Chromite in the Fiskenæsset stratiform anorthosite complex, West Greenland

Peter W. Uitterdijk Appel

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Ujarassiortut Kalaallit Nunaanni Misissuisoqarfiat
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ABSTRACT

The Fiskenæsset anorthosite complex hosts a major low grade chromite resource, which is estimated to be of the order of 100 million tonnes. The chromite occurs in chromitite layers which attain widths of up to 20 m in fold closures, but more commonly are less than metre wide. The chromitite layers can sometimes be traced for a few hundred metres along strike, but for the most part only for a few metres or tens of metres; this is due to magmatic slumping as well as the effects of repeated deformation. The anorthosite complex has been metamorphosed to amphibolite facies, locally to granulite facies. The average chromite content in the chromitite is 37 % by weight. A number of beneficiation tests have been carried out yielding chromite concentrates with the following composition: 35.1 % Cr_2O_3, 18.6 % Al_2O_3, 41.5 % FeO and a Cr/Fe ratio of 0.75. Rutile is a common acessory in the chromitites amounting to 0.35 weight %, mostly occurring as tiny inclusions.

INTRODUCTION

The Fiskenæsset complex is a large layered anorthosite complex, which hosts numerous chromite layers. During the 1960's the complex was investigated in some detail by Ghisler (1966) and Windley (1966, 1969). Until 1970 only the coastal part of the Fiskenæsset area had been investigated. During the seventies the Geological Survey of Greenland (GGU) carried out detailed investigations in the Fiskenæsset area, which among other things revealed that whereas the anorthosite complex occurs as fairly thin but continuous horizons in the coastal area, it is found in much larger bodies in the inland areas. Regional mapping was carried out at a 1 : 20 000 scale, and three detailed coloured geologic maps at 1 : 100 000 have been published: Grædefjord (63 V1 S), Sinarsuk (63 V2 S) and Bjørnesund (62 V1 N). GGU's mapping programme also resulted in a series of papers on various aspects of the geology, which are listed at the end of this Open File.

The Fiskenæsset area first attracted foreign mining companies in 1969, when Platinomino A/S, owned by Renzy Mines Ltd, Toronto, Ontario, Canada obtained an exclusive exploration concession. Platinomino started exploration in 1969 and work continued with varying intensity up until the mid 1980's.

The primary goal for Platinomino was to explore for platinum group element (PGE) deposits of Merensky reef type and for nickel-copper occurrences. In addition Platinomino carried out some exploration for chromite, which included bulk sampling of major chromitite horizons as well as detailed mapping of the most promising zones. Some beneficiation tests were also made. All data collected by Platinomino A/S are embodied in reports (see References and relevant papers below) which are available for inspection at GGU. Photocopies of these reports can be purchased.

GGU's Mineralization Data Bank includes information on the chromite exploration in the Fiskenæsset area. The data has been compiled from Platinomino's reports as well as from papers published by GGU. Information from the Mineralization Data Bank can be obtained on request. Fig. 5 is an extract from the Mineralization Data Bank which shows some of the main chromitite showings in the Fiskenæsset area.

GENERAL GEOLOGY

The dominant rock types in the Fiskenæsset area are quartzo-feldspathic orthogneisses, which occupy well over two thirds of the area. The gneisses are derived from tonalites, granodiorites and granites, and have yielded a radiometric age of 2800 Ma (Myers, 1978; Kalsbeek & Pidgeon, 1980). Within the gneisses are found several supracrustal enclaves of varying composition and age.

The Fiskenæsset complex (Fig. 1), which comprises anorthosites and associated layered plutonic rocks, is intrusive into supracrustal amphibolites (Myers, 1985). An age determination carried out on molybdenite in the anorthosites has given an intrusive age of 3080 ± 70 m.y. (Herr *et al.*, 1967).

The gneisses, supracrustal rocks and the Fiskenæsset complex have been strongly deformed and metamorphosed. Most of the area was affected by amphibolite facies metamorphism, but large parts were also subjected to granulite facies metamorphism. All rock types mentioned in this Open File Report are thus metamorphosed to varying degrees, but for reasons of simplicity all rock names are used below without the prefix 'meta'.

GEOLOGY OF THE ANORTHOSITE COMPLEX

The Fiskenæsset complex occurs as disrupted fragments in an area about 100 km long and 50 km wide. The stratigraphic details of the fragments show that they all once formed part of an extensive intrusive body. The preserved fragments or sheets are generally less than 500 m wide, with outcrop lengths of about 25 km (Myers, 1985). A remarkable feature displayed by the Fiskenæsset complex is composition of the plagioclase, most plagioclase is very calcic with an anorthite content ranging from 80 to 96 %. A simplified stratigraphic succession of the complex is presented in Fig. 2.

Myers (1985) subdivided the Fiskenæsset complex into seven units (Fig. 2), but not all of these are exposed at a single locality.

Lower Gabbro unit. This is a generally poorly preserved unit only rarely depicting relict igneous textures, and is thus often difficult to recognise. No clear cut contact to the host amphibolites has been observed.

The best exposures occur at Majorqap qâva and west of Qagsse (Myers, 1985). This unit is up to 50 m thick.

Ultramafic unit. This unit is up to 40 metres thick, and consists of cyclic mineral-graded sub-units of dunite, peridotite and hornblende rocks, frequently displaying relict igneous textures (Myers, 1985). Some of the minerals are presumed to be relict igneous minerals (such as olivine, pyroxene and spinel). This unit is exposed at Majorqap qâva, west of Qagsse and due south of "Midgård", the former GGU base (Fig. 1).

Lower Leucogabbro unit. This unit consists mainly of leucogabbro with minor layers of gabbro and ultramafics with a total thickness of about 50 m (Myers, 1985). Igneous textures are often well preserved. The unit has been studied in most detail at Majorqap qâva, but it is also commonly present in other parts of the Fiskenæsset area.

Middle Gabbro unit. This up to 40 m thick unit is locally underlain by a 6 m thick ultramafic layer of hornblende-orthopyroxene-spinel rock grading up into a fairly massive peridotite. The gabbro can be subdivided into three sub-units of uniform gabbro alternating with mineral-graded gabbro.

Upper Leucogabbro unit. Generally up to 60 m thick, this unit is divisable into four sub-units. Igneous textures are common. In the lower part lenticular mineral-graded ultramafic trough layers are found. Many of the massive ultramafic layers occurring in this unit are graded from dunite through peridotite and hornblendite to leucogabbro. Chromite is concentrated in thin layers in some of the ultramafics, these were found by Platinomino to contain up to 0.3 ppm platinum, 3 ppm palladium, 3 ppm gold and 57 ppm silver (Fig. 5, $Cr_{81/24}$). Similar contents were found by Platinomino in grab samples from other ultramafic lenses and layers (Appel, in press). At higher levels in this unit layers of chromitite up to 10 m thick are frequently encluntered.

Anorthosite unit. This is the thickest unit of the Fiskenæsset complex, attaining thicknesses up to 250 m, but lacks significant internal compositional layering. Chromitite is quite abundant at several stratigraphic levels.

Upper gabbro unit. This is an up to 50 m thick unit consisting of gabbro with layers of peridotite, dunite, leucogabbro and anorthosite. In the ultramafics magnetite and ilmenite is locally abundant in up to one metre thick layers. The top of this unit is in contact with pillow structured amphibolite.

Magmatic structures such as mineral-graded layering, size-graded layering, trough layers, slump structures and pipes are commonly seen in the Fiskenæsset complex, and have been described in detail by Myers (1985).

GEOLOGY OF THE CHROMITE HORIZONS

The most exhaustive account of the Fiskenæsset chromite is that of Ghisler (1976), to which the reader is referred for further details. The following is a brief description only.

Chromite occurs at several stratigraphic levels in the complex, but is by far most abundant in the anorthosite unit (Fig. 2). At Majorqap qâva chromite also occur in substantial amounts in the upper leucogabbro unit. Chromite-rich layers (chromitite) also occur as narrow but distinct seams in ultramafic rocks in the lower units of the complex. The chromite in the ultramafic rocks is not considered economically interesting as a source of chrome. Thus only the chromitites occurring in the anorthosites are further considered here.

CHROMITE IN ANORTHOSITES

The greater part of the chromite is found in the anorthosite unit. Here chromite occurs in one or two distinct stratigraphic chromitite horizons traceable through most of the outcrops of the anorthosite unit. Where these horizons are lacking, they have probably either been removed in the original magma chamber by magmatic slumping or been disrupted tectonically at a much later stage. Locally up to six chromitite horizons are found.

Two main types of chromitite occur in the anorthosites hornblende chromitite and augen chromitite.

Hornblende chromitite forms well defined layers normally about one centimetre thick, but locally up to 1 m thick layers have been found. Each chromitite horizon is usually composed of a multitude of chromite-rich layers alternating with plagioclase layers. The chromitite consists mainly of chromite and hornblende in varying proportions.

Augen chromitite is a spotted rock consisting of plagioclase augen in a black matrix of chromite and hornblende. The augen vary in size from a few mm to 2 cm. Augen chromitites form layers from a few centimetres to several decimeters thick separated by narrow layers of plagioclase. Augen chromitite is found in up to 20 m thick layers.

All gradations between hornblende chromitite and augen chromitite are found in the field.

Compositionally the chromitites are quite simple, consisting of chromite-rich layers and plagioclase layers, or augen. Chromite makes up 53-60 % of the massive hornblende chromitite and about 50 % in chromitite layers of the augen chromitite. In the whole rock, which include chromite-rich layers and plagioclase layers or augen, the chromite content normally lies between 30 to 40 % by volume, and often is even lower. This corresponds to an average chromite content of about 37 % by weight (Ghisler, 1976).

The chromitite horizons mostly dip steeply to vertically, but shallow dips have also been encountered. Some repetition of the horizons is found as the result of isoclinal folding. Strong deformation has also caused considerable variations in thickness of the chromitite horizons. They are found in widths from 50 cm to 3 m, locally attaining widths of up to 20 m in fold closures. The chromitite horizons often pinch out. Frequently, however, the chromitite horizons have reacted in a brittle fashion to deformation, which has resulted in often quite spectacular boudinage. The chromitite horizons can thus rarely be traced continuously along strike for more than about 100 m, and far the most part can only be traced continuously for a few tens of metres.

MINERALOGY OF THE CHROMITITES

The mineralogy and chemistry of chromitites in the Fiskenæsset complex has been described in detail by Ghisler (1976). The following is a brief summary.

In hornblende chromitite the dominating mineral is chromite with lesser amounts of hornblende and small amounts of biotite and plagioclase. In augen chromitite, plagioclase, chromite and hornblende occur in approximately equal amounts. In both types of chromitite the most common accessory minerals are rutile, ilmenite and sulphides.

Chromite mostly occurs as idiomorphic grains with rounded corners, but in many places a complete intergrowth with silicates is seen. The grain size of the chromite varies between 0.05 to 0.7 mm, most commonly grain size is close to an average of about 0.3 mm. Ghisler (1976) distinguished between two different types of chromite, poikilitic, and "nonpoikilitic" or pure chromite. The poikilitic chromite contain numerous inclusions of silicates usually in the size range 0.01 to 0.03 mm. There appears to be some correlation between type of chromite and type of chromitite. Thin hornblende chromitites often contain pure chromite only, whereas augen chromitite usually contain high amounts of poikilitic chromite.

Rutile is a common accessory ore mineral in both types of chromitite. It occurs as small inclusions in chromite and as individual grains. The inclusions range typically between 0.02 to 0.04 mm in size, but they also occur down to micron size. The rutile content of hornblende chromitites is in the order of about 0.35 % by weight (Ghisler, 1976), whereas augen chromitite generally contain much less rutile.

Ilmenite, which is rare, has the same mode of occurrence as rutile, but generally is occurs in much lesser amounts.

Magnetite is a rare mineral, found as an exsolved phase in a few samples only.

Ghisler (1976) found tiny blebs of sulphides in 25 % of the investigated chromite samples. These inclusions range in size from 0.01 to 0.08 mm, but the total content rarely exceeds 0.01 % of the rock. Pyrite is the most common sulphide followed by chalcopyrite, while small amounts of pyrrhotite and pentlandite also have been found.

Gangue minerals include hornblende, biotite and plagioclase together with minor sphene, chrome epidote and fuchsite.

Fuchsite and chrome epidote are commonly seen in chromitites of the anorthosite unit, where the fuchsite was clearly formed at a late stage, but mainly prior to the main deformation of the anorthosite complex.

CHEMISTRY OF THE CHROMITE

Ghisler (1976) carried out detailed investigations of the chemistry of the chromite, mainly based on analyses of chromite concentrates from chromitite horizons.

Major element composition of 33 chromites from anorthosites was determined by Ghisler (1976) by a combination of microprobeanalyses and wet chemical methods:

Cr_2O_3	35.1 %	Al_2O_3	18.6 %
FeO	29.4 %	MgO	3.5 %
Fe_2O_3	13.4 %		

X-ray fluorescence analyses of 168 chromite concentrates from anorthosites yielded the following results:

Cr_2O_3	32.1 %	FeO	36.4 % (total iron)
V_2O_5	0.36 %	Cr/Fe	0.78

Minor element composition of the chromites show Ti contents of 0.44 %, Ni contents of 0.04 % and Co contents of 0.02 % (Ghisler, 1976). However, only rather few analyses for these elements have been carried out.

A few analyses for phosphorus have been carried out recently on chromite concentrates at the request of some mining companies. The contents were all found to be low, that is less than 0.01 % P_2O_5.

COMPARISON WITH OTHER CHROMITE DEPOSITS

Ghisler (1976) presents a brief discussion comparing the Fiskenæsset complex with chromite bearing complexes elsewhere.

The closest analogy is with the Sittampundi complex, India. Both the Sittampundi complex and the Fiskenæsset complex have high Ca-plagioclase, and an anorthosite mafic rock ratio of 4:1, as well as comparable chromite layers. Both complexes intrude supracrustal rocks, and were subsequently metamorphosed and folded repeatedly.

The magmatic setting and to some extent the chemistry of the Fiskenæsset chromite resembles that of the Dwars River chromite horizons of the Bushveld complex. In respect of the average chemical composition of the Fiskenæsset complex, Ghisler (1976) found some analogies with the chemistry of the Stillwater complex.

EXPLORATION FOR CHROMITE

The only systematic exploration for chromite was carried out by Ghisler who made detailed mapping of chromite horizons in selected areas (Ghisler, 1967).

Platinomino A/S prospected for a Merensky reef type deposit, and their exploration strategy was to traverse the Fiskenæsset complex across strike at intervals of 500 m. Sketches of the traverses were made, and wherever chromite horizons were found, they were indicated on the traverse; however, only rarely were any of the chromite horizons followed along strike in order to test their continuity. Showings close to the summit of Qagsse and one in an area on the east side of Qeqertarssuatsiaq were, however, investigated in some detail. In these areas detailed mapping was carried out and two maps were produced (Figs 3 & 4).

The Qagsse showing is at an altitude of 500 m on a south sloping hill (Fig. 3). Most of the chromite is in hornblende chromitite, but minor amounts of augen chromitite are also found. The showing can be traced at intervals for several hundred metres downhill towards the west, and also some hundred metres uphill eastwards. The chromitites are steeply dipping, but no drilling has been carried out in order to test down-dip continuity.

Along the east coast of Qeqertarssuatsiaq (Fig. 1) an anorthosite with two fairly continuous chromitite horizons occurs. The chromitite horizons were mapped at a scale of 1:500 by Platinomino (1975). Fig. 4 shows part of the detailed maps, and clearly illustrates the major problem with the chromitite, that is general tectonic disturbance. The layers have been broken up into short fragments, often only a few metres in length, with barren anorthosite in between. The chromitite layers generally dip at a fairly shallow angle towards the east.

ORE RESERVES

Tonnage estimates made by Ghisler & Windley (1967) indicate 2.5 million tonnes of chrome ore in the 1400 m long chromitite zone along the east coast of Qeqertarssuatsiaq. Ghisler & Windley (1967) assumed widths of the chromitite horizon of 1 to 7 metres and an extension down dip to 50 metres below the surface.

A rough estimate made by Ghisler (1976) indicates that the Fiskenæsset complex has a low grade chromite resource in the order of 100 million tonnes.

BENEFICIATION TESTS

Platinomino A/S had a number of beneficiation test carried out by various companies. The tests were carried out on bulk samples of chromitite, but it is not obvious from Platinomino reports where these bulk samples came from. However, most of the samples are assumed to have been taken from the chromitite horizons on the east side of Qeqertarssuatsiaq (Fig. 5, $Cr_{81/25}$).

In 1971 Outukumpu Oy carried out a preliminary separation test on a 2.5 kg sample of chromitite. The ore was crushed to minus 28 mesh and run through a two stage magnetic separation. The maximum recovery was 88.3 %. The concentrate composition was:

Cr	27.0 %	(39.4 % Cr_2O_3)
Fe	34.7 %	(44.6 % FeO)
Cr/Fe	0.78	

Outukumpu concluded that there were only a small chance of producing rutile concentrates.

In 1972 Platinomino A/S engaged Woodall Duckham Ltd. to carry out separation tests on chromite ore from Fiskenæsset. The ore was crushed, ground and passed through minus 16 mesh sieves. One split was analyzed yielding the following results:

Cr_2O_3	20.5 %	Al_2O_3	20.2 %
Fe	20.6 %	V_2O_5	0.3 %
Cr/Fe	0.68	SiO_2	17.7 %

Woodall Duckham carried out electrostatic separation followed by magnetic separation, tabling and acid extraction tests. Their conclusion was that the chrome ore from Fiskenæsset had a Cr/Fe ratio too low for metallurgical grade chromite. The concentrate had too high an Al_2O_3 content to meet refractory grade specifications. Acid extraction methods to upgrade the concentrate were not worth while. They recommended the ore could be used for chrome chemicals.

In 1976 Platinomino A/S had several laboratories engaged with work on various aspects of beneficiation and use of the Fiskenæsset chrome ore:

Pittsburgh Plate Glass produced a chromite concentrate from a 300 kg sample. No formal report was made, but the results are shown in Platinomino report (1975). The bulk sample contained 14-15 % Cr_2O_3. After electrostatic separation and dry magnetic separation a concentrate with the following composition was produced:

Cr_2O_3	33.5 %	Al_2O_3	26.0 %
FeO	31.5 %	SiO_2	1.6 %
Cr/Fe	0.93	Ca	0.4 %

British Chrome and Chemicals Limited employed Head Wrightson to make separation tests on the basis of few large pieces of chromite ore only. The rock was crushed, ground and dry magnetic separated. Subsequently various upgrading methods were carried out. Dry magnetic separation proved unsatisfactory, and it was suggested that high intensity wet magnetic separation would be more advantageous since it could be used on finer grained material with fewer silicate inclusions. A single flotation test was carried out using sulphuric acid as a regulator, Aero R825 and Tall Oil as chromite promotor, sodium fluosilicate as silica depressor and Aeroforth 65 as frother. The test was promising, but more tests were suggested. British Chrome doubt whether a concentrate with less than 1 % silica can be produced from the Fiskenæsset chromitite.

The National Research Council found that water fluidization would allow recovery of 85 % of the chromite in a concentrate containing slightly more than 2.6 % SiO_2.

In 1977 Geselschaft für Metallurgie M.B.H. carried out beneficiation tests on a one tonne sample of chromitite. The bulk sample composition was:

Cr_2O_3	16.8 %	MgO	7.95 %
FeO	13.2 %	SiO_2	22.5 %
Fe_2O_3	4.5 %	P_2O_5	0.01 %
Al_2O_3	19.9 %		

The tests which involved Humphry spirals and magnetic separation produced a concentrate containing up to 29.29 % Cr_2O_3 .

In 1978 FMC Natural Resources Department, Pocatello, carried out recovery tests on a sample of chromitite. Different methods were tested, but the best appeared to be elutriation and tabling. This method would be expected to yield a recovery of 81.7 % of the Cr_2O_3. The company recommended that no further tests made to upgrade the ore by physical means. It was suggested that chemical or pyrometallurgical upgrading might be worthwhile paths to follow in order to increase the grade to more than 34 % Cr_2O_3 and the Cr/Fe ratio to more than 1.

CONCLUSION

The Fiskenæsset complex hosts a very large chrome resource, probably in the order of 100 million tonnes (Ghisler, 1976). The following features are important in an evaluation of the chromite potential of the Fiskenæsset area.

1. The chromite content in the ore is low.
2. The chrome content in the chromite is low.
3. The Cr/Fe ratio is low.
4. The aluminium content in the chromite is high.
5. The ore body is strongly deformed and frequently disrupted due to boudinage.

There are still several unknowns, such as:

6. Lateral extent of continuous chromitite horizons.
7. Down dip extension of the chromitite horizons.

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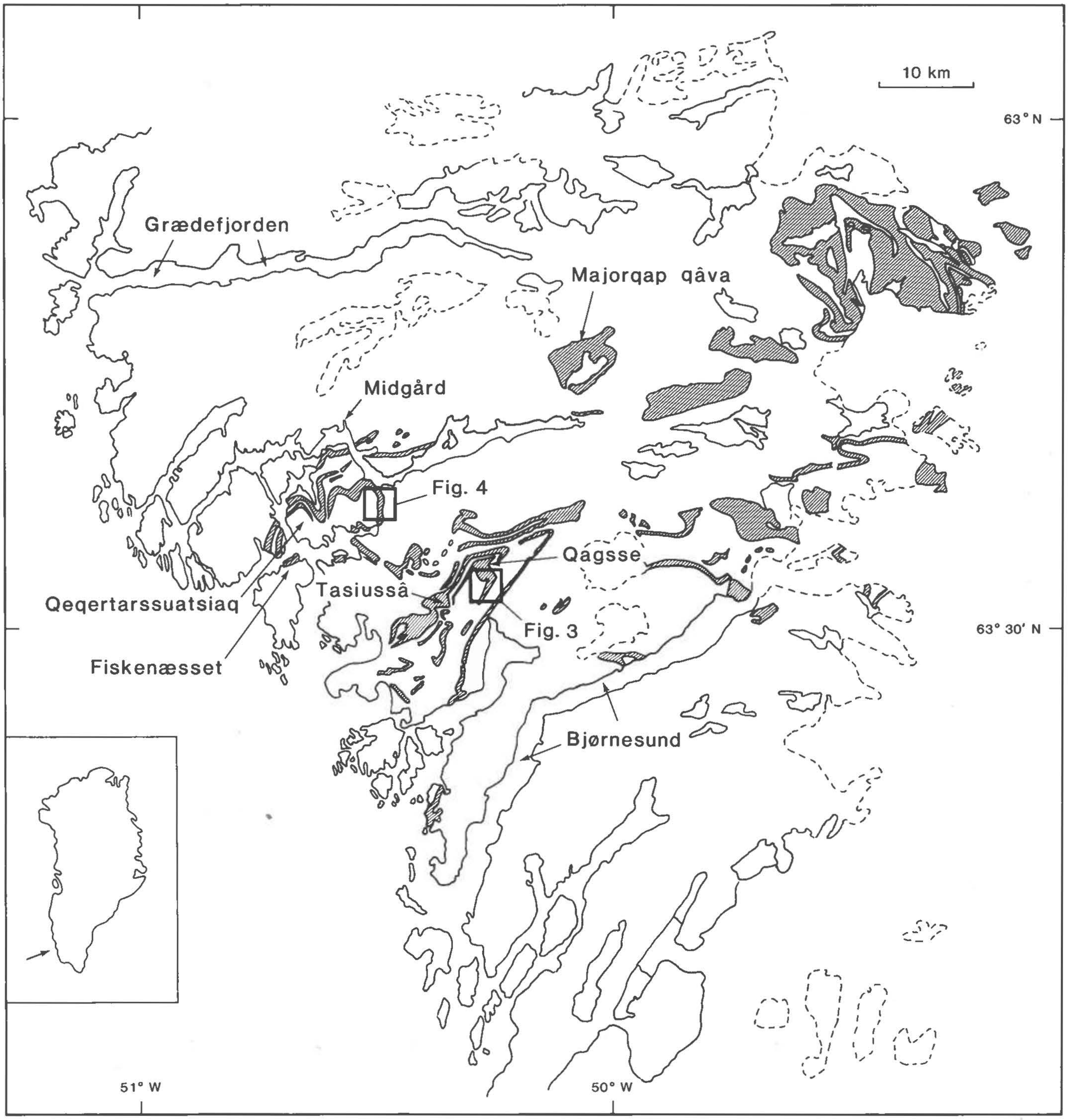

Fig. 1 Sketch map of the Fiskenæsset area showing the outline of the main anorthosite outcrops.

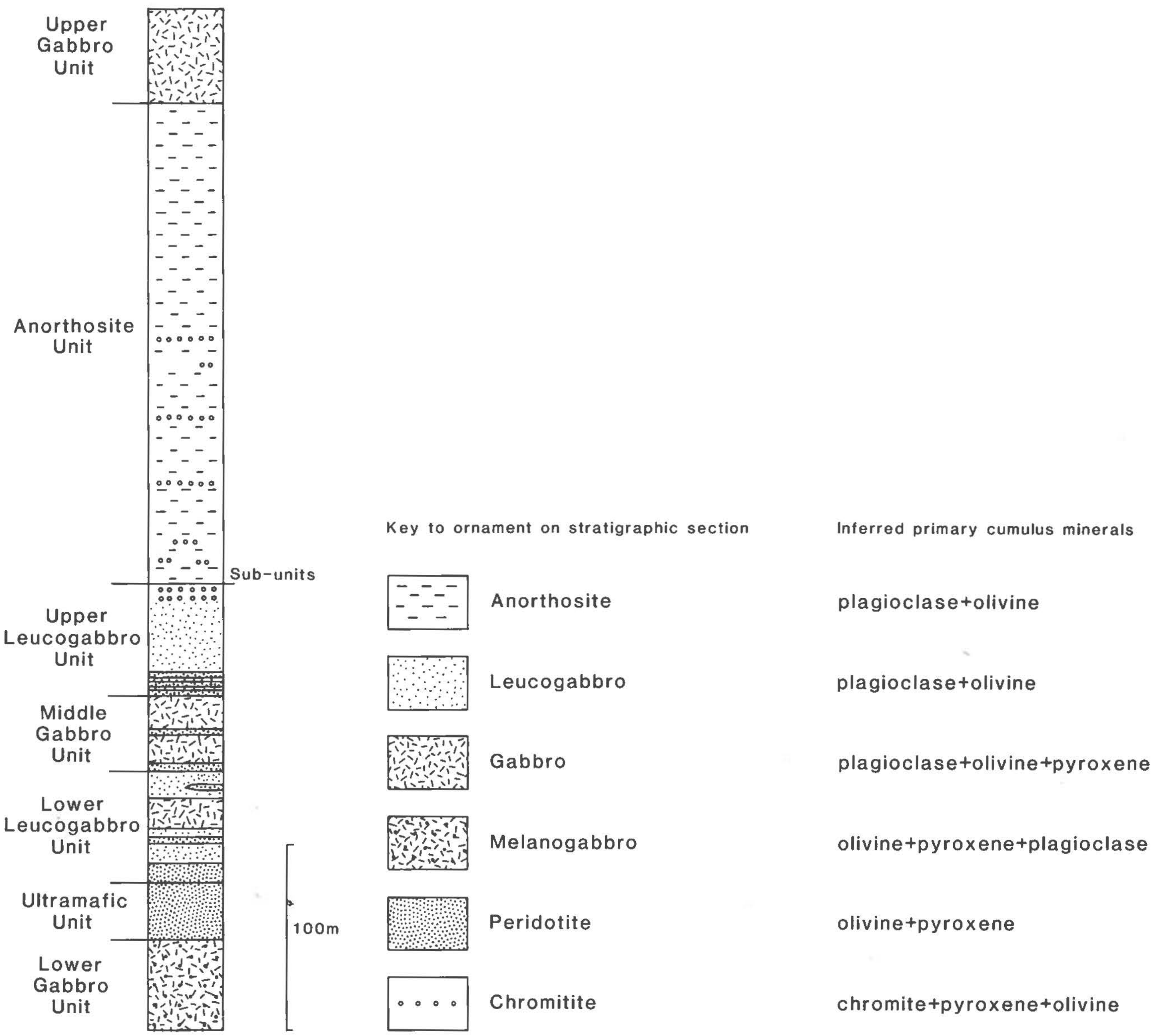

Fig. 2

Simplified stratigraphic succession of the anorthosite complex (from Myers, 1985)

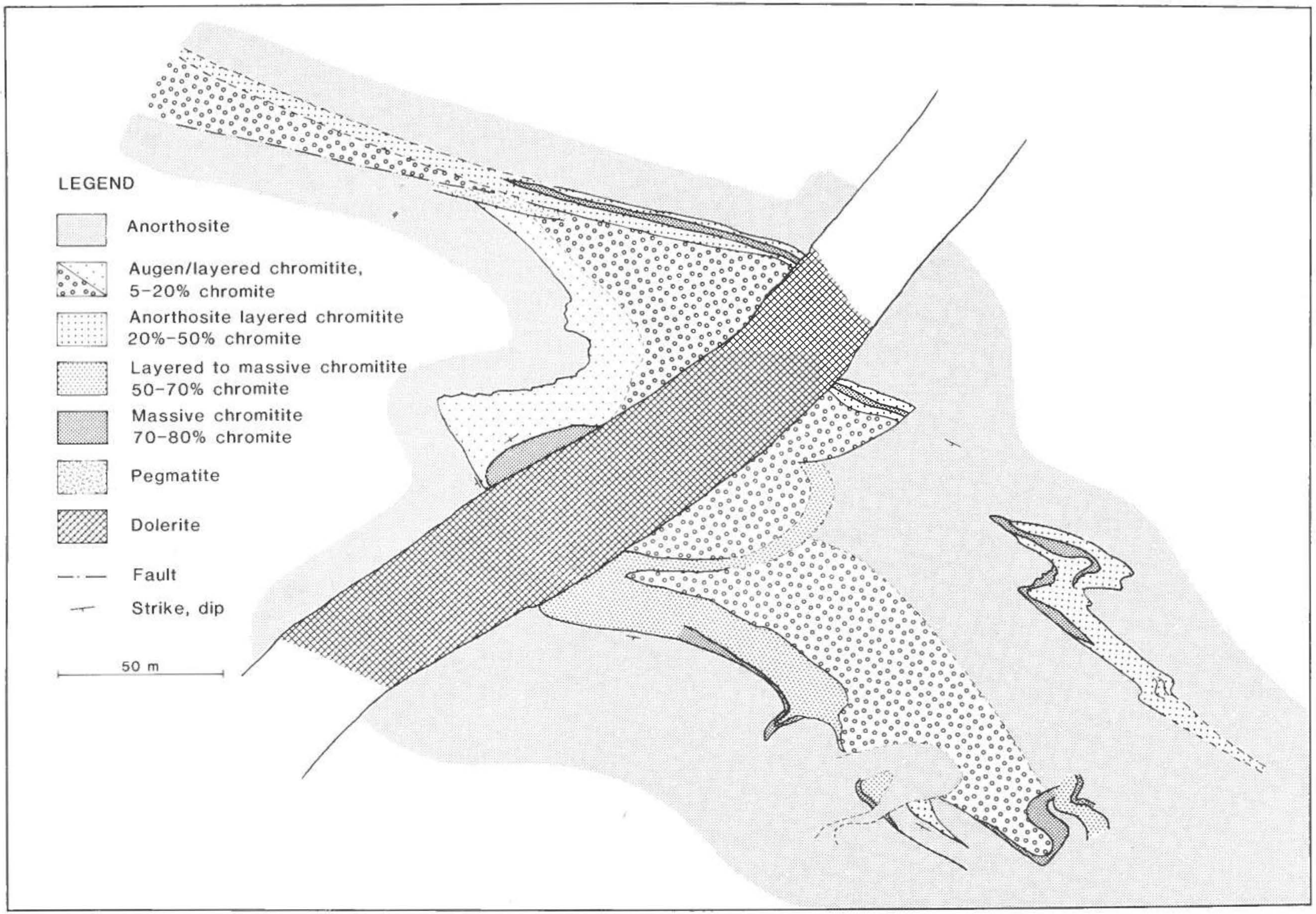

Fig. 3 Detailed map of part of the Qagsse chromitite showing (from Platinomino mapping).

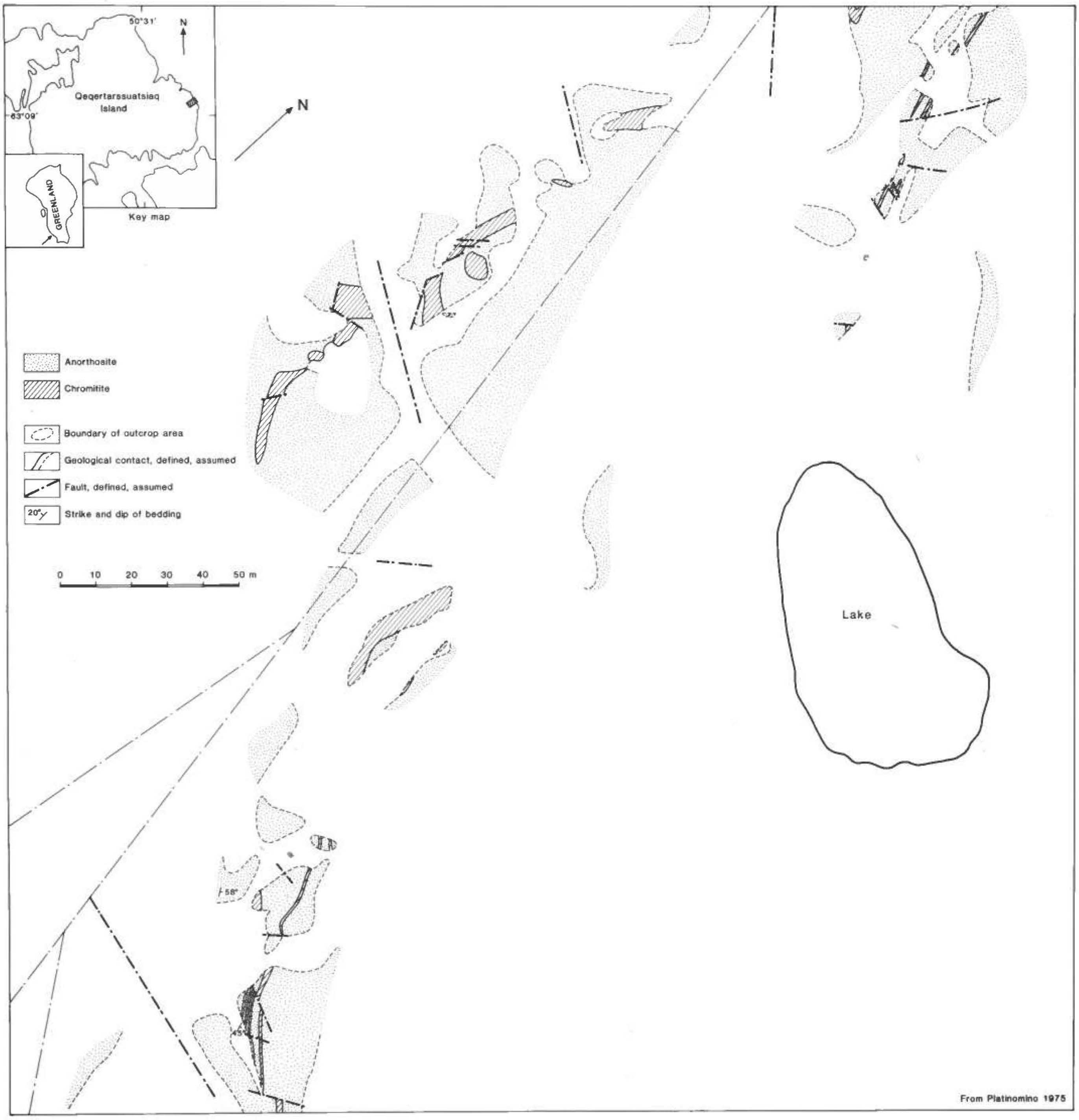

Fig. 4 Detailed map of part of the eastern Qeqertarssuatsiaq chromitite showing (from Platinomino mapping).

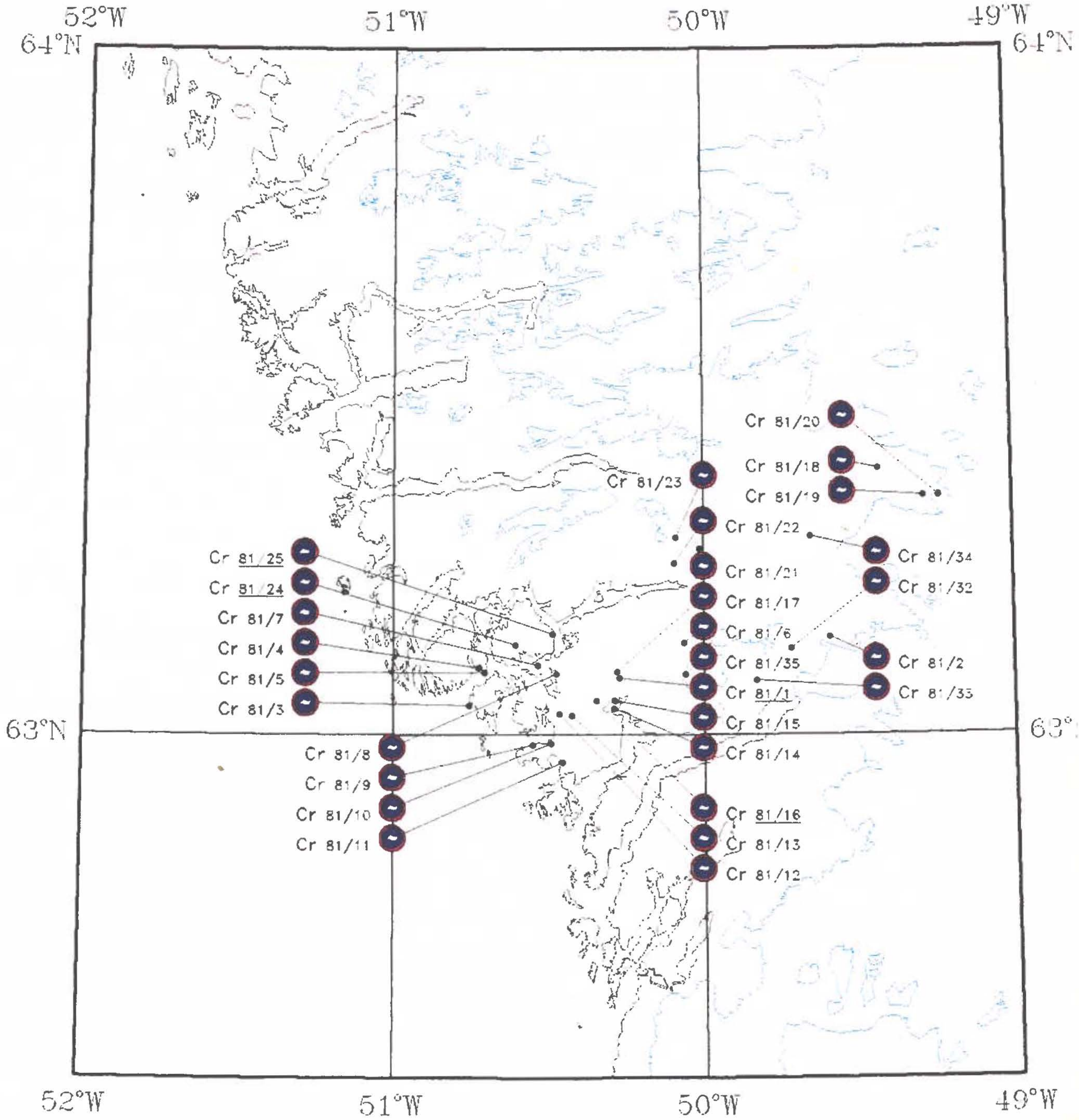

Fig. 5

Mineral occurrence map showing selected chromitite occurrences in the Fiskenæsset area. Data extracted form GGU Mineralization Data Bank 81/13 shows that the data for this chromite showing can be found in the GGU mineralization data bank, case 81 subcase 13. For explanation of symbols see Fig. 6.

Fig. 6 Legend for the Mineral occurrence map (Fig. 5)

LEGEND

HOST ROCK

- Metamorphic
- Volcanic
- Igneous
- Sedimentary
- Unknown

GENETIC ENVIRONMENT

- Magmatic
- Volcanogenic
- Igneous
- Sedimentary
- Syngenetic
- Epigenetic
- Hydrothermal
- Unknown

MORPHOLOGY

- Stratiform
- Stratabound
- Lenticular
- Massive
- Disseminated
- Vein
- Pipe
- Stockwork
- Other

RESOURCE

- Fe, V, Ti, Mn, Cr
- PGE, Au
- Mo, W, Sn, Hg, Sb ,Bi
- Pb, Zn, Ag
- Gemstone, indust. mineral
- Cu, Ni, Co
- U, Th, Zr, Nb, REE

MINERALOGY

- Sulphide
- Native element
- Gemstone
- Silicate
- Other
- Oxide
- Sulphate
- Phosphate Carbonate Indust. min.

DATA SOURCE

The Greenland mineral occurrence database.

The data have been compiled from Survey reports, industry mineral assessment reports and published and unpublished research data.

All localities represent mineral occurrences observed on surface, in drill holes or mine workings.

SYMBOL SIZE / ECONOMIC IMPORTANCE

Mine
Prospect
Showing

EXAMPLE

Pb 24/13

Disseminated lead sulphide(s) of hydrothermal origin hosted by volcanic rock(s). More detailed information available from the Greenland mineral occurrence database, occurrence ID: 24/13. Underlining indicates the presence of several occurrence IDs on the same site.

Projection: Lambert conformal conic
Standard parallel: 66° 30' N
Scale factor: 0.99700
Ellipsoid: Hayford
Datum: Qornoq
Scale: 1:1 000 000

Ice margins and coast lines digitized from 1:250 000 topographic maps.
Permission No: KMS A.200/87

Released: 01–DEC–90

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