



PROCESSING  
OF NGU AIRBORNE GEOPHYSICAL DATA

For

PROSPEKTERING A/S

Digheem Limited

March 28, 1983

## SUMMARY

NGU survey data were processed by Dighem Limited to yield:

1. Resistivity contour maps for 3330 km of survey.
2. EM anomaly maps for 3330 km of survey.
3. Enhanced magnetic contour maps for 4330 km of survey.

The electromagnetic data were used to produce resistivity contour maps. This involved a considerable amount of releveling to yield maps of acceptable quality. The resistivity maps are useful as an aid to geologic mapping. They also help in the evaluation of the probable cause of EM anomalies.

The NGU EM data were characterized by high drift, high noise, and phasing errors. EM anomalies were identified using a novel digital filtering and correlation technique. The technique categorized EM responses on the basis of the probability that they reflect bedrock sources.

Some of the NGU magnetic data were digitally filtered to produce enhanced magnetic maps. These maps contain a large amount of detail which should be of use in Prospekting's exploration program.

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## INTRODUCTION

The Norwegian Geological Survey (NGU) flew geophysical surveys for A/S Sydvaranger Iron Ore Company (now Prospektering), using the Sander helicopter EM system and a proton magnetometer. The NGU displayed the EM and magnetic data as stacked profiles on maps, and also prepared total field magnetic contour maps with a contour interval of 100 nT.

Prospektering requested that Dighem reprocess the EM and magnetic data. This report, and attached maps, summarize the results of this work. The maps suggest that flight path recovery errors occur in a few places. These generally are not serious. A correction of the flight path did not form part of this work.

## ELECTROMAGNETICS

### Preprocessing Procedures

A magnetic tape was obtained from Prospektering containing the airborne geophysical and flight path information. Certain initial calibrations and other preprocessing procedures were employed, as follows:

- \* The EM values were calibrated by setting 30 mv = 1 ppm.
- \* The EM and altimeter data were lagged by two seconds, or approximately 60 m.
- \* The magnetic data were lagged by 1 second, or approximately 30 m.

The lags were determined statistically. Those lags were selected which best eliminated herringbone in the geophysical patterns.

The calibrated data were interpolated at 12.5 metre intervals, and the main processing then proceeded.

#### Resistivity Mapping

NGU electromagnetic survey data totalling 3330 km were used to produce Dighe-style resistivity maps according to the buried (or pseudo-layer) half space model<sup>1</sup>. This required extensive manual releveling of the EM data. As many as nine segments along a line were individually levelled. In addition, three computer processing runs were required, with iterative releveling, to eliminate herringbone due to levelling problems. The procedure was tedious and time consuming, but yielded resistivity

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<sup>1</sup> Fraser, D.C., 1978, *Geophysics*, v. 43, p. 144-172.

contour maps of fairly acceptable quality. The advantage of the resistivity parameter is that it is independent of altitude changes. The resistivity analysis also helps the interpreter to differentiate between conductive trends in the bedrock and those patterns typical of conductive overburden. For example, discrete conductors will generally appear as narrow lows on the contour map and broad conductors (e.g., overburden) will appear as wide lows.

The resistivity map often yields more useful information on conductivity distributions than the EM map. In comparing the EM and resistivity maps, keep in mind the following:

- (a) The resistivity map portrays the absolute value of the earth's resistivity.
- (b) The EM map portrays anomalies in the earth's resistivity. An anomaly by definition is a change from the norm and so the EM map displays anomalies, (i) over narrow, conductive bodies and (ii) over the boundary zone between two wide formations of differing conductivity.

The resistivity map might be likened to a total field map and the EM map to a horizontal gradient in the

direction of flight<sup>2</sup>. Because gradient maps are usually more sensitive than total field maps, the EM map therefore is to be preferred in resistive areas. However, in conductive areas, the absolute character of the resistivity map usually causes it to be more useful than the EM map. In all cases, the resistivity map is more useful for geologic mapping.

A problem exists with the resistivity maps which were produced from the NGU data. Phasing errors exist in the data, with errors occasionally being as large as 30 degrees. This has the effect of yielding significant errors in the absolute value of the resistivity. However, the resistivity patterns are affected only a little because of the highly resistive background. Efforts were made to correct the data by phase rotation. However, the phase error was quite variable, making it impractical to produce rotational corrections. Fortunately, the anomaly recognition procedure, described below, is virtually immune to phasing errors.

#### EM Anomaly Recognition

The NGU helicopter-borne EM data contain a high level of noise as well as fairly rapid non-linear drift. The

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<sup>2</sup> The gradient analogy is only valid with regard to the identification of anomalous locations.

data also contain obvious EM anomalies with responses many times larger than the noise level. Therefore, it can be reasonably assumed that smaller anomalies exist in the data and are masked by noise and/or drift. Dighem has developed techniques for the identification of such anomalies for Prospekting's NGU survey data.

The extraction of anomalies which exist within the noise level was accomplished by a digital filtering and correlation technique. Digital filtering works well if there is minimal spectral overlap between anomalies and noise. However, the NGU data contains severe spectral overlap, so special techniques were employed to render the digital processing useful. The method yields "anomalies" which are calibrated crudely in terms of the probability that they reflect bedrock conductors.

The categorization of anomalies by probability is unusual. By itself, there is a large chance of judgmental error. This is obvious since a decision might be made to follow up a 70% anomaly when, by definition, there is a 30% chance that it is noise.

A means of improving the decisions regarding the selection of anomalies for follow-up exploration is provided by plotting them on resistivity base maps. These base maps contribute to the evaluation of EM anomaly patterns.

The EM anomaly recognition procedure used the relevelled EM data. The data were passed through a digital filter to yield inphase and quadrature filter functions. These functions are shown as channels 42 and 43 on the plotted profiles. These channels contain those spectral components which are characteristic of anomalies.

The inphase filter function (channel 42) was multiplied by the quadrature filter function (channels 43) to produce a cross-correlation profile (channel 44). An anomaly on this profile has an amplitude which is crudely proportional to the probability that the anomaly reflects a bedrock conductor. The cross-correlation anomalies were plotted on the resistivity base maps. The procedure works remarkably well, as is evident from the resulting conductor patterns.

The plotted anomalies have four probability grades, as follows:

<u>Probability Grade</u>	<u>Probability Rating</u>
4	>90%
3	75-90
2	60-75
1	40-60

The probability rating expresses the likelihood that a particular response reflects a bedrock conductor in a

statistical sense. Thus, a grade 4 anomaly, while probably indicating a bedrock conductor, still has up to a 10% chance of being caused by noise. Such noise may simply reflect a sudden offset in the EM data due to an electronic problem. Prospektering should review the maps and the associated profiles, to delete those responses due to noise. This service could have been provided by Dighem, but Prospektering has elected to handle this aspect.

#### MAGNETICS

NGU magnetic survey data totalling 4350 km were used to produce Dighem-style enhanced magnetic maps. The magnetic data were treated mathematically to enhance the magnetic response of the near-surface geology. The response of the enhancement operator in the frequency domain is illustrated in Figure 1. This figure illustrates that the passband components are amplified 20 times by the enhancement operator. This means, for example, that a 100 nT anomaly on the enhanced magnetic map reflects a 5 nT anomaly for the passband components of the airborne data.

The enhanced map, which bears a resemblance to a downward continuation map, is produced by the digital bandpass filtering of the total field data. The enhancement

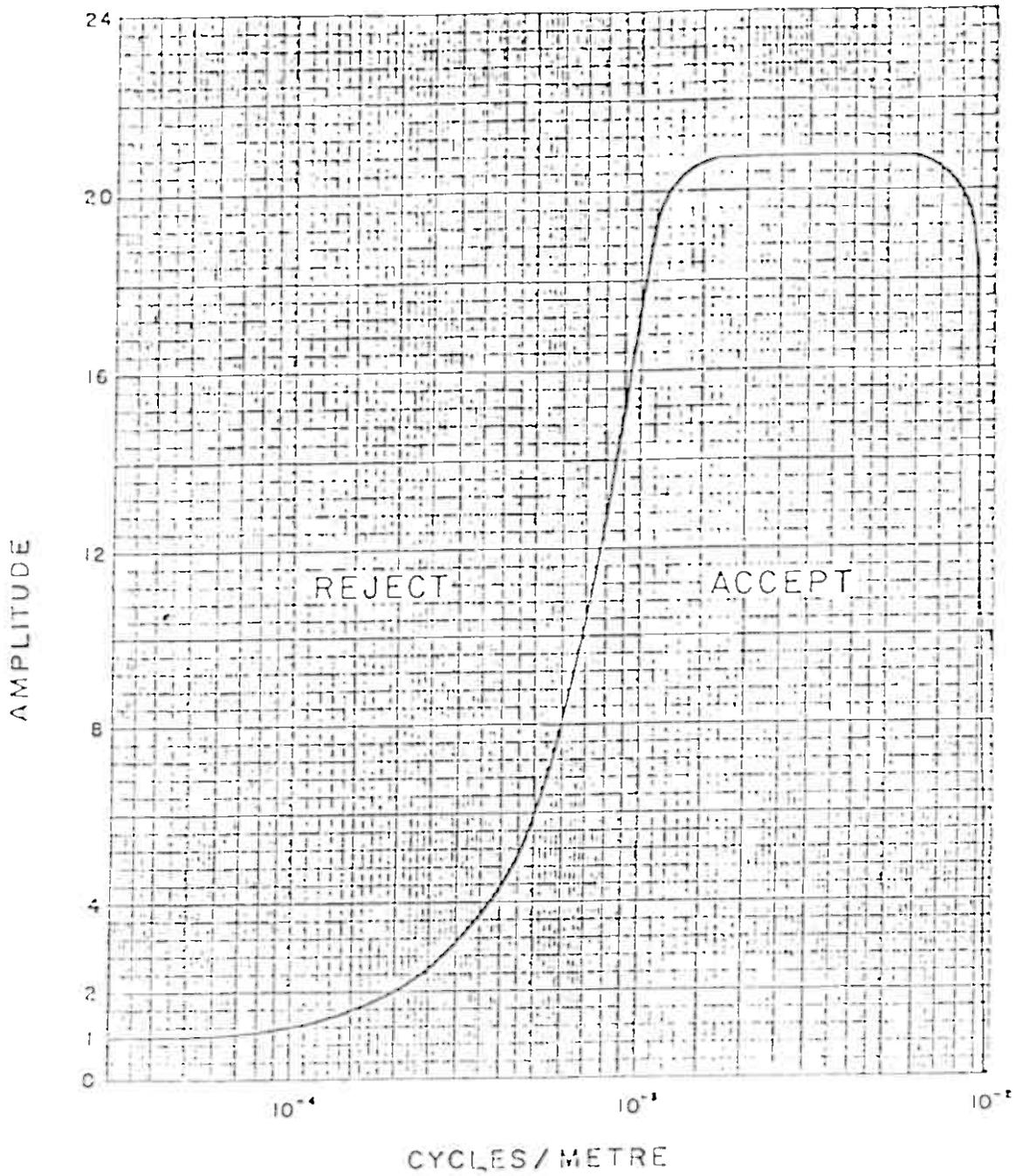


Figure 1 Frequency response of magnetic enhancement operator.

is equivalent to continuing the field downward to a level (above the source) which is 1/20th of the actual sensor-source distance.

Because the enhanced magnetic map bears a resemblance to a ground magnetic map, it simplifies the recognition of trends in the rock strata and the interpretation of geological structure. It defines the near-surface local geology while de-emphasizing deep-seated regional features.

The NGU has produced total field magnetic contour maps for Prospektering with a 100 nT contour interval at a scale of 1:50,000. For Prospektering's interest, Dighem has produced a sample plot of total field magnetics contoured at 25 nT at a scale of 1:20,000. A comparison illustrates the excellent quality of Dighem's contouring package. It also illustrates the advantage to Prospektering of recontouring the total field magnetics using the four-fold increase in contour sensitivity and the more open scale.

Respectfully submitted,  
DIGHEM LIMITED



D.C. Fraser  
President

MAPS ACCOMPANYING THIS REPORT

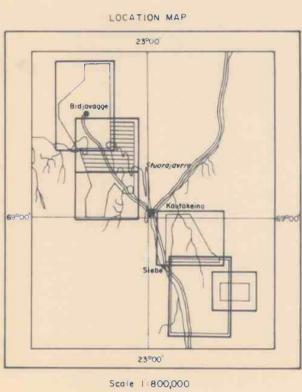
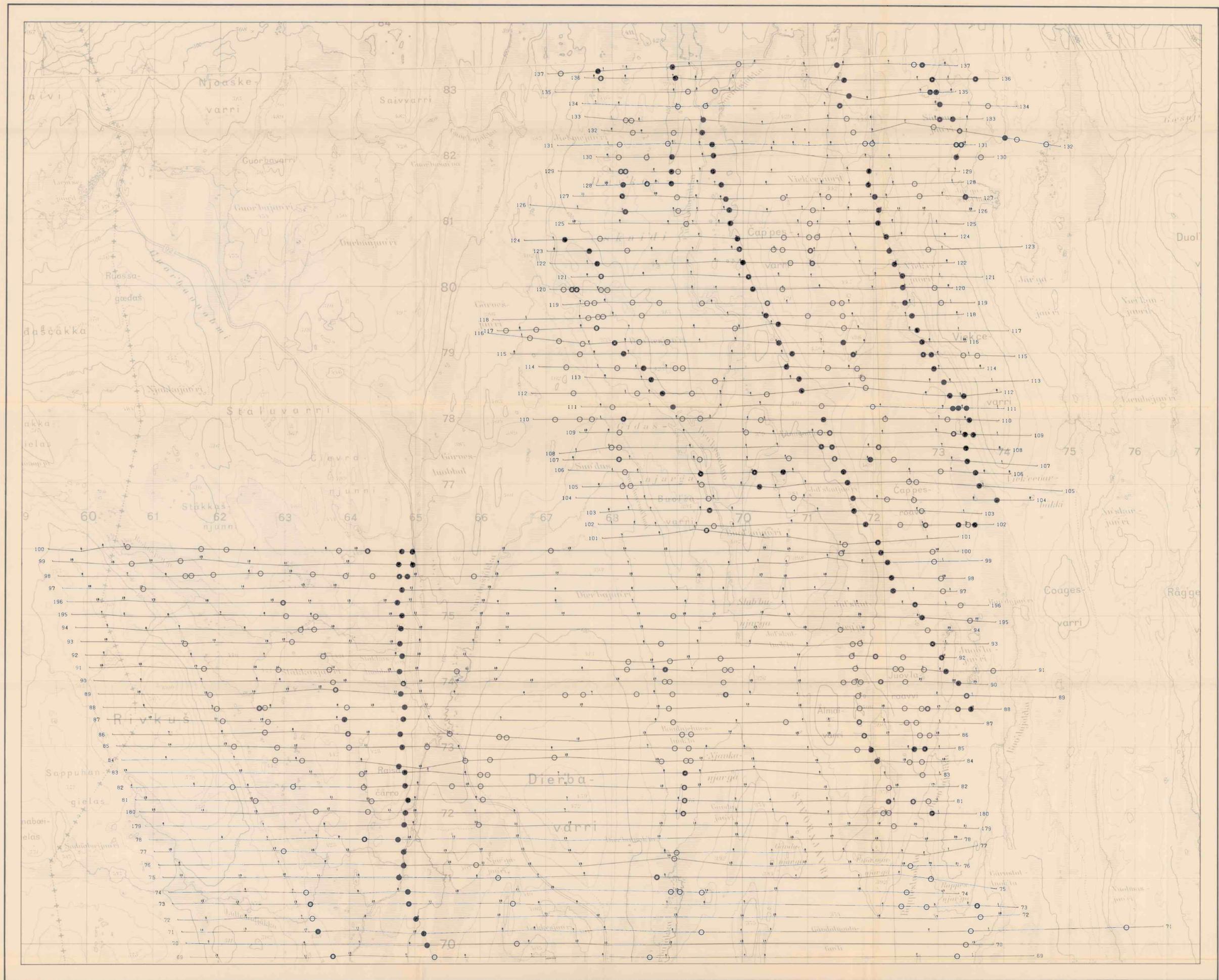
17 map sheets accompany this report:

Electromagnetics	5 map sheets
Resistivity	5 map sheets
Enhanced Magnetics	6 map sheets
Total Field Magnetics	1 sample portion

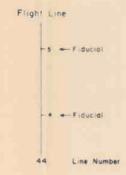
Profiles for each line also accompany this report showing channels of:

Magnetics	channel 20
Bird height	channel 21
EM inphase	channel 22
EM quadrature	channel 23
Resistivity	channel 40
Inphase filter function	channel 42
Quadrature filter function	channel 43
(Channel 42)*(Channel 43)	channel 44

Q DCF-233



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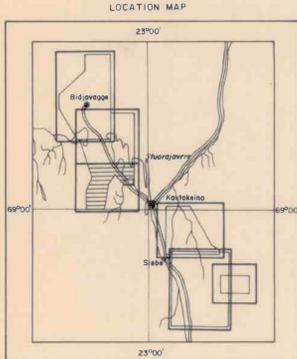
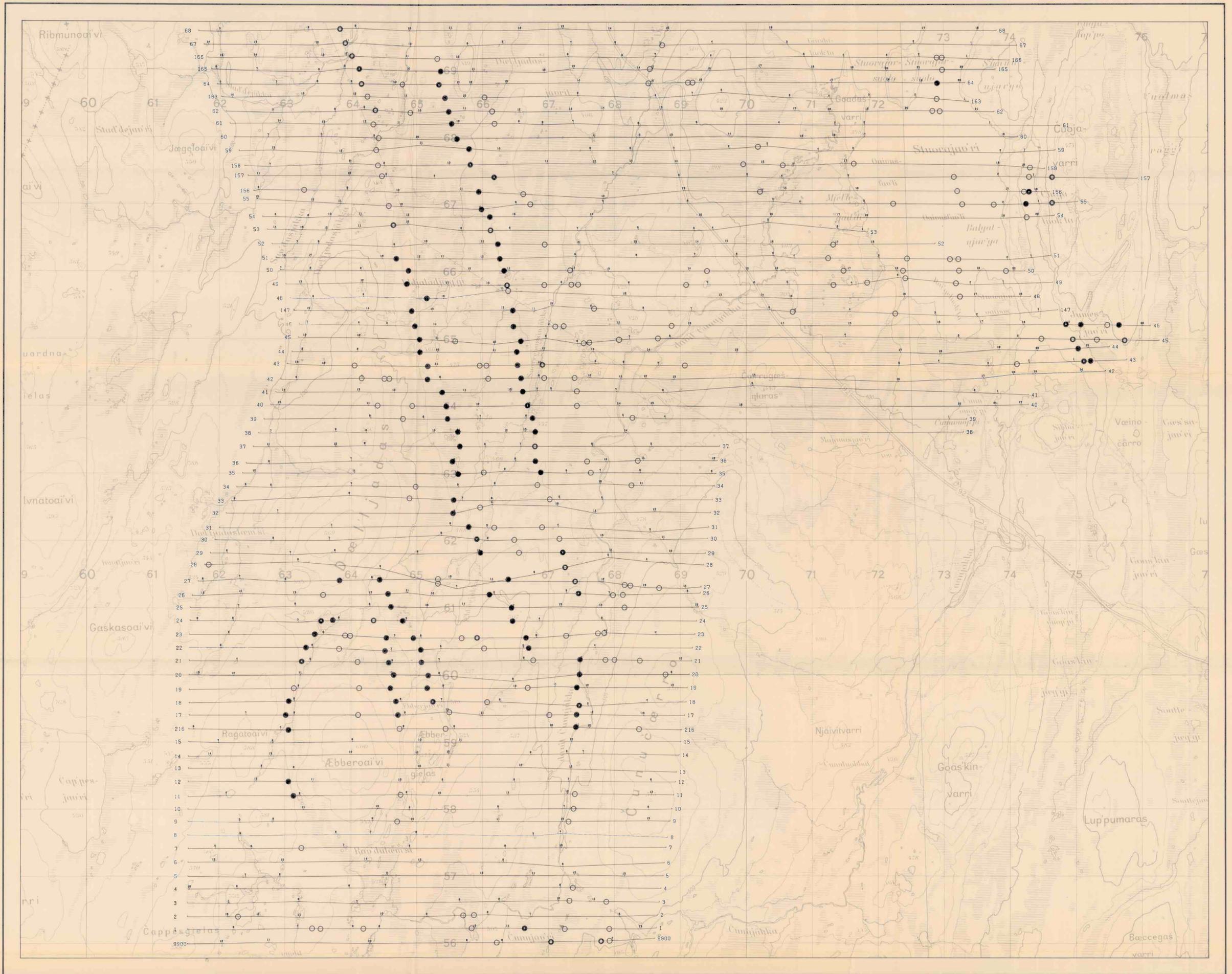


**LEGEND**

EM anomalies are graded as to the probability that they reflect bedrock conductors. There are four grades as follows:

Symbol	Probability Grade	Probability Rating
●	4	> 90%
◐	3	75-90%
◑	2	60-75%
○	1	40-60%





Scale 1:800,000



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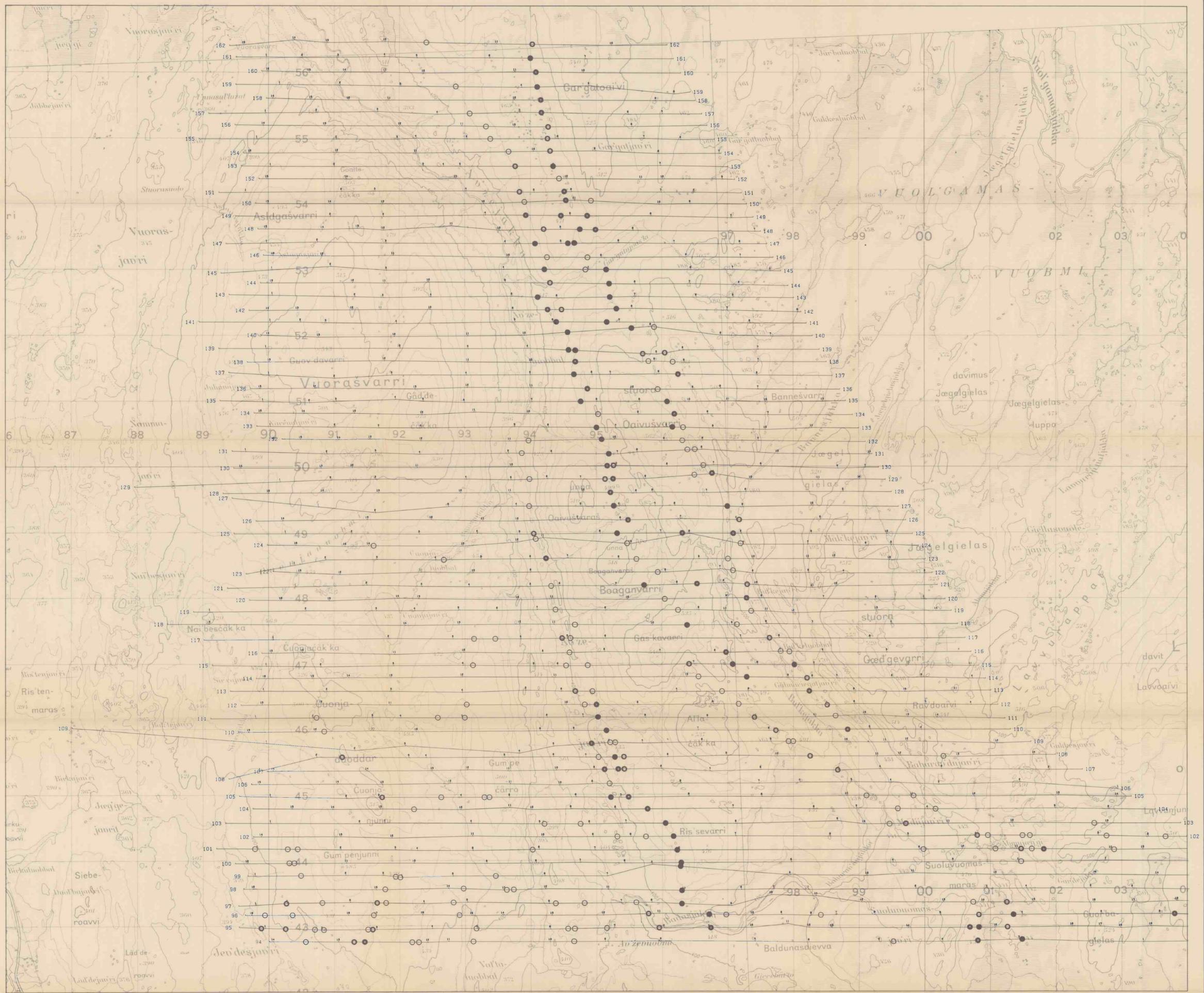


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*E.M.*

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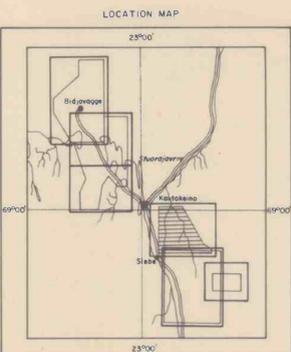
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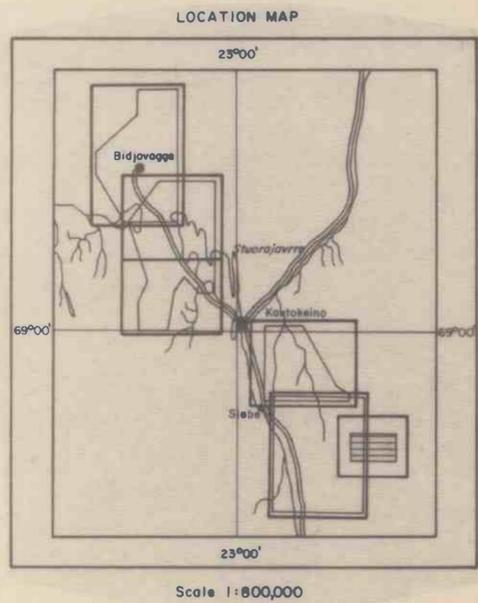
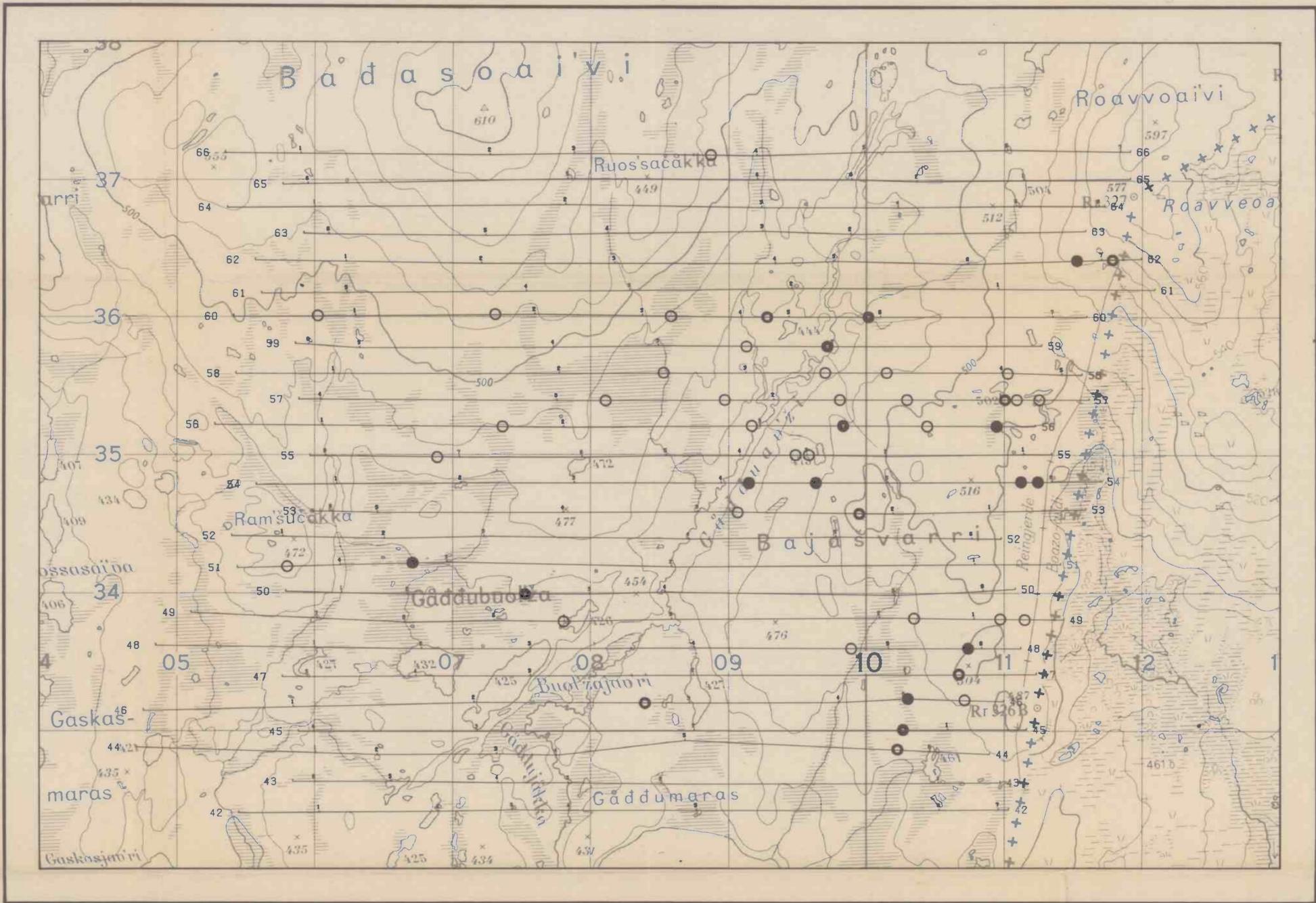
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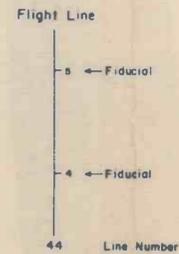
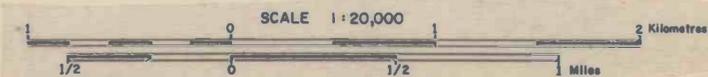
Vertical coaxial coils  
 Coil separation 6.7m  
 Frequency 1000 Hz

Flight Line  
 — Fiducial  
 — Fiducial  
 44 Line Number





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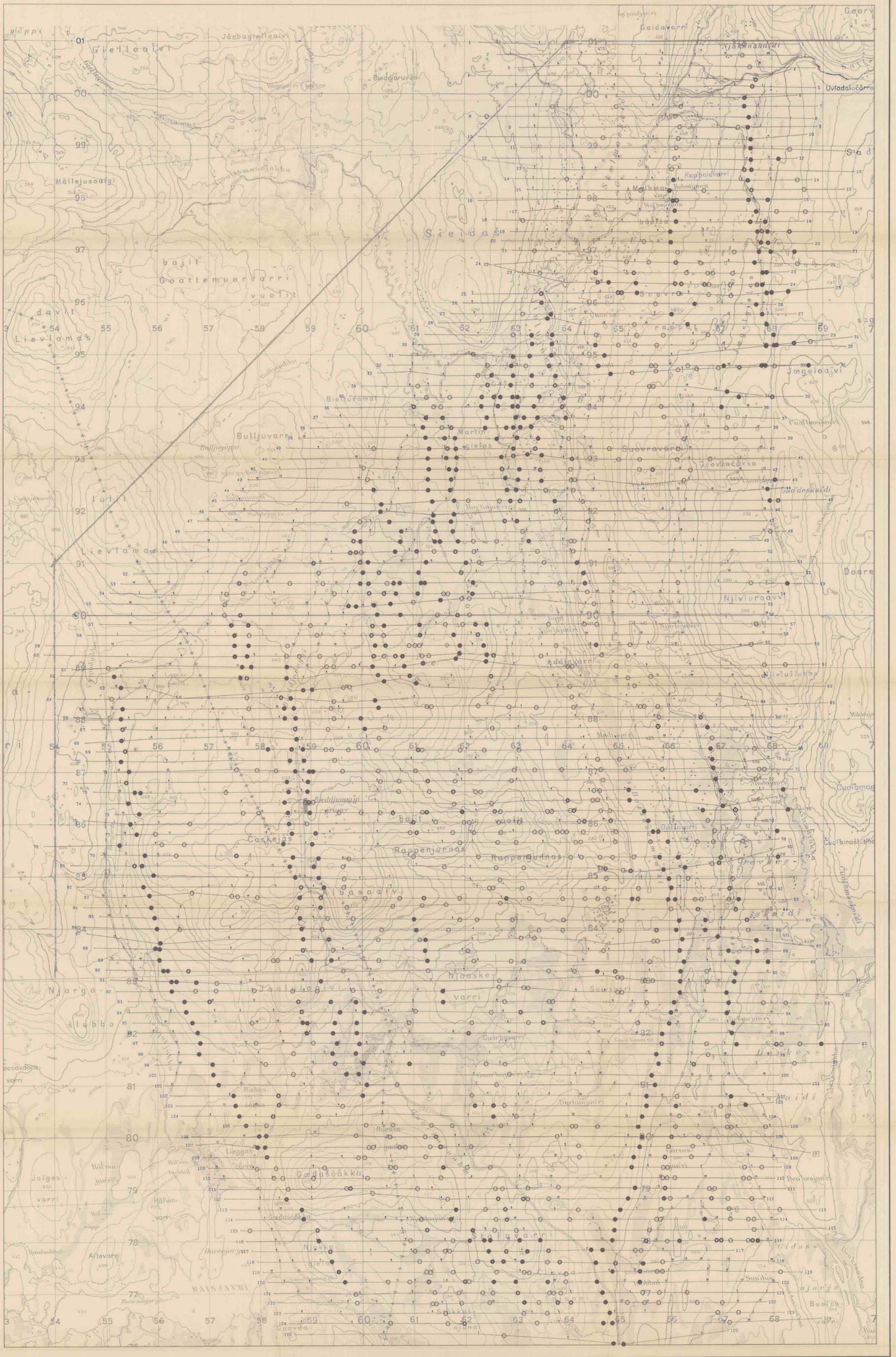


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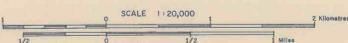
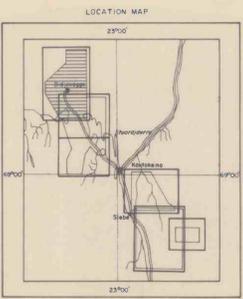
Vertical coastal coils  
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Flight Line

— F-deret

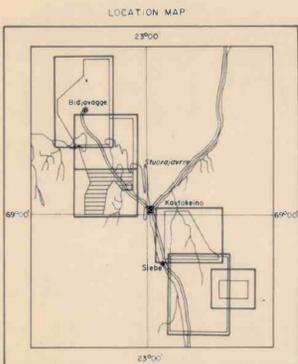
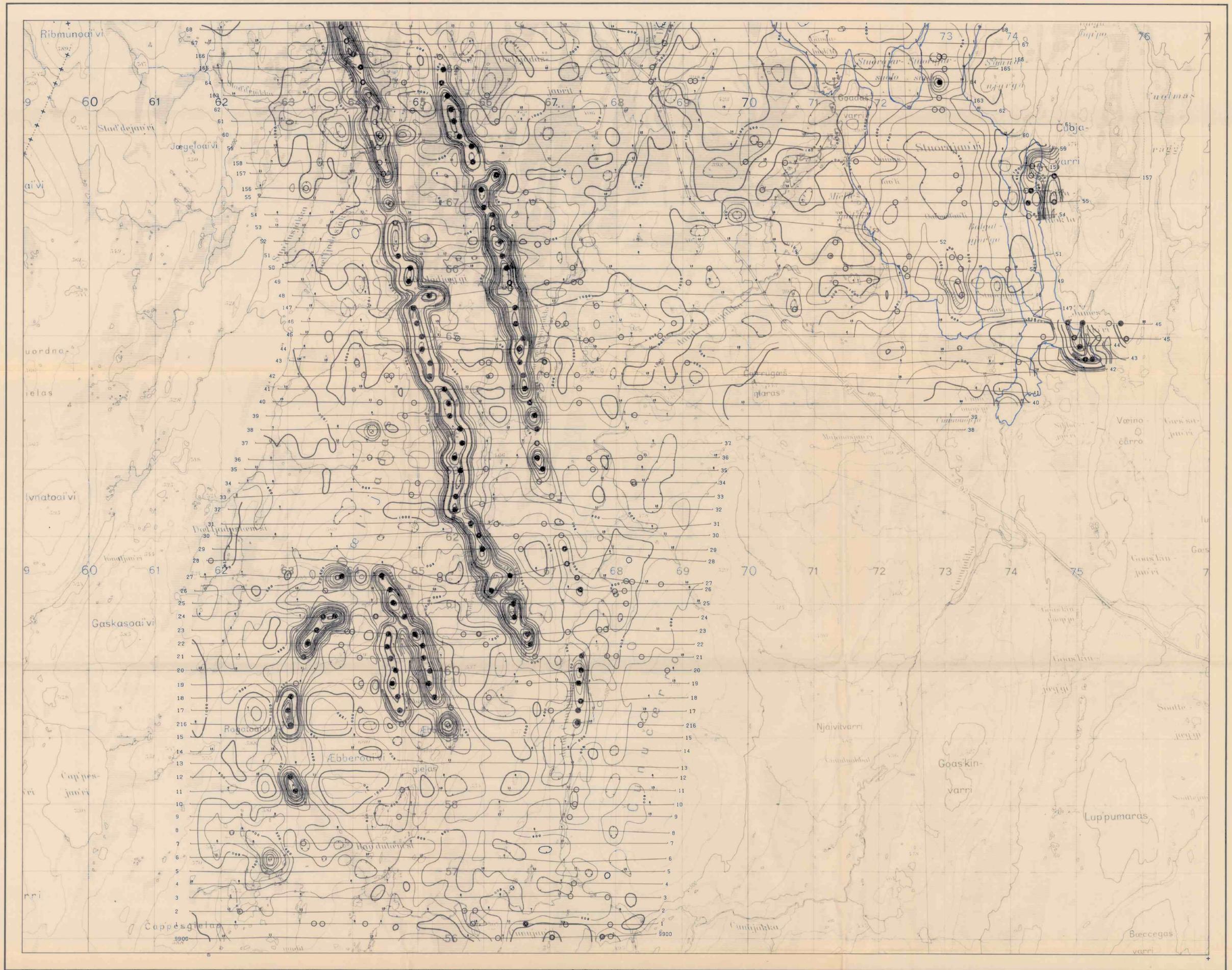
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44 Line Number





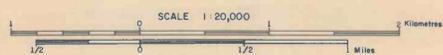




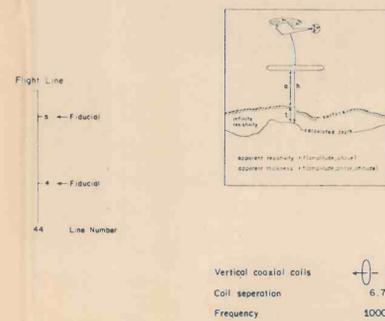
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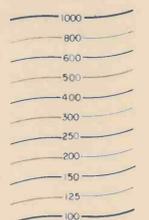


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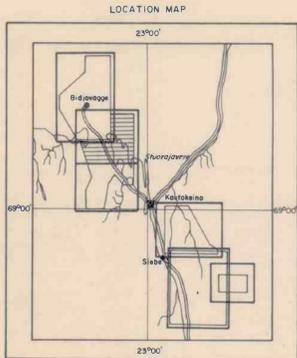
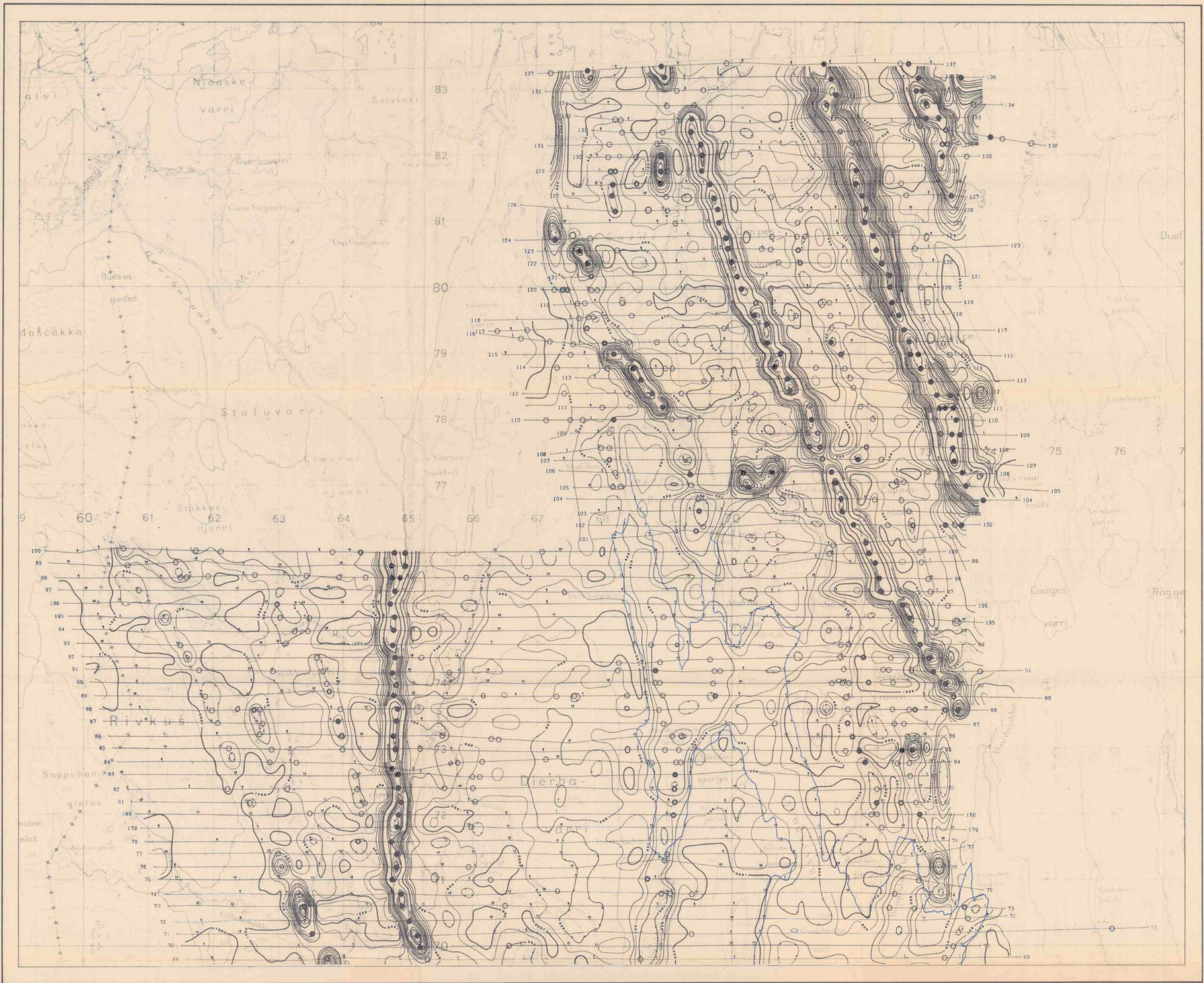


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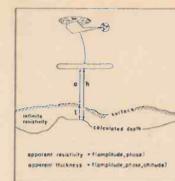
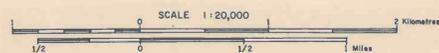
Contours in ohm-m  
at ten intervals per decade



**Note**  
The numbers face in the direction of increasing value

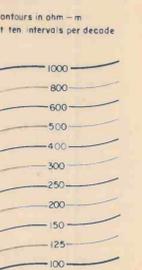


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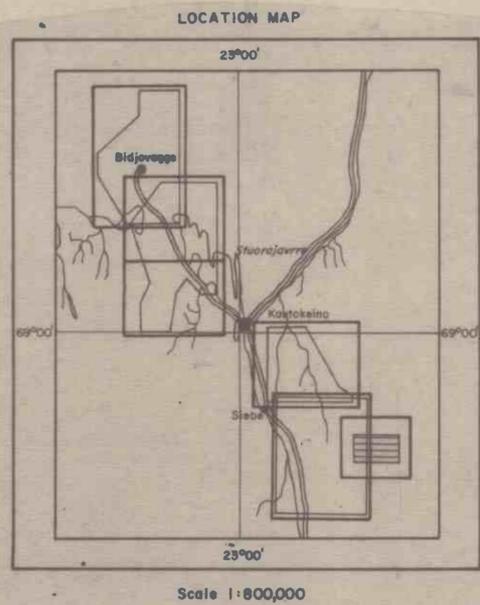
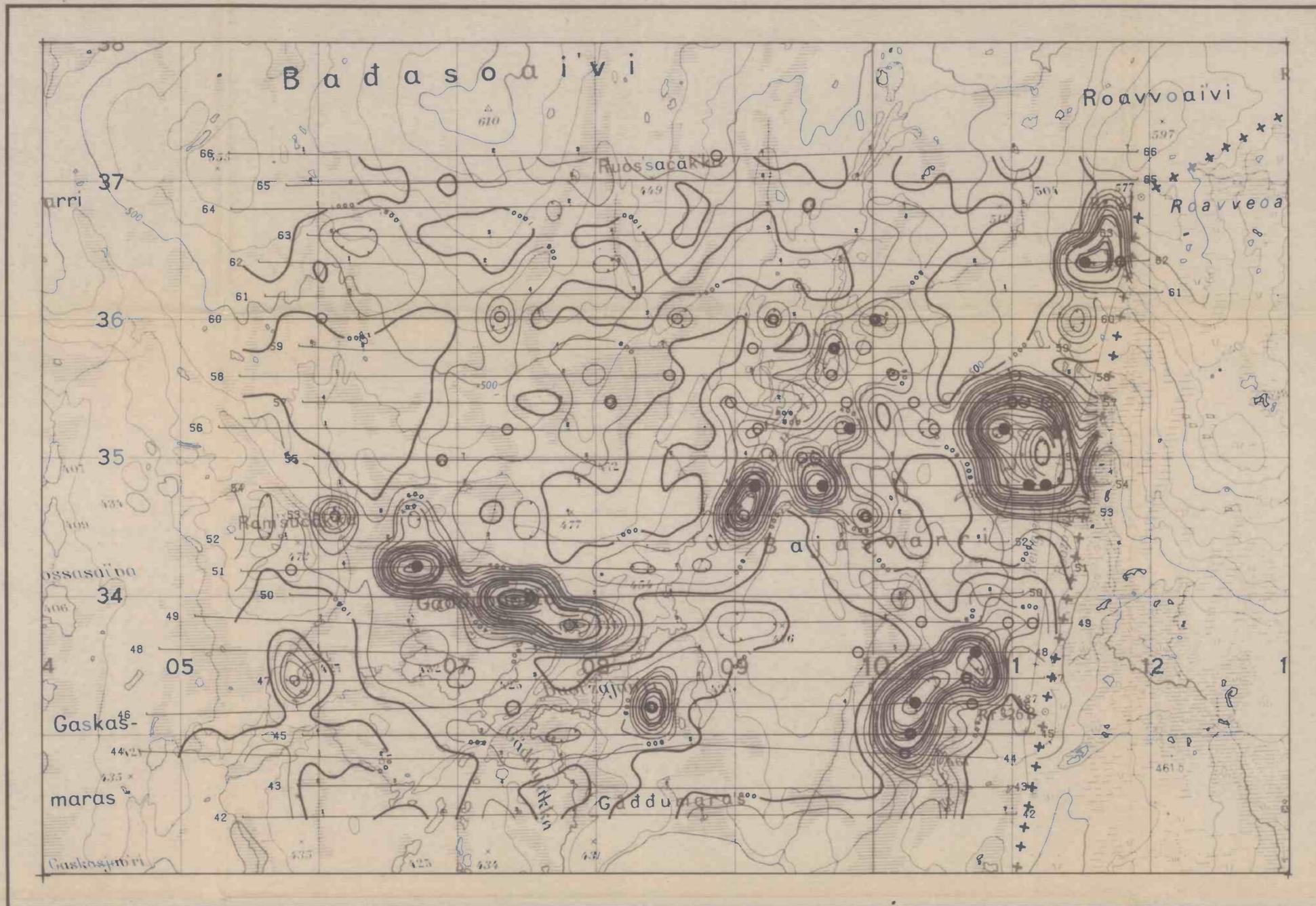


Vertical coaxial coils  
 Coil separation 6.7m  
 Frequency 1000 Hz

**LEGEND**



**Note**  
 The numbers face in the direction of increasing value



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**RESISTIVITY**

**KAUTOKEINO AREA, NORWAY**

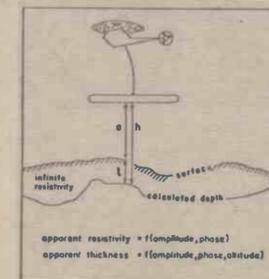
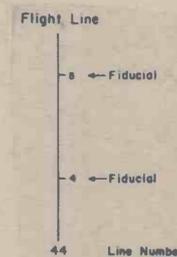
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**PROSPEKTERING A/S**

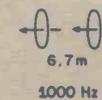
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SHEET 2

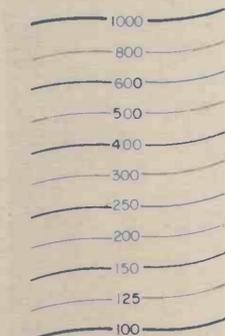


Vertical coaxial coils  
Coil separation  
Frequency



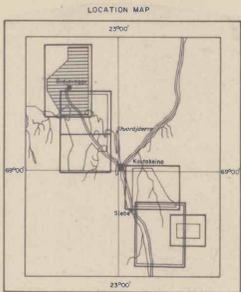
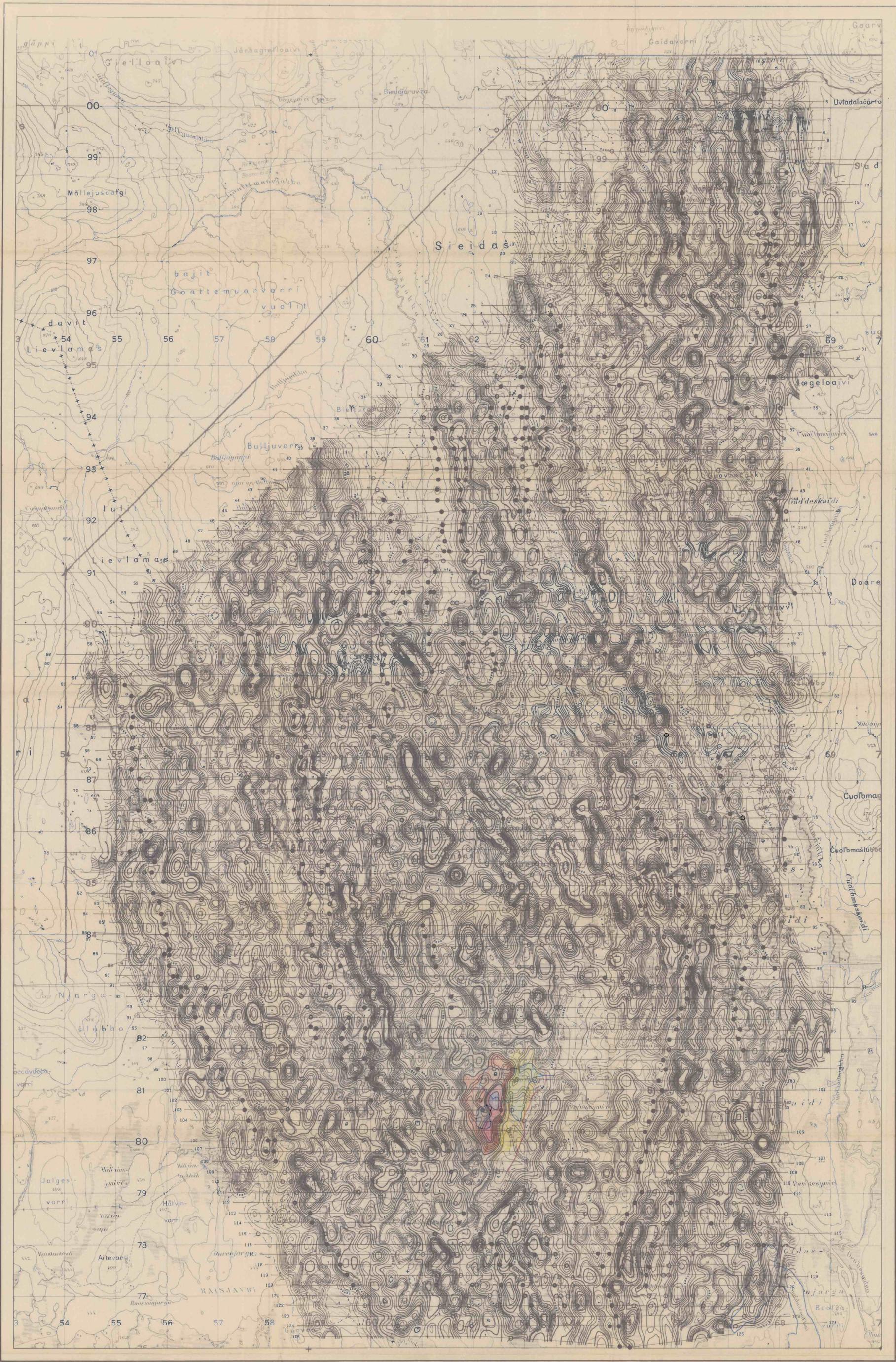
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Contours in ohm-m  
at ten intervals per decade

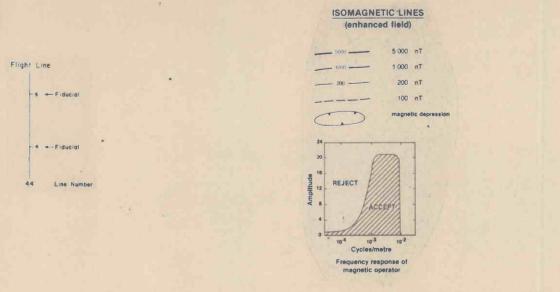


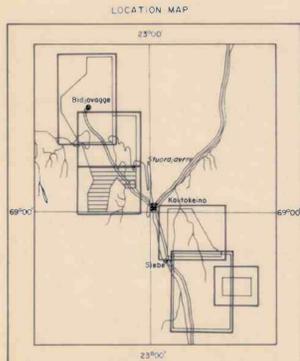
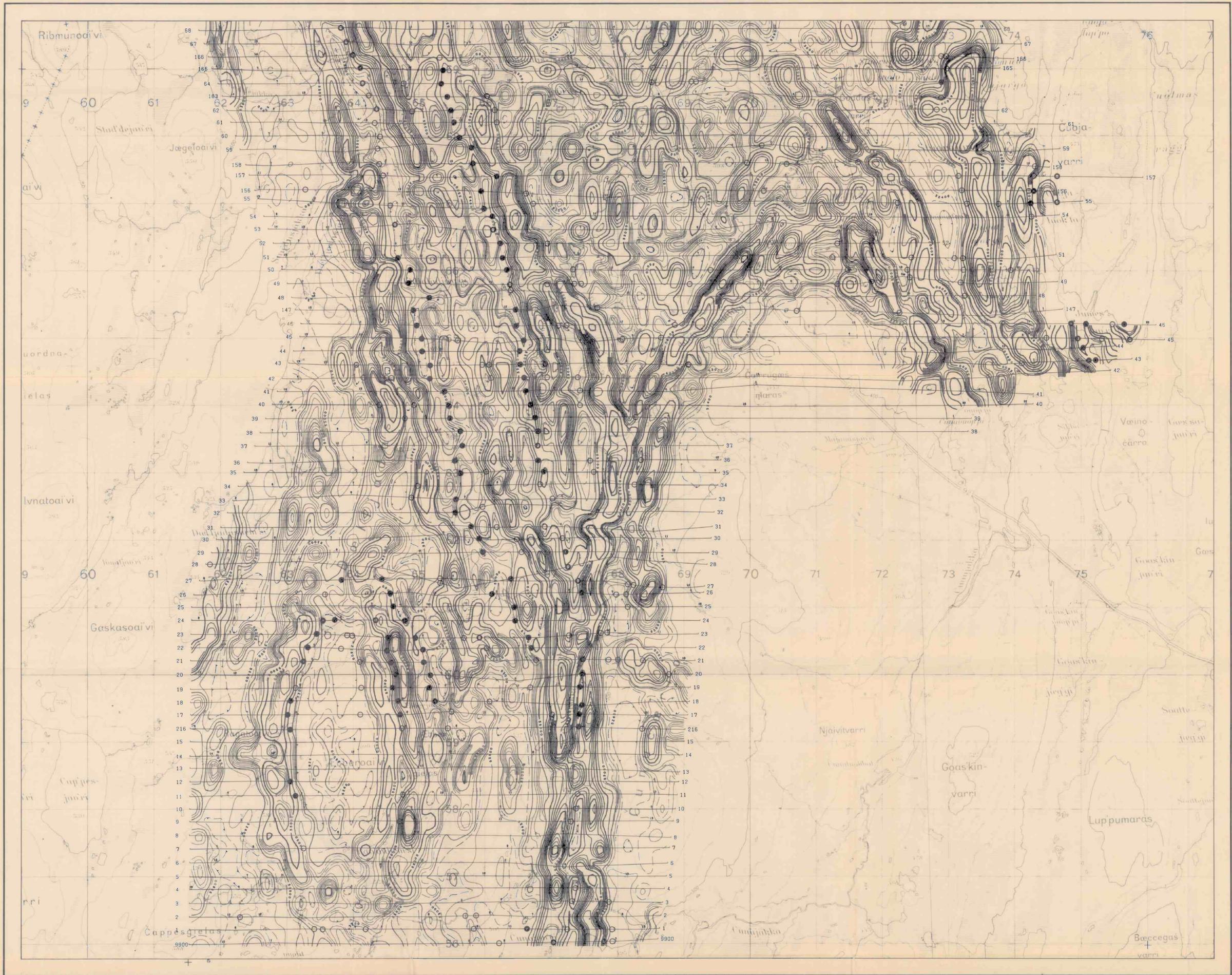
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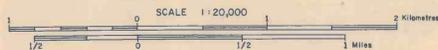




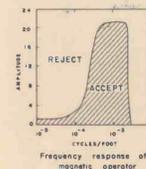
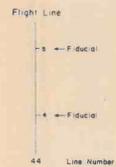
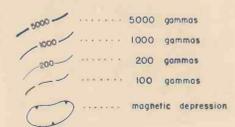
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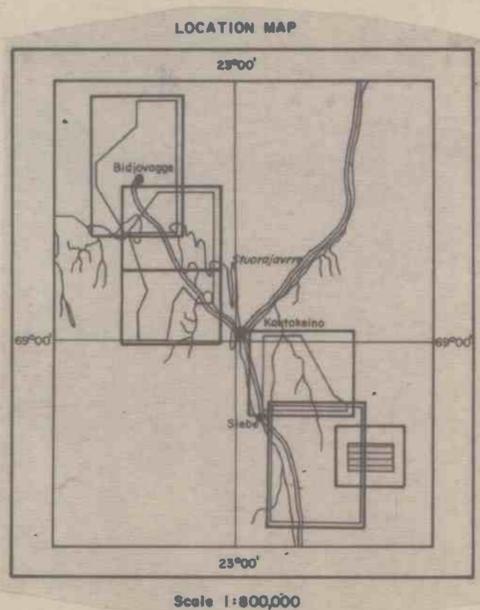
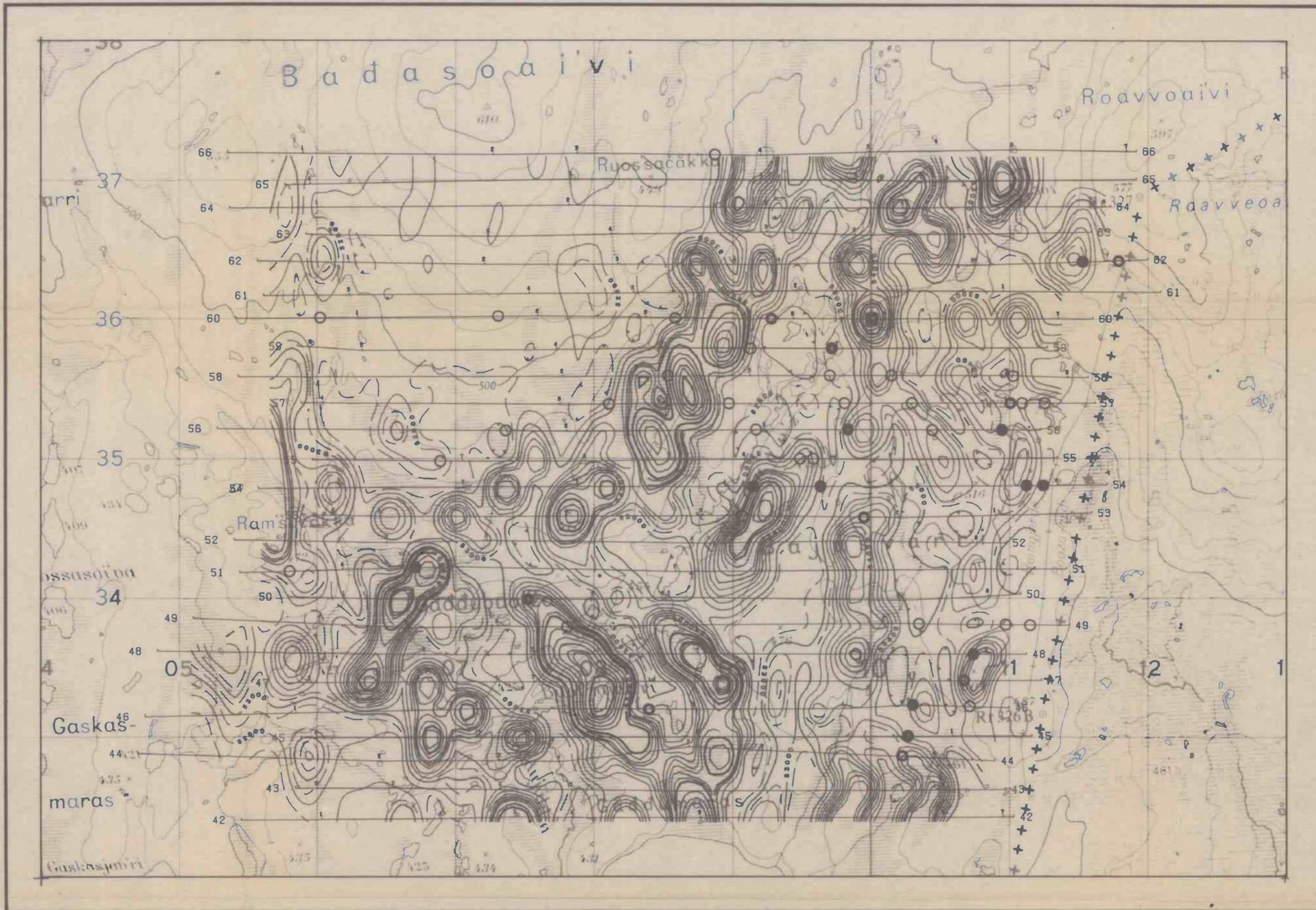


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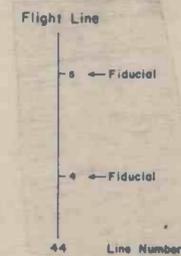


**ISOMAGNETIC LINES**  
(enhanced field)

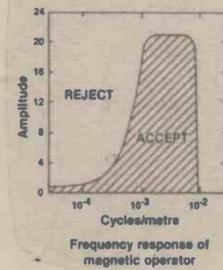
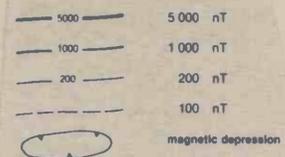


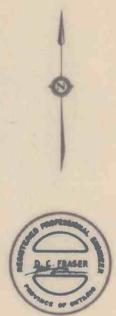
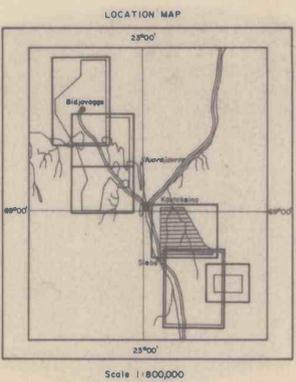
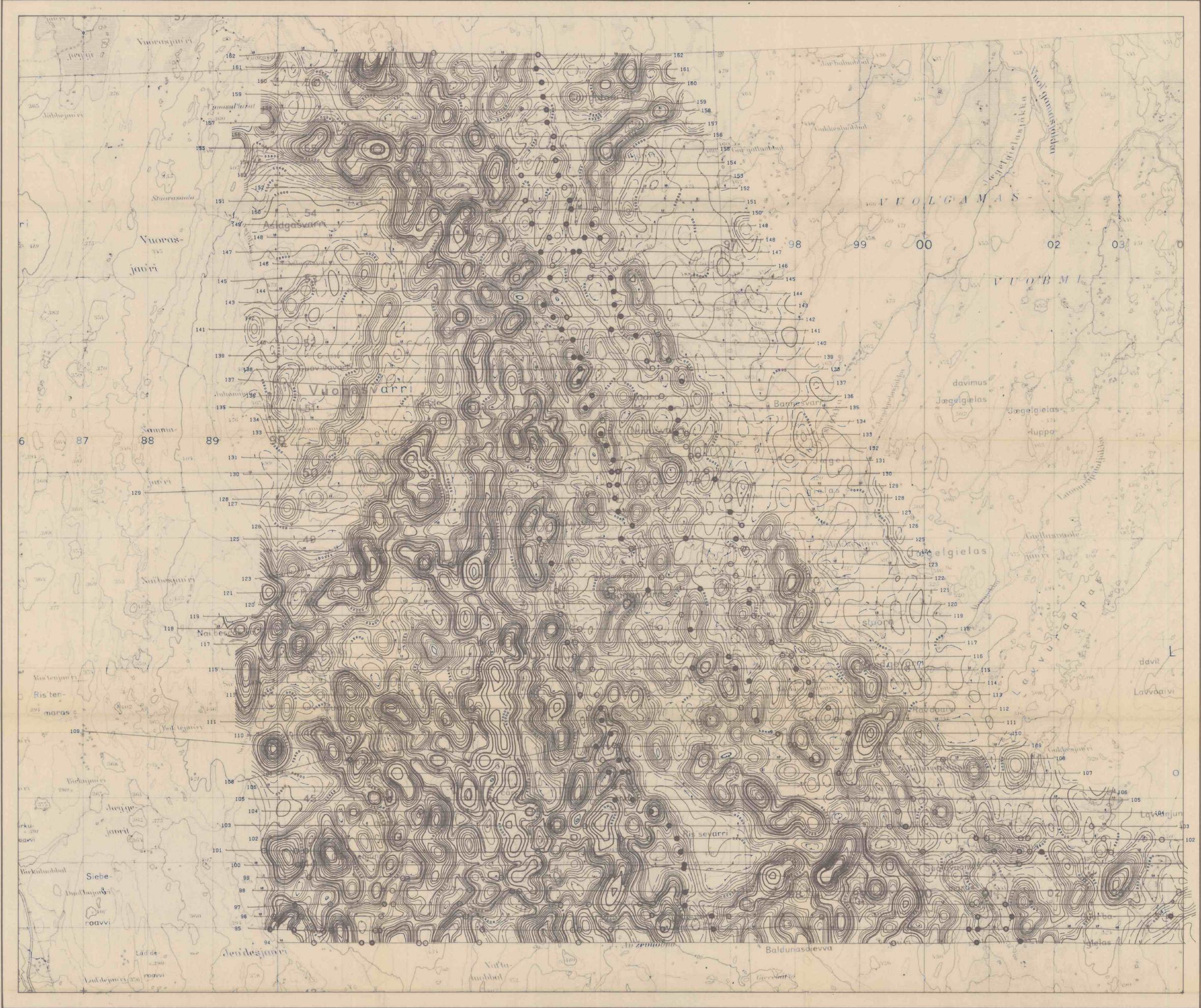


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**PROSPEKTERING A/S**  
**SURVEY FLOWN BY NGU**

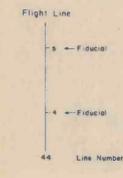
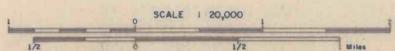


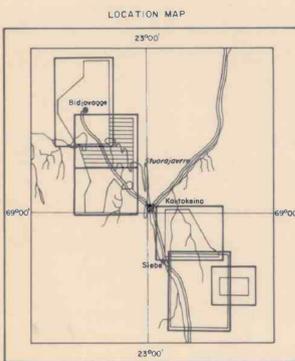
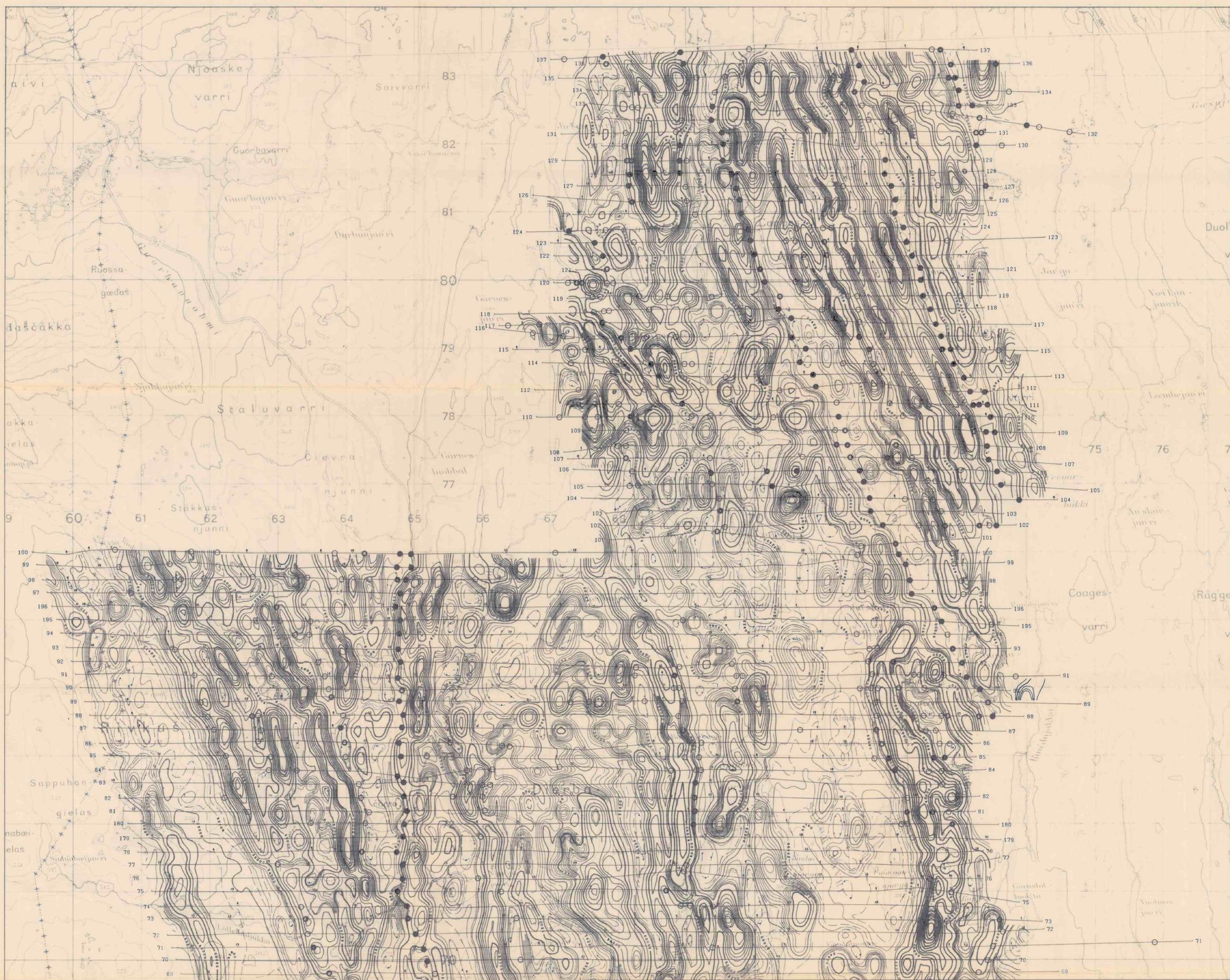
**ISOMAGNETIC LINES**  
(enhanced field)



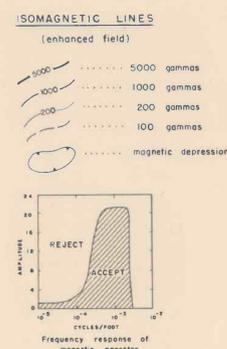
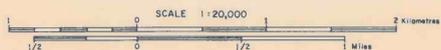


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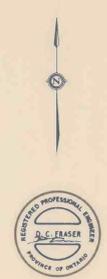
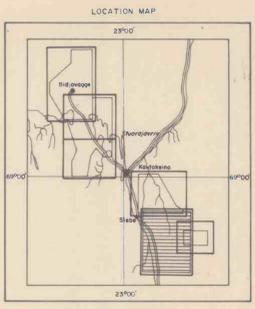




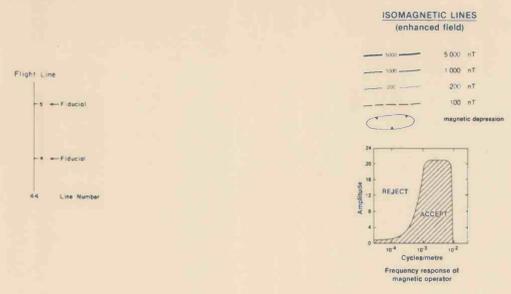
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**SURVEY FLOWN BY NGU**



Flight Line  
 — Fiducial  
 — Fiducial  
 44 Line Number

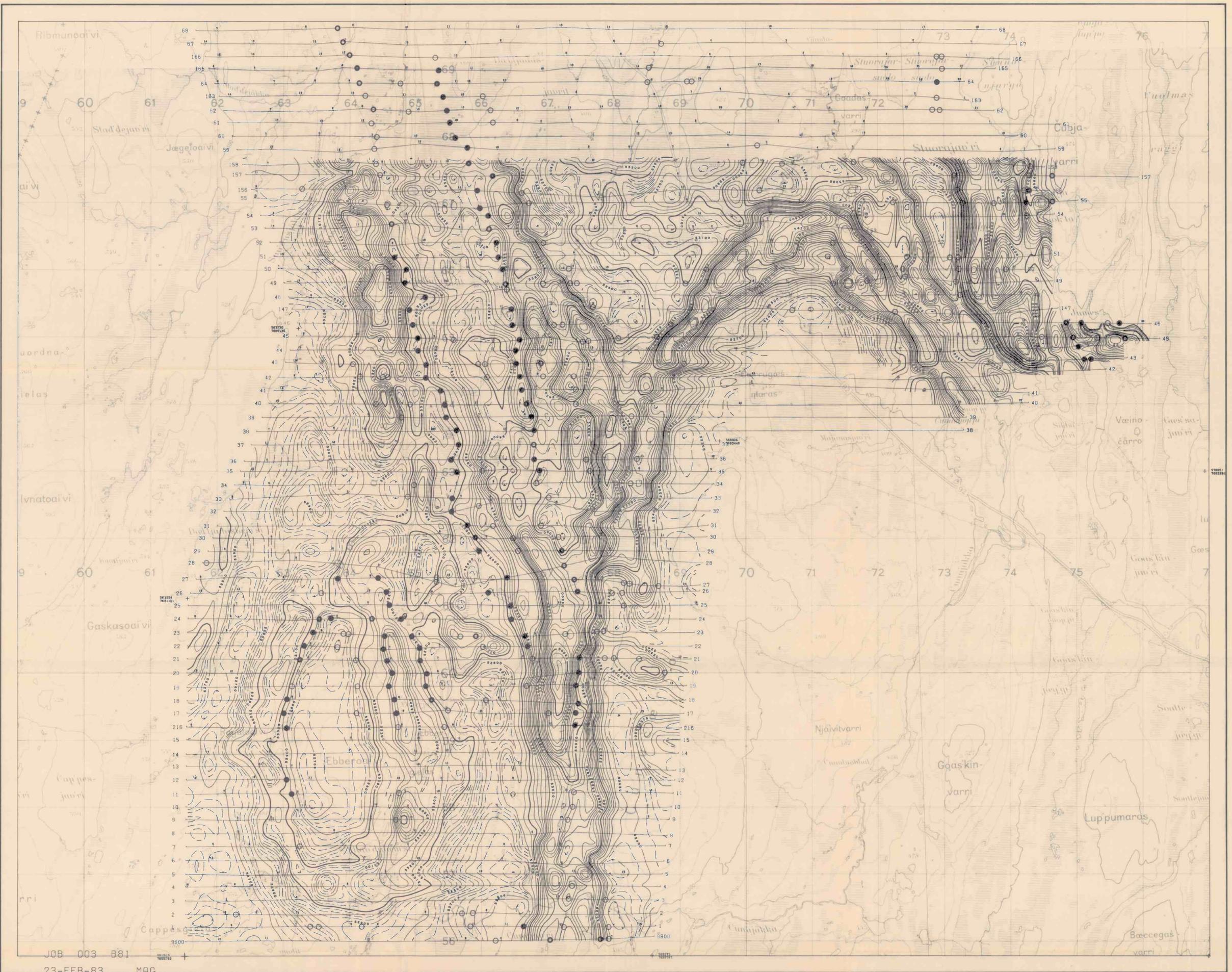


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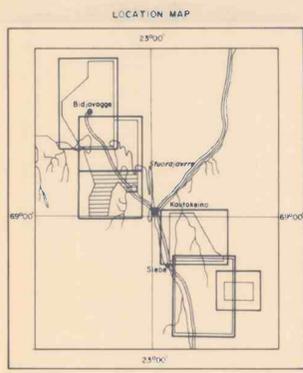


## MAGNETICS

Please find enclosed a sample plot of total field magnetics from Job 1833, at 25 nT contour interval and at a scale of 1:20,000. It is overlain onto the flight path and EM anomalies. As discussed in our preliminary report "Processing of NGU Airborne Geophysical Data", the excellent quality of Dighem's gridding and contouring package is shown when this sample plot is compared with the original NGU produced total field magnetic contour maps which are at 100 nT contour interval and at a scale of 1:50,000. Our sample also illustrates the advantage to Sydvaranger of recontouring the total field magnetics using the four-fold increase in contour sensitivity and the more open scale.



JOB 003 B81  
23-FEB-83 MAG



Scale 1:800,000



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**MAGNETICS**  
**BIDJOVAGGE 81 AREA, NORWAY**  
**FOR**  
**PROSPEKTERING A/S**  
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**LEGEND**

EM anomalies are graded as to the probability that they reflect bedrock conductors. There are four grades as follows:

Symbol	Probability Grade	Probability Rating
●	4	> 90%
◐	3	75-90%
◑	2	60-75%
○	1	40-60%

**ISOMAGNETIC LINES (total field)**

—	1000 nT
—	100 nT
—	20 nT
—	10 nT
○	magnetic depression

Magnetic Inclination within the survey area 77°

Vertical coaxial coils  
 Coil separation 6.7m  
 Frequency 1000 Hz

