerable SSW-NNE and, subordinate, NW-SE-trending faults.

Some of the rust-stained localities on Clavering Ø are shown in Fig. 48. Most of them are situated in the metamorphic complex. Ground information is avaible from the four localities described in the following.

Rustplateau (98)

On Rustplateau, Carboniferous sediments rest with a slightly SW-dipping depositional contact on a crystalline basement consisting of banded and graphite-bearing

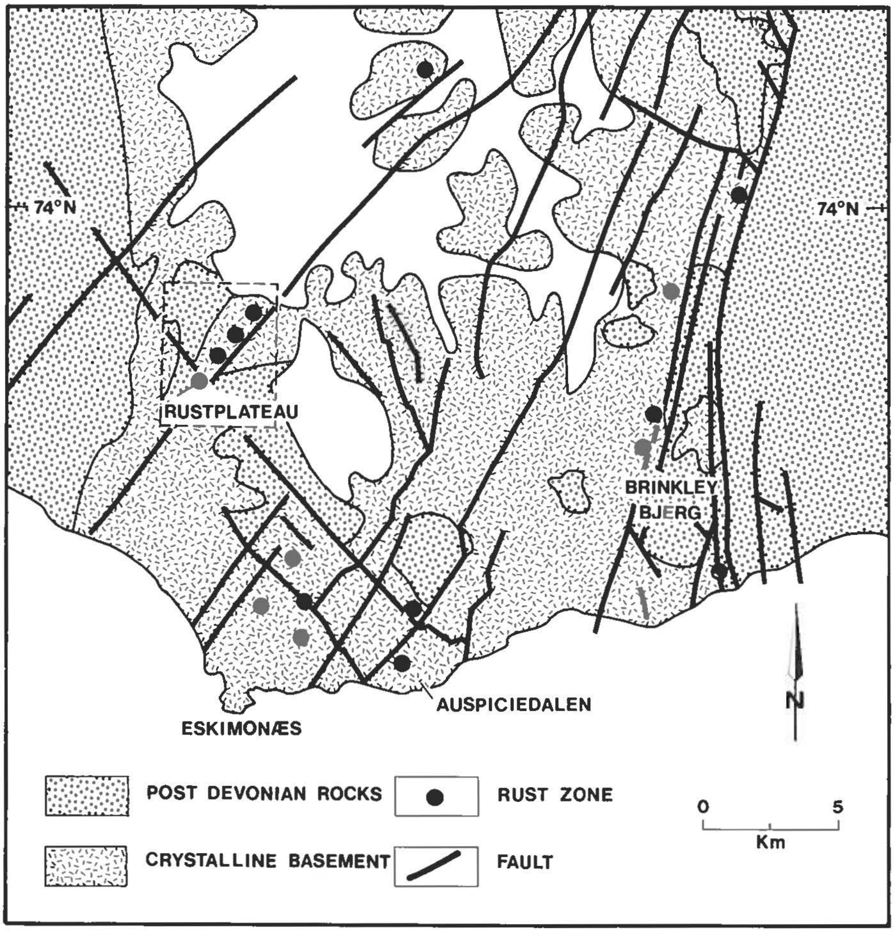


Fig. 48. Geological sketch map of southern Clavering Ø with major rust zones indicated. Framed area is shown in Fig. 50.

garnet-biotite gneisses (Fig. 50). The basal *c.* 30 m of the sediments consist of greyish quartz-pebble conglomerates and porous, coarse, arkosic sandstones. These sediments often have a reddish weathering colour due to minor disseminated pyrite. Above follows *c.* 100 m of well cemented arkosic sandstones which are unconformably overlain by Tertiary plateau basalts. A set of apparently contemporary post-Carboniferous, but pre-basaltic, faults (40° and 140°) with throws of less than 50 m exists in the area. The faults form distinct morphological escarpments, especially along the 40° direction, and host the mineralization. They are cut by minor N-S and NNW-SSE faults.

Vivid red and yellow weathering colours characterize Rustplateau. The basal part of the clastic sediments in general exhibits a red colouration, but particularly strong colours appear in the solifluction material from the western fault-generated escarpment of the local main river. This colour zone extends 5.5 km towards SW from a local ice cap and reappears on some nunataks further to the NE. Mineralized outcrops or boulders have been found over 3.3 km of the zone. Less intense colouration with sporadic outcropping mineralization exists along the 140° faults for some 2.7 km. Two types of mineralization can be distinguished: 1) Silicified and kaolinized fault-breccias rich in pyrite and locally containing minor fluorite, galena, sphalerite and traces of chalcopyrite. This type mainly occurs in gneiss, but due to deep weathering it is only known from boulders along the 40° faults. Two outcrops along the 140° faults display faintly mineralized breccia with clay gouge for a few metres thickness. 2) Quartz-fluorite veins with galena, sphalerite and pyrite. The veins occur both in gneiss and in the sediments. Outcropping veins in sediments are of cm-dm thickness and only locally rich in sulphides. Boxwork structures are typical of both types of mineralization and are believed to represent weathered-out fluorite and pyrite.

Microscopic investigations reveal pyrite, galena and sphalerite as main ore minerals with minor marcasite, chalcopyrite and tetrahedrite. The sulphides often form disseminations of anhedral, from mm-sized to sub-mi-

Fig. 49. Entrance of adit to the Auspiciedalen pyrite vein on Clavering Ø. From Koch (1955).

croscopic grains. Intergrowth is common among galena-sphalerite-chalcopyrite and pyrite-marcasite. Tetrahedrite occurs as scarce, minute inclusions in galena.

Analyses of 16 mineralized samples show: lead max. 14.5%, zinc max. 2.5%, gold max. 0.05 ppm, silver max. 60 ppm, copper max. 0.03%, and barium max. 0.35%. Selected analyses are given in Table 4.

Soil samples were collected along 4 lines parallel with and downslope from the main mineralized faults in order to detect a possible along-strike trend. The *c.* 200 g large samples were taken 50 m apart at a depth of 15–20 cm, i.e. below the zone of possible organic influence. Sample values are summarized in Table 5 and Fig. 50. It appears that the high metal contents are concentrated along the 40° fault zone. While high lead values occur scattered all along this zone, high zinc and copper values are clearly concentrated along the NE half of the sections. No significant metal enrichment is indicated at the intersection of the faults. Silver was detected (2 ppm) only in two soil samples.

Auspiciedalen (100)

In Auspiciedalen the country rock consists of biotite-garnet schists and gneisses which are cut by pegmatite veins of metamorphic origin. A pyrite vein (15°/45°E) is traceable for 1500 m as a distinct yellow gossan. It contains *c.* 90% pyrite, has a mean thickness of 1.3 m and near the contact, the gneisses are brecciated, silicified, kaolinized and pyritized. Two generations of brecciation and quartz-pyrite mineralization are distinguishable. Minor galena and arsenopyrite (the postulated gold-bearer) have also been reported. The pyrite contains max. 0.5 ppm Au and 25 ppm Ag. The area is estimated to contain some million tons of massive pyrite (Eklund 1944).

North of Eskimonæs (99)

Several rust zones have been observed along the NE-SW running rivers north of Eskimonæs. These zones seem to be controlled by the same set of faults as on Rustplateau, i.e. 40° and 140°. A number of rusty boulders were collected during a helicopter reconnaissance in 1981. They consist of brecciated, silicified gneiss or of vein quartz and contain pyrite and minor galena and fluorite. Under the microscope, granulated pyrite with tiny inclusions of marcasite, sphalerite, galena and chalcopyrite together with some graphite have been observed. Analyses of the samples show only low contents of precious and base-metals (Table 4).

Brinkley Bjerg (101)

A rust zone north of Brinkley Bjerg was superficially checked in 1980. It consists of a 30°-orientated belt of reddish-coloured solifluction material in crystalline terrain near the fault contact to Permian limestones. The coloured belt contains blocks of limonite crusts, silicified breccias of garnet gneiss with disseminations or blebs of pyrite, garnet gneiss with pyrite on joints, and minor breccia-fillings of white calcite with cm-sized blebs of pyrite. Mineralized outcrops were not observed. Microscopy reveals disseminated pyrite with minor marcasite and a few small grains of sphalerite and

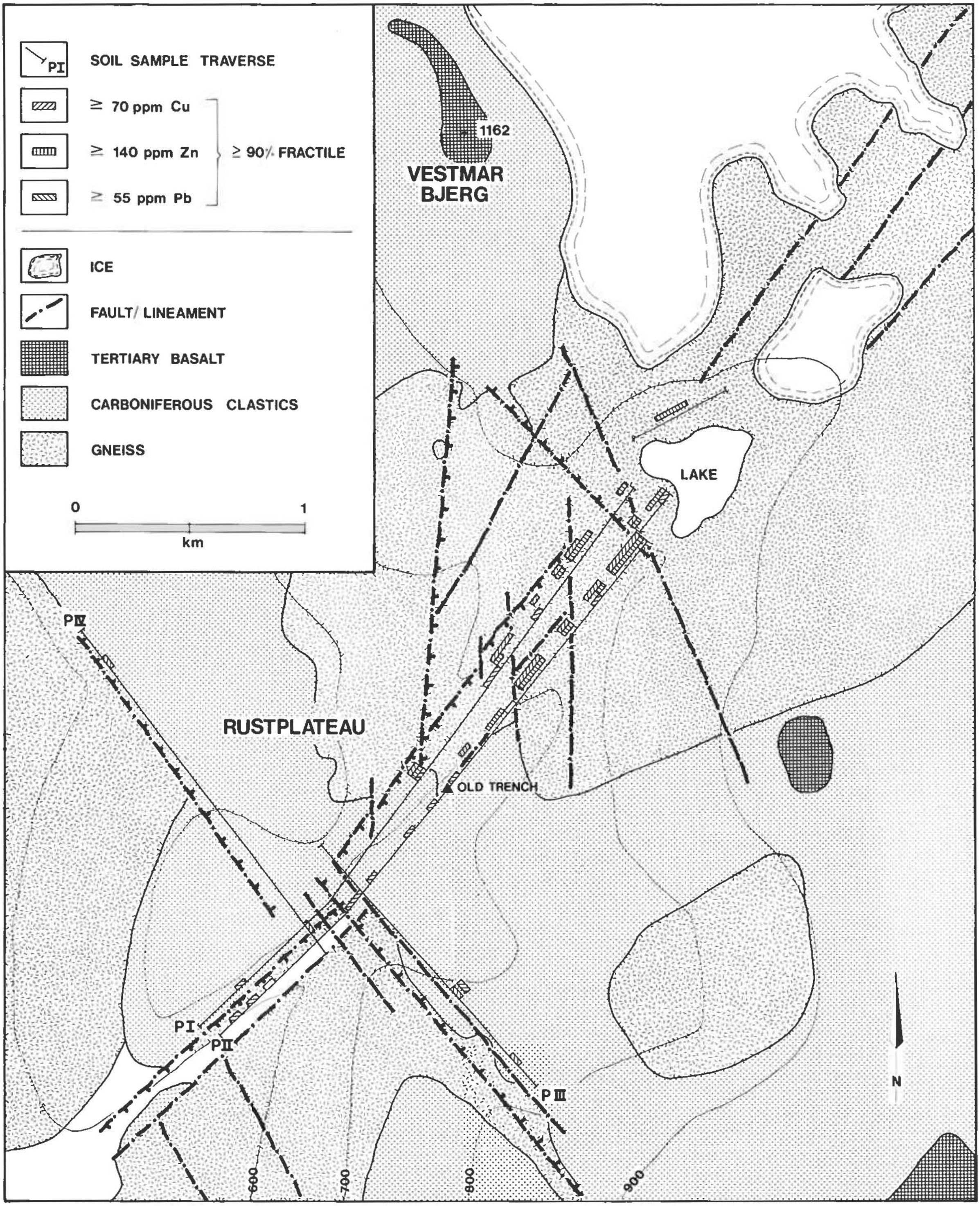


Fig. 50. Geological sketch map of the Rustplateau area, Clavering Ø. Soil sample values larger than the 90%-fractile value are plotted.

Table 4. Analytical results of selected samples from Clavering Ø. Note that all samples contain less than 0.1% As.

Locality/sample description	Pb (%)	Zn (%)	Cu (%)	Au (ppm)	Ag (ppm)
Rustplateau – type (1)	0.015	<0.05	0.004	<0.02	<2
Rustplateau – type (2)	8.5	0.6	0.02	0.05	60
Auspiciedalen	0.02	0.03	0.003	0.1	4
Auspiciedalen	0.15	<0.05	0.004	0.1	2
North of Eskimonæs	0.02	<0.05	0.03	0.02	<2
Brinkley Bjerg	1.4	<0.05	0.02	<0.02	8

chalcopyrite. Analysis shows low contents of precious and base-metals (Table 4).

Lead-zinc at Karstryggen, Schuchert Dal (102–103)

Strata-bound lead-zinc mineralization was found in Karstryggen by Nordmine in 1980 during reconnaissance exploration of the Upper Permian (Harpøth 1981). The following year more detailed investigations were performed in the northern part of Karstryggen (Harpøth 1982).

The geology of Karstryggen, which is situated close to the Stauning Alper Fault, has been described by Kempter (1961), and recent investigations by GGU have added important new information in particular on the Upper Permian sequence (Surlyk et al. 1984 and Surlyk et al. in press). The Upper Permian of the area comprises a basal fluvio-marine sandy conglomerate unit (Huledal Formation) overlain by a marginal marine carbonate and evaporite unit (Karstryggen Formation) with a more open marine carbonate unit on top (Wegener Halvø Formation) (Surlyk et al. in prep.). The Wegener Halvø Formation, which hosts most of the lead-zinc mineralization, represents a carbonate platform at least 30 km long and up to 10 km wide at Karstryggen. The carbonate platform, which is dominated by non-reef facies, is divided into an eastern and a western, more rapidly subsiding, half by a N-S hinge zone. Intra-Permian karsting is reflected as widespread karst breccias in the underlying formation.

Lead-zinc mineralization has been found in both northern and southern Karstryggen (Fig. 51).

In northern Karstryggen (102) strata-bound lead-zinc mineralization occurs in a 1500x500 m area *c.* 1 km south of Revdal (Fig. 51). Mineralization occurs throughout all the different carbonate facies of the Wegener Halvø Formation and in the karst breccia sequence of the underlying Karstryggen Formation, and a vertical mineralized section of 40 m has been observed. However, the estimated average thickness is 20–25 m.

Mineralization occurs partly as galena octahedra dispersed in micritic limestone and partly associated with subvertical joints and fractures striking 20° and 160°. The latter type contains galena octahedra (up to 1/2 cm), yellowish white sphalerite (hardly macroscopically recognizable) and subordinate pyrite and marcasite in a predominantly calcite gangue with subordinate celestite and fluorite.

Analyses of selected samples revealed high contents of lead (max. 10%), zinc (max. 42% – oolitic limestone replaced by whitish sphalerite), cadmium (max. 0.15%) and Ag (max. 150 ppm). A chip sample over 15 m returns 0.15% Pb and 0.26% Zn which confirms the low grade of the mineralization. A preliminary tonnage estimate indicates several tens of million tons (Harpøth 1982).

In southern Karstryggen (103), mineralization occurs on the western bank of Schuchert Flod *c.* 10 km north of Nordostbugt (Fig. 51). Lead-zinc mineralization which occurs in a 50x50 m area and has been observed over a height of 10 m is both lithologically and structurally controlled. The most import control is a set of joints 160°/subvertical (major) and 20°/subvertical (minor). Macroscopically, mm-cm thin veinlets of pyrite, galena, sphalerite, marcasite and minor calcite (Fig. 52) occur mainly in micritic limestone. Mineralization is concentrated in the uppermost part of the micritic limestone as well as in limestone breccia below black shale which represents a barrier of permeability. Analyses of selected samples revealed lead max. 25%, zinc max.

Table 5. Summary of soil sampling results, Rustplateau. N = number. x̄ = mean. M = median. s = standard deviation.

Section	N	Cu ppm				Pb ppm				Zn ppm			
		Range	x̄	M	s	Range	x̄	M	s	Range	x̄	M	s
PI	71	10–130	46	45	20	<5–110	26	25	18	15–260	94	95	41
PII	58	10–120	46	35	24	10–600	49	30	82	20–250	103	95	47
PIII	25	10–270	40	30	49	5–380	37	20	73	40–130	70	65	21
PIV	30	5–50	30	33	12	<5–85	21	15	17	20–130	63	65	22
PI–IV	184	5–270	43	35	27	<5–600	34	25	56	15–260	89	80	41

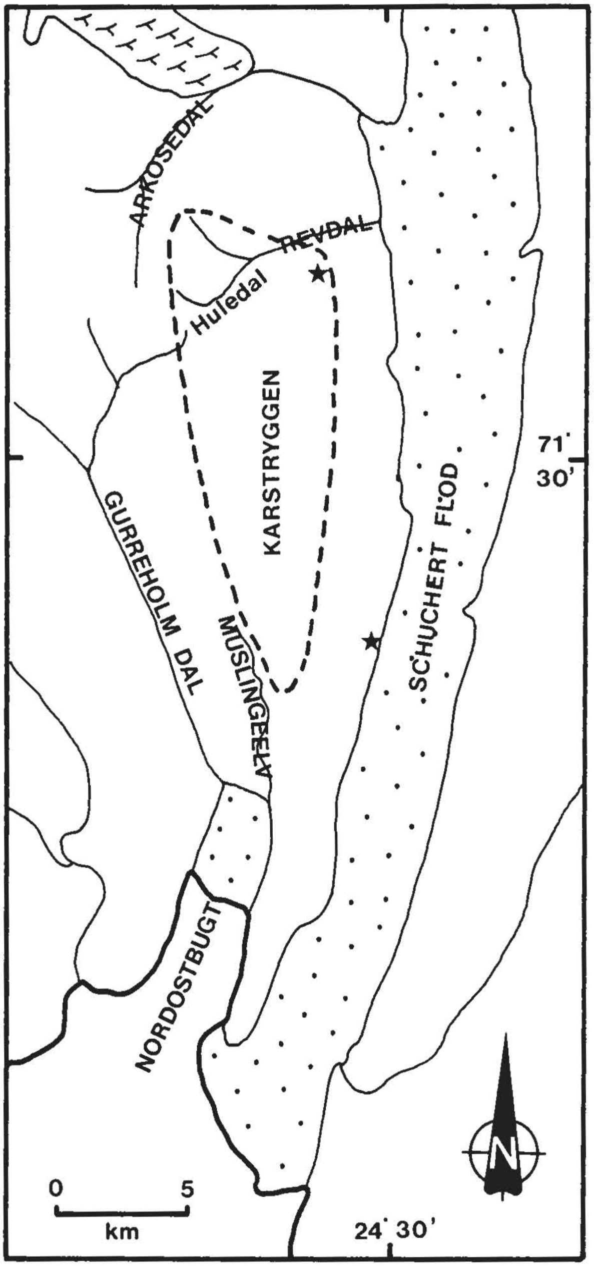


Fig. 51. Location map of the Karstryggen area. Stippled line surrounds area with celestite mineralization. Stars indicate lead-zinc mineralization.

3.5%, and silver max. 70 ppm. The average grade is estimated to be 1–2% combined lead-zinc.

Genetically, both mineralized localities are believed to be associated with the N-S hinge zone in Karstryggen. This zone again is related to the Post-Devonian Main Fault System of the area.

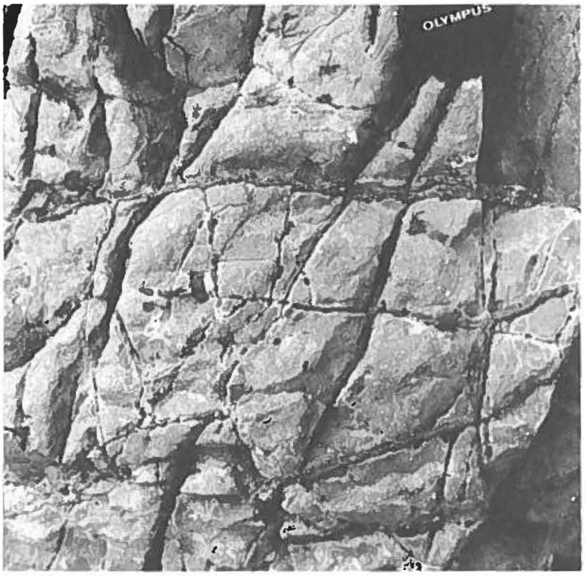


Fig. 52. Galena-sphalerite-marcasite veinlets in micritic limestone. Western bank of Schuchert Dal.

Celestite at Karstryggen, Schuchert Dal (104–106)

Strata-bound celestite ($SrSO_4$) mineralization in Upper Permian carbonates was first noted at Karstryggen by Thomassen (1980) and later investigated by Harpøth (1981). A detailed description is given by Harpøth et al. (in prep.).

The Upper Permian sequence of Karstryggen comprises a basal fluvio-marine sandy conglomerate unit (Huledal Formation) overlain by a marginal marine carbonate and evaporite unit (Karstryggen Formation) with a more open marine carbonate unit on top (Wegener Halvø Formation) (Kempter 1961, Surlyk et al. 1984 and Surlyk et al. in prep.).

The Karstryggen Formation, which hosts the celestite mineralization, is dominated by limestone deposited in hypersaline shallow marine and supratidal environments. The sequence comprises algal-laminated limestone, homogenous and laminated lime mudstone, oolitic grainstone and intraclast limestone. Subordinate penecontemporaneous evaporite is interbedded with these facies, but in localized areas (for example Revdal) more than 100 m thick sequences of laminated gypsum occur. In particular in the western part of Karstryggen, widespread erosion and deposition of both polymict and intraclast conglomerate is associated with intense karstification before the deposition of the overlying Wegener Halvø Formation (Surlyk et al. in press).

Celestite mineralization occurs in an approximately 80 km² area of Karstryggen (Fig. 51). Mineralization occurs both in a lower 3–10 m thick algal-laminated limestone unit and in an at least 50 m thick overlying karst breccia sequence (Fig. 53). In the laminated limestone sequence mineralization occurs in laminated sparite, in algal-laminated/stromatolitic limestone and in nodular bedded limestone (Fig. 54) where calcite and gypsum is partly replaced by celestite. The observed degree of replacement is up to 80%. This specific mode of celestite occurrence is in particular widespread in the Revdal-Huledal and in the Muslingeelv areas (Fig. 51) where a $SrSO_4$ content of 15–30% is common over several metres thickness. Locally, fibrous pale blue celestite-crystal bands (1–2 cm) occur interbeddded with laminated gypsum.

In the karst breccia sequence, mineralization has been observed for more than 50 m vertically, but in general the lowermost 20 m of the section are mineralized, in particular in an area around Huledal-Revdal (*c.* 4 km^2). Mineralization occurs as redeposited early diagenetic celestite from the underlying laminated limestone sequence, as celestite cement and fillings in the karst breccias and as pockets, lenses and veins of celestite in karst fractures and caves. This mode of mineralization is by far the most important one and a common feature is a large-scale veining superimposed on an intense small-scale veining and/or breccia-filling. Vein thicknesses of up to half a metre occur, but a thickness in the range of 5–20 cm is dominant (Fig. 55). Celestite

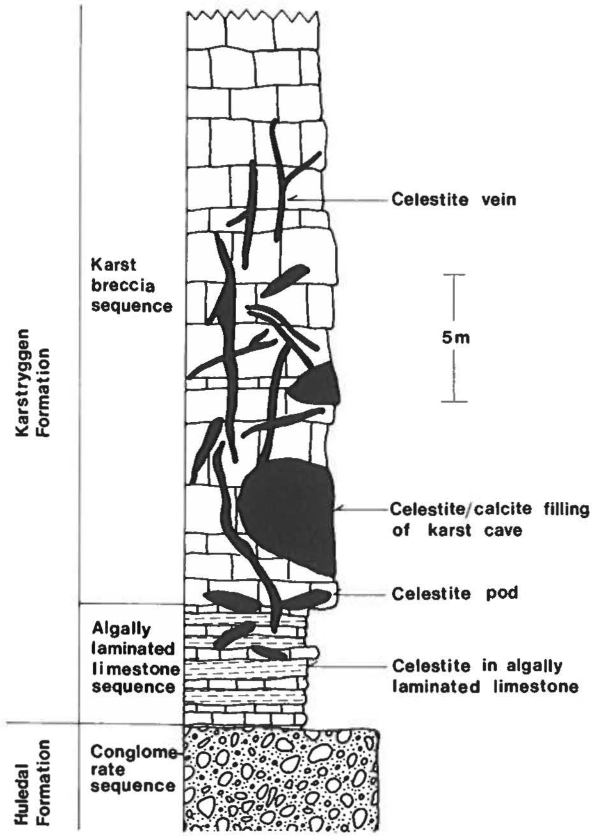


Fig. 53. Modes of celestite mineralization in the Upper Permian Karstryggen Formation.

Fig. 54. Nodular bedded limestone with celestite nodules, Revdal.

commonly occurs as tabular euhedral crystals as much as 15 cm in maximum dimension (Fig. 56). The larger crystals are always associated with up to 25 cm long calcite scalenohedra. The colour varies considerably with colourless, white, pale blue, dark blue, orange and red crystals. Chemically, the celestite crystals have an average barium content of 0.3%, thus pointing at the end member celestite in the baryte-celestite solid-solution series.

In general the intensity of mineralization varies considerably both laterally and vertically. Preliminary estimates of tonnage and grade based on a combination of visual evaluation of outcropping mineralization and of scattered chip-sample sections indicate 25–50 million tons with a grade of *c.* 50% $SrSO_4$ in the Huledal area (104) (Harpøth 1981).

Strontium isotope data (Harpøth et al. in prep.) from Karstryggen show that the evaporites (gypsum) ($^{87}Sr/^{86}Sr$ 0.7074 to 0.7082) and primary precipitated calcite ($^{87}Sr/^{86}Sr$ 0.7068 to 0.7076) stem from seawater which was in equilibrium with the Upper Permian world ocean ($^{87}Sr/^{86}Sr$ 0.7070 to 0.7075 (Veizer & Compston 1974)). Analyses of both modes of celestite ($^{87}Sr/^{86}Sr$ 0.7131 to 0.7137) and karst calcite ($^{87}Sr/^{86}Sr$ 0.7134) indicate that they all have a common origin in water derived from the western highlands (surface or subsurface water). This means that an early diagenetic replacement of gypsum/anhydrite with celestite occurred in the algal-laminated limestones during interaction with Sr-rich terrestial ground water. The remaining celestite mineralization is associated with the karst episodes when caves and fractures were filled with coarse-grained celestite originating in Sr-rich surface and subsurface fresh water.

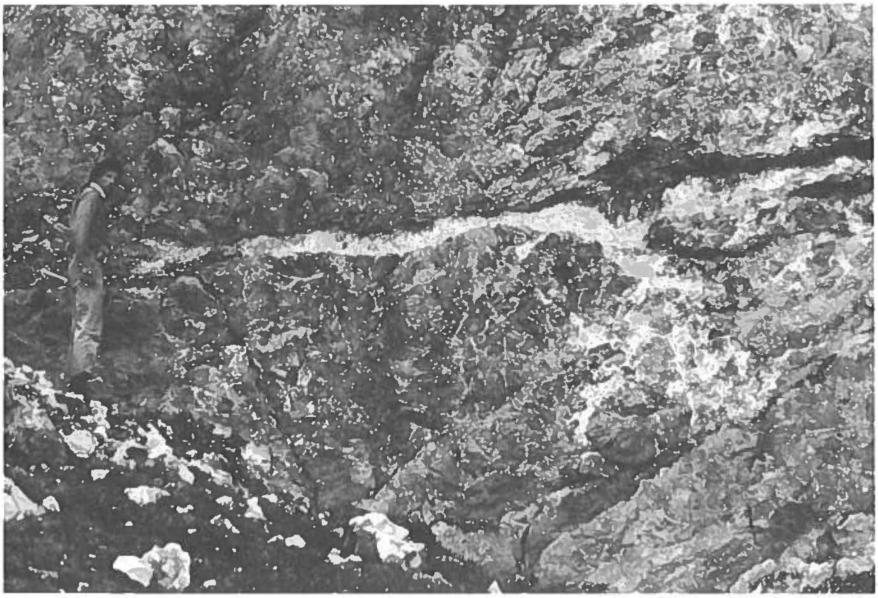


Fig. 55. Intensely celestite-mineralized karst breccia. Note larger celestite vein. Western Schuchert Dal.

Baryte-lead-zinc at Bredehorn, Scoresby Land (107)

Baryte-lead-zinc mineralization was found in Upper Permian sediments 3 km south of Bredehorn, Scoresby Land during Nordmine reconnaissance in 1971. Prospect investigations in 1972 and 1975 included mapping, chip sampling, trenching, geophysics (induced polarization, resistivity, self potential and magnetic methods) and shallow diamond drilling (10 holes; total 121 m) (Paar 1974, Bruneau 1976). Continued investigations in 1980–82 comprised mapping at scale 1: 5000, chip sampling and VLF geophysics (Thomassen & Schønwandt 1981, Damtoft & Grahl-Madsen 1982, Thomassen et al. 1982, Harpøth 1983). The Permian host rocks were mapped on a regional scale by GGU 1968–72 (Henriksen et al. 1980) and sedimentological studies were carried out in 1982–83 (Surlyk et al. in prep.).

Fig. 56. Coarse celestite crystals from cavity in Huledal.

The Bredehorn area consists of a number of slightly SE sloping plateaus situated 1000–1300 m a.s.l. and covered by scree and regolith. Good outcrops are restricted to the nearly vertical cliffs towards Breithorn Gletscher to the west. The local Upper Permian sequence consists of 20–40 m of fluviatile to shallow marine conglomerates (Huledal Formation) followed by 50–60 m marginal marine, gypsiferous, algal-laminated limestones and open marine, dm-bedded lime mudstones (Karstryggen and Wegener Halvø Formations), and 100–150 m of shallow marine sandstones (Bredehorn Member of the Schuchert Dal Formation). These sediments dip 5°–15° SE, rest with an angular unconformity on Lower Permian continental sandstones, and are overlain conformably by Triassic marine shales and sandstones (Wordie Creek Formation). The sediments are block-faulted and slightly tilted by post-Triassic normal faults with mainly N-S to NNW-SSE directions, easterly dips and throws of up to 300 m (Fig. 57).

Mineralization occurs inside a *c.* 1 km² fault-bounded area and appears both as sheets conformable to the bedding and as cross-cutting veins. The conformable mineralization is hosted in a specific level of the basal part of the carbonate sequence (Karstryggen Formation) and spatially associated with vein-type mineralization hosted in *c.* 160°-striking faults. It appears that the conformable type occurs in up to 200 m wide belts along these faults.

The conformable mineralization is known from excellent exposures along the cliffs of Breithorn Gletscher ("Zebra Klint"), and from a number of large block fields. At "Zebra Klint" the uppermost Huledal Formation consists of 5 m of red and grey siltstones which are overlain by 8 m of laminated, marly limestone of the lo-

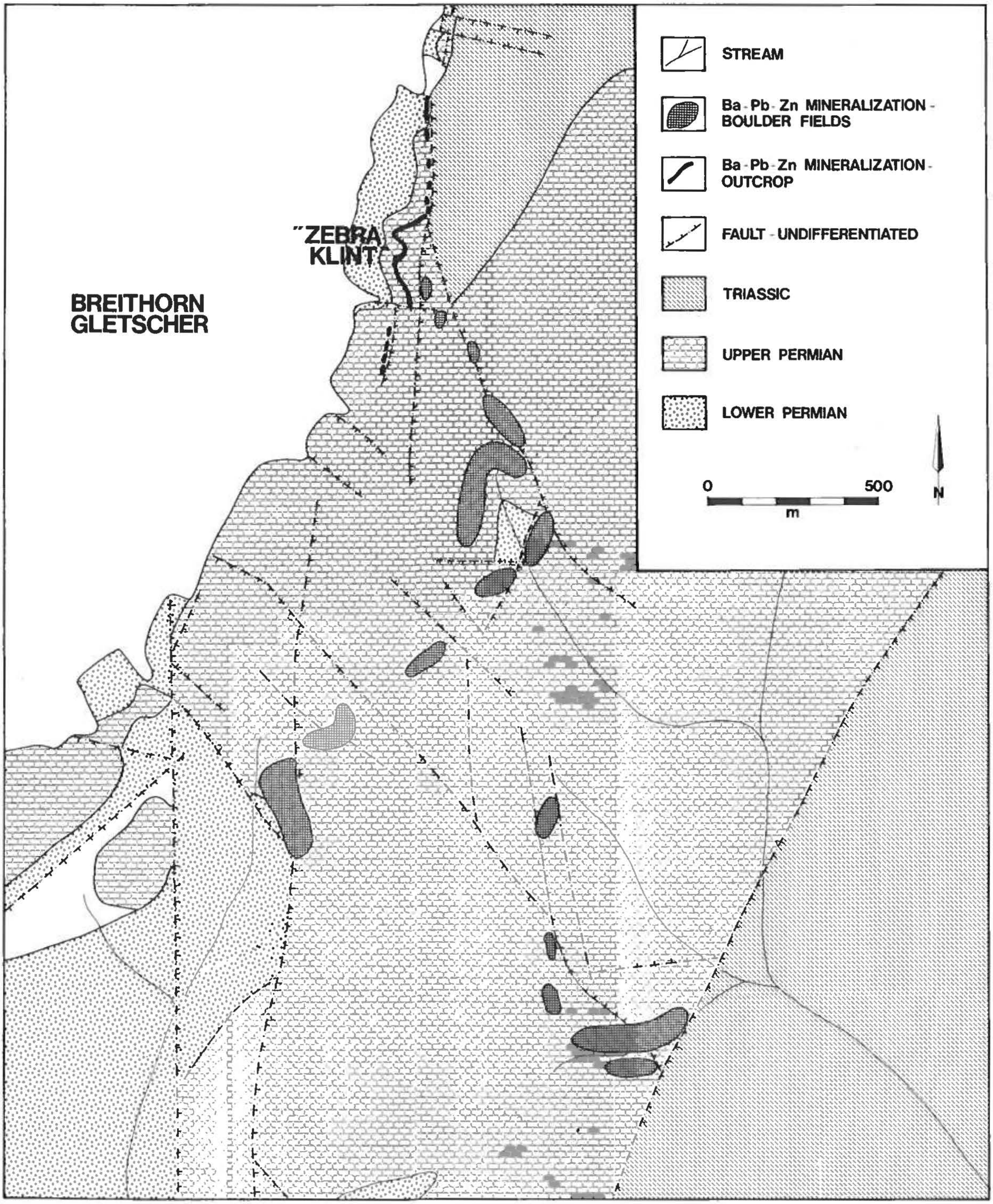


Fig. 57. Simplified geological map of the Bredehorn area with mineralized localities.

wermost Karstryggen Formation. Above follows a *c.* 10 m thick baryte horizon, massive in the middle part with transition zones of limestone/baryte beds in the upper and lower parts. The uppermost 20–30 m of the cliff consist of well-bedded limestones (20–30 cm thick units) with a few intercalated baryte beds. The main baryte horizon is exposed for 300 m along "Zebra Klint". To the south a lateral transition to porous, gypsiferous,

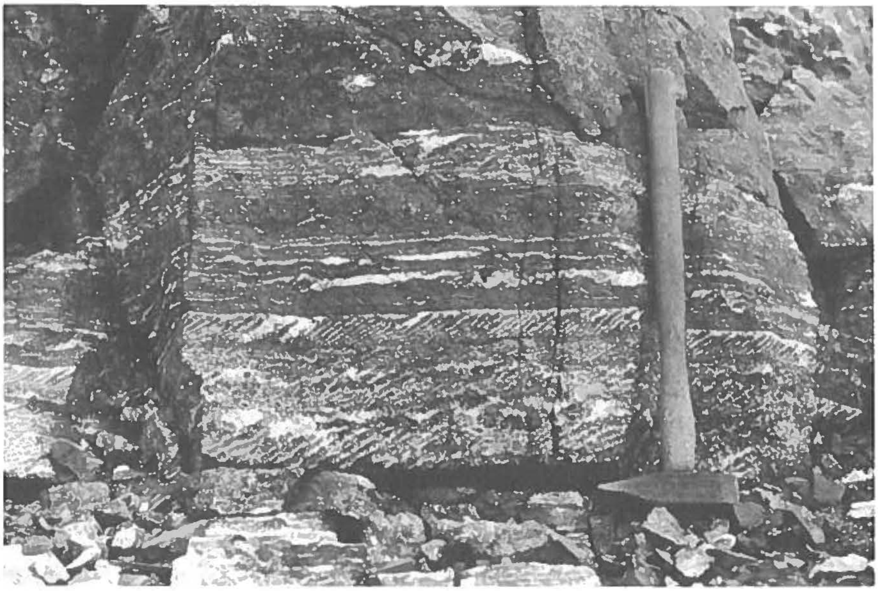


Fig. 58. "Zebra" baryte, Bredehorn.

laminated limestones occurs, and to the north the horizon has mostly been eroded away, but remnants of conformable baryte beds exist for another 300 m. The baryte horizon is characterized by rhythmically bedded units consisting of alternating mm to cm-thick bands of white and grey baryte, the so-called zebra structures (Fig. 58). The baryte beds display a number of apparent sedimentary structures as documented by Paar (1974). Galena occurs partly as 5–15 cm thick layers and lenses in the uppermost, silicified part of the baryte horizon, and partly as disseminations together with sphalerite (grain sizes 1–10 mm) in the whole baryte horizon. As sphalerite weathers easily, it is scarcely recognizable in the field. Oblique, cross-cutting, coarse-grained quartz-baryte-galena veins of cm-dm thickness indicate partial remobilization. The boulder fields on the plateaus further southeast (Fig. 57) display the same mineralization dominated by "zebra baryte". Shallow bore holes (max. 18 m deep) on the intervening part of the plateaus did not reach the baryte horizon.

The results of three chip sampling programmes along the "Zebra Klint" are summarized in Table 6. Based on the 1982 results, approximately 300 000 tons of baryte ore with an average density of 4.0 (72% baryte) have been proved along the cliff (Harpøth 1983), and the overall reserves are probably in the order of several million tons.

Baryte-quartz veinlets of cm-thickness are abundant throughout the area. A 1–2 m thick baryte vein is exposed in the cliff north of "Zebra Klint". It occupies a 0°/70°E-orientated fault and has conglomerate of the Huledal Formation as footwall and limestone of the Wegener Halvø Formation as hanging wall. Other large veins are mainly known from plentiful boulders of hydrothermally altered rocks and of galena-sphalerite-bearing vein quartz-baryte including up to 0.5 m large blocks of massive galena. The boulders are lined across the plateaus along the trends of mainly 160°/70° E orientated faults. These veins are also mappable as I.P. and VLF anomalies and have been followed as such for more than 1 km along strike (Fig. 59). The veins appear in the entire Upper Permian sequence, although the highest galena contents occur in the Bredehorn Member. As the veins have not been observed in the overlying Triassic sediments, they are assumed to be of uppermost Permian age.

Table 6. Chip-sample results from "Zebra Klint", Bredehorn. *Analyzed by AA or XRF. **By specific gravity measurements. The average amount of soluble salts expressed as Ca-ion concentration is *c.* 200 ppm.

Year	Number of chip sections	Total length of sections (m)	Weighted average values			
			Length of section (m)	Pb (%)	Zn (%)	$BaSO_4$ (%)
1972	19	129	6.8	2.7	0.3	65*
1980	9	75	8.4	1	0.4	55*
1982	5	31	6.2	–	–	72**

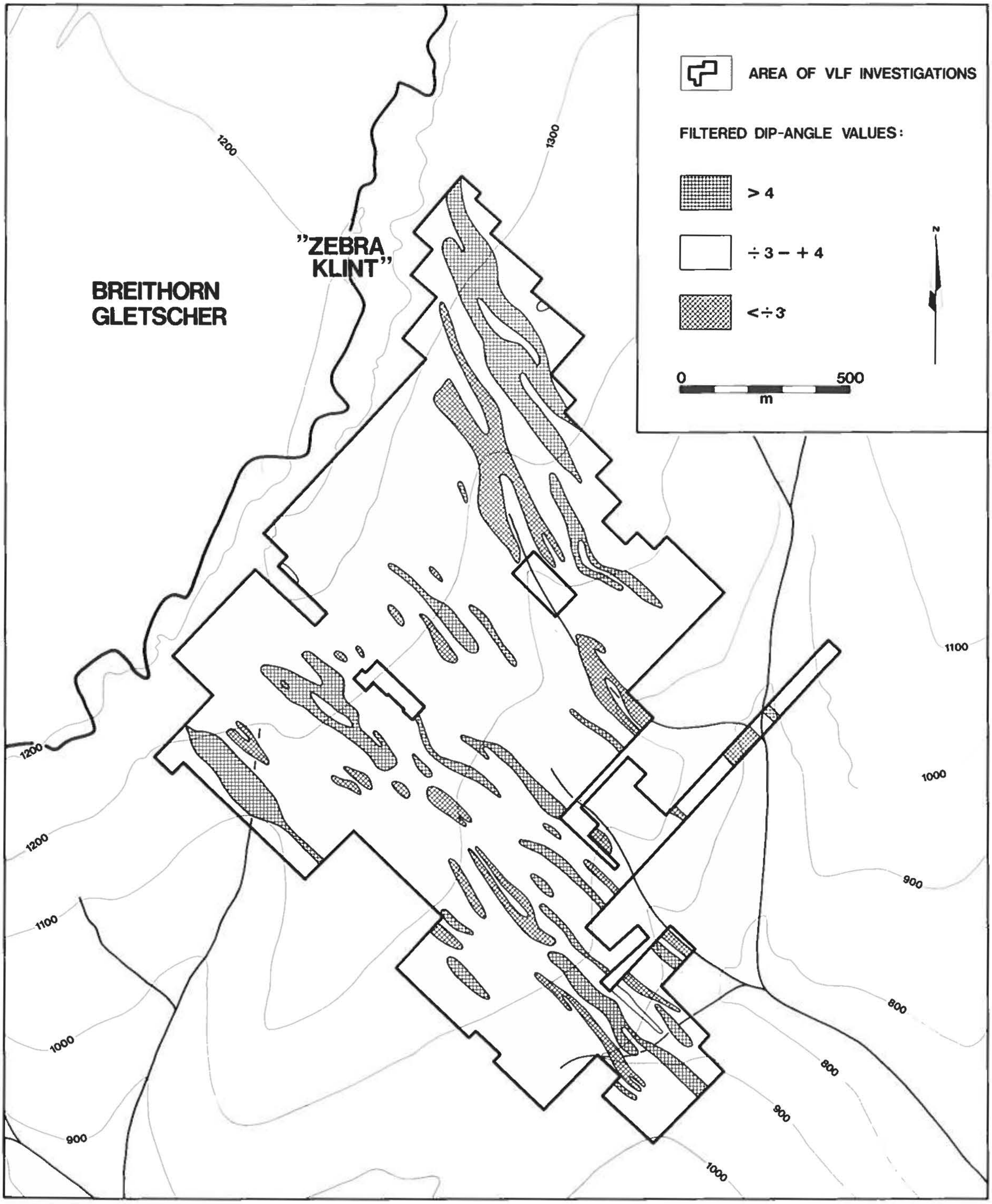


Fig. 59. Simplified VLF map of Bredehorn area. The anomalies express NW-SE and NNW-SSE-striking faults. Modified after Damtoft & Grahl-Madsen (1982).

Silicification of the limestones is widespread and often overlaps or interfingers with the baryte horizons. As the silica often replaces baryte, it is a relatively late phenomena. Dolomitization appears as brownish colourations of the limestones, especially along faults and joints.

Ore microscopy of mineralized samples from the Bredehorn area reveals, in addition to galena, minor sphalerite, pyrite and marcasite along with traces of chalcopyrite, tetrahedrite and stibnite. Galena is often strained and contains abundant small inclusions of tetrahedrite, stibnite and pyrite, and rarely chalcopyrite and sphalerite. Analyses of 21 samples rich in galena average 36% Pb, 632 ppm Sb, 181 ppm Ag and 0.1 ppm Bi, with no significant difference in the trace element contents between samples from conformable and vein mineralization.

The conformable mineralization is believed to have formed by selective replacement of the porous limestone/evaporite horizon at the base of the Upper Permian sequence. The feeders are the 160°–180°-trending faults now occupied by vein mineralization and the mineralizing episode is of uppermost Permian age.

Strata-bound base metals on Wegener Halvø (108–124)

Signs of base-metal mineralization in the Upper Permian limestones of Wegener Halvø were first observed by members of "De Danske Treårsekspeditioner 1931-34" (Noe-Nygaard 1934, Eklund 1944). During a Nordmine reconnaissance of the peninsula in 1968, mineralization was also found in black shales,and the following year a 20 m long trench was blasted and sampled (Lehnert-Thiel & Walser 1968, Thomassen 1973). Following air observation of malachite staining of the limestones of Quensel Bjerg on south Wegener Halvø, a reconnaissance of this area was carried out in 1971–72 (Paar et al. 1972), and further observations were made here during Nordmine investigations of the Triassic in 1973–76 (Thomassen 1977). Finally, the Upper Permian of the whole peninsula was traversed and mapped at scale 1:10 000 in 1979 (Harpøth 1980, Thomassen 1980, Thomassen et al. 1982).

During the Lauge Koch expeditions, the geology of Wegener Halvø was investigated and mapped by Noe-Nygaard (1934) and Grasmück & Trümpy (1969). GGU geologists mapped the area at 1:100 000 in 1968–71 (Perch-Nielsen et al. 1972) and carried out sedimentological studies of the Upper Permian in 1978 and 1982–83 (Surlyk et al. 1984, in press, in prep.).

The Upper Permian sequence of Wegener Halvø is *c.*

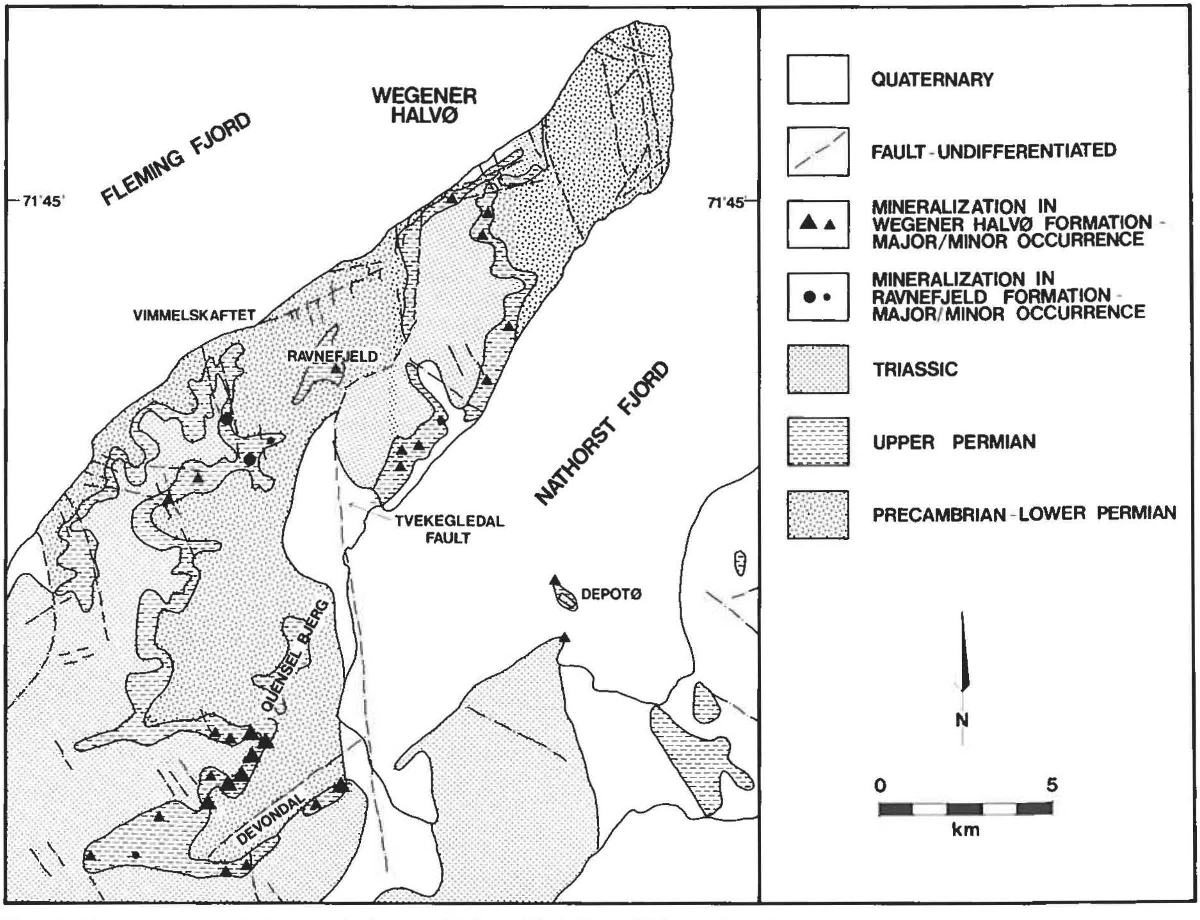


Fig. 60. Simplified geological map of Wegener Halvø with indicated Upper Permian mineralization.

300 m thick and rests with an angular unconformity on continental Middle Devonian to Lower Permian sediments (Fig. 60). It is dominated by an up to 250 m thick carbonate sequence (Karstryggen and Wegener Halvø Formations) with local black shale basins (Ravnefjeld Formation). These sediments are under- and overlain by coarse, clastic rocks (Huledal and Schuchert Dal Formations). The peninsula is dissected by numerous Upper Palaeozoic and post-Triassic, mainly N-S-trending faults.

Mineralization occurs both in the black shales of the Ravnefjeld Formation (the former Posidonia Shale, cf. Maync 1961) and in the carbonates of the Wegener Halvø Formation (upper part of the former Limestone-Dolomite Member).

Ravnefjeld Formation (117,118)

The black shales are bituminous and micaceous, laminated mudstones with a high content of calcareous concretions and concretionary beds. Locally, calcareous beds containing abundant brachiopods, corals and bryozoans derived from the adjacent topographically higher carbonate buildups occur. The shales represent basinal and inter-buildup mud, whereas the bioclastic beds are resedimented downslope from the carbonate buildups of the Wegener Halvø Formation. The shales have a good potential as oil source rocks (Surlyk et al. in press) and have been compared with the European Kupferschiefer (Maync 1961, Thomassen 1973).

Stratiform fine-grained mineralization occurs throughout the Ravnefjeld Formation. The sulphides exhibit colloform textures and replacement of fossils is widespread (Fig. 61). The main ore minerals are sphalerite and galena with minor chalcopyrite, pyrite and marcasite. Rare sulphides on joints indicate minor remobilization.

Channel samples collected southwest of Vimmelskaftet (118) through the lowermost 15 m of the formation average 0.13% Pb, 350 ppm Zn, 200 ppm Cu, 79 ppm V, 72 ppm Ni, 30 ppm Co, 11 ppm Th, 7 ppm U and contain up to 80 ppm Mo and 30 ppm Ag (Thomassen 1973). In general, the metal content decreases upwards in the sequence. A chip sample over 2.5 m of black shale in Devondal averages 200 ppm Pb, 200 ppm Cu, <500 ppm Zn, 350 ppm V, 70 ppm Ni, 50 ppm Co, 50 ppm Mo and 4 ppm Ag. Thin, richly mineralized beds are known from several localities, for example south of Vimmelskaftet (119). Here 1–3 cm beds of biosparite contain *c.* 10% combined zinc and lead. These beds may grade laterally into barren, silicified horizons. The mineralization is clearly of syngenetic character.

Wegener Halvø Formation

The Wegener Halvø Formation comprises eight lithofacies of marine limestones representing a transgressive sequence (Surlyk et al. in press). Mineralization is

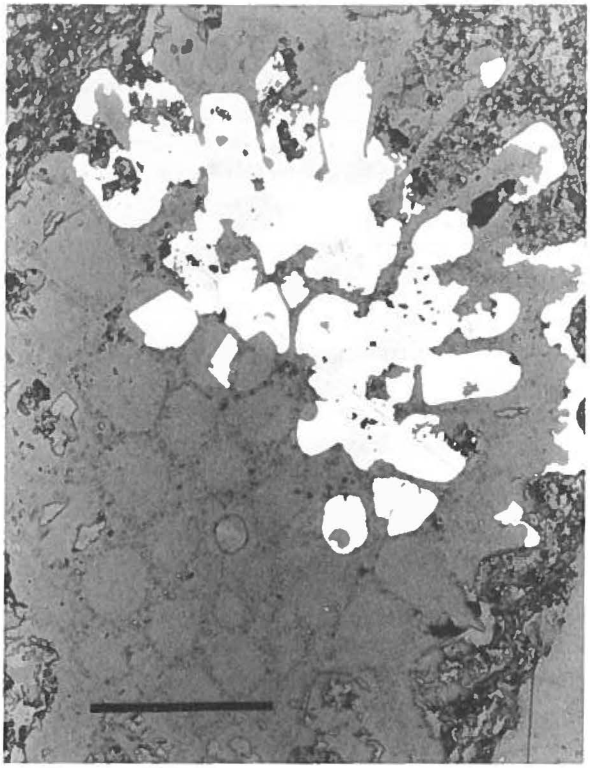


Fig. 61. Photomicrograph (reflected light) showing intergrown galena and pyrite replacing fossil. Ravnefjeld Formation, Wegener Halvø. Bar scale 0.5 mm.

mainly associated with up to 150 m thick buildups of massive, bryozoan limestones and their surrounding bedded flank sediments. Downslope from the carbonate buildups, the flank deposits pass gradationally into the black shales of the Ravnefjeld Formation. Mineralization is scattered over the whole peninsula, but important base-metal concentrations are confined to the Quensel Bjerg-Devondal area to the south. Pronounced silicification and quartz veining is also restricted to the same area, whereas calcite-baryte veining and minor irregular dolomitization occurs all over Wegener Halvø. The individual mineralized areas (Fig. 60) are described below:

Quensel Bjerg (108,109). – At Quensel Bjerg, mineralization is known from a 2x7 km area (Fig. 62). Mineralization is concentrated in a 2–4 m thick quartz-baryte zone at the contact between the limestones and the overlying Schuchert Dal Formation. This zone is associated with feeder-like, nearly vertical baryte veins cutting the limestones along N-S-striking faults and joints. Continuous mineralization is exposed for a distance of 2 km along the steep north slope of Devondal. A lateral zonation seems to exist with dominance of baryte and copper mineralization towards the southwest and quartz and lead-zinc mineralization to the northeast. Tennan-

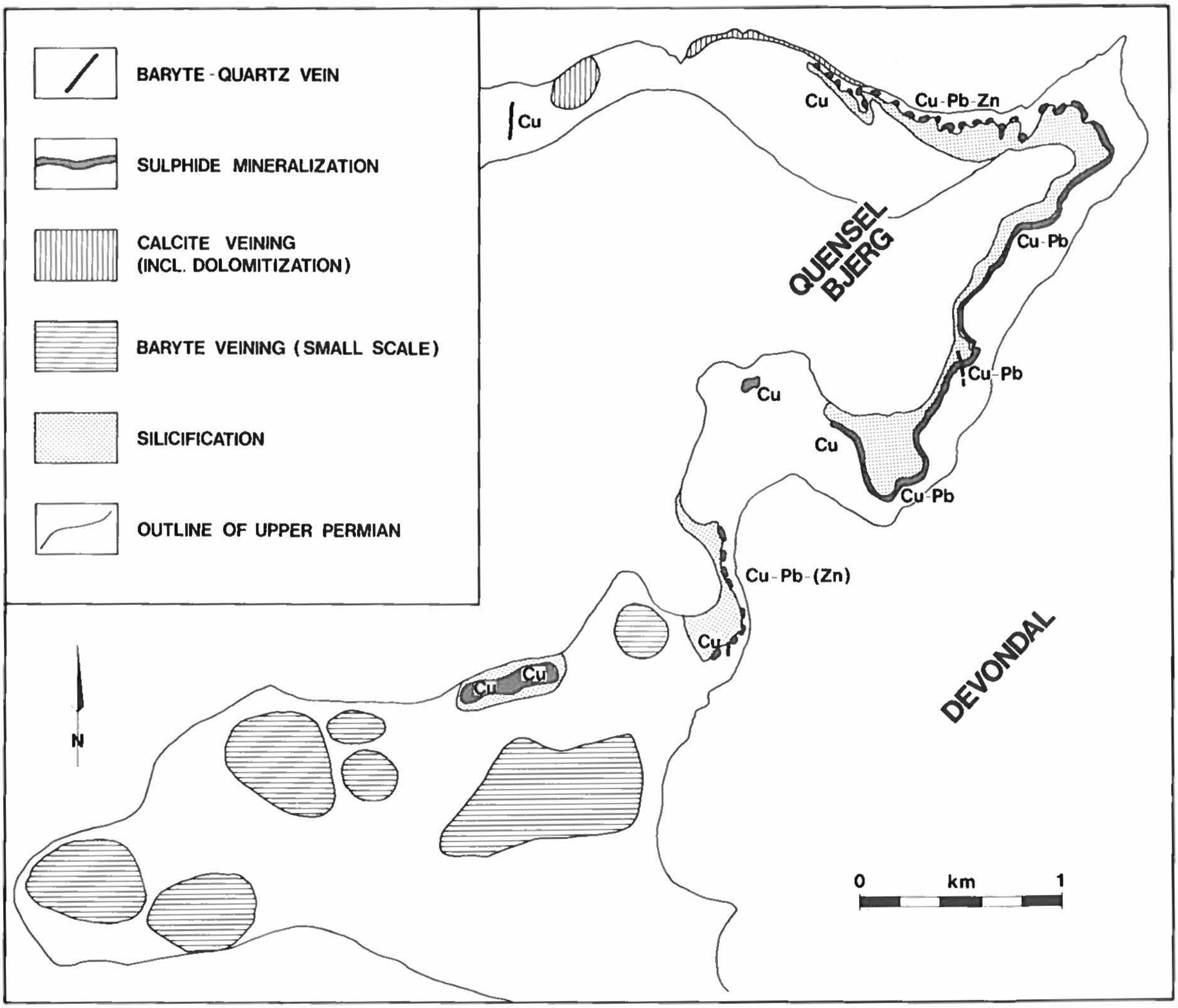


Fig. 62. Mineralization and alteration pattern of the Upper Permian mineralization at Quensel Bjerg.

tite-tetrahedrite, galena and minor chalcopyrite and sphalerite are mainly associated with baryte and only subordinately with quartz. The mineralized zone of Quensel Bjerg is estimated to host *c.* 10 million tons with 2–4% sulphides and 30–40% baryte (Harpøth 1980).

Devondal (112,113). – On the south side of Devondal mineralization occurs along the 5 km of Upper Permian outcrops. In general, it is scattered and less pervasive than on Quensel Bjerg. However, the intensity increases going from west towards east. The copper-lead-zinc-silver mineralization is associated with quartz and baryte veinlets in the uppermost part of the carbonate buildups and surrounding flank sediments. The largest single vein which occurs in the easternmost outcrop is up to 5 m wide and outcrops for 400 m along strike. In addition to abundant drusy quartz it contains scattered sulphides precipitated as open-space fillings. The sulphides are tennantite, chalcopyrite, galena, sphalerite and pyrite. A lateral zonation exists with baryte-copper to the west and a dominance of quartz-copper-lead-zinc to the east. Twenty chip samples from this area covering a 100x500 m area average 0.5% Cu, 0.2% Pb and 0.1% Zn. However, these copper and zinc contents are most likely misleadingly low due to partial weathering out of tennantite and sphalerite.

Depotø (115). – On Depotø and the neighbouring headland, massive cm-dm-sized lenses and veins with galena and pyrite exist.

Central and northern Wegener Halvø (116 and 119–124). – In the central and northern parts of Wegener Halvø, widespread baryte-calcite-(fluorite) veining occurs in the limestones, typically on the flanks of the buildups, just below the covering Schuchert Dal Formation. These veins are irregular with thicknesses in the mm-dm range. Scattered sulphides occur in these veins and also in several metres wide breccia zones, typically striking 140°–160°. The ore minerals are tennantite-tetrahedrite, chalcopyrite and galena with minor sphalerite and pyrite. The copper minerals are accompanied by conspicuous malachite and azurite staining. The lead and copper minerals tend to occur separately. Small amounts of copper are scattered all over the area, but lead is confined to the eastern part of the peninsula, where the limestones contain *c.* 1% disseminated galena over fairly large areas.

Microscopic and microprobe investigations of samples from the whole of Wegener Halvø confirm tennantite-tetrahedrite, chalcopyrite, galena and sphalerite as the main ore minerals with minor enargite, pyrite and marcasite. The main ore minerals occur as mm-cm-sized single grains and aggregates, whereas pyrite and marcasite form micron-sized colloform disseminated grains. The relative age relationship of the sulphides is: pyrite, marcasite (oldest) – galena, sphalerite, chalcopyrite – tennantite/tetrahedrite (youngest). Tennantite/tetrahedrite typically replaces chalcopyrite. Over 160 microprobe analyses (S. Karup-Møller, pers. comm. 1984) of tennantite-tetrahedrite from 15 different localities show a distinct compositional trend. Samples taken west of the Tvekegledal Fault all represent the tennantite end member whereas samples taken east of the fault represent intermediate phases of the tennantite-tetrahedrite solid solution series. The western samples show relatively high values of arsenic, iron and lead and relatively low values of antimony, zinc and silver, whereas the opposite applies to the eastern samples. The compositional molecular ranges are:

$$(Cu_{9.45\text{-}9.96}Ag_{0.01\text{-}0.09})\ (Fe_{0.37\text{-}1.39}Zn_{0.55\text{-}1.50}Pb_{0\text{-}0.11})$$
$$(Sb_{0.04\text{-}1.29}As_{2.61\text{-}3.86})S_{13}$$

Chemical analyses of six galena samples only average 145 ppm Ag and thus indicate that silver is basically associated with tennantite-tetrahedrite which contains up to 0.5%. Fluid-inclusion studies (P.A. Scholle, pers. comm. 1985) on coarse-grained fluorite from upper Devondal and on coarse-grained quartz from Quensel Bjerg, both associated with sulphide mineralization, indicate formation temperatures of 115°–130°C (fluorite) and 125°–150°C (quartz), with salinities of 16–22%. Furthermore, both minerals contain abundant petroleum inclusions. The mineralization probably originates from hydrothermal solutions which percolated through the major faults of Wegener Halvø. The metals may have been supplied by the adjacent black shales.

Lead-zinc at Mesters Vig, Scoresby Land (125–127)

Mesters Vig is the only area in central East Greenland where mining has taken place. Galena-bearing quartz veins were discovered by members of the Lauge Koch expedition in 1948. Follow-up investigations in 1948 and 1949 led to the finding of most of the lead-zinc-mineralized occurrences known at present including the two most important occurrences – Blyklippen and Sortebjerg (Eklund 1949). Detailed mapping and deposit investigations were undertaken at Blyklippen by the Lauge Koch expeditions in 1950 and 1951. From 1952 to 1954 the investigations were continued by the newly established company – Nordisk Mineselskab A/S. The company also conducted diamond drilling at Sortebjerg in 1952 and continued the regional exploration. Mining at Blyklippen was initiated in 1956 and lasted to 1962. A total of 545 000 tons of ore with 9.3% Pb and 9.9% Zn was produced (Table 7).

The detailed geology of the area was described by Witzig (1954), Bondam & Brown (1955) and Perch-Nielsen et al. (1972). Description of the Blyklippen deposit were given by Brown (1955) and Gross (1956). Technical aspects of the mining were considered by Kampmann (1953), Astlind & Fahlström (1957) and Fischer et al. (1958). Recently, new field observations and a compilation of all existing data have been made by Swiatecki (1981 and 1983) (Fig. 63).

The Mesters Vig area consists of Carboniferous, Permian and Triassic sediments and post-Permian, presumably Tertiary, doleritic sills and dykes. Towards south the area is intruded by the Tertiary, syenitic Werner Bjerge complex, and towards west it is cut off by the Stauning Alper Fault which exposes older rocks to the west. Recent palynological studies by Piasecki (1984) indicate that most of the sediments previously assumed to be of Carboniferous age are actually of Lower Permian age.

Continental Carboniferous and predominantly Lower Permian sediments make up most of the area. They are divided into five members:

- The Skeldal Member consists of arkose with minor silty and carbonaceous intercalations. It only outcrops in the Skeldal area along the Stauning Alper Fault and most likely represents deposits of the uppermost Carboniferous.

Table 7. Annual ore production from the Blyklippen lead-zinc deposit.

Period (1/10–30/9)	Tonnage	Lead (%)	Zinc (%)
1955–1956	45 000	8.2	10.5
1956–1957	87 400	8.5	10.7
1957–1958	90 200	10	8
1958–1959	92 500	12	10
1959–1960	86 200	8	12
1960–1961	101 500	10.7	8.7
1961–1962	41 800	3.8	10.3
Total	544 600	9.3	9.9

Concentrate production:
58 500 tons Pb-conc. (82.7% Pb, 115 ppm Ag)
74 600 tons Zn-conc. (63.7% Zn)

- The Blyklippen Member (the former Blyklippen Series) comprises 800–1000 m of cross-bedded sandstone with subordinate up to 3 m thick conglomerate horizons. This and the succeeding members are all of Lower Permian age.
- The Profilbjerget Member (the former Lebachia Series) comprises 1300–1500 m of fluviatile arkose and sandstone with subordinate limestone, calcareous and bituminous shale and mudstone.
- The Domkirken Member comprises 200 m of continental arkose and conglomerates.
- The Aggersborg Member consists of arkosic sandstones and siltstones with subordinate shale. The member is preserved in the area southeast of Mesters Vig.

Northwest of Mesters Vig the sediments are orientated 70°/10°–20° N whereas to the southeast the general orientation is 25°/20° E. The sequence is unconformably (8°–12°) overlain by 250 m of Upper Permian marine sediments, which northwest of Mesters Vig are flat-lying (0°–5° N) whereas they are orientated 25°/10° E southeast of Mesters Vig. The Upper Permian sediments south of Mesters Vig comprise a basal conglomerate unit (Huledal Formation), overlain by marginal marine evaporites and carbonates (Karstryggen and Wegener Halvø Formations), bituminous shale (Ravnefjeld Formation) and a variegated clastic sequence (Schuchert Dal Formation). Lower Triassic silty shale overlie the Permian sequence.

Igneous intrusions comprise lamprophyric and doleritic dykes and doleritic sills with four distinguishable groups:

- Lamprophyric dykes occur at Sortebjerg. They are up to 5 m wide and are intersected by a quartz vein and doleritic dykes.
- Subhorizontal doleritic sills up to 100 m thick are widespread in the Mesters Vig area. Locally they intersect quartz veins and they are faulted along N-S, NNE-SSW and NNW-SSE directions.
- Subvertical doleritic dykes striking 160°–180° are abundant within the whole Mesters Vig area. Their thickness varies from 0.1–4 m and they intersect both the sediments, the quartz veins and the doleritic sills.
- Subvertical doleritic up to 2 m thick dykes striking 20°–30° occur in the southeastern part of the Mesters Vig area. Locally they intersect the 170°-striking dykes.

Two fold structures have been outlined in the Mesters Vig area. A small domal structure occurs just east of Noret and is probably due to the igneous activity. The other is a 15–20 km long, anticlinal structure along Mesters Vig and Deltadal. Based on facies and thickness variations of the Upper Permian sediments, Witzig (1954) argues that the folding is pre-Upper Permian.

Faulting is widespread with the so-called Mesters Vig graben as the most conspicuous structure (Fig. 63). It is 4 km wide and 12 km long, occurs at the northern flank of the anticlinal structure and is approximately perpendicular to it. Upper Permian and Triassic sediments are only preserved inside the graben. The graben is outlined by normal faults orientated 140°–160°/70°–80° NE and 140°–160°/70°–80° SW at the western and eastern side respectively. Another frequent fault orientation is 0°–25°/75° E-75° W. Faulting occurs within the entire section, but obviously faulting has taken place at different times, because the displacement of Tertiary sills is far less than for the Permian sediments, which may be up to 1000 m.

Sulphide-bearing quartz-baryte veins are associated with the major graben faults. Most vein outcrops occur along the Sortebjerg-Blyklippen fault and the Deltadal-Rungsted Elv fault, but other veins occur outside the graben (Fig. 63). Descriptions of the individual occurrences and/or vein systems shown in Fig. 63 are presented below.

Blyklippen (125)

The Blyklippen lead-zinc deposit, which is now exhausted, comprised a sulphide lens within a major quartz vein zone occurring from 300 m to 490 m a.s.l. The quartz vein zone, which is orientated 150°/40°–90° E, is developed along a normal fault which brings sandstones and arkoses from the Domkirken Member in contact with similar rocks of the Blyklippen Member. The quartz vein zone is at least 1000 m long. It is cut at the northern end by a fault (40°/50° SE) and it gradually disappears to the south. Due to pinching and swelling the thickness varies from a few metres up to 50 m. The pinch and swell axis plunges *c.* 40° S. The quartz vein zone is sharply delineated to the east (along the hanging wall) by a fault plane. The western limit (the footwall) is less sharp, being a transitional zone with decreasing intensity of quartz veining and kaolinization. Small-scale, late-stage, west-dipping faults intersect and brecciate the main quartz vein zone. Minor amounts of galena, sphalerite and baryte are invariably associated with the quartz veins. However, the main sulphide lens occurred close to the footwall of the quartz vein zone within a swell structure at the northern end of the vein. There is no correlation between thickness of quartz vein zone and the sulphide lens. The mined-out sulphide lens was 2–10 m thick, 300 m long and 160 m high. It consisted of 65% quartz, 15% sphalerite, 10% galena, 5–10% baryte and trace amounts of chalcopyrite and fahlore. The copper and silver contents were 120 ppm and 15 ppm respectively. Across the lens it is characteristic that galena- and sphalerite-enriched sections alternate. In general, sphalerite is enriched in the lower and the northern part of the lens whereas galena is enriched near the surface and in the southern part of the lens (Fig. 64). The 40° transverse fault also delimits the sulphide lens to the north. Brown (1955) argues that the fault is later than the ore formation due to the existence of sheared and

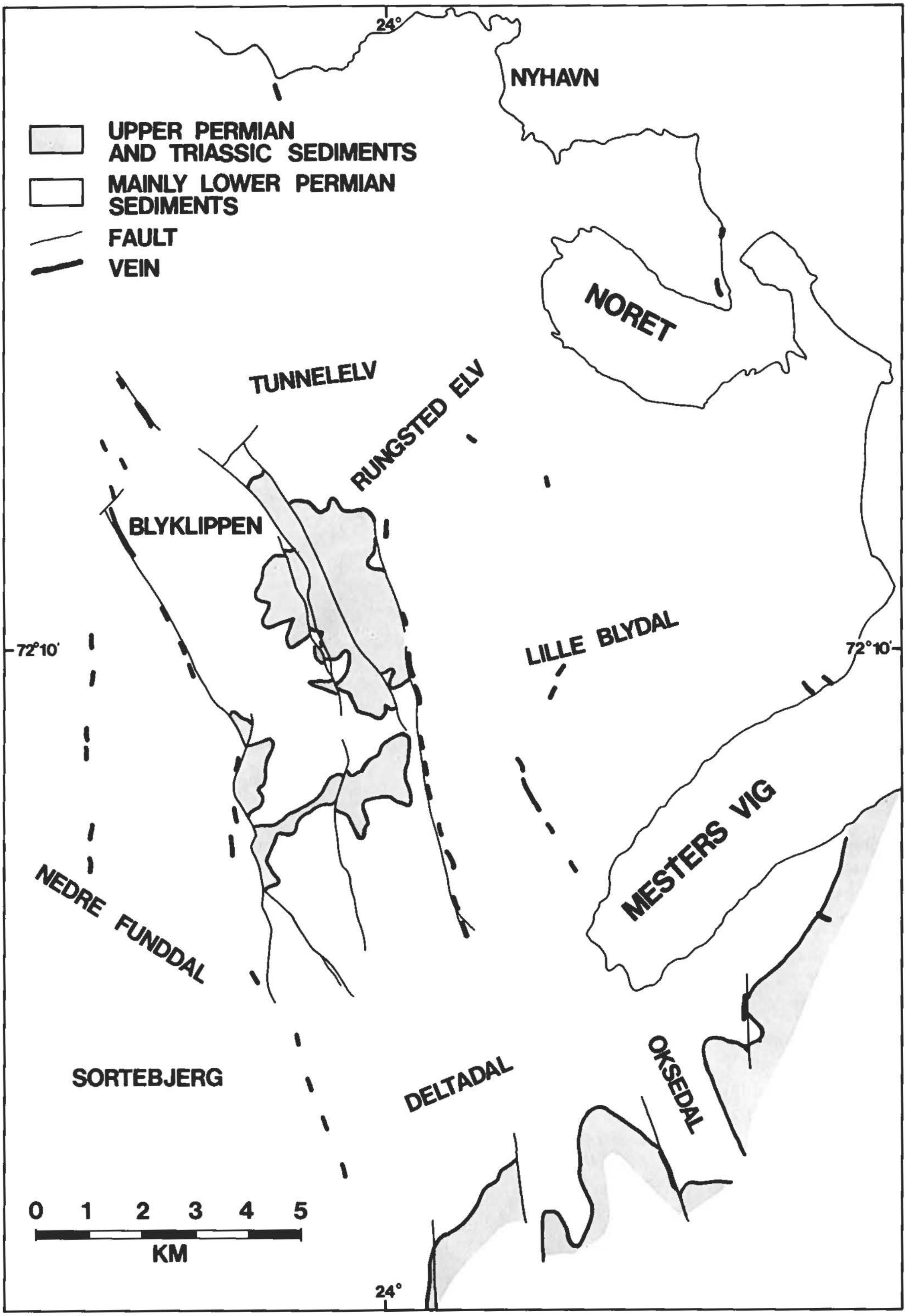


Fig. 63. Distribution of quartz veins and faults in the Mesters Vig area. Modified after Witzig (1954).

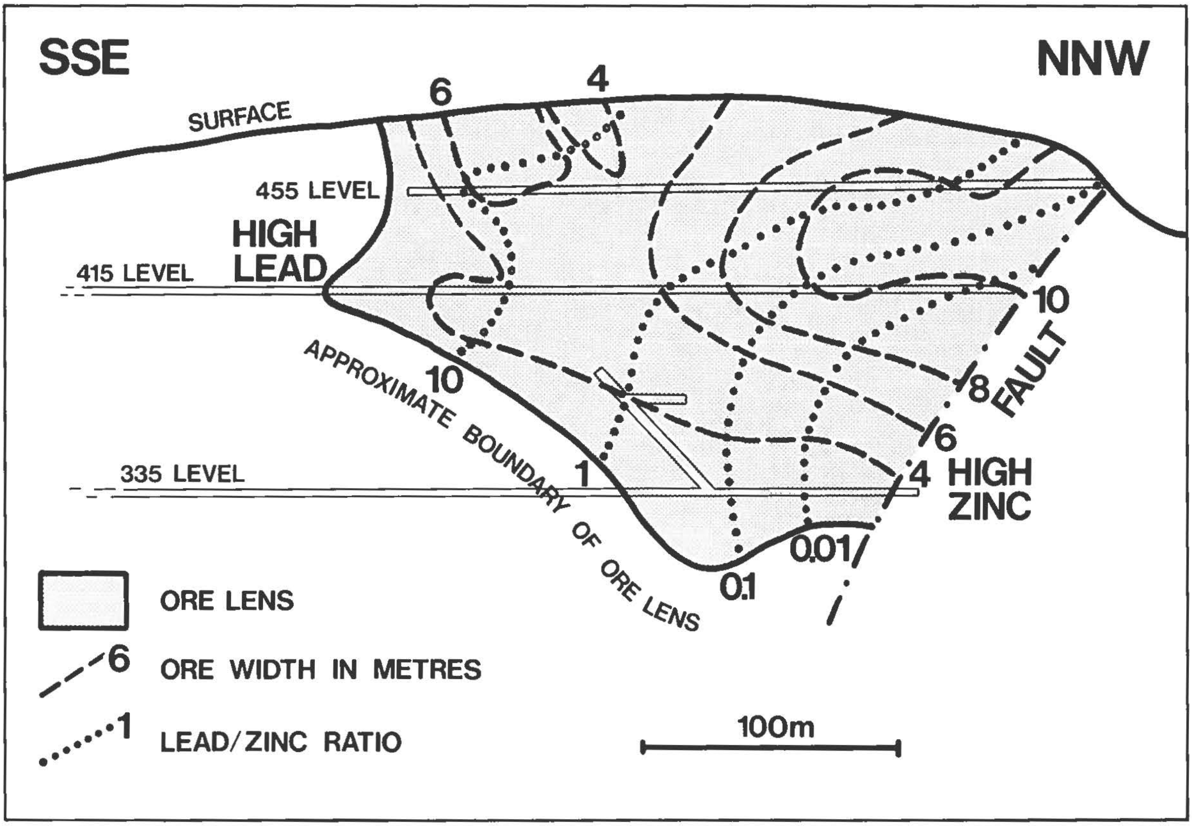


Fig. 64. Length section of the Blyklippen lead-zinc deposit. Modified after Brown (1955).

mylonitized ore lenses in the fault plane. Gross (1956) assumed the ore lenses along the transverse fault to be primary and argued that the transverse fault had acted as a channel for mineralizing solutions.

Vein system 3 km southeast of Blyklippen ("Langelinie Vein")

Three km south of Blyklippen along the same graben fault structure three quartz vein zones outcrop at 350–480 m a.s.l.. The largest and only sulphide-bearing is 30 m long and up to 15 m wide. The sulphides include galena, chalcopyrite, sphalerite and pyrite. A single chip sample of the vein yielded 9.0% Pb, 1.6% Cu, 0.04% Zn, 28 ppm Ag, 0.02 ppm Au and 36 ppm Sb.

The Sortebjerg vein system ("Sorte Hjørne", "Pings Elv" etc.) (126)

The vein system is found at the southern end of the fault structure which also hosts the Blyklippen deposit at an altitude of 10–300 m. For a distance of 4 km, five outcrops occur where rivers or streams have removed the overburden. The outcrops follow a line trending 150°. Individual outcrops are 20–200 m long and the silicified and quartz-veined zone is up to 20 m wide. The mean orientation is 150°/70° E. Galena and sphalerite are found as irregularly distributed pods and lenses, which are generally concentrated along the hanging wall. The largest lens, which consists of massive galena, is 13 m long and 0.75 m wide. Diamond drilling at several of the outcrops has confirmed the irregular distribution and also demonstrated that sphalerite is more abundant than galena. Within the local area there is a tendency for sphalerite to be the main sulphide at levels below 270 m a.s.l., with minor amounts of chalcopyrite and galena, whereas at higher levels galena predominates with only trace amounts of sphalerite and chalcopyrite. Based on a few diamond drill holes along one of the outcrops, 220 000 tons with 9.3% Zn, 2.1% Pb and 0.7% Cu is indicated over a vein length of 250 m (Swiatecki 1981).

Northern Nedre Funddal – lower Gefion Elv

One to three km west of the Blyklippen – Sortebjerg fault a number of small barren quartz vein outcrops occur along a line trending 0°–5°.

Deltadal – Rungsted Elv vein system ("Holberg Vein", "Rungsted Vein")

This 8 km long discontinuous vein system is situated along the eastern border fault of the Mesters Vig graben. At the southern end near Deltadal the vein is in contact with sandstones of the Blyklippen and Profilbjerget members. Further north the veins are in contact with the Blyklippen Member at the footwall and Upper Permian limestone at the hanging wall.

The most southerly outcrop is situated 170–210 m a.s.l.. Quartz veins up to 0.3 m thick and quartz stringers occur sporadically within a 100x20 m zone. Two vein directions – 172°/65° W and 136°/86° W – exist in the area. The latter intersects the former. Sphalerite and galena are found in small amounts. A 5 m chip sample profile contains 1.5% Zn, 0.3% Cu and 0.1% Pb.

The next outcrop to the north is situated 280–350 m a.s.l.. It is a strongly silicified up to 50 m wide zone with massive quartz veins up to 1 m thick. Galena and sphalerite are concentrated in the southwestern part of the zone and in addition veinlets with massive chalcopyrite occur in the central part. The average base-metal content of five 10 m long chip sample profiles is 4.4% Pb, 0.8% Zn, 0.2% Cu and 10 ppm Ag.

Further north at altitudes of 460–560 m a.s.l. the vein zone can be followed for 300 m. The diffuse vein zone is up to 100 m wide. Quartz and baryte are the gangue minerals and minor galena only occurs in the western upper part of the outcrop. Chip samples yielded less than 1% combined base-metals.

Other vein outcrops exist along several kilometres to the north. The "Holberg Pass" outcrop is situated 760–910 m a.s.l. and can be traced for 1000 m. It ranges in thickness from 2 to 30 m. Quartz and baryte are the gangue minerals. Galena occurs as up to 10 cm large aggregates with subordinate sphalerite and chalcopyrite. A chip sample contains 2.1% Pb and is low in zinc and copper. At this level Upper Permian limestone occurs at the hanging wall side although not in direct contact with the vein mineralization. The limestone contains calcite of the "zebra type" and locally cm-thick baryte veinlets.

At the northern end of the vein system a major outcrop occurs in the upper reaches of Rungsted Elv at an altitude of 490 m a.s.l.. The vein zone is 10 m wide and can be traced for 50 m. It comprises up to 0.4 m thick massive quartz veins, quartz stringers and minor baryte. Two massive 0.3 m thick galena veins occur in the northern part of the outcrop. Sphalerite and chalcopyrite are subordinate. The average of analyses from two 10 m long chip sample profiles shows 4.1% Pb, 0.5% Cu, 0.2% Zn and 14 ppm Ag.

Vein system 2 km east of Deltadal – Rungsted Elv ("Nuldal Vein")

From Mesters Vig to three km north five quartz vein outcrops occur at altitudes from 100–730 m a.s.l.. The vein zone is up to 10 m wide and consists of silicified sandstone, massive quartz veins and locally calcite veins. The quartz veining is orientated 150°/75° E. Galena is the most common sulphide. The most conspicuous occurrence is a 1 m thick, 8 m long and at least 2 m high lens of massive galena.

Veins in the area between Mesters Vig and Noret

Within this area scattered quartz vein occurrences exist. Along the ridge south of Lille Blydal several small quartz veins are found. The sulphide content is low. Near the coast at the north side of the entrance to Mesters Vig two quartz veins orientated 22°/76° E with malachite staining and minor sulphide were the first veins to be discovered in the area. A similar quartz vein occurs just west of the Tunnelelv delta.

Veins in the area southeast of Mesters Vig (127)

A vein zone occurs on the western slope of Oksedal at an altitude of 260–300 m a.s.l. The vein zone, which can be followed for 500 m, is parallel to a normal fault (160°/75° W) with a throw of *c.* 300 m. The hanging wall comprises Upper Permian conglomerates and limestones. The vein zone is up to 30 m wide and consists of metre-thick massive quartz veins, silicified host rock, baryte veins and dm-sized patches of galena and sphalerite.

Furthermore, the lower 5–9 m of the Upper Permian limestone sequence is replaced by alternating mm-thick layers of grey and white baryte ("zebra-baryte"). The zone with replacement is parallel with the vein zone and extends up to 150 m from the zone. Based on outcrops, distribution of baryte floats and a few diamond drill holes a near-surface area of 300 metres length is estimated to contain 440 000 tons with 60% baryte, but only trace amounts of galena and sphalerite. Of this tonnage, 260 000 tons represent high grade material with 90% baryte (Swiatecki 1981). The replacement mineralization is assumed to continue into the mountain. Boulder finds indicate that baryte-replaced limestone may also exist along the footwall of the vein. The mineralization is identical to the Bredehorn baryte occurrence.

Two kilometres north of Oksedal another vein occurs ("The Albis Vein"). It is a 3–5 m wide massive quartz vein with minor baryte and traces of galena, sphalerite and malachite. It is orientated 0°/70° E. Also in this area the Permian limestone is replaced by baryte and minor galena. A 2–3 m thick baryte horizon has been traced for 100 m at 400 m a.s.l. 1.5 km to the north of the "Albis Vein", Permian limestone is silicified and barytized for a thickness of 8 m. The altered section has been traced for 200 m.

Based on field observations a paragenetic sequence has been established for the Mesters Vig veins by Swiatecki (1983). The first and main mineralizing phase comprises quartz veining with major concentrations of sphalerite and galena. Succeeding the main mineralizing event shearing and brecciation took place. The next mineralizing phase comprises silicification and quartz cementing of the breccias and formation of baryte-bearing quartz veinlets which intersect the main mineralization. This vein generation contains only minor amounts of sphalerite and galena. Finally, calcite veinlets were formed.

The mineralogy of the veins is dominated by quartz, baryte, galena and sphalerite. In the early vein generation, quartz occurs as up to 5 cm large partly transparent crystals, or as fine-grained aggregates. Baryte occurs as 1–2 cm large crystals at the centre of the early quartz vein generation. Sphalerite and galena associated with the early generation are rarely found together and their age relation is not known. Both sulphides occur as up to m-sized massive coarse-grained lenses, and in addition sphalerite and quartz often display rhythmic growth. Microscopy reveals that both galena and sphalerite have undergone deformation, in some cases so intense that recrystallization with formation of fine-grained aggregates has taken place. The younger veins consist, in addition to quartz, of baryte, sphalerite, galena and chalcopyrite. Chalcopyrite also occurs as coronar overgrowth on both sphalerite and galena and as inclusions in sphalerite. Swiatecki (1983) showed that most chalcopyrite inclusions were not formed as exsolutions but were precipitated at a late stage in a three-dimensional network of thin pipes. Pyrite and pyrrhotite are rare constituents, and galena from the quartz veins has inclusions of tetrahedrite and bournonite. In addition, galena from the limestone replacement mineralization has inclusions of pyargyrite and stibnite. The Pb/Ag ratio varies from 2000 to 10 000 and there is a tendency for the ratio to decrease with increasing copper content.

The age of the mineralization is generally assumed to be Tertiary and the mineralizing event is correlated with the formation of the alkaline Werner Bjerge complex (Bondam & Brown 1955, Gross 1956). However, it may be noted that the quartz veins have never been observed in Triassic sediments and aeromagnetic measurements (H.C. Larsen, pers. comm.) show that the Mesters Vig mineralization is not related with the pronounced magnetic anomalies which otherwise outline the Tertiary intrusions. The lack of any zonation with respect to the intrusive complex indicates the same.

In general, all the post-Caledonian veins are difficult to date. The more important ones include veins associated with the Post-Devonian Main Fault System (nos 85–101), veins and strata-bound occurrences on Wegener Halvø and Canning Land (nos 47–56 and 108–124), the Bredehorn strata-bound occurrence (no. 107) and veins in the Mesters Vig area (no. 125–127) with host-rock ages ranging from Middle Devonian to Upper Permian. Of these, only the Mesters Vig veins have previously been described and attributed a Tertiary age. However, the Mesters Vig veins are closely related to for example the Bredehorn strata-bound occurrence, which is believed to be of Upper Permian/Lower Triassic age. Furthermore, many of the veins along the Post-Devonian Main Fault System and on Wegener Halvø/Canning Land might be even older (Upper Devonian–Lower Permian). Specifically, arguments supporting an Upper Permian/Lower Triassic age for the Mesters Vig veins and strata-bound occurrences of Bredehorn and Wegener Halvø include:

- Evidence of several tectonic phases, including a prominent rifting phase.
- Pronounced veining and alteration occur in the uppermost Permian deposits, whereas no sign whatsoever of hydrothermal activity is observed in the directly overlying Lower Triassic sediments. In fact, no veins have been found in post-Upper Permian sediments exept in direct contact with Tertiary alkaline intrusives in Werner Bjerge (no. 162) and Traill Ø (no. 166).
- Pb-isotope data (Coomer et al. 1974) show that the isotopic composition of the Mesters Vig veins, Schuchert Dal veins (nos 88–90) and the strata-bound occurrences of Bredehorn and Wegener Halvø is similar to that of a *c.* 420 Ma Caledonian granite from southern Stauning Alper (B.T. Hansen, pers. comm. 1985), whereas two galena-bearing samples from the Tertiary Malmbjerg occurrence (no. 160) have a slightly different composition.

Arguments supporting a Tertiary age include:

- Important rifting has occurred.
- A single lamprophyre dyke (of probable Tertiary age) is seen to be cut by one of the Mesters Vig quartz veins.
- Recent microscopic investigations of Upper Permian carbonates from Wegener Halvø indicate that mineralizing ferroan calcite cements were precipitated at a late stage of compaction (Surlyk et al. in press).

In summary, it is not possible to date these occurrences, which in theory together could span the time from Upper Devonian to Tertiary.

Copper on Traill Ø and in Giesecke Bjerge (128,129)

Strata-bound copper mineralization in the Upper Permian Huledal Formation was first noted by Nordmine/GGU in 1975 in Giesecke Bjerge on Gauss Halvø (Ryan & Sandwall 1975). This area was later investigated by Thomassen (1981 and 1982) who also noted minor occurrences in the Mesters Vig area (Thomassen 1980) and at Bredehorn (Thomassen & Schønwandt 1981). Finally, Harpøth (1982) noted and investigated a minor occurrence at Karstryggen and a major occurrence at Rubjerg Knude on central Traill Ø. Only the occurrences at Rubjerg Knude and in Giesecke Bjerge are described in some detail.

Rubjerg Knude (128)

In the central Traill Ø area, which has been described by Putallaz (1961), the 80–110 m thick Upper Permian Huledal Formation unconformably overlies Upper Carboniferous sediments. The formation consists of a 30–60 m thick conglomerate unit dominated by conglomerate with a high proportion of quartz and quartzitic pebbles and cobbles, and abundant limestone/dolomite and granite pebbles. Locally, thin sandstone beds interfinger with the conglomeratic beds. All the sediments are of braided alluvial plain origin with NNE transport direction.

Scattered outcrops of low-grade copper-silver and lead mineralization occur in the conglomerates in a 6x2 km ENE-WSW-striking belt (Fig. 65). Mineralization is confined to yellowish weathering conglomerate beds (representing slightly reducing conditions), which dominate in the mineralized belt. Outside this belt brownish red colours (representing oxidizing conditions) dominate the conglomerate unit. In general mineralization is associated with palaeochannels (70°) in the central part of the unit. At some localities, a vertical thickness of up to 20 m is mineralized, but on the average the outcropping thickness is 5–10 m. Continuous mineralization has been observed laterally for 200–300 m. The ore minerals are chalcocite with minor bornite, chalcopyrite and galena disseminated within the cement and in the coarser beds typically as encrustations on the pebbles and cobbles. In more fine-grained sandstone beds the sulphides occur disseminated and as blebs. Secondary malachite and azurite occur only in minor amounts. Vertical zonation is observed as copper at lower and lead(-zinc) at higher stratigraphic levels. Possible lateral zonation is observed as copper-mineral zoning. In the easternmost mineralized outcrops of the belt (Fig. 65) chalcopyrite is the dominant ore mineral, whereas chalcocite-(bornite) is the only primary copper mineral elsewhere.

Microscopically, the primary ore minerals chalcocite, bornite, chalcopyrite, galena and pyrite occur as cementing phases together with quartz and rutile/anatase. The cementing sulphide aggregates are often surrounded by fine-grained organic mattter. Authigenic quartz overgrowths on clastic grains often contain minor sulphide-phase inclusions. Secondary ore minerals comprise blaubleibender covellite, covellite, chalcopyrite, native copper, malachite, azurite and cerussite.

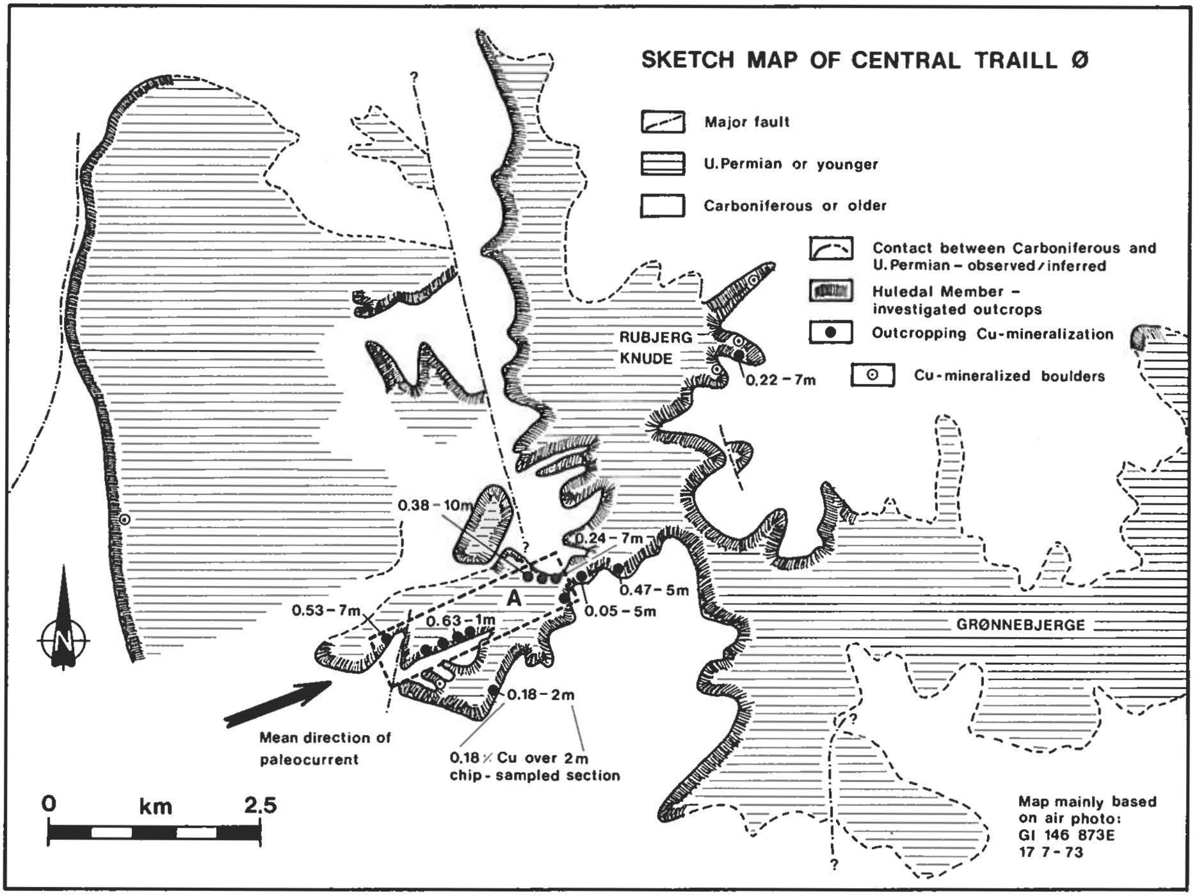


Fig. 65. Sketch map of central Traill Ø with copper occurrences in the Upper Permian Huledal Formation. Framed area – see text.

Based on 13 chip-sampled sections from a 1300x2500 m area with the highest mineralization intensity (Area A, Fig. 65), a tonnage-grade of *c.* 5 million tons with 0.3% Cu and minor Ag (*c.* 5 ppm), Pb and Zn has been suggested (Harpøth 1982).

An early diagenetic precipitation of copper and lead sulphides from silica-saturated mineralizing ground waters is suggested on the basis of microscopic observations of authigenic quartz overgrowths with sulphide inclusions. The sulphide precipitation could be explained by reducing conditions provided by the observed organic matter.

Giesecke Bjerge (129)

The Huledal Formation is only developed in the central and northern part of Giesecke Bjerge, where it has an average thickness of 10 m (Maync 1942). The conglomerates of the formation unconformably overlie Caledonian/Devonian granites, Devonian acid volcanics or Devonian–Carboniferous clastic sediments. The braided alluvial plain conglomerates consist of well-rounded quartzite pebbles/cobbles with a sand matrix and carbonate cement.

Scattered strata-bound copper and lead mineralization occurs in the Huledal Formation at several localities in Giesecke Bjerge. The most significant mineralization occurs in a 1000x400 m area SE of Ladderbjerg.

A pronounced lateral metal zonation is observed with copper in the southeastern part and lead in the northwestern part. In the transition zone a distinct vertical zonation exists with copper in the lower part and lead in the upper part of the formation. The copper mineralization is observed as irregular malachite and subordinate azurite stain with malachite and azurite coating the larger clasts and forming part of the cement together with goethite and chalcopyrite. The lead mineralization is barely noticable with scattered mm-sized galena spots.

Preliminary tonnage-grade estimates are based on eight chip-sample sections throughout the area. The copper mineralization, which extends over a thickness of *c.* 10 m, is estimated to contain a minimum of 2.5 million tons with a grade of 0.15% Cu and minor Ag (8 ppm), Pb and Zn. The lead mineralization, which on the average extends over a thickness of *c.* 8 m, is estimated to contain at least 2.5 million tons with a grade of 0.1% Pb.

The mineralization is believed to have a similar early diagenetic origin as that of central Traill Ø.

Mesozoic

In the Mesozoic (225–65 Ma), mineralization is mainly restricted to the Triassic of eastern Jameson Land,

Table 8. Triassic lithostratigraphy and mineralization in the Jameson Land Basin. Modified after Thomassen et al. (1982).

Series	Formation	Member	Beds	Max. thick.	Dominant lithology	Mineralization
Upper Triassic	Fleming Fjord	Ørsted Dal	Tait Bjerg	70 m	Light-coloured carbonate rocks and variegated mudstones	
				150 m	Red mudstones and light grey sandstones	*Cu*
		Malmros Klint		200 m	Red mudstones and fine sandstones	(Cu)
			Pingel Dal	35 m	Variegated cyclic-bedded sandstones and mudstones	Cu
		Edderfugledal	Sporfjeld	35 m	Yellowish cyclic-bedded dolomitic sediments	
Middle Triassic	Gipsdalen	Kap Seaforth		160 m	Variegated cyclic-bedded gypsiferous sediments	*Cu, Pb, Zn*
		Solfaldsdal		150 m	Red gypsiferous sandstones	
			Gråklint	30 m	Dark grey limestones and mudstones	*Pb, Zn, Cu*
		Kolledalen		180 m	Yellowish gypsiferous sandstones	
Lower Triassic	Pingo Dal	Klitdal and Paradigmabjerg		>450 m	Pink arkoses and conglomerates	Cu, Ag, Pb, (Zn)
		Rødstaken		330 m	Dark red sandstones	
	Wordie Creek			500 m	Greenish silty shales and sandstones	(Cu), (Pb), (Zn)

Cu = major mineralization; *Cu* = minor mineralization; (Cu) = trace of sulphides where numerous stratiform and strata-bound occurrences exist.

The observed mineralization comprises:

Base metals in east Jameson Land
Zirconium and rare-earth elements on Milne Land

Base metals in east Jameson Land (130–158)

Prior to 1972, mineralization in the Triassic was virtually unknown. Malachite-stained boulders of Triassic sandstone had been observed in Pingel Dal in 1900 (Nordenskjöld 1907) and traces of galena had been noted in Triassic limestone on Wegener Halvø (Grasmück & Trümpy 1969). During Nordmine reconnaissance of the Upper Permian limestones in 1972, copper- and lead-bearing boulders were collected in Devondal and in the following year mineralization was found in outcrop in Lower Triassic arkoses (Thomassen 1974). This find led to a semi-regional reconnaissance of the Triassic of the Jameson Land Basin, as well as detailed investigations of the Devondal area in 1974–76 and 1979–80. The exploration programme comprised stream, soil and rock geochemistry, lithostratigraphical mapping of selected areas as well as chip sampling and shallow diamond drilling (4 holes – total 41 drill metres) (Thomassen 1975, 1976, 1977 and 1979, Harpøth 1977, 1979, 1980 and 1981, Schønwandt 1980). The results have been summarized by Thomassen et al. (1982) (Table 8).

The Triassic geology of the Jameson Land Basin has been studied by Stauber (1942), Grasmück & Trümpy (1969), Perch-Nielsen et al. (1974) and Clemmensen (1977, 1978a and b, 1980) (Fig. 66). It comprises a *c.* 1700 m thick sequence of shallow marine to continental and lacustrine clastics with intercalations of evaporites and thin carbonates as summarized in Fig. 67. Mineralization of stratiform or strata-bound character occurs at six stratigraphical levels (Figs 67 and 68):

Wordie Creek Formation

The formation comprises marine silty shales with minor coarse, fluviatile arkoses. Insignificant mineralization occurs as scattered galena, sphalerite and pyrite (often replacing fossils) in calcareous concretions in the shales, and as occasional chalcocite, bornite, chalcopyrite and pyrite, rimming clay galls in the arkoses.

Pingo Dal Formation

Along the eastern border of the Jameson Land Basin, the Lower Triassic Pingo Dal Formation is developed as a belt of alluvial fan deposits (Klitdal Member) grading into and interfingering with braided river deposits and floodplain sediments (Paradigmabjerg Member) towards the west and north (Fig. 67). The alluvial fan sediments comprise pink and red, crossbedded conglomerates and pebbly arkoses with subordinate fine sandstones and mudstones. The braided river-flood-

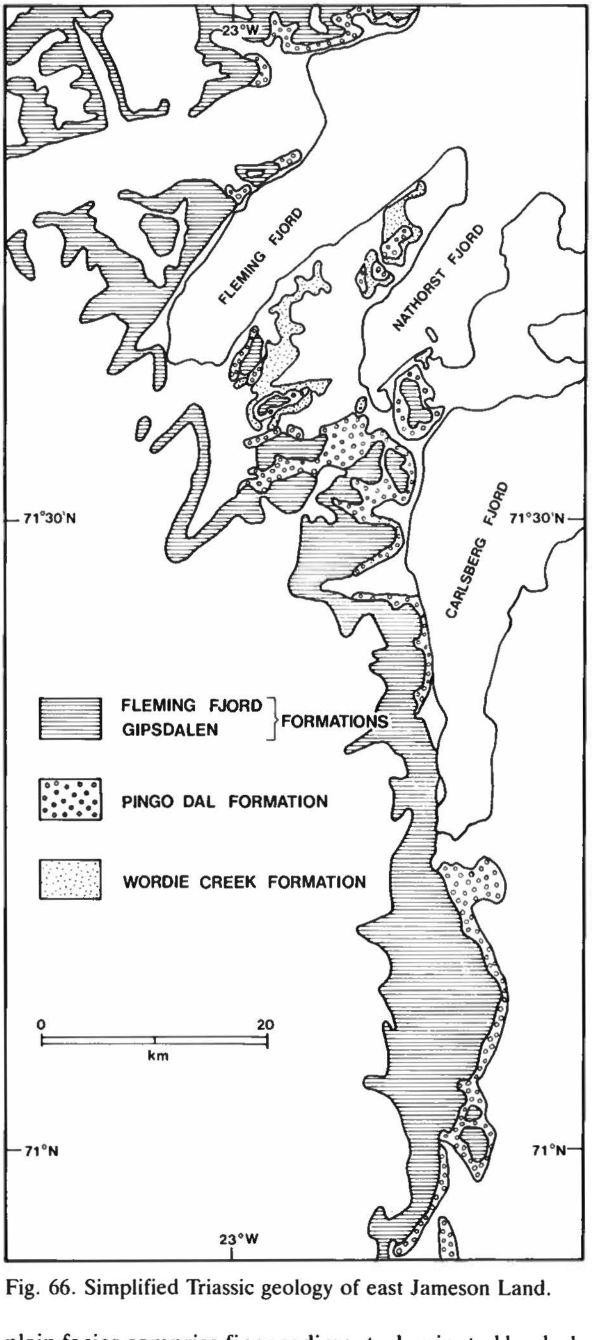


Fig. 66. Simplified Triassic geology of east Jameson Land.

plain facies comprise finer sediments dominated by dark red arkoses and abundant silt- and mudstones. Caliche horizons occur locally in the Devondal area.

In the Devondal area (Fig. 69) where the most significant mineralization occurs, a general trend in the direction of sediment transportation from southeast towards northwest is observed. A characteristic SE-NW decrease in the formation thickness from more than 500 m to 50 m and a pronounced colour shift from pinkish to dark red, i.e. from slightly reduced to oxidized conditions, also occurs.

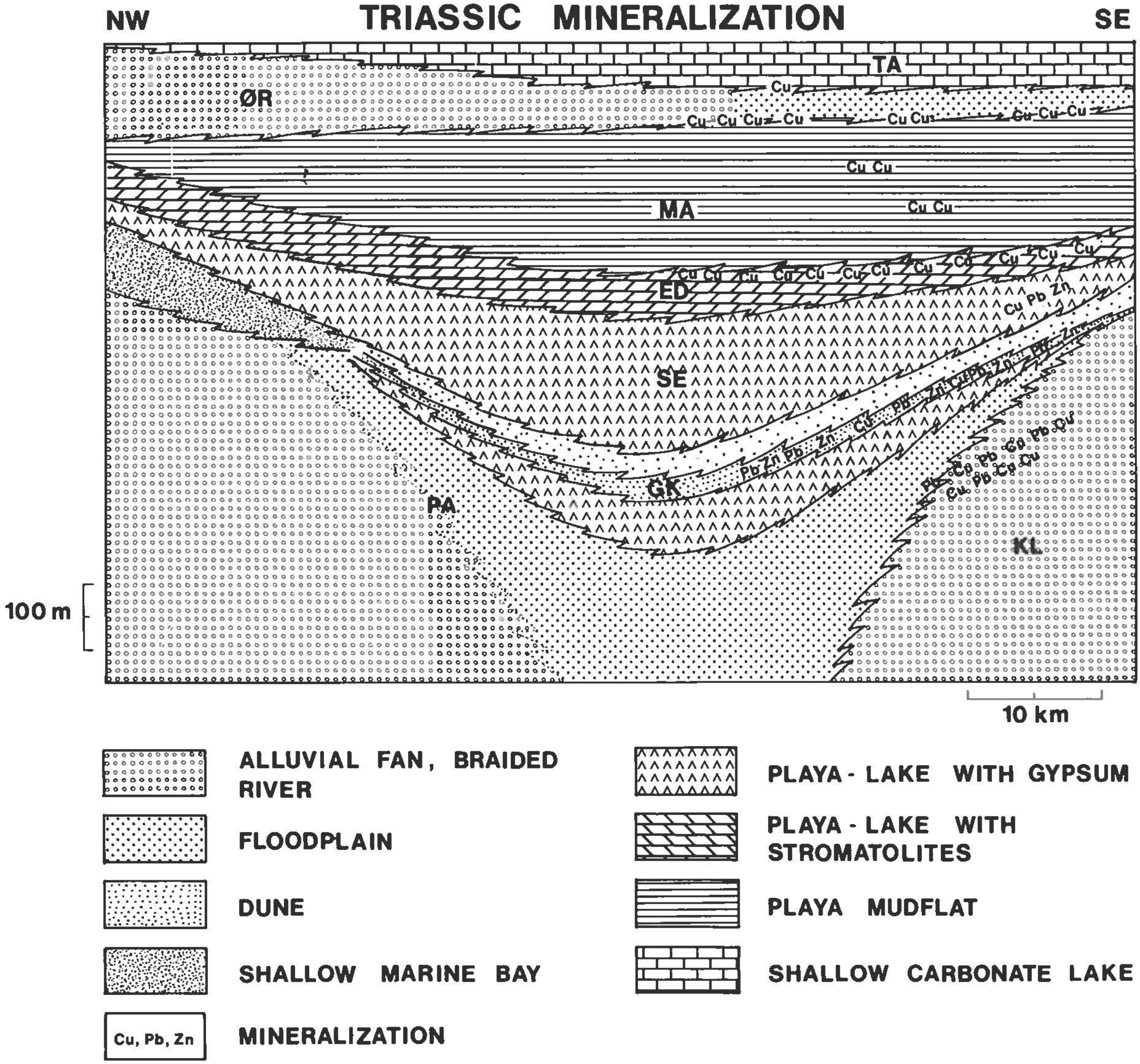


Fig. 67. Generalized facies pattern and mineralization of the Pingo Dal, Gipsdalen and Fleming Fjord Formations. KL = Klitdal Member, PA = Paradigmabjerg Member, GK = Gråklint Beds, SE = Kap Seaforth Member, ED = Edderfugledal Member, MA = Malmros Klint Member, ØR = Ørsted Dal Member, TA = Tait Bjerg Beds. The section runs from east of Bredehorn to the head of Carlsberg Fjord. Modified after Thomassen et al. (1982).

Copper-silver and lead mineralization is confined to a belt of distal alluvial fan sediments along the southern and eastern borders of the elevated, fault-bounded block of southwest Wegener Halvø – the Devondal area and the Paradigmabjerg area (Fig. 69). Mineralization occurs at several stratigraphical levels in 0.5–3 m thick pinkish-whitish arkose and conglomerate beds in both areas. The sulphides occur as irregular blebs, as mm-thick stratiform layers in the most coarse-grained foresets (Fig. 70), or as disseminations in m-thick beds. Subordinate, remobilized sulphides occur in cm-thick, cross-cutting, massive veins and lenses. The intensity of mineralization varies considerably both vertically and laterally. In particular, copper mineralization is erratic whereas lead-mineralized beds generally show much greater persistency. Within the mineralized levels, copper and lead mineralized beds occur separately, whereas both copper and lead sulphides occur in the remobilized veins. A vertical zonation with copper dominance in the lower part and lead in the upper part of the formation is observed throughout the area, and a lateral zonation with predominance of copper to the southeast and lead to the northwest exists for a distance of 6 km in the Devondal area.

The primary ore minerals are chalcocite and galena with minor bornite, chalcopyrite, pyrite, sphalerite, tennantite and betekhtinite. Secondary minerals include "blaubleibender" and normal covellite, cuprian galena (Clark & Sillitoe 1971), malachite, azurite, cerussite and goethite. Intergrowths are common among the copper minerals, but rare between the copper and lead minerals except in the remobilized veins. The ore minerals form the cement of the arkoses together with authigenic quartz, calcite and traces of albite, baryte and anatase. Replacement of clastic feldspar, especially by the copper minerals, is common in the remobilized parts. The relative age relationship of the cementing phases is: quartz (oldest) – lead and copper sulphides – calcite (youngest). The occurrence of small sulphide inclusions in authigenic quartz overgrowths on clastic grains indicates a certain overlap between the precipitation of quartz and sulphides. Geochemically the copper minerals are characterized by high silver contents. Microprobe analyses show an average silver content of 0.38% in chalcocite (32 analyses), 0.42% in bornite (13 analyses), 0.40% in covellite (10 analyses) and 1.05% in blaubleibender covellite (7 analyses). Other elements which show sporadic raised values in the copper-dominated paragenesis are in addition to lead and zinc, molybdenum (max. 1500 ppm), bismuth (max. 300 ppm) and cobalt (max. 300 ppm). In particular molybdenum is often anomalously high, although molybdenite has never been observed. The lead-dominated paragenesis is always low in silver with an average Pb/Ag ratio of 15 000. Zinc and to some extent copper are the only other metals which are enriched in these beds.

Due to the poor exposure of the easily weathering Pingo Dal Formation, only limited systematic sampling of the mineralization has been carried out. The existing data are compiled in Table 9. It appears that the lead-mineralized beds in the Devondal area have an average grade of 2–2.5% Pb with minor zinc and subordinate silver. The average grade of copper-mineralized beds is 0.1–1.0% Cu and 5–80 ppm Ag.

The observed mineralized localities (Fig. 69) are described below:

- In south Devondal, mineralization occurs 60–70 m below a marker horizon – the Gråklint Beds. The mineralized sequence is exposed at four localities (A-D, Fig. 69) for a lateral distance of 1.6 km. As the local end-moraines in between these exposures carry abundant mineralized boulders (Loc. E, Fig. 69), the level is assumed to be more or less continuously mineralized. Additional minor copper-bearing beds occur some 150 m stratigraphically below the Gråklint Beds.
- South of Kassen (Loc. F, Fig. 69) a sequence comprising several mineralized beds 5–20 m below the Gråklint Beds is deduced from sub-outcrops. Lead dominates and the highest copper content occurs in the basal part. Tennantite is the main copper mineral. The lateral extension is more than 200 m as evidenced by scree boulders. Systematic sampling indicates 2.4% lead for 17 m vertically and 0.44% Cu for 2 m. Furthermore, another copper (chalcocite)-mineralized level (Loc. G, Fig. 69) is indicated by mineralized boulders 50 m below.

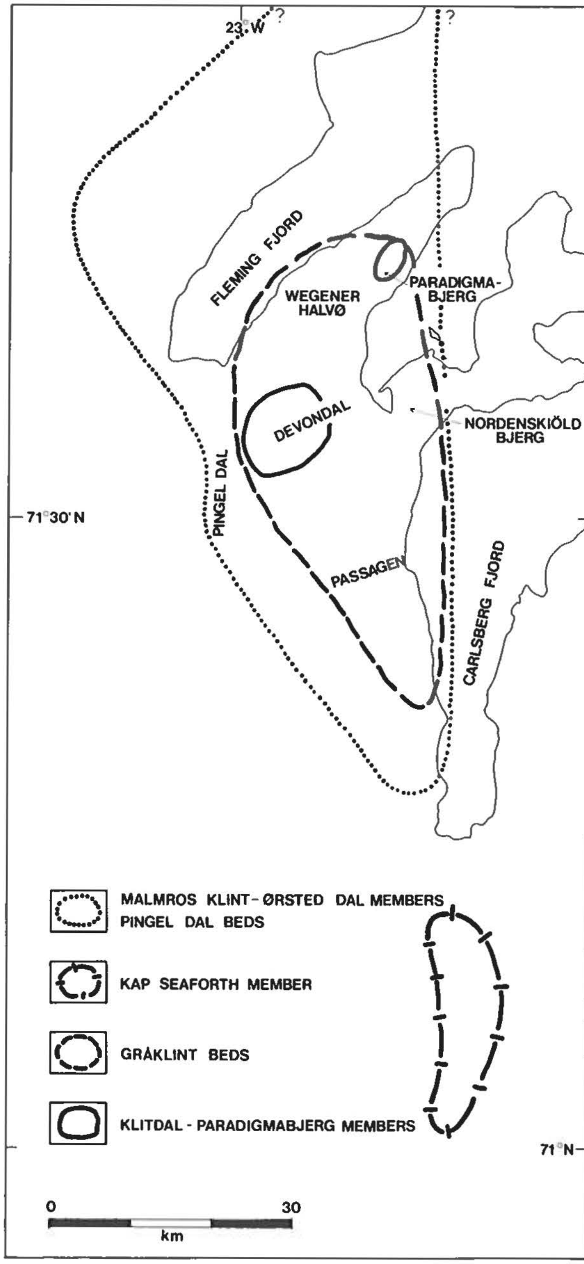


Fig. 68. Distribution of Triassic mineralization in east Jameson Land.

- North Myalinadal (Loc. H, Fig. 69) is dominated by sub-outcropping, metre-sized mineralized arkose blocks from 30–60 m below the marker beds. Again lead is dominant with copper restricted to the lower parts. Scattered copper- and lead-bearing boulders represent a lateral continuation for some 400 m towards the northeast. Systematic sampling indicates

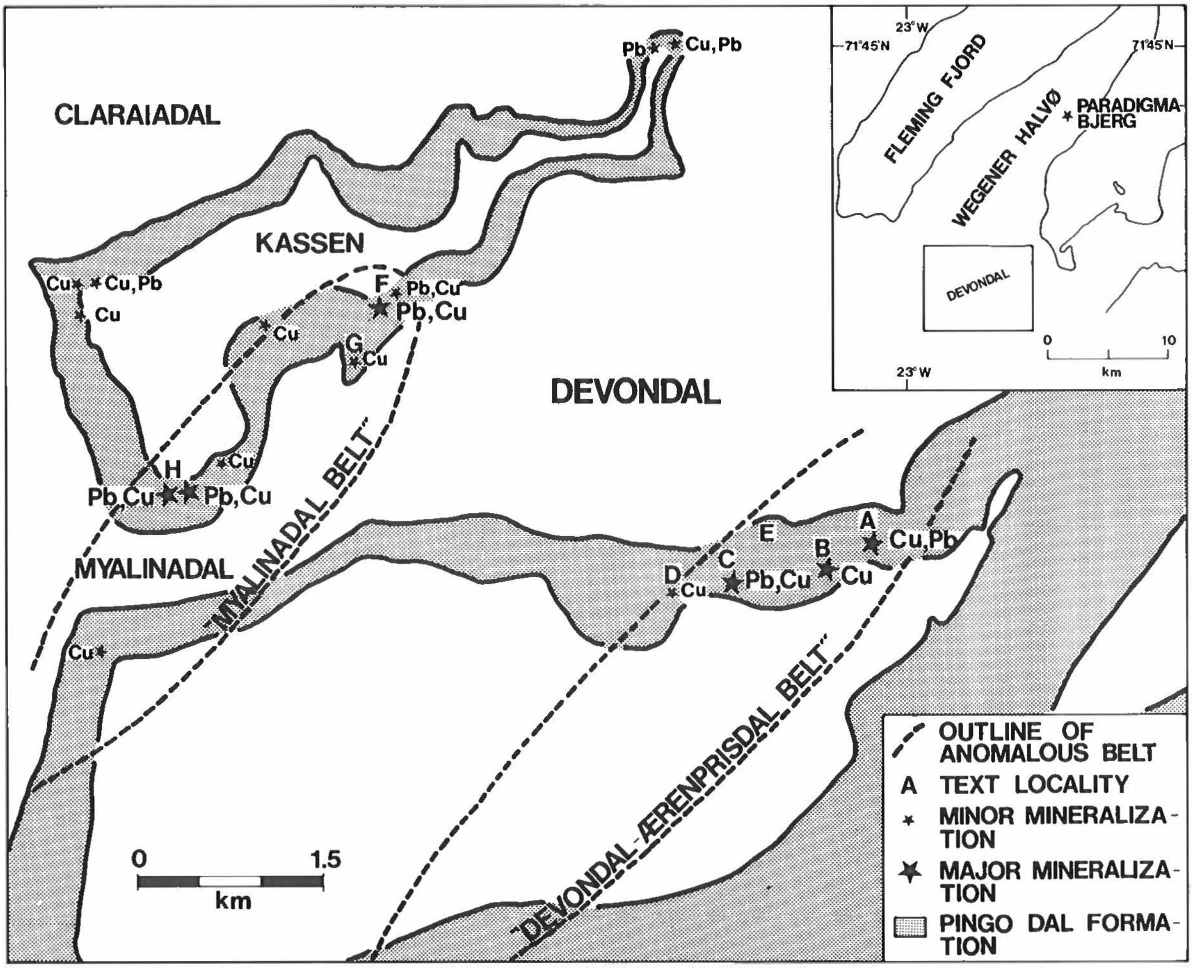


Fig. 69. Distribution of mineralization in the Triassic Pingo Dal Formation in the Devondal area.

1.1% lead for 27 m vertically and 0.23% copper for 8 m. Another copper-mineralized level 50 m below is indicated by boulder findings.

- In the Paradigmabjerg area (Fig. 69), copper and lead mineralization is similar to that of the Devondal area. At Paradigmabjerg proper, an up to 5 m thick copper- and lead-mineralized arkose sequence outcrops for 500 m. It displays a distinct lateral zonation with chalcocite-galena to the south and chalcopyrite-pyrite to the north. Similar mineralization exists on nearby smaller erosional remnants to the north.

As most exposures of the Pingo Dal Formation are covered by a thin blanket of scree or regolith, visual recognition of the mineralization is often impossible. To overcome this problem, and to gain systematic information about metal trends, a geochemical "soil" sample survey was carried out in the Devondal area. Samples of the loose surface material were collected with 10 m vertical spacing in 46 sections through the formation, giving a total of 717 samples. Based on statistical treatment of the analytical results, threshold values of 50 ppm Cu and 50 ppm Pb were selected to define anomalous samples (Harpøth 1980). These samples outline two anomalous areas: The *c.* 4 km^2 large Devondal-Ærenprisdal belt, and the 0.2 km^2 large Myalinadal belt (Fig. 69). The two belts are orientated SW-NE, i.e. perpendicular to the palaeotransport direction.

In summary the following picture of the Pingo Dal Formation mineralization emerges: In alluvial cones with transport directions towards northwest sulphides are hosted in permeable beds at the transition zone between distal alluvial fan sediments and braided river deposits. The zones are orientated perpendicular to the transport direction and characterized by interfingering of reduced and oxidized beds. It is assumed that the sulphides were precipitated in palaeochannels inside the zones by percolating ground-water during diagenesis (Fig. 71). Subsequently, some of the sulphides have been remobilized into cross-cutting fractures.

Fig. 70. Lead-mineralized, cross-bedded arkose boulder from the Triassic Pingo Dal Formation. Galena (dark grey) occurs as mm-thick stratiform layers in the most coarse-grained foresets. Devondal.

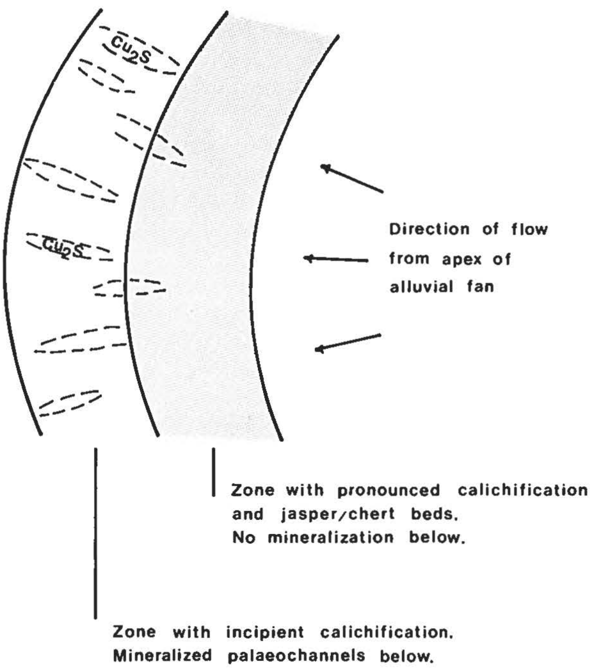


Fig. 71. Sketch with indicated zonal pattern of calichification and mineralization in the Triassic Pingo Dal Formation.

Gråklint Beds

This unit is 5–30 m thick in northeastern Jameson Land from where it wedges out towards both west and south. The beds are typically cliff-forming and display a variable lithology of grey, calcareous sandstone and limestone with intercalated black limestone and shale. The sediments represent a short marine episode in the continental-lacustrine Middle Triassic sequence.

Stratiform mineralization occurs over a *c.* 500 km^2 large area between Fleming Fjord and Carlsberg Fjord (130, 131) (Fig. 68). Disseminated, fine-grained sulphides are hosted in one or more dm-m thick beds of black shale/limestone and in the uppermost 10–50 cm of underlying grey, calcareous sandstone or limestone. The mineralized horizons are continuous for several hun-

Table 9. Summary of chip-sample and drill-core analyses from the Pingo Dal Formation, Devondal area. Localities refer to Fig. 69.

Locality	Sample type	Total length (m)	Average true width	Average			
				Cu (%)	Pb (%)	Zn (%)	Ag (ppm)
A	Chip samples	26.05	1.63	0.07	0.13	0.00	3
A	Drill core	–	2.22	0.18	1.31	–	3
B	Chip samples	17.90	1.49	0.28	0.00	0.00	11
E	Chip samples (Cu-boulders)	5.80	0.83	0.94	0.05	0.00	81
E	Chip samples (Pb-boulders)	9.35	1.34	0.05	2.52	0.24	5
F	Chip samples	–	16	0.09	2.39	–	3
H	Chip samples (upper beds)	–	8	0.00	1.84	–	2
H	Chip samples (lower beds)	–	10	0.23	0.27	–	4

dreds of metres laterally, but metal contents are relatively low – typically 1–2% combined lead-zinc-copper.

Galena and pale sphalerite are the main sulphides, pyrite and chalcopyrite occur in varying amounts, and bornite, chalcocite and marcasite are subordinate. Irregular intergrowths are common among the sulphides which often exhibit colloform textures.

A synsedimentary-diagenetic origin is presumed.

Kap Seaforth Member

The member is composed of cyclically-bedded sandstones, mudstones, carbonates and gypsum beds of shallow lake, sabkha and aeolian origin (Clemmensen 1978a). Mineralization is restricted to a *c.* 100 km^2 large sub-basin south of Carlsberg Fjord (130 and 131) (Fig. 68). The unit is here up to 100 m thick and poorly exposed.

Lead-zinc-mineralized mudstones and dolostones occur at several stratigraphical levels. Below the lowermost mudstone bed, a 20–50 cm copper-bearing, grey, calcareous sandstone horizon occurs. Chalcocite and covellite with subordinate bornite, galena and sphalerite form part of the cement together with calcite and quartz. The horizon also contains relatively abundant plant fragments, and plant cells may be replaced by sulphides. The black mudstones and dolostones contain disseminated, fine-grained galena, sphalerite and minor pyrite, typically with colloform textures. Although an extremely base-metal-rich sample (50% Cu, 9% Pb and 0.7% Ag) has been found, base-metal contents are generally below one per cent in the mineralized layers.

A synsedimentary-diagenetic origin is presumed.

Pingel Dal Beds

This 20–40 m thick unit comprises cyclically bedded grey quartz sandstone, red sandstone and siltstone, yellow dolostone, green mudstone, flat pebble conglomerate and stromatolitic limestone. Ripple marks, dessication cracks and non-marine trace fossils are common. A fluctuating shallow lacustrine depositional environment has been proposed for this Late Triassic unit (Clemmensen 1978b, 1980).

Copper mineralization is known over a *c.* 1000 km^2 large area from northwest of Fleming Fjord to the head of Carlsberg Fjord (Fig. 68). Three lithofacies with mineralization can be distinguished: (1) a 0.5–1 m thick, black, silty mudstone with sand lenses which laterally interfingers with (2) 1–2 m thick beds of alternating light grey, flaser-bedded sandstone and black, silty shales. The two types occur in the upper part of the unit and are overlain by red mudstones, whereas type (3) is situated 15 m higher in the sequence where it forms two 0.2–1.3 m thick, yellowish weathering dolomitic mudstone horizons interbedded in red mudstones. It appears that the mineralization is controlled more by the chronostratigraphical position than by lithofacies. Type (1) is mainly known south of Passagen, type (2) in the area between Passagen and Fleming Fjord, and type (3) northwest of Fleming Fjord.

The copper minerals form stratiform, very fine-grained disseminations in the whole thickness of types (1)–(3) and the mineralized horizons show an extreme lateral persistency. The clay-silt laminae in the mineralized sediments are characterized by relatively abundant microscopic plant fragments. The ore minerals are mainly located in coarse-grained laminae, and especially concentrated along the contacts of fine-grained laminae and in mud cracks and burrows. The main sulphide is chalcocite, accompanied by minor bornite, blaubleibender covellite, chalcopyrite and pyrite. Bornite, with orientated chalcopyrite needles, is locally the main sulphide (Fig. 72).

A lateral mineral zonation can be distinguished with a chalcocite-bornite paragenesis in the central part of the palaeobasin surrounded by a chalcocite paragnesis. The Cu/Ag ratios indicate a similar lateral zoning, with the highest relative silver contents (Cu/Ag <1000) along the basinal axis (cf. Thomassen et al. 1982). Chip sample values are summarized in Table 10.

A synsedimentary-diagentic origin is presumed.

Malmros Klint and Ørsted Dal members

Overlying the Pingel Dal Beds are *c.* 200 m of red mudstones of playa flat origin of the Malmros Klint Member which grade upwards into the more sandy, distal flood-

Table 10. Summary of average chip-sample results of the copper-mineralized Pingel Dal Beds. Ranges in brackets.

Mineralization type	Locality	Number of sections	Thickness (cm)	Cu (%)	Zn (ppm)	Pb (ppm)	Ag (ppm)
(1)	South of Passagen	10	45 (30–100)	0.22 (0.015–0.48)	–	–	–
(2)	South-east of Fleming Fjord	13	165 (140–190)	0.12 (0.06–0.22)	90	30	1.2
(3)	North-west of Fleming Fjord	6	120 (100–130)	0.24 (0.05–0.52)	100	15	2.4

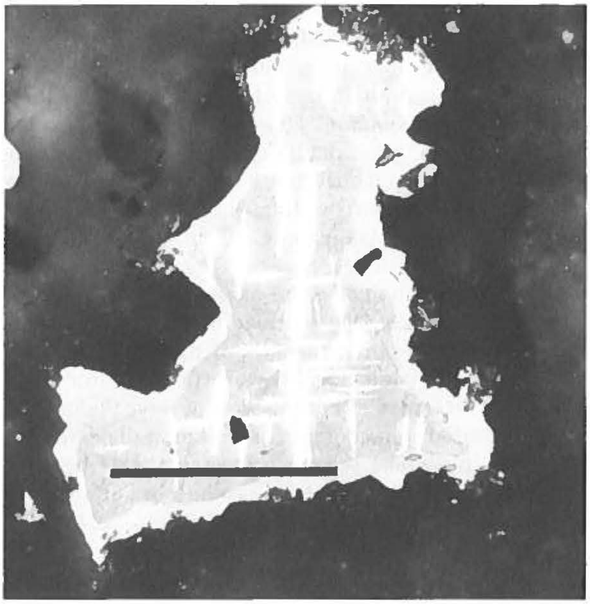


Fig. 72. Photomicrograph (reflected light) showing bornite with orientated chalcopyrite needles and rimming chalcocite. Pingel Dal Beds, east Jameson Land. Bar scale 50 microns.

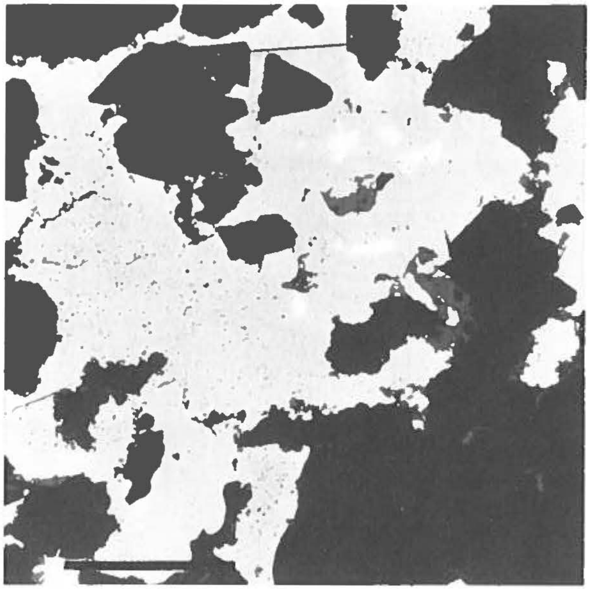


Fig. 73. Photomicrograph (reflected light) showing native copper (grey) with inclusions of native silver (white) in sandstone from the Ørsted Dal Member, east Jameson Land. Bar scale 100 microns.

plain deposits of the *c.* 130 m thick Ørsted Dal Member. Copper mineralization is located in the transition zone between the two members and has approximately the same areal distribution as in the Pingel Dal Beds.

Mineralization is hosted in two or more 10–100 cm thick, grey, pale-yellowish weathering beds intercalated with red mudstones. The beds consist of fine-grained, muscovite-bearing, carbonate-rich sandstone with conspicuous cross-lamination. Thin intraformational breccias, septarian nodules and plant fragments up to 30 cm long occur locally. The ore minerals appear partly as up to 10 cm long plates and blebs of native copper and copper arsenides, and partly as more fine-grained disseminations in few cm thick zones. Native copper, often rimmed by secondary cuprite, is the main mineral. Varying amounts of chalcocite with minor intergrown bornite and chalcopyrite, native silver (Fig. 73), and minerals of the domeykite-algodonite group also occur.

A lateral mineral zoning exists, with chalcocite dominating west of Fleming Fjord, native copper and domeykite-algodonite between Fleming Fjord and Passagen and domeykite-algodonite south of Passagen (Fig. 68). Chip samples from 21 sections collected for 650 m laterally in the uppermost mineralized bed at Nordenskiøld Bjerg show an average of *c.* 500 ppm Cu (range 27–3500 ppm) and 1.3 ppm Ag (range 0.8–4.8 ppm) over a thickness of 38 cm (range 25–60 cm). Maximum values of silver (787 ppm) and gold (0.5 ppm) stem from a sample with 27.5% Cu and 5% As. Furthermore, scattered raised vanadium values (max. 0.25%) are characteristic of this mineralization.

A genesis involving metal precipitation from percolating ground water during diagenesis is assumed.

Zirconium and rare-earth elements on Milne Land (159)

The first indication of fossil placers in Milne Land came from pan samples highly anomalous in zirconium, rare-earth elements and thorium, collected in 1968. In 1970, a number of thorium anomalies were detected over the Mesozoic sediments of east Milne Land during an airborne radiometric survey carried out by Nordmine and the Research Establishment Risø (Hintsteiner et al. 1970). Subsequent ground follow-up was carried out by Nordmine in 1971–72. The investigation of the most anomalous locality included geological mapping, surface grid sampling, measurements by scintillometer (U, Th) and portable X-ray spectrometer (Zr, Ce+La) as well as trenching and shallow diamond drilling (8 holes, total of 127 drill metres) (Schatzlmaier et al. 1973).

The Mesozoic sediments of east Milne Land have been divided into three formations, all of clastic composition and of Middle Jurassic to Lower Cretaceous ages (Birkelund et al. 1984). They rest on a basement of kaolinized, Middle Proterozoic migmatitic granite which forms an irregular erosional surface with a pronounced palaeorelief. The sediments represent a marine transgression from the east over a deeply eroded part of the Caledonian Fold Belt.

The basal part of the lowermost formation – the 100–200 m thick Charcot Bugt Formation – displays a vari-

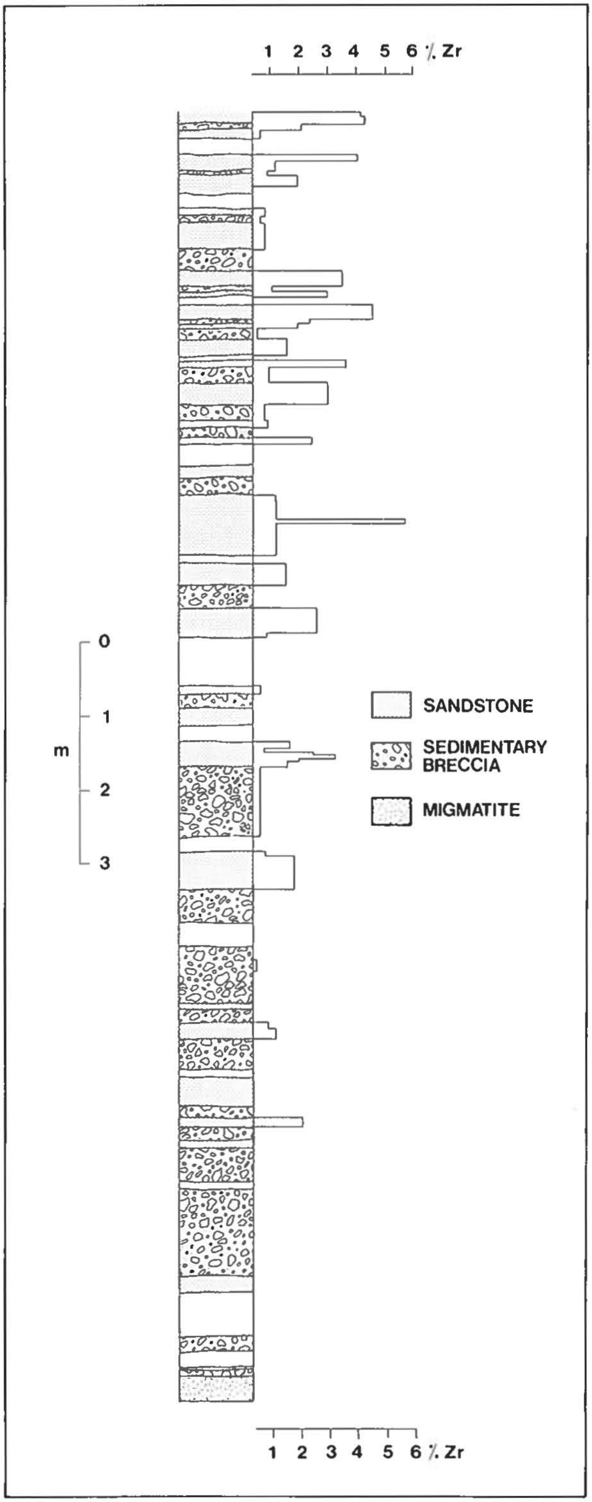


Fig. 74. Log of drill core from the basal unit of the Charcot Bugt Formation. Zirconium values were recorded on location by portable XRF. Total core loss (white areas in core log) of approximately 30% is probably due to unconsolidated sands and heavy sands.

able lithology (Callomon & Birkelund 1980). In some areas it commences with up to 25 m thick beds of conglomerates. In other areas conglomerates are subordinate, while intraformational breccias and cross-bedded sandstones are common. Near hill tops in the underlying basement, fossil-rich beds (mainly corals and bivalves) may be intercalated with coarse sandstones. The middle and upper parts of the Charcot Bugt Formation mainly consist of laminated and cross-bedded sandstones and gravelstones.

The thorium anomalies are associated with the basal part of the Charcot Bugt Formation which crops out in the western and northern parts of the sediment area. The most anomalous locality, an isolated outlier situated on an 800 m high hill-top west of Bays Fjelde, was investigated in some detail. It is 500 m in diameter and 40–50 m thick. The sequence has tentatively been divided into three units based on colour and grain size.

The basal unit is *c.* 20 m thick and comprises: (1) sedimentary breccias normally immediately above the contact to the basement, with up to 10 cm large fragments of crystalline rocks. (2) Coarse-grained arkosic sandstones with accessory garnet, mica and plant debris. This sequence is well sorted, often finely bedded and cross-bedded, with abundant trace fossils. 3) Mainly unconsolidated, violet, heavy mineral sands rich in garnet, ilmenite, rutile, zircon and monazite, which interfinger with the arkosic sandstone. The heavy mineral sands occur as irregularly distributed 10–40 cm thick lenses within the unit (Fig. 74).

The middle and upper units of the outlier mainly consist of arkosic sandstones with only accessory zircon or monazite.

Various analytical results from the heavy sands are presented in Table 11. Thorium, uranium and rare-earth elements are mainly hosted in monazite. The Th/U ratio is *c.* 10 and cerium constitutes approximately half of the rare-earth elements. The 20 m thick basal unit is estimated to contain 5 million tons with 1–3.8% Zr and 0.5–1.9% REO (Schatzlmaier et al. 1973).

The sediments described are assumed to have been laid down in a coastal to deltaic depositional environment with the continent to the west and the sea to the east. The heavy mineral lenses are thus regarded as coastal or fluviatile placers. The migmatites adjacent to the sediments have an unusually high radioactivity and are locally enriched in garnet, zircon and monazite (Nielsen & Løvborg 1976). The immediate hinterland therefore forms an obvious source area for the heavy minerals.

Tertiary

The Tertiary (65–1.8 Ma) consists mainly of plateau basalts. Furthermore felsic igneous intrusions occur in Scoresby Land, Traill Ø and Hold with Hope (Fig. 12).

Table 11. Analytical results of heavy-mineral sands from Milne Land. All values given in per cent.

Sample	Fe	Ti	Zr	Hf	Th	U	CeO_2	La_2O_3	Nd_2O_3	Y_2O_3	Gd_2O_3	Eu_2O_3
Drill core. 9 samples. Weighted average 4.8 cm	6.8	3.6	4.7	0.09	<0.1	<0.05	1.2	0.6	0.6	0.06	0.04	0.005
50 kg bulk sample of heavy sand from trenches	3.5	12.5	14.4	0.15	0.63	0.064	3.5	1.75	1.75	0.1	0.1	0.02
Heavy sand from trench No. 2	9.3	13.5	5.5	0.08	0.17	0.019	3.0	1.5	1.5	0.07	0.09	0.02
Composite sample from surface grid. 24 samples	5.0	2.5	0.5	<0.02	<0.1	<0.05	0.4	0.2	0.2	0.03	<0.01	0.05

REO	CeO_2	La_2O_3	Nd_2O_3	Pr_2O_3	Y_2O_3	Sm_2O_3	Yb_2O_3	Gd_2O_3	$(Dy, Ho, Eu)_2O_3$
100%	48.0	17.7	16.7	4.9	4.0	2.7	2.0	2.0	2.0

Widespread and important mineralization is associated with the intrusives.

The observed mineralization comprises:

- Molybdenum at Malmbjerg, Werner Bjerge
- Molybdenum at Mellempas, Werner Bjerge
- Lead-zinc in Werner Bjerge
- Magnetite skarn at Oksehorn, Scoresby Land
- Base metals in Slugtdal, Scoresby Land
- Molybdenum on Traill Ø
- Lead-zinc at Kap Simpson, Traill Ø
- Niobium on Traill Ø
- Gold on southern Hold with Hope

Molybdenum at Malmbjerg, Werner Bjerge (160)

Malmbjerg (Fig. 75) is a porphyry-molybdenum deposit of the Climax type. The deposit was discovered in 1954 during systematic mapping of the Werner Bjerge complex by members of the Danish East Greenland Expeditions (Bearth 1959).

The finding was followed up by Nordmine in 1955–56 by surface sampling (Pargether 1955). Deposit investigations were initiated in 1958, when a total of 1200 m was drilled and 28 m of adit (Schuchert Adit) excavated (Purdy & Hurd 1958). In 1959 a further 900 m of dia-

Fig. 75. The Malmbjerg molybdenum deposit seen from the west. The granite cupola is outlined against darker sediments. Schuchert Gletscher in the foreground.

mond drilling was performed. During the winter 1959–1960 a consortium mostly comprising shareholders in Nordisk Mineselskab A/S agreed to pay on behalf of Nordmine for the continued exploration and evaluation of the prospect. From 1960–62 the consortium drilled 9961 m, extended the Schuchert Adit 182 m and furthermore excavated the 477 m long Arcturus Adit.

In 1962 Arktisk Minekompagni A/S, a subsidiary company equally owned by AMAX and Nordisk Mineselskab A/S, was formed and all rights to the Malmbjerg prospect were transferred to this company. An intense exploration programme followed. A third adit, South Adit, was excavated for 277 m and again the Schuchert Adit was extended – this time by 365 m. From the adits a total of 9844 m was drilled. During the period 1963–69 mainly logistic and feasibility studies were undertaken. In 1970 a rock mechanics survey was performed and a surface alteration map produced in 1971 (Werneck et al. 1971).

In 1974 a relogging programme involving 10 300 m of drill core was undertaken to investigate the possibility of a second ore body at depth at Malmbjerg. The programme resulted in a comprehensive report on the geology of Malmbjerg and the hypothesis of a deeper ore body was further substantiated (Schassberger & Galey 1975).

Encouraged by this report a joint venture (EGMO) was formed by AMAX Inc. and Nordisk Mineselskab A/S in 1978 to continue exploration since the concession of Arktisk Minekompagni had expired. This joint venture drilled in 1979 a 972.3 m deep hole from the entrance of the Schuchert Adit (Fig. 9). No deep ore shell was found; only a weakly mineralized zone was intersected from 420 m to 530 m (Schassberger & Newall 1980). As a consequence Amax withdrew from East Greenland.

From 1954 to 1979, 147 bore holes totalling 22 877 m (including *c.* 1000 m through ice) were drilled and 1329 m of adits excavated to investigate the Malmbjerg deposit. An ore body of 150 million tons with a grade of 0.23% MoS_2 and 0.02% WO_3 at a cut-off of 0.16% MoS_2 has been proven (T. Schassberger, pers. comm. 1977).

Lately, three research projects partly sponsored by the Commission of the European Communities have dealt with various aspects of the Malmbjerg occurrence. These include two remote sensing projects carried out in 1979–81 by GGU and the Technical University of Denmark (Thyrsted & Friedman 1982, Conradsen et al. 1982, Conradsen & Harpøth 1984) and a project on porphyry-molybdenum deposits associated with rift environments started up in 1983 at the Geological Institute at the University of Århus.

The Malmbjerg porphyry-molybdenum deposit is associated with a composite alkali granite stock. The granite stock is part of the subvolcanic Werner Bjerge alkaline complex and is situated in the northwestern part of the complex (Fig. 80) (Bearth 1959). The Werner Bjerge complex is roughly circular with a diameter of about 17 km. Bearth (1959) subdivided the complex into three lithological units: 1) a mafic subcomplex in the southeastern part of the area, 2) a nepheline syenite subcomplex in the southwest and 3) an alkali syenite-granite subcomplex, to which Malmbjerg belongs, in the northern part of the complex (Fig. 80).

The mafic subcomplex is the oldest unit, whereas the age relation between the other two units is uncertain. However, nepheline syenite inclusions in the lower part of the Malmbjerg stock indicate that the syenite-granite subcomplex is younger than the nepheline syenite subcomplex.

Radiometric dating of syenites yields whole rock Rb-Sr ages of 30±2 Ma (Rex et al. 1979). K-Ar ages of the Malmbjerg granite stock range from 26.0±1.1 Ma to 21.1±0.9 Ma indicating that the granite stock belongs to the youngest events in the Werner Bjerge complex. The lithogeochemistry of the Werner Bjerge complex (Bearth 1959) and its mineralogy (Brooks et al. 1982) point towards a comagmatic origin for the units of the complex.

The Malmbjerg granite stock, which is isolated from the other Werner Bjerge intrusives, is exposed for 1 km along the Schuchert Gletscher (Figs 75 and 79). The stock intruded Carboniferous to Lower Permian sediments (arkose, shale and conglomerate) which dip moderately towards NE. At the southern contact the stock clearly cuts the sediments whereas along the northern part of the contact the granite is subparallel to the bedding of the sediments. Evidence of assimilation of sediments occur in the southern part of the stock. The contact relations indicate that the stock intruded from south towards north (Kirschner 1964). Schassberger & Galey (1975) described the granite stock as a passive intrusion.

As mentioned, the granite intrusion is a composite stock. It consists of three lithological units, each of which can be further subdivided into two texturally different subunits. The three main lithological units dominate successively lower levels of the stock (Figs 76 and 77; unit 3 not shown). The uppermost part of the stock consists of unit 1), a perthite granite with a quartz-feldspar porphyry roof phase. This is underlain by unit 2), a very heterogeneous porphyritic aplite. Part of the aplite, which is characterized by the occurrence of "eye-like" quartz phenocrysts, has been termed the Schuchert porphyry. The Schuchert porphyry subunit cuts the perthite granite. In the lower part of the stock unit 3) occurs. It comprises two texturally different porphyritic granites. The upper one has an equigranular to slightly porphyritic texture with rounded quartz whereas the other has plagioclase and orthoclase phenocrysts in a fine- to medium-grained groundmass. Dykes of different composition (basalt, trachyte, lamprophyre) postdate all units of the granite stock.

Three types of mineralization are associated with the Malmbjerg granite stock: 1) molybdenite mineralization, 2) greisen mineralization and 3) base-metal mineralization. Molybdenite mineralization occurs in a large

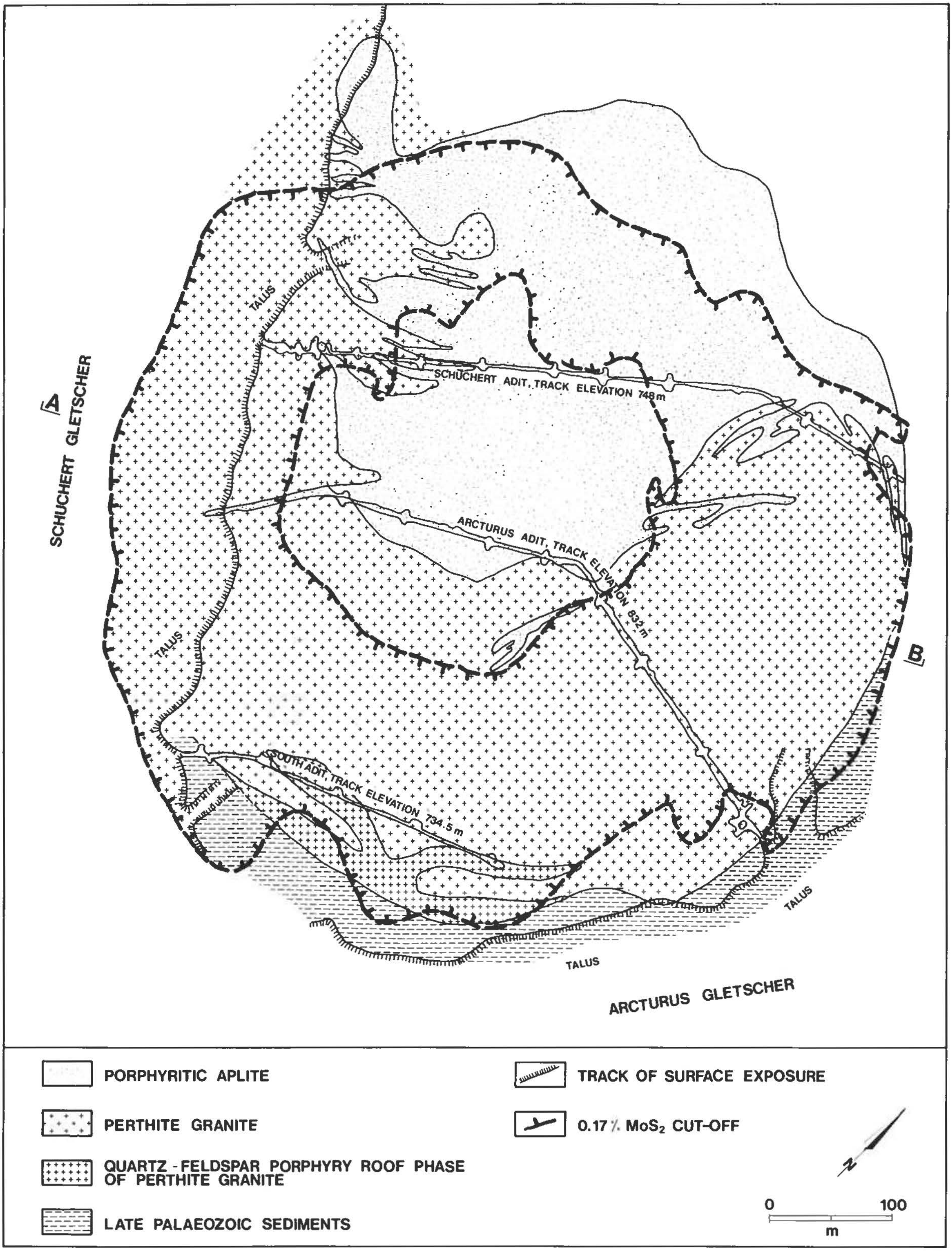


Fig. 76. Outline of geology and ore body at Malmbjerg. 600 m level. A-B indicates position of vertical section shown in Fig. 77. Modified after Schassberger & Galey (1975).

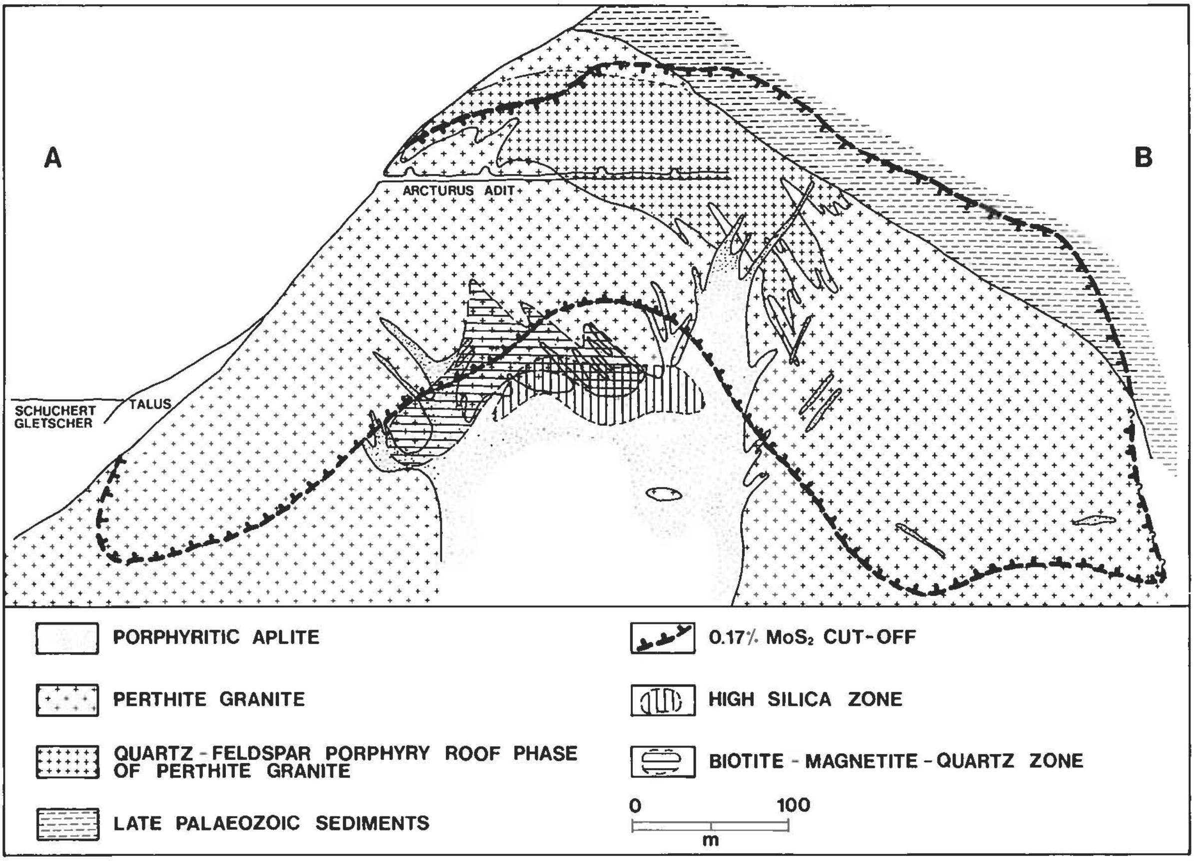


Fig. 77. Outline of geology and ore body at Malmbjerg. Vertical section. For position see Fig. 76. Modified after Schassberger & Galey (1975).

inverted bowl-shaped body (Sugden 1963) and represents the major mineralizing event. Greisen mineralization appears as flat-lying veins of up to 1 m thickness and locally makes up more than 10% of the volume. Base-metal mineralization occurs as vertical up to 30 cm thick argillized fracture zones, but represents only a minor mineralizing event.

Molybdenite mineralization is mainly located in the perthite granite and its equivalent roof phase. In addition, sediments immediately above the granite cupola are also mineralized (Fig. 77). Scattered mineralization occurs in the heterogenous porphyritic aplite subunit. It is a characteristic feature that the Schuchert porphyry part of the porphyritic aplite is only weakly mineralized. A weakly mineralized zone, only encountered in the deep hole from 1979 and now believed to represent a seperate mineralization, occurs below the Schuchert porphyry in the top of the porphyritic granite.

Molybdenite occurs in veinlets ranging in thickness from hairline up to about 5 cm. The veinlets form a network of mutually offsetting veins. Four mineral assemblages can be distinguished in the network: 1) biotite-molybdenite-quartz-magnetite±fluorite±siderite, 2) biotite-molybdenite, 3) molybdenite-quartz, and 4) fluorite-molybdenite±quartz. In the molybdenite-quartz veins, molybdenite generally occurs along the contact with quartz filling the central part of the vein; however, veins with the opposite zonation are also found in the network. Veins with repeated quartz-molybdenite bands (ribbon type) also form part of the network. Molybdenite is generally fine-grained in the biotite and quartz-molybdenite assemblages whereas it is more coarse-grained in the fluorite assemblages. Pyrite occurs only as an accessory mineral in the ore with an overall content of less than one per cent. Age relations between the four assemblages are not well established. However, the biotite assemblages are often cut by the other assemblages. This indicates that the biotite assemblages in general are the older ones. Molybdenite mineralization of lower grade than the 0.17% MoS_2 cut off shown in Figs 76 and 77 extends outwards for at least 150 m.

Greisen mineralization occurs as flat-lying up to one metre thick veins, which individually can be followed for several hundred metres, occurring both in the granite stock and in the surrounding contact-metamorphosed sediments. Horizontal greisen veins are abundant in the upper contact zone of the heterogeneous porphyritic aplite subunit, where they locally make up more than 10%. Very few greisen veins occur in the uppermost 100 m of the granite cupola. Generally, the greisen veins appear as open-space fillings dominated by columnar quartz. Other minerals are: topaz, wolframite, fluorite, coarse-grained molybdenite and locally beryl, cassiterite, siderite, pyrite, sphalerite, chalcopyrite, bismuth and bismuthinite. Locally, the greisen veins show a complex paragenetic development with up to three generations of topaz and pyrite (Kirschner 1964). In general the veins cut the network molybdenite mineralization; however, quartz-molybdenite veinlets cutting greisen have been noted. This places the greisen event at the final stage of the network molybdenite formation.

Base-metal mineralization occurs in subvertical argillized fracture zones mostly outside the network molybdenite mineralization. Two assemblages can be distinguished: 1) quartz-biotite-sphalerite-chalcopyrite-galena±pyrite±siderite and 2) dolomite/ankerite-fluorite-sphalerite±pyrite. The base-metal mineralization cuts both the greisen and the network mineralization and is clearly the youngest mineralizing event. No age relation has been established between the two base-metal assemblages, however the carbonate-fluorite assemblage is believed to represent the lower temperature of formation of the two assemblages (Kirschner 1964).

Pronounced alteration is associated with the mineralization. Alteration occurs both inside, below and above the network molybdenum mineralization. A biotite-magnetite-quartz alteration zone is entirely confined to the network mineralization (Schassberger & Galey 1975). The zone is irregular in shape and roughly located along the upper surface of the porphyritic aplite subunit (Fig. 77). It extends for about 300 m (N-S), 120 m (E-W) and is up to 70 m thick. The alteration zone is characterized by quartz veining and flooding (up to 40% of the volume), by disseminated biotite (up to 40% of the volume) and by magnetite (up to 20% of the volume). In the most intensely altered part of the zone the original rock textures are destroyed. Below the ore zone a high silica zone (Schassberger & Galey 1975) is located in the central part of the stock (Fig. 77). It measures 130 m (N-S) by 90 m (E-W) and is up to 45 m thick. The zone is characterized by an almost complete replacement of the primary rock phases by massive as well as vein quartz. The high silica zone is further characterized by a sharp decrease in both molybdenum and potassium content.

Above the ore zone three alteration zones have been distinguished at surface (Geyti 1981). Closest to the granite the surface is intensely black-stained due to manganese oxides. In this zone veins and veinlets of quartz are abundant, whereas molybdenite, fluorite and pyrite only occur in minor amounts. Outside the manganese-oxide zone a prominent yellowish and reddish-coloured zone occurs in the sediments. In this zone sericitic/argillaceous alteration and quartz veining occur in up to metre-wide envelopes around fracture zones. Pyrite, as disseminated grains and in cross-cutting veinlets, invariably occurs in the zone with an estimated overall content of one volume per cent. Within this more or less homogeneously stained area a zone of more intense alteration known as "Gelbe Rinne" (Fig. 79) occurs. The outermost alteration zone is characterized by epidotization of the sediments. Epidote is found in small veinlets, but also as a more penetrative alteration of the shales.

In summary, the relation between the various intrusive phases, the mineralizing events and the alteration episodes are shown in Fig. 78. The perthite granite and its roof phase predate the network molybdenum miner-

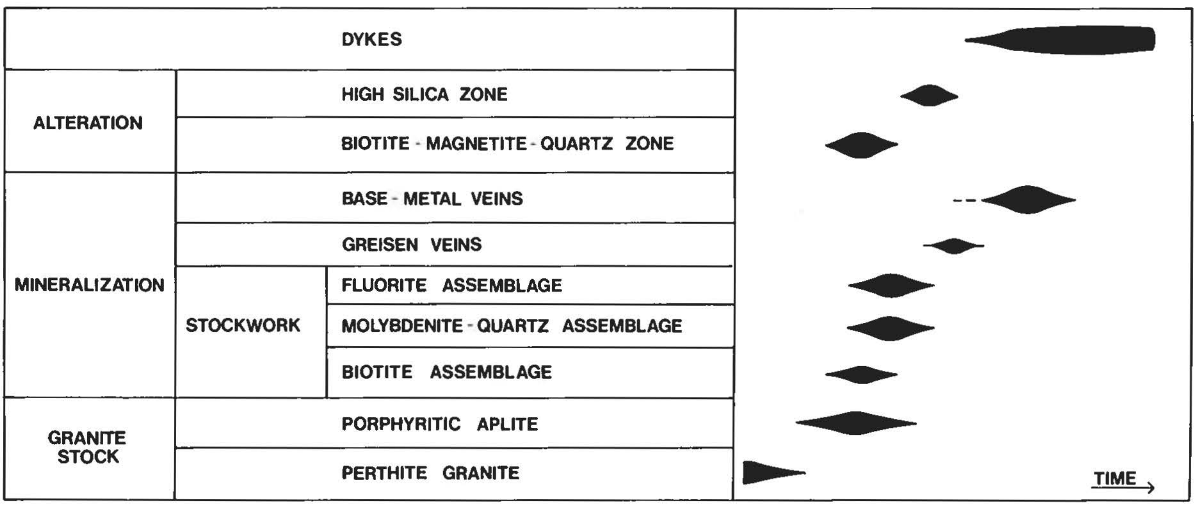


Fig. 78. Paragenetic development of the Malmbjerg porphyry-molybdenum deposit.

alization, whereas the porphyritic aplite subunit (the Schuchert porphyry) both cuts and is cut by all assemblages of the network mineralization. The biotite assemblages are generally older than the other veins of the network mineralization and the biotite-magnetite-quartz alteration zone is associated with the mineralizing biotite assemblages. The formation of greisen took place during and mainly after the latest stage of the network mineralization. The high silica zone invades the biotite-magnetite-quartz zone and the porphyritic aplite subunit. This indicates that the high silica zone is associated with the formation of greisen and probably was formed during the beginning of greisen formation. The base-metal mineralization postdates not only the Malmbjerg stock and the network mineralization, but also some of the dykes cutting the network. As no dyke chronology has been established it is impossible to conclude if only a part of the base-metal mineralization is related to the porphyry mineralization and the remaining part is associated with the intrusion of the dykes. However, some dykes have been affected by greisenization (Schassberger & Galey 1975), which shows that the dyke activity started at the final stage of the molybdenum mineralizing event.

Molybdenum at Mellempas, Werner Bjerge (161)

Molybdenite-bearing moraine boulders were discovered in 1949 in Deltadal by members of the Danish East Greenland Expeditions (Eklund 1949). In 1952 E. Kvale (working for the newly founded Nordisk Mineselskab A/S) located *in situ* disseminated molybdenite mineralization in a large area of the northwestern part of Røde Mur (Brown 1953). Kvale also reported *in situ* molybdenum mineralization at Kolossen (Brown 1953). Following the systematic mapping of Werner Bjerge in 1953–54, Bearth (1959) reported several findings of molybdenite-bearing moraine boulders at Mellemgletscher. In 1958 Nordmine geologists located in situ molybdenum mineralization just northwest of Mellempas, on the northern slope of Mellemgletscher and in the eastern part of Røde Mur (Polesnig & Vohryzka 1958). Finally, the area was investigated in 1980 by Geyti (1981).

Mellempas is situated 5 km northeast of the Malmbjerg porphyry-molybdenum occurrence (Fig. 79). In Mellempas an approximately 15 km^2 large (surface area) biotite granite stock has intruded syenites, porphyries and volcanic breccias of the alkali-syenite-granite subcomplex of the Werner Bjerge complex (see previous section on Malmbjerg). The biotite granite stock is genetically related to this subcomplex (Bearth 1959). The biotite granite intrusion is a composite stock dominated by medium- to coarse-grained granite. In the western part of the intrusion the coarse-grained granite has been intruded by quartz-feldspar-porphyry and aplite (Geyti 1981). The age relation between the aplite and the quartz-feldspar porphyry has not been established. Belonging to the granite stock is also the so-called black aplite which occurs in the extreme north of the granite intrusion (Fig. 79). The black aplite intrudes sediments and syenites, but show no other contact relations. Intense manganese-oxide coating on the highly fractured rock is responsible for its black appearance. All the granites in the stock are metaluminous alkali granites. The average molybdenum content of the entire stock is 14 ppm, however a faint distribution pattern, with the highest content (20–30 ppm) occurring in the quartz-feldspar porphyry and the black aplite, is indicated (Geyti 1981).

Mineralization occurs as disseminated grains of molybdenite in the coarse-grained granite. Furthermore it occurs in vugs and pegmatites in the coarse-grained granite and especially in the quartz-feldspar porphyry. The minerals in the vugs and pegmatites are: molybdenite, quartz, K-feldspar, fluorite, and pyrite. Bearth (1959) also reports wolframite. In addition, molybdenite has been observed in a few localities in the aplite mass as moly-paint and fine-grained molybdenite in veinlets occasionally with quartz-sericite-pyrite alteration. The observed overall grade is very low. The location of in situ molybdenum mineralization is shown in Fig. 80.

Prominent alteration in the Mellempas area is reflected as colour anomalies. These include a reddish-brown iron-oxide staining due to decomposition of pyrite and a black staining of manganese-oxide. The two alteration zones are roughly centered around the aplite mass (Fig. 79). The black staining form a ring-like pattern within the reddish-brown stained area. The manganese-oxide staining mainly occurs in the quartz-feldspar porphyry and the black aplite (Geyti 1981). The reddish-brown staining occurs partly as homogeneous staining, especially in the coarse-grained granite and partly as metre-wide subvertical clay-pyrite-quartz zones enveloped by argillaceous and/or sericite alteration. The subvertical clay zones occur over the entire granite intrusion, but are more frequent near the aplite mass.

The distribution and occurrence of the mineralization in the Mellempas area indicate a roof-zone mineralization, which is also supported by the lithology of the stock.

At Jernhatten, 8 km ESE of Mellempas, pyrite-bearing fragmental felsic rocks of vent-like character occur. Chip samples indicate a moderate molybdenum content (13–85 ppm); however one sample returned *c.* 600 ppm Mo without visible molybdenite.

Lead-zinc in Werner Bjerge (162)

The first finds of galena-bearing moraine boulders in Werner Bjerge were made in 1949 by members of the Danish East Greenland Expeditions (Eklund 1949). The finds were followed up in 1950–51 by Berglund and Ljungren (Bearth 1959), but the first *in situ* lead-zinc

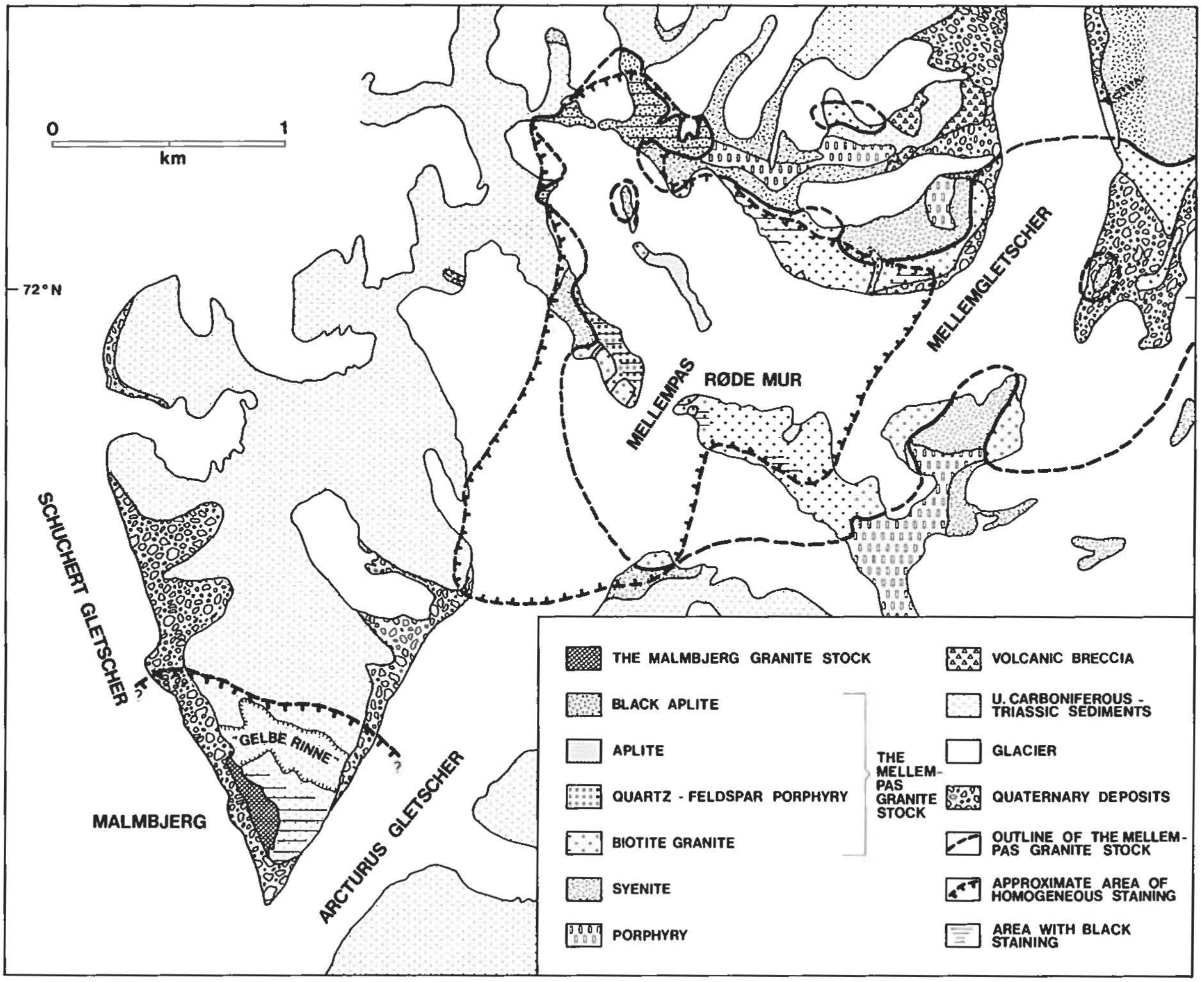


Fig. 79. Geology and alteration pattern of Mellempas area. Werner Bjerge. Based on Geyti (1981).

mineralization was observed by Bearth in 1954 at Malmbjerg, where sporadic veins are associated with the molybdenum mineralization (Bearth 1959). Later investigations by Nordmine in 1957–1958 confirmed the existence of scattered lead-zinc vein mineralization (Young 1957, Polesnig & Vohryzka 1958) in the northern part of Werner Bjerge (Fig. 80).

Three types of lead-zinc occurrences are known: a) veins in granite, b) veins in Carboniferous – Lower Permian arkoses and c) skarn in Upper Permian carbonates.

In the eastern part of Røde Mur (Locality A, Fig. 80) several small NW-striking quartz-fluorite veins occur in biotite granite of the Mellempas granite stock. The veins contain abundant pyrite and locally, massive galena-sphalerite bodies of up to 0.5 m thickness and up to 2 m length occur. However, the overall grade is believed to be a few per cent combined lead-zinc.

At locality B (Fig. 80) a WNW-striking 1–4 m wide, 300 m long and 150 m high vein zone occurs in Carboniferous–Lower Permian arkoses. The vein zone occurs in a fault where mylonitization is widespread. The vein is not observed in outcrop, but as semi-outcropping scree boulders along the fault. The gangue consists of quartz and carbonate (mainly ankerite) with minor fluorite. Galena (up to 0.5 cm crystals), sphalerite (up to 2 cm aggregates) and chalcopyrite (small grains) occur in varying amounts. At locality E (Fig. 80) a vertical, NNW-striking vein zone occurs. It is 5 m thick and is exposed for a length of 250 m and a height of 200 m. The zone comprises a vertical fault with a basalt dyke intruding the eastern part. Mineralization occurs as veins and veinlets of pyrite, sphalerite and galena. Pyrite is the most abundant sulphide mineral, but locally fine-grained sphalerite may form up to 50% of the infilling material. Sphalerite is also replacing shaly intervals near the basalt dyke and the fault plane. Galena is found mainly near the top of the zone. The zone is estimated to contain at least 300 000 tons with 1–2% zinc. Similar but minor occurrences are located in the west-

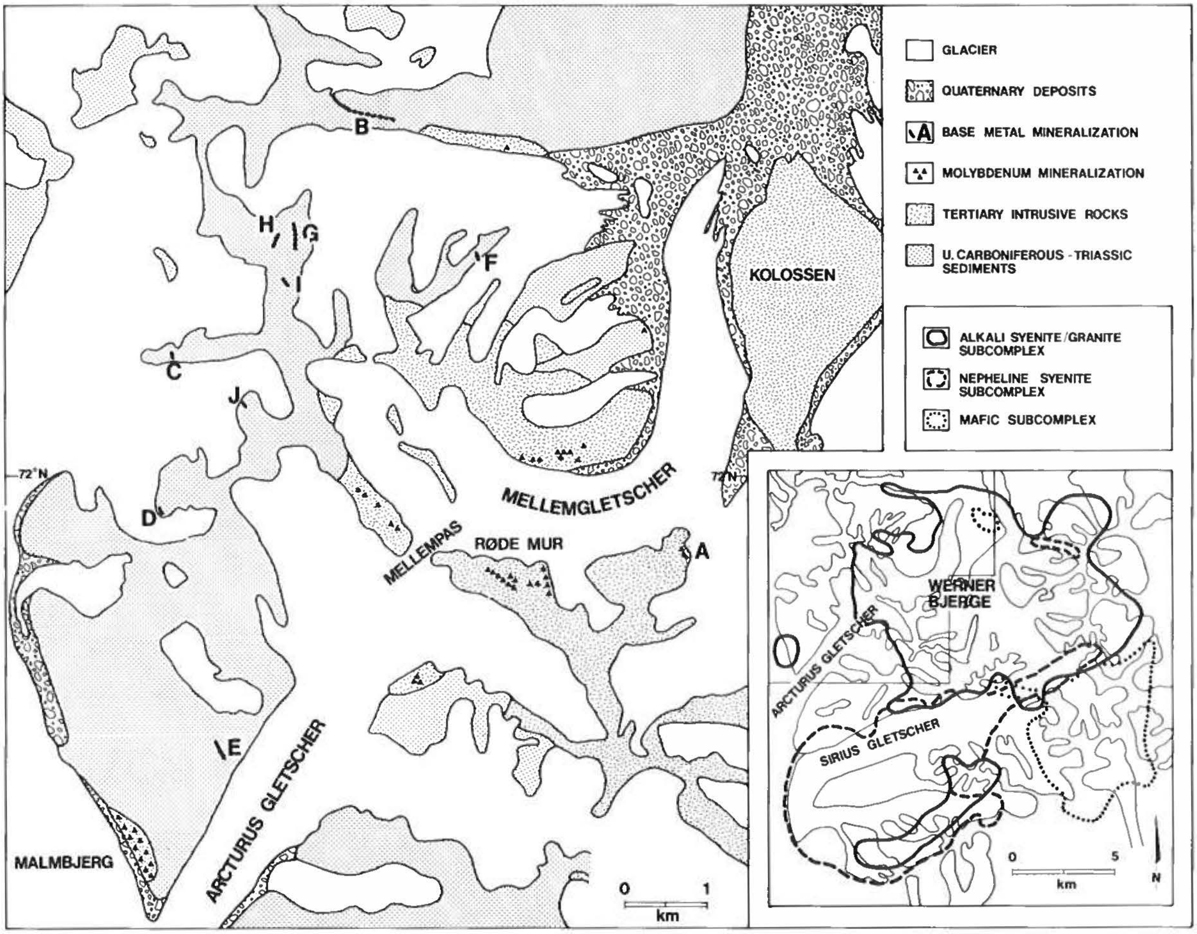


Fig. 80. Location of molybdenum and lead-zinc mineralization in northwestern Werner Bjerge. Inset shows subdivision of the Werner Bjerge by Bearth (1959).

ernmost part of Werner Bjerge (Localities C and D, Fig. 80).

Skarn development with associated lead-zinc mineralization has been found at five localities within the Upper Permian sequence of northwestern Werner Bjerge (Localities F–J, Fig. 80). In general skarn development occurs along faults or associated with quartz-porphyry dykes in the carbonates of the Wegener Halvø Formation and the overlying clastics of the Schuchert Dal Formation. The vertical, NNW-NNE-striking skarn lenses are locally up to two metres wide (Locality H, Fig. 80), 200 m long and 75 m high (Locality G, Fig. 80). The skarn consists of varying amounts of quartz, calcite, diopside, brown garnet and tremolite. The ore minerals, which occur as disseminated grains or as small massive lenses, comprise galena and sphalerite with minor pyrite and chalcopyrite. The estimated grade is a few per cent combined lead and zinc.

The veins and skarns are genetically associated with Tertiary late intrusive and tectonic events.

Magnetite skarn at Oksehorn, Scoresby Land (163)

A magnetite skarn occurrence was found at the southern contact of the Oksehorn complex by Kapp (1960) and investigated in 1971 by Nordmine (Paar et al. 1972, Paar 1975).

The Oksehorn alkali syenite intrudes slightly dipping mainly clastic Triassic sediments, and thermal overprinting close to the intrusive contact is widespread. Magnetite-skarn formation occurs within a 1–2 m thick horizon of calcareous and dolomitic sediments, and outcrops for a length of 20 m. Individual beds of massive or semi-massive magnetite skarn are 0.1–0.2 m thick. Magnetite is intergrown with calcite, epidote and andradite. Quartz, mica, apatite, pyrite and chalcopyrite are minor constituents. Other minerals of restricted and more localized occurrence include ferrosalite, prehnite, babingtonite, chabasite and heulandite (Paar 1975). Analyses of selected samples gave the following maximum values: lithium (300 ppm), beryllium (30 ppm), copper (300 ppm), zinc (0.1%), molybdenum (50 ppm) and tin (50 ppm).

Paar (1975) interprets the occurrence as a contact skarn formed during the intrusion of the alkali syenite and later overprinted by hydrothermal processes at gradually decreasing temperatures.

Base metals in Slugtdal, Scoresby Land (164)

Hydrothermal alteration and mineralization was found in 1957–58 in a restricted area in syenitic rocks on the west slope of Slugtdal in the Theresabjerg complex (Kapp 1960). Reconnaissance exploration for rare-earth elements was carried out in the general area by Nordmine in 1969 (Frisch et al. 1970) and for molybdenum in 1977 (Geyti 1977, Schassberger & Spieth 1978).

In the Theresabjerg complex the petrographic variation ranges from gabbro, gabbro-diorite and monzonite to several modifications of syenite. The variation from mafic to felsic rock types is thought to be a product of fractional crystallization. Furthermore, volcanic breccias and felsic and mafic dykes and sills are widespread.

According to Kapp (1960), widespread late-magmatic hydrothermal activity occurs as red, brown, yellow and black staining of both intrusive and sedimentary rocks. This is due to disseminated limonite and manganese oxides. In particular the syenites exhibit pronounced alteration of the mafic components.

Analyses of 40 hydrothermally altered grab samples from Oksehorn, Theresabjerg, Kap Syenit and Pictet Bjerge complexes return persistently anomalous values of lead (max. 1%), copper (max. 0.1%) and silver (max. 130 ppm), whereas molybdenum (max. 0.1%) and tungsten (max. 800 ppm) occur sporadically (Kapp 1960).

No further description of the mineralization in Slugtdal exists.

The exploration for rare-earth elements and molybdenum showed no positive indications.

Genetically, the mineralization is associated with Tertiary late-magmatic hydrothermal activity.

Molybdenum on Traill Ø (165)

The first report on mineralization in the Kap Simpson complex, excluding pyrite mineralization associated with intense alteration, were made by Eklund (1944), who mentions impregnations of gold-bearing arsenopyrite in volcanic rocks in the vicinity of Drømmebugten. The exact locality has never been located by Nordmine. Since then, exploration has been carried out during the years 1955, 1968–70, 1972, 1977, 1979 and 1981 by both Nordmine and Amax (Brown 1956, Lehnert-Thiel & Walser 1968, Paar & Punzengruber 1970, Paar & Westerholt 1971, Martens 1973, Geyti 1977, Schassberger & Spieth 1978, Geyti 1980, Schassberger & Newall 1980, Damtoft & Grahl-Madsen 1982, Geyti 1982). The first signs of molybdenite mineralization were noted in 1977 in Føndal (Geyti 1977, Schassberger & Spieth 1978).

The Kap Simpson complex comprises a northwestern alkali syenite part and a southeastern zone consisting of sedimentary, volcanic and intrusive rocks surrounded by a syenite ring-dyke system (Fig. 81). The entire southeastern part (the "Dreibuchten" zone) probably represents a caldera (Schaub 1938, 1942). The caldera-related igneous activity can be divided into three episodes: 1) an early volcanic episode, 2) an episode of syenite and granite intrusion and 3) a late volcanic episode. In the early volcanic episode quartz porphyries, rhyolitic flows (often spherolitic), rhyolite ash and lapilli-ash tuffs, ignimbrites, intermediate ash and lapilli-ash tuffs and feldspar-porphyry stocks were formed. During the intermediate episode medium- to coarse-grained syenite and subordinate granite and quartz-syenite intruded the early volcanic rocks. In the contact zone the syenite often shows a feldspar-porphyritic texture. There is no lithological difference between syenites of the northwestern intrusion and the syenites of the caldera. During the late volcanic episode rhyolite dykes and plugs (with flow banding) and intrusive feldspar porphyries of intermediate composition were formed.

Pronounced alteration in the form of large colour-anomalous areas is widespread in particular in the southern part of the caldera between Kap Simpson and Drømmebugten (Schaub 1942, Conradsen et al. 1982, Thyrsted & Friedman 1982, Conradsen & Harpøth 1984). Rocks within the colour-anomalous areas are typically pyritized, argillized and silicified and the occurrence of fluorite is a characteristic feature (Fig. 81). Fluorite mainly occurs in cm-thick veinlets and veins with minor quartz and locally pyrite. However, a single massive fluorite vein more than 0.3 m in thickness and 250 m in length has been found in Fluoritdal. Fluorite in vugs has also been reported. Molybdenite mineralization has been found at four localities (Fig. 81). It occurs as scattered grains in quartz veinlets and disseminated in granite. The size and grade are however insignificant. High molybdenum contents (65–645 ppm) have also been encountered in fluorite veins, although molybdenum-bearing minerals have not been identified.

The mineralization and alteration pattern observed suggests that fumarolic activity was responsible for the major part of the alteration. Locally, mineralization and alteration are clearly related to granite intrusions, without however any signs of porphyry-type mineralization. If porphyry-molybdenum mineralization is present, it must be deeply buried.

Lead-zinc at Kap Simpson, Traill Ø (166)

Sulphide-bearing veins at Kap Simpson were found and investigated by Nordmine in 1969 and 1970 (Paar & Punzengruber 1970, Paar & Westerholt 1971).

At Kap Simpson, only a thin strip of land along the coast consists of Jurassic/Cretaceous shales intruded by

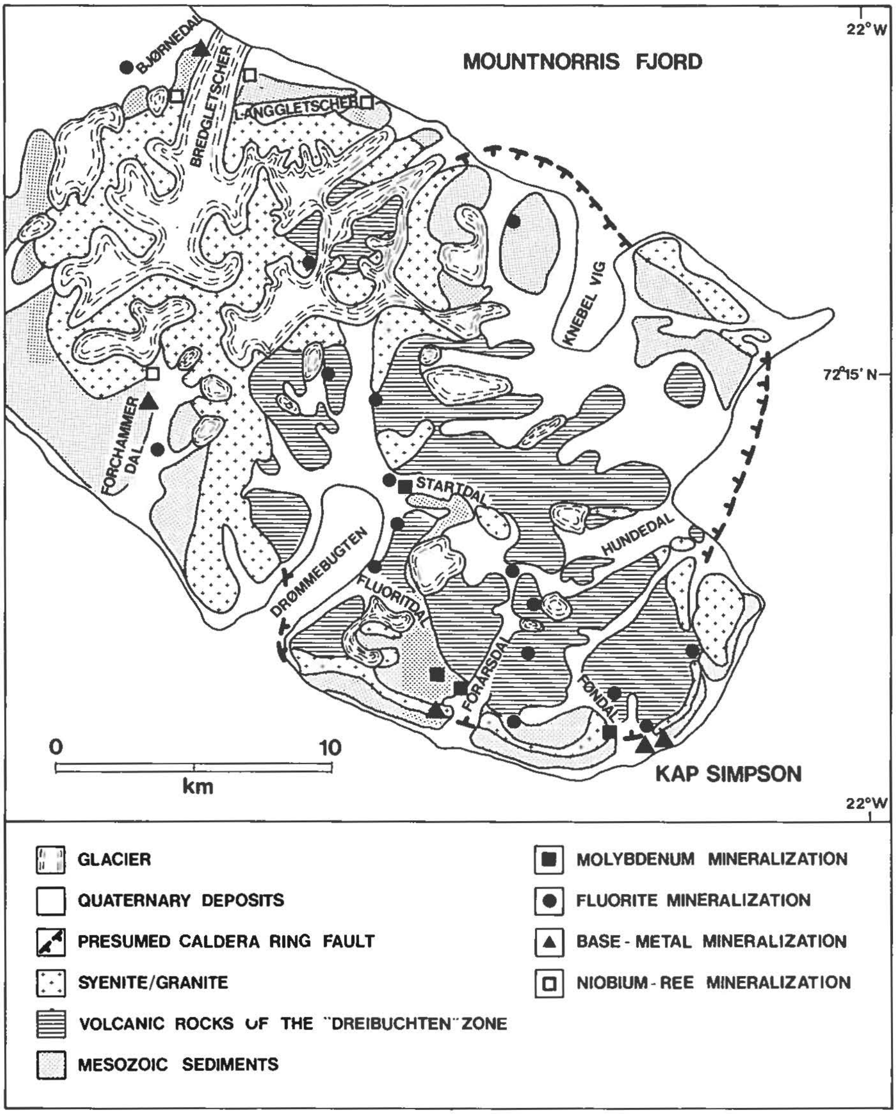


Fig. 81. Simplified geological map with mineralized localities. Kap Simpson Complex, Traill Ø. Geology based on Schaub (1938 and 1942).

Tertiary basaltic sills and acid dykes whereas the Kap Simpson complex occurs inland (Schaub 1938, Stauber 1938). Normal faults 40°–55°/60°–75° SE are frequent within the mixed sedimentary-subvolcanic sequence. Where the faults intersect the basaltic sills, shale has been mylonitized and dragged into the fault planes and, locally, formation of sulphide-bearing calcite veins has occurred.

The largest occurrence is found at the northeastern entrance of Føndal (Fig. 81). It is a *c.* 20 m long and 2 m wide vein hosted in pyrite-bearing mylonized shale. The vein (43°/75°SE) consists of calcite, galena, chalcopyrite, sphalerite and pyrite with minor fluorite. The overall sulphide content is estimated at 30–50%.

Approximately one km further to the northeast another vein of similar mineralogy occurs (Fig. 81). This vein has a strike length of *c.* 30 m and is up to 0.5 m thick. Chemically the mineralization is characterized by high contents of lead, zinc and copper. Other analytical results include: titanium max. 2.5%, manganese max. 1.8%, vanadium max. 0.4%, cobalt max. 250 ppm, nickel max. 400 ppm, cadmium max. 0.19%, silver max. 125 ppm, gold max. 0.4 ppm, bismuth max. 200 ppm, molybdenum max. 100 ppm, and tin max. 50 ppm.

In addition, minor lead-zinc occurrences are known from Forårsdal, Forchammer Dal and Bredgletscher (Fig. 81) (Paar & Punzengruber 1970, Paar & Westerholt 1971, Damtoft & Grahl-Madsen 1982, Geyti 1982).

The veins are assumed to have formed formed contemporaneously with the intrusion of the alkali syenite complex.

Niobium on Traill Ø (167)

The first rock samples with high contents of rare-earth elements from the Kap Simpson complex were collected by Nordmine in 1969 (Paar & Punzengruber 1970). Subsequent investigations in 1970 (Paar & Westerholt 1971), 1971 and 1972 (Martens 1973) led to the identification of various Nb-REE-bearing types of mineralization, mainly along the western contact of the intrusive complex.

In situ niobium mineralization has only been located at one place on the southeast side of Bjørnedal (Fig. 81). Here a few hundred metres from intrusive alkali syenite, the sediments contain mineralized quartz veins intermittently for a distance of 400 m. The sediments comprise thermally overprinted shales, siltstones and sandstones dipping 10°–20° E. The veins are sub-vertical and strike 50°–100°. The largest vein is 30 m long and up to 15 cm wide. Coarse-grained quartz predominates with minor oligoclase, chlorite, biotite, carbonate, zircon, leucoxene and various Nb-bearing minerals. Locally, the contact is enriched in mica. Tentatively, the following niobium and rare-earth element-bearing minerals have been identified: columbite, euxenite, samarskite, fergusonite, monazite and bastnaesite (Martens 1973). Selected samples contain up to 3.2% Nb and 3% REE and in addition beryllium (max. 0.15%), yttrium (max. 0.3%), zinc (max. 0.35%) and barium (max. 0.3%). The overall content is not reported, but the niobium content of the veins is estimated to be <0.2%.

In the side and end moraines of Langgletscher and in the eastern side moraine of Bredgletscher various types of niobium-mineralized boulders have been found (Fig. 81). Niobium-mineralized boulders have also been found in Forchammer Dal. They comprise alkali granite and syenite and quartzites with up to 0.3% Nb. Niobium enrichment is associated with quartz aggregates.

Similar types of niobium contact mineralization have also been reported from the Werner Bjerge complex (Sørensen 1971). The most frequent mineralized type met is alkali syenite with quartz aggregates with associated enrichment in niobium and rare-earth elements. Further, niobium-rich pan samples from the Kolossen area (Fig. 80) contain up to 50% perowskite. In situ perowskite mineralization has never been found.

Gold on southern Hold with Hope (168,169)

Southern Hold with Hope was briefly visited and mapped during (and before) the Lauge Koch Expeditions (Koch & Haller 1971), and a coherent investigation was accomplished in 1976 by GGU geologists (Upton & Emeleus 1976, Upton et al. 1984 a,b). On this occasion, sulphide mineralization was discovered at Kap Broer Ruys, and the following year the survey performed follow-up work at this locality (Nielsen & Johansson 1977). In 1981 the Kap Broer Ruys and Myggbukta areas were reconnoitred for porphyry-type mineralization by Nordmine (Geyti 1982).

The area comprises Cretaceous shales and sandstones overlain by a *c.* one km thick pile of Tertiary plateau basalts. The basalts are intruded by a SW-NE-striking, 10–15 km wide dyke swarm and, to the south, by two shallow igneous complexes at Myggbukta and Kap Broer Ruys.

Myggbukta central complex occupies a subcircular area 10–12 km in diameter and represents a collapse structure related to a caldera. The complex comprises a succession of extrusive rocks penetrated by shallow intrusions. Although dominantly mafic, the complex contains a range of compositions from mafic through intermediate rocks to potassic rhyolites and granophyres. These rocks exhibit pervasive propylitic alteration of probably fumarolic origin.

The Kap Broer Ruys complex is situated some 30 km east of the Myggbukta complex. It consists of a subcircular area of plateau lavas and underlying sediments and sills, approximately 12 km in diameter, which have been affected by contact metamorphism. Several felsite sheets and the upper part of one *c.* 1 km wide granophyre stock are exposed. The metamorphism is believed to have been caused by a blind intrusion at shallow depth.

Mineralization occurs at Myggbukta (169) in the form of common quartz-calcite-hematite-fluorite veining. Pyritization is frequent, but mostly of limited areal extent and of weak intensity. A scree boulder of felsite with 3–5% disseminated pyrite returned 0.26 ppm Au.

Three types of mineralization exist at Kap Broer Ruys (168).

- Massive pyrrhotite or magnetite lenses and layers, 5–15 cm thick and conformable to bedding in hornfels. The lenses, which may contain minor pyrite, chalcopyrite, sphalerite and ilmenite, are probably of pre-intrusive, sedimentary origin.
- Intense pyritization in local areas, often associated with felsic intrusions. The pyritized rocks are bleached and argillized. In addition to rare quartz-pyrite-fluorite veinlets, pyrite occurs disseminated and in amygdales together with magnetite, ilmenite and minor pyrrhotite, sphalerite, cobaltite and arsenopyrite. This mineralization was probably formed by fumarolic activity.
- Tourmaline-bearing breccias at several localities. The breccias are mainly known from scree boulders and their origin is uncertain, perhaps both tectonic and intraformational. They consist of hornfels fragments cemented by vuggy quartz and minor tourmaline. The cement may also contain pyrite, fluorite and, in one case, 5–10% bismuthinite. The last mineral occurs as irregular, up to 3 mm large grains, typically rimmed by fluorite (Nielsen & Johansson 1977). The breccias may also be enriched in antimony (max. 1500 ppm), silver (max. 20 ppm) and gold (max. 0.6 ppm).

The whole Kap Broer Ruys complex forms a distinct boron anomaly as reflected both in rock samples (max. 700 ppm B) and in pan samples (max. 300 ppm B). This common occurrence of boron and tourmaline indicates a widespread pneumatolytic activity, which may be responsible for the gold-bismuth mineralization.

Geochemical maps

In connection with the exploration activity of Nordmine a large number of samples of different types have been collected during the period 1967 to 1983.

- Rock samples (10 298 samples) include various types of mineralized samples from outcrop (selected hand samples, grab samples, chip samples and drill cores), and boulders, and unmineralized samples.
- Pan samples (3823 samples) or more correctly panned heavy mineral concentrates, have been collected and prepared according to the scheme presented in Fig. 82.
- Stream sediment samples and soil samples (2812 samples) represent the fine fraction after sieving at 80 mesh.

Only a portion of the samples has been analyzed (Figs 83–99), most frequently by semi-quantitative multi-element emission spectrography. Other methods applied include atomic absorption spectrography for base metals, X-ray fluorescence spectroscopy for the determination of tungsten, antimony, arsenic, barium and rare-earth elements, neutron activation for determination of uranium, thorium, gold, tungsten and antimony and fire-assay for the determination of gold and silver. A few interesting boulder finds not described in the previous section are summarized in Table 12.

Because different laboratories were used, different analytical methods applied, with different detection limits and different levels of accuracy and precision, it is not strictly correct to compare the analytical values. However, in geochemical exploration it is often the content within an order of magnitude that is of interest, and

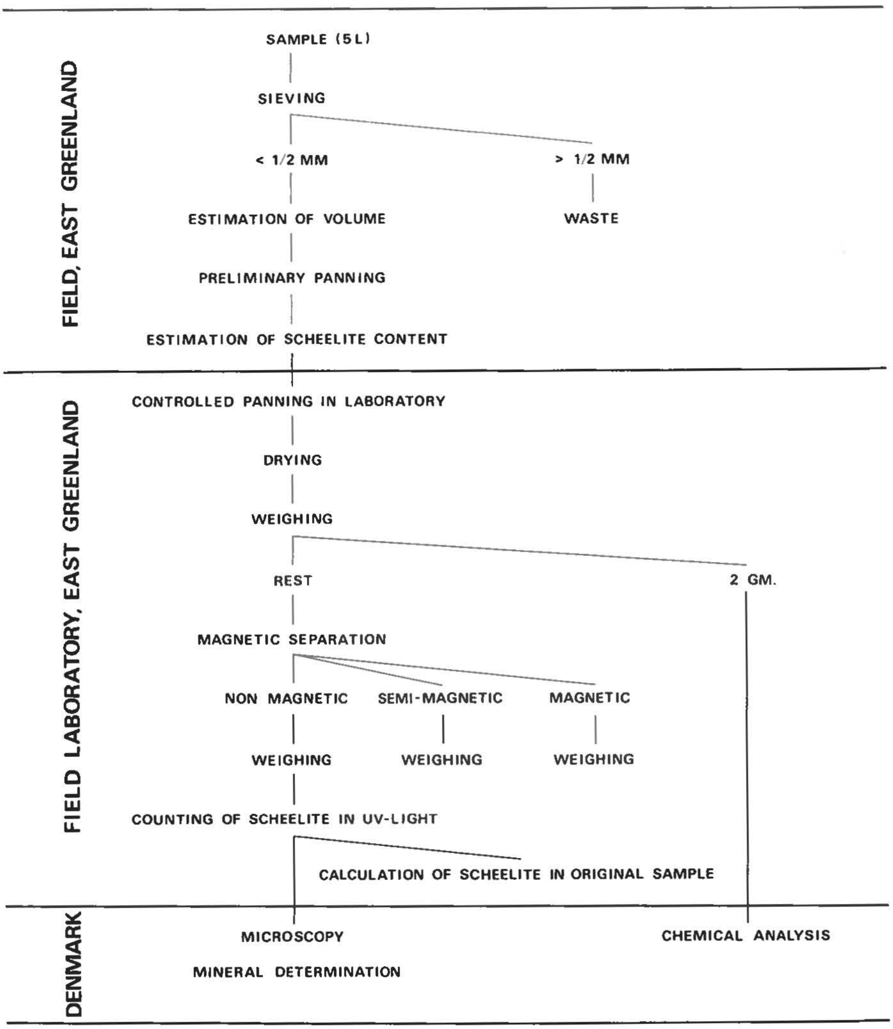


Fig. 82. Flow sheet for treatment of heavy-mineral samples (pan samples).

Table 12. Summary of interesting boulder finds not mentioned in the section on mineral occurrences.

Locality	Sample description/reference	Analytical results
East of Hjørnedal, Gåseland	Moraine boulder of hydrothermally altered ultramafic rock with pyrrhotite, chalcopyrite, pentlandite and scheelite. (Kirchner 1968)	Cu (0.4%), Ni (0.2%), Cr (0.25%), W (700 ppm), Ag (10 ppm)
Borgbjerg Gletscher, Nordvestfjord	Moraine boulder of vein quartz with chalcocite (Lind 1980)	Cu (1.75%), Zn (0.2%), Pb (500 ppm), Bi (100 ppm), Sn (100 ppm)
North Klitdal, Liverpool Land	Moraine boulder of brecciated granite with chalcocite (Thomassen 1975)	Cu (7%), Ag (20 ppm), Au (0.014 ppm)
Southwestern Eremitdal, Andrée Land	Moraine cobble of semi-massive pitchblende. (Lind 1980)	U (32.2%), Pb (6%), Cu (5%), V (0.25%)
East of Granitelv, Geologfjord	Local boulder of vein quartz with arsenopyrite and pyrite. (Thomassen 1984)	Au (3.5 ppm), Ag (24 ppm), As (0.6%), Mo (700 ppm)
East of Granitelv, Geologfjord	Local boulder of vein quartz with arsenopyrite, galena, sphalerite, pyrite and pyrrhotite. (Stendal & Ghisler 1980)	Pb (3.5%), Zn (4.0%), Ag (73 ppm), As (8.5%), Au (0.2 ppm)
Wiman Bjerg, Gauss Halvø	Plate of native copper in Devonian sandstone. (Bøggild 1953).	Ag (0.11%), As (0.2%), Bi (80 ppm)

Table 13. Summary statistics for the sixteen elements considered. Number of original samples includes 10 298 rock samples and 3823 pan samples. The detection limits shown are mainly for emission spectrographical analyses.

	Sb %	As %	Ba %	Bi %	Ce %	Cu %	Au ppm	Pb %	Mo %	Ni %	Nb %	Ag ppm	Sn %	W %	U %	Zn %
Rock samples																
99%-fractile	0.85	8.5	34.8	0.05	0.5	12.5	1.8	42.7	0.05	0.16	0.35	460	0.1	2.6	0.03	5.0
95%-fractile	0.05	0.25	3.5	0.003	<DL	1.3	0.12	2.4	0.008	0.03	0.05	90	0.01	0.01	0.0005	0.6
90%-fractile	<DL	<DL	0.5	<DL	<DL	0.35	0.03	0.3	0.005	0.015	0.03	20	0.003	<DL	<DL	0.1
75%-fractile	<DL	<DL	0.1	<DL	<DL	0.03	<DL	0.02	0.002	0.007	<DL	3.3	<DL	<DL	<DL	<DL
Average crust (ppm)	0.2	1.8	425	0.17	60	55	0.004	12.5	1.5	75	20	0.07	2	1.5	2.7	70
Pan samples																
Max. value	0.15	6	17.5	0.08	6.9	0.25	50	1.0	0.15	0.1	3.5	30	5.0	4.0	0.11	0.35
99%-fractile	<DL	0.2	3.0	0.015	2.0	0.05	0.13	0.2	0.009	0.03	0.5	5	0.07	0.2	0.005	0.1
95%-fractile	<DL	<DL	0.35	<DL	0.3	0.02	0.02	0.05	0.005	0.02	0.1	<DL	0.02	0.01	0.002	<DL
90%-fractile	<DL	<DL	0.15	<DL	0.2	0.015	<DL	0.04	0.003	0.02	0.05	<DL	0.005	<DL	0.0008	<DL
75%-fractile	<DL	<DL	<DL	<DL	<DL	0.007	<DL	0.02	0.003	0.01	0.03	<DL	0.002	<DL	<DL	<DL
Median	<DL	<DL	<DL	<DL	<DL	0.005	<DL	0.01	0.002	0.007	<DL	<DL	<DL	<DL	<DL	<DL
Detection Limit (DL)	0.02	0.1	0.05	0.003	0.1	0.0005	10/ 0.02	0.001	0.001	0.001	0.03	0.0002	0.001	0.01	0.05/ 0.0002	0.05

to obtain as detailed coverage as possible, this lack of a consistent approach is accepted in the following.

The geochemical data for rock samples and pan samples are presented in two ways, as simple statistical parameters in Table 13 and as grid maps (Figs 83–99). Individual grids are 4x4 km large, and only grids which contain one or more analyzed samples are shown. All analysed samples are grouped into three classes, and depending on the element in question the group with the highest values represents between 1% and 5% of the analysed samples. The next group includes 5 to 10% of the analysed samples, and the third group includes the remaining, lowest values. Each grid is attributed an analytical value corresponding to the highest value within the grid of the element in question, classified according to the grouping mentioned above, and presented in black, grey or white respectively. For a selected range of elements both the rock sample and pan sample maps are presented. Each element will be briefly commented on.

Antimony (Fig. 83)

Antimony in rock samples seems to originate from either stibnite or tetrahedrite. The major findings on Ymer Ø are due to stibnite, and minor amounts of stibnite also occurs at Bredehorn and in the Mesters Vig area. The anomalies on Wegener Halvø, Strindberg Land and Hudson Land are due to tetrahedrite. Unexplained anomalies exist on Lyell Land and on Hold with Hope.

The pan sample anomaly pattern is due to stibnite, whereas areas with tetrahedrite are not reflected. The anomalies on Ymer Ø are well explained, but on Lyell Land *in situ* mineralization remains to be found. Microscopy of the concentrates from the latter locality has confirmed the existence of stibnite grains. It should be noted that the detection limit for antimony (Table 13) is relatively high.

Known antimony mineralization is of Caledonian to Tertiary age.

Arsenic (Fig. 84)

Arsenic in rock samples reflects the occurrence of arsenopyrite, which is known from Canning Land, north Stauning Alper, Alpefjord, Randenæs, Noa Dal, Hudson Land and Geologfjord, and of fahlore (mainly tennantite), which occurs on Wegener Halvø and in Hudson Land. The occurrence in Geologfjord represents arsenopyrite-bearing quartz veins in granite, which also are anomalous in gold (Table 12). Finally, anomalies occurring both south and north of Wegener Halvø are due to domeykite-algodonite.

The pan sample anomaly map only reflects some of the known arsenopyrite occurrences. Arsenic anomalies not investigated exist on central Traill Ø, north Lyell Land, Hudson Land, Rendalen and on Hold with Hope. It is characteristic that gold is associated with arsenopyrite at several localities. The very restricted distribution of arsenic both in rock samples and pan samples is probably due to a high detection limit for the analytical method applied (Table 13).

Known arsenic mineralization is of Caledonian to Tertiary age.

Barium (Fig. 85)

Known barium occurrences exist along the Post-Devonian Main Fault System and on Wegener Halvø and Canning Land and are of vein type or replacement type.

The pan sample anomaly map reveals all of these occurrences, but in addition indicates that extensive areas on Lyell Land, Suess Land, Ymer Ø, Andrée Land and Strindberg Land are anomalous in barium. The areas consist of late Precambrian, Cambrian and Ordovician sediments, mainly dolomites and limestones, and baryte mineralization must occur within this sequence.

Known baryte mineralization is most probably of Upper Proterozoic and Upper Palaeozoic ages.

Bismuth (Fig. 86)

Several types of mineralization show enrichment in bismuth. The highest contents are associated with skarn and contact vein mineralization around Caledonian intrusives (Kalkdal, Milne Land, Canning Land, Bersærkerbræ, Randenæs, Luciagletscher and Gemmedal) and around Tertiary intrusives (Werner Bjerge, Kap Simpson and Hold with Hope). Enhanced values of bismuth are further associated with precious-metal-bearing, base-metal veins as on Wegener Halvø, Galenadal, Noa Dal, Brogetdal and Hudson Land.

Bismuth in pan samples is due to either native bismuth or bismuthinite. Most of the known occurrences are reflected by pan samples, and in addition anomalies exist in Hasdal on Lyell Land and at Knivbjerg. It is noteworthy that bismuth is a good pathfinder for tungsten and gold mineralization.

Known bismuth mineralization is of Lower Palaeozoic to Tertiary age.

Cerium (Fig. 87)

The distribution of cerium corresponds to the distribution of other rare-earth elements. Mineralization is primarily known from southeastern Milne Land in fossil Jurassic placers. Other occurrences are allanite-bearing pegmatite and skarn in Gletscherland and veins associated with the Tertiary intrusives in Werner Bjerge and at Kap Simpson.

The known occurrences are all reflected by the pan samples. Pronounced anomalies which have not been followed up exist in the Gurreholm Dal area and in Hudson Land. The latter locality – Blokadedal – is further commented on in the section describing niobium.

Known cerium mineralization and rare-earth element mineralization are in general mainly of Caledonian to Tertiary age.

Copper (Fig. 88)

Copper mineralization is found in east Jameson Land, Wegener Halvø, Canning Land and along the Post-Devonian Main Fault System. Furthermore, scattered high copper values are associated with nickel in Vestfjord and Kalkdal, with strata-bound chalcocite mineralization in the Eleonore Bay Group basin, with skarn-type mineralization in the Gletcherland area and with the Tertiary intrusive complexes of Werner Bjerge, Traill Ø and Hold with Hope.

High copper values in pan concentrates are mainly due to chalcopyrite. The known occurrences are all reflected in the anomaly pattern. However, it is evident that the Archaean–Middle Proterozoic metamorphic complexes – especially Gåseland and Gletcherland – and the Eleonore Bay Group basin are much more anomalous than indicated by investigations made so far.

Known copper mineralization is of Archaean to Tertiary age.

Gold (Fig. 89)

Gold is associated with Archaean–Lower Proterozoic rocks (Vestfjord and Flyverfjord), Caledonian intrusives (Milne Land, Kalkdal, Canning Land, north Stauning Alper, Alpefjord, Randenæs, Forsblad Fjord, Noa Dal, Luciagletscher, Geologfjord and Hudson Land), Devonian volcanics (Wegener Halvø and Canning Land), the Post-Devonian Main Fault System (Hudson Land) and the Tertiary intrusives (Werner Bjerge, Kap Simpson and Hold with Hope).

The pan samples reflect nearly all known occurrences and in addition show many other gold anomalies for example on Gåseland, Liverpool Land, Andrée Land, Strindberg Land and Hudson Land.

Known gold mineralization is of Archaean to Tertiary age.

Lead (Fig. 90)

The distribution of lead is comparable to that of copper, except that lead mineralization is rare within the metamorphic complexes. Most occurrences are located on Wegener Halvø, Canning Land and along the Post-Devonian Main Fault System. In addition mineralized samples originate from the Eleonore Bay Group basin and the Tertiary intrusive complexes.

The pan sample anomaly pattern is a good mirror of the known mineralization. Additional anomalies exist in the northern part of Hudson Land, where Cambrian-Ordovician carbonates obviously have a potential for lead mineralization.

Known lead mineralization is predominantly of Lower Palaeozoic to Tertiary age.

Molybdenum (Fig. 91)

The rock sample map reflects the molybdenite occurrences associated with the Tertiary intrusives – Malmbjerg, Mellempas and Kap Simpson. The high values on Wegener Halvø and east Jameson Land originates from strata-bound Triassic base-metal mineralization. In the Gurreholm Dal area molybdenum is associated with galena-bearing veins, in Kalkdal powellite occurs in quartz veins, on Lyell Land molybdenite occurs in pyrite aggregates, and molybdenite also occurs in Dickson Fjord.

The pan sample anomaly pattern reflects most of these occurrences. Additionally, pronounced anomalies exist in Blokadedal, and on Canning Land. At the former locality molybdenite has been identified in the concentrates.

Known molybdenum mineralization is mainly of Caledonian to Tertiary age with a clear maximum during the Tertiary.

Nickel (Fig. 92)

Contrary to most other described elements, enhanced nickel values originate in the Archaean–Lower Proterozoic part of central East Greenland, for example in the Vestfjord area.

Compared with the copper, lead and zinc, the nickel content of the pan samples is very low. This probably indicates that pan samples are a poor sampling medium for nickel exploration. Anyhow, high values seem to be correlated either with the metamorphic complexes (for example Suess Land) or with the Tertiary basaltic flows and sills (for example Hold with Hope). The high values from the latter locality could be due to a high content of olivine in the concentrates.

Known nickel mineralization is mainly of Archaean to Proterozoic age.

Niobium (Fig. 93)

Rock samples with a high niobium content are restricted to the Tertiary intrusive complexes of Werner Bjerge and Traill Ø. In addition, enhanced values are associated with cassiterite veins in north Stauning Alper and skarn mineralization in Dickson Fjord.

The pan sample anomaly pattern reflects the occurrence of the Tertiary intrusive complexes (including Pictet Bjerge and Kap Parry). However, the most pronounced anomaly occurs in Blokadedal in Hudson Land. This area is anomalous in a wide range of other elements including tin, molybdenum and rare-earth elements. All these anomalies are unexplained. Less pronounced anomalies such as those on Milne Land and in Alpefjord are probably associated with fossil placers and tin mineralization, respectively. Other anomalies on central Traill Ø, Clavering Ø and Rendalen are not well understood.

Known niobium mineralization is mainly of Caledonian to Tertiary age with a clear maximum during the Tertiary.

Silver (Fig. 94)

Silver in rock samples reflects several types of mineralization. The most common type is galena-bearing quartz vein mineralization of Caledonian to Tertiary age. Other types are strata-bound lead-zinc-baryte occurrences of Upper Permian age and chalcocite mineralization in the Upper Permian and the Triassic.

Silver anomalies in pan samples are very scattered, and correlation with known occurrences is difficult. The reason is not well understood. Several anomalies which have never been followed up in the field, for example in south Liverpool Land, Frederiksdal, Skeldal and Pictet Bjerge, exist.

Known silver mineralization is mainly of Caledonian to Tertiary age.

Tin (Fig. 95)

Known tin mineralization is associated with the Caledonian or Tertiary magmatic activity. Cassiterite is found in greisen veins at Malmbjerg, at Bersærkerbræ and at Randenæs. Enhanced tin content occurs in tungsten skarn at Trekantgletscher, Knivbjerg and Gemmedal, and in tourmaline fels in Blokadedal.

The pan sample anomaly map reflects the known mineralization, with Hudson Land as the most anomalous area.

Known tin mineralization is of Caledonian or Tertiary age.

Tungsten (Fig. 96)

High tungsten values are mainly due to the different types of scheelite mineralization associated with Caledonian intrusives (Milne Land, Kalkdal, Canning Land, north Stauning Alper, Alpefjord, Forsblad Fjord, Knivbjerg, Ymer Ø and Blokadedal). The occurrences at Roslin Gletscher and Gemmedal are interpreted as being of Middle Proterozoic age, and minor scheelite is also associated with the Tertiary Kap Simpson complex. Tungsten anomalies which are due to wolframite have been identified at Malmbjerg and in Noa Dal.

The pan sample anomaly map is a very good reflection of the known tungsten occurrences. Anomalies which remain to be investigated exist in Frederiksdal, on Canning Land and in Hudson Land. The detection limit for tungsten is relatively high (Table 13) and the scheelite grain content of pan samples generally gives a more detailed picture of the tungsten distribution (Fig. 99).

Known tungsten mineralization is mainly of Caledonian age.

Uranium (Fig. 97)

Except for a single moraine boulder rich in pitchblende from Andrée Land (Table 12), no samples contain above one per cent uranium. However, it must be noted that samples collected by Nordmine do not reflect all known uranium occurrences. High uranium values originate from fossil placers on Milne Land, fluorite mineralization in Arkosedal, Devonian phosphorite mineralization on Wegener Halvø, allanite-bearing skarn in Dickson Fjord, and from two-mica granites in the inner fjord zone and on Gauss Halvø. Raised uranium values are also known from various parts of the Archaean and Lower Proterozoic basement.

As uranium oxides are very soluble the pan sample anomaly map reflects either uranium-bearing silicate minerals resistent to erosion or samples collected close to outcropping mineralization. In addition to the anomalies in Hudson Land, which have been investigated by GGU, anomalies exist on central Traill Ø, north Stauning Alper and in the Luciagletscher area.

Known uranium mineralization is of Archaean to Mesozoic age.

Zinc (Fig. 98)

The location of most high zinc values is the same as for copper and lead.

The pan sample anomaly map displays a different picture. The known occurrences are only reflected by a few anomalous samples. Instead, zinc anomalies exist in north Hudson Land (see lead), in west Andrée Land, on Ymer Ø, in Forsblad Fjord, in Renland and in Gåseland. Stendal (1980b) showed that pan samples are not a good sample medium for zinc as most sphalerite seems to go into solution, and furthermore the detection limit is high.

Known zinc mineralization is of Proterozoic to Tertiary age.

Scheelite grains (Fig. 99)

Counting of scheelite grains in UV-light has served as the principal exploration method in the search for scheelite occurrences (Hintsteiner 1977, Hallenstein et al. 1980). The method is not as exclusive as could be desired, because several other minerals may have a fluorescence colour quite similar to scheelite. These include diopside, hydrozincite, quartz, alkali feldspar and powellite. With this uncertainty in mind it is recognized that, except for the Mesozoic basin, scheelite occurs in all parts of central East Greenland. Only major and easily accessible anomalies have been followed up, and the occurrences located are mentioned in the section on tungsten. Significant anomalies which have not yet been investigated exist in Gåseland, Canning Land, Stauning Alper and on Hudson Land.

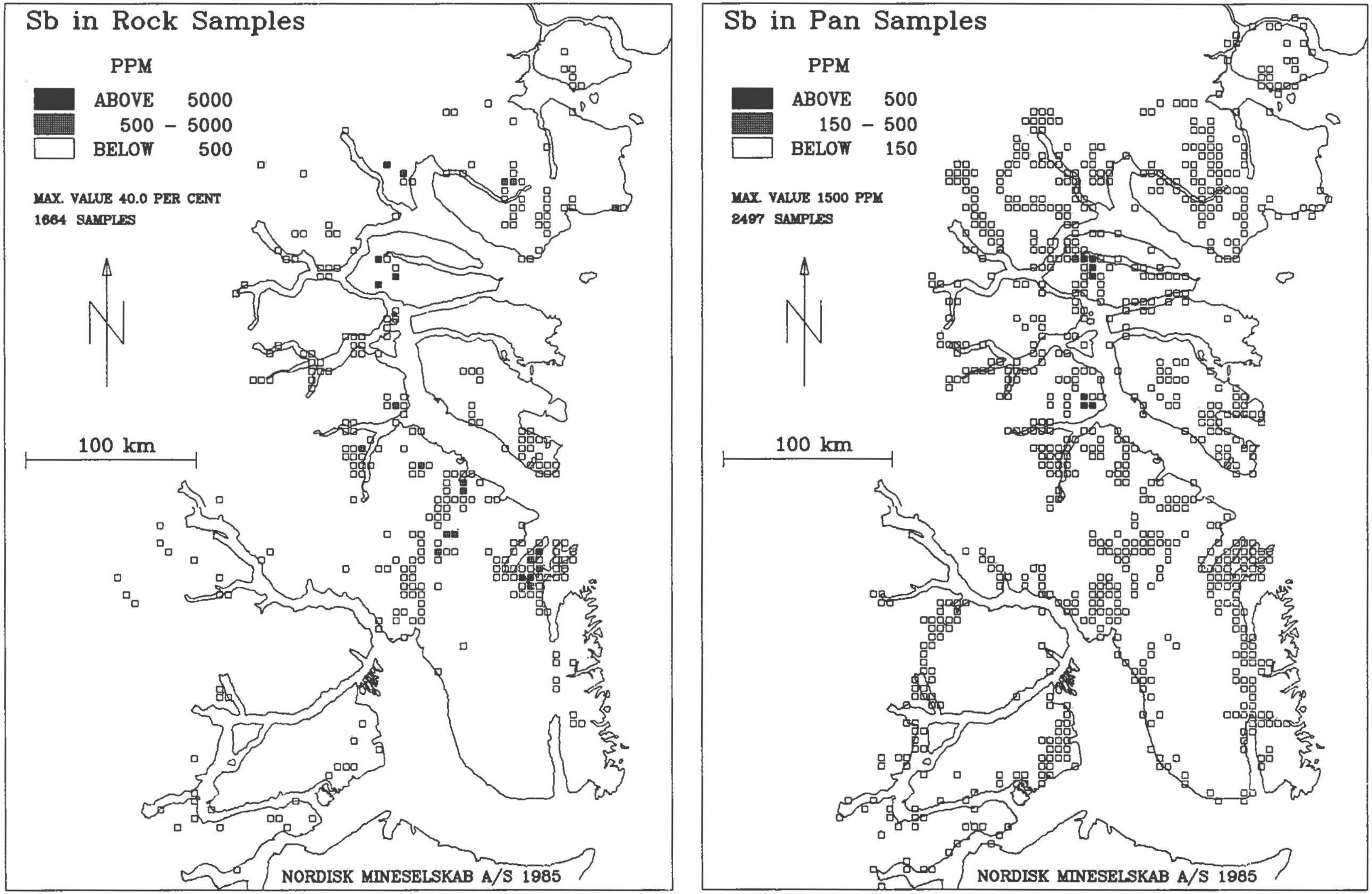


Fig. 83. Geochemical maps of antimony in rock and pan samples, central East Greenland.

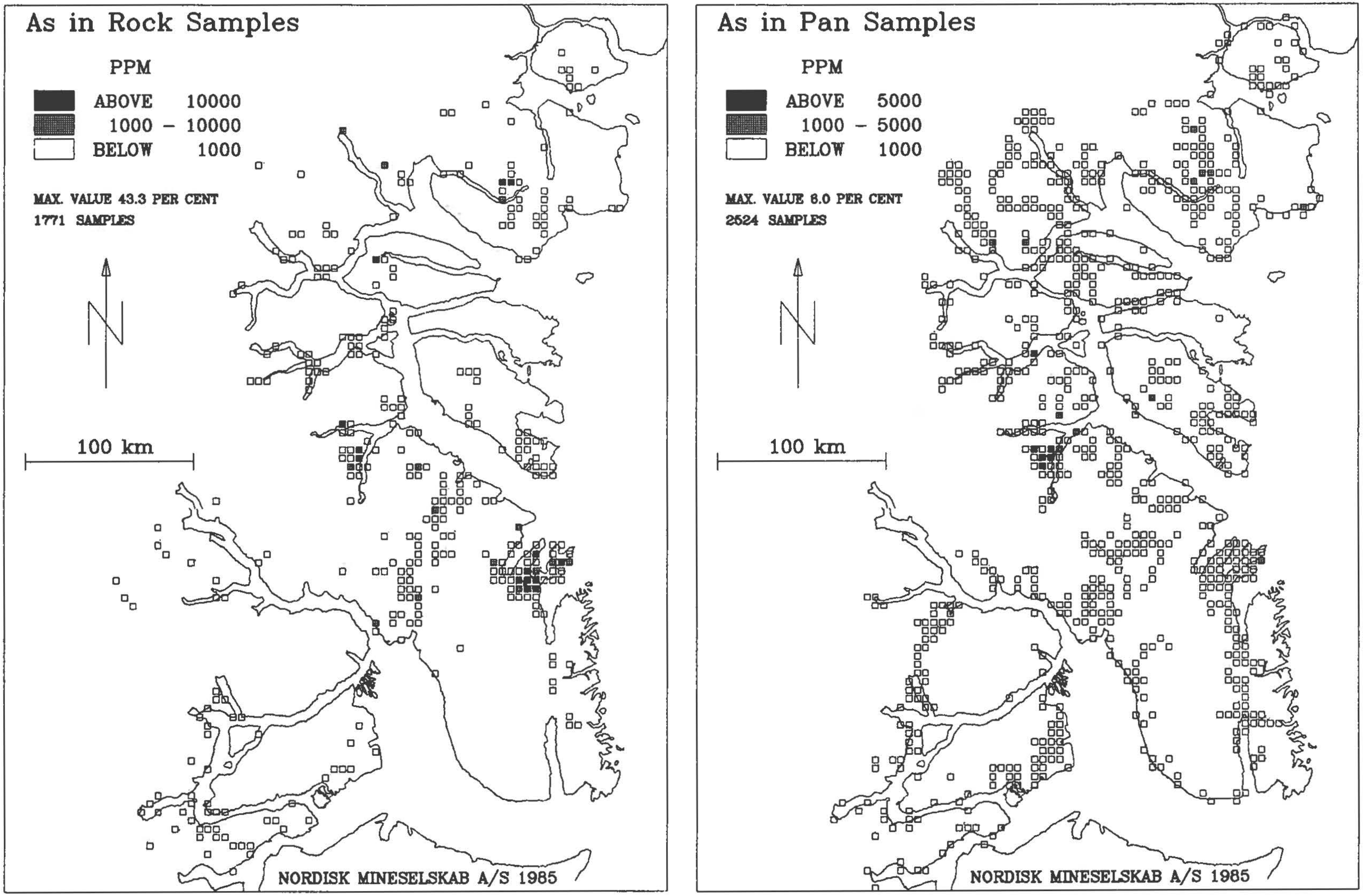


Fig. 84. Geochemical maps of arsenic in rock and pan samples, central East Greenland.

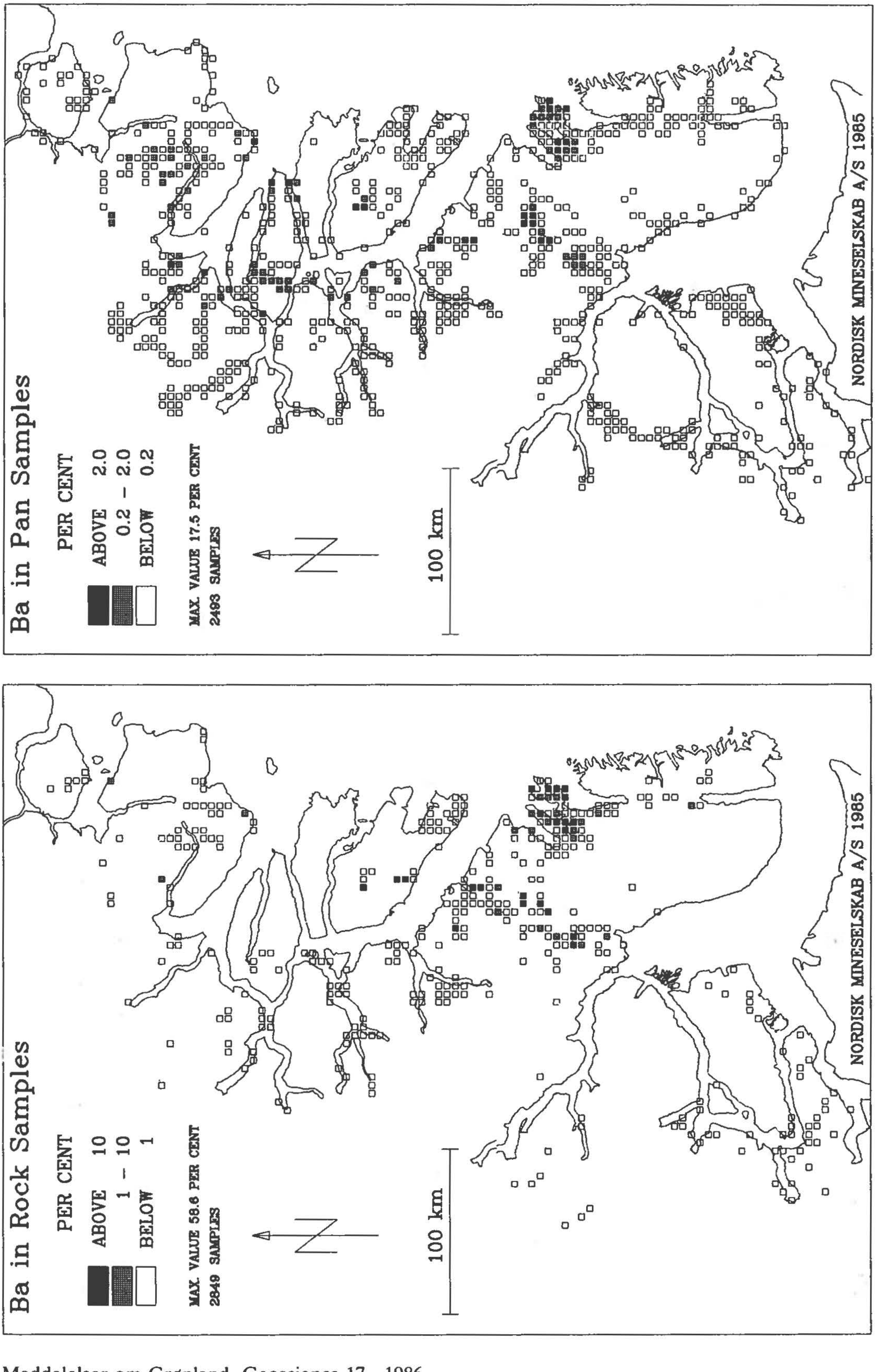


Fig. 85. Geochemical maps of barium in rock and pan samples, central East Greenland.

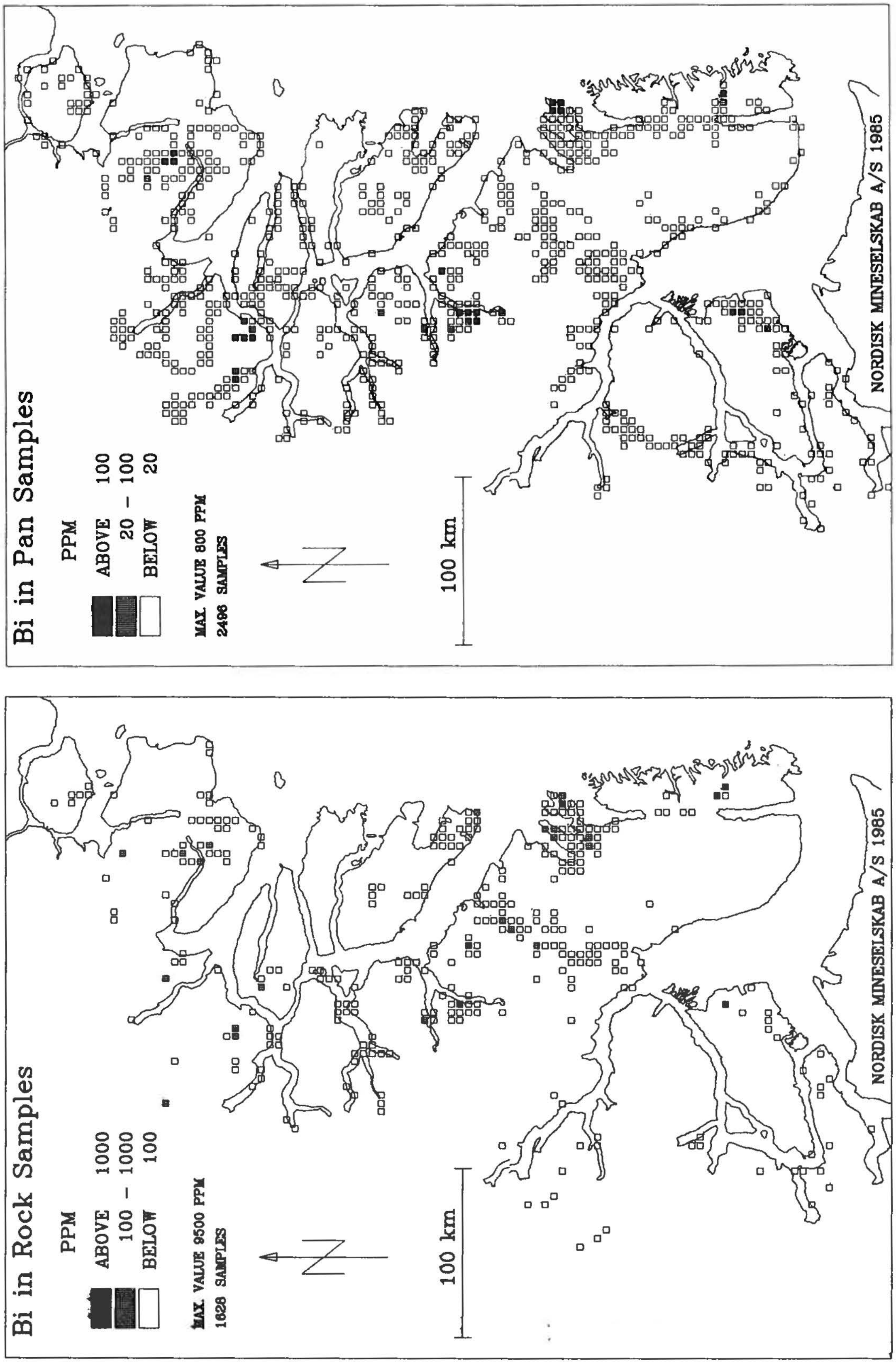


Fig. 86. Geochemical maps of bismuth in rock and pan samples, central East Greenland.

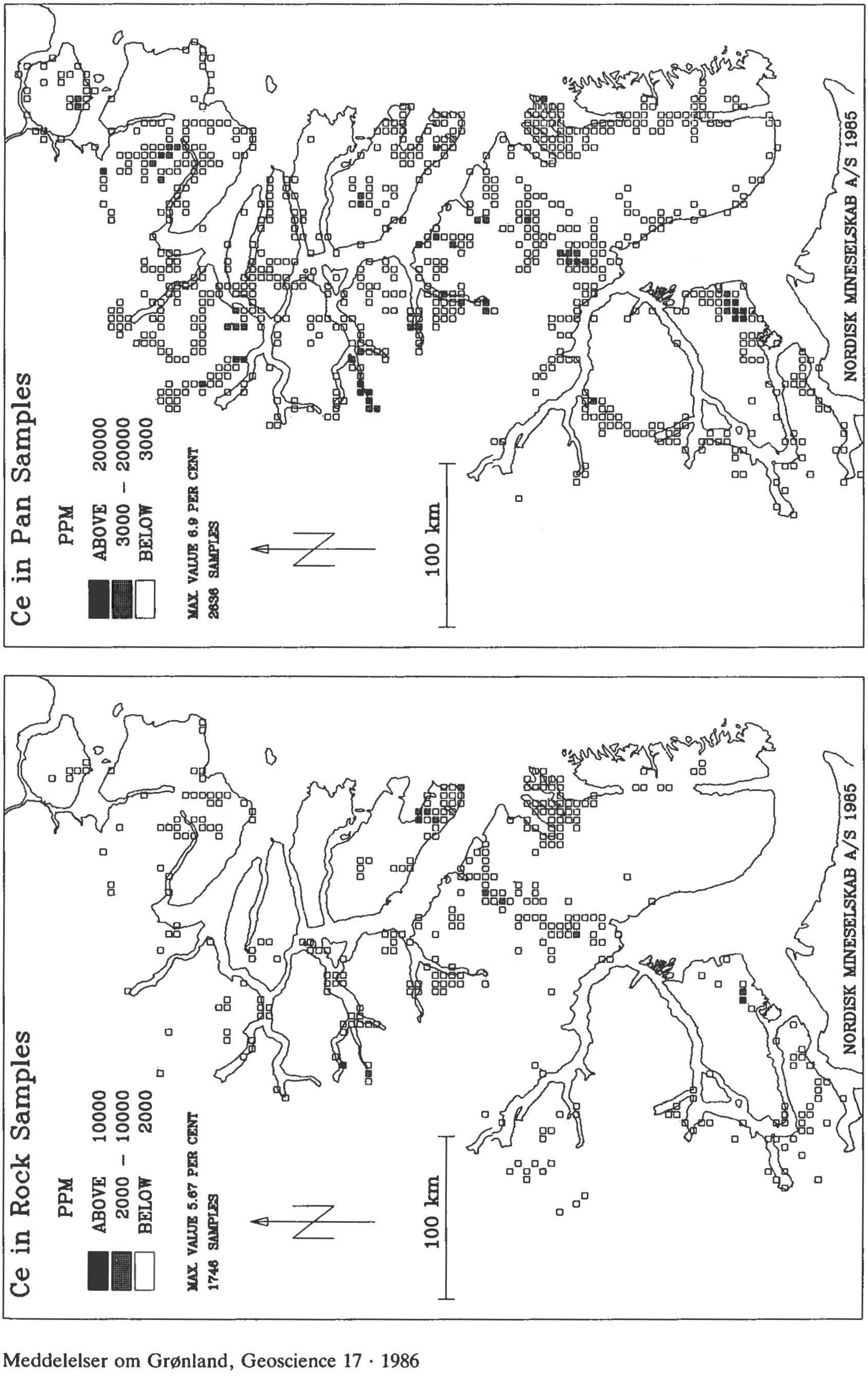


Fig. 87. Geochemical maps of cerium in rock and pan samples, central East Greenland.

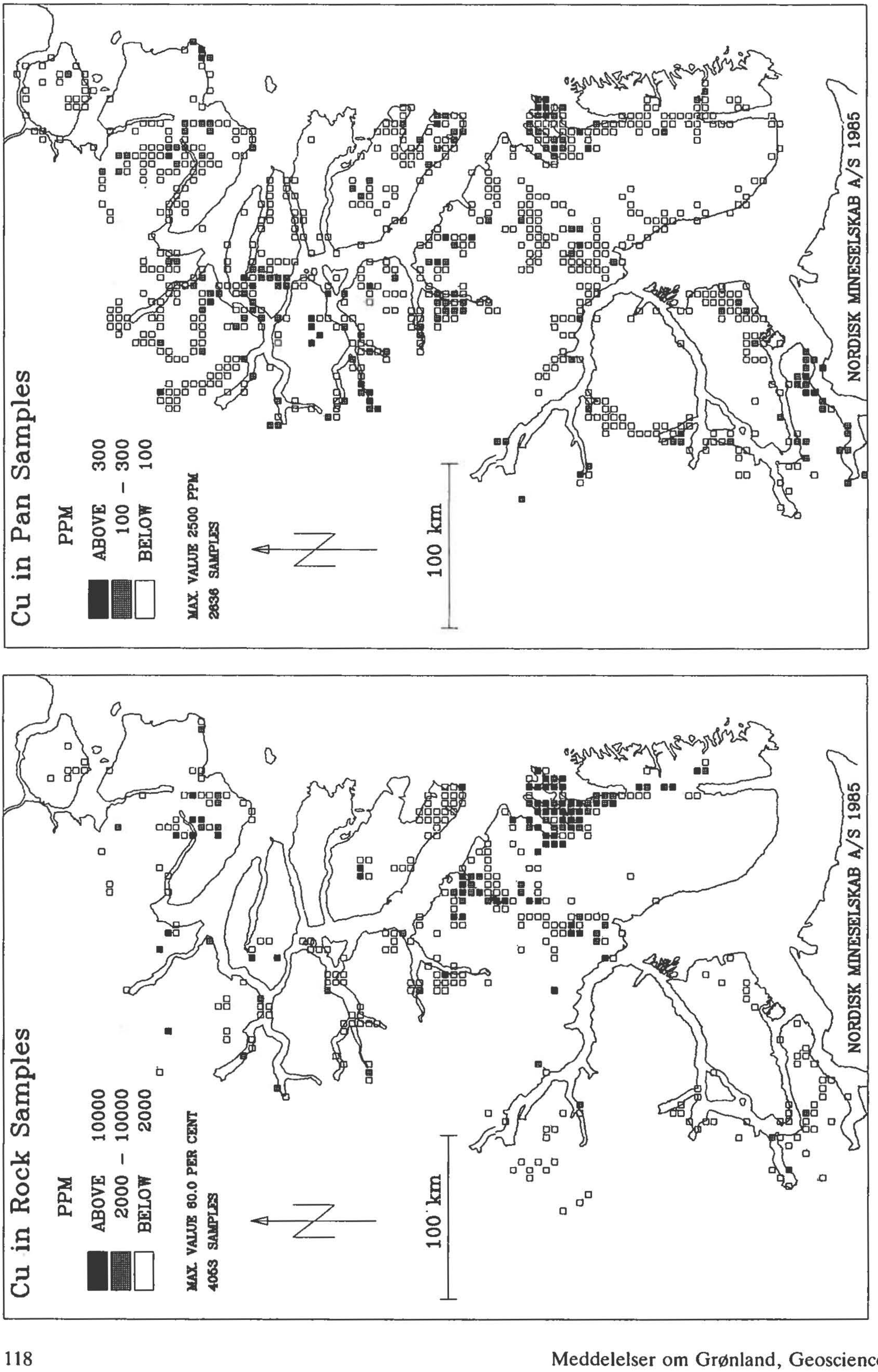
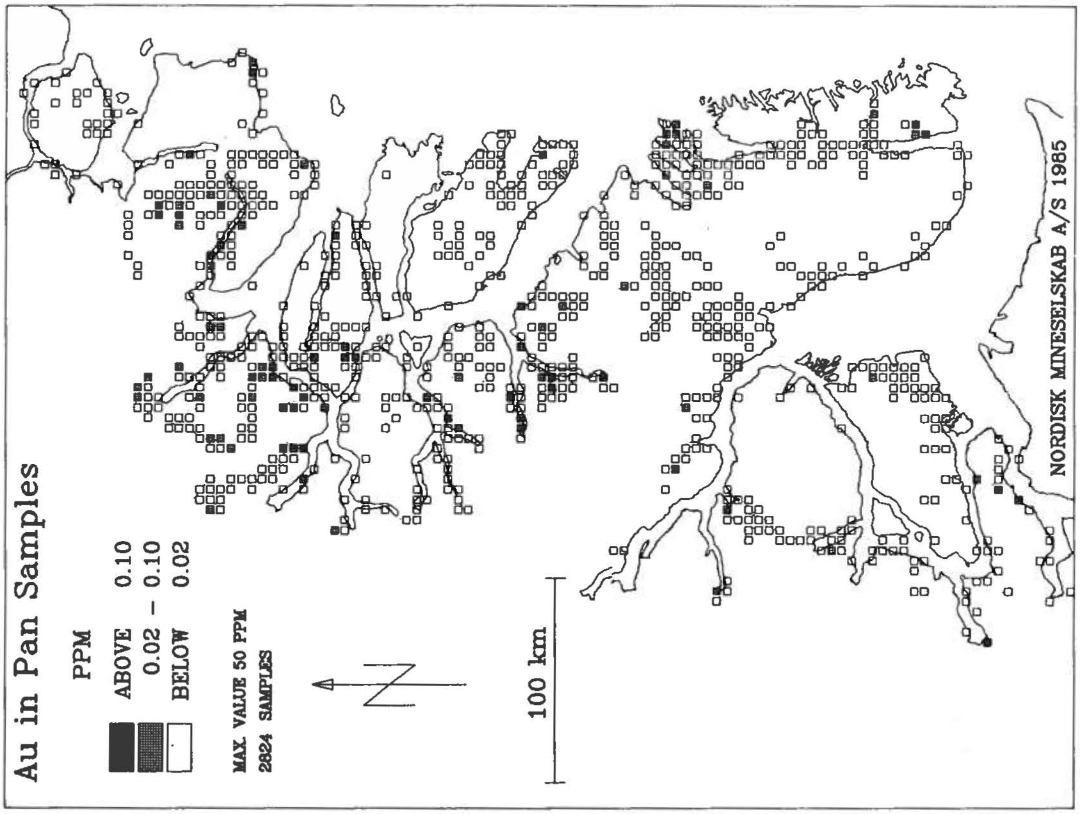


Fig. 88. Geochemical maps of copper in rock and pan samples, central East Greenland.



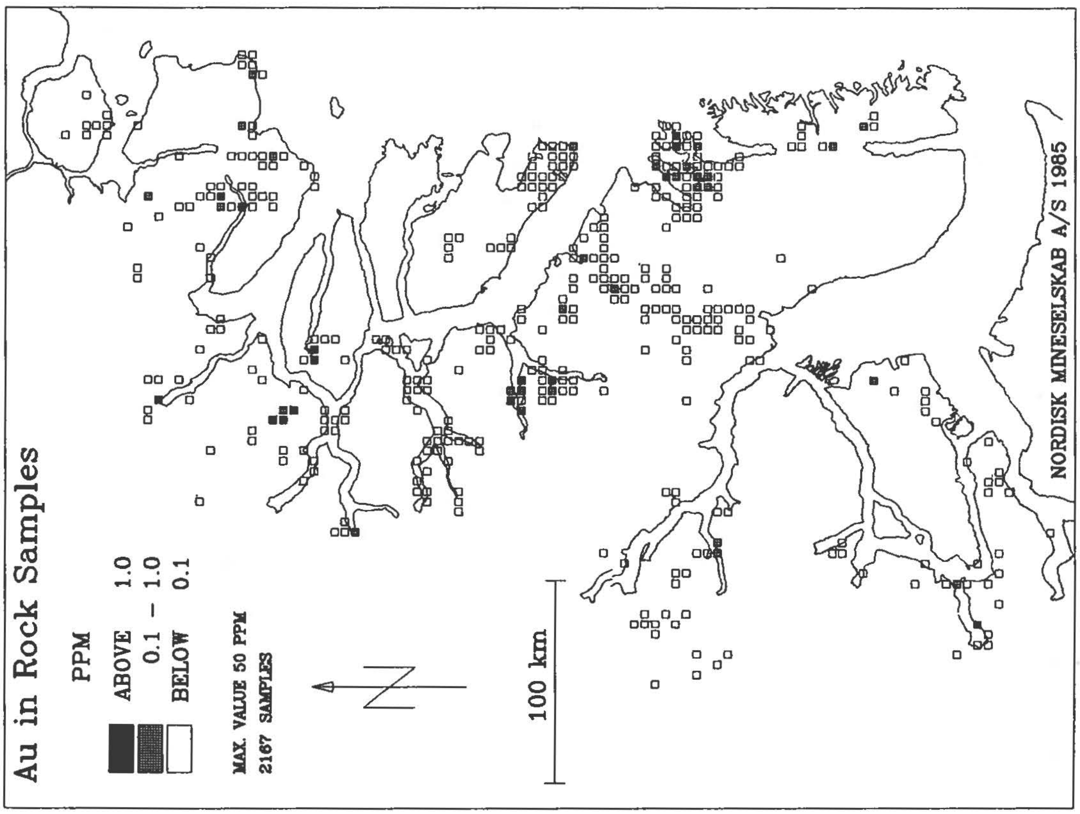


Fig. 89. Geochemical maps of gold in rock and pan samples, central East Greenland.

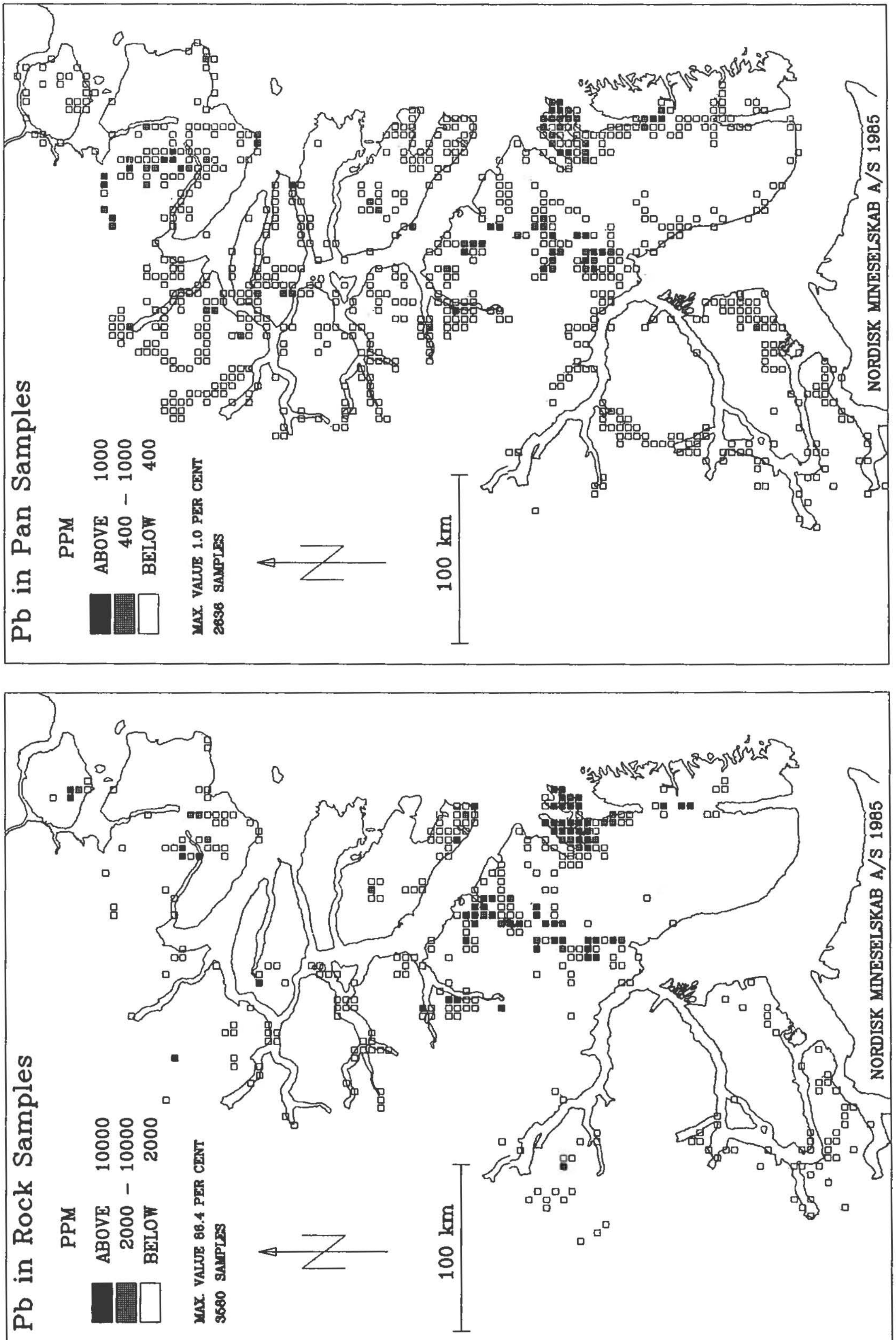


Fig. 90. Geochemical maps of lead in rock and pan samples, central East Greenland.

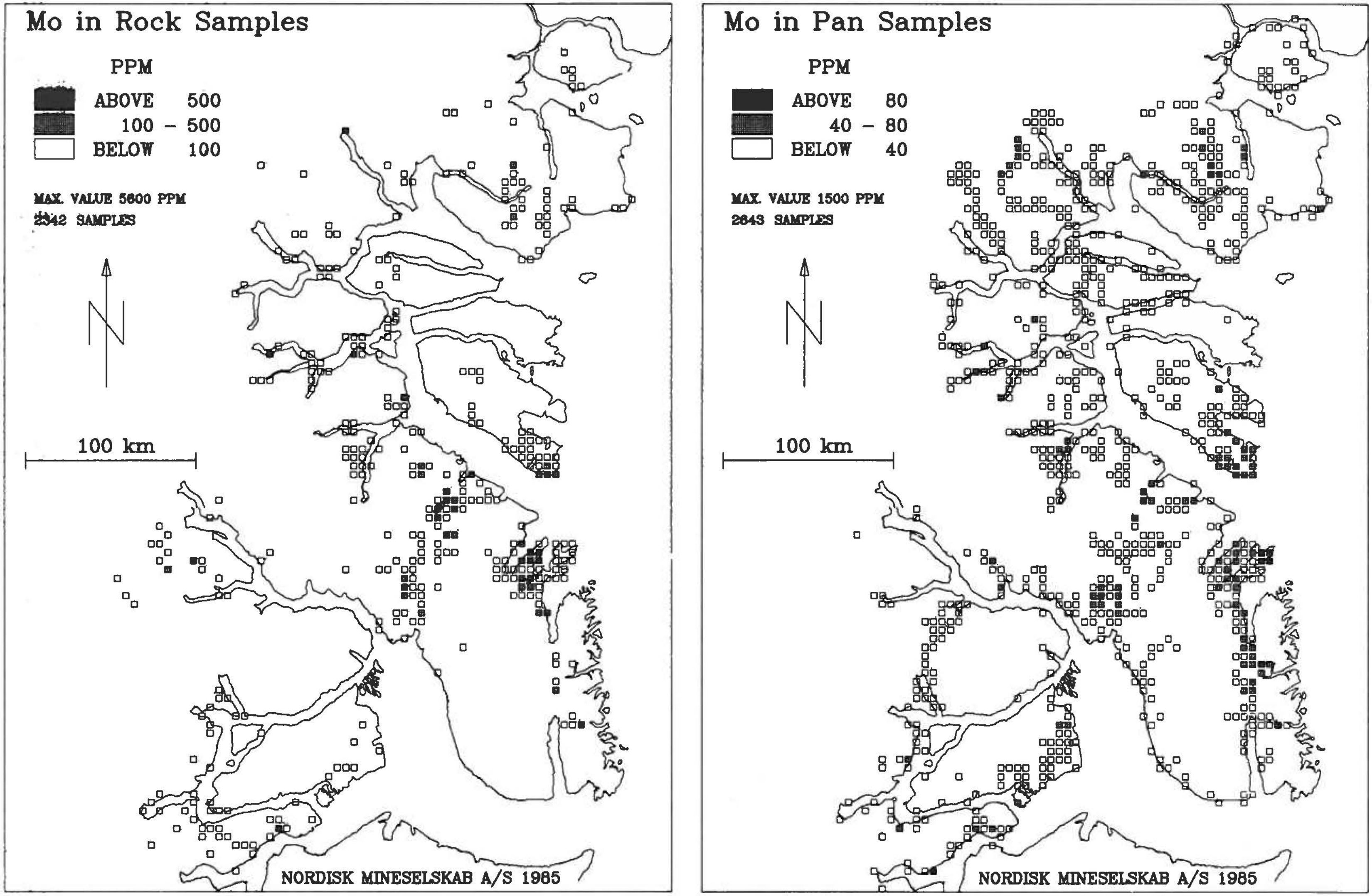


Fig. 91. Geochemical maps of molybdenum in rock and pan samples, central East Greenland.

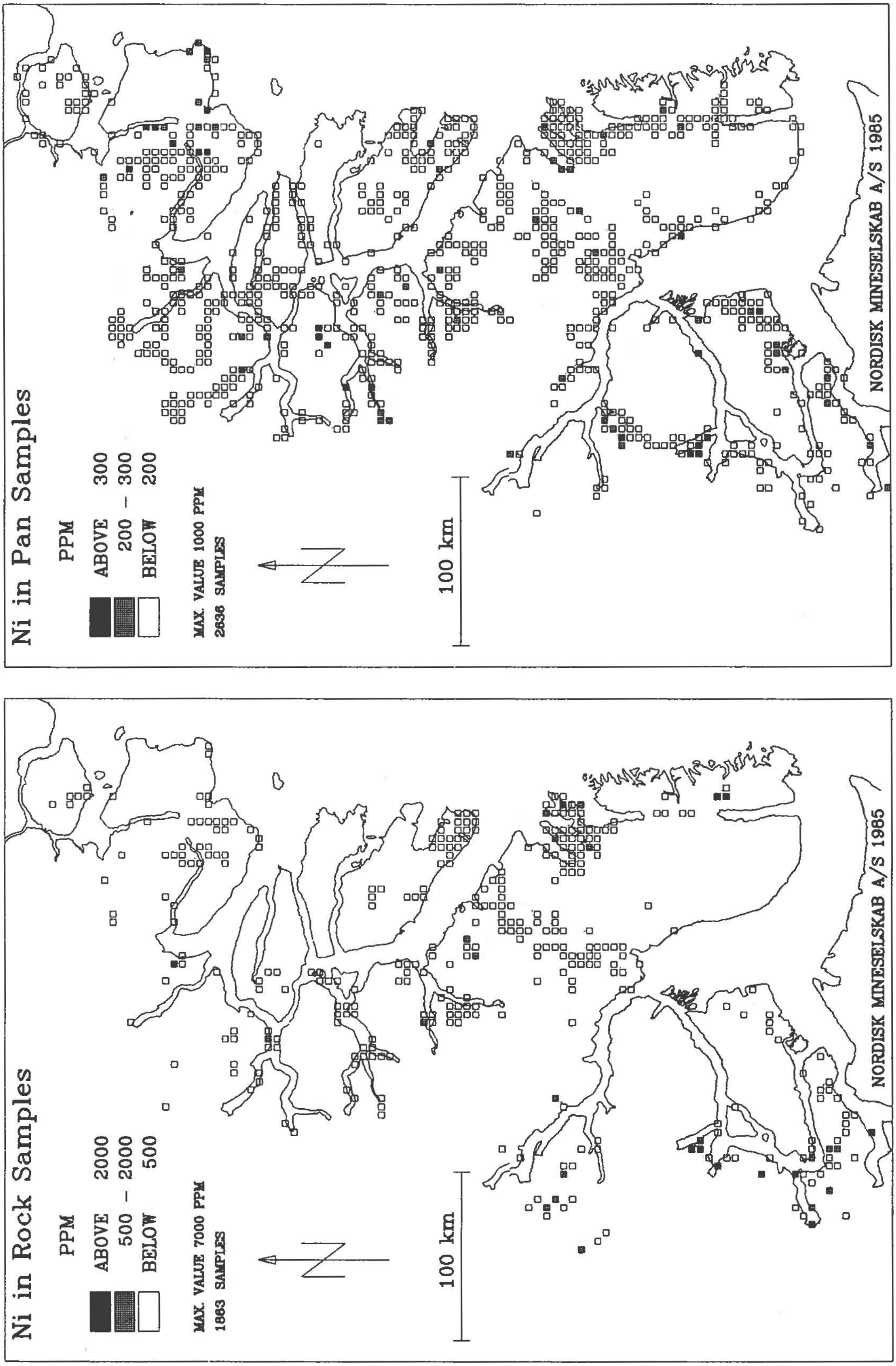


Fig. 92. Geochemical maps of nickel in rock and pan samples, central East Greenland.

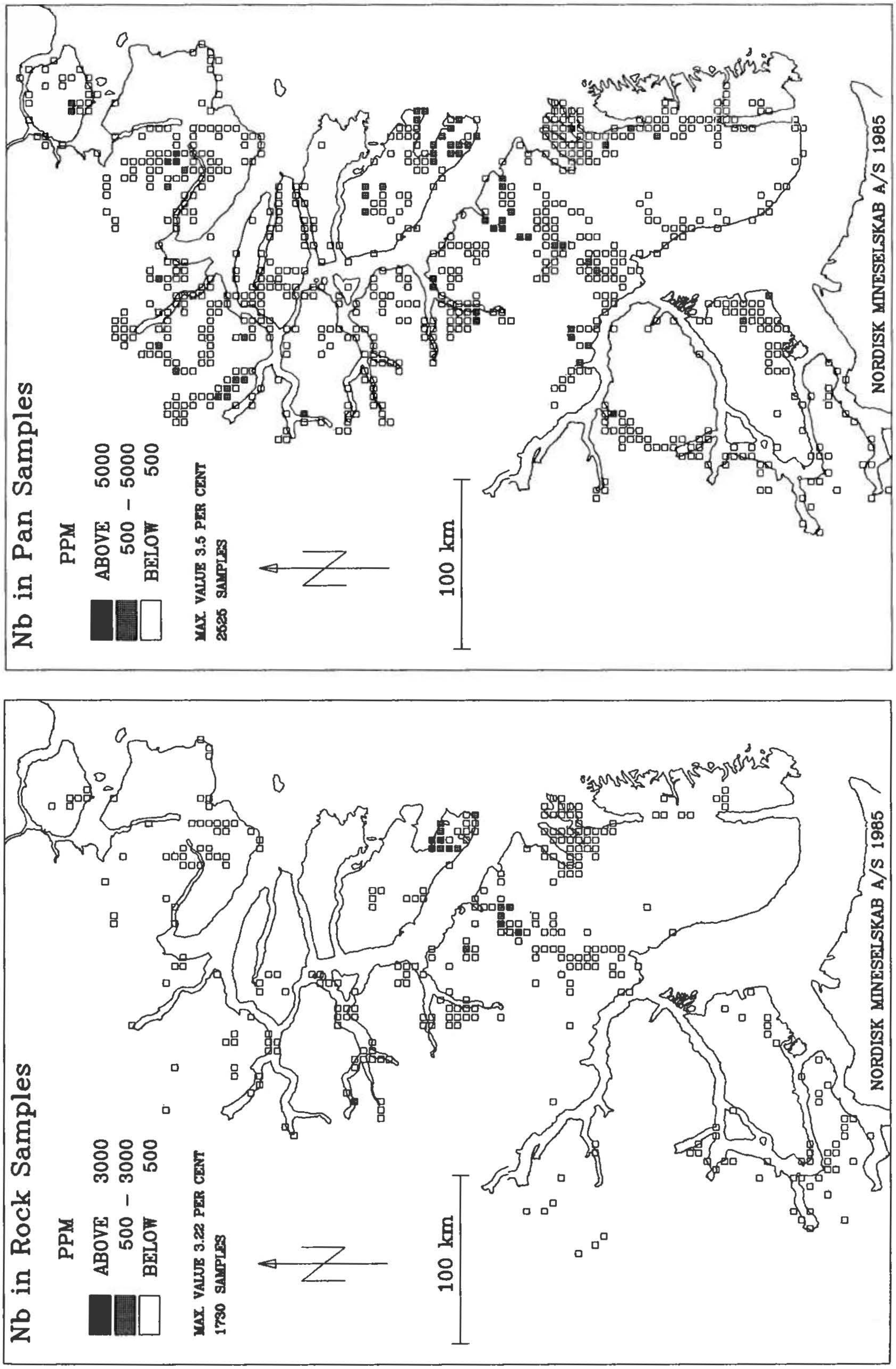


Fig. 93. Geochemical maps of niobium in rock and pan samples, central East Greenland.

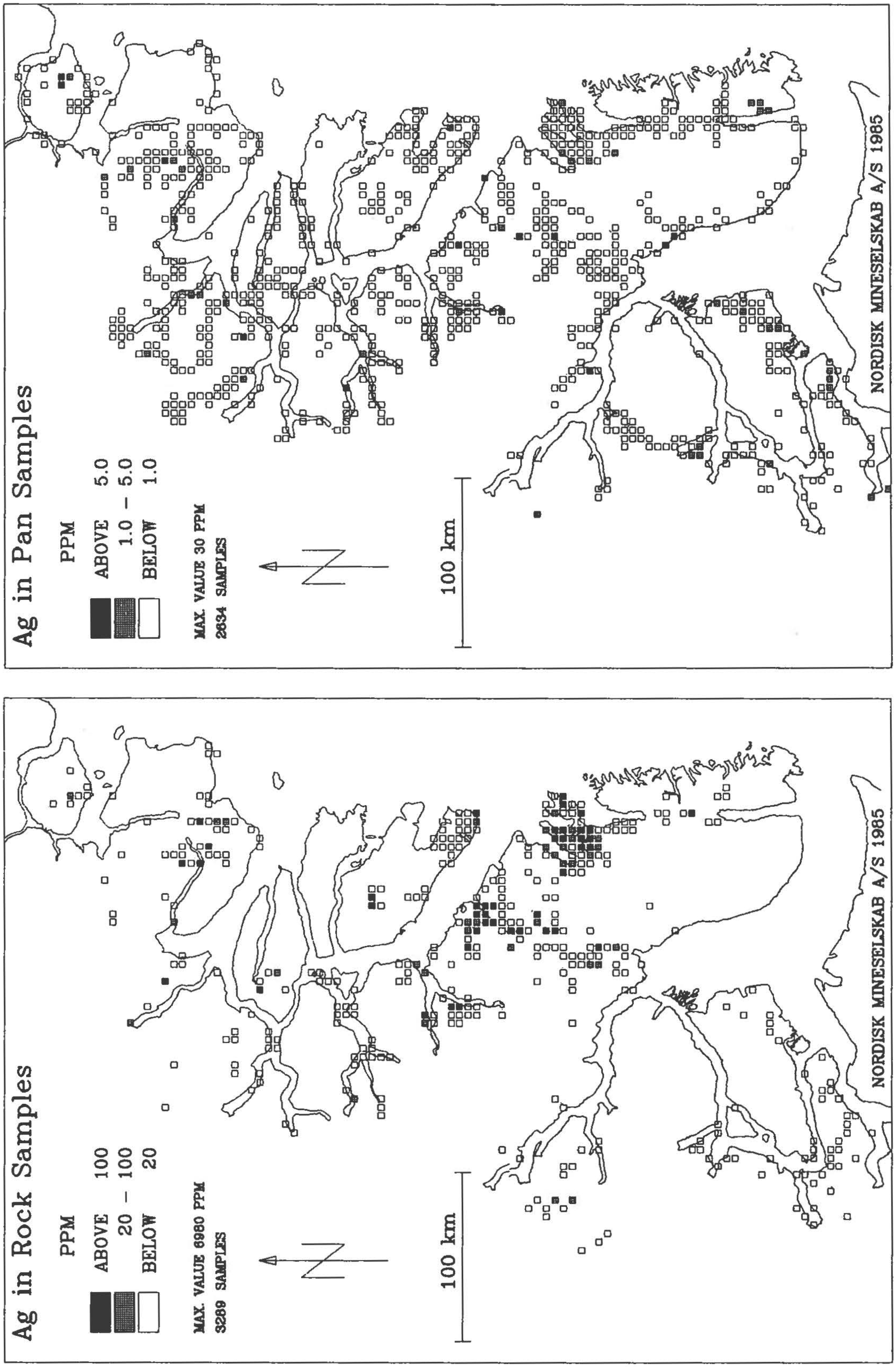


Fig. 94. Geochemical maps of silver in rock and pan samples, central East Greenland.

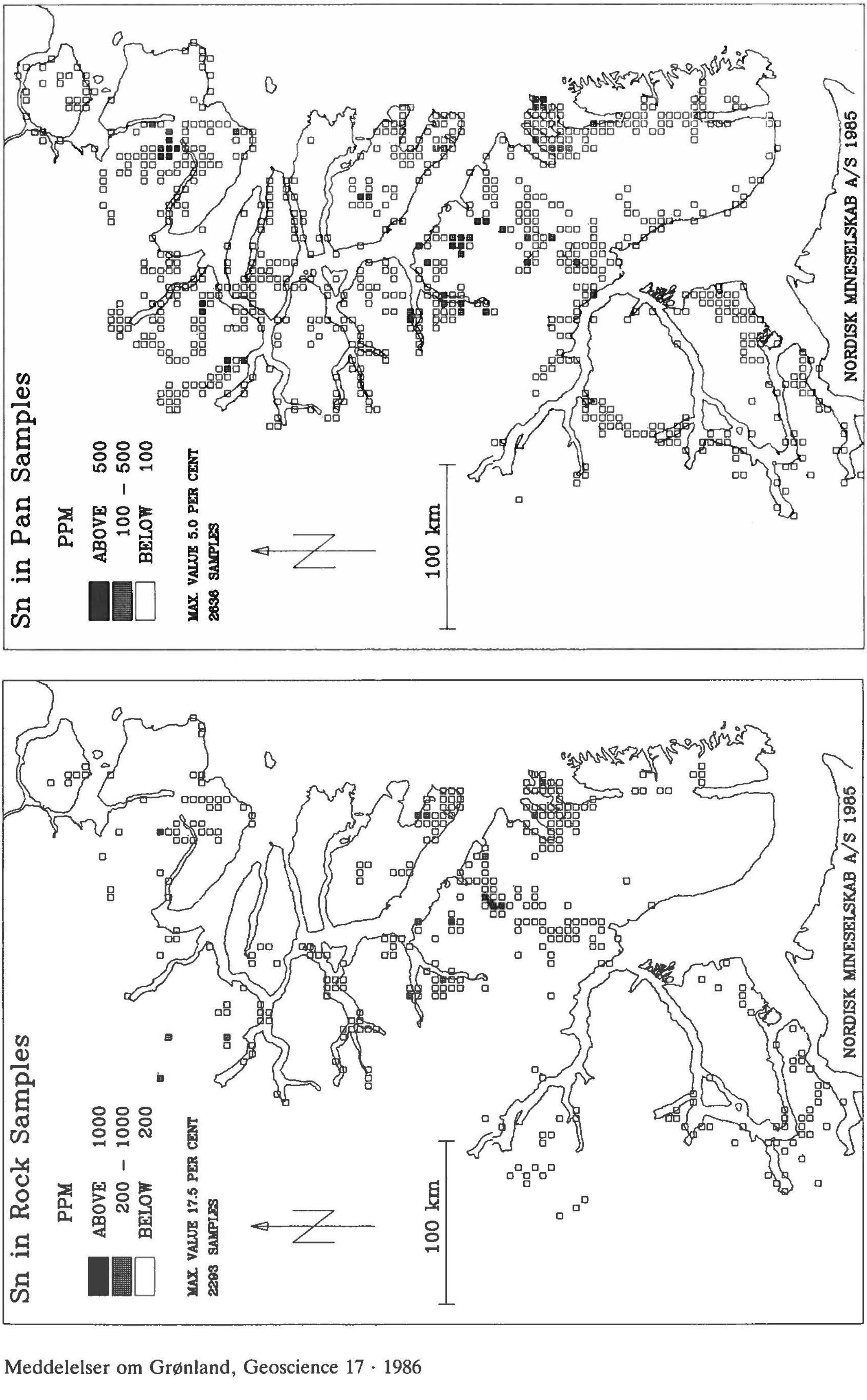
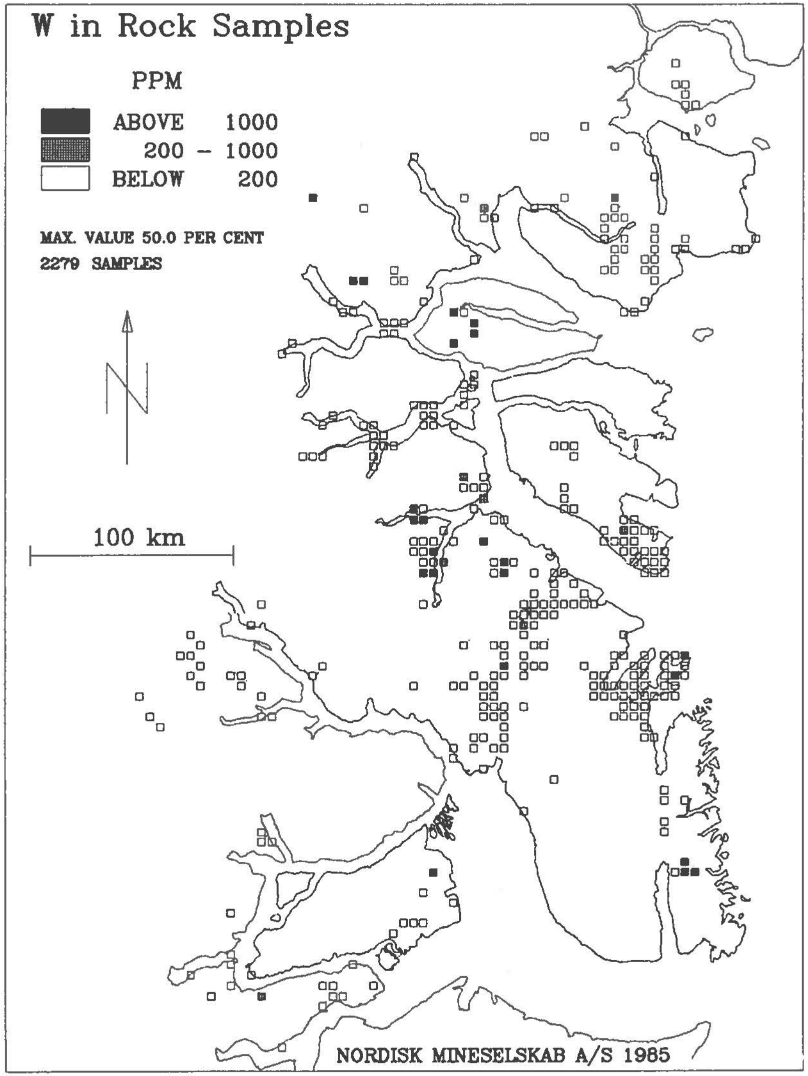


Fig. 95. Geochemical maps of tin in rock and pan samples, central East Greenland.



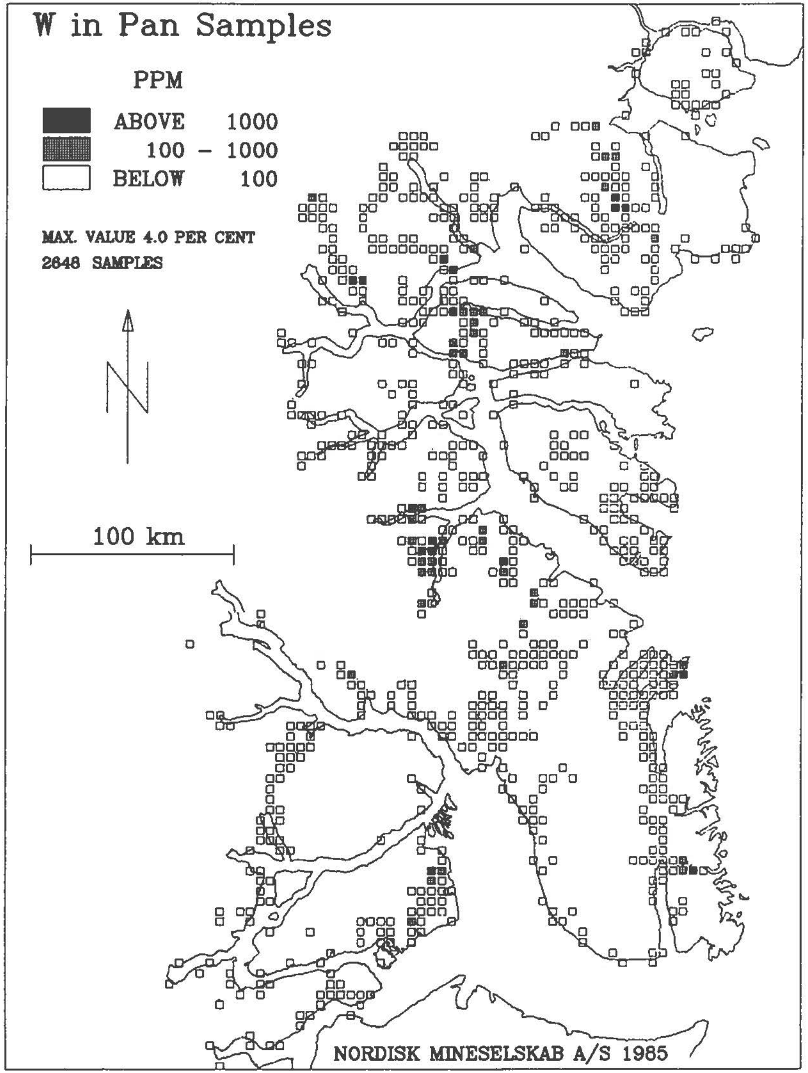


Fig. 96. Geochemical maps of tungsten in rock and pan samples, central East Greenland.

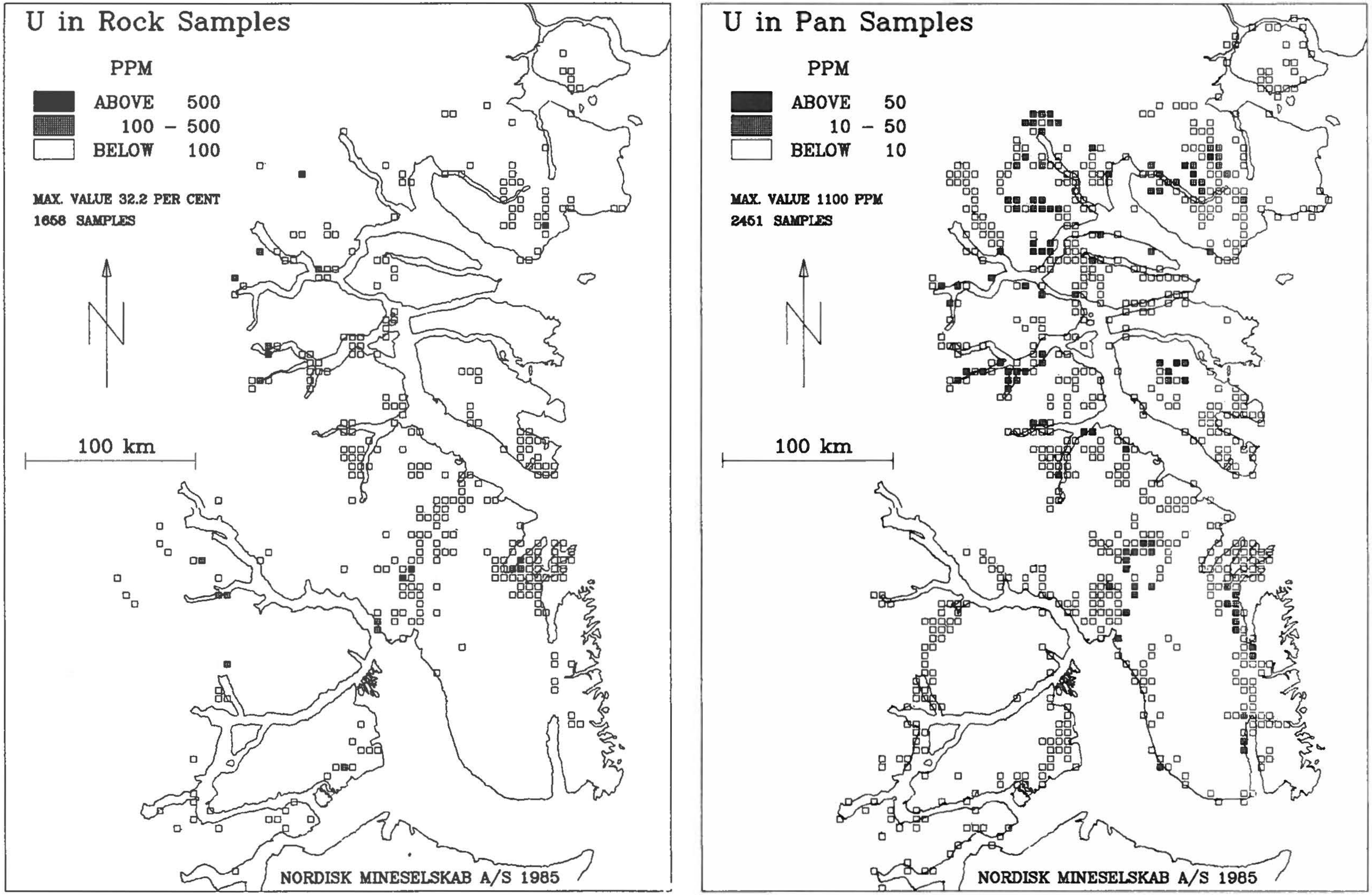
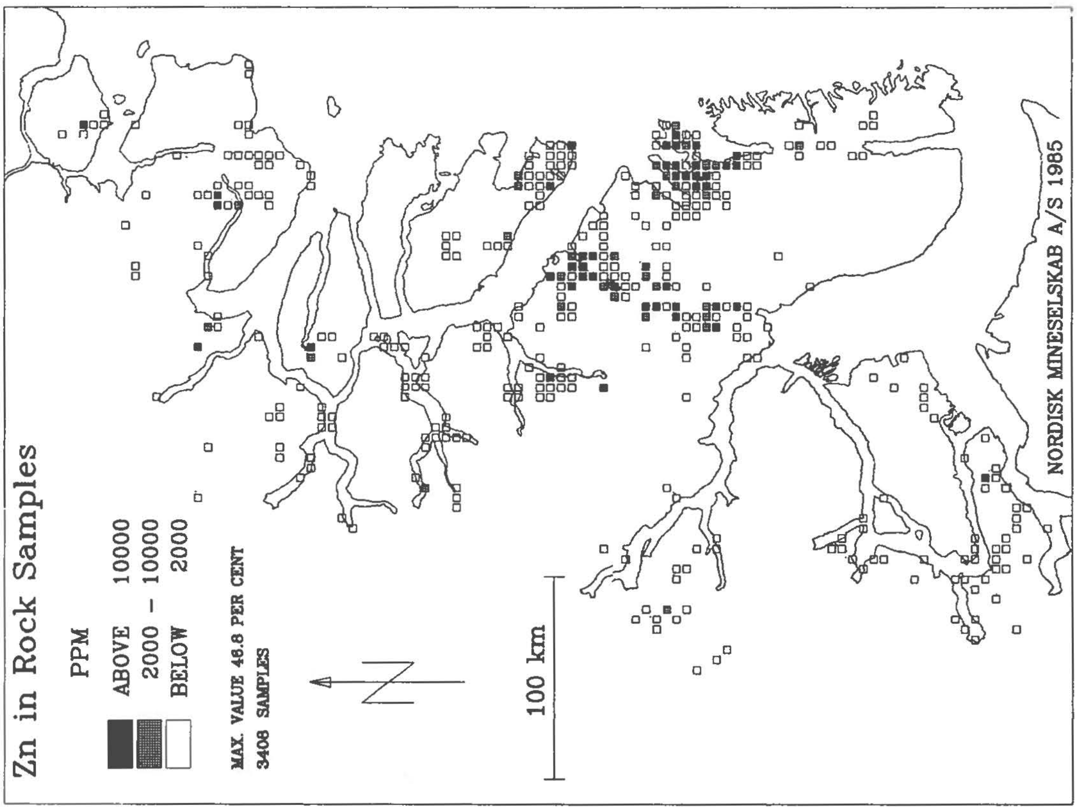


Fig. 97. Geochemical maps of uranium in rock and pan samples, central East Greenland.



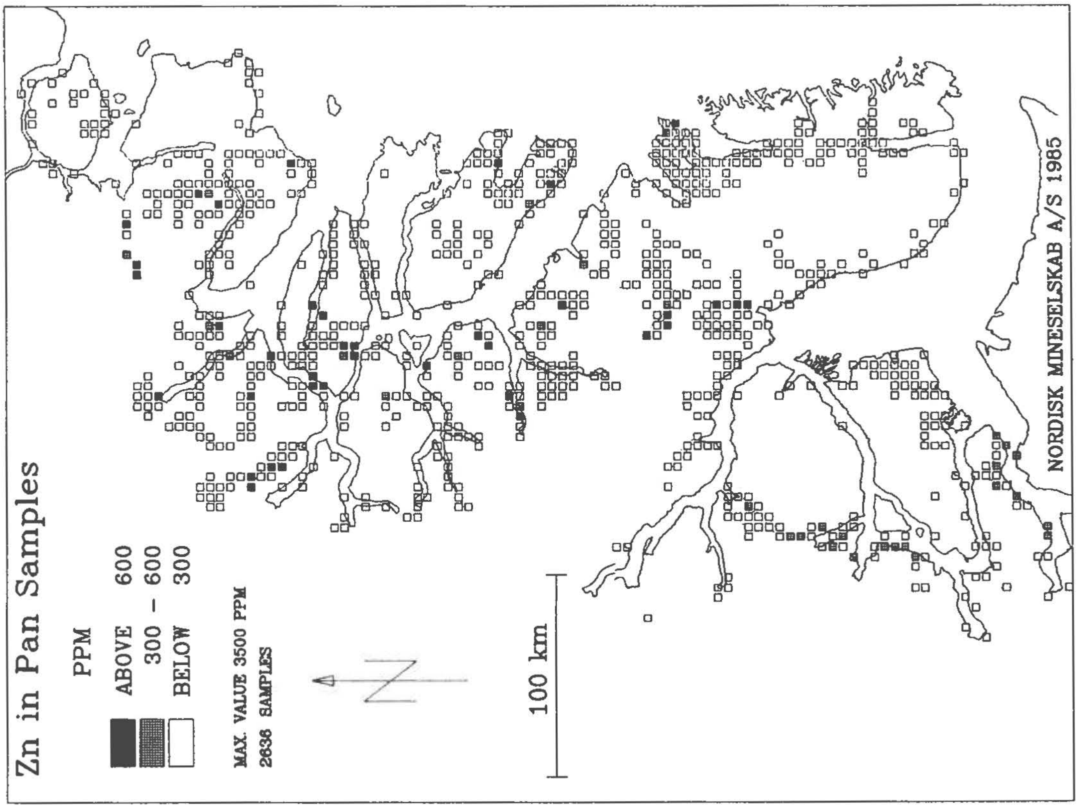
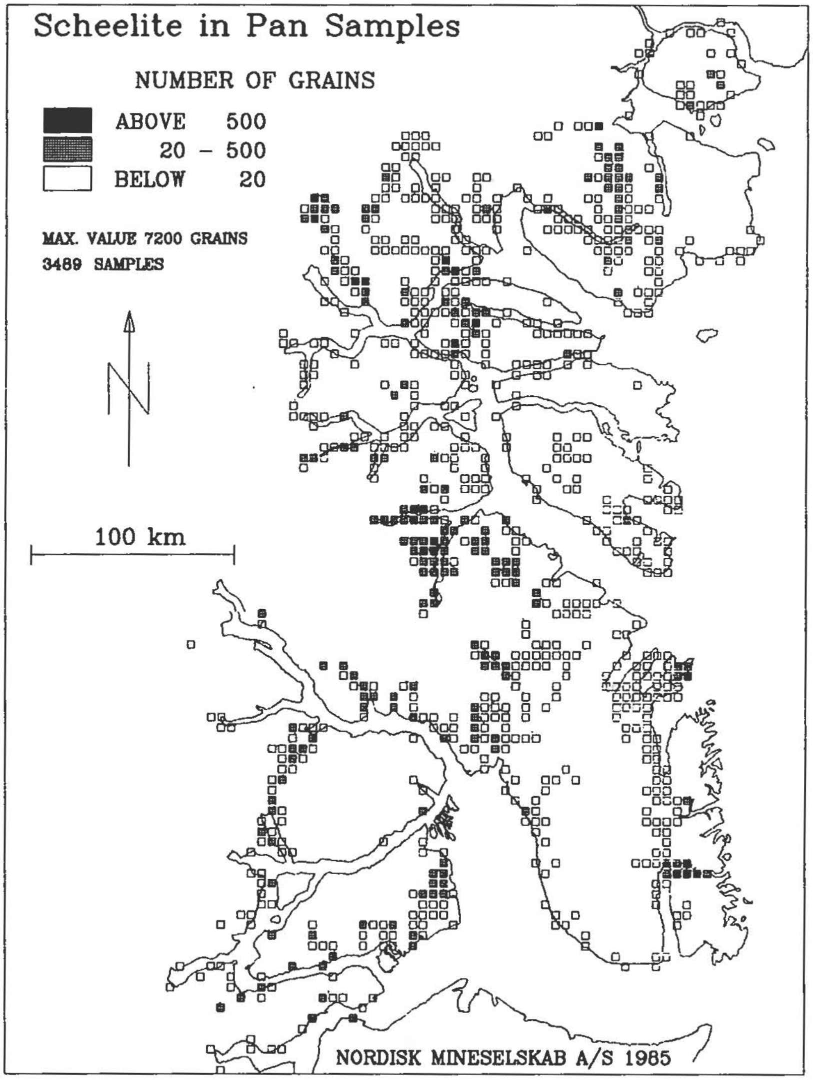


Fig. 98. Geochemical maps of zinc in rock and pan samples, central East Greenland.

Fig. 99. Geochemical map of scheelite grains in pan samples, central East Greenland.



Acknowledgements

First of all we wish to thank R. Kayser, Managing Director of Nordisk Mineselskab A/S, who made this work possible. Special thanks are also due to C. Hallenstein and F.D. Pedersen for improving the manuscript. A.K. Higgins, H.J. Bengaard, J.D. Friderichsen and K. Secher kindly reviewed parts of the text. B. Iversen prepared most of the drawings and B.L. Olesen computed the geochemical maps.

References

Note that the internal NM-reports and notes referred to are filed at the Geological Survey of Greenland.

Alexander-Marrack, P.D. & Friend, P.F. 1976. Devonian sediments of East Greenland III. The eastern sequence, Vilddal Supergroup and part of the Kap Kolthoff Supergroup. – Meddr Grønland 206,3: 122pp.

Appel, P. 1974. Report 1974. – Internal NM-report 7/74: 57pp.

Appel, P.W.U. 1978. On a banded iron-formation in the early Precambrian Isua supracrustal belt, West Greenland. – In: Smith, I.E.M. & Williams, J.G. (eds), Proc. 1978 Archean Geochemistry Conf. – University of Toronto: 326–328.

Appel, P.W.U. & Secher, K. 1984. On a gold mineralization in the Precambrian Tartoq Group, SW Greenland. – J. geol. Soc. London. 141: 273–278.

Asmund, G. 1974. Hydrochemical investigations on river water in West, South and East Greenland. – Rapp. Grønlands geol. Unders. 65: 71–73.

Asmund, G. & Steenfelt, A. 1976. Uranium analysis of stream water, East Greenland. – J. geochem. Explor. 5,3: 374–380.

Astlind, B. & Fahlström, P.H. 1957. Greenland lead-zinc mine beats elements with underground mill. – Mining World. Nov.: 46–50.

Backlund, H.G. & Malmqvist, D. 1932. Zur geologie und Petrographie der nordostgrönländischen Basaltformation. Teil I. Die basische Reihe. – Meddr Grønland 87,5: 61pp.

Bay, E. 1896. Den østgrønlandske Expedition, udført i Aarene 1891–1892 under Ledelse af C. Ryder, 3. Del. Geologi. – Meddr Grønland 19,6: 147–187.

Bearth, P. 1959. On the alkali massif of the Werner Bjerge in East Greenland. - Meddr Grønland 153,4: 63pp.
Beddoe-Stephens, B. & Secher, K. 1982. Barian wölsendorfite from East Greenland. - Mineral. Mag. 46: 130-132.
Bengaard, H.J. 1985. Beskrivelse til et geologisk, et metamorft og et strukturelt kort i målestokken 1:1 000 000 over Østgrønland 70°-82°N. - Unpublished thesis, University of Copenhagen: 145 pp.
Birkelund, T., Callomon, J.H. & Fürsich, F.T. 1984. The stratigraphy of the Upper Jurassic and Lower Cretaceous sediments of Milne Land, central East Greenland. - Bull. Grønlands geol. Unders. 147: 56pp.
Birkelund, T. & Perch-Nielsen, K. 1976. Late Palaeozoic-Mesozoic evolution of central East Greenland. - In: Escher, A. & Watt, W.S. (eds), Geology of Greenland. - Geol. Surv. Greenland, Copenhagen: 304-339.
Bjørlykke, A. & Sangster, D.F. 1981. An overview of sandstone lead deposits and their relation to red-bed copper and carbonate-hosted lead-zinc deposits. - Econ. Geol. 75th Anniversary Volume: 179-213.
Boast, A.M., Coleman, M.L. & Halls, C. 1981. Textural and stable isotopic evidence for the genesis of the Tynagh base metal deposit, Ireland. - Econ. Geol. 76: 27-55.
Bondam, J. & Brown, H. 1955. The geology and mineralisation of the Mesters Vig area, East Greenland. - Meddr Grønland 135,7: 40pp.
Brinch, V. 1969. Er der økonomisk grundlag for minedrift i Østgrønland. - Tidsskriftet Grønland: 171-179.
Brooks, C.K., Pedersen, A.K., Larsen, L.M. & Engell, J. 1982. The mineralogy of the Werner Bjerge Complex, East Greenland. - Meddr Grønland Geosci. 7: 35pp.
Brooks, R.R., Trow, J.M. & Fredskild, B. 1980. Lead level in Viscaria alpina from Greenland. - OIKOS, Copenhagen. 35: 425-428.
Brown, H. 1953. Notes on outcrops and prospects, Mestersvig area. - Internal NM-report 3/53: 7pp.
Brown, H. 1955. Lead-zinc occurrences in East Greenland. - J. R. School Mines, Lond. 4: 33-45.
Brown, H. 1956. Exploration of Traill Island, 1955. - Internal NM-report 2/55: 16pp.
Bruneau, C. 1976. Geophysical survey in East Greenland, 1975. - Internal NM-report SP3/75: 64pp.
Bugge, J.A.W. 1978. Norway. - In: Bowie, S.H.U., Kvalheim, A. & Haslam, H.W. (eds), Mineral Deposits of Europe. Volume I: Northwest Europe. - The Institution of Mining and Metallurgy and the Mineralogical Society, London: 199-249.
Bütler, H. 1935. Some new investigations of the Devonian stratigraphy and tectonics of East Greenland. - Meddr Grønland 103,2: 1-35.
Bütler, H. 1948. Notes on the geological map of Canning Land (East Greenland). - Meddr Grønland 133,2: 97pp.
Bütler, H. 1955. Das Variscisch gefaltete Devon zwischen Dúsens Fjord und Kongeborgen in Zentral-Ostgrönland. - Meddr Grønland 155,1: 131pp.
Bütler, H. 1957. Beobachtungen an der Hauptbruchzone der Küste von Zentral-Ostgrönland. - Meddr Grønland 160,1: 79pp.
Bütler, H. 1959. Das Old Red-Gebiet am Moskusoksefjord. Attempt at a correlation of the series of various Devonian areas in central East Greenland. - Meddr Grønland 160,5: 188pp.
Bøggild, O.B. 1905. Mineralogia Groenlandica. - Meddr Grønland 32: 642pp.
Bøggild, O.B. 1953. The mineralogy of Greenland. - Meddr Grønland 149,3: 442pp.
Caby, R. 1972. Preliminary results of mapping in the Caledonian rocks of Canning Land and Wegener Halvø, East Greenland. - Rapp. Grønlands geol. Unders. 48: 21-38.
Caby, R. 1976a. Preliminary results on stratigraphy, depositional environment, tectonics and high grade Caledonian progressive metamorphism of the lower Eleonore Bay Group, Alpefjord region, central East Greenland. - Grønlands geol. Unders., open file report: 19pp.
Caby, R. 1976b. Tension structures related to gliding tectonics in the Caledonian superstructure of Canning Land and Wegener Halvø, central East Greenland. - Rapp. Grønlands geol. Unders. 72: 24pp.
Caby, R. 1976c. Investigations on the Lower Eleonore Bay Group in the Alpefjord region, central East Greenland. - Rapp. Grønlands geol. Unders. 80: 102-106.
Callomon, J.H. & Birkelund, T. 1980. The Jurassic transgression and the mid-late Jurassic succession in Milne Land, central East Greenland. - Geol. Mag. 117,3: 211-226.
Clark, A.H. & Sillitoe, R.H. 1971. Cuprian galena solid solutions, Zapellar mining district, Atacama, Chile. - Am. Mineral. 56: 2142-2145.
Clausen F.L. & Harpøth, O. 1983. On the use of discriminant analysis techniques for classifying chemical data from panned heavy-mineral concentrates- central East Greenland. - J. geochem. Explor. 18: 1-24.
Clemmensen, L.B. 1977. Stratigraphical and sedimentological studies of Triassic rocks in central East Greenland. - Rapp. Grønlands geol. Unders. 85: 89-97.
Clemmensen, L.B. 1978a. Alternating aeolian, sabkha and shallow-lake deposits from the Middle Triassic Gipsdalen Formation, Scoresby Land, East Greenland. - Palaeogeography, Palaeoclimatology, Palaeoecology 24: 111-135.
Clemmensen, L.B. 1978b. Lacustrine facies and stromatolites from the Middle Triassic of East Greenland. - J. sediment. Petrol. 48: 1111-1128.
Clemmensen, L.B. 1980. Triassic rift sedimentation and palaeography of central East Greenland. - Bull. Grønlands geol. Unders. 136: 72pp.
Coats, J.S., Smith, C.G., Fortey, N.J., Gallagher, M.J., May, F. & McCourt, W.J. 1980. Stratabound barium-zinc mineralization in Dalradian schist near Aberfeldy, Scotland. - Trans. Instn Min. Metall. 89,B: B110-B122.
Coe, K. 1975. The Hurry Inlet granite and related rocks of Liverpool Land, East Greenland. - Bull. Grønlands geol. Unders. 115: 34pp.
Coe, K. & Cheeney, R.F. 1972. Preliminary results of mapping in Liverpool Land, East Greenland. - Rapp. Grønlands geol. Unders. 48: 7-20.
Collinson, J.D. 1972. The Røde Ø conglomerate of inner Scoresby Sund and the Carboniferous (?) and Permian rocks west of the Schuchert Flod. A general sedimentological account. - Bull. Grønlands geol. Unders. 102: 48pp.
Conradsen, K. & Harpøth, O. 1984. Use of Landsat multispectral scanner data for detection and reconnaissance mapping of iron oxide staining in mineral exploration, central East Greenland. - Econ. Geol. 79: 1229-1244.
Conradsen, K., Gunulf, J., Harpøth, O. & Nilsson, G. 1982. The application of remote sensing in mineral exploration. Part 1. - Department of Mathematical Statistics and Operations Research (IMSOR). Technical University of Denmark: 175pp.
Conradsen, K., Knudsen, J.G., Larsen, M. & Schønwandt, H.K. 1976. Multivariate statistical methods as a tool in the interpretation of heavy mineral data. A case study on statistical pattern recognition of earth data. - 14th International Symposium on the Application of Computer Methods in the Mining Industries. Pennsylvania State University: 13pp.
Cooke, H.R. 1976. Geochemical prospecting at Mesters Vig, central East Greenland and at Marmorilik, central West Greenland. - Rapp. Grønlands geol. Unders. 80: 116-120.
Coomer, P.G., Brooks, C.K. & Thomassen, B. 1974. The isotopic composition of lead in some galenas from East Greenland. - Internal NM-note 9/74: 14 pp.
Cowie, J.W. & Adams, P.J. 1957. The geology of the Cambro-Ordovician rocks of central East Greenland. Part I. Stratigraphy and structure. - Meddr Grønland 153,1: 193pp.
Dahlkamp, F., Polesnig, W. & Vohryzka, K. 1960. Bericht über montangeologische Untersuchungen im westlichen

Føhnfjordgebiet, Ostgrönland. – Internal NM-report 1/60: 11pp.
Damtoft, J.S. & Grahl-Madsen, L. 1982. Geological and VLF-geophysical mapping of the Bredehorn Ba-Pb prospect and preliminary mapping on SE Traill Ø for porphyry molybdenum mineralisation. – Internal NM-report 2/81: 118pp.
Donovan, D.T. 1957. The Jurassic and Cretaceous systems in East Greenland. – Meddr Grønland 155,4: 214pp.
Dunham, K.C., Beer, K.E., Ellis, R.A., Gallagher, M.J., Nutt, M.J.C. & Webb, B.C. 1978. United Kingdom. – In: Bowie, S.H.U., Kvalheim, A. & Haslam, H.W. (eds). Mineral Deposits of Europe, Volume I: Northwest Europe. – The Institution of Mining and Metallurgy and the Mineralogical Society, London: 263–317.
Dunning, F. W. 1984. Metallogeny of the United Kingdom of Great Britain and Northern Ireland. – In: Explanatory memoir of the metallogenic map of Europe and neighbouring countries. – Earth Sciences 17, UNESCO: 11–16.
Eha, S. 1953. The pre-Devonian sediments on Ymers Ø, Suess Land, and Ella Ø (East Greenland) and their tectonics. – Meddr Grønland 111,2: 105pp.
Eklund, J. 1949. Blyforekomsterne ved Mestersvig, Østgrønland. – Internal NM-report 1/49: 34pp.
Eklund, O. 1944. Malmgeologisk forskning på Nordostgrönland. – Teknisk Tidsskrift, Stockholm 14: 393–401.
Escher, A. & Watt, W.S. (eds) 1976. Geology of Greenland. – Geol. Surv. Greenland, Copenhagen: 603pp.
Favard, J.C., Scanvic, J.Y., Friedman, A.L. & Thyrsted, T. 1982. Le Groenland oriental, un exemple d'application du traitement interactif des données de télédétection à la cartographie géologique et à la recherche minière. – Chronique de la Recherche Minière 464: 27–44.
Fischer, B., Heider, E. & Kirchner, G. 1958. Der Blei-Zink-Bergbau Mesters Vig in Ostgrönland. – Berg- und Hüttenm. Monatsh. 103,8: 145–153.
Fränkl, E. 1951. Die untere Eleonore Bay Formation im Alpefjord. – Meddr Grønland 151,6: 15pp.
Fränkl, E. 1953a. Geologische Untersuchungen in Ost-Andrées Land (NE-Grönland). – Meddr Grønland 113,4: 160pp.
Fränkl, E. 1953b. Die geologische Karte von Nord-Scoresby Land (NE-Grönland). – Meddr Grønland 113,6: 56pp.
Friedrich, O.M. 1974. Berichte über Begehungen im Ostgrönland, Sommer 1974. – Internal NM-report 11/74: 32pp.
Friedrich, O.M. 1975. Descriptions of Upper Permian mineralization at Bredehorn and Quensel Bjerg. – Internal NM-report 11/75: 29pp.
Friend, P.F., Alexander-Marrack, P.D., Allen, K.C., Nicholson, J. & Yeats, A.K. 1983. Devonian sediments of East Greenland VI. Review of results. – Meddr Grønland 206,6: 96pp.
Frisch, W. & Thum, I. 1969. Montangeologischer Bericht über die Gebiete Vestfjord, westlicher Føhnfjord, Rødefjord – Rypefjord. – Internal NM-report 2/68: 40pp.
Frisch, W., Heinricher, G.M., Kutchera, S. & Heyrowsky, W. 1970. Montangeologischer Bericht über die Gebiete Skeldal, Hinks Land, Charcot Land, Pictet Bjerge, Nathorst Land. – Internal NM-report 2–8/69: 58pp.
Geyti, A. 1977. Geological field report. Amax-Nordisk Mineselskab. Joint venture 1977. – Internal NM-report 7/77: 12pp.
Geyti, A. 1980. Drilling and mapping in the EGMO concession area. – Internal NM-report 13/79: 44pp.
Geyti, A. 1981. Porphyry molybdenum in the Malmbjerg-Mellempas area. Geological mapping and sampling, 1980. – Internal NM-report 11/80: 98pp.
Geyti, A. 1982. Geological reconnaissance for porphyry-type mineralization 1981. Hudson Land, Hold With Hope, Bontekoe Ø, Scoresby Land, and Traill Ø. – Internal NM-report 4/81: 57pp.
Geyti, A., Hallenstein, C., Schønwandt, H.K. & Thomassen, B. 1979. A compilation of mineral exploration projects in Nordisk Mineselskab A/S' East Greenland concession. – Internal NM-note 4a: 49pp.
Geyti, A. & Thomassen, B. 1984. Molybdenum and precious metal mineralization at Flammefjeld, South-East Greenland. – Econ. Geol. 79: 1921–1929.
Ghisler, M. 1976. The geology, mineralogy and geochemistry of the pre-orogenic Archaean stratiform chromite deposits at Fiskenæsset, West Greenland. – Monograph series on mineral deposits 14. Gebrüder Borntraeger, Berlin: 156 pp.
Ghisler, M., Jensen, Aa., Stendal, H. & Urban, H. 1980 a. Stratabound scheelite, arsenopyrite and copper sulphide mineralization in the late Precambrian sedimentary succession of the East Greenland Caledonides. – Geol. Surv. Irl. Special Paper 5: 19–24.
Ghisler, M., Jensen, Aa., Stendal, H. & Urban, H. 1980 b. Stratabound copper mineralization in the late Precambrian of the East Greenland Caledonides. – In: Janković, S. & Sillitoe, R.H. (eds), European copper deposits. – Soc. Geol. appliquée Spec. Publ. 1: 160–165.
Graeter, P. 1957. Die sauren devonischen Eruptivgesteine des Kap Franklingebiets am Kejser Franz Josephs Fjord in Zentral-Ostgrönland. – Meddr Grønland 155,3: 102pp.
Grasmück, K. & Trümpy, R. 1969. Triassic stratigraphy and general geology of the country around Fleming Fjord (East Greenland). – In: Defretin-Lefranc, S., Grasmück, K. & Trümpy, R. (eds), Notes on Triassic stratigraphy and paleontology of north-eastern Jameson Land (East Greenland). – Meddr Grønland 168,2: 5-71.
Gross, W.H. 1956. The direction of flow of mineralizing solutions, Blyklippen Mine, Greenland. – Econ. Geol. 51: 415–426.
Gruner, U. & Probst, P. 1976. Geologische Detailuntersuchungen im Gebiet der Kupfervererzung des Mittleren Brogetdal (Strindbergsland). – Internal NM-report 13/75: 30pp.
Hallenstein, C. 1976. Uranium and thorium prospecting in Nordmine concession, East Greenland. – Internal NM-report 4/75: 111pp.
Hallenstein, C. 1977. Uranium and thorium prospecting in Nordmine concession, East Greenland. – Internal NM-report 4/76: 109pp.
Hallenstein, C. 1979. Scheelite exploration in the Rendal, W Ymers Ø, Alpefjord and Kalkdal areas, East Greenland. – Internal NM-report 5/79: 55pp.
Hallenstein, C. 1981. Scheelite exploration in the west Andrées Land, east Andrées Land, west Ymers Ø, east Milne Land areas of East Greenland. – Internal NM-report 5/80: 38pp.
Hallenstein, C. 1982. Scheelite exploration in Andrées Land, Ymers Ø and NE Suess Land. – Internal NM-report 5/81: 45pp.
Hallenstein, C. & Moeri, E. 1975. UV-prospecting in Alpefjord area. – Internal NM-note 5/75: 6pp.
Hallenstein, C. & Pedersen, J. 1982. Study of scheelite mineralization in central East Greenland. – Nordisk Mineselskab A/S, Copenhagen: 153pp.
Hallenstein, C.P. & Pedersen, J.L. 1983. Scheelite mineralization in central East Greenland. – Mineral. Deposita 18: 315–333.
Hallenstein, C.P., Pedersen, J.L. & Stendal, H. 1981. Exploration for scheelite in East Greenland – A case study. – J. geochem. Explor. 15: 381–392.
Haller, J. 1953. Geologie und Petrographie von West-Andrées Land und Ost-Frænkels Land (NE-Grönland). – Meddr Grønland 113,5: 196pp.
Haller, J. 1955. Der "Zentrale Metamorphe Komplex" von NE-Grönland. Teil I. Die geologische Karte von Suess Land, Gletscherland und Goodenoughs Land. – Meddr Grønland 73,3: 174pp.
Haller, J. 1958. Der "Zentrale Metamorphe Komplex" von NE-Grönland. Teil II. Die geologische Karte der Staunings Alper und des Forsblads Fjordes. – Meddr Grønland 154,3: 153pp.

Haller, J. 1970. Tectonic map of East Greenland (1: 500,000). An account of tectonism, plutonism and volcanism in East Greenland. – Meddr Grønland 171,5: 286pp.
Haller, J. 1971. Geology of the East Greenland Caledonides. – Interscience Publishers. New York: 413pp.
Hansen, B.T. & Steiger, R.H. 1971. The geochronology of the Scoresby Sund area. Progress report I: Rb/Sr mineral ages. – Rapp. Grønlands geol. Unders. 37: 55–57.
Hansen, B.T., Steiger, R.H. & Higgins, A.K. 1981. Isotopic evidence for a Precambrian metamorphic event within the Charcot Land window, East Greenland Caledonian fold belt. – Bull. geol. Soc. Denmark 29: 151–160.
Hansen, B.T. & Tembusch, H. 1979. Rb-Sr isochron ages from east Milne Land, Scoresby Sund, East Greenland. – Rapp. Grønlands geol. Unders. 95: 96–101.
Hansen, B.T., Frick, U. & Steiger, R.H. 1973. The geochronology of the Scoresby Sund area. Progress report 5: K/Ar mineral ages. – Rapp. Grønlands geol. Unders. 58: 59–61.
Harpøth, O. 1977. Detailundersøgelser af Cu-Pb-Zn-As-Ag-mineraliseringer i triassiske sedimenter Pingel Dal Øst. – Internal NM-report 6/76: 84pp.
Harpøth, O. 1979. Lagbundne Pb-Cu-Ag-mineraliseringer i Pingo Dal Formationen (Nedre Trias), Wegener Halvø, Østgrønland. – Unpublished thesis, University of Århus: 155pp.
Harpøth, O. 1980. Field Work in Southern Wegener Halvø, East Greenland – Detailed investigation of Upper Permian mineralisation in the Quensel Bjerg Area and geochemical soil sampling of Klitdal Member (Lower Triassic). – Internal NM-report 3/79: 154pp.
Harpøth, O. 1981. Field work in the Jameson Land basin, East Greenland. Internal NM-report 3/80: 88pp.
Harpøth, O. 1982. Prospecting in Karstryggen, central Traill Ø, Broget Dal, Bersærkerbræ and Canning Land, central East Greenland. – Internal NM-report 3/81: 76pp.
Harpøth, O. 1983. Summary of detailed chip sampling of the Bredehorn and Oksedal baryte occurrences. – Internal NM-note 1/83: 31pp.
Harpøth, O. 1984. Precious metal and tin exploration in Hudson Land and Andrées Land, central East Greenland. – Internal NM-report 14/83: 50pp.
Harpøth, O. & Pedersen, J. 1984. Supplementary note on gold indications in central East Greenland. – Internal NM-note 4/84: 27pp.
Harpøth, O., Scholle, P.A. & Stemmerik, L. In prep. A major celestite occurrence in the Upper Permian of central East Greenland.
Henriksen, N. 1981. The Charcot Land tillite, Scoresby Sund, East Greenland. – Earth's Pre-Pleistocene Glacial Record, Cambridge Earth Science series: 776–777.
Henriksen, N. 1985. The Caledonides of central East Greenland 70°–76°N. – In: Gee, D.G. & Sturt, B.A. (eds), The Caledonide Orogen: Scandinavia and related areas. – John Wiley and Sons Ltd, Chichester: 1095–1113.
Henriksen, N. & Higgins, A.K. 1969. Preliminary results of mapping in the crystalline complex around Nordvestfjord, Scoresby Sund East Greenland. – Rapp. Grønlands geol. Unders. 21: 5–20.
Henriksen, N. & Higgins, A.K. 1970. Preliminary results of mapping in the crystalline complex of Renland, the southern Stauning Alper and south-west Liverpool Land, Scoresby Sund, East Greenland. – Rapp. Grønlands geol. Unders. 30: 5–17.
Henriksen, N. & Higgins, A.K. 1971. Preliminary results of mapping in the crystalline complex around Rypefjord and Rødefjord, and on northern Milne Land, Scoresby Sund, East Greenland. – Rapp. Grønlands geol. Unders. 37: 5–18.
Henriksen, N. & Higgins, A.K. 1976. East Greenland Caledonian fold belt. – In: Escher, A. & Watt, W.S. (eds), Geology of Greenland. – Geol. Surv. Greenland, Copenhagen: 182–246.
Henriksen N., Perch-Nielsen, K. & Andersen, C. 1980. Descriptive text to 1: 100 000 sheet Sydlige Staunings Alper 71 Ø.2 N and Frederiksdal 71 Ø.3 N. – Grønlands geol. Unders.: 46pp.
Higgins, A.K. 1974. The Krummedal supracrustal sequence around inner Nordvestfjord, Scoresby Sund, East Greenland. – Rapp. Grønlands geol. Unders. 67: 34pp.
Higgins, A.K. 1976. Pre-Caledonian metamorphic complexes within the southern part of the East Greenland Caledonides. – J. geol. Soc. Lond. 132: 289–305.
Higgins, A.K. 1982. Descriptive text to 1: 100,000 sheet Charcot Land 71 Ø.4 N and Krummedal 71 Ø.4 S. – Grønlands geol. Unders.: 26pp.
Higgins, A.K. & Friderichsen, J.D. 1979. Boundary relationships between pre-Caledonian and Caledonian lithostructural units in the East Greenland Caledonides 72°–74° N. – Rapp. Grønlands geol. Unders. 95: 87–90.
Higgins, A.K. & Phillips, W.E.A. 1979. East Greenland Caledonides – an extension of the British Caledonides. – In: Harris, A.L., Holland, C.H. & Leake, B.E. (eds), The Caledonides of the British Isles – reviewed. – Spec. Publ. geol. Soc. Lond. 8: 19–32.
Higgins, A.K., Friderichsen, J.D. & Thyrsted, T. 1981. Precambrian metamorphic complexes in the East Greenland Caledonides (72°–74°N) – their relationships to the Eleonore Bay Group, and Caledonian orogenesis. – Rapp. Grønlands geol. Unders. 104: 4–46.
Hintsteiner, E. 1964. Aufschlussarbeiten und Schurfbohrungen auf Erz im Grönland. – Berg- und Hüttenm. Monatsh. 109,8: 270–272.
Hintsteiner, E.A. 1972. Bericht A – 72. – Internal NM-report SP/72.
Hintsteiner, E.A. 1977. Scheelitprospektion in Ostgrönland. – Berg- und Hüttenm. Monatsh. 122,2a: 31–35.
Hintsteiner, E.A., Kramers, J.D., Løvborg, L. & Wollenberg, H. 1970. Uran. – Internal NM-report SP1/70.
Hopfengärtner, F. 1974. Die Prospektion auf Scheelit auf der Halbinsel Randenæs, Forsblads Fjord vom 23.08 bis 27.08.74. – Internal NM-note 3/74: 2pp.
Jameson, R. 1823. List of specimens of the rocks brought from the eastern coast of Greenland, with geognostical memoranda.-In: Scoresby, W. Jr. (ed.), Journal of a Voyage to the Northern Whale Fishery. – A. Constable, Edinburgh: 399–409.
Jørgensen, J. B. 1980. Prospecting of the Permo-Carboniferous sediments of the Gurreholm Dal area, South Scoresby Land, East Greenland. – Internal NM-report 4/80: 27pp.
Kampmann, P. 1953. Bly- og zinkforekomster i Nordøstgrønland. – IVA, Stockholm, 24,7: 294–303.
Kapp, H. 1960. Zur Petrologie der Subvulkane zwischen Mesters Vig und Antarctic Havn (Ost-Grönland). – Meddr Grønland 153,2: 203pp.
Karup-Møller, S. 1979. Feltrapport over prospekteringsarbejdet efter scheelit i Rendal-Gemmedal området, Kalkdalen og Roslin Gletscher. – Internal NM-report 8/79: 27pp.
Katz, H.R. 1952. Zur Geologie von Strindbergs Land (NE-Grönland). – Meddr Grønland 111,1: 150pp.
Kempter, E. 1961. Die jungpaläeozoischen Sedimente von Süd-Scoresby Land (Ostgrönland), 71 1/2°N), mit besonderer Berücksichtigung der kontinentalen Sedimente. – Meddr Grønland 164,1: 123pp.
Kirchner, G. 1964. Die Molybdänlagerstätte des Erzberges bei Mesters Vig, Ostgrönland. – Berg- und Hüttenm. Monatsh. 109,4: 162–173.
Kirchner, G. 1968. Geologisch-lagerstättenkundliche Untersuchung im mittleren Gåseland, Milneland und Røde Ø. – Internal NM-report 3/68: 43pp.
Koch, L. 1929. The geology of East Greenland. – Meddr Grønland 73,2: 1–204.
Koch, L. 1955. Report on the expeditions to central East Greenland 1926–39 conducted by Lauge Koch. – Meddr Grønland 143,2: 642pp.
Koch, L. 1963. Rapport om den geologiske kortlægning af Øst-

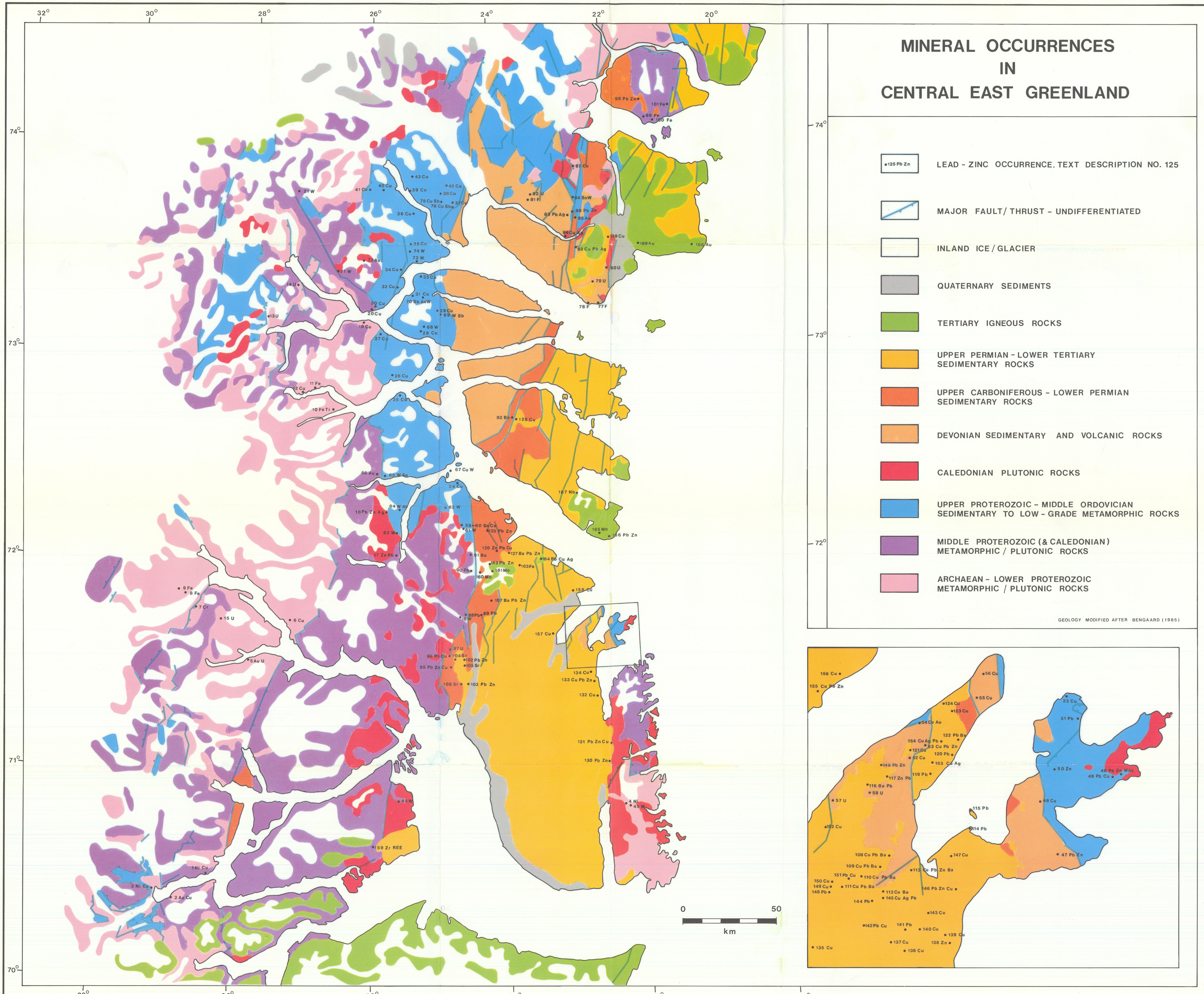
grønland fra 1926–1958. Bilag nr. 10. – In: Betænkning Nr. 340. Minelovskommission for Grønland: 104–115.
Koch, L. & Haller, J. 1971. Geological map of East Greenland 72°–76°N Lat. (1: 250,000). – Meddr Grønland 183: 26pp, 13 map sheets in portfolio.
Köck, H. & Pogöschnik, E. 1970. Bericht über Prospektionsarbeiten im südlichen Milneland, Hjørnedal, Vestfjord, Rødefjord. – Internal NM-report 1/69: 86pp.
Knup, P. 1958. Rapport über die Prospektierungsarbeiten im Sommer 1958 in Ostgrönland. – Internal NM-report 2/58: 9pp.
Kramers, J.D. 1972. Bericht über die Prospektionsarbeiten der Gruppe 12 im Sommer 1972. – Internal NM-report 12/72: 23pp.
Martens, P.N. 1973. Prospektionsbericht 1972. – Internal NM-report 7/72: 37pp.
Kunzendorf, H., Løvborg, L. & Wollenberg, H. 1971. Assay of powdered metallic ores by means of a portable X-ray fluorescence analyser. Risø Report 251: 29pp.
Kunzendorf, H., Friedrich, G.H.W., Koensler, W. & Steenfelt, A. 1978. Application of geochemical exploration in the Kap Franklin area, northern East Greenland. – Risø Report 375: 39pp.
Larsen, H.C. 1975. Aeromagnetic investigations in East Greenland. – Rapp. Grønlands geol. Unders. 75: 88–91.
Larsen, H.C. 1977. Aeromagnetiske undersøgelser i Østgrønland 1974. – Unpublished thesis, University of Copenhagen: 124pp.
Larsen, H.C. 1984. Project NAD – East Greenland. An integrated aeromagnetic and marine geophysical project off the east coast of Greenland. – Pre-final report no. 7. Geol. Surv. Greenland, Copenhagen: 44pp.
Lehnert-Thiel, K. & Vohryzka, K. 1968. Untersuchungen an Hg-Aureolen um polymetallische Sulfidgänge im Permafrostboden Ostgrönlands, 72° nl. Breite. – Montan-Rundschau 16,5: 104–108.
Lehnert-Thiel, K. & Walser, P. 1968. Montangeologischen Bericht über die Gebiete der Wegener Halbinsel, das nordwestliche Gebiet des Canning-Landes und den SE-Teil der Traill Ø. – Internal NM-report 5/68.
Lehnert-Thiel, K., Vohryzka, K., Demmer, H. & Walser, P. 1967. Mestersvig gebiet. – Internal NM-report 1/67.
Lethbridge, R.F. 1956. Prospecting operations in Greenland 1956. – Internal NM-report 3/56: 73pp.
Lind, M. 1980. Scheelitprospektering i Forsblads Fjord, Alpefjord, Jelsdal, Ymers Ø og Kalkdal. – Internal NM-report 6–10/79: 58pp.
Lind, M. 1981a. Scheelitprospektering i Vest Andrée Land og Syd Stauning Alper – Frederiksdal. – Internal NM-report 6/80: 40pp.
Lind, M. 1981b. Scheelitprospektering i Polhems Dal, Fuchs Bjerg, Lucia Dal, Geologfjord, Eleonores Bugt – Kap Weber, Murgangsdalen, Rosinante, Kalkdal. – Internal NM-report 6/81: 38pp.
Løvborg, L. & Nielsen, B.L. 1973. Processing and interpretation of radiometric flight data from central East Greenland. – Rapp. Grønlands geol. Unders. 55: 48–51.
Maync, W. 1942. Stratigraphie und Faziesverhältnisse der ober-permischen Ablagerungen Ostgrönlands (olim "Oberkarbon-Unterperm") zwischen Wollaston Forland und dem Kejser Franz Josephs Fjord. – Meddr Grønland 115,2: 128pp.
Maync, W. 1961. The Permian of Greenland. – In: Raasch, G.O. (ed.), Geology of the Arctic, I. – Toronto: 214–223.
Meyer, C. 1981. Ore-forming processes in geologic history. – Econ. Geol. 75th Anniversary Volume: 6–41.
Mittelholzer, A.E. 1941. Die Kristallingebiete von Clavering Ø und Payer Land (Ostgrönland). Vorläufiger Bericht über die Untersuchungen im Jahre 1938/39. – Meddr Grønland 114,8: 42pp.
Moeri, E. 1975. Strata-bound copper indications in the Precambrian Eleonore Bay Group of central East Greenland. – Internal NM-report 6/75: 18pp.
Nielsen, B.L. 1972. Aeroradiometric survey in the Scoresby Sund region, East Greenland. – Rapp. Grønlands geol. Unders. 45: 42–43.
Nielsen, B.L. 1973. A survey of the economic geology of Greenland (exclusive fossil fuels). Rapp. Grønlands geol. Unders. 56: 45pp.
Nielsen, B.L. 1976. Economic minerals.-In: Escher, A. and Watt, W.S. (eds), Geology of Greenland. – Geol. Surv. Greenland, Copenhagen: 460–486.
Nielsen, B.L. & Johansson, R. 1977. Field report 1977, North East Greenland. – GGU Open File Report: 89pp.
Nielsen, B.L. & Larsen, H.C. 1974. Airborne geophysical survey in central East Greenland. – Rapp. Grønlands geol. Unders. 65: 73–76.
Nielsen. B.L. & Løvborg, L. 1976. Radiometric survey between Scoresby Sund and Hold with Hope, central East Greenland. – Rapp. Grønlands geol. Unders. 76: 44pp.
Nielsen, B.L. & Steenfelt, A. 1975. Prospecting for uranium in central East Greenland. – Rapp. Grønlands geol. Unders. 75: 107–110.
Nielsen, B.L. & Steenfelt, A. 1977. Distribution of radioactive elements and the recognition of uranium mineralizations in East Greenland. – In: Recognition and evaluation of uraniferous areas. – Int. Atomic Energy Agency, Vienna (IAEA-TC-25/3): 87–105.
Noe-Nygaard, A. 1934. Stratigraphical outlines of the area round Fleming Inlet (East Greenland). – Meddr Grønland 103,1: 88pp.
Noe-Nygaard, A. 1937. Die palaeozoischen Eruptivgesteine von Canning-Land. – Meddr Grønland 118,6: 153pp.
Noe-Nygaard, A. 1976. Tertiary igneous rocks between Shannon and Scoresby Land, East Greenland. – In: Escher, A. & Watt, W.S. (eds), Geology of Greenland. – Geol. Surv. Greenland, Copenhagen: 386–402.
Nordenskjöld, O. 1907. On the geology and physical geography of East Greenland. – Meddr Grønland 28,5: 151–284.
Paar, W. 1974. Die Gefüge der synsedimentär-syndiagenetischen Schwerspat-Bleiglanz-Lagerstätte "Breithorn", Ostgrönland. – Archiv für Lagerstättenforschung in den Ostalpen, Sonderband 2: 215–237.
Paar, W. 1975. Babingtonit in einer skarnartigen Kontaktparagenese vom Oksehorn, Ostgrönland. – Der Karinthin, Austria 72/73: 169–175.
Paar, W. & Punzengruber, K. 1970. Der Forchhammerpluton, Traill Ø, Ostgrönland. – Internal NM-report 7/69: 31pp.
Paar, W. & Westerholt, W. 1971. Der Forchhammerpluton, Traill Ø, Ostgrönland. – Internal NM-report 7/70: 79pp.
Paar, W., Tichy, G. & Faupl, P. 1972. Montangeologische Bericht über die Prospektionsgebiete Werner Bjerge Süd und Ost Wegener Halvø. – Internal NM-report 7/71: 49pp.
Pargeter, R. 1955. Mineral exploration in the Werner Mountains (72°N 24°W) East Greenland. – Internal NM-report 5/55: 70pp.
Pedersen, J. 1980a. Report on geological field work 1980. – Internal NM-report 8/80: 35pp.
Pedersen, J. 1980b. Scheelite exploration in the Ymers Ø, Niklausdal, Nord Stauning Alper, Kalkdal and Alpefjord areas, central East Greenland. – Internal NM-report 7/79: 80pp.
Pedersen, J. 1981. Scheelite exploration in the Ymers Ø, E-Andrées Land, Nord Stauning Alper, Alpefjord and Roslin Gletscher areas, central East Greenland. – Internal NM-report 7/80: 94pp.
Pedersen, J. 1982. Scheelite exploration in the Alpefjord, Ymers Ø and East Andrées Land areas, central East Greenland. – Internal NM-report 7/81: 54pp.
Pedersen, J. 1984. Supplementary notes on diamond drilling and prospection on Ymers Ø, central East Greenland. – Internal NM-report 7/83: 43pp.
Pedersen, J.L. & Olesen, B.L. 1984. Vein type tungsten and

antimony mineralization in central East Greenland. – Nordisk Mineselskab A/S, Copenhagen: 136pp.
Perch-Nielsen, K., Birkenmajer, K., Birkelund, T. & Aellen, M. 1974. Revision of Triassic stratigraphy of the Scoresby Land and Jameson Land region, East Greenland. – Bull. Grønlands geol. Unders. 109: 51pp.
Perch-Nielsen, K., Bromley, R.G., Birkenmajer, K. & Aellen, M. 1972. Field observations in Palaeozoic and Mesozoic sediments of Scoresby Land and northern Jameson Land. – Rapp. Grønlands geol. Unders. 48: 39–59.
Petrascheck, W.E., 1971. Die Erzhöffigkeit Grönlands im Lichte der Kontinentalverschiebung. – Erzmetall 24,6: 257–260.
Phillips, W.E.A. & Friderichsen, J.D. 1981. The Late Precambrian Gåseland tillite, Scoresby Sund, East Greenland. – In: Hambrey, M.J. & Harland, W.B. (eds), Earth's pre-Pleistocene glacial record. Cambridge Univ. Press: 773–775.
Phillips, W.E.A., Stillman, C.J., Friderichsen, J.D. & Jemelin, L. 1973. Preliminary results of mapping in the western gneiss and schist zone around Vestfjord and inner Gåsefjord, south-west Scoresby Sund. – Rapp. Grønlands geol. Unders. 58: 17–32.
Piasecki, S. 1984. Preliminary palynostratigraphy of the Permian – Lower Triassic sediments in Jameson Land and Scoresby Land, East Greenland. – Bull. geol. Soc. Denmark. 32: 139–144.
Plant, J.A., Simpson, P.R., Green, P.M., Watson, J.V. & Fowler, M.B. 1983. Metalliferous and mineralized Caledonian granites in relation to regional metamorphism and fracture systems in northern Scotland. – Trans. Instn Min. Metall. 92,B: B33-B42.
Polegeg, S. 1971. Prospektionserfahrungen in Ost-Grönland. – Montan-Rundschau 19,1: 7–12.
Polesnig, W. & Vohryzka, K. 1958. Die Erzvorkommen der Nordlichen Wernerberge. – Internal NM-report 3/58: 19pp.
Purdy, C.P. & Hurd, D.V. 1958. Mt. Erzberg molybdenite deposit near Mesters Vig, East Greenland. AMAX. – Internal NM-report MB-1958: XXpp.
Putallaz, J. 1961. Géologie de la partie médiane de Traill Ø (Groenland Oriental). – Meddr Grønland 164,2: 84pp.
Ramdohr, P. 1980. The ore minerals and their intergrowths. 2nd edn. – Pergamon Press, Oxford: 1207pp.
Rasmussen, L. 1980. Nathorst Land Projekt. En undersøgelse af bly-zink mineraliseringen i Schaffhauserdalen, Østgrønland. – Internal NM-report 6/79: 34pp.
Rasmussen, L. 1982. En malmgeologisk undersøgelse af en hydrothermal Pb-Zn-Ag mineralisering i Schaffhauserdalen, Østgrønland. – Unpublished thesis, University of Copenhagen: 90pp.
Reece, A. 1957. Prospecting in Northeast Greenland. – Internal NM-report 5/57: 37pp.
Reece, A. & Mather, A.L. 1961. Geochemical prospecting for base metals in Schuchert Dal, Northeast Greenland. – In: Raasch, G.O. (ed.), Geology of the Arctic 2. – Toronto: 1157–1166.
Rex, D.C. & Gledhill, A. 1974. Reconnaissance geochronology of the infracrustal rocks of Flyverfjord, Scoresby Sund, East Greenland. – Bull. geol. Soc. Denmark 23: 49-54.
Rex, D.C. & Gledhill, A.R. 1981. Isotopic studies in the East Greenland Caledonides (72°–74°N)- Precambrian and Caledonian ages. – Rapp. Grønlands geol. Unders. 104: 47–72.
Rosenkrantz, A. 1970. Træk af den geologiske udforskningshistorie. – In: Nielsen, N., Skautrup, P. & Vibe, C. (eds), J.P. Trap DANMARK, 5. udg., Grønland, 14. – København: 43–51.
Ryan, M. & Sandwall, J. 1975. Field work in the Moskusoksefjord – Kejser Franz Josephs Fjord region of East Greenland, 1975. – Internal NM-report 7/75: 88pp.
Säve-Söderbergh, G. 1933. Further contributions to the Devonian stratigraphy of East Greenland, I. Results from the summer expedition 1932. – Meddr Grønland 96,1: 40pp.
Säve-Söderbergh, G. 1934. Further contributions to the Devonian stratigraphy of East Greenland, II. Investigations on Gauss Peninsula during the summer of 1933. With an Appendix: Notes on the geology of the Passage Hills (East Greenland). – Meddr Grønland 96,2: 1-74.
Schassberger, H.T. & Galey, J.T. 1975. Report on 1974 core relogging Erzberg project, East Greenland. Part I + II. AMAX. – Internal NM-report MB-1974: 41pp.
Schassberger, H.T. & Newall, G.C. 1980. The East Greenland Molybdenum Project 1979. AMAX. – Internal NM-report MB-1979: 53pp.
Schassberger, H.T. & Spieth, V. 1978. Molybdenum Exploration in NE Greenland 1977 (AMAX). – Internal NM-report MB-1977: 9pp.
Schatzlmaier, P., Schöllnberger, W. & Thomassen, B. 1973. Untersuchung des Vorkommens am Zirkon und seltenen Erden auf Kote 800 Milneland. – Internal NM-report 4/72: 91pp.
Schaub, H.P. 1938. Zur Vulkanotektonik der Inseln Traill und Geographical Society (Nordostgrönland). – Meddr Grønland 114,1: 29–44.
Schaub, H.P. 1942. Zur Geologie der Traill Insel (Nordostgrönland). – Eclog. geol. Helv. 35: 1–54.
Schønwandt, H.K. 1980. Prospektering i trias-sedimenterne i Klitdal-Passagen området. – Internal NM-report 2/75: 23pp.
Secher, K., Nielsen, B.L. & Steenfelt, A. 1976. Uraniferous hydrocarbons(carburan) associated with Devonian acid volcanic rocks, Randbøldal, northern East Greenland. – Rapp. Grønlands geol. Unders. 80: 112–115.
Smith, D.C. & Cheeney, R.F. 1981. A new occurrence of garnet-ultrabasite in the Caledonides: a Cr-rich chromite-garnet-lherzolite from Tværdalen, Liverpool Land, East Greenland. – Terra cognita 1: 74.
Sommer, M. 1957. Geologie von Lyells Land (NE-Grönland). – Meddr Grønland 155,2: 157pp.
Stauber, H. 1938. Stratigraphische Untersuchungen postdevonischer Sedimente auf den Inseln Traill und Geographical Society. – Meddr Grønland 114,1: 23–28.
Stauber, H. 1942. Die Triasablagerungen von Ostgrönland. – Meddr Grønland 132,1: 325pp.
Steck, A. 1971. Kaledonische Metamorphose der praekambrischen Charcot Land Serie, Scoresby Sund, Ost-Grönland. – Meddr Grønland 192,3: 69pp.
Steenfelt, A. 1976. Uranium exploration in northern East Greenland. – Rapp. Grønlands geol. Unders. 80: 110–112.
Steenfelt, A. 1982. Uranium and selected trace elements in granites from the Caledonides of East Greenland. – Mineral. Mag. 46: 201–210.
Steenfelt, A. & Kunzendorf, H. 1979. Geochemical methods in uranium exploration in northern East Greenland. – In: Watterson, J.R. & Theobald, P.K. (eds), Geochemical exploration 1978. – Association of Exploration Geochemists, Colorado: 429–442.
Steenfelt, A. & Nielsen, B.L. 1978. Field work in uranium geology and prospecting, northern East Greenland. – Rapp. Grønlands geol. Unders. 90: 89–94.
Steenfelt, A., Kunzendorf, H. & Friedrich, G.H.W. 1976. Randbøldal: Uranium in stream sediments, soils and water. – J. geochem. Explor. 5,3: 300–305.
Steiger, R.H., Hansen, B.T., Schuler, C., Bär, M.T. & Henriksen N. 1979. Polyorogenic nature of the southern Caledonian fold belt in East Greenland. – J. Geol. 87: 475–495.
Stendal, H. 1979a. Geochemical copper prospecting by use of inorganic drainage sediment sampling in central East Greenland. – Trans. Instn Min. Metall. 88,B: B1-B4.
Stendal, H. 1979b. Mineralogiske og geokemiske undersøgelser af tungmineraler og tungmetaller i de arenitiske og i de argillitiske fraktioner af recente sedimenter fra det centrale Østgrønland (72°–74° N). – Unpublished thesis, University of Copenhagen: 178pp.
Stendal, H. 1980a. Scheelite Exploration in the Alpefjord and Schaffhauserdal Regions. – Internal NM-report 9/79: 94pp.
Stendal, H. 1980b. Distribution of metals and heavy minerals

in drainage sediments in late Precambrian rocks of central East Greenland (72°–74° N). – Norges geol. Unders. 360: 99–111.
Stendal, H. 1980c. Scheelite investigations in Hudson Land, Andrée Land, Ymers Ø and Nathorst Land. – Internal NM-report 9/80: 104pp.
Stendal, H. 1982a. Geochemical trends for metals in inorganic sediment samples in an arctic area, East Greenland. – In: Davenport, P.H. (ed.), Prospecting in areas of glaciated terrain, 1982. – Can. Inst. Mining Metall.: 160–178.
Stendal, H. 1982b. Geochemistry and genesis of arsenopyrite mineralization in late Precambrian sediments in central East Greenland. – Trans. Instn Min. Metall. 91,B: B187-B191.
Stendal, H. & Ghisler, M. 1984. Strata-bound copper sulfide and nonstrata-bound arsenopyrite and base metal mineralization in the Caledonides of East Greenland – a review. – Econ. Geol. 79: 1574–1584.
Stendal, H. & Hock, M. 1981. Geochemical prospecting for stratabound mineralization in late Precambrian sediments of East Greenland (72°–74°N). – J. geochem. Explor. 52: 261–269.
Stern, P. 1964. Zur Petrographie von Nordhoeks Bjerg und Nörlunds Alper, Hudson Land (Zentral-Ostgrönland). – Meddr Grønland 168,5: 112pp.
Strangway, D.W. 1957. Geophysical report, North-East Greenland. – Internal NM-report 3/57: 11pp.
Sugden, F.J. 1963. Erzberg Project East Greenland. Summary Report of 1962 Exploration Program. + Accompanying plans and sections. – Internal NM-report MB-1962:
Surlyk, F. 1977. Stratigraphy, tectonics and palaeogeography of the Jurassic sediments of the areas north of Kong Oscars Fjord, East Greenland. – Bull. Grønlands geol. Unders. 123: 56pp.
Surlyk, F., Callomon, J.H., Bromley, R.G. & Birkelund, T. 1973. Stratigraphy of the Jurassic-Lower Cretaceous sediments of Jameson Land and Scoresby Land, East Greenland. – Meddr Grønland 193,5: 76pp.
Surlyk, F., Clemmensen, L.B. & Larsen, H.C. 1981. Post-Paleozoic evolution of the East Greenland continental margin. – In: Kerr, J.W. & Ferguson, A.J. (eds), Geology of the North Atlantic Borderlands. – Mem. Can. Soc. Petrol. Geol. 7: 611–645.
Surlyk, F., Piasecki, S., Rolle, F., Stemmerik, L., Thomsen, E. & Wang, P. 1984. The Permian basin of East Greenland. – In: Norwegian Petroleum Society (ed.), Petroleum geology of the North European Margin. – Graham and Trotman, London: 303–315.
Surlyk, F., Frazier, T.C., Harpøth, O., Hurst, J.M., Rolle, F., Piasecki, S. & Stemmerik, L. in prep. Lithostratigraphy of the Upper Permian Foldvik Creek Group, East Greenland. – Bull. Grønland geol. Unders.
Surlyk, F., Hurst, J.M., Piasecki, S., Rolle, F., Scholle, P.A., Stemmerik, L. & Thomsen, E. in press. The Permian of the western margin of the Greenland Sea – a future exploration target. – Mem. Am. Ass. Petrol. Geol. 40.
Swiatecki, A. 1981. Prospecting of the Pb-Zn-Cu mineralised veins, Mesters Vig area, and drill programme Oksedal baryte body, Mesters Vig South, East Greenland. – Internal NM-report 10/80: 121pp.
Swiatecki, A. 1983. En undersøgelse af de Pb-Zn-Cu mineraliserede gange i Mesters Vig området (Østgrønland). – Unpublished thesis, University of Århus: 88pp.
Swiatecki, A. & Damtoft, J.S. 1980. VLF-geophysics Blyklippen, Pings Elv, Oksedal, Bredehorn, Ymers Ø. – Internal NM-report SP1/80: 50pp.
Sørensen, H., Nielsen, B.L. & Jacobsen F.L. 1978. Denmark and Greenland. – In: Bowie, S.H.U., Kvalheim, A. & Haslam, H.W. (eds), Mineral Deposits of Europe. Volume I: Northwest Europe. – The Institution of Mining and Metallurgy and the Mineralogical Society, London: 251–261.
Sørensen, P. 1971. Prospection report – Traill Island, Werner Mountains, Arkose Dal, Q 16 and Milne Land kote 800. – Internal NM-report 12/71: 19pp.
Thomassen, B. 1971. Prospektering i Østgrønland. – Tidsskriftet Grønland: 365–374.
Thomassen, B. 1973. Heavy metal content of the Posidonia Shales on Wegener Halvø. – Rapp. Grønlands geol. Unders. 58: 33–35.
Thomassen, B. 1974. Kobber-sølv-bly-mineraliseringen i Devondal (Quenseldal), Wegener Halvø. – Internal NM-report 5/73: 15pp.
Thomassen, B. 1975. Stratabound Permo-Triassic copper-lead-zinc-mineralization at the eastern border of the Jameson Land Basin. – Internal NM-report 8–9/74: 98pp.
Thomassen, B. 1976. Fortsatte undersøgelser af de lagbundne permo-triassiske mineraliseringer i det nordøstlige Jameson Land. – Internal NM-report 1/75: 60pp.
Thomassen, B. 1977. Lagbundne permo-triassiske kobber-bly-sølv-zink-mineraliseringer i østranden af Jameson Land bassinet, Østgrønland. – Unpublished thesis, University of Copenhagen: 168pp.
Thomassen, B. 1979. Prospecting of the Permo-Triassic sediments of the Flemming Fjord, Mesters Vig and SW Traill Ø areas, East Greenland. – Internal NM-report 5/76: 85pp.
Thomassen, B. 1980. Prospecting of the Permian sediments of the Wegener Halvø, Mesters Vig South and Schuchert Dal areas, East Greenland. – Internal NM-report 1/79: 70pp.
Thomassen, B. 1982. Prospecting for Cu-Pb-Zn-Au-Ag in the Clavering Ø, Giesecke Bjerge and Canning Land areas. – Internal NM-report 1/81: 59pp.
Thomassen, B. 1983. Reconnaissance for gold in Flyverfjord and Forsblads Fjord 1983. – Internal NM-note 4/83: 41pp.
Thomassen, B. 1984. Gold indications in central East Greenland 66°–74°30'N lat. – Internal NM-note 2/84: 32 pp.
Thomassen, B. & Schønwandt , H.K. 1981. Prospecting for Cu-Pb-Zn-Ag-Au in the Upper Permian sediments and Devonian volcanics of East Greenland. – Internal NM-report 1–2/80: 100pp.
Thomassen, B., Clemmensen, L.B. & Schønwandt, H.K. 1982. Stratabound copper-lead-zinc mineralisation in the Permo-Triassic of central East Greenland. – Bull. Grønlands geol. Unders. 143: 42pp.
Thum, I., Walser, P. & Walser, W. 1971. Lagerstättenkündlicher Bericht. – Internal NM-report 2/70: 43pp.
Thyrsted, T. & Friedman, A.L. 1982. Airborne remote sensing in East Greenland – Final report. – Geol. Surv. Greenland, Copenhagen: 130pp.
Upton, B.G.J. & Emeleus, C.H. 1976. The Tertiary Geology of Hold with Hope, East Greenland. – Grønlands geol. Unders., open file report: 70pp.
Upton, B.G.J., Emeleus, C.H. & Beckinsale, R.D. 1984a. Petrology of the northern East Greenland Tertiary flood basalts: Evidence from Hold with Hope and Wollaston Forland. – J. Petrology. 25: 151–184.
Upton, B.G.J., Emeleus, C.H., Beckinsale, R.D. & Macintyre, R.M. 1984b. Myggbukta and Kap Broer Ruys: the most northerly of the East Greenland Tertiary igneous centres(?). – Mineral. Mag. 48: 323–343.
Veizer, J. & Compston, W. 1974. $^{87}Sr/^{86}Sr$ composition of seawater during the Phanerozoic. – Geochim. cosmochim. Acta. 38: 1461–1484.
Vidal, G. 1976. Late Precambrian acritarchs from the Eleonore Bay Group and Tillite Group in East Greenland. – Rapp. Grønlands geol. Unders. 78: 19pp.
Vidal, G. 1979. Acritarchs from the Upper Proterozoic and Lower Cambrian of East Greenland. – Bull. Grønlands geol. Unders. 134: 40pp.
Vischer, A. 1943. Die postdevonische Tektonik von Ostgrönland zwischen 74° und 75°N Br., Kuhn Ø, Wollaston Forland, Clavering Ø und angrenzende Gebiete. – Meddr Grønland 133,1: 195pp.

Vohryzka, K. & Vohryzka, E. 1969. Traill Ø NW und Ymers Ø W. – Internal NM-report 6/69: 33pp.
Wenk, E. 1961. On the crystalline basement and the basal part of the Pre-Cambrian Eleonore Bay Group in the southwestern part of Scoresby Sund. – Meddr Grønland 168,1: 54pp.
Werneck, W.L., Honig, W. & Krisch, K.H. 1971. Malmbjerg. – Internal NM-report 9/70:
Williams, C.E. & McArdle, P. 1978. Ireland. – In: Bowie, S.H.U., Kvalheim, A. & Haslam, H.W. (eds), Mineral Deposits of Europe, Volume I: Northwest Europe. – The Institution of Mining and Metallurgy and the Mineralogical Society, London: 319–345.
Witzig, E. 1954. Stratigraphische und tektonische Beobachtungen in der Mesters Vig-Region (Scoresby Land, Nordostgrönland). – Meddr Grønland 72,5: 26pp.
Young, B.B. 1957. Erzberg East, Gurreholmdal Dal and Mellemgletscher. – In: Reece, A. (ed.), Prospecting in Northeast Greenland. – Internal NM-report 5/57: Appendix V.

Locality index


MINERAL OCCURRENCES
IN
CENTRAL EAST GREENLAND
125 Pb Zn
LEAD - ZINC OCCURRENCE. TEXT DESCRIPTION NO. 125
MAJOR FAULT / THRUST - UNDIFFERENTIATED
INLAND ICE / GLACIER
QUATERNARY SEDIMENTS
TERTIARY IGNEOUS ROCKS
UPPER PERMIAN - LOWER TERTIARY SEDIMENTARY ROCKS
UPPER CARBONIFEROUS - LOWER PERMIAN SEDIMENTARY ROCKS
DEVONIAN SEDIMENTARY AND VOLCANIC ROCKS
CALEDONIAN PLUTONIC ROCKS
UPPER PROTEROZOIC - MIDDLE ORDOVICIAN SEDIMENTARY TO LOW - GRADE METAMORPHIC ROCKS
MIDDLE PROTEROZOIC (& CALEDONIAN) METAMORPHIC / PLUTONIC ROCKS
ARCHAEAN - LOWER PROTEROZOIC METAMORPHIC / PLUTONIC ROCKS
GEOLOGY MODIFIED AFTER BENGAARD (1985)
0
50
km
74°
73°
72°
71°
70°
32°
30°
28°
26°
24°
22°
20°

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Published by
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for Scientific
Research
in Greenland

AiO Print Ltd., Odense, Denmark