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A/S BIDJOVAGGE GRUBER

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RAPPORT VEDRØRENDE:

Processing and presentation of helicopterborne geophysical surveys from the Gulf joint venture, Finnmark.

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RESYMÉ:

A total of 4240 line km of helicopterborne geophysical surveys have been flown in the Gulf joint venture area. Two systems have been used, The NGU/Sander system and the Dighem system. Data from the NGU/Sander system have been reprocessed by Dighem and by Geoterrex.

Experiences gained during interpretation and follow up work are presented. The various processing and presentation techniques are compared by the display of results from a well known test area. The main conclusions are:

1. A good navigation and flight path recovery is the first requirement for a satisfactory result.
2. Noise and levelling errors are serious problems of the Sander EM 3 system. Substantial improvements were made by a careful reprocessing.
3. Resistivity maps should be included with the EM processing.
4. Multicoil EM systems give important additional information compared with a single coil system.
5. The enhanced magnetic map, produced by a filtering of the total field data, bears great resemblance to a ground magnetic map. The enhanced map is an exellent supplement to the total field magnetic map.

KOMMENTAR:

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INTRODUCTION

A helicopterborne geophysical survey generally has got a dual purpose:

1. Detection of ore related anomalies.
2. To provide geophysical maps as a support for the geological interpretation.

Item 1 puts heavy requirements on the processing and presentation of data. The processing must ensure that weak anomalies from ore bodies do not drown in geological and technical noise. The presentation must enhance the ore related anomalies to secure a high priority for follow-up work.

The basis of this report is mainly experiencies gained in the joint venture between Norwegian Gulf Exploration Co A/S and A/S Sydvaranger in the Bidjovagge - Kautokeino area, West Finnmark. In this project the Norwegian Geological Survey (NGU) flew about 3400 line km with the Sander EM-3 system. Dighem Ltd surveyed 840 line km with their Dighem II system and reprocessed 2540 line km of NGU data. Also Geoterrex Ltd has presented a sample of their reprocessing of NGU data.

The Suovrarappat area which is well known from geophysical ground surveys, detailed geological mapping and diamond drilling has been chosen as a test area. The Suovrarappat area is situated 15 km north-east of the Bidjovagge Mine. The various presentations of the airborne surveys of the test area are compared with each other and with ground results. Radiometrics were included with the NGU surveys. Due to heavy overburden, swamps and lakes radiometric results are not encouraging and they will not be discussed here.

The aim of this report is not to give a technical judgement of the systems and the processing techniques, but to evaluate the usefulness of the various presentations in an exploration situation.

GEOLOGY

A geological map of the Suovrarappat test area is presented in Fig. 1. The map is mostly based on work by Hans Delin (Geological map of Suovra-rappat, 1976) and by Jan S. Sandstad (report no 1471).

The main structure in the area is a north-south striking anticline with a plunge towards south of about 40^{o}. The lowermost units in the sequence are meta diabase and meta tuff in the core of the anticline. With the meta diabase also massive finegrained units, probably extrusives are included. The main orebearing units of albite felsite and graphite felsite are generally enveloped in the lowermost meta tuff. This tuff is succeded by alternating units of meta diabase and meta tuff. Higher in the succession towards east meta tuff and meta tuffite become dominant. Thin layers of carbonate rocks are found at this level. The youngest rocks in the Pre-cambrian sequence are the argillite and sandstone in the eastern part of the area. The western limb of the anticline is cut by a major fault. The western block is probably downfaulted more than 100 m, but no outcrops have been found in this area. The Eocambrian autochtonous Dividal Group is overlying the Precambrian in the western part of the test area. In the extreme west also Eocambrian nappe units are found.

Disseminated and vein-type copper mineralization is found in albite felsite and graphite felsite in the lower part of the Precambrian sequence. At a small showing about 1.0 km south-east of the main zone, the same type of mineralization occur in albite felsite and graphite felsite enveloped in argillite.

Carbonatization is common within the area and seems to be related both to fault zones and mineralization.

NAVIGATION AND POSITIONING

Good navigation and positioning procedures are the first requirements of a map from an airborne survey. All surveys in the joint venture were flown without an automatic navigation system. Dighem used a simple photo mosaic as their flight map. NGU used a standard topographic map (series 711), enlarged to a scale of 1:20 000. Fig. 2.1 shows a small part of a NGU flight map (outside the test area). The arrows point out fiducials that cannot be related to topographic features on the map. These fiducials therefore should not have been placed on the map, and they are completely useless for the flight path recovery. The use of a topographic map as flight map also limits the possibilities to use the pictures taken continously during the flight for flight path recovery. The topographic map contain very few details that can be related to features seen in the relative large scale pictures taken from the helicopter. The follow up work has shown that Dighems method of using a photomosaic for navigation and flight path recovery, and then transferring the flight lines to the topographic map is a satisfactory method in the Bidjovagge - Kautokeino area.

Fig. 2.2 shows the NGU EM-map with magnetic profiles of the test area. There are several obvious positioning errors on the map. The yellow arrows show how fiducials should be moved to create a more correct positioning. If the fiducial marked A is moved as indicated the off-set EM-anomaly marked with red will fall in line with the three other red-marked conductors, and form a picture which is in agreement with geology and ground surveys. If fiducial B is moved according to arrows the magnetic high east of the fiducial will fall in line with the magnetic high on adjoining lines. These two errows can clearly be seen by the anomaly patterns and by the vertical hatching of the magnetic profiles. Each line in the hatching represents one sampling point. Sampling interval for the magnetics of this survey was 0.5 seconds. Since the sampling interval is a time constant the open hatching on one side of the fiducials A and B and the dense hatching on the other side demonstrates an impossible speed change of the helicopter. When fiducials are moved as indicated the hatching will become move even which corresponds to a constant helicopter speed. Positioning errors in the north-south direction are probably also present but these are not easily detectable with a north-south strike.

The blue arrows in Fig. 2.2 show positioning errors which transform linear geological features into a zig-zag pattern. This error occurs to a certain extent in the whole area, only the most outstanding example is marked in the Figure. During the flight the navigator marks fiducials which he can see a little bit ahead of the helicopter. The EM-bird is towed at same distance behind the helicopter. Bearing in mind the change of flight direction from one flight line to the other, this may explain a part of the zig-zag pattern. The rest must be explained by a technical delay in the EM-recording system. The overall amplitude of the zig-zag pattern may be up to 250 m. ASPRO has brought this matter to the attention of NGU and in later surveys a time constant has been introduced to reduce the zig-zag pattern.

In the future most contractors will offer automatic navigation systems. With these systems positioning problems as described here will be avoided. At present these systems are more expensive than a traditional flight path recovery.

ELECTROMAGNETICS

In Fig.3.1 raw EM-data from a NGU survey are displayed. Both components contain a high level of noise as well as fairly rapid non-linear drift. Phasing errors occur in the NGU EM-data. Fig. 3.1. shows that negative inphase anomalies (NGU sign convention not followed) are accompanied by weak negative quadrature anomalies. The only way to explain the negative quadrature anomalies is by a phasing error. The data also contain obvious EM anomalies caused by geological conductors. Filtering and levelling are the first steps of the processing. The purpose of the levelling is to adjust the components to a zero level in areas where no anomaly sources are present. This is a necessity before σ x t (conductance) or resistivity calculations can be made. Since the drift is non linear the levelling is a complicated operation and should involve the hand labor of an experienced geophysicist.

The removal of high frequency noise may be done by digital filtering. In the NGU data there is a spectral overlap between anomalies and noise. A filtering may therefore also remove anomalies.

The most common presentation of airborne EM anomalies involves a σ x t (conductance) interpretation using a vertical dike model. In Fig. 3.2 the EM maps of NGU (Sander EM 3 system) and Dighem (Dighem II system) are displayed with a map of conductors from a ground Turam survey. The north-east corner of the test area is not covered by the Turam survey.

The NGU EM-map is presented with a background of magnetic profiles (very weak copy in Fig. 3.2.) EM anomalies are divided into four conductance grades. Quadrature anomalies with negative inphase component (magnetic permeability) are also included.

Dighem anomalies are divided into six conductance grades plus one indeterminate. With each anomaly an interpretation of shape, dip, depth, magnetic correlation and conductor axis is given. Symbols for the amplitude of inphase and quadrature are also shown for each anomaly.

The strong conductors of the test area are caused by graphitic units. A north-south striking very complex conductive sone is found in the eastern part of the area. This zone consists of up to four individual conductors. To the east of this zone several short conductors with varying strike and dip are found.

Ore related graphitic units are found at two stratigraphic levels. The main level occur in the central part of the anticline (see Fig. 1) forming a slightly curved east-west striking conductor. To the west this conductor is cut by a fault. The western edge of the graphite felsite occurs as a north-south striking Turam conductor (Fig. 3.2 top) with an increasing depth towards south. The eastern limb of the zone continues towards north with a varying conductance. The second level occurs about 1.0 km south-east of the main zone. The Turam survey shows several parallell conductors with a strike length of less than 1.0 km. It should be noted that mineralizations is related to breaks and irregularities of long conductors or related to short conductors.

North-northwest striking conductors occur in the south-western part of the test area. On the Turam survey these can be followed towards north-west under the flatlying Eocambrian rocks.

There is generally a good agreement between the Dighem EM map and the ground survey. Some of the weak Turam anomalies and some of the deep conductors are not picked up by the helicopter system. The interpretation given by Dighem usually fits with what is known about the geology.

The NGU EM-map contains several anomalies that cannot be related to Turam indications. These anomalies are caused by noise. The correlation between the NGU EM-map and the Turam map is made difficult because of the very poor positioning and zig-zag pattern of NGU anomalies. Many difficulties were encountered in the follow up work of the NGU survey. The poor quality of the geophysical maps made a good geological interpretation and a priority of anomalies impossible. In the field time and money was wasted in the search for anomalies caused by noise in the helicopter system. This led to the conclusion that a reprocessing of the NGU data was necessary.

A total of 2540 line km of NGU data from the Bidjovagge area was reprocessed by Dighem Ltd. The EM processing included a levelling and an anomaly recognition procedure. The anomaly recognition involved a digital filtering of inphase and quadrature components. The inphase component filter function was then multiplied by the quadrature filter function to produce a cross correlation profile. The amplitude of cross-correlation anomalies are crudely proportional to the probability that the anomaly reflects a bedrock conductor. The cross correlation anomalies are divided into four grades. Included in the EM-processing was also introduction of a time constant to minimize the zig-zag pattern, digital profiles and resistivity maps.

The EM-anomaly map (cross correlations) of the test area is presented in Fig.3.3. (upper). A comparasion with the Turam map and the original NGU EM-map (Fig. 3.2.) shows that the Dighem processing of NGU data has removed some false anomalies and other false anomalies have been given a low probability of being bedrock conductors. The zig-zag pattern has been removed. The EM anomalies have been plotted on a topographic background which is an option that is not offered by the NGU.

By utilizing the magnetic map, resistivity map and digital profiles included with the reprocessing an EM-interpretation was made. The EM interpretation of the test area is presented in Fig. 3.3. (second from top). The interpretation involves conductor quality and conductor axis. Unrecognized anomalies, anomalies caused by conductive overburden and magnetic permeability and anomalies caused by noise are marked. Obvious positioning errors are also indicated. Together with the probability rating this interpretation forms a good EM map which is a suitable basis for follow-up work.

Geoterrex Ltd. has presented a sample of their processing of the NGU EM-data. The data were filtered and levelled. Two different plots of a $\sigma \times t$ (conductance) map are shown in Fig. 3.3. Inphase component profiles form a background for the EM symbols on both plots.

The Geoterrex processing has removed some false anomalies compared with the NGU EM-map (Fig 3.2, middle), but several new false anomalies have been added by the new processing. The choice of EM symbols is mainly a matter of taste. The NGU EM-symbols (Fig. 3.2, middle) are just as good as the diamonds and spikes used by Geoterrex (fig. 3.3, second from bottom,bottom). For some purposes the inphase component profiles included in the Geoterrex EM map may be an advantage. However for a careful study of each anomaly, both components should be used.

As a part of their EM presentation Dighem provides a map of apparent resistivity. The resistivity is calculated from the co-planar coils using a buried half space model. The resistivity map has been found very useful as a support for the geological interpretation. The following information can be extracted from Dighems resistivity map (Fig. 3.4, top) when used in combination with the standard EM map.

1. The conductor of the central part of the area (the ore bearing units of graphite felsite and albite felsite) is folded in an open east-west-striking structure, probably plunging towards south.

2. The westernmost conductor continues under the Eocambrian cover. This continuation cannot be seen as discreet conductors, but as a low resistivity trend.

3. Dip is indicated for most of the conductors apart from the very complex zone in the east. The EM anomalies (from co-axial coils) give the location of the upper edge of the conductor while the resistivity (from co-planar coils) "follows" the conductor along dip. This is very clearly seen at the westernmost conductor. The resistivity low is located at the western side of the EM anomalies, indicating a westerly dip.

4. In the north west part of the test area conductive overburden (water saturated finegrained sediments) are indicated by weak and broad resistivity lows.

The Dighem processing of NGU-data included a resistivity map. This is shown in Fig. 3.4 (middle). The map bears resemblance to Dighems own resistivity map (Fig. 3.4, top). When the positioning errors of the NGU data are taken into account the result is satisfactory. There is a diverging pattern between the two maps in the resistivity area between 1000 Ωm and about 500 Ωm. This is explained by phase errors and minor levelling errors in the NGU-data. The resistivity map processed from the NGU-data is calculated from the co-axial coils. Dip information is therefore limited on this map compared with Dighems own product.

The resistivity map processed by Geoterrex Ltd from NGU data is shown in Fig. 3.4 (bottom). This map contains few features that can be related to geology. Only the very strong resistivity lows of the two upper maps can be recognized in the lower map. Geoterrex clearly has not managed to do a proper levelling job. The resistivity surface seems very smoothed and cannot be used for geological interpretation.

MAGNETICS

A magnetic total field map shown as stacked profiles (with EM anomalies) is shown in Fig. 4.1 (top). The map is a presentation by NGU. Magnetic profiles are suitable for the study of individual anomalies. The correlation with a geological map and the interpretation of a stacked profile map is difficult. In areas with very strong magnetic gradients (not so in the test area) profiles tend to overlap and each individual profile cannot be distinguished.

A magnetic total field map, contoured by NGU is shown in Fig. 4.1 (middle). The map seems very smothed and the contour interval is only 100 nT. The bottom map of Fig. 4.1 is contoured total field magnetics of the Dighem survey. Both surveys are flown with magnetometers with a similar precision (about 1 nT), but the output is quite different as shown by Fig. 4.1. The general trends are the same, but the NGU map lacks a large amount of details. The same colour code is used for both maps. The highest magnetic levels of both maps have got roughly the same magnitude (a little higher on the NGU map) while the lowest magnetic level of the NGU map is about 52 500 nT versus 51 700 nT of the Dighem map. The total amplitude of the magnetic field of the test area is reduced by about 600 nT when comparing the NGU map with the Dighem map. It may therefore be concluded that NGU contour map involves an extreme smoothing of the magnetic data.

In addition to the total field magnetics Dighem provides an "enhanced" magnetic map. This map is created by a digital bandpass filtering of the total field data. The map bears a resemblance to a downward continuation map and is equivalent to continuing the field downward to a level which is 1/20 th of the actual sensor-source distance. The frequency responce of the magnetic operator is shown in the legend of Fig. 4.2. The purpose of the enhanced magnetic map is to strengthen the magnetic responce from the near surface geology.

Fig. 4.2 shows that the enhancement works extremely well in the test area. Dighem's enhanced magnetic map (middle) fits with the ground survey (top) both with respect to anomaly shape and relative magnitude.

The enhanced magnetic map makes it possible to reduce the amount of magnetic ground surveys to a minimum and ground results can easily be correlated with the regional data from airborne surveys.

The enhanced magnetic map from the Dighem processed NGU data (Fig. 4.2, bottom) show that the NGU magnetic data does contain a lot more information than what is displayed by the NGU total field map (Fig. 4.1, top and middle). If the positioning errors were corrected, the enhanced map made from NGU data would be almost identical with the Dighem map.

Most of the meta diabase units of the test area are magnetite rich. The meta tuffite has got a bimodal distribution of magnetite. Some units are magnetite rich and some are magnetite poor. Generally the argillite is magnetite poor, but a few, thin argillite units have got a high magnetite content. Although there are variations within each unit, some of the magnetite rich members form exellent marker horizons. Albite felsite, graphite felsite, carbonate rocks, sandstone and the Eocambrian rocks are all magnetite poor.

The general strike directions of the area can easily be seen from the magnetic maps. The fault in the western part of the area occurs as a linear feature with a strong magnetic gradient, best seen on the Dighem total field map (Fig. 4.1, bottom).

Megnetic lows occur in the usually magnetite rich meta diabase below the main mineralized units. These lows are caused by carbonatization during the ore forming process and therefore closely related to mineralization. On both the ground magnetic map and on the enhanced magnetic map these lows may easily be seen, while on the total field map (Fig. 4.1) they are not visible.

The colouring of magnetic contour maps may be of tremendous help in the interpretation of the data. The maps in Fig. 4.1 and 4.2 have all been coloured by hand. The colouring may also be done by a computer. Fig. 4.3 shows the Dighem enhanced magnetic map of the test area coloured with an Applicon colour plotter. The colour plots were made by Dataplotting Services Inc. Original colour plots are enclosed only with the archives copy of this report. The remaining copies are supplied with ciba-chrome photographs of the plots. A revolving colour spectrum has been used for the top plot. With this technique a constant interval of magnetic field strength is covered by each colour. If the variation of the field is greater than what equals one colour spectrum, the spectrum is repeated. This way small variations in magnetic low areas and in high areas are given equal importance.

One colour spectrum is used in the middle plot. The scale is adjusted to give each colour an equal area. The plot shows that small variations in magnetic low areas are enhanced compared to variations in high areas.

After some sample plots decision was taken to colour plot all enhanced magnetic maps of the Dighem survey with the revolving spectrum technique. The colour plots make nice displays and experience show that working with geological data on a transparency of the EM map with the colour plotted enhanced magnetic map as an underlay is an exellent method.

The bottom plot in Fig. 4.3 is a standard spectrum plot (equal area as above) combined with the "shadow" plot from an imaginary sun. The "shadow" plot enhances strongly the structures that strike perpendiculary to the direction to the sun. In the test area the technique does not seem successful. The enhanced magnetic map of the test area contains strong and well defined structures that do not need the shadows.

Other examples show that the shadow technique may be very useful, especially in areas that are magnetic "quiet". The method should be used in an interactive mode with the geologist/geophysicist sitting by the screen and varying the position of the sun (both direction and height) to produce the best possible results. Working on a more regionale scale would probably be more suitable for the method.

For regional work the newly developed technique of "greyshade" processing looks very promising and should also be considered.

VLF - EM

VLF - EM systems were included in both the NGU surveys and in the Dighem survey. The VLF primary field sets up currents which tend to collect in low resistivity zones such as shears, river valleys, unconformities, sulphide zones and graphite units. Fig. 5 shows the Dighem VLF filtered total field of the test area. Most of the EM conductors also occur as VLF anomalies. There are however four strong EM anomalies that do not produce VLF anomalies, these are marked with X in Fig. 5. These four anomalies illustrates very well one weakness of the VLF system. Conductors that strike perpendiculary to the direction to the transmitter will not be energized and yield VLF anomalies. Features that strike parallell with the VLF transmitter azimuth will be well energized and the apparent strength of these features (north-northeast) will be overestimated.

The fault that cut the western limb of the anticline (Fig. 1) has got a favourable direction for the VLF transmitter used in this survey. The fault occurs as a well defined VLF anomaly marked F in Fig. 5.

The VLF anomaly marked T in Fig. 5 coincides with a weak Turam anomaly. This anomaly occur at the contact between meta diabase and argillite. A very weak sulphide mineralization may be the explanation. The zone is not registrated by the helicopter EM.

The energizing problems of the VLF system may be minimized by the use of two receivers tuned to two different VLF transmitters. With irregular shut downs of the transmitters this dependency of two transmitters will often delay the survey.

SURVEY AND PROCESSING COSTS

Total costs for the NGU surveys was about NOK 250 pr. line km (1980/81). To operate at such a low cost is possible only for a gouvernment organization. The total costs for the Dighem survey was NOK 580 pr. line km. The Dighem processing of the NGU data amounted to NOK 100 pr. line km.

Estimates show that the helicopter survey costs are only 15 - 20 percent of the total exploration costs. With a high quality helicopter survey follow-up expences are reduced. This reduction may be greater than the additional survey costs compared with a low quality survey. What also must be considered is if the low quality survey provides the necessary information that is required for a proper follow up work.

The quality of the processing of the NGU survey was so low that the problem was not a question of reprocessing or not, but of reprocessing or a new survey. The results show that the processing is cost-effective compared with a new survey.

The colour plotting of four copies of the enhanced magnetic maps cost NOK 1700 pr. sheet (about 1.10 x 0.80 cm). This could have been done at a lower cost by hand colouring (about NOK 1200 pr. sheet). The hand-coloured maps are however not nearly as nice as the colour plotted ones. With more copies of each sheet the colour plotting will be more costeffectiv.

CONCLUSIONS

Helicopterborne geophysical surveys contain a large amount of information. By a poor processing information may be removed or remain hidden in geological and technical noise. The exploration for Bidjovagge type deposits in the Gulf joint venture area has shown that the following points are important:

1. Navigation and flight path recovery must be as exact as possible. This means the use of a photo mosaic as a navigation map and in the future an automatic navigation device.

2. The electromagnetic system must be technically up to date to ensure a minimum of technical noise and drift.

3. Both digital filtering and hand labour by an experienced geophysicist must be used to remove false anomalies from the EM data.

4. A multicoil EM system is superior to a single coil system. Valuable information about conductor geometry may be extracted from multicoil data.

5. Resistivity maps are very useful for geological interpretation, but require high quality EM data.

6. The best way to display magnetic data is by the use of an advanced contouring computer programme.

7. The enhanced magnetic map bears great resemblance to ground magnetic results and is a very important part of the magnetic presentation.

8. For the study of individual anomalies digital profiles containing all measured and calculated parameters should be used.

9. Compared with low frequency EM, VLF gives additional information about large scale geological features. The main limitation of the VLF method is that features that strikes perpendiculary to the transmitter azimut do not yield anomalies.

10. The most useful maps when exploring for Bidjovagge-type deposits are EM and resistivity in combination with enhanced magnetics. Detailed EM and resistivity maps detect breaks and irregularities of the long graphitic conductors. These features are often associated with mineralization. The enhanced magnetic map may detect ore related carbonatization of the greenstones.

Stabekk, 13.02.1985

Ragnar Hagen

Fig. 1.

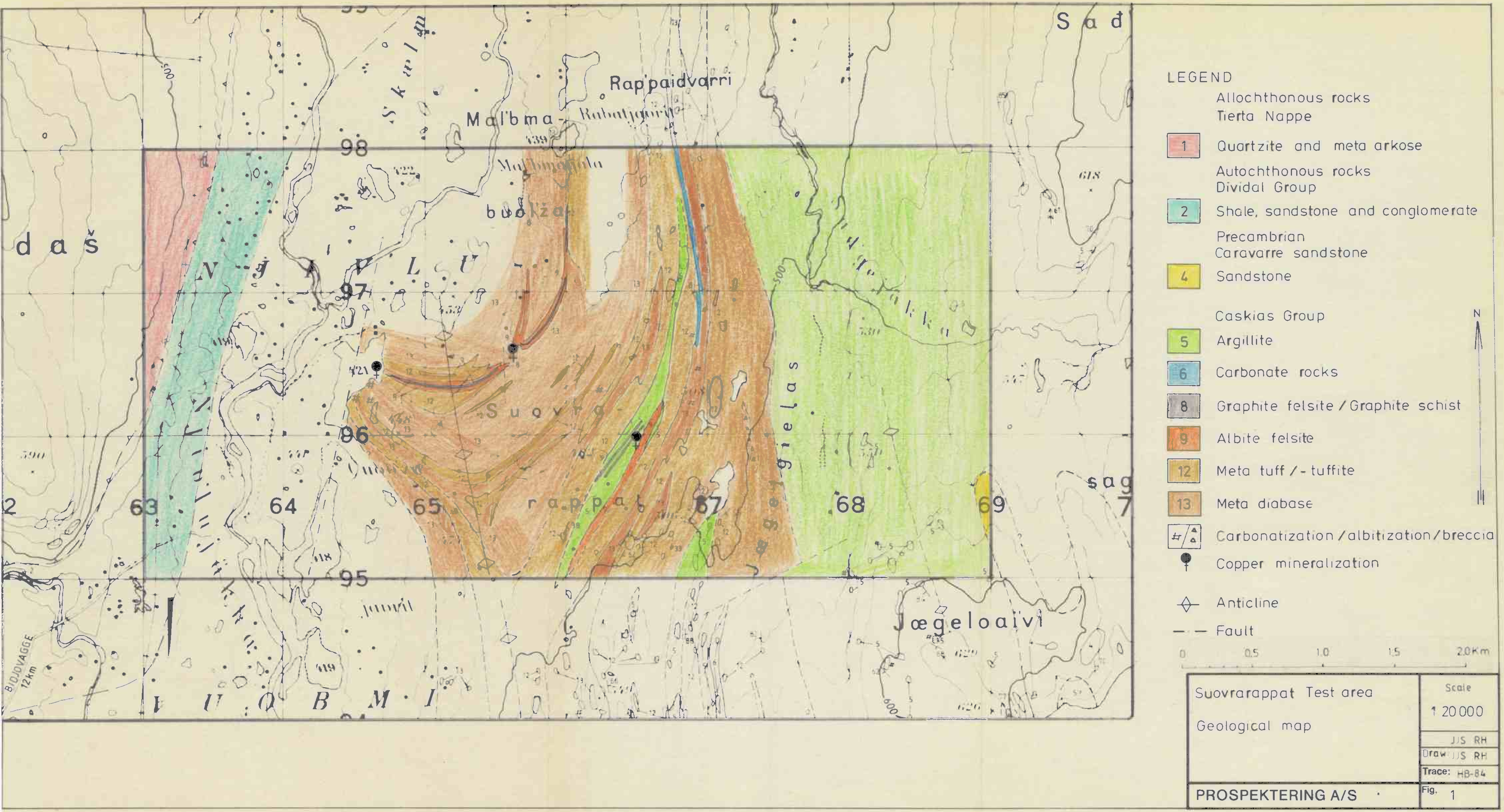
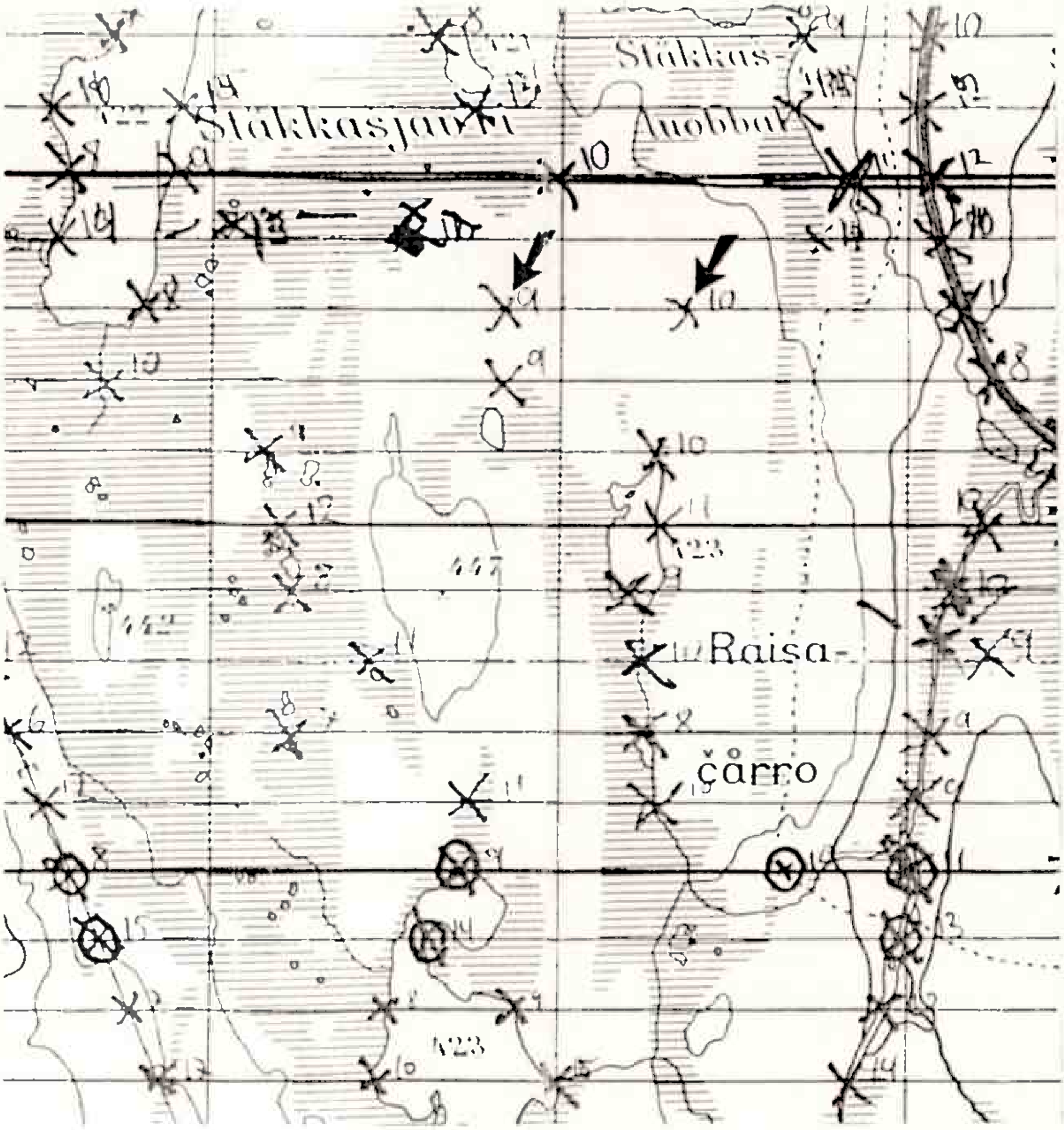
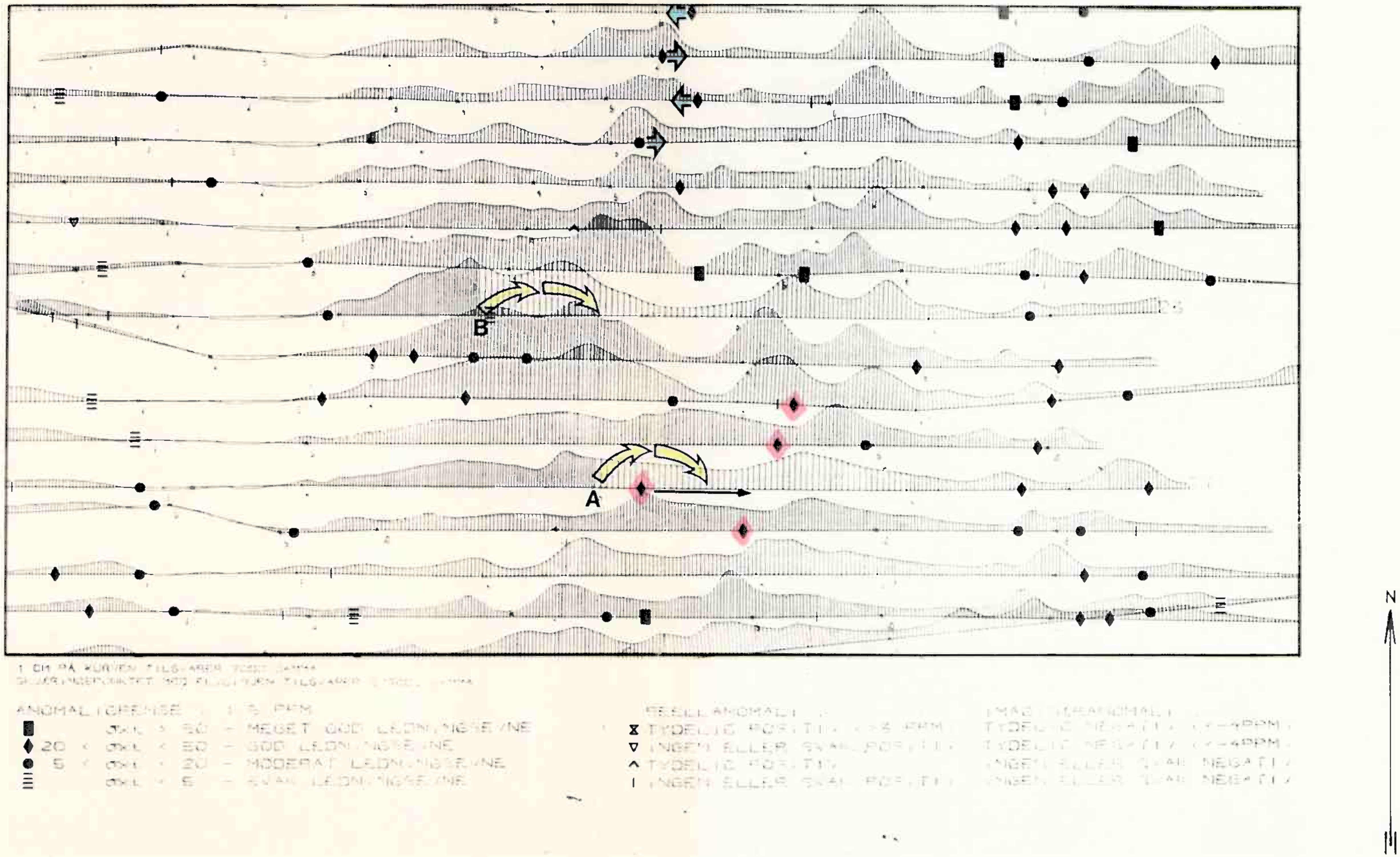

Rap'paidvarri
Mal'bma-
buolža
Suovra-
rappat
Jægeloaivi
BIDJOVAGGE 12km
LEGEND
Allochthonous rocks
Tierta Nappe
1 Quartzite and meta arkose
Autochthonous rocks
Dividal Group
2 Shale, sandstone and conglomerate
Precambrian
Caravarre sandstone
4 Sandstone
Caskias Group
5 Argillite
6 Carbonate rocks
8 Graphite felsite / Graphite schist
9 Albite felsite
12 Meta tuff / - tuffite
13 Meta diabase
Carbonatization / albitization / breccia
Copper mineralization
Anticline
Fault
0 0.5 1.0 1.5 2.0Km
N
Suovrarappat Test area
Geological map
Scale
1 : 20 000
JJS RH
Draw: JJS RH
Trace: HB-84
PROSPEKTERING A/S
Fig. 1

Fig. 2.



Navigation map NGU 1981	Scale 1:20000
	Obs. NGU 80
	Draw RH 84
	Trace HB 84
PROSPEKTERING A/S	Fig 2.1

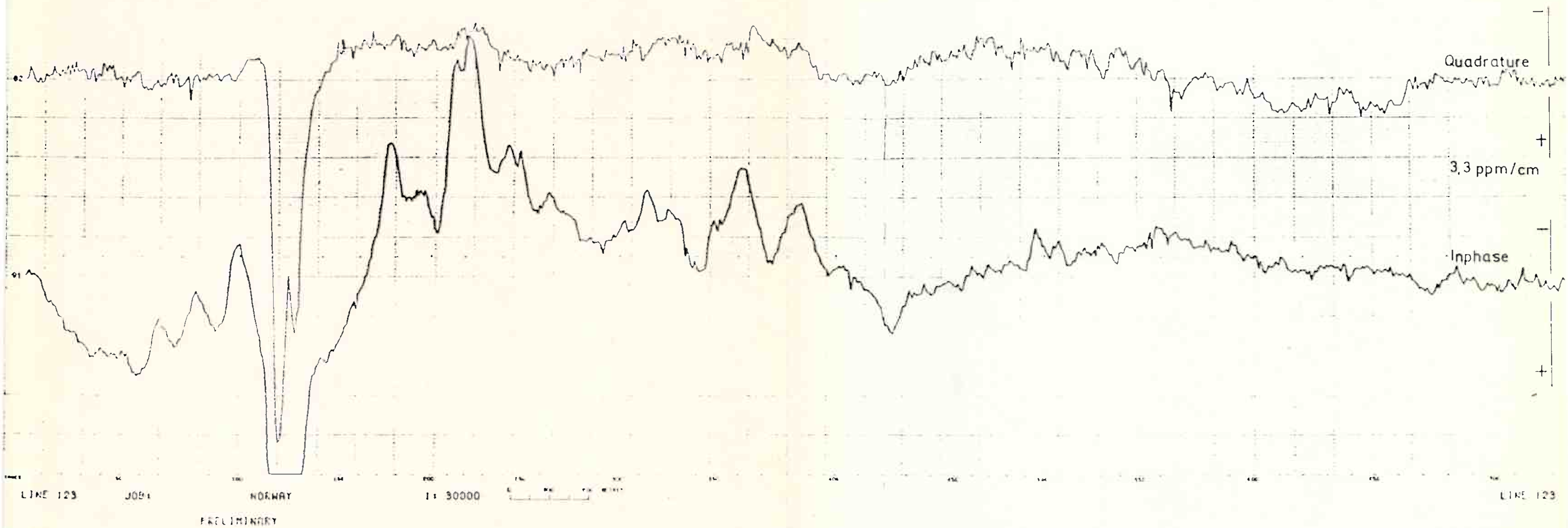


Positioning errors

0 0.5 1.0 1.5 2.0 Km

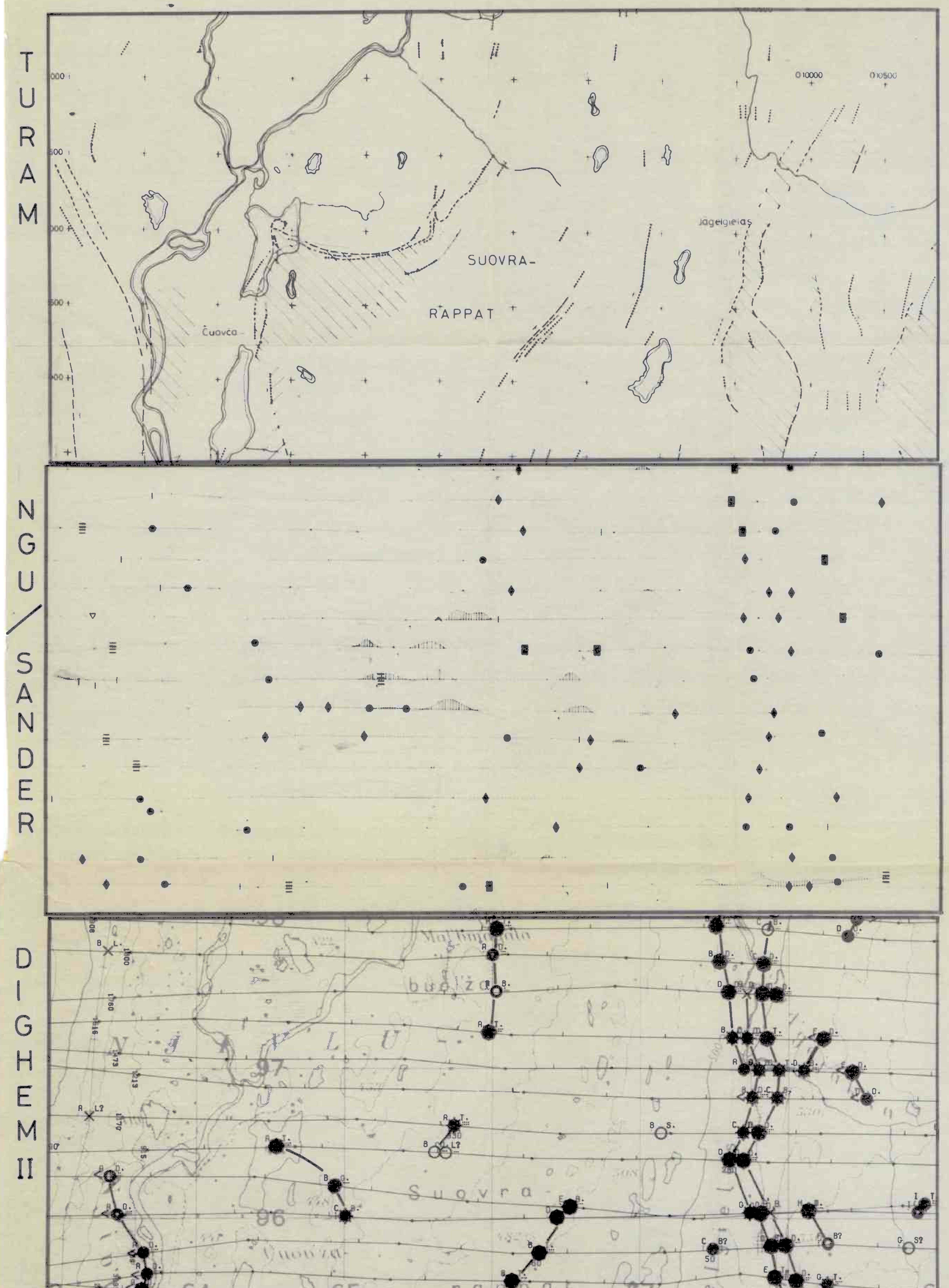
Test area Suovrarappat NGU EM + mag.	Scale 1:20 000
	Measured: NGU 80
	Draw: R.H. 84
	Trace: HB 84
PROSPEKTERING A/S	Fig. 2.2

Fig. 3.



Helicopter EM Raw data NGU/Sander	M 1:30000
	Målt NGU /80
	Tegn RH 2/85
	Trace RH 2/85
PROSPEKTERING A/S	Fig. 3.1

ELECTROMAGNETICS



TURAM INDICATIONS

- Very good conductor
- Good
- Weak
- Very weak conductor

N

0 0,5 1,0 1,5 2,0 Km

ANOMALY GRADE	EM GRADE SYMBOL	CONDUCTANCE RANGE (MHOS)
6	●	> 99
5	✸	50 — 99
4	●	20 — 49
3	●	10 — 19
2	○	5 — 9
1	○	< 5
—	×	indeterminate

DIGHEM anomalies are divided into six grades of conductivity-thickness product. This product in mhos is the reciprocal of resistance in ohms. The mho is a measure of conductance, and is a geologic parameter.

identifier name → interpretive symbol

Depth is greater than 15 m, 30 m, 45 m, 60 m

Inphase and Quadrature of Coaxial Coil is greater than 5 ppm, 10 ppm, 15 ppm, 20 ppm

Refer to list of anomalies in survey report for the actual ppm values for all coils, and for the conductance and depth of conductors

The interpretation is shown by the interpretive symbol (see legend below). The left letter is the anomaly identifier. The horizontal rows of dots indicate anomaly amplitude on the flight record, and the vertical column gives the estimated depth. This depth may be unreliable because the stronger part of the conductor may be deeper or to one side of the flight line, or because of a shallow dip or conductive overburden effects.

SYMBOL	GEOPHYSICAL MODEL	BEDROCK CONDUCTOR	or	NON-BEDROCK CONDUCTOR	MOST LIKELY
D.	steeply-dipping thin dike	steeply dipping planar conductor	or	metal culture which contacts conductive ground	discrete bedrock conductor
T.	thick dike	thick conductor, with thickness greater than 10 m	or		
B.	indeterminate	bedrock conductor	or		
P.	conductor to one side of flight line	flight line passed off the end or side of conductor	or	flight line passed off the end or side of culture	
H.	half space (close to surface)	conductive rock unit	or	deep conductive weathering or thick conductive cover	conductive rock or cover
G.	buried half space	conductive rock unit "buried" under non-conductive cover or under a dense forest canopy	or	deep conductive weathering or thick conductive cover "buried" under a dense forest canopy	
S.	horizontal sheet	weak bedrock conductor masked by conductive cover	or	thin conductive cover or, occasionally, culture which contacts conductive cover	conductive cover
R.	horizontal ribbon	flatly-dipping narrow conductor (not computer picked)	or	narrow surface conductor, e.g., stream sediments; or large fenced area	culture
C.	sphere, horizontal disk	steeply-plunging compact conductor	or	metal roof or fenced yard	
L.	line	bedrock conductor masked by culture	or	fence, pipeline, power line	
a?	"a" is one of the above symbols, "a?" means that the correct identification of the geophysical model is only a reasonable possibility, rather than being a reasonable probability				
?	probable aerodynamic noise, meaning that conductive material may, in fact, not exist				

Test area Suovrarappat Electromagnetics	Scale 1:20000
	Draw R.H. 84
	Trace H.B. 84
PROSPEKTERING A/S	Fig. 3.2

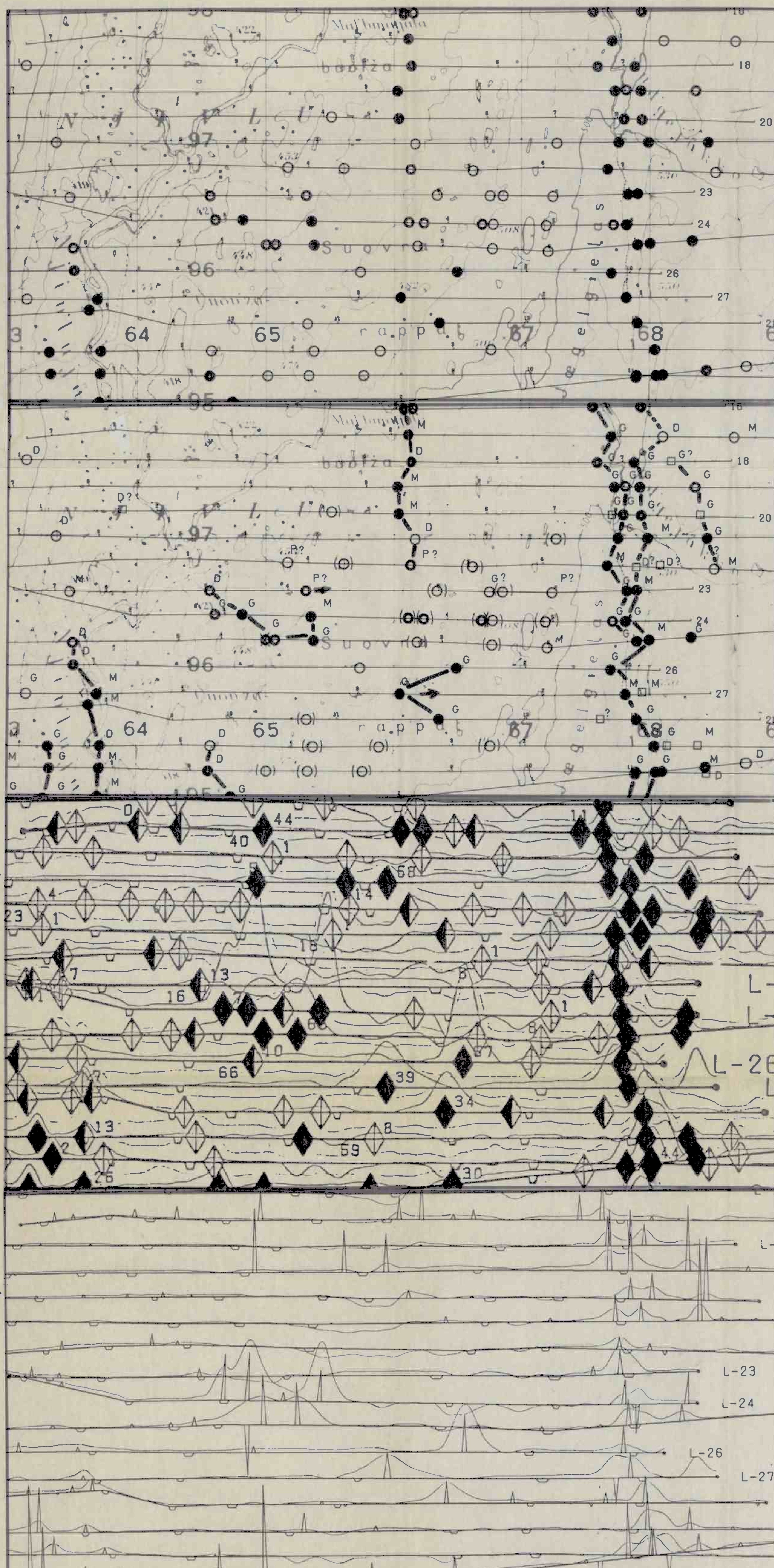
ELECTROMAGNETICS

NGU / DIGHEM

NGU / DIGH. + INTERP.

NGU / GEOTERREX

NGU / GEOTERREX



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%

Vertical coaxial coils

Coil seperation 6.7m

Frequency 1000 Hz

LEGEND

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○	1	40–60%

Vertical coaxial coils:

Coil seperation: 6.7m

Frequency: 1000 Hz

EM interpretation

- G Good conductor (R/I > 2)
- M - Medium conductor (1 < R/I < 2)
- D - Poor conductor (R/I < 1)
- P - Quality of conductor undefined due to magnetic polarization.
- □ Anomaly not recognized by Dighem's processing
- (○) Anomaly caused by magnetic polarization or by conductive overburden.
- ⊗ Anomaly caused by noise.
- ? Interpretation uncertain.
- Conductor axis
- Conductor axis, uncertain.
- ← Positioning error.

◆ σ×t > 20

◆ 10 ≤ σ×t ≤ 20

◇ σ×t < 10

Inphase only anomalies + both (IP+Q) anomalies

Quadrature only anomalies

N

0 0.5 1.0 2.0 km

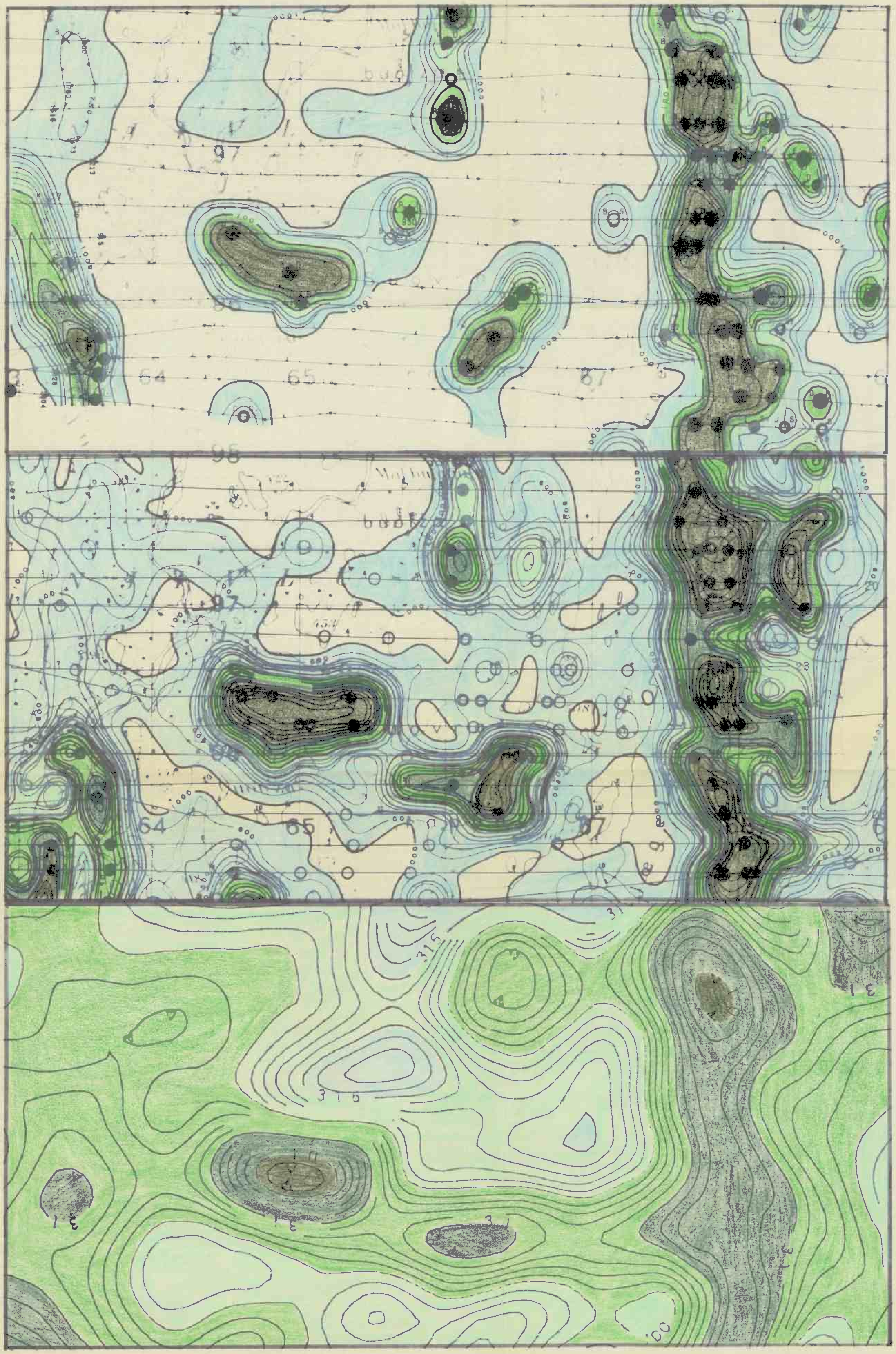
Test area Suovrarappat Electromagnetics	Scale 1 20 000
	Draw. R.M. 84
	Trace: H.B. 84
PROSPEKTERING A/S	Fig. 3.3

RESISTIVITY

DIGHEM II

NGU/DIGHEM

NGU/GEOTERREX



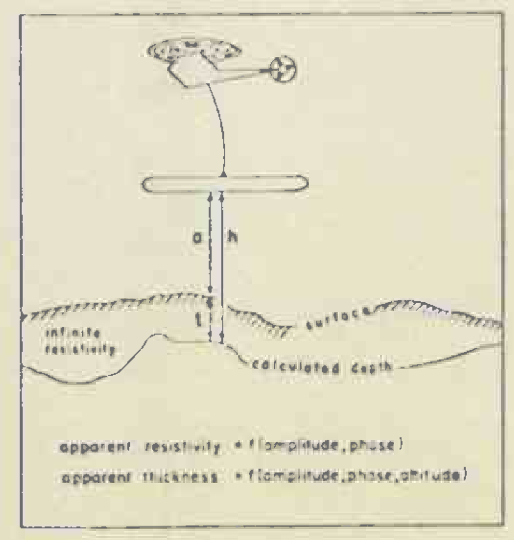
LEGEND

Contours in ohm – m
at eight intervals per decade

100
75
56
42
31
23
17
13
10

Note

The numbers face in the direction of increasing value.



Vertical coaxial coils

Coil seperation 6.7 m

Frequency 1000 Hz

LEGEND

Contours in ohm – m
at ten intervals per decade

1000
800
600
500
400
300
250
200
150
125
100

Note

The numbers face in the direction of increasing value

< 10 Ω m

10 - 25 / 31 Ω m

25/31 - 100 Ω m

100 - 250 / 315 Ω

250 / 315 - 1000 Ω

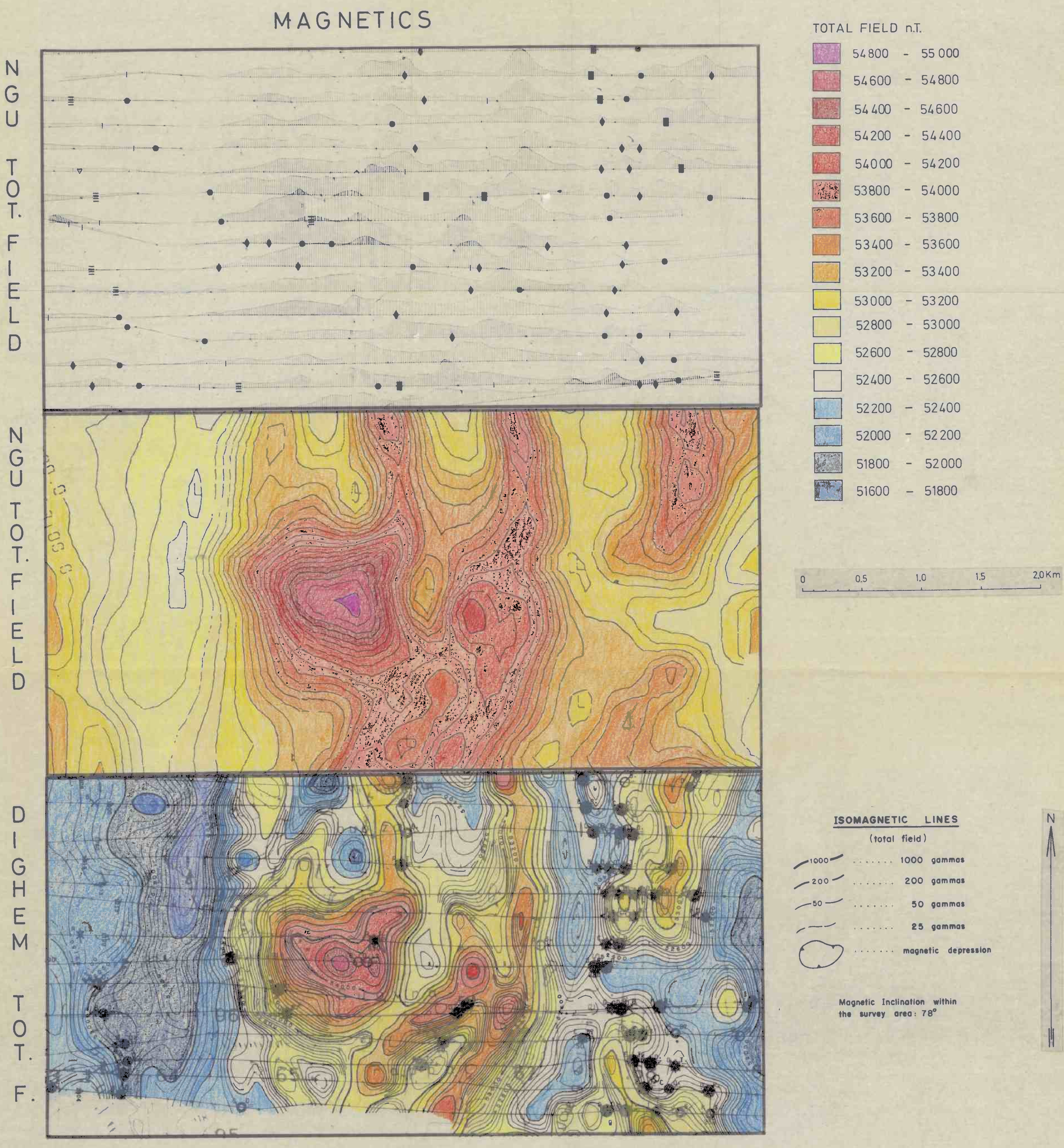
> 1000 Ω m

0 0.5 1.0 1.5 2.0 Km

N

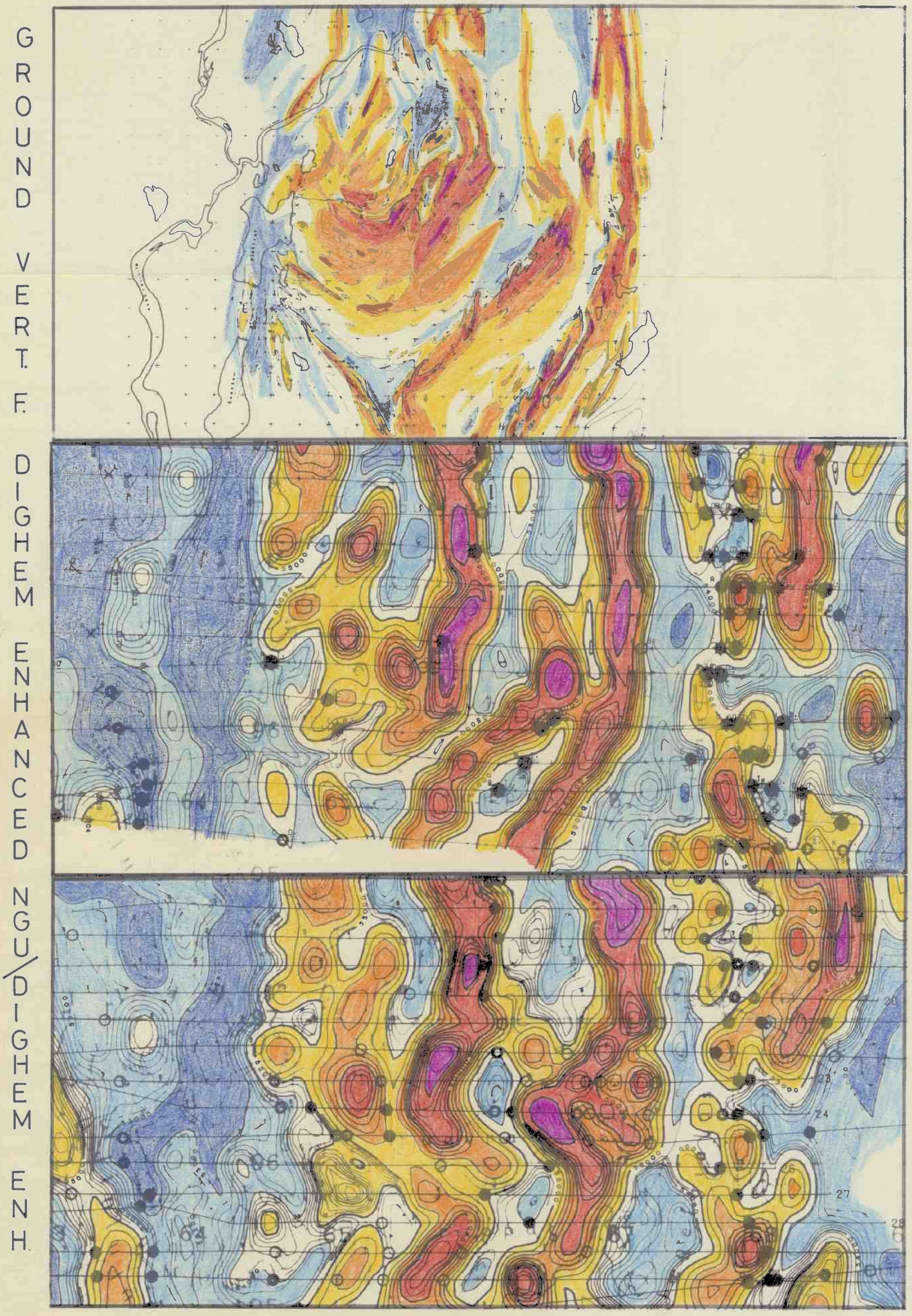
Test area Suovrarappat Resistivity	Scale 1:20 000
	Draw R.H. 84
	Trace H.B. 84
PROSPEKTERING A/S	Fig. 34

Fig. 4.



Test area Suovrarappat Magnetics	Scale 1:20 000
	Draw R H 84
	Trace H.B. 84
PROSPEKTERING A/S	Fig 4.1

MAGNETICS



n.T.

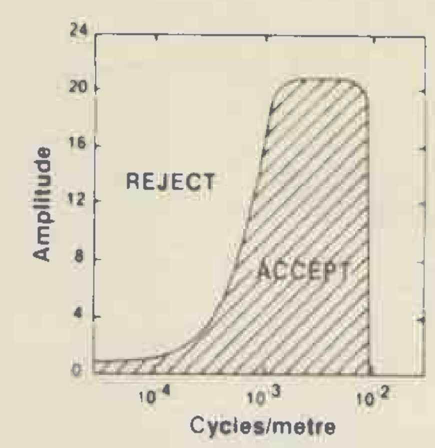
Ground vertical field	Enchanced
> 4000	> 65000
2000 - 4000	60000 - 65000
1000 - 2000	57000 - 60 000
500 - 1000	55000 - 57000
0 - 500	54000 - 55000
-200 - 0	53000 - 54000
< -200	<53000

0 0.5 1.0 1.5 2.0 Km

N

ISOMAGNETIC LINES
(enhanced field)

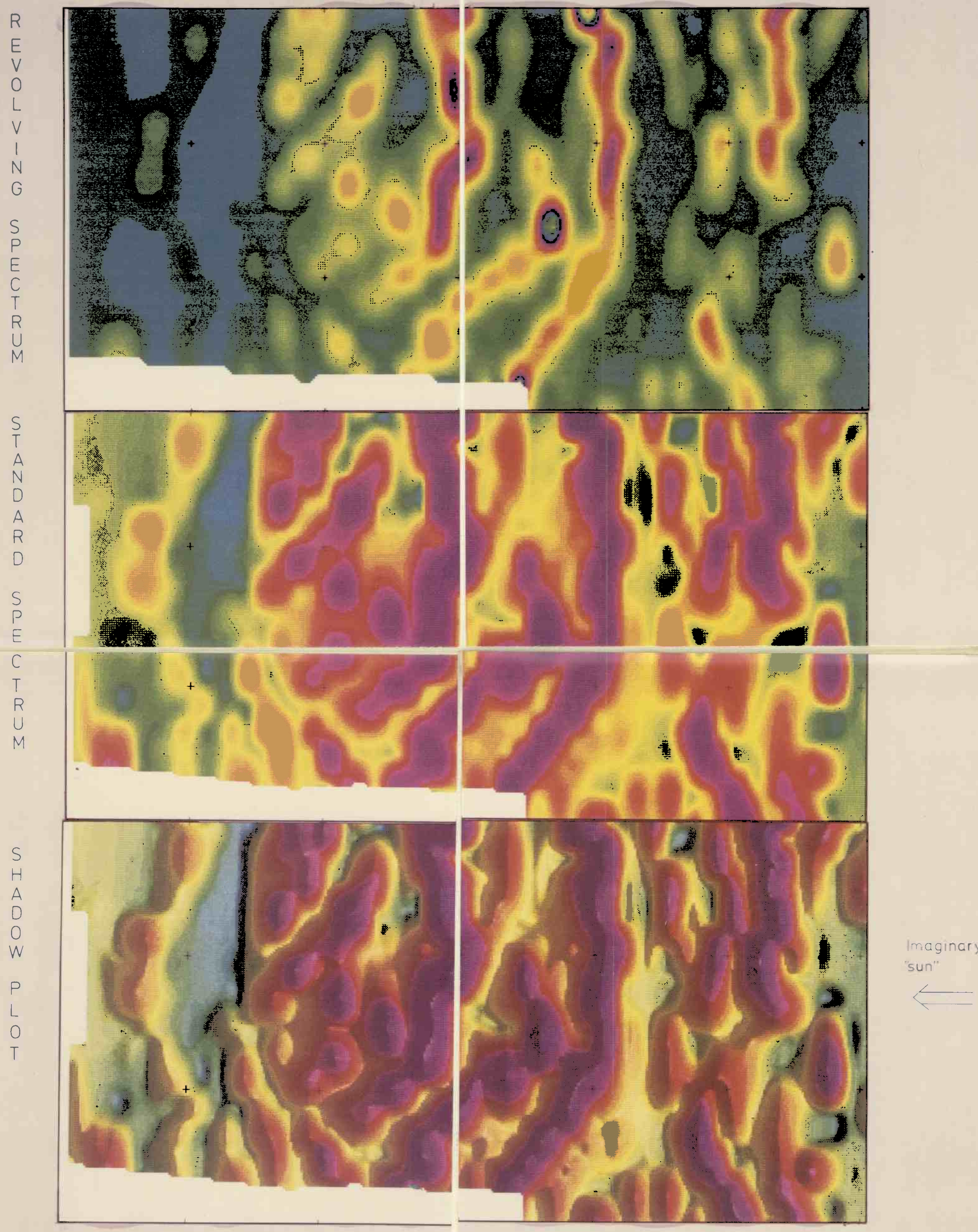
5 000 nT
1 000 nT
200 nT
100 nT
magnetic depression



Frequency response of magnetic operator

Test area Suovrarappat Magnetics	Scale 1 20 000
	Draw R H 84
	Trace: H B 84
PROSPEKTERING A/S	Fig. 4 2

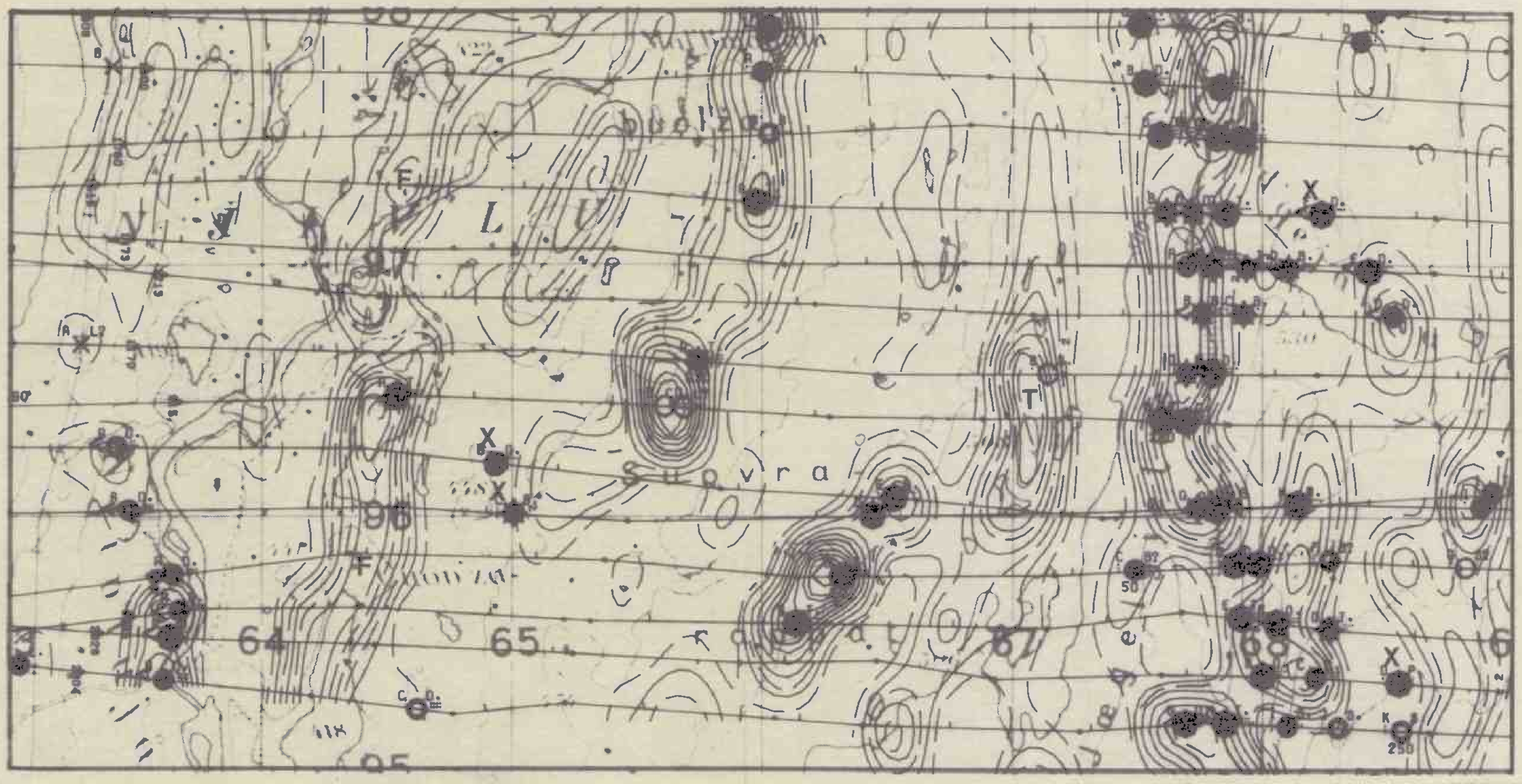
COLOUR-PLOTTING ENHANCED MAGNETICS



Test area	M
Suovrarappat	1:20 000
Enhanced magnetics	Målt
Colour plotting	Tegn RH 1/85
	Trace HB 1/85
PROSPEKTERING A/S	Fig. 4.3

Fig. 5

VLF-EM Filtered total field.



LEGEND

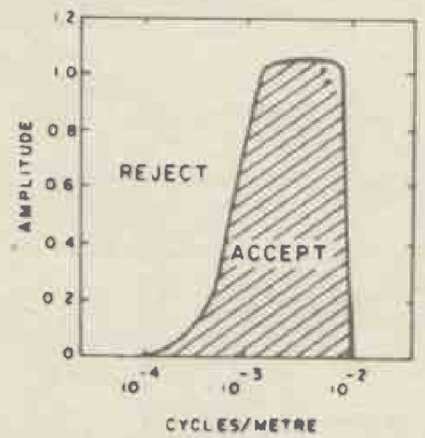
Contours in percent

10

4

2

The numbers face in the direction of increasing value



Frequency response of VLF – EM filter

N

VLF transmitter azimut (~225°)

0 0.5 1.0 1.5 2.0 Km

Test area Suovrarappat VLF-Dighem	Scale 1:20000
	Trace
PROSPEKTERING A/S	Fig. 5