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Peter W. U. Appel, Peter R. Dawes
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Ujarassiortut Kalaallit Nunaanni Misissuisoqarfiat
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Øster Voldgade 10, DK-1350 Copenhagen K, Denmark

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ABSTRACT

An airborne geophysical programme in Inglefield Land in 1994 revealed numerous magnetic anomalies. Field investigations in 1995 of the strongest anomaly revealed a source concealed by overburden, although abundant magnetite float occurs in the surficial deposits. The float consists of about 90% magnetite and 10% olivine. Chemical analyses of the magnetite float proved up to 0.26% V_2O_5 and 0.10% Ni. No sulphides were found in polished sections. Several kilometres along strike to the east, in an amphibolite succession magnetite outcrops in up to 40 cm wide bands composed of olivine, magnetite and pleonaste.

The magnetite is of magmatic origin and associated with basic and ultrabasic rocks. Geophysical data suggest that the magnetite-bearing intrusions can be traced for about 100 km along strike.

CONTENTS

1. INTRODUCTION

In 1994 a five-year airborne geophysical project (Project AEM Greenland 1994-1998) was launched. The first-year target was Inglefield Land in North-West Greenland, where commercial exploration previously had investigated the extensive gossans in the Precambrian crystalline shield. As part of the first-year AEM work a photogeological interpretation of Inglefield Land was carried out (Bengaard, 1995).

During the regional electromagnetic and magnetic survey of Inglefield Land (Stemp & Thorning, 1995) several geophysical anomalies were discovered. Along with a geological reconnaissance and a regional geochemical survey, these anomalies were checked in the field in 1995. During this field work the Minturn Elv magnetite occurrence was discovered.

2. EXPOSURE

Geomorphologically, Inglefield Land is a dissected plateau of rolling relief. The bedrock geology is concealed to varying degrees by Quaternary deposits (Fig. 1) that are in places very profuse. For example, a broad belt of glacial drift crosses southern Inglefield Land adjacent to the front of the Inland Ice (Koch, 1933). In the south-east and south-western parts of this belt, particularly, extensive flat areas are covered by continuous blankets of drift, through which outcrops are sporadic.

The Minturn Elv magnetite occurrence is located in the central part of this glacial drift belt. Exposures of magnetite-bearing rocks occur in several valleys and deep gullies. On the plateau surface outcrops are poor but magnetite float is locally abundant.

3. REGIONAL GEOLOGY

Inglefield Land is composed of two main geological complexes: high-grade crystalline rocks of the Precambrian Canadian-Greenlandic shield forming about 60% of the bedrock, are overlain by a cover sequence of unmetamorphosed Proterozoic to Cambrian strata

(Fig. 1). The cover sequence, representing deposits of two overlapping sedimentary basins (the middle to late Proterozoic Thule Basin, and the lower Palaeozoic Franklinian Basin), were deposited on a Precambrian peneplain, the surface of which dips shallowly to the north-west.

The Minturn magnetite occurrence is associated with Precambrian crystalline rocks. Thus, this account on regional geology is restricted to the Precambrian shield.

Geological summaries of the Precambrian shield, based mainly on the initial investigations of Koch (1929, 1933), together with the later collections of the Geological Survey of Greenland, have been given by Dawes (1976, 1988). The main results of the 1995 field work relating to regional geology and geochemistry are pending; thus for convenience, the geological subdivisions of Dawes (1976, 1988) are used for this summary.

The Precambrian shield can be divided broadly into three main complexes, all of which show a wide variety of rock types and all contain rocks that are repeatedly deformed and have been metamorphosed under high amphibolite to granulite facies conditions. The three rock complexes are: the Etah Group supracrustal rocks, the Etah meta-igneous complex and a variable gneiss group.

Etah Group. This metasedimentary group is composed of marble, calc-silicate rocks, pelitic schists and gneisses with units of psammitic rocks, including siliceous garnet gneisses. The group forms conspicuous linear outcrops in south-western Inglefield Land but has been traced throughout the region. The age of the supracrustal rocks is unknown but comparisons with Canadian geology suggest an early(?) Proterozoic age.

Etah meta-igneous complex. This is a multiphase plutonic suite of rocks in which hypersthene is a common mafic mineral. The complex contains a compositional range from ultrabasic and basic through tonalites and diorite and to later phases of granodiorites and granites. The complex is of early Proterozoic age and probably contains magmatic rocks of a variety of ages from 1960 Ma to 1850 Ma. Rocks of the complex intrude the Etah Group on a variety of scales.

Variable gneisses. This is a multiphase gneiss group that contains gneisses derived from both the Etah Group and the Etah meta-igneous complex. Quartzo-feldspathic, garnet-biotite(-sillimanite) gneisses outcropping over large parts of Inglefield Land were referred to this gneiss group by Sharp (1991). Many of the gneisses must be of early Proterozic age but it is unknown to what extent the variable gneisses contain older crustal material, i.e. a basement to the Etah Group supracrustals.

4. THE MINTURN ELV MAGNETIC HIGH

The geophysical results of the 1994 survey reported in Stemp & Thorning (1995) included a large number of magnetic anomalies. The strongest of these is a regional linear, E-W trending magnetic high stretching from the south-west coast between Kap Alexander and Cairn Pynt to the margin of the Inland Ice, where it is obscured by a group of non-linear magnetic highs (Fig. 2).

The highest magnetic field value of the entire survey was recorded near this linear feature on line 192 (utm-coordinates x= 366450, y=8719885, zone 20) with a peak value of 15.400 nT relative to the International Geomagnetic Reference Field at the time of surveying. A weak EM anomaly is associated with this very strong magnetic anomaly (EM anomaly # 35, Appendix I on line 192, Stemp & Thorning 1995) and probably generated by the magnetite. Just off the magnetic anomaly to the north and concordant with this is a linear conductor of intermediate strength stretching from line 186 to line 193 and caused probably by sulphides or graphite.

Part of line 192 and neighbouring lines are shown as stacked profiles in figure 3, superimposed on a shaded relief anomaly map corresponding to figure 4, see below. Although the highest value is on line 192, the anomaly is clearly defined from line 190 to line 204, and after a break corresponding to line 205, it seems to continue again until it merges with the more widespread magnetic highs to the west. In figure 4 a residual magnetic intensity anomaly map of the same area is shown . The original line data have been gridded at 50 by 50 metres using the method of total minimum curvature.

The peak value of 15.400 nT (on line 192) can be seen to be part of an at least 7-8 km long and straight magnetic high. Although peak values west and east of line 192 do not reach the same magnitude, but only range from 1.500 nT to 4.000 nT, this elongated high is clearly distinguishable from the surrounding anomalies, including others along the regional linear feature shown on figure 2. The eastern termination of the high occurs near the intersection of several faults. One of the faults striking NE-SW seems to exhibit sinistral movement of approximately 1.5 km, i.e. the probable western continuation of the anomaly can be seen to the WSW, where peak values are near 1.000 nT, quite typical for many locations along the regional linear trend evident in figure 2. The anomaly map (Fig. 4) also shown many geological trends, and structures, which will not be discussed here.

From the magnitude of the magnetic anomaly alone it can be surmised that the source of the anomaly must contain abundant magnetite as the dominant magnetization carrying mineral. In order to obtain an indication of the petrophysical properties involved, four hand samples from the site (Loc. A, see below) of the strongest anomaly have been measured (L. Kivakäs and R. Puranen, private communication). The results are summarized in Table 1. Although the material is too limited for a proper statistical evaluation, the measurements convincingly demonstrate a significant difference in petrophysical properties between country rock (gneiss and granites), and the magnetic ore rock. Thus, further ground geophysical studies like gravity, magnetics, electromagnetics and IP would undoubtedly provide valuable detail on properties, shape and depth extent of the magnetic body.

Using suitable values for magnetic susceptibility and remanence, a simple two-and-a-half dimensional model indicates a minimum width of the mineralized zone of 200-300 meters and dipping steeply to the north. However, given the uncertainties involved, this must remain a preliminary conclusion. It is not possible on the basis of the magnetic anomalies to distinguish individual layers of magnetite in the mineralized zone. If such layers exist their magnetic expressions merge completely into one single anomaly. The anisotropy of the magnetic properties is most likely related to preferred orientation of crystals or exsolution products. Along strike variations in magnetic properties and geometry are indicated by the shape and magnitude of the anomaly.

Table 1. Petrophysical parameters of selected samples

Sample number	**406985**	**406986**	**406987**	**406991**	**406987A**
Rock type	gneiss	magnetite ore	magnetite ore	granite	magnetite ore
Density, D (kg/m^3)	2935	4295	4750	2865	-
App. mag. susceptibility, k (SI)	0.00938	2.39	2.57	0.0326	1.24
True mag. susceptibility, K (SI)	0.00938	8.0	10.2	0.0330	-
App. int. of remanence, j (mA/m)	200	31000	13390	307	16410
True int. of remanence, J (mA/m)	200	103400	53100	310	-
Königsberger ratio, Q	0.48	0.29	0.12	0.21	0.30
Conductivity s (mS/m)	0.04	70	2000	0.02	-
Demagnetization factor, N	-	0.293	0.291	0.332	-

Comments: The measurements of four samples (406985-406987, 406991) were carried out by L. Kivakäs and R. Puranen, Geological Survey of Finland. Difficulties were encountered measuring the strongly magnetic ore samples, and sample shape demagnetization had to be taken into account. True intensity and susceptibility are calculated from corresponding apparent (measured) values using the formula $K = k/(1-Nk)$ for susceptibilities. Königsberger ratio is calculated as $Q= J/KH$, where $H = 44.5$ A/m is the Earth's magnetic field intensity in Inglefield Land. Furthermore, the ore samples exhibited magnetic anisotropy, which may be of importance in magnetic interpretation, e.g. sample 406986 showed a variation in true susceptibility of 6.6 to 9.5 (SI), when measured in three orthogonal directions. Sample 406987A was measured by P. Fris, University of Aarhus, and also exhibited signs of anisotropy. This sample was demagnetized and shown to have a minor, but stable component in the NRM, but by far the largest part of the NRM was of the viscous type, i.e. will align itself with any present magnetic field, when the rock is *in situ*.

5. SETTING OF THE MINTURN ELV MAGNETITE

Over the strongest part of the magnetic anomaly (locality A, see below) magnetite is not seen *in situ*. There the only bedrock outcrops are granites, which appear to be discordant to the regional trend of the anomaly.

However, to the east along the strike of the magnetic anomaly (locality B, see below) magnetite-bearing rocks are found within a dark-weathering, steeply-dipping succession of foliated granitic and syenitic rocks, that contains units of garnet-bearing amphibolites and green ultramafics. Regional dips to the north are up to 75°. This succession is regarded as a high-grade, highly-deformed occurrence of the Etah meta-igneous complex. Both to the north and south of the magnetite-bearing rocks, units of marble-dominated supracrustal rocks occur (Etah Group) that are invaded by reddish granitoids. A granite mass of similar appearance cuts the magnetite-bearing succession.

Three main locations were sampled; marked A to C on figure 1. Magnetite float on the at near the peak of the magnetic anomaly (loc. A at 6895.49 W, 7850.83 N; samples 406952, 53, 86, 87, 87a, 91 and 425378). Approximately 4 km east of locality A float of massive magnetite from a poorly outcropping sequence in ultrabasite was sampled (loc. B at 6874.02 W, 7850.36 N; sample 425364). About 1.5 km further east at Minturn Elv magnetite occurs as massive to semi-massive bands up to ten centimetres thick in an ultrabasic rock in amphibolite. Nearby the ultrabasitic rock is locally brecciated and cut by a network of calc-silicate-rich veins (loc. C at 6836.00 W, 7839.72 N; samples 425340, 60).

6. INVESTIGATION OF SOIL SAMPLES

Above the peak of the magnetic anomaly (locality A) magnetite occurs only in float. In order to quantify the amount of loose magnetite on the surface three samples each about 10 l (ca. 20 kg) of soil were collected. The samples were collected a few hundred metres apart along the magnetic anomaly. The material was sieved and three fractions were gravitated in the sieves, and the fine fraction -20 mesh was panned. In the laboratory the fractions <-8 mesh were magnetically separated. The results are shown in Table 2.

Table 2. Magnetite content in soil samples collected near the magnetic anomaly

Sample no	+8 mesh	8 - 12 mesh	12 - 20 mesh	20 mesh
406988	538.8	50.4	38.9	79
406989	9.8	12.5	16.5	42
406990	129.7	12.8	25.8	32

The figures given are in grams. The magnetite content of the overburden ranges from 0.4 - 3.5 %.

7. ORE MICROSCOPY

Five samples (406952, 53, 86, 87 and 425378) from locality A, two samples (425340,60) from locality C and one sample (425364) from locality B, were investigated in reflected and transmitted light. Microprobe checks were made on the spinels.

The samples of magnetite float from the peak magnetic anomaly (loc. A) are all quite similar. They contain about 10% silicates often in millimetre-sized round shapes, mainly highly altered olivine. Magnetite grains are up to a few millimetres in size with virtually no exsolutions of spinel. Martitization is common. Mostly less than 5% hematite is seen along tiny cracks (Fig. 5). However, in one sample (425378) most of the magnetite is completely altered into hematite.

The samples from locality B and C are somewhat different. The magnetite is less martitized and spinel exsolutions in magnetite are very common. They occur as fine grains and spindless (Fig. 6) presumably oriented parallel to {111} of the magnetite. Some of the spinel exsolutions are coarser grained and highly irregular (Fig. 7).

Discrete grains of pleonaste (Mg, Fe, Al - spinel) are abundant. They are up to a few millimetres in size, anhedral to subhedral in shape often consisting of a green transparent part and an opaque part, both of which show very low reflectivity. Qualitative microprobe investigations revealed no significant difference in chemical composition between the opaque and the transparent pleonaste. The pleonaste has frequently numerous minute exsolutions of magnetite as blebs and irregular shapes (Fig. 8). No sulphides have been seen in any of the samples. Fresh grains of olivine make up about 10% of the rock. The grain-size of the magnetite is a few millimetres, whereas some silicates can attain size of more than 5 millimetres. Many of the smaller olivine grains occur as round inclusions in magnetite (Fig. 9). Sample 425360 is peculiar in consisting mainly of medium-grained olivine, about 15% spinel (pleonaste?) and an unidentified green mineral.

8. CHEMISTRY

Four samples of magnetite float have been analyzed for major and selected minor elements by XRF at the Surveys laboratory. The results are shown in Table 3. Of particular interest are the high contents of nickel and vanadium.

One sample of magnetite float has been analyzed by neutron activation and ICP at Activation Laboratories Ltd., Canada. The results are shown in Table 4. The high nickel and vanadium values found by XRF are confirmed by these analyses. Gold values seem to be quite low.

Table 3. Major and selected trace elements in samples of magnetic float

	406952	406953	406986	406987
SiO_2	7.739	1.354	1.158	1.656
TiO_2	0.353	0.159	0.064	0.234
Al_2O_3	1.811	0.532	0.133	0.644
Fe_2O_3	57.853	78.395	69.675	68.437
FeO	23.220	16.040	26.270	23.410
MnO	0.191	0.165	0.148	0.220
MgO	5.866	2.314	2.184	2.732
CaO	1.599	0.205	0.000	0.802
Na_2O	0.210	0.030	0.030	0.040
K_2O	0.082	0.014	0.015	0.015
P_2O_5	0.180	0.074	0.021	0.375
Volat	1.344	0.845	0.064	1.186
Total	100.448	100.126	99.762	99.750
V	1100	1437	1230	1353
Cr	235	3	12	24
Ni	1039	941	866	1003
Cu	10	9	12	11

Table 4. Selected trace element composition, analyzed by neutron activation and ICP

	Au	Ag	Co	Cr	Ni	Cu	Pb	Zn	V
	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
406951	11	<5	99	41	740	638	5	34	72
406952	<2	<5	75	250	1300	10	5	6	733
406953	<2	<5	46	15	1100	10	5	5	736
406987	<3	<5	65	24	1000	10	5	2	1030

9. CONCLUSIONS AND RECOMMENDATIONS

From the limited information so far available we can define the Minturn Elv magnetite occurrence as a magmatic deposit with elevated contents of nickel and vanadium. It is hosted in basic-ultrabasic rocks in a multiphase igneous complex cut by felsic intrusives. No nickel and vanadium minerals have been found and thus the two elements are probably in solid solution either in magnetite or in the silicates.

The magnetite seen *in situ* shows abundant exsolutions of spinel, whereas the magnetite float from the main magnetic anomaly shows virtually no exsolution.

In most samples martitization has slightly altered the magnetite. But one boulder indicates that martitization can form massive hematite. It is not known when the martitization took place.

Based on the airborne geophysics, the Minturn Elv magnetite occurrence is seen as a regional anomaly of several kilometres in length, and the magnetite-bearing rock complex may extend for about 100 km. It is interesting to note the presence of a conductor zone next to the main magnetic anomaly in the drift covered area.

The petrophysical results indicate that several geophysical methods may be of use in a detailed ground geophysical survey.

10. ACKNOWLEDGEMENTS

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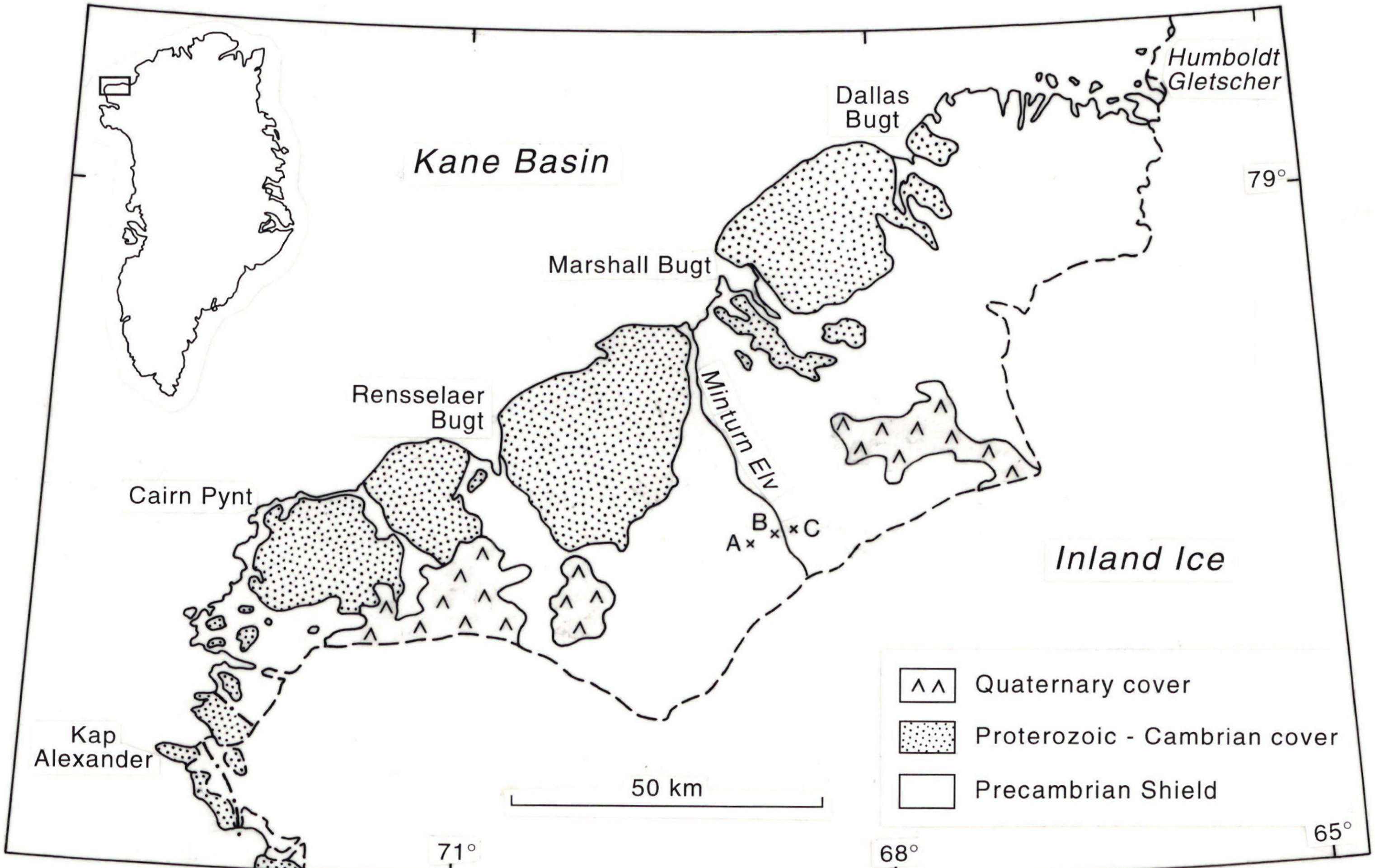

Fig. 1. Simplified geological sketch map of Inglefield Land showing the three sample locations, A, B and C.

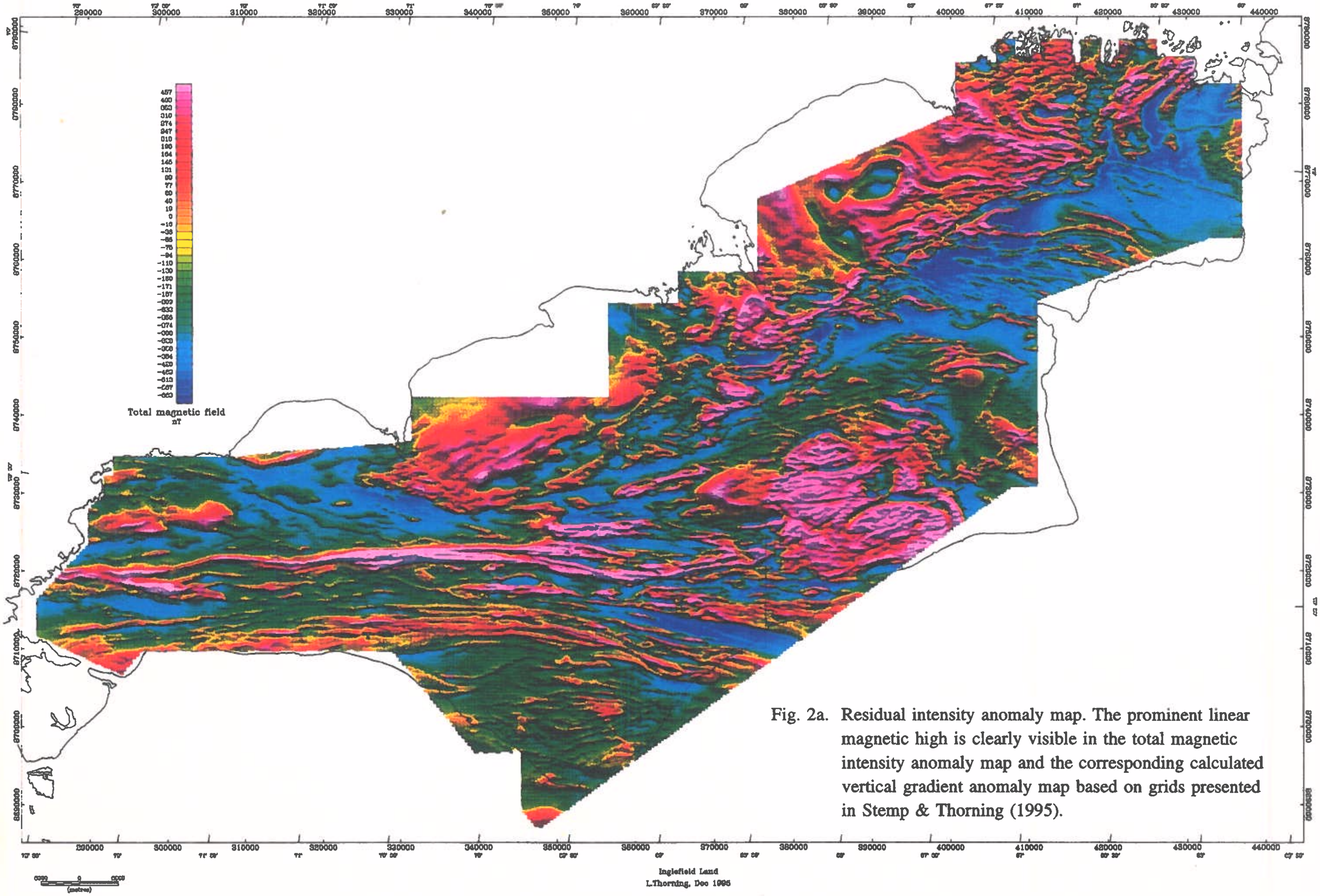

Fig. 2a. Residual intensity anomaly map. The prominent linear magnetic high is clearly visible in the total magnetic intensity anomaly map and the corresponding calculated vertical gradient anomaly map based on grids presented in Stemp & Thorning (1995).

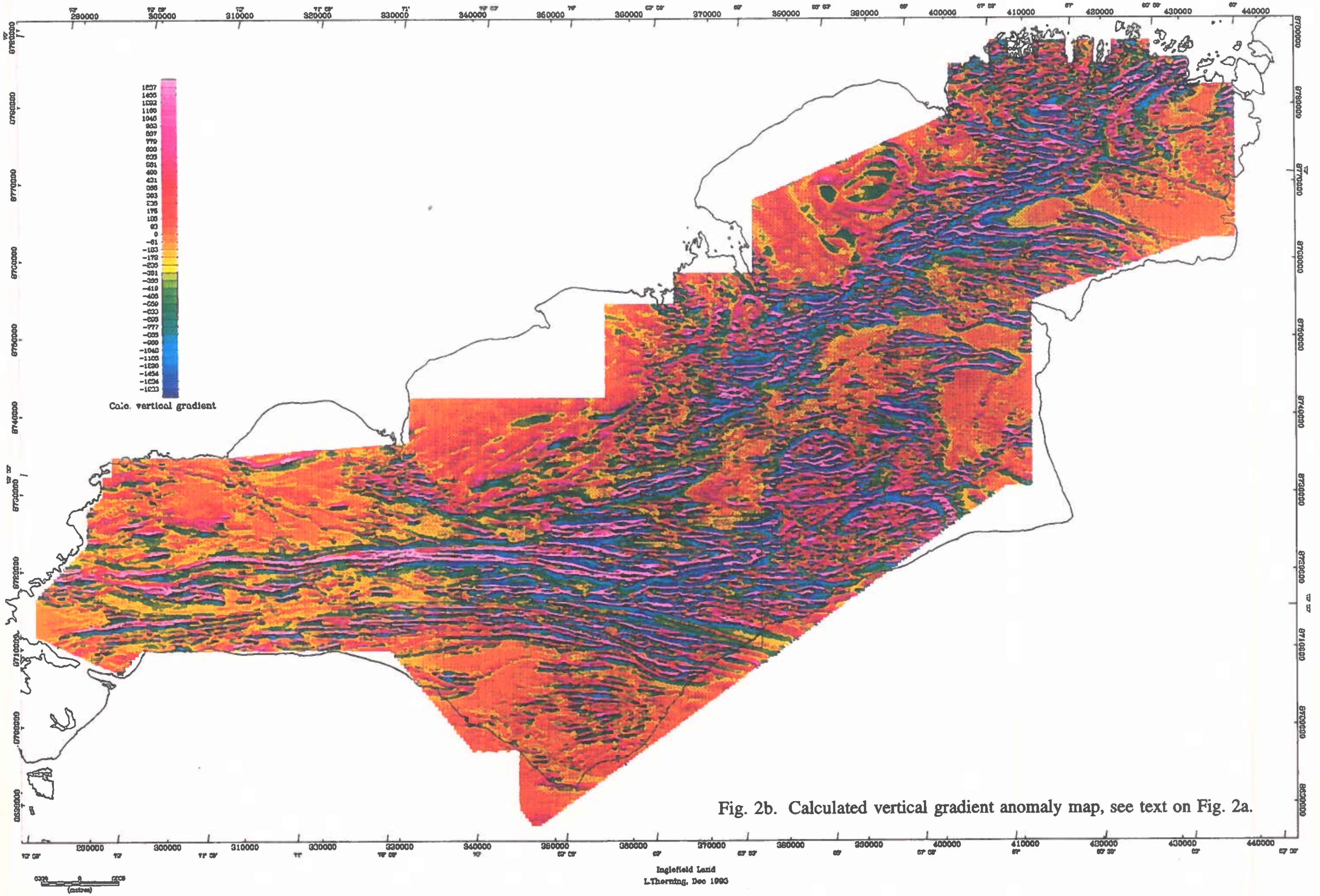

Fig. 2b. Calculated vertical gradient anomaly map, see text on Fig. 2a.

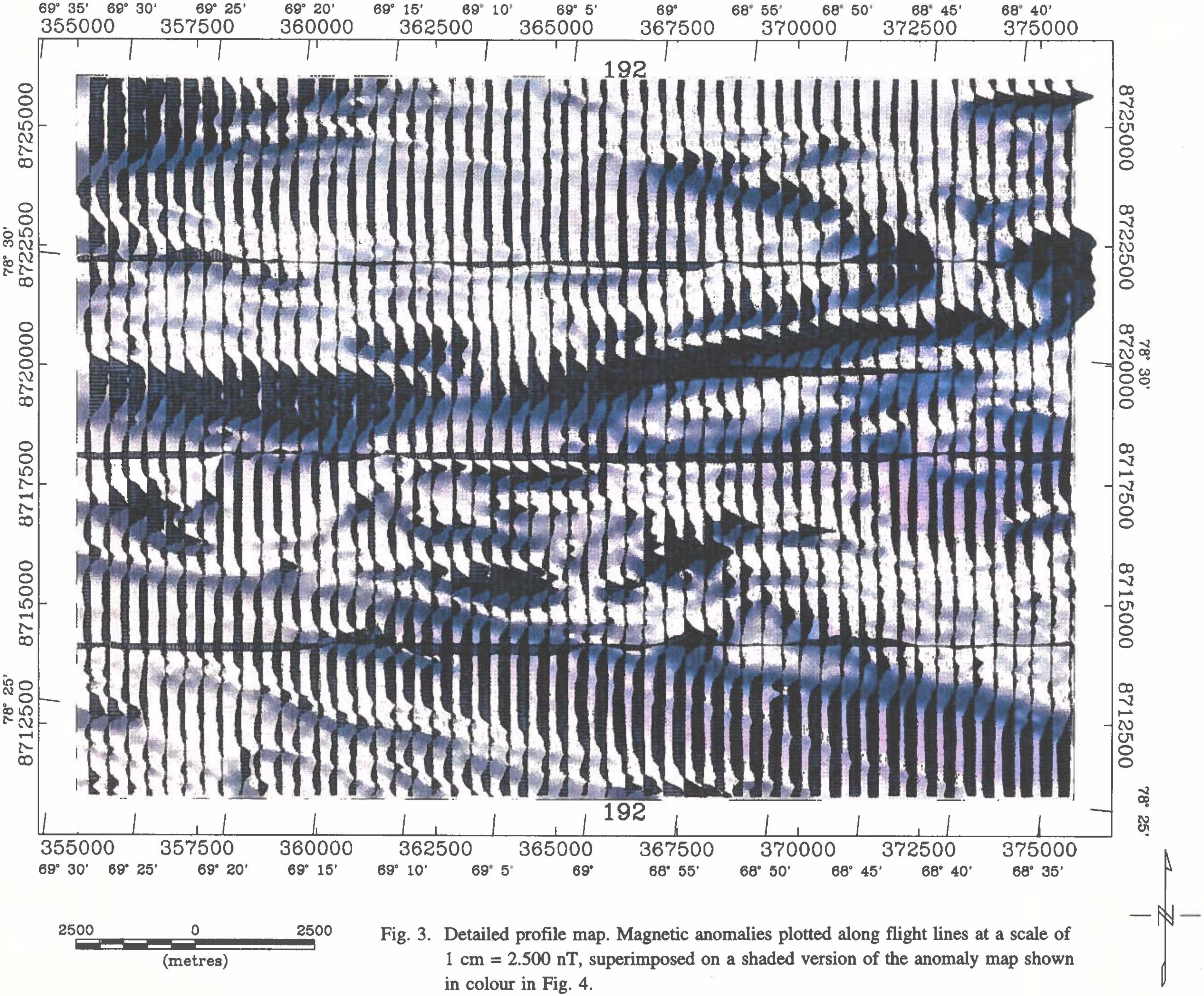

Fig. 3. Detailed profile map. Magnetic anomalies plotted along flight lines at a scale of 1 cm = 2.500 nT, superimposed on a shaded version of the anomaly map shown in colour in Fig. 4.

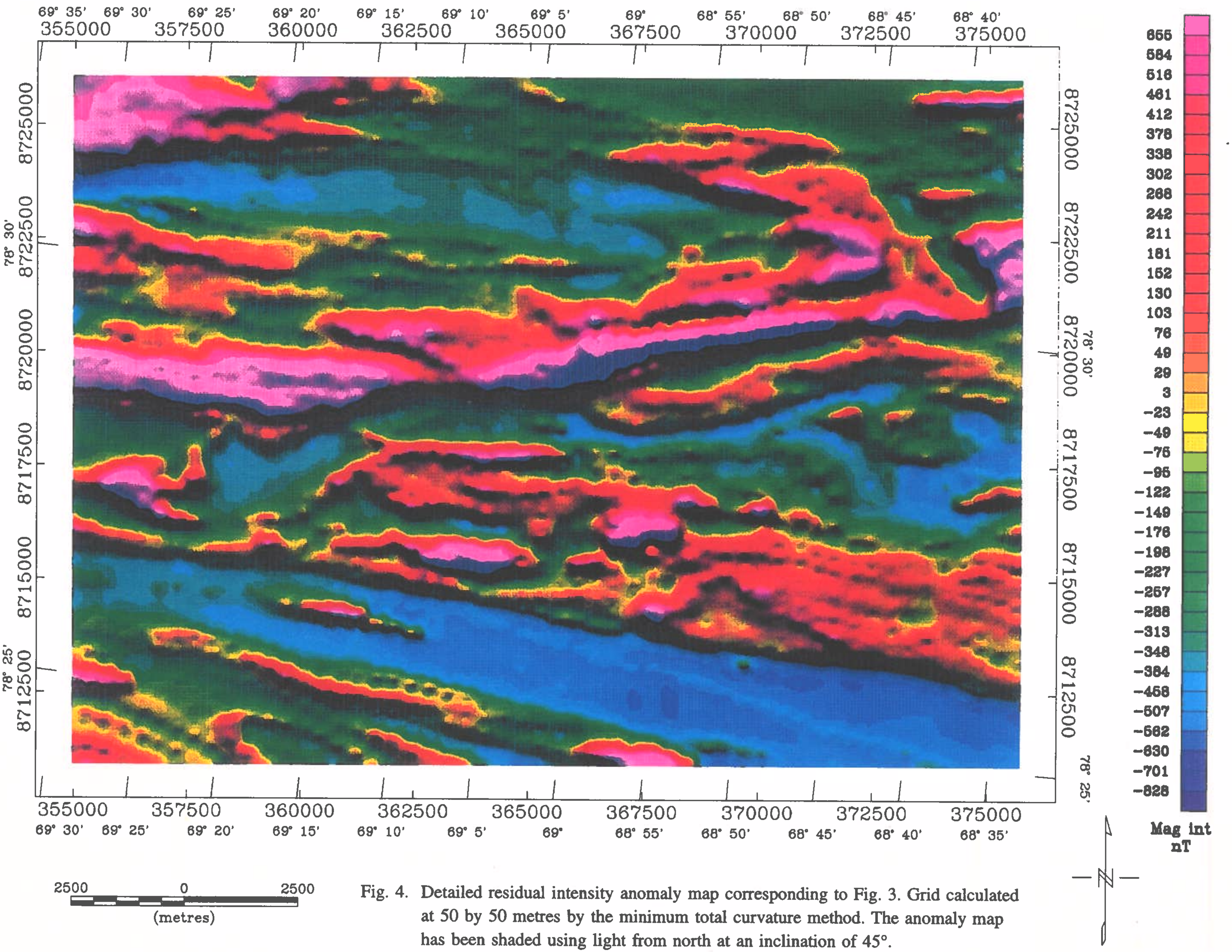

Fig. 4. Detailed residual intensity anomaly map corresponding to Fig. 3. Grid calculated at 50 by 50 metres by the minimum total curvature method. The anomaly map has been shaded using light from north at an inclination of 45°.

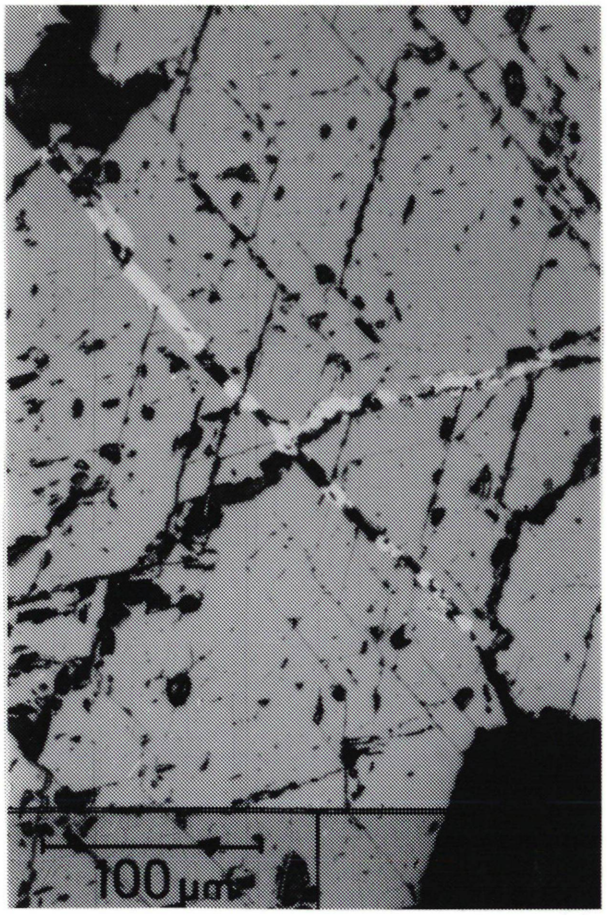

Fig. 5. Martitization along cracks. Photomicrograph in reflected light. Magnetite light grey, hematite white. Sample 406953.

Fig. 6. Exsolutions of spinel in magnetite. Photomicrograph in reflected light. Magnetite grey, spinel exsolutions dark grey. Sample 425364.

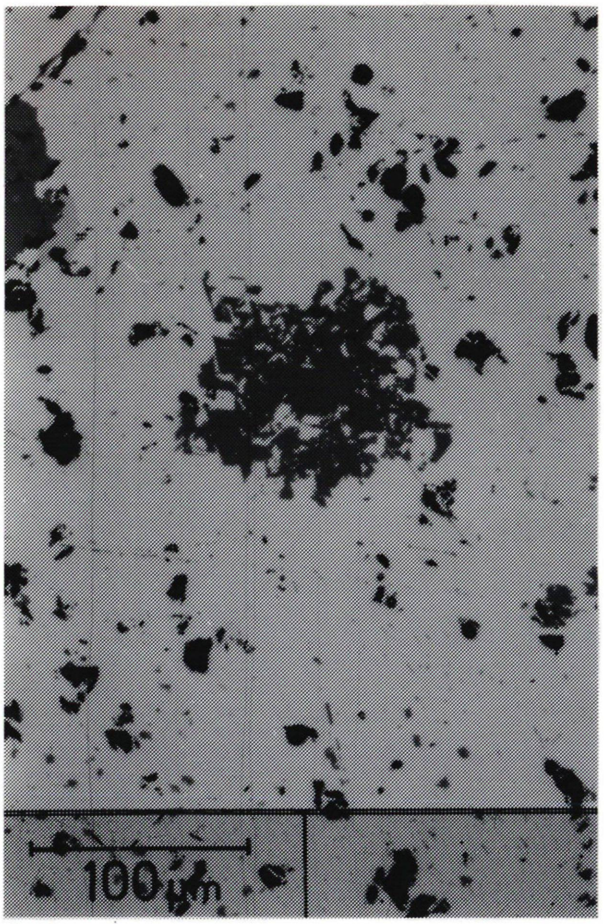

Fig. 7. Coarse exsolutions of spinel in magnetite. Photomicrograph in reflected light. Magnetite grey, spinel dark grey. Sample 425364.

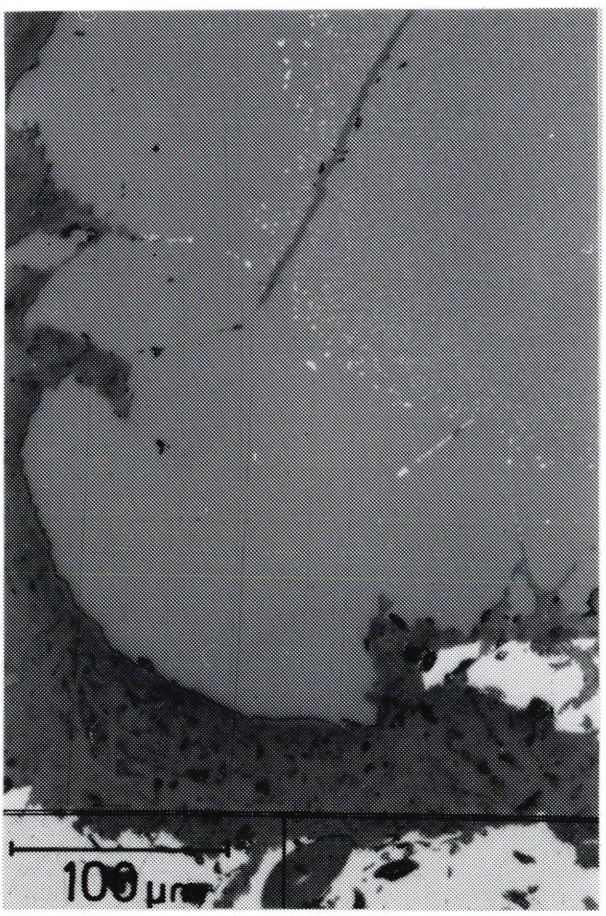

Fig. 8. Pleonaste with minute exsolutions of magnetite. Photomicrograph in reflected light. Pleonaste grey, magnetite white and olivine dark grey. Sample 425364.

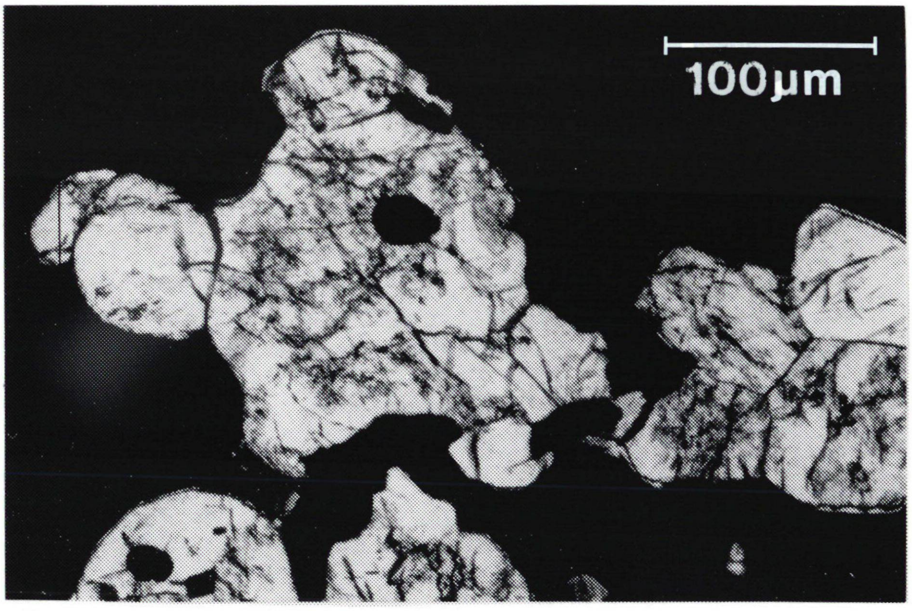

Fig. 9. Round olivine inclusions in magnetite. Photomicrograph in transmitted light. Magnetite black, olivine translucent. Sample 425364.

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