Airborne electromagnetic and magnetic survey of Inglefield Land, North-West Greenland

Results from project AEM Greenland 1994

Robert W. Stemp and Leif Thorning

Open File Series 95/1

February 1995

GGU

GRØNLANDS GEOLOGISKE UNDERSØGELSE
Ujarassiortut Kalaallit Nunaanni Misissuisoqarfiat
GEOLOGICAL SURVEY OF GREENLAND

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ABSTRACT

The first year of a 5-year airborne electromagnetic project (project AEM Greenland) has been successfully concluded with the release of the survey data and report on 1 February 1995. The new geophysical data support earlier geological observations and supplements with new geological features. This is especially evident in areas covered by Quaternary deposits.

The airborne survey suggests that massive sulphide mineralization is widespread in the region. Seventy-five specific anomalous targets have been identified for mineral investigation as part of a ground follow-up programme.

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Fig. 1. Inglefield Land gossans mapped by video camera on board survey aircraft. Width of scenes *c.* 240 m.

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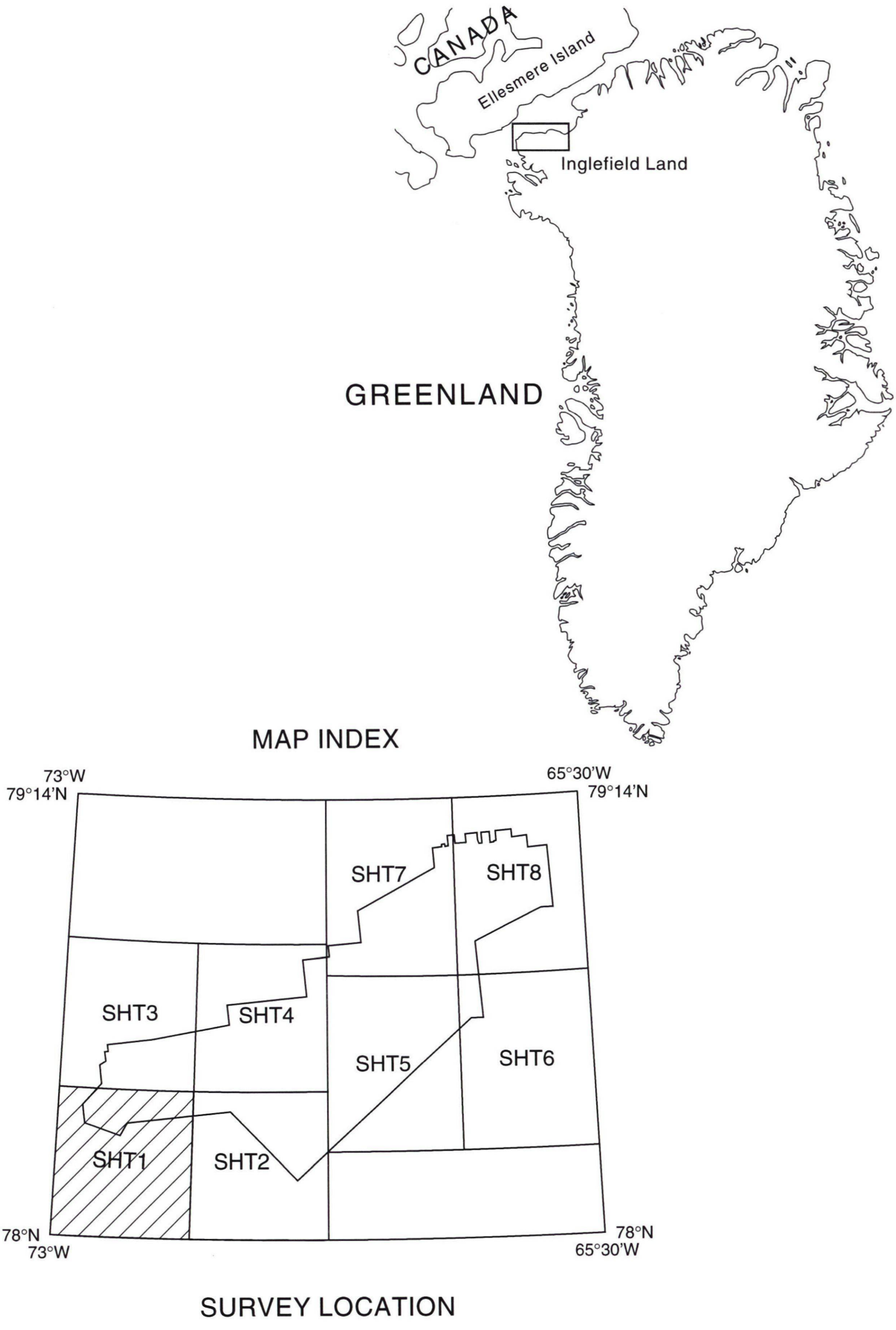

Fig. 2. Survey location map and 1:50 000 scale map sheet index.

1. INTRODUCTION

This report pertains to a combined airborne electromagnetic and magnetic survey carried out over Inglefield Land in north-western Greenland as the first year of a planned 5 year airborne geophysical project (Project AEM Greenland 1994-98). The report provides an initial interpretation of the airborne data with respect to geology, and especially aspects important to an analysis of the economic evaluation of the mineral resources of the area. A detailed list of ground follow-up targets of possible economic interest is also provided.

All information relating to the survey operations, equipment and data processing techniques is given in a separate report by Geoterrex Ltd. (1994), the airborne survey contractor.

The final digital data were not available during the writing of this report. Consequently, no quantitative model evaluations have been carried out.

The main body of this report is a qualitative geological analysis of the results, presented from different view points supported by maps and illustrations. It is not a full geological interpretation, but a discussion of interesting features detected by the various survey parameters. Most of the report can be used as a stand alone, general reference; parts are best used if the reader has access to the original maps and profiles (see Appendix II).

Appendix I contains a detailed list of ground follow-up targets based on a quantitative and somewhat subjective analysis of the geophysical profiles in association with all other reference material. To be used fully this section should be accompanied by geophysical profile data and/or EM anomaly and flight line maps.

Appendix II describes data items available for purchase or viewing, and how these can be accessed for preliminary study.

2. PROJECT HISTORY AND OBJECTIVES

Project AEM Greenland 1994 - 1998 is a five year airborne electromagnetic and magnetic surveying programme financed by the Greenland Home Rule Government in recognition of the important role of the mining industry in the future development of Greenland.

The principle objective is to stimulate mining exploration activity in Greenland over the short term. The secondary objective is to provide data which will have a lasting effect in the interpretation of the geology in selected parts of Greenland.

The main emphasis is on the acquisition of electromagnetic and magnetic data, but other types of geophysical data can be considered. Field work and subsequent basic compilation is performed by geophysical contractors.

The Geological Survey of Greenland (GGU) manages the project and supervises the collection and distribution of the data. Project leader is Leif Thorning, and Robert W. Stemp has been employed full time on the project since April 1994. A contact group with members from the Greenland Home Rule Government, the Mineral Resources Administration for Greenland (Ministry of Environment and Energy), and GGU supervises the project and makes final decisions concerning, e.g. choice of areas to survey.

During the autumn of 1993 input and suggestions to the programme were solicited from all holders of valid exploration or prospecting licences in Greenland. A list of possible targets was worked out by GGU, and the first priority was given to Inglefield Land, North-West Greenland. Based on this, the survey was designed to be flown in the summer of 1994. A public round of tenders was held in January-February 1994 and in April 1994 a contract was signed with Geoterrex Ltd, Ottawa, Canada.

The very successful survey was flown during July - August 1994 out of Thule Air Base. Final delivery of maps and digital data to GGU took place in December 1994.

In accordance with the objectives of the project, the digital data will be a part of GGU's geoscientific database and available for the public, and especially the mining exploration industry. After release of the data for the Inglefield Land survey on 1 February 1995, digital data, maps and processing report can be obtained at non-profit prices from GGU, see Appendix II.

In the following years the project will follow similar schedules. The target for the 1995 operation has been chosen: the 'Norite Belt', Maniitsoq, central West Greenland. Targets for the subsequent years will be analyzed during 1995.

3. GEOLOGY

A summary of the geology of Inglefield Land, as it was known before the start of this project, is given by Dawes (1988). Most of the information is based on coast-line mapping by boat (particularly in the south-west) and photogeological interpretation.

The area is underlain by an Early Proterozoic (and possibly Archaean) crystalline basement which traditionally has been subdivided into three main units:

- Etah group of metasedimentary supracrustal rocks
- Etah meta-igneous complex
- Variable gneisses

The basement is overlain by a succession of younger platform strata (Proterozoic to Cambrian age) in a number of coastal regions.

A recent photointerpretation by Bengaard (1994), carried out as a part of AEM Greenland 1994, suggests that the basement can be subdivided into two crystalline complex units, separated by an easterly trending, discontinuous belt of granitoids. Very few occurrences of metasedimentary rocks are reported in the northern complex. This study also indicates the presence of a swarm of volcanic pipes in central Inglefield Land.

Commercial exploration has so far been limited to a surficial check of some of the large, bright yellow gossans, which are very prevalent in the region (RTZ, 1991).

4. AIRBORNE SURVEY RESULTS

4.1 General

Preliminary interpretation of the airborne data was initiated in the field and continued throughout the course of the flight operations. This study was carried out primarily on the profile data, but preliminary total field and conductivity anomaly maps produced on-site at a scale of 1:50 000 were also used.

This field processing and interpretation stage was very important to the overall programme for a number of reasons:

- the limited time period to fly, compile, interpret and release the results for use during the 1995 field season by GGU and the mining industry.
- the wish to start an important running dialogue between Geoterrex and GGU personnel on all aspects of the survey while still in the field.
- the necessity to adjust survey boundaries during the field programme to provide

maximum benefit of the resources spent.

- the determination of which map compilation products would be most useful.

The survey area and the 1:50 000 map sheet index are shown in Fig. 2. These map sheets will be referred to by number throughout this report, but the maps themselves are not part of this report. The scale was chosen as the basic compilation scale for GGU, but it is envisaged that more detailed maps will be required over certain areas.

The following map products were delivered to GGU as part of the contract. For a full description of terms and concepts used, see Geoterrex (1994).

1:50 000 scale

- EM anomaly and flight line maps with full topographic base
- EM decay constant maps
- Broadband conductivity maps
- Total field magnetic anomaly maps
- Calculated vertical gradient anomaly maps

1:250 000 scale

- EM decay constant map
- Broadband conductivity map
- EM channel 2 amplitude map
- Total field magnetic anomaly map
- Calculated vertical gradient anomaly map

1:1 000 000 scale prints

- EM decay constant
- Broadband conductivity
- Total field magnetic anomaly map
- Calculated vertical gradient anomaly map

4.2 Aeromagnetic results

Since the high sensitivity magnetic data were acquired at a low survey altitude (75 m) and at a high sampling rate (10 samples/sec.), very detailed total field magnetic data are available along each survey line. The regular traverses are oriented north–south and spaced at 400 metre intervals with a set of orthogonal tie lines at 4 000 metre intervals.

The total dynamic range across the survey area is in the order of 4 000 nanoteslas (55 000-59 000 nT) which is moderate for a low altitude survey of this magnitude. There are no indications of any massive magnetite deposits. There are also no obvious indications of reversely magnetised features which are common in certain other areas of Greenland. This may be of interest when age relationships are analyzed.

The most striking feature in the profile data is the multitude of low amplitude, narrow features throughout most of the survey area, i.e. a fine magnetic fabric. Geologically, this reflects varying lithology (e.g. narrow banding, non-homogeneity) and multiple fracture patterns. These features have not yet been mapped out, but it is clear that the magnetic data can be used successfully to map geologic features with dimensions ranging from less than 100 metres up to 50 km or more.

The profile data, for the most part, is dominated by anomalies of short wave length, indicating that the Precambrian bedrock is at or near surface, even in areas covered by glacial outwash. There are, however, three main exceptions:

(1) Smoother (longer wave lengths) patterns are observed over the flat-laying sedimentary cap rocks. This shows that the sediments are non-magnetic, thus creating a greater distance between the magnetometer sensor and the magnetic sources at or near the buried Precambrian surface.

(2) The same effect can be seen where some survey lines traverse the ice cap in the southern part of the area.

(3) In a few other areas where the magnetic susceptibility is low and uniform, some apparently deeper features can be observed in the data. Fig. 3 (NE corner of map sheet 5) is an intriguing example of this. Note, e.g. the deeper looking, circular feature, bordered on the north and west by sharp, near surface magnetic features.

The magnetic data contain information relating to features at great depths, and various processing (filtering) routines can be carried out to enhance deeper regional features, if desired.

The magnetic profile data will be referred to extensively during the detailed analysis of GEOTEM anomalies for ground follow-up (Appendix I). Most other references will relate to contour maps. However, it should be emphasized that much of the finer magnetic information recorded is lost during the basic map compilation at a scale of 1:50 000. If any specific area is to be interpreted in detail, the profile data must be used, and maps should

Fig. 3. Near surface *vs* deep magnetic features.

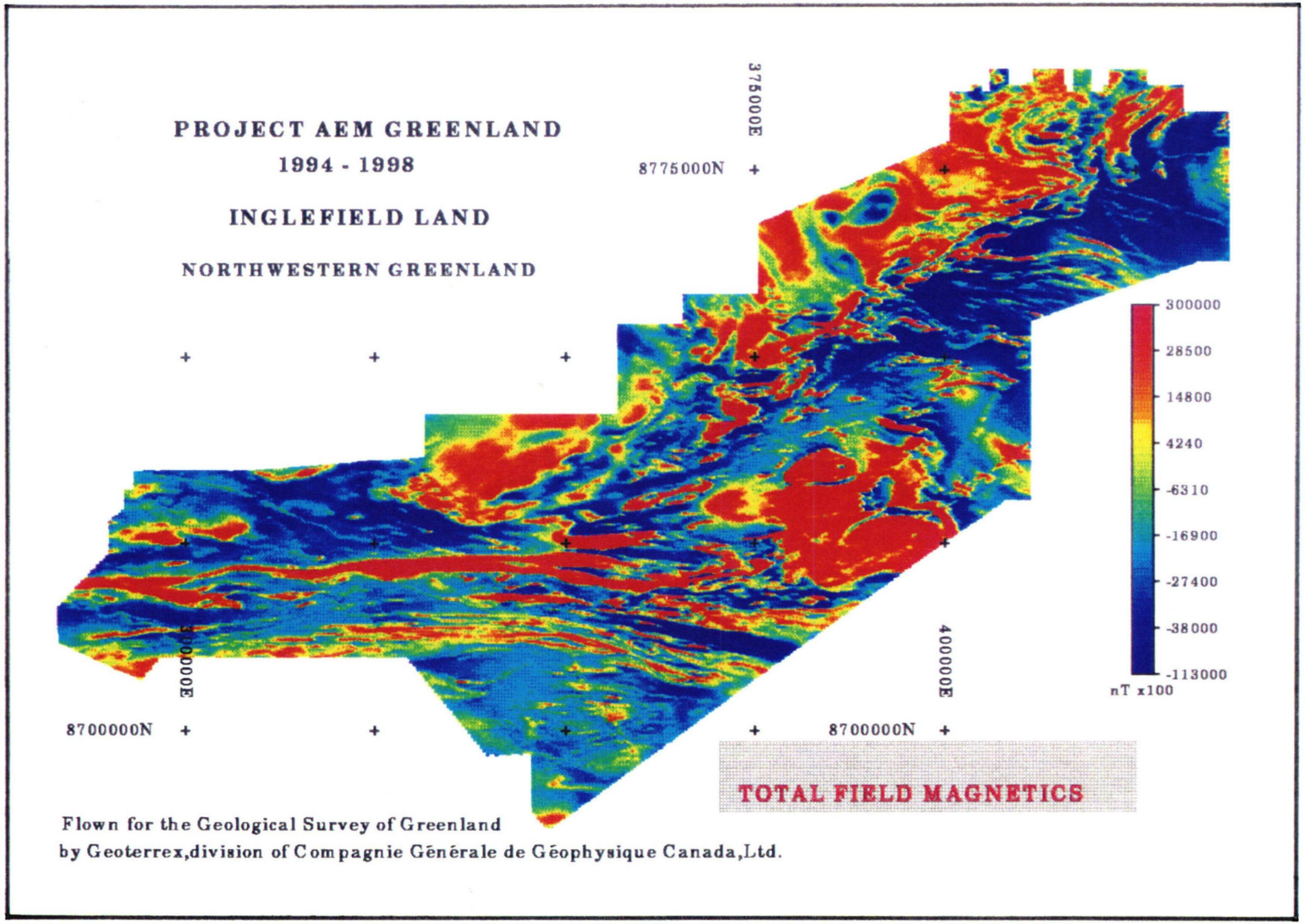

Fig. 4. Total field magnetics.

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be compiled at larger scales from the original digital data.

4.2.1 Total field magnetic anomaly maps

A number of major and distinct features stand out in the magnetic anomaly map data, even at a scale of 1:1 000 000 (Fig. 4). Some are discussed in the following under headings relating to their probable geological source.

East–west linear belt. The most dominant feature is the wide belt of variable magnetic intensity extending from the western survey boundary to the ice cap, clearly outlined by the abruptly varying magnetic intensity. This structure has been mapped for approximately 100 km and is still open at both ends. It correlates well to the mapped Etah group supracrustals. The magnetic data furthermore have the advantage of continuously mapping the lithological units, also in areas of extensive Quaternary cover, and thus provide a more complete picture than has hitherto been possible to obtain.

From a geophysical standpoint three distinct, generally conformable units can be identified within this east–west linear belt:

(1) Units of uniform, low magnetic intensity (blue colours).

(2) Units containing narrow, multiple bands of intermediate magnetic intensity (yellow and green colours).

(3) Units of higher magnetic intensity but quite uniform (red colours).

Group (1) seems to coincide with resistive marble-rich metasediments of the Etah group as delineated by the recent photogeological study (Bengaard, 1994). Group (2) is interpreted as a variable, banded gneiss unit, whereas group (3) appears to be a more basic, homogeneous unit with a distinct magnetic signature. Note that the term 'more basic' here is used relative to the other rock types.

Large basic unit. A large complex shaped, basic unit has been delineated north of the eastern end of the mapped linear belt (map sheet 5). This is a previously unknown unit, but it has since been partly verified by the photogeological study. It is an unusual feature because of its complex shape as revealed by the magnetic pattern, and it may actually be caused by more than one source. A more precise determination of this unit is not possible at the present time, but some questions need to be answered:

- is this an intrusive feature or a flat lying sill?

- is it caused by single or multiple sources?
- what is the relationship to linear basic units previously described?

Sedimentary cap rocks. As indicated previously, these sediments are not mapped directly, but indirectly are related to lower frequency magnetic profiles.

Strikes and folds. With the exception of the major east–west linear belt, linear trends elsewhere within the crystalline basement complex are highly variable.

The Wulff structure was previously known because of the excellent bedrock exposure along the north–east coast (Dawes, 1988). However, the magnetic data has outlined many other fold features of all scales. This is particularly evident in the region south of the linear belt, and in the region extending north–east from the centre of the survey block.

The north-south survey flight line direction was selected to accommodate the major east-west trends. This was a proper choice, but in a number of regions, particularly near the northern coast, flight lines tend to be almost parallel to some of the geological features. In these situations, the geophysical information is not diagnostic.

Dykes and lineaments. Dykes in Inglefield Land show up as long, narrow, positive magnetic features that cut across the older basement trends at various oblique angles. Magnetically, they are fairly weak, and thus are most easily traced in areas with rocks of low magnetic susceptibility. There is no evidence for major dyke swarms, but many (single) dykes can be recognized when the data are examined in detail. In fact, many of the lineaments and faults mapped in the photogeological study are actually dykes.

The longest dyke, that can be readily observed in the data, starts in the north–west corner of the survey area and strikes in an ESE direction. There are indications that this dyke continues across the entire survey area to the southern boundary. This seems to be one of the preferred dyke directions, but NW, NE and ENE strikes are also present. This dyke may cut through the sedimentary cap rocks, but in general the dykes appear to be confined to the older crystalline basement rocks. Fig. 5 (map sheet 8) is an example of some easterly trending dykes.

Some broader, dyke-like features of more limited strike length are also present. They could be referred to as thick dykes, but in some cases they may be small intrusives intermittently appearing along a structural trend (not to be confused with patterns, caused by dykes at a very oblique angle to the flight line).

Some of the strong bedrock conductors mapped by the electromagnetic survey (see

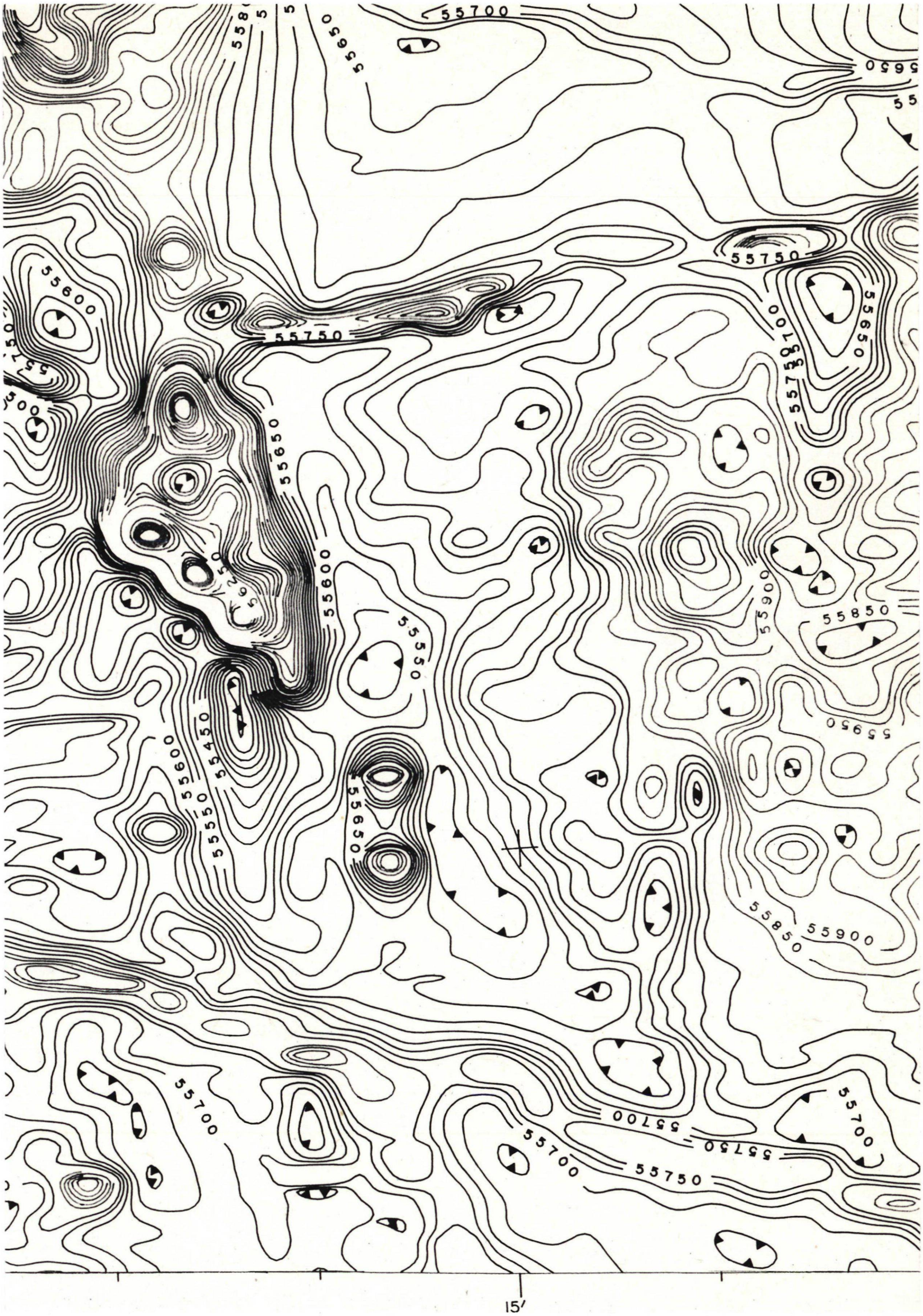

Fig. 5. Dyke patterns.

later) are also magnetic and display linear, dyke-like patterns on the contour maps. However, these are usually more conformable with the bedrock trends. Massive pyrrhotite is believed to be the source of the associated magnetic anomaly in most cases, but magnetite in combination with other massive sulphides or graphite would give the same geophysical expression.

In addition to the dykes, the crystalline rocks are cut by numerous linear fractures. These are well documented by the photogeological study, particularly in northern and eastern Inglefield Land, where the bedrock is well exposed. The faults that have been recognized will not be discussed further, but the magnetic data gives some hints of other possibly important major structural breaks not visible by photogeology.

Two other lineament directions emphasized by the magnetic data are ENE and WNW.

There seems to be a distinct difference in magnetic character north and south of a line extending from central Inglefield Land in a north–easterly direction south of the Wulff structure. This trend roughly parallels the coastline and could represent a major geologic structure, even though part of the visual pattern is due to the positioning of the cap rocks. However, it is strictly a hypothesis at this time and requires much further study.

4.2.2 Vertical magnetic gradient

A vertical gradient anomaly map (Fig. 6) has been produced from the total field data. Although this is a calculated (as opposed to measured) parameter, it is important in that it provides a view of the data from a different perspective.

The vertical gradient enhances near surface features with respect to deeper source rocks, and emphasizes vertical contacts. This simplifies the interpretation of total field data. In Fig. 6 note how the vertical gradient map tends to sharpen the anomalies related to most of the features described in the previous section. The contacts are much more clearly defined. There is also a much greater contrast with deeper geological features, such as under the younger cap rocks. At the same time this confirms that most bedrock features are at or near surface.

The large basic complex shows even more interior structure, and the strong, somewhat circular contacts are emphasized. Note that there is a similar, circular-type pattern directly north under the sedimentary strata.

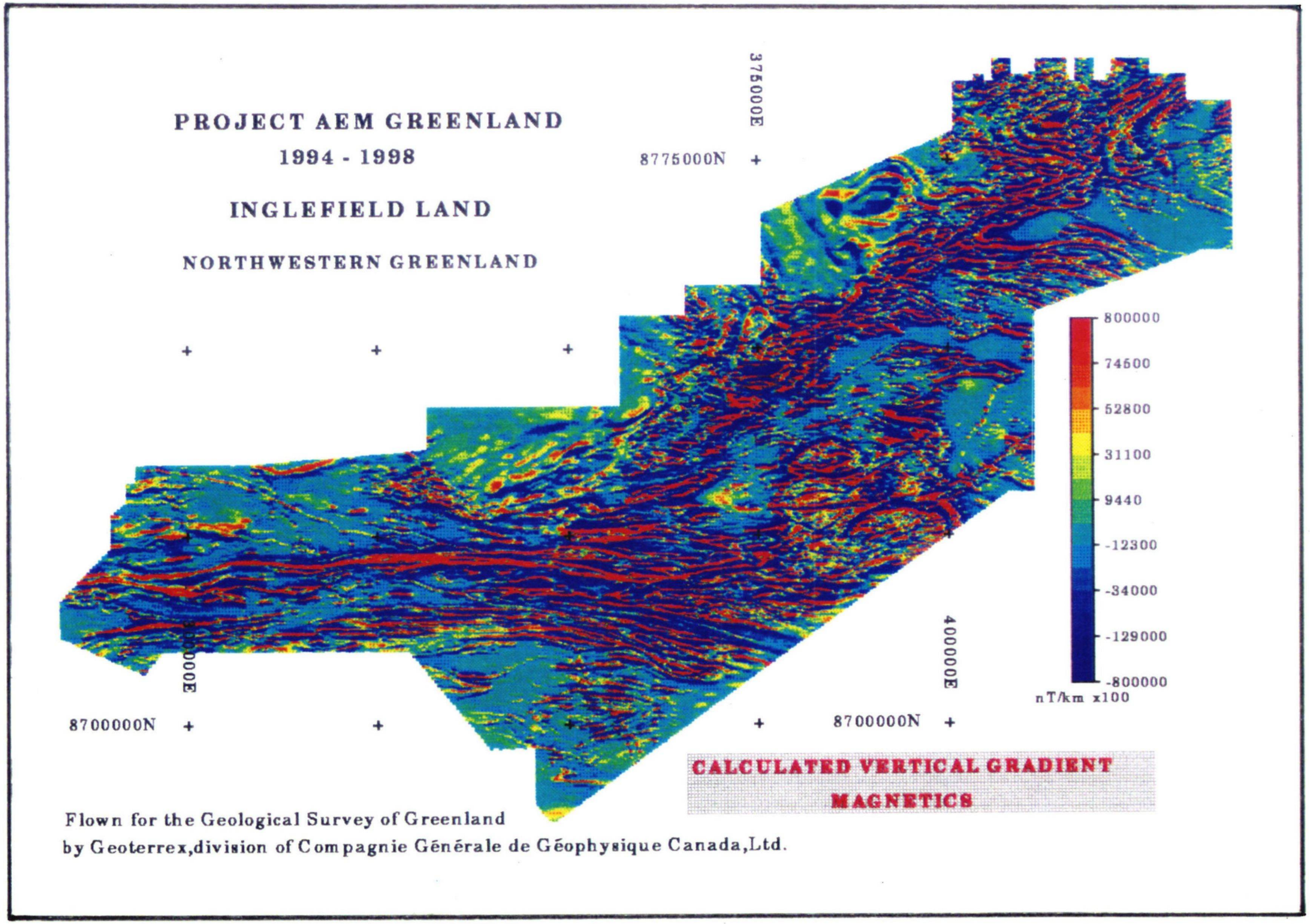

Fig. 6. Calculated vertical gradient magnetics.

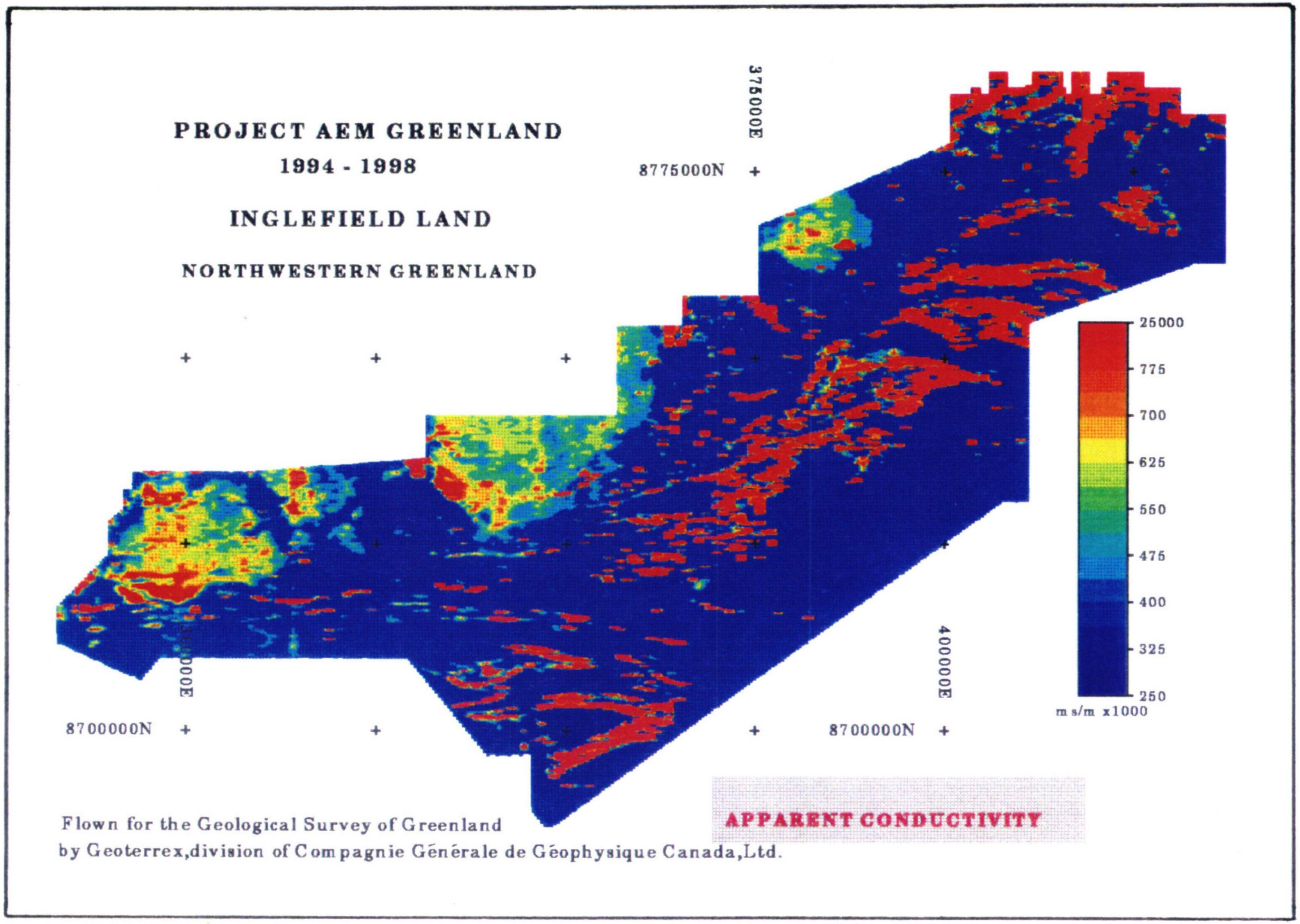

Fig. 7. Apparent conductivity.

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The gradient data emphasizes the sharp cut-off in near surface magnetic signatures seen in Fig. 3. This is an important geological change that will be referred to again in the following section of this report concerned with the EM results.

4.3 Electromagnetic (GEOTEM) results

Inglefield Land is very well suited for the application of EM prospecting techniques because of:

- flat topography.
- generally sunny, cool stable weather, no spherics.
- resistive Precambrian bedrock at or near surface.
- massive sulphide mineralization.
- no conductive overburden.
- little salt water penetration.

The EM survey was designed primarily to detect massive sulphide mineralizations, but new geological information has been obtained.

4.3.1 Apparent conductivity map

Airborne resistivity mapping is a geophysical mapping technique that has not yet reached its maximum potential. Fig. 7 has been produced by using all the channels of EM information (i.e. the full spectrum) and a standard homogeneous half-space model to calculate apparent conductivity values. Variation in these reflects the geological variations, and the resulting map is a totally independent view of the geology of Inglefield Land, based solely on rock conductivities. Together with the magnetic view and the photogeological view, a wealth of information is now available to assist in producing a true geological map. It only requires the next step of confirmation and correlation on the ground.

On a regional basis there are three distinct areas emphasized by the conductivity data:

(1) highly resistive bedrock areas (dark blue colour) which exhibit no EM response.

(2) areas of very weak conductivity (middle colour ranges) which correlate remarkably well with younger sedimentary rocks.

(3) the dark red areas which relate to the strong bedrock conductors as well as some salt water in the extreme north–east. These long multiple bedrock conductors emphasize geological trends and may indirectly map a specific host lithology.

4.3.2 Formational EM conductors

The term 'formational EM conductor' is here used to describe long, multiple, often discontinuous bedrock conductors which are conformable to the geology and may extend for many kilometres. The source of the high conductivity may be graphite, massive sulphides or a combination of the two.

A total of over 4 600 individual EM anomalies has been detected and plotted on the combined flight line/EM anomaly maps. This is an impressive number when it is considered that they are essentially all bedrock anomalies, since little conductive overburden is present, and obvious salt water anomalies have not been plotted. Also, the true number of anomalies is actually greater because a number of weak, early GEOTEM channel anomalies, many of which relate to conductors at greater depths, are not plotted.

These anomalies have been examined and correlated on a line to line basis. The vast majority of them can be grouped into multiple formational conductor zones (see Fig. 8 map sheet 7). There are so many formational conductors detected in Inglefield Land that they become an important mapping tool on both regional and detailed scales. For example:

- strike directions and fold patterns are indicated since these conductors are conformable with bedding planes (e.g. note 'Z' shaped pattern on Fig. 9 and map sheet 2).
- discontinuities or offsets in the conductor pattern can indicate faulting (although conductors may also pinch out)
- conductors often follow major geological contacts
- there is often an indirect association between the presence of formational conductors and a specific host lithology
- the converse also holds true, i.e. the lack of formational conductors in a region can indicate other lithologies

The location of the formational conductors within the survey area coincides very well with the areas of intermediate, but variable banded gneisses. Their presence, or lack

Fig. 8. Formational EM conductors.

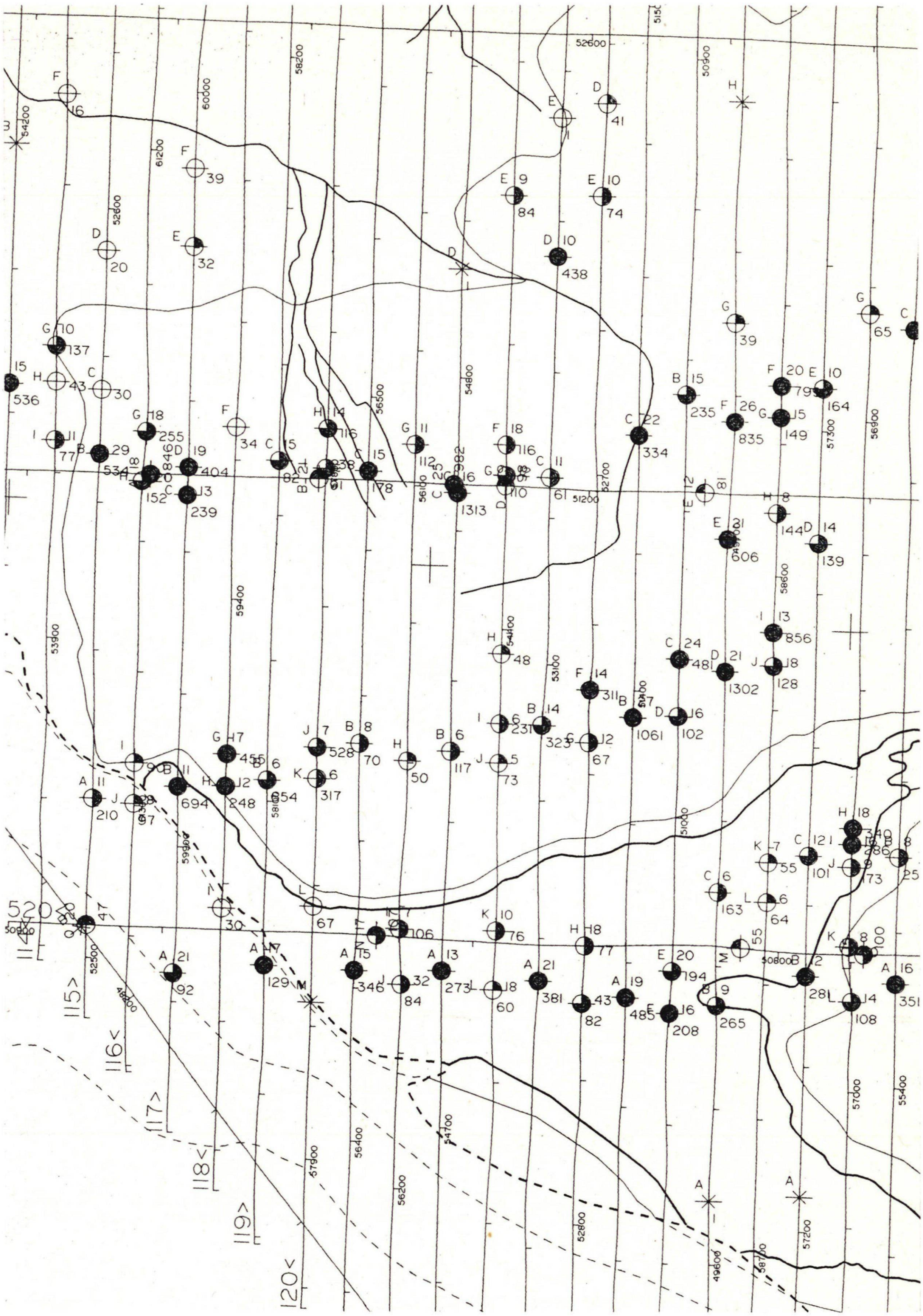

Fig. 9. "Z"-shaped conductor pattern.

thereof, may help differentiate between the gneisses. Other than near the contacts, the formational conductors are never associated with the most basic rocks, or the uniformly low magnetic intensity areas. This correlation with the magnetic data is very consistent and predictable throughout the survey.

In certain areas along the coast, conductors extend into the sea where they cannot be differentiated from the salt water.

Since the EM technique is much more limited in terms of penetration than magnetics, information is lacking in certain areas of thick cap rock and ice cover. Approximately 200 metres of ice thickness seems to be the detection limit, although this has not been analyzed in detail.

It should also be noted that no formational conductors were mapped within sedimentary cap rocks.

From an economic standpoint, formational conductors are usually considered lower priority targets than more localized EM anomalies. However, this is partly due to the fact that graphitic horizons are commonly the source, and secondly the practical difficulty of deciding where to examine these long multiple conductors on the ground.

The airborne survey has established that there is a definite relationship between the widespread and highly visible gossans in Inglefield Land (Fig. 1) and the formational GEOTEM conductors. This was established during the survey flights and also by later examination of colour video tapes. The gossan check carried out by RTZ in 1991 concludes "Without exception, all the gossans checked occur in garnet gneiss country rocks, ...". All these gossans are exclusively or largely the result of weathering of disseminated to locally massive pyrrhotite". Unfortunately, no economic sulphides were found during this limited search.

The new proven relationship between the gossans, gneisses, EM conductors, and sulphide mineralization localities suggests that massive sulphides are widespread in Inglefield Land and that the gossans may actually be a distraction. Although the gossans by no means have been <u>proven</u> to be economically uninteresting, there is certainly good reasons to suggest that the highest priority as targets for ground follow-up should be given to the more localized, shorter conductors, of which there are many.

4.3.3 Localized EM conductors

The GEOTEM profiles have been examined in considerable detail and many short, localized conductors have been detected in a wide variety of magnetic and geological settings. No further discussion of these are given here, but a selection of them are listed in detail in Appendix I which provides information on specific ground follow-up targets, identified by project AEM Greenland 1994.

4.3.4 Negative EM responses

During the course of the survey, large areas of negative EM response in the early off-time GEOTEM channels were detected. These areas are shown in Fig. 10 (GEOTEM decay constant map) in dark blue and correspond with certain cap rock areas. This phenomena has not been studied in any detail and at this time is considered to be of more academic interest. Further information on this subject, which may have to do with an as yet unexplained induced polarization effect, can be found in Geoterrex (1994).

4.4 Colour video

One of the ancillary products derived from the airborne survey is a complete set of colour video tapes. Video cameras are used in aerial surveying for visual flight path recovery, but are becoming obsolete with the progress in GPS navigation and flight path recovery techniques. In Inglefield Land, the colour video is an added geological mapping tool because of the large percentage of bedrock exposure.

This video information could have many other useful applications in the future, such as logistical planning for field parties, vegetation and glaciological studies.

Sample prints taken from the video are shown in Figs. 1 and 11.

5. NOTES ON THE PHOTOGEOLOGY STUDY

Since so little geological information was available on the project area, a photogeological study (Bengaard, 1994) was commissioned and financed as part of project

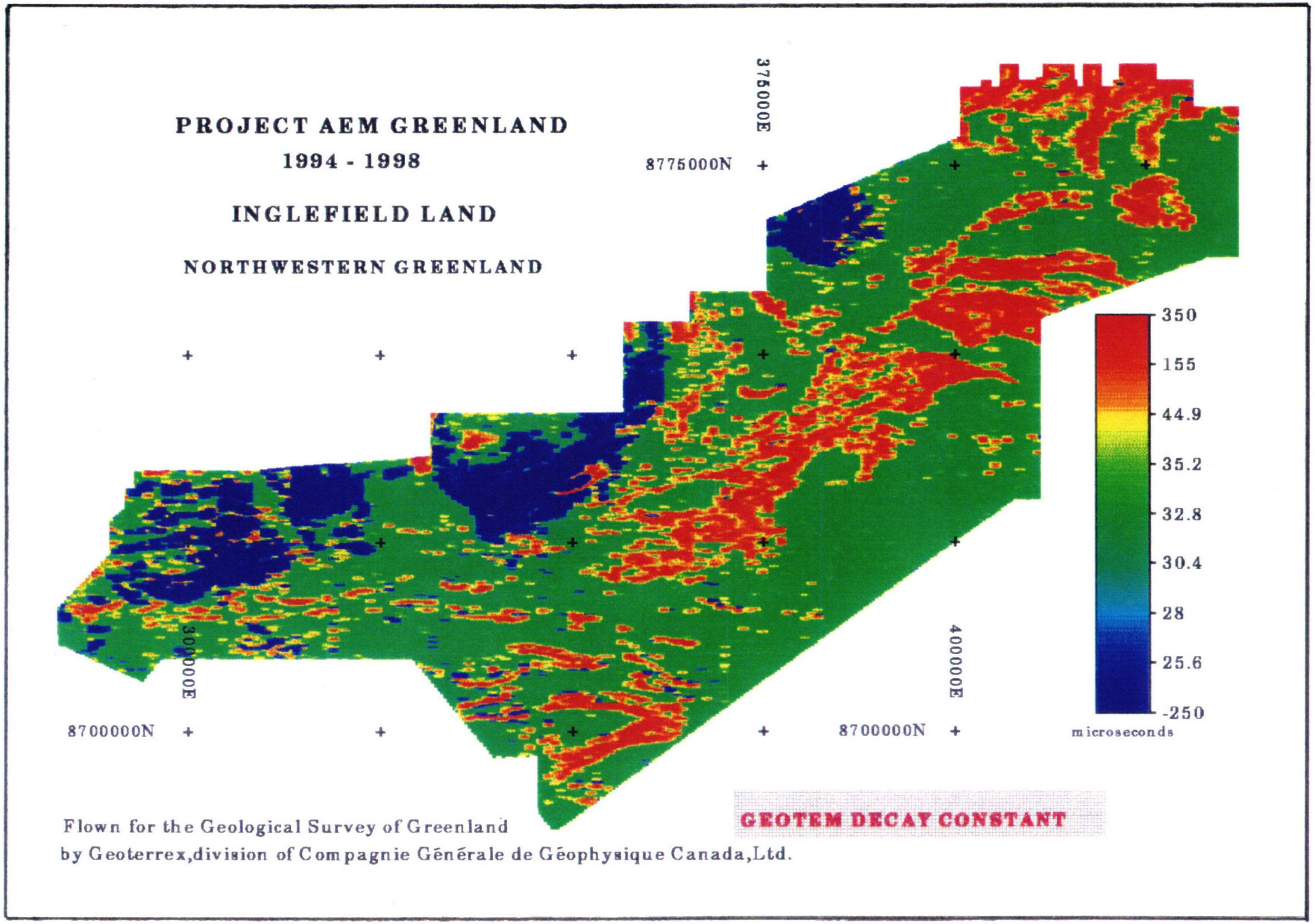

Fig. 10. GEOTEM decay constant.

Fig. 11. Dark circular pipe? recorded by video camera. Width of scene about 240 m.

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AEM Greenland 1994. Although it was intended to be an independent study, two specific directives were given:

(1) concentrate on the crystalline basement rocks which are of greatest interest with respect to the EM results.

(2) look for small circular structures because of the number of weak, single-line magnetic features observed in the data.

This current study greatly enhanced the geological knowledge of the area, particularly from a structural standpoint. It also resulted in the discovery of a major "pipe swarm" in central Inglefield Land which was later verified on the colour video.

Since this study was not completed until January 1995, detailed comparisons with the airborne geophysical data have yet to be carried out.

6. CONCLUSIONS

The AEM Greenland 1994 project has confirmed that Inglefield Land is well suited to the application of airborne electromagnetic and magnetic techniques. As a result the primary goal of the AEM project has been realized - to stimulate exploration by geophysically identifying and mapping a wide variety of anomalous mineral exploration prospects. The geophysical prospects are exciting, but also overwhelming, and will require a dedicated ground follow-up programme, including constant re-assessment of the data, for maximum success.

A second, somewhat unexpected, result of the project is the important discovery of a swarm of pipes in central Inglefield Land.

One of the major results of the survey is the addition to GGU geological data base. This will provide a detailed foundation for all future mapping in the region, and hopefully stimulate and encourage the development of new geological concepts.

7. ACKNOWLEDGEMENTS

Geoterrex staff are thanked for their total dedication to the project and for carrying out the airborne contract in a professional and timely manner. The local support, provided by Erik Thomsen and his staff at the Danish Liaison Office in Thule, is acknowledged.

Thanks also to the authorities and personnel of USAF/TAB for their full co-operation.

Project AEM Greenland 1994–1998 is financed by the Greenland Home Rule Government.

8. REFERENCE

Bengaard, H.-J. 1994: Photointerpretation of Inglefield Land, northwest Greenland. Unpublished report and manuscript maps. GGU map archive.

Dawes, P. R. 1988: Etah meta-igneous complex and the Wulff structure: Proterozoic magmatism and deformation in Inglefield Land, North–West Greenland. *Rapp. Grønlands geol. Unders.* **139,** 24 pp.

Geoterrex 1994: Logistic to processing report of an airborne GEOTEM electromagnetic at magnetic survey over Inglefield Land, Greenland. Unpublished report. Geoterrex, Canada.

Sharp, G. 1991: Gossan search on Inglefield Land, northwest Greenland. RTZ Mining and Exploration Limited. Unpublished company report. [GGU Greenmin database no 1084].

APPENDIX I - Suggested Ground Follow-up Targets

Appendix I is intended for readers with a direct interest in mineral exploration in Inglefield Land. It is a detailed tabulation of mineral exploration targets, based primarily on a quantitative study of the GEOTEM and magnetic results, supported by geological references and past experience with similar airborne surveys worldwide (particularly Canada).

Since Inglefield Land is essentially unexplored, i.e. there are no drill holes and no economic mineralization has been reported, a wide variety of prospects are listed, selected on geophysical, geological, and geographical criterias. However, these targets should be continually re-assessed, as ground information becomes available. Saturation prospecting requires that the source of every possible bedrock EM conductor, regardless of conductivity, magnetic association, geological setting etc., be determined. However, economic considerations usually dictate that some follow-up priority plan be initiated, particularly in remote, unexplored areas such as Inglefield Land.

It should be stressed that this list is subjective, since there is no absolute way of distinguishing between massive sulphides and graphite or ascertaining the type of sulphides present. For ease of reference, priority targets are listed on an individual map sheet basis. Individual anomalies are listed by flight line, anomaly letter and fiducial number in brackets. If EM anomaly or flight line maps are available to the reader, locations can be identified using the line number and anomaly letter. If digital data are being used, the flight line number and fiducial number are required.

MAP SHEET 1

(1) 410 A (54267)	•	appears to be a short conductor, but may be structurally related to long EM conductor to north
(2) 29 B (49729)	•	associated with magnetic "nose"
(3) 51 C (50700)	•	narrow, weak EM anomaly with sharp magnetic feature

MAP SHEET 2

(4) 73 A (51435)
- an excellent geophysical prospect
- high conductivity
- localized
- 20 nT coincident magnetic anomaly

(5) 125 D (53155)
- broad EM response
- structural setting uncertain

(6) 136 I (53456)
(7) 142 K (50292)
(8) 144 J (48250)
- the area containing prospects 6, 7 and 8 should be examined in detail, as the geology is complex with local intrusions
- geophysical signatures are excellent, but line to line correlation is difficult

(9) 157 H (49171)
- very weak, local GEOTEM response

MAP SHEET 3

(10) 418 C (57081)
- strong EM with coincident magnetic anomaly
- open to the west since on survey boundary

(11) 62 B (57459)
- adjacent to north–west trending fault?

(12) 62 D (57553)
- sharp, local EM and magnetic anomaly

(13) 71 E (52656)
- weak, local EM on magnetic/geological contact

MAP SHEET 4

(14) 86 B (48221)
- short conductor within(?) basic rock unit

(15) 117 J (60243)
- a very sharp, single-line EM response associated with a weak magnetic feature

(16) 138 C (51360)
- double peak, low amplitude EM

(17) 152 E (54156)
- narrow, isolated EM anomaly possibly hosted by carbonate rocks

(18) 156 F (50270)
- similar EM response to (17), but hosted by basic rocks

(19) 163 L (59796) • weak, local EM
• probable carbonate host

(20) 157 Q (49499) • localized 12-channel GEOTEM response within high magnetic unit (basic rocks)

(21) 170 E (52743) • similar to (20), but may be related to conductor to east

The "pipe swarm" referred to in the main body of the report, extends onto this map sheet in a WNW direction, centred on the intersection of traverse 175 and tie line 511.

MAP SHEET 5

The majority of the observed pipes are located in the north–west quarter of this map sheet (see photogeology reference for exact locations). At this stage of exploration, until the pipes and their mineralogy have been confirmed, they must be considered potential kimberlite targets.

(22) 209 U (52514) • part of a long, arcuate conductive zone
• very high EM anomaly amplitudes
• associated 500 nT magnetic feature

(23) 214 B (47387) • single line EM and magnetic anomaly, just south of (22)

(24) 529 F (53368) • on geological contact
• see sharp magnetic low

(25) 216 E (58822) • a massive EM anomaly with coincident magnetics > 1000 nT
• part of a larger SW trend

(26) 214 D (47443) • single line EM and positive magnetic anomaly

(27) 217 P (57826) • similar to (26)

(28) 196 H (53843) • a local EM feature associated with a larger magnetic unit

(29) 199 O (51191) • excellent geophysical target

(30) 201 N (49073) • sharp one-line EM feature on geological contact

(31) 199 N (51074) • narrow EM anomaly that coincides with a "pipe"

(32) 222 L (52469) • part of a very high amplitude NE trending conductor
• the associated magnetic feature is believed to be caused by mineralization

(33) 205 H (56142) • very strong, multiple EM anomaly in a region that exhibits

both near surface and deep magnetic signatures together with visible pipe structures
- geology?

(34) 208 J (53319)
- the strongest individual GEOTEM response in the survey area, but within a wide zone of conductors, see Fig. 12
- same geology ? as (33)
- this area needs to be better understood structurally

(35) 192 S (58335)
- weak EM associated with the strongest magnetic feature mapped in the survey area

(36) 181 K (48700)
- a strong EM response in a localized geological setting
- one of the highest priority targets

(37) 516 A (55463)
- isolated EM anomaly associated with magnetic low
- confirmed on both a tie line and regular flight line

(38) 229 C (58178)
- similar to (37), but a very weak anomaly

(39) 225 B (48881)
- minor EM indication related to a single line magnetic high > 3000 nT

(40) 247 A (46788)
- part of a long conductor that wraps around the contact of the mapped basic intrusion?

(41) 263 A (46230)
- EM conductor on N-flank of a magnetically mapped basic rock unit

(42) 286 R (57999)
- strong EM anomaly coincident with a very sharp magnetic anomaly
- an excellent prospect

MAP SHEET 6

This map sheet covers the eastern extension of a large area on map sheet 5, containing few EM anomalies and especially no long, formational-type conductors. A significant change in lithology is inferred.

All of the anomalies plotted are considered to be massive sulphide prospects.

(43) 293 B (49624)
- high conductivity
- situated east of a NE–trending dyke feature
- minor magnetic association

(44) 293 A (49546)
- weaker conductivity

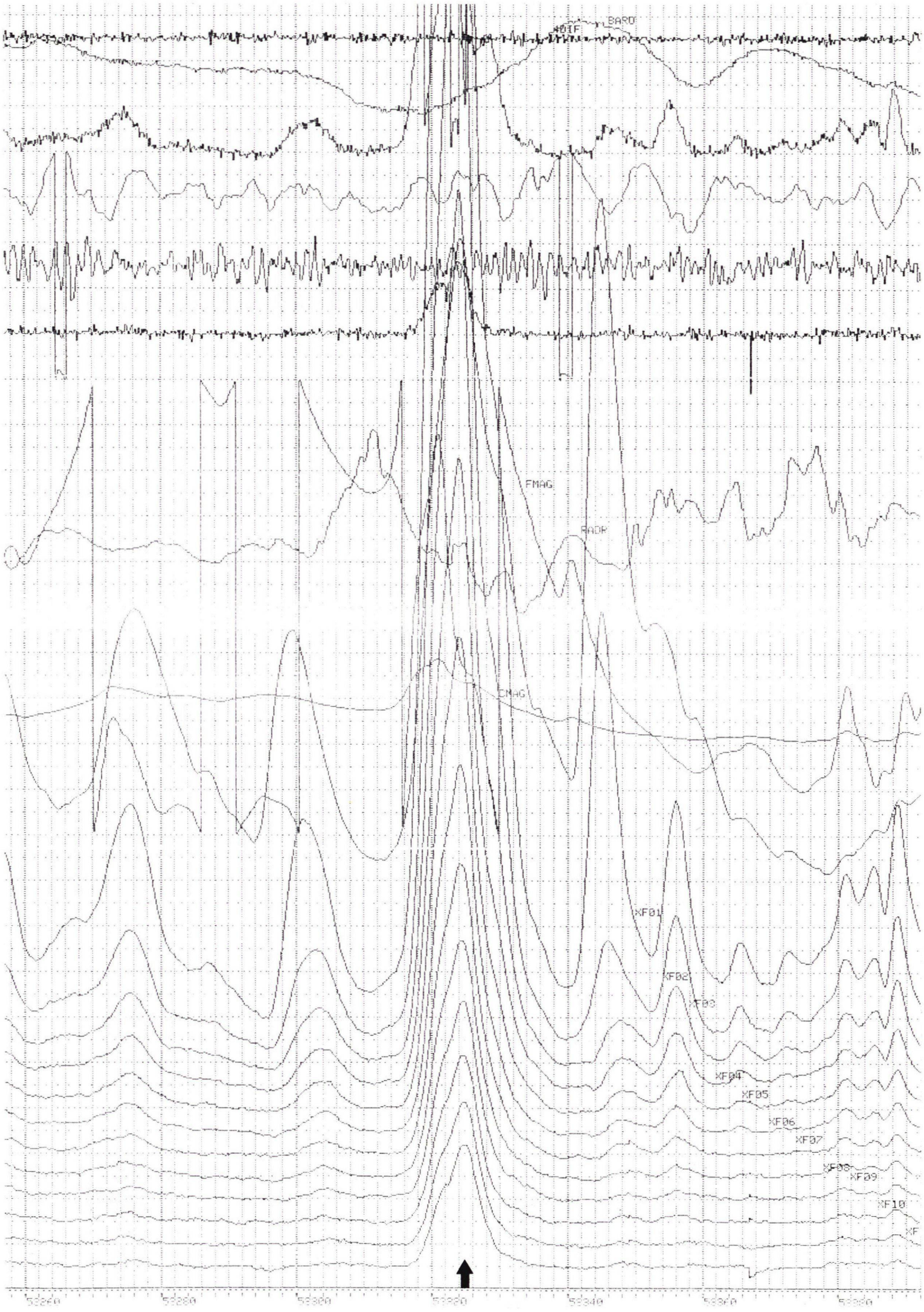

Fig. 12. Prospect No. 34.

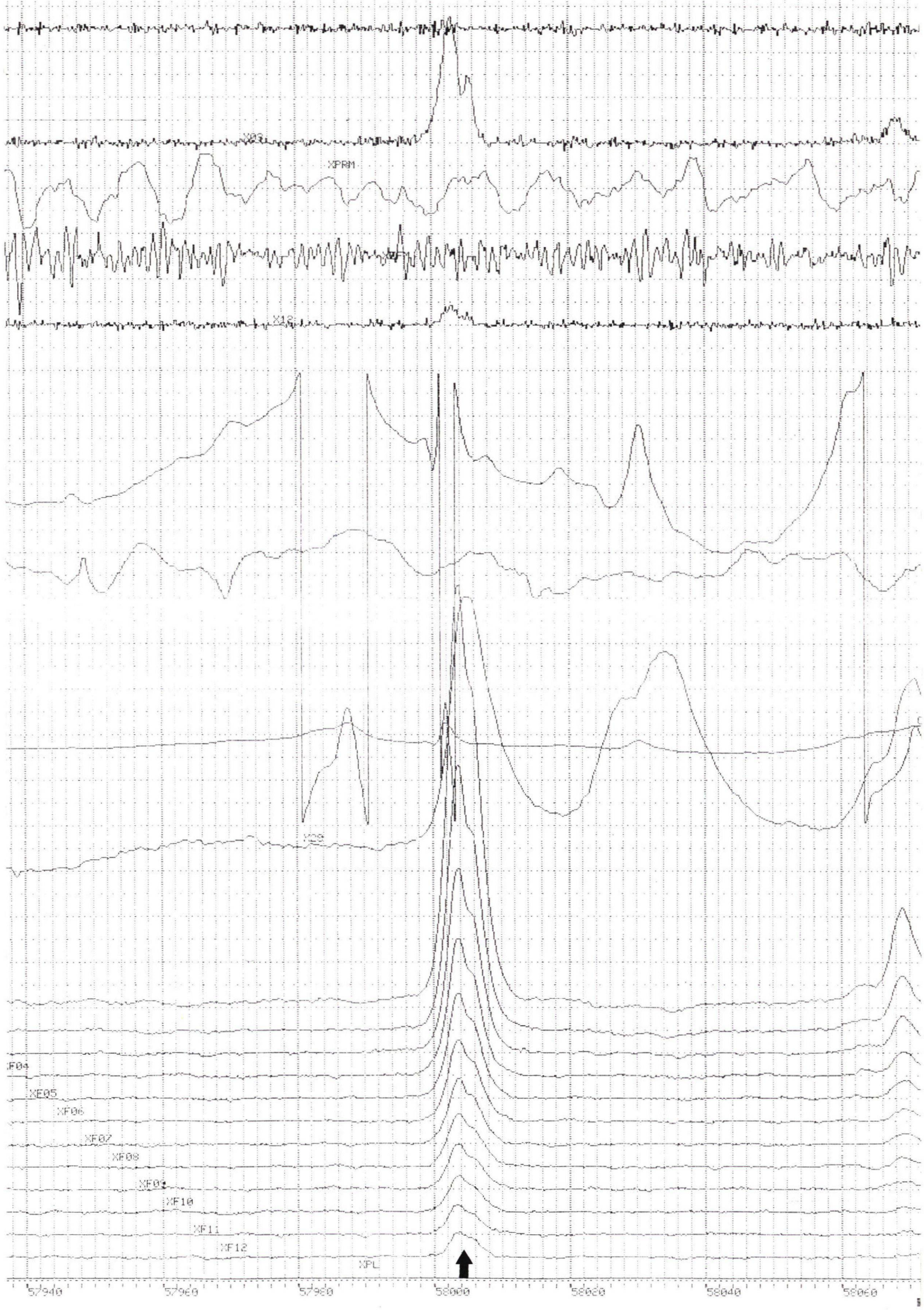

Fig. 13. Prospect No. 42.

	• a deeper magnetic feature indicated
(45) 298 P (56379)	• part of a cluster of low amplitude EM anomalies associated with NW–trending magnetic features
(46) 290 P (54002)	• strong local EM anomaly with minor magnetic feature
	• near intersection of NE dyke and cross cutting NW fault
(47) 287 A (56328)	• sharp EM feature associated with a broader, multi-source ? magnetic unit

MAP SHEET 7

(48) 203 V (58499)	• weak EM
	• single line, extremely sharp (narrow) magnetic anomaly (350 nT)
(49) 198 A (51617)	• strong GEOTEM feature associated with N-W trending magnetic body
(50) 205 U (56535)	• appears isolated, but probably related to a N-S structure parallel to the flight lines
(51) 263 Q (46577)	• based on magnetic patterns it seems to be a separate, short conductor
(52) 271 N (52762)	• high conductivity anomaly
	• may be separate from the long, formational conductors
(53) 271 M (52736)	• very strong EM
	• related to a local magnetic high
(54) 281 J (52524)	• situated on magnetic contact
	• may be related to EM anomalies to east
	• excellent GEOTEM response
(55) 259 M (48049)	• single line EM response
	• in the sedimentary cap rock area, but associated with a river valley which could expose basement rocks
(56) 292 E (51174)	• strongest of a scattered group of EM anomalies near west nose of Wulff structure
(57) 294 D (48510)	• broader EM along fold structure
	• possibly related to (56)

(58) 295 P (48190)
- near coast (does not appear to be salt water)
- part of high amplitude, NE–trending conductor

MAP SHEET 8

(59) 306 C (49042)
- salt water contamination a possibility since EM response is so strong

(60) 299 R (55458)
- sharp, single-line EM response

(61) 307 K (48754)
- sharp, single-line EM associated with a magnetic low

(62) 311 I (58212)
- similar, but broader than (61)

(63) 501 J (54778)
- a longer conductor of moderate conductivity

Please note that prospects (60)-(63) are all within the Wulff fold structure.

(64) 297 T (57357)
- another short isolated massive sulphide prospect

(65) 307 I (48650)
- sharp, low amplitude EM conductor on south flank of fold structure
- may be related to (66)

(66) 311 H (58086)
- strong EM zone, not magnetic

(67) 319 P (53262)
- strong EM conductor near northern coast
- no indication of salt water

(68) 336 A (54335)
- part of major NE–trending massive EM conductor

(69) 337 I (53988)
- on contact of basic rock unit
- weaker EM anomalies along strike to NE

(70) 328 C (59330)
- a short, moderate conductivity feature

(71) 340 E (51936)
- appears isolated, but may be part of a folded, formational conductor

(72) 347 E (48122)
- low amplitude massive sulphide prospect on local intrusive contact

(73) 367 A (49382)
- strongest portion of a conductor which extends easterly from a fault to the edge of the survey block

(74) 299 N (55222)
- sharp, isolated EM anomaly on major geological contact
- possible intersecting fault structure

(75) 297 L (57101)
- very sharp EM anomaly
- also on tie line
- relationship to nearly conductors uncertain

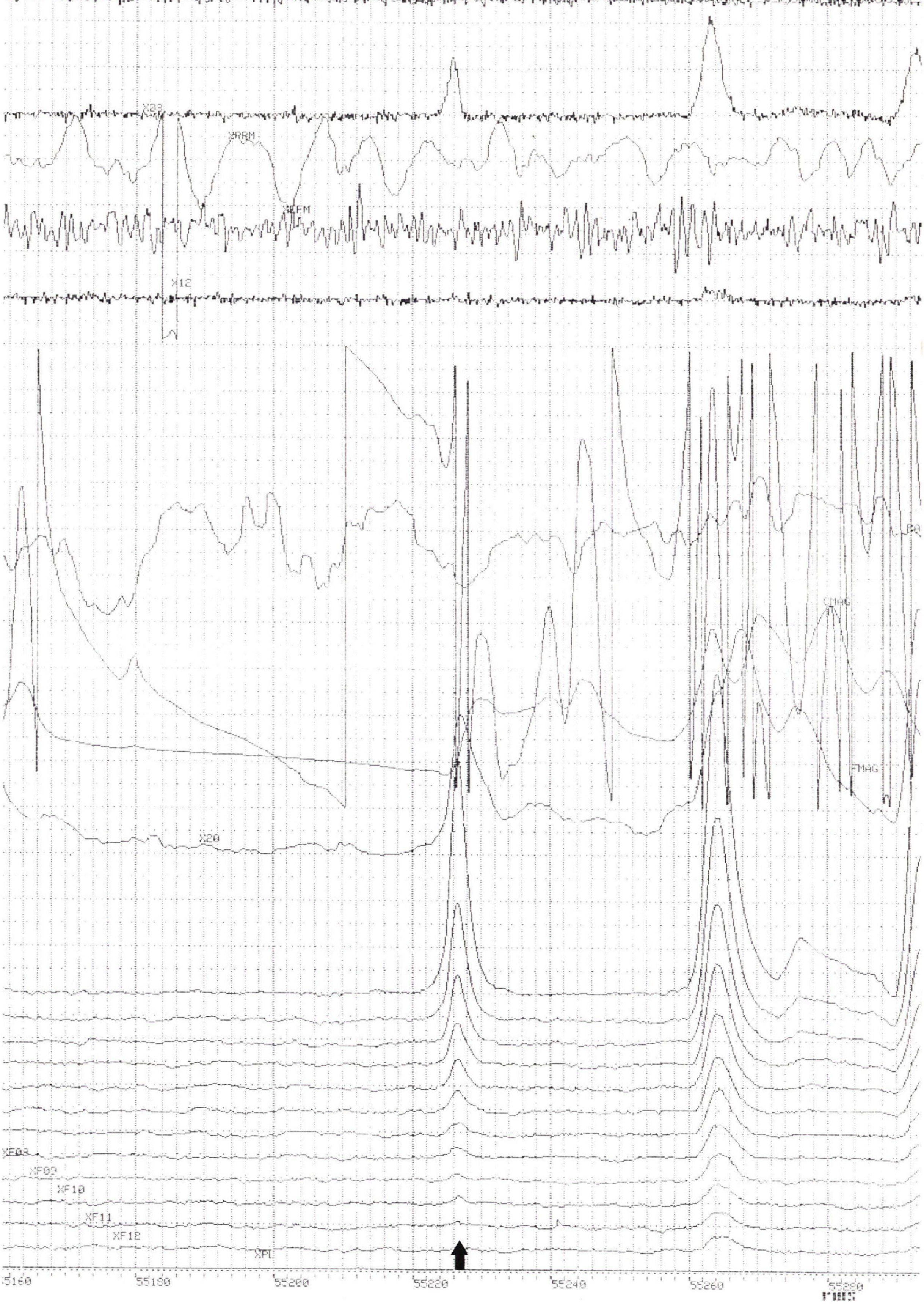

Fig. 14. Prospect No. 74.

APPENDIX II - Data available for purchase

In accordance with the objectives of project AEM Greenland 1994 - 1998, GGU wishes to encourage, e.g. the mining exploration industry, to exploit the new data as much as possible. GGU will also use the data extensively in several research programmes.

A package of digital data is available for purchase at a price of 18 000 Danish kroner (excl sales tax), which is reasonable compared with a total value of over 5 million Danish kroner for the survey. The data can be used freely by the purchaser, but cannot be resold or given to third parties. The package contains:

- the Geoterrex (1994) report
- original digital data and grid files on CD-ROM

Orders must be addressed to GGU, and GGU will invoice the customer. However, to save time delivery will be direct from Geoterrex Ltd.

The maps, the original analogue profiles and the flight path video can be inspected at GGU. Please contact GGU if you would like to enquire about this. Purchase of maps can be arranged on an *ad hoc* basis at cost of reproduction. Again, please contact GGU for details.

APPENDIX III - Logistics near Inglefield Land

Inglefield Land is a fairly remote part of Greenland. However, access is not as difficult as one could expect. This appendix contains a few hints that may be useful.

The best entrance to the region is probably via Thule Airbase (TAB) which is operated by the US Air Force. Because it is an American military base, there are operational restrictions which do not apply to the rest of Greenland. Permits to operate out of Thule Airbase, together with permission to land, purchase fuel and supplies, lodgings, etc. must be arranged and cleared beforehand with the US Air Force. There are weekly scheduled flights into Thule Airbase from West Greenland and Denmark. Transit through Thule Airbase is subject to certain conditions.

The largest community close to Inglefield Land is the town of Qaanaaq [local government office, telephone +299 5 00 77, fax +299 5 00 73; suggest contact Mr Bo Nørreslet]. There are other smaller settlements in the area. These are best reached by helicopter. A Greenlandair Bell 212 helicopter is usually stationed at Thule Airbase.

Qaanaaq has world-wide telephone and fax connections. There is at least one telephone in each settlement. Local banking facilities are limited and there are limitations on how much money (Danish kroner) can be drawn locally. There is no local exchange of foreign currencies.

There is one hotel in Qaanaaq (Hotel Qaanaaq, fax +299 5 00 64); other accommodation may occasionally be arranged. A number of tourist services are available. A geophysical observatory is situated in Qaanaaq (northern lights, geomagnetic). A simple landing strip for STOL aircraft in Qaanaaq may also be useful for some operations.

There is no habitation in Inglefield Land itself. The western coast may sometimes be reached by boat, but it must be considered uncertain due to local sea ice conditions. GGU expects to operate in the area during the summer 1995, subject to allocation of funds, and will look out for natural landing strips and good sites for base camp operations.

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