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On the applicability of magnetic prospecting for chromite in the Fiskenæsset region, West Greenland

by

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ON THE APPLICABILITY OF MAGNETIC PROSPECTING FOR CHROMITE IN THE FISKENÆSSET REGION, WEST GREENLAND

by

Martin Ghisler and P. Vallabh Sharma

With 2 figures and 1 map

1969

Abstract

The chromite deposits of the Fiskenæsset region belong to a metamorphosed igneous complex of stratiform type occurring in the basement gneiss unit of older Precambrian age in West Greenland. Short descriptions and modal compositions of the different rock types are given together with the results of magnetic measurements on 60 rock samples (data shown in tables 1-5). On the basis of known geology and rock susceptibilities different models are discussed with respect to the applicability of both an airborne and a ground magnetometer survey. It is concluded that the susceptibility contrasts involved are sufficient for locating favourable host rocks by aeromagnetic survey, but direct magnetic prospecting for chromite horizons predominantly occurring within anorthosites may not be feasible.

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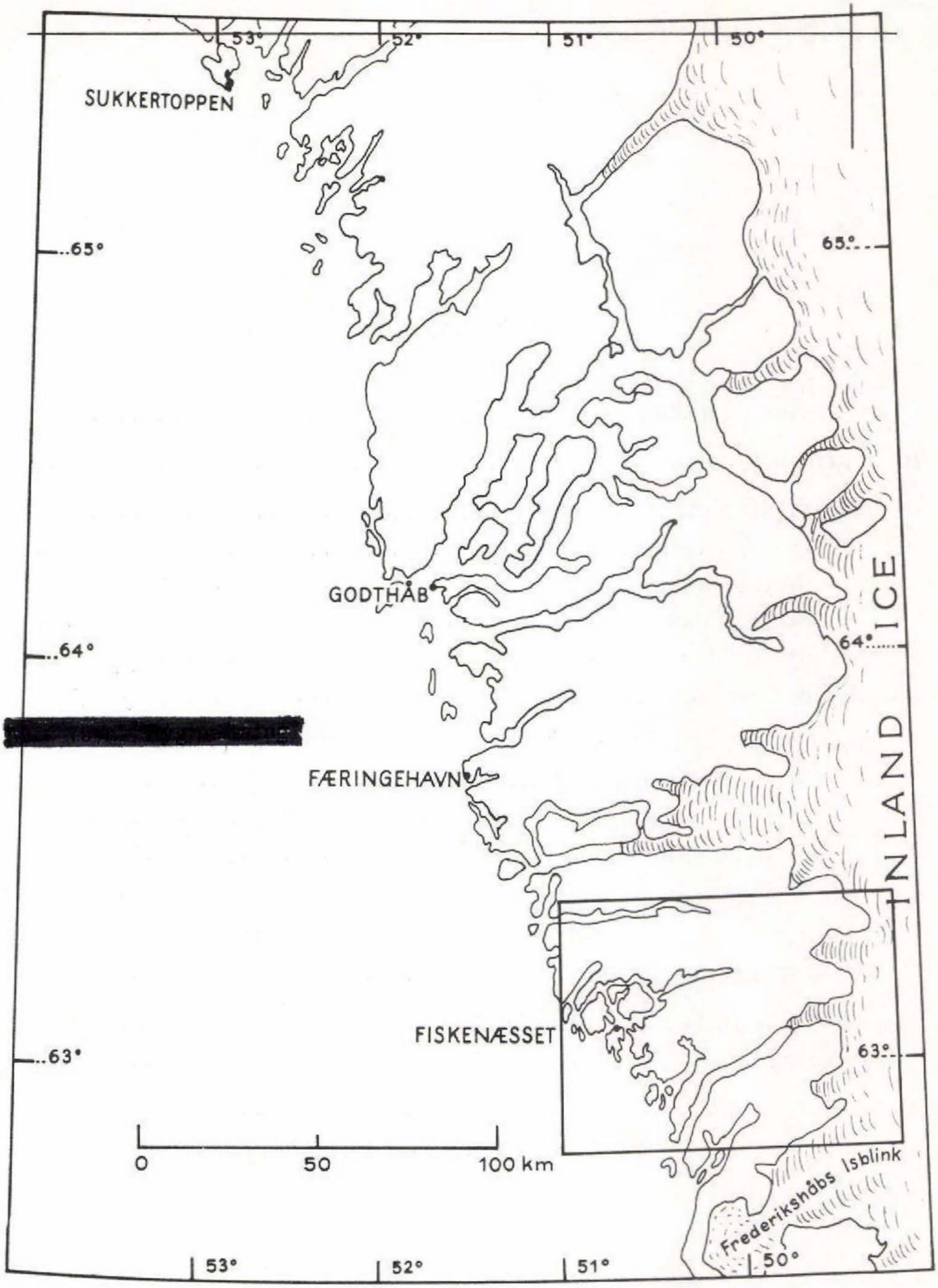

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Fig. 1. Map of southern West Greenland showing the position of map **1**.

I INTRODUCTION

Chromite was found in the Fiskenæsset region (fig. 1) in West Greenland in 1964 during regional mapping by the Geological Survey of Greenland (GGU). Detailed studies in 1965 and 1966 in that part of the area which was accessible by boat revealed extensive chromite deposits occurring as layers within a metamorphosed igneous complex of stratiform type as described earlier by Ghisler and Windley (1967).

In the literature many publications exist which deal with various methods of prospecting for chromite (Woodtli, 1964). Geophysical methods have to date been of little use in the direct prospecting for stratiform chromite deposits, and according to Jackson (1964) detailed geological mapping is by far the most valuable prospecting method. Applicability of geophysical methods has been recognised only as an indirect aid (Bosum, 1964; Hawkes, 1951) in favourable cases where the chromite-bearing host rock shows a marked difference in physical properties (e.g. density, magnetic susceptibility, electric resistivity, etc.) in relation to the general country rock. No generalisation can, however, be made about the category of host rocks suitable for the application of a particular geophysical technique, and each case must be considered on its merits in close cooperation with the geologist.

The investigations reported in this paper have been made primarily to examine the applicability of the magnetic method to chromite prospecting in the inland area up to the Inland Ice, where further deposits might be expected to occur. A detailed study of the magnetic properties of the ore-bearing and associated rocks, in combination with the related geological and mineralogical data, might provide some information on the basis of which the practical feasibility of both airborne and ground magnetometric prospecting could be ascertained.

The first author (MG) is responsible for the geological and mineralogical data presented in this report, whereas the second author (PVS) is responsible for the geophysical findings based on the use of palaeomagnetic instruments at the Geological Institute, University of Copenhagen.

Dr B. F. Windley and stud. mag. scient. K. Gormsen very kindly put a number of samples at the disposal of the authors for this investigation.

II GEOLOGICAL SETTING

Gneisses are the dominating rocks of the Fiskenæsset region, belonging to the central basement gneiss unit of early Precambrian age in the Precambrian of West Greenland (Pulvertaft, 1968). The chromite deposits are related to an original layered igneous complex, which now occurs as a metamorphosed anorthosite-pyribolite* /amphibolite-ultra mafic suite forming conformable stratigraphic horizons within the gneisses (Ghisler and Windley, 1967). This rock series, collectively termed the Fiskenæsset complex (Windley, in press), is dominated by anorthosites with varying proportions of amphibolite. The complex is usually between 100 m and 1000 m wide with an average of about 400 m. Ultramafic rocks form a subsidiary group within the complex, occurring as discontinuous layers and lenses rarely more than 50 m wide.

The Fiskenæsset complex together with the surrounding gneisses has been affected by two periods of regional metamorphism. A granulite facies metamorphism was followed by an amphibolite facies metamorphism, which has variably downgraded the higher grade assemblages. Three major phases of folding have modified the original form of the complex by tectonic thinning and thickening, and the distribution of horizons in the area as a whole is seen to represent a complicated triple-folded interference pattern at a large scale (map 1). In general the orientation of the horizons is steep to vertical, but in cases it may go down to a dip of only 20°.

The chromite occurs within the anorthosites as horizons generally 0.5 - 3 m wide, but reaching a maximum width of 20 m. These horizons consist of alternating anorthosite and chromitite layers of varying thickness and relative proportions. The original magmatic layering has, however, in many places been veiled during metamorphism, when thin anorthosite layers were recrystallised as plagioclase porphyroblasts or glomeroblasts, giving the chromitite rock a typical augen structure. The chromite horizons are not continuous; they were disrupted and boudinaged during repeated

*)pyroxene amphibolite

folding and faulting. Chromitite layers have been found in ultramafic rocks also, but in the area so far studied geologically, these are very insignificant from an economic point of view.

The area investigated covers about 750 km^2 mainly showing a typical "skærgård" landscape with many islands and undulating topography reaching a height of 300 m. The eastern part up to the Inland Ice covers an area of about 2000 km^2 with higher terrain at a level of about 600-900 m, in places showing extreme relief varying from 400-1500 m. The geology of this area is unknown, but near the Inland Ice a group of several distinct anorthosites is visible on the aerial photographs (see map 1). As there is a general north-easterly structural trend, anorthosites with their chromite horizons can thus be expected to occur in the unknown highland in between. It is emphasized that the rocks generally are entirely exposed; only locally are there Quaternary deposits of low thickness.

It has to be mentioned that conformable amphibolite horizons of unknown relations to the Fiskenæsset complex occur within the gneisses throughout the region. A number of dolerite dykes cut the area mainly in an east-west direction.

III COMPOSITION OF ROCKS

In order to investigate the composition of the different rock types of the Fiskenæsset complex and its host rock, a number of representative unoriented samples were selected from a big collection. They should give an idea of the mineralogical variation through the area as well as within a single layer. Perpendicular to the axes of the cylinders drilled for the magnetic measurements were cut sections for modal analyses of both the non-opaque and the ore minerals. To get an impression of the representative value of the slides for each rock-type two or three specimens were cut from the same sample. A total of 49 thin sections and 58 polished sections were investigated microscopically. In a thin section the rock-forming minerals were analysed with a point-counter, regarding 1000 points as adequate for this purpose. In order to get a reasonable accuracy for the accessory ore minerals, the number of points counted on a grid-ocular, however, varied between 3500 and 10 000 depending on the frequency of the ore minerals in each section. The results of the modal analyses are presented in tables 1-5. For the rock-forming minerals only components forming at least 1 % of the rock are given, whereas minor amounts are marked with a "+". For ore minerals this symbol means that the content is below 0.05 %. The localities where the samples have been collected are shown on map 1.

a) Chromitites

The modal compositions of 20 chromitite samples are presented in table 1. Chromitite is used to define a metamorphic rock composed of chromite as the dominant mineral, hornblende, and minor amounts of biotite, plagioclase and rutile, in few cases accompanied by ilmenite and magnetite. As earlier described, the intercalations with anorthosite layers occur in all proportions, giving rise to the following different types of chromite-bearing rocks at the scale of a thin or polished section, with varying amounts of mainly the same minerals:

a) chromitite (the whole section from a single chromitite layer),
b) anorthosite-layered chromitite (section composed of thin alternating layers of anorthosite and chromitite),
c) augen chromitite (section composed of plagioclase porphyroblasts or glomeroblasts in a matrix of chromitite).

The grain size of the chromite averages 0.5 mm, the grains forming elongated aggregates up to 0.5 cm parallel to the layering. Two specimens give the variation of the chromite content within the same sample (78430), whereas three specimens (78698_{1-3}) illustrate the variation across a 2 m wide chromite horizon.

Mineralogically chromite belongs to the spinel group which can be expressed by the following formula:

$$(Mg,\ Fe^{2+},Mn)\ (Cr,Al,Fe^{3+})_2O_4 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The Cr_2O_3 content of the Fiskenæsset chromite varies between 26 % and 37 %, averaging 33 %. The total iron oxide content is very high compared with other chromites and varies between 31 % and 47 %, averaging 35 % (as FeO), with a resulting Cr/Fe ratio of about 1 :1. The chemical composition of a typical chromite (53282) corresponds to the following formula (Ghisler and Windley, 1967, p. 31):

$$(Mg_{28}Fe_{71}Mn_1)\ (Cr_{45}Al_{47}Fe_8)_2O_4 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

b) Anorthosites

The anorthositic rocks commonly have between 70 % and 95 % plagioclase, the dominating mafic mineral being hornblende, with various minor amounts of hypersthene, diopside, biotite, garnet and spinel. The plagioclase, a calcic bytownite-anorthite between An_{80} and An_{95}, is recrystallised and also structurally seen to be of metamorphic origin as the augen often are oriented oblique to the layering. Thus the rocks are more correctly called meta-anorthosites, which also better corresponds with the above mineral assemblages. Within the anorthosites occur layers of varying thickness richer in mafic minerals, forming gabbroic anorthosites.

As seen in table 2 this group of rocks is more or less free of ore minerals. Some sulphide grains may occur, mostly as pyrite and copper sulphides. Only in one sample (53243) were magnetite and ilmenite observed, the grain size being 0.4 mm. One of the specimens (78634) is strongly altered to chlorite, white mica and carbonate and the mode given in the table is thus only an approximate value of the main components before alteration, which took place along a major fault. Also the anorthosite from the southernmost part (74433) has a partly saussuritised plagioclase, whereas hornblende is completely altered to chlorite. This together with a low An content of the plagioclase (oligoclase) in some samples from that area reflects an advanced grade of retrogression.

c) Amphibolites

Amphibolites and pyribolites (pyroxene amphibolites) form the chief basic component of the Fiskenæsset complex. They are layered rocks showing variations in the amounts of hornblende, plagioclase, hypersthene, diopside, biotite and garnet. The analysed samples (table 3) are poor in pyroxene and thus all belong to the amphibolite group. It has to be mentioned that the two specimens (92609 and 74650) with a considerable amount of quartz were collected in the border areas which have undergone a higher degree of retrometamorphism. The plagioclase from the latter amphibolite (74650), which does not belong to the complex, is accordingly strongly altered.

The characteristic ore mineral occurring in the amphibolites is ilmenite, sometimes with exsolution lamellae of hematite. It is accompanied by varying amounts of sphene due to different degrees of alteration, forming aggregates with an average grain size of 0.2 mm. Magnetite may be found but the only sample in table 3 with a very fine-grained (<0.02 mm) but significant content (68623) originates from an amphibolite horizon of unknown relation to the Fiskenæsset complex. The sulphides observed are pyrite, chalcopyrite and pyrrhotite. The limonite content (1 %) of a rusty rock (78584) is regarded as an alteration product of the last of these sulphides, of which a few grains remain.

d) Ultramafic rocks

The ultramafic rocks are less important quantitatively compared with the two foregoing main components of the complex, but mineralogically they show the greatest variation, forming a number of different rock types. The mineral assemblages are all metamorphic with hornblende as the most characteristic constituent, but their igneous origin as dunites, peridotites and pyroxenites is still easily recognisable. The dominating minerals occurring in the specimens presented in table 4 are olivine, bronzite and hornblende in varying proportions, with minor amounts of diopside, garnet, spinel, plagioclase and ore minerals.

Magnetite is an important constituent of this group forming up to 15 % of the rock (78506). The grains, generally 0.2 mm in size, are homogenously distributed. Exsolution lamellae of ilmenite have only been observed in one section (92617), whereas intergrowths of magnetite and spinel are very common. Magnetite also occurs as small grains distributed along fractures and cleavage planes and around grain boundaries due to the serpentinisation of olivine. Ilmenite is the dominatant ore mineral in one specimen (78694), occurring together with magnetite as coarse grains 0.5-1.0 mm in size forming aggregates up to several cm in length. Sulphides are generally present in small amounts, with pyrrhotite and chalcopyrite as the most common and pyrite and copper sulphides as minor accessories.

e) Gneisses

The rocks belonging to the Fiskenæsset complex still have many igneous features preserved and are usually homogeneous, although the magmatic layering often gives them a distinct orientation. The gneisses, however, mostly show a well developed foliation. As seen in table 5 the gneisses are plagioclase-rich rocks, only occasionally with considerable amounts of microcline. The mafic minerals are hornblende, biotite and hypersthene, and accessories such as muscovite, apatite, carbonate and ore minerals are common. At the northern end of the complex rocks showing granulite facies assemblages are still preserved, whereas the gneisses of the central part are amphibolite facies rocks. To the south the saussuritisation of the plagioclase and the alteration of biotite to chlorite reflect the highest grade of retrogression (74438).

Magnetite is the most common ore accessory, but as it is coarse-grained (0.5 mm) and often concentrated in aggregates up to 3 mm, the inhomogeneity is rather high and the mineral may be completely lacking in a section even though its presence in the rock is known from another section of the same sample (74143). It is thus seen that the representative value of a section from this group of rocks, in contrast to the foregoing, is not sufficiently good for modal analyses of the mineralogical composition. Incipient martitisation of the magnetite is common, and limonite occurs as another alteration product. Ilmenite was found in some sections, but is only of significance in the least retrogressed rock with about 0.5 % hypersthene still preserved (74519). Some grains of copper sulphides may occur in the gneisses.

Table 1

Modal composition and magnetic data of chromitites

	Cr	Hb	Bi	Pl	Ru	k	J_r	Q
53282^a	61	36	+	1	1.1	1.3	0.4	< 0.1
53242^a	69	30	+	+	0.4	1.5	44	5.4
$78430_1{}^a$	53	36	1	9	0.7	1.3	16.4	2.4
$78430_2{}^a$	46				0.1	0.7	22.3	5.8
53261^a	60	30	7	1	0.7	1.2	5.5	0.9
78459^a	46				0.2	0.1	w	w
53291^a	64				+	0.4	w	w
53251^a	70	29			+	18	650	7
53215^b	44				+	0.7	2.4	0.9
53226^b	37				0.2	0.4	0.7	0.3
53229^b	35	23	+	42	0.1	0.4	0.4	< 0.1
78648^b	9				+	w	w	w
$78698_1{}^b$	46				0.4	0.9	w	w
$78698_2{}^b$	46	31	2	21	0.2	0.2	0.4	0.5
$78698_3{}^c$	21				0.1	w	w	w
53231^c	41				0.1	1.3	72	11
53217^c	36				0.2	0.6	6.5	2.1
53241^c	41	26	+	33	0.1	w	w	w
53259^c	35	30		34	0.3	0.4	0.4	< 0.1
53293^c	36	38	1	24	0.2	0.4	0.8	0.4

k = average isotropic susceptibility (e.m.u. x 10^{-4})
J_r = remanence (e.m.u. x 10^{-5})
Q = Königsberger's ratio (J_r/J_i)
a = chromitite
b = anorthosite-layered chromitite
c = augen chromitite
w = too weak to give a measurable response
+ = for rock-forming minerals < 1 %, for ore minerals < 0.05 %, for rutile < 0.1 %.

Table 2

Modal composition and magnetic data of anorthosites

	Pl	Hb	Py	Bi	Sp	Sul	Mag	Ilm	k	J_r	Q
53243_1	90	9		+				0.06	0.9	1.9	0.4
53243_2						0.1	0.2		0.9	2.4	0.5
53276_1	93	7				0.3			0.5	1.4	0.6
53276_2	90	7		2	1	0.3			0.7	4.8	1.3
74433	94	5		1					0.4	1.6	0.7
73072	76	22		2					w	w	w
53290	70	30				0.07					
68687	75	14	11	+					do.	do.	do.
78596	29	69			2						
78634	37	63									

Table 3

Modal composition and magnetic data of amphibolites

	Hb	Pl	Py	Bi	Qz	Gt	Sul	Ti	Ilm	Mag	k	J_r	Q
53230	62	36					+		1.8		5.4	51	1.8
53270	70	27				2			0.4	+	5.8	5	0.2
92608	64	33	2				+	0.7			0.8	3.2	0.7
92609	59	12			15	12	+		1.3		0.7	4.2	1.1
73017	66	32	+					1.2	0.6		0.9	3.6	0.7
68584_1	77	22						0.8	0.2		0.8	w	w
68584_2	76	22						1.2	0.2		0.6	w	w
78584	59	33	6				+				6	58	1.9
74650	50	21		18	9			2.0	+		w	w	w
68623	63	32	4							1.0	16	10	0.1

Table 4

Modal composition and magnetic data of ultramafic rocks

	Ol	Py	Hb	Pl	Sp	Sul	Ilm	Mag	k	J_r	Q
78694_1	39	32	7		9		6.7	5.4	244	3800	3
78694_2	32	33	15		8				143	527	0.7
53272	50	11	34		4	+		0.3	9.7	38	0.8
78506	12	33	40		+	+	+	15	186	280	0.3
78554	22	34	37	3		+		3.7	74	220	0.6
78536	22	32	41			+		4.8	92	185	0.4
78589	22	18	59			0.7		0.2	11	24	0.4
92617	24	42	32				+	2.1	36	117	0.6
78629		40	55	4		0.3			2	4.4	0.4
78534		42	50		8				0.7	1.5	0.4

Table 5

Modal composition and magnetic data of gneisses

	Qz	Pl	Mic	Bi	Hb	Ilm	Mag	k	J_r	Q
74480	26	63	1	9		+	0.7	18	39	0.4
74519	21	61		7	8	0.6	1.3	43	51	0.3
68638	28	30	39	2		+	0.5	15	24	0.3
74525	18	48		7				0.6	19	6
74143_1								4.8	14	0.5
74143_2	24	68	2	6				5.4	23	0.8
74143_3	22	68	2	7			0.05	5.7	25	0.8
68548	39	48	6	7			+	0.8	1.3	0.3
68635	39	42	13	6			0.2	9.2	63	1.3
74438	31	63		6				w	w	w

IV MAGNETIC MEASUREMENTS ON THE ROCK SAMPLES

The magnetic method of prospecting depends upon measuring accurately the anomalies of the local geomagnetic field caused by the differences in the intensity of magnetisation in rock formations. The magnetisation of rocks is due partly to induction in the present Earth's field (F) and partly to their permanent (remanent) magnetisation. The induced magnetisation J_i (= k. F) depends primarily on the magnetic susceptibility k of the rock body containing a distribution of ferromagnetic minerals (in particular, the magnetite), whereas the remanent magnetisation (J_r) depends on the geological history of the rock. The effective magnetisation in a rock body is, therefore, a vector sum of the aforesaid two components and is given by $J_e = J_i + J_r$.

A study of magnetic properties (in particular, the susceptibility and the remanence) of the ore-bearing rocks and the associated host rocks is of great utility in an exploration programme. The success of the magnetic method in ore-prospecting might largely depend on the intensity of the "magnetisation contrast" shown by the ore-bearing rock formation in relation to the host rocks. With this objective in mind, measurements of the susceptibility and remanence were undertaken on the specimens collected from the chromitites, the host rocks belonging to the Fiskenæsset complex, and the gneisses.

a) Preparation of the samples

In practice, the magnetic effect of a rock body of irregular shape is difficult to evaluate precisely, and therefore, for attaining better accuracy in measurements, rock samples are often prepared as cubes or short cylinders. From the field collection of samples, 10 cylindrical specimens each from anorthosites, amphibolites, ultramafics, gneisses and 20 cylindrical specimens from the chromitites were prepared in the laboratory with the aid of a core drill (42 mm in diameter). In view of the optimum value for the ratio of length to diameter for a point dipole representation of a uniform cylinder (Sharma, 1965), each of the cylindrical specimens was sliced to be about 37 mm in length. To facilitate the measurement of three components of magnetisation, two arbitrary but mutually perpendicular radial directions were marked on the top of the cylinder as x and y, and the axial direction as z.

b) The fluxgate instrument and the measuring method

A commercial Oerstedmeter in conjunction with a four-probe configuration device recently built up at the Geological Institute of Copenhagen University was used for measuring the components of induced and remanent magnetisation. The theory of the design of the four-probe configuration has been dealt with in a recent publication (Sharma, 1968). Practical details of the configuration device are shown in fig. 2. The specimen holder made of perspex can accommodate cylinders of diameter up to 42 mm, and it rests on a circular disc marked with four quadrants. The two pairs of measuring fluxgate probes in an antiparallel alignment are fixed to the four plastic frames on each side of the specimen holder, and the whole assembly is mounted on non-magnetic bronze rails attached to a firm wooden base. The centre of the specimen and the four fluxgate measuring elements are all aligned in a horizontal plane by making use of the built-in spirit levels.

Before starting the measurements, the bench-like system is so oriented that the axes of the fluxgate probes are aligned in the magnetic N-S direction. Any field difference locally existing between the two pairs of fluxgate probes is cancelled by means of the compensation device provided with the Oerstedmeter. The prepared rock cylinder with its x direction pointing N is now placed in the specimen holder. This produces a new field difference due to the x component of the effective magnetisation ($J_{ix} + J_{rx}$). The specimen is now rotated through 180^{o} to reverse the direction of the remanent component and the new deflection is noted. This process is repeated in a similar way to measure the y and z components of magnetisation. In all, six different orientation positions for a specimen are needed to determine the three components of remanent and induced intensity. In order to gain a comparatively high magnetic signal/noise ratio, all the measurements with the fluxgate device were made at a locality far from the city disturbances.

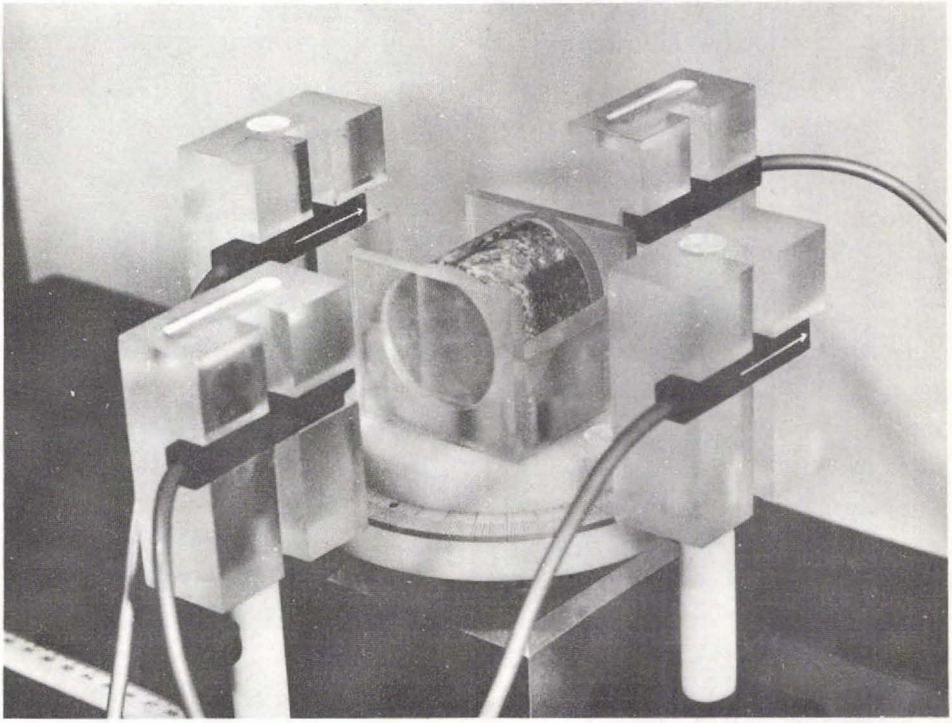

Fig. 2. Four-probe configuration device as set up at the Geological Institute, Copenhagen University.

c) Method of calculations

In general, the field due to a uniformly magnetised sample at a point in outer space is given by

$$H_i = \sum_k J_{ek} \cdot T_{ik} \ (i, k = x, y, z) \quad .... \quad (3)$$

where J_{ek} is the effective magnetisation in direction k and T_{ik} is the linkage tensor dependent on the geometry of the sample and the configuration employed.

For the configuration shown in the fig. 2, significant components of the linkage tensor T_{ik} are only T_{xx}, T_{yy} and T_{zz}. A computer programme in ALGOL developed earlier for evaluating the magnetic effects of cylindrical bodies (Sharma, 1966) was used for the calculation of T_{xx}, T_{yy} and T_{zz} components.

Now if H_1 and H_2 are the magnetic field readings of the Oersted-meter due to the $(J_{ix} + J_{rx})$ and $(J_{ix} - J_{rx})$ components of magnetisation, then

$$H_1 = (J_{ix} + J_{rx}) \cdot T_{xx} \qquad \ldots\ldots \quad (4)$$

$$H_2 = (J_{ix} - J_{rx}) \cdot T_{xx} \qquad \ldots\ldots \quad (5)$$

Addition and subtraction of the equations (4) and (5) yields both J_{ix} and J_{rx}. Likewise, from the other two sets of measurements J_{iy}, J_{ry} and J_{iz}, J_{rz} could be determined.

Since $J_{ix} = k.F_x / (1 + 4\pi . N . k)$, a knowledge of F_x i.e. of the horizontal component of the Earth's field (ca. 16000 γ at Copenhagen) and of N, the demagnetisation factor, (= 1/3 for a cylindrical dipole-like specimen) enables calculation of k (the magnetic susceptibility). Relatively large differences between the three values of k determined from J_{ix}, J_{iy} and J_{iz} components are indicative of a marked magnetic anisotropy existing in a specimen.

The intensity of J_r and J_i can be determined from the three components simply by

$$J_r = \sqrt{J_{rx}^2 + J_{ry}^2 + J_{rz}^2} \qquad \ldots\ldots \quad (6)$$

$$J_i = \sqrt{J_{ix}^2 + J_{iy}^2 + J_{iz}^2} \qquad \ldots\ldots \quad (7)$$

and the ratio J_r/J_i gives the Q factor (Königsberger's ratio) for the rock specimen.

d) Summary of results of magnetic measurements

The calculated values of k, J_r and Q for the 60 measured specimens are shown for each group in the last three columns of tables 1-5. It might be noticed that variations in the susceptibility and remanence in specimens of the same group are quite signigicant in the ultramafics as compared to the other groups. On the basis of susceptibility values the five groups of rock samples could be graded in order of increasing susceptibility as follows:

Anorthosites - very low (10^{-5} e.m.u. or less)
Chromitites - generally low (10^{-4} - 10^{-5} e.m.u.) but in one exceptional case (53251) moderately high
Amphibolites - low to medium (10^{-4} e.m.u.)
Gneisses - medium to moderate (10^{-3} - 10^{-4} e.m.u.)
Ultramafics - generally high (10^{-2} - 10^{-3} e.m.u.)

As seen from the Q values, the remanent magnetisation intensity is in general insignificant except for some chromitites and amphibolites for which the Q factor is of the order of unity or more. Thus the magnetic properties of most of the rock samples are largely dependent on the susceptibility and as such on the bulk distribution of ferromagnetic minerals in the rock formations.

V CORRELATION OF THE MAGNETIC PROPERTIES WITH MINERALOGY

Magnetic properties of rocks are for the most part related to the mineralogy and petrology of the two geochemical groups of minerals : the iron-titanium-oxygen group and the iron-sulphur group. A comprehensive investigation of this mutual relationship is beyond the scope of this paper, nonetheless some general observations of relevant interest may be mentioned. In regard to mineral composition, it is not only the Fe content which determines the magnetisation, but mainly its valency, since trivalent iron is more magnetic than bivalent. The susceptibility and remanence of a mineral are greatly influenced by the particle size of the magnetic grains. In addition, the state of magnetisation in minerals might alter by varying degrees during the geological history of the rocks, e.g. due to tectonic and metamorphic processes.

As seen from the data (tables 1-5), the susceptibility of the chromitite specimens is generally low, and the samples collected from the same area or even from the same site show apparent variations in the k values. It is evident from the formula (1) that both bivalent and trivalent iron are present in the lattice of the spinel group, most iron in chromite occurring as Fe^{2+} (formula 2). In general the total iron content (as Fe_2O_3) may vary by several percent around an average of about 35 % without any significant influence on the susceptibility of the chromitite rock. Of 175 samples analysed by X-ray fluorescence only a few show peak values of about 40 % Fe_2O_3. These samples, such as 53251 with a chromite containing 47 % total iron, show a distinctly higher susceptibility, which might be attributed to a comparatively high trivalent iron content. It has to be mentioned tioned that magnetite has been observed as an associated mineral in a few cases, but even in samples with peak Fe values it may be completely absent. Ilmenite also occurs sometimes, as in 53251 with 0.7 %, but generally it has been completely altered to rutile during metamorphism. Locally these two minerals may influence the magnetic properties of the chromitites, but for the group as a whole they are of little importance.

The susceptibility of the anorthosites is very low, and generally too weak to give a measurable response with the instrument used. This may be due to the absence of ore minerals except for some unimportant sulphides. Only one sample (53243) shows a higher k value due to the presence of very little magnetite and some ilmenite.

The amphibolites show a low to medium susceptibility corresponding to varying amounts of ilmenite, more or less altered to titanite, the lowest value reflecting the highest degree of metamorphism. The specimen with a considerable magnetite content (68623) giving the highest k value has already been mentioned as probably not belonging to the complex. The susceptibility measured on specimen 78584 seems to be influenced by the presence of secondary limonite, which is supported by the relatively high remanence intensity.

The magnetic properties of the ultramafic rocks show extreme variations due to considerable differences in the magnetite contents. It is remarkable that the specimen (78506) showing by far the highest magnetite content of 15 % has a lower susceptibility than a rock containing only about one third of this amount (78694). This is explained by the difference in grain size, which is extraordinarily large for the latter rock which contains aggregates of magnetite and ilmenite several cm long.

The susceptibility of the gneisses is medium, mainly due to a small magnetite content, and reveals marked anisotropy in excess of 25 %. Again the lowest value corresponds to the highest degree of retrogression. It might be mentioned that the representative value of a single section with respect to the content of ore minerals is insufficient, as illustrated by the three specimens from the same sample (74143). The magnetic data from the three specimens show, however, a reasonably fair agreement and seem to be more representative even for a single specimen.

VI APPLICABILITY OF THE MAGNETIC METHOD FOR CHROMITE PROSPECTING IN THE FISKENÆSSET AREA

The problem of prospecting for chromite is usually twofold first, to locate formations of favourable host rocks (in our case the meta-anorthosite-amphibolite-ultramafic complex) and, second, to locate the chromite horizons within the host rocks. In either case, for rocks of low Q values the applicability of the magnetic method would largely depend on the susceptibility contrasts shown by the associated rocks. In the light of the results of susceptibility measurements and known geology of the area, the possibility of application of the magnetic method (both airborne and ground surveys) may now be examined.

On the basis of geological knowledge of the area, two postulated causative models of host rock are examined. The first is an infinitely long bottomless prismatic block of anorthosite ($k = 10^{-5}$) of width 400 m embedded in a widely extending gneiss mass ($k = 5 \times 10^{-4}$). The maximum total field anomaly ΔT_m (taken as roughly equal to the vertical field anomaly ΔZ_m for higher latitude areas) caused by this model at a flight altitude of 200 m (above ground level) can be theoretically calculated (Sharma, 1967) and works out to be about -80 γ. If the above block of host rock is assumed to be a composite one of both anorthosite and amphibolite (50 % each, $k = 5 \times 10^{-5}$), the calculated anomaly would be about 10 % less than in the former case. A second model of an ultramafic block ($k = 5 \times 10^{-3}$) is assumed to be 50 m in width, 200 m in length and extends to a depth of 200 m, and its ΔT_m anomaly is also calculated for the same flight elevation of 200 m. It works out to be about + 36 γ.

If the flight elevation is increased to 400 m, the ΔT_m anomaly falls to about -50 γ in the first two cases, and to about + 20 γ in the third case. These anomalies of the order of some tens of gamma, are easily detectable by airborne fluxgate type magnetometers, and as such the aeromagnetic method for locating favourable host rocks in the Fiskenæsset complex seems to be fairly promising. Besides this, the detection of faults, which is often of great importance in ore-prospecting, might be possible by this method.

Now we might examine the second part of the problem, namely that of locating the chromite horizons ($k = 5 \times 10^{-5}$) within the possible favourable host rock bodies. On geological considerations two models of vertical sheets of chromite deposits, one 20 m in width, and the other only 2 m in width, are considered. If the enclosing rock is anorthosite (which in the known area is the predominant associated host rock), the ΔT_m anomaly at 200 m elevation works out to be extremely small ($< 0.5\ \gamma$) to be detected by an airborne magnetometer. Assuming a low depth of burial to be 2-20 m for this model, the ΔT_m anomaly even at the ground level would be only about + 9 to + 4 γ - low values which could be easily overshadowed by "noise" arising due to random magnetisations in the associated rocks. Thus direct prospecting for chromite horizons occurring within the anorthosites may not be feasible owing to the poor susceptibility contrast.

However, if the host rock is ultramafic ($k = 5 \times 10^{-3}$), which could be expected as a possibility in the hitherto geologically unknown area, the theoretical anomaly ΔT_m rises to about 100 times that in the case of anorthosite. In this case, therefore, chromite horizons of width 20 m might be easily detected by ground surveys. Even for the case of second model, a thin chromite horizon of width 2 m, the ΔT_m anomaly at ground level would be about - 50 γ. Thus in the case of ultramafics, where the susceptibility contrast with respect to chromites is quite clear, a ground magnetometer survey with a fairly close station spacing might be successfully used in the prospecting routine.

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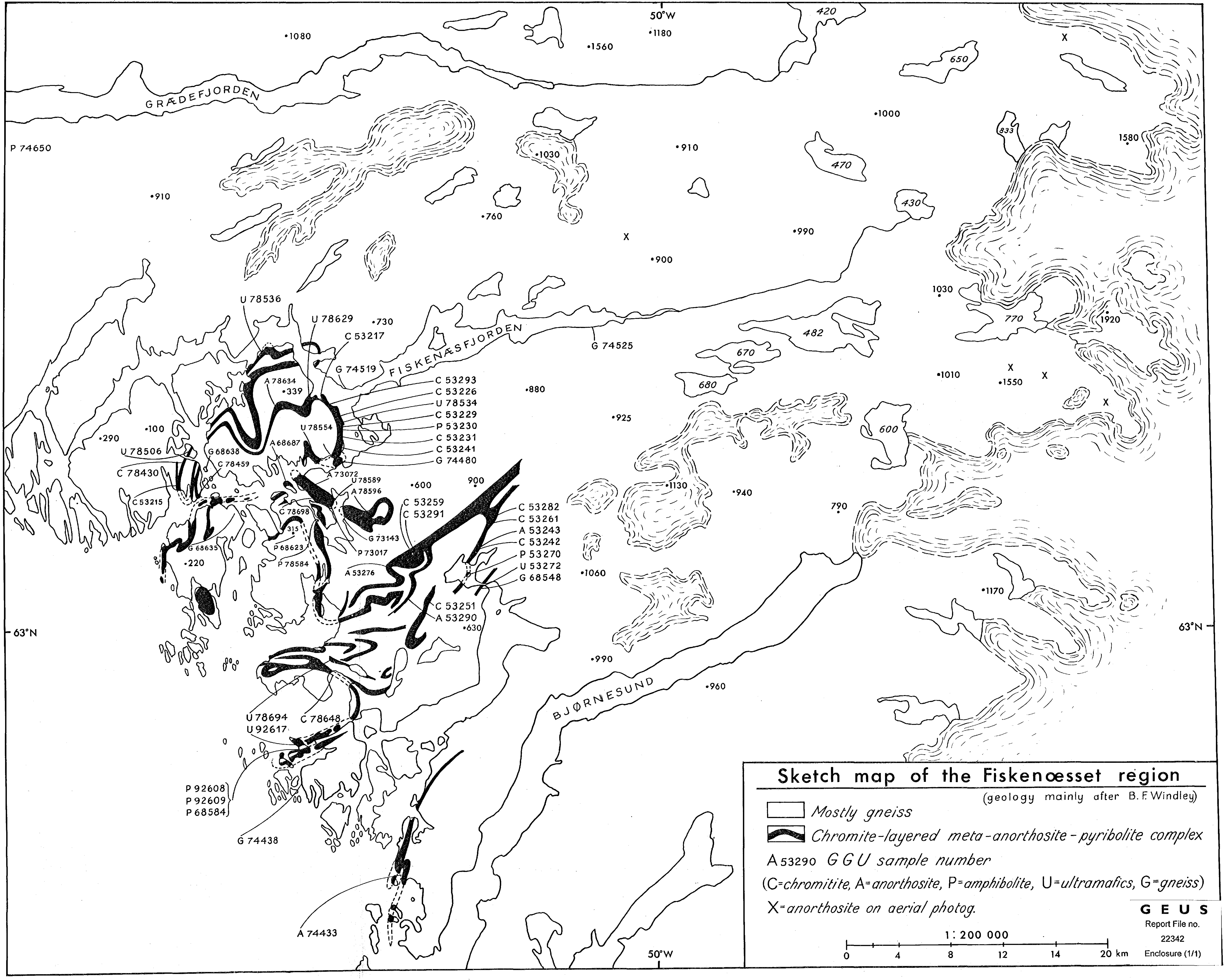

Sketch map of the Fiskenœsset region

(geology mainly after B. F. Windley)

▭ *Mostly gneiss*

▬ *Chromite-layered meta-anorthosite-pyribolite complex*

A 53290 *G G U sample number*

(C=*chromitite*, A=*anorthosite*, P=*amphibolite*, U=*ultramafics*, G=*gneiss*)

X=*anorthosite on aerial photog.*

1 : 200 000

0 4 8 12 14 20 km

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