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Report on the results of ground geophysical surveys for verifying airborne local magnetic anomalies in Norway (South Pasvik Area)

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Report on the results of ground geophysical surveys for verifying airborne local magnetic anomalies in Norway (South Pasvik Area)

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Sammendrag:

Det er gjort bakkegeofysikk over 4 utvalgte anomalier fra flymålinger. Flymålingene ble gjort sommeren 1993 som et samarbeid mellom NGU, Pechenganikel og Petersburg Geophysical Survey (PGE), og dekket de sørlige deler av Pasvik og tilstøtende deler av Russland. De ble utført av PGE med russisk fly og utstyr. PGEs erfaring i leting etter diamantførende diatremer ble lagt til grunn for utvelgelse av anomalier for bakkeoppfølging sommeren 1994. Undersøkelsene ble utført av 3 russere fra PGE og Thorleif Lauritsen, NGU. Rapporten er skrevet av NGUs russiske samarbeidspartner (PGE) uten redigering fra NGUs side.

Flyanomaliene ble undersøkt i felt med magnetometri, gravimetri og susceptibilitetsmålinger. Innsamlede bergartsprøver er laboratoriemålt og mikroskopert.

Anomali 1 løste seg opp i flere skarpe, lineære anomalier som sannsynligvis skyldes magnetitt og sulfider.
Anomali 2 ble ikke detaljundersøkt.
Anomali 3 antas å ha en rør-liknende årsak. Detaljert gravimetri bør utføres.
Anomali 4 skyldes magnetittførende amfibolitter.

Dersom videre undersøkelser av anomali 3 bekrefter muligheten for en rørformet anomaliårsak (diatrem) må også den nærliggende anomali 2 undersøkes.

Emneord: Mineralressurser	Diamanter	
Geofysikk		
Geologisk undersøkelse		Fagrapport

R E P O R T

ON THE RESULTS OF GROUND GEOPHYSICAL SURVEYS FOR VERIFYING AIRBORNE LOCAL MAGNETIC ANOMALIES IN NORWAY

(South Pasvik area)

PETERSBURG GEOPHYSICAL EXPEDITION
State Enterprise

Saint Petersburg
Russia
1994

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INTRODUCTION

This report deals with the results of the joint ground geophysical surveys effected for the purpose of verifying the local airborne magnetic anomalies supposedly of a diatreme type, as they had been detected by airborne magnetic-EM survey on a scale of 1/25000 over the Shuort area in Norway.

Work was carried out by the specialists of the "Petersburg Geophysical Expedition" State Enterprise (PGE, Russia) under the Contract with the Geological Survey of Norway (NGU) within the framework of a joint Norwegian-Russian Project. As it is specified in the Contract, during a field season in a period August 17-25, 1994, three airborne anomalies were subject to integrated geophysical measurements of a magnetic field intensity and magnetic susceptibility. On some profiles these measurements included gravimetric and electrical surveys. Besides, one airborne other-than-diatreme-type anomaly was also checked. At the midpoints of magnetic anomalies rock samples were picked to be analyzed for their physical properties. An overall quantity of the profiling with integrated measurements amounted to 17.8 line kilometers.

Field measurements were performed by three specialists of the PGE (Anatoli Chepik - geophysicist, a head of the team; Igor Zuikov - geophysicist; Victor Novitski - geodetic surveyor) and one specialist of the NGU (Thorleis Lauritzen - geophysicist).

The Report has been drawn up by Anatoli Chepik, while Igor Zuikov and Victor Novitski have made their contribution in preparing the text of "Survey Procedure" section. Analyses of the picked rock samples have been made in a Petrophysical Laboratory of the PGE and in a Mineralogical Laboratory of VSEGEI All-Russian Geological Research Institute.

* * *

I. USING THE MAGNETICS IN DIATREME PROSPECTING

Magnetics, and in particular - airborne magnetic survey, is known to be a basic geophysical method of prospecting for kimberlite pipes in many regions all over the world. In Russia, for instance, it was using this very method that nearly all of the presently known target bodies were discovered. Cited here, in the first place, should be, of course, the Yakutian diamond-bearing basin, Archangel area and Kola peninsula.

Normally, the kimberlite rock series display higher magnetic susceptibility than that of the host rocks and, thanks to this, one will in most cases detect over the volcanic pipes the contrasting local anomalies with their geometry close to isometric.

The local anomalies over the pipes may be located within the confines of both an undistorted magnetic field with relatively low horizontal gradients (up to 20-30 nT/km) and a differentiated, highly energized, magnetic field with horizontal gradients ranging 50-500 nT/km. An easiest solution will be, of course, to detect local isometric anomalies within the areas of a steady and quiet magnetic field.

Along with the sought-after kimberlite pipes, the local anomalies possessing similar parameters can be produced also by the accumulations of magnetic minerals in unconsolidated rock masses, or by small magmatic bodies, magmatic rock outliers, etc.

Having gained a certain experience of flowing the airborne magnetic surveys when searching for, and plotting, the diatremes in Archangel area and Kola peninsula, we know already a whole set of relatively persistent indicators and guiding features that the anomalies over the pipe-like targets have. These are: a half maximum distance less that 0.5-0.6 km; nearly isometric geometry, rather restricted locality; contrasting distinction; pretty smooth pattern of a curve along a profile; lack of the accompanying lows; finally, a source object is to be interpreted as a vertical body, its top edge occurring at a depth no less than a thickness of overlying formations. Measuring a magnetic field at an altitude of 80-120 m above the ground, we provide a, so to say, filter that helps to pick the anomalies on the basis of a difference in the height-depending intensity of a delta-Ta magnetic field caused by the bodies of varying vertical thickness.

Figures 1,2,3,4,5,6 show the case histories proving a high efficiency of airborne magnetic survey and a follow-up detail ground study done for the purpose of predicting and plotting the diatremes in the South Kola peninsula area. As seen from the magnetic field maps, the pipe-like anomalies (Anomaly-7, Khlebnoe-1, Anomaly-218) detected by airborne magnetics have an unmistakable outline and because of their parameters are regarded as promising for finding the diatremes therein.

As a result of the ground checking of the aeromagnetic anomalies, the confines of the supposed pipe-like bodies were outlined more definitely, their parameters were determined, and borehole sites were located. Each of those target bodies (Anomaly-7, Anomaly-20, Khlebnoe-1, Anomaly-218) was struck by drilling, and two of them (Anomaly-7 and Anomaly-20) turned out to have a kimberlite composition.

When sorting the aeromagnetic anomalies into promising and not promising for diatremes, what we analyzed in the first place was a magnetic field structure and a presence of distinct local anomalies that would correspond to the aeromagnetic anomalies in question and that would be proven by other geophysical measurements (gravimetric and electrical prospecting surveys). Subject to sorting were those anomalies that broke up into a series of linear zones, or into a swarm of minor broken anomalies, and those accompanied by contrasting lows related to an influence of the bodies' bottom edges.

Owing to such integrated geophysical survey technique the specialists managed to discover about 150 promising local anomalies in the Kola peninsula: more than 100 of those were drilled and 46 volcanic pipes were revealed (as of January 1, 1991). Samples of the geophysical parameters the magnetic anomalies over the known pipes possess are given in Table 1.

When analyzing the airborne magnetic survey data, covering the Shuort area on the scale 1/25000, in terms of pinpointing the pipe-like anomalies, we used those criteria that had been, so to speak, elaborated and mastered in the process of airborne magnetic surveys over the Kola peninsula. These criteria are:

- intensity in a range of 15-60 nT and up to 100 nT;
- size of anomaly in plan view 100 x 100 m, max 500 x 600 m; a ratio range from 1/1 to 1/3 as most favorable;
- no signs of that an anomaly is related (according to aerial visual observation and topographic maps of 1/50000 scale) to the localities of man-made/surface magnetic noises and interferences;
- the best case: an anomaly is confined to a low topography, watered areas, etc;
- higher magnetic susceptibility as compared to host rocks;
- geological/structural setting and local topography of anomalous area; none of the known outcrops of magnetized rocks encountered.

Considering all the abovelisted indicative criteria, within the surveyed portion of the Shuort area (South Pasvik, Fig. 7), in its magnetic field pattern, we picked about 10 local anomalies with their geometry close to isometric. Within the frame of the Contract, ground verification was effected on three most promising pipe-like anomalies (# 1,2,3).

PGE has worked up and put in practice a sequential procedure of geophysical operations for diatreme prospecting in the Kola-Karelian region:

(1) Airborne magnetic survey, scale 1/25000 and 1/10000.

(2) Airborne magnetic survey data processing and interpretation, plotting

Table 1

EXAMPLES OF THE PARAMETERS CALCULATED FOR THE MAGNETIC ANOMALIES OVER THE DIATREMES

Anomaly name/number	Intensity,nT		Linear dimensions		Horizontal gradient in nT/km, airborne	Depth of a target, m		Magnetization, calculated, in $Ix10^{-3}$ A/m	Rock composition of a body, based on drilling data
	airborne delta-Tloc	ground delta-Ta	airborne delta-Tloc	ground delta-Ta		by grnd geophysics	by drilling		
Khlebnoe-1	37	800	350x300	140x70	230	10	7	1300	Olivine-pyroxene-melilitite
Khlebnoe-4	100	1380	550x350	110x60	220	-	21	-	Melilitite-pyroxene pycrite
Zaporozhny-51	25	1800	250x250	150x50	200	10	2	-	Olivine-pyroxene melilitite
Zaporozhny-5a	15	130	600x250	120x50	37	40	21	800	Same
5/83-K	5	700	90x80	80x70	75	15	20	400	Same
7/83-K	56	620	350x300	100x70	220	10	11	2000	Kimberlite
20/83-K	4	86	350x200	60x30	40	15	12	230	Same
218	14	150	250x170	80x100	130	25	15	500	Basic/ultrabasic foidite pipe

CONTOUR MAP OF DELTA-Ta MAGNETIC FIELD, PARTLY SHOWN

AIRBORNE MAGNETIC SURVEY, SCALE 1/10,000

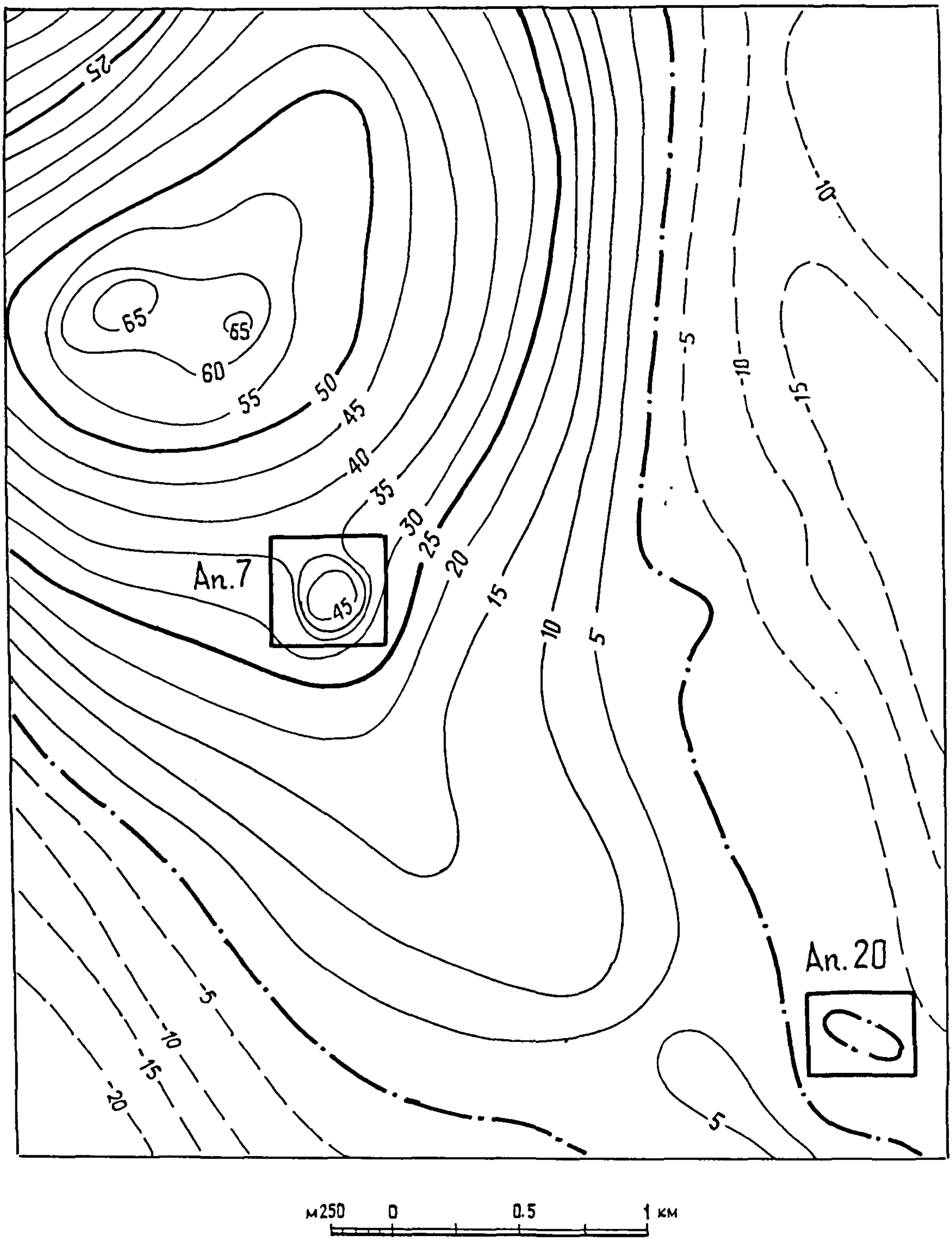


Figure 1

CONTOUR MAP OF DELTA-T_{loc} MAGNETIC FIELD LOCAL ANOMALIES (FRAGMENT)

AIRBORNE MAGNETIC SURVEY, SCALE 1/10,000

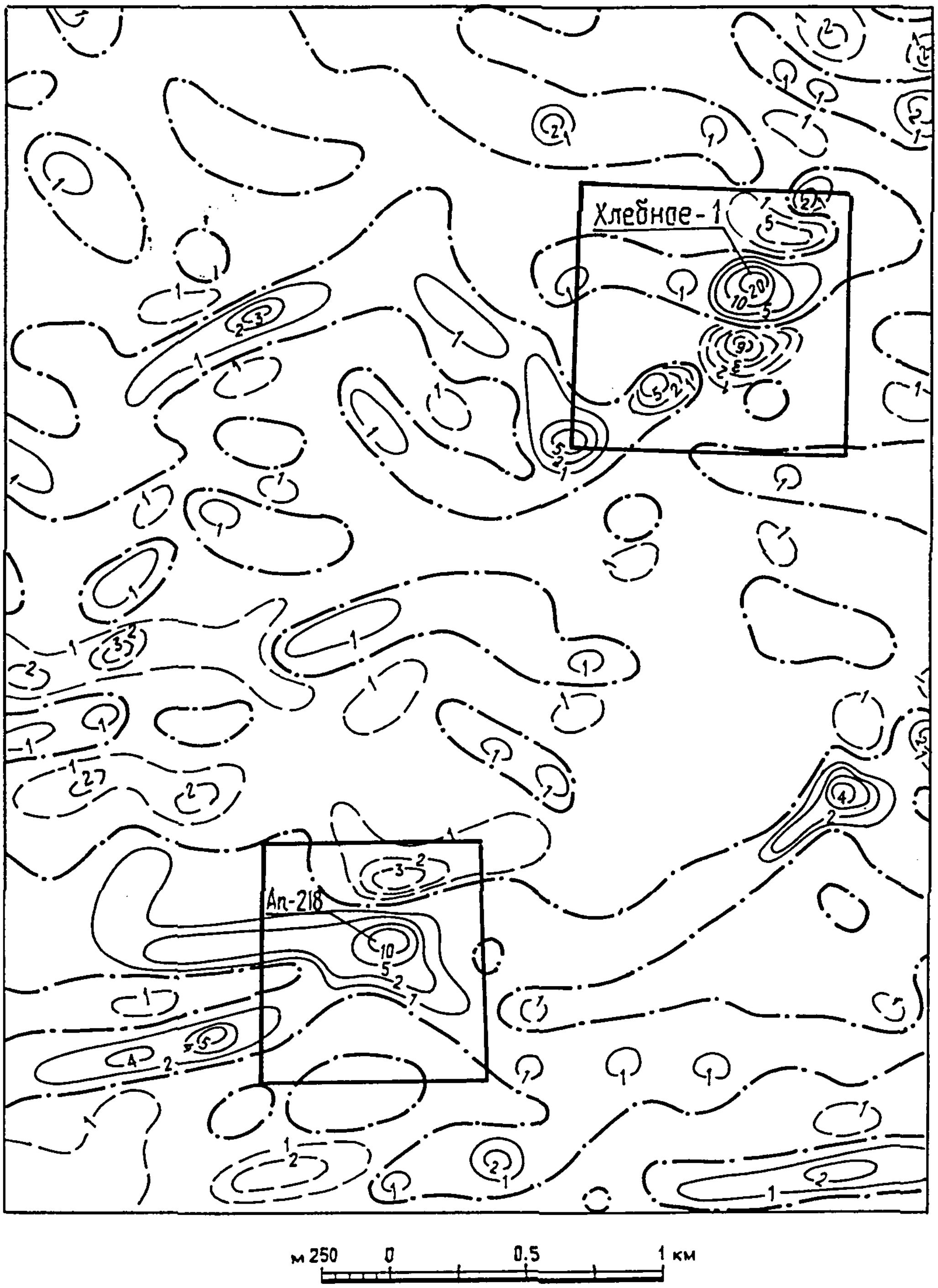


Figure 2

Delta-Ta magnetic field graph and geological section along the profile crossing anomaly #7's center

Scale 1/2000

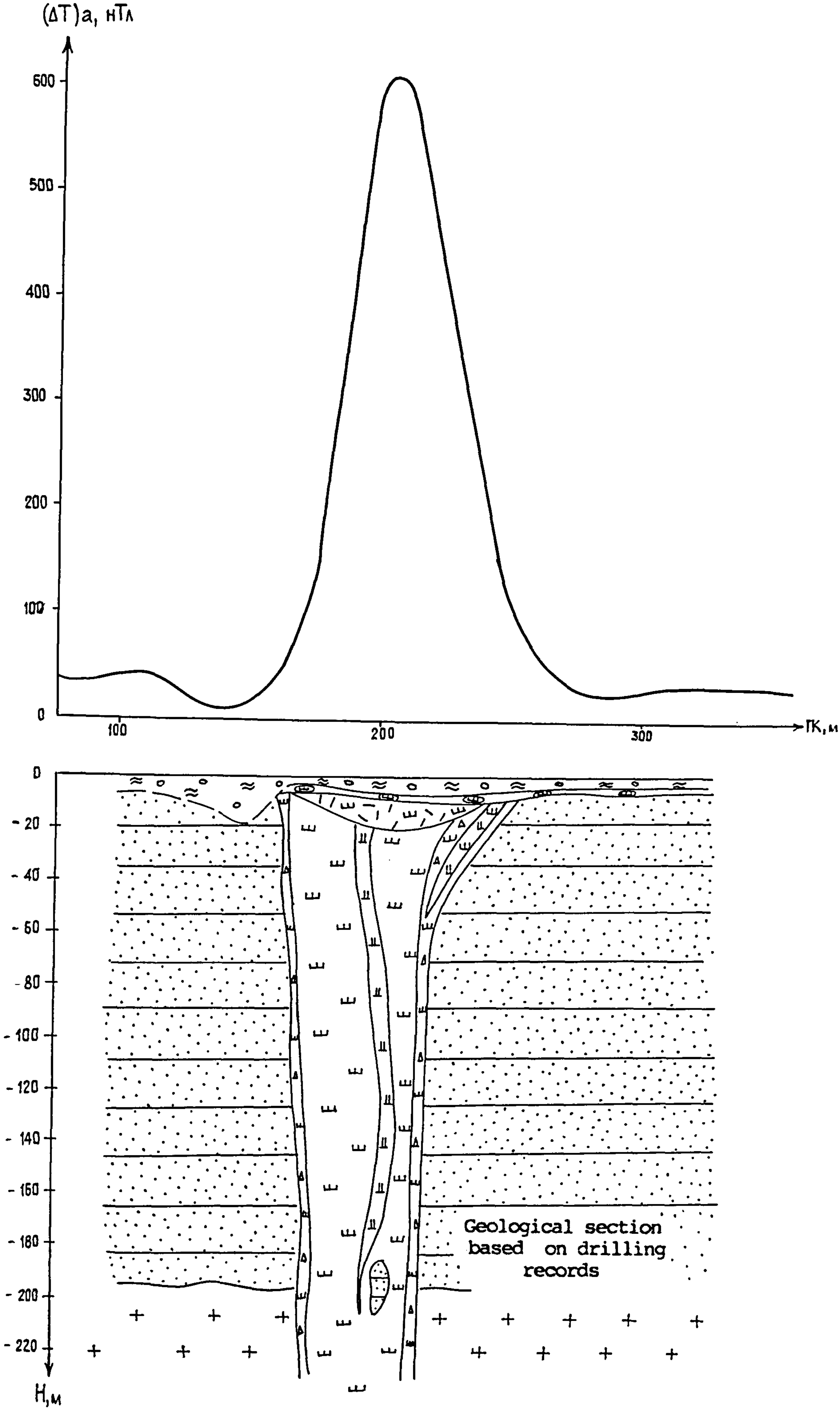
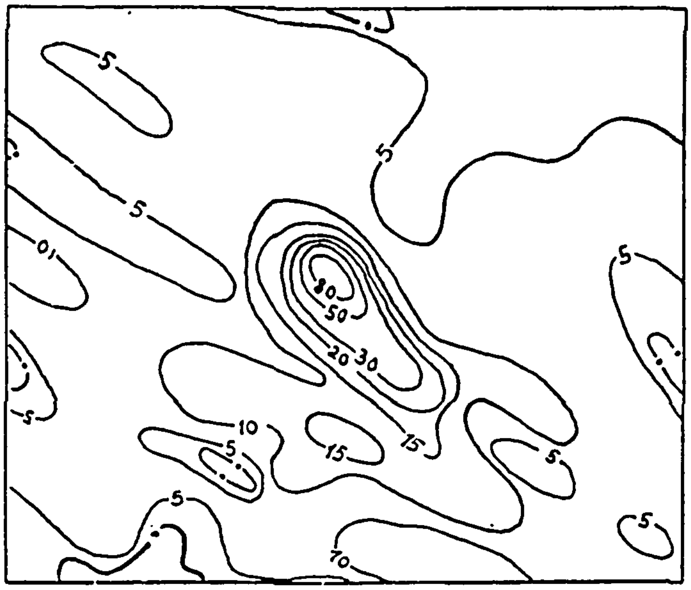


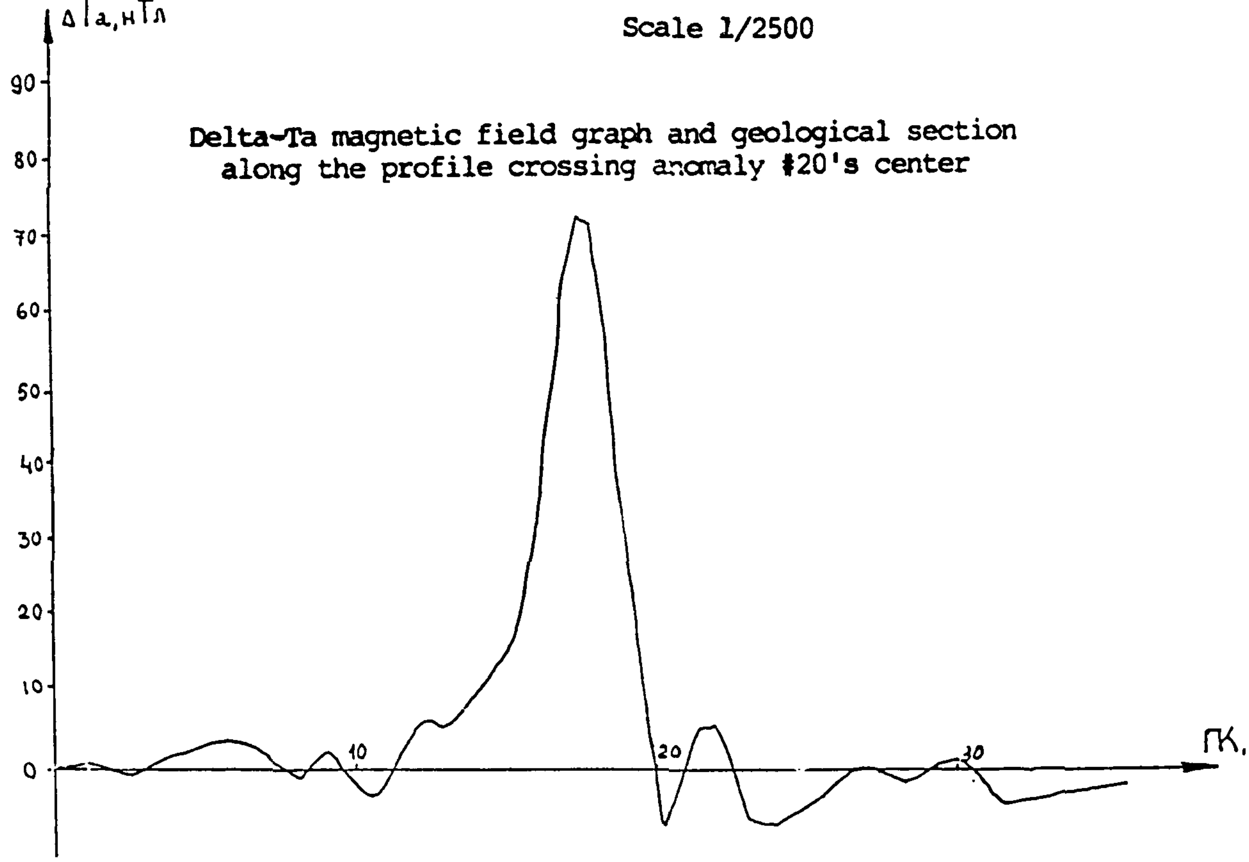
Figure 3

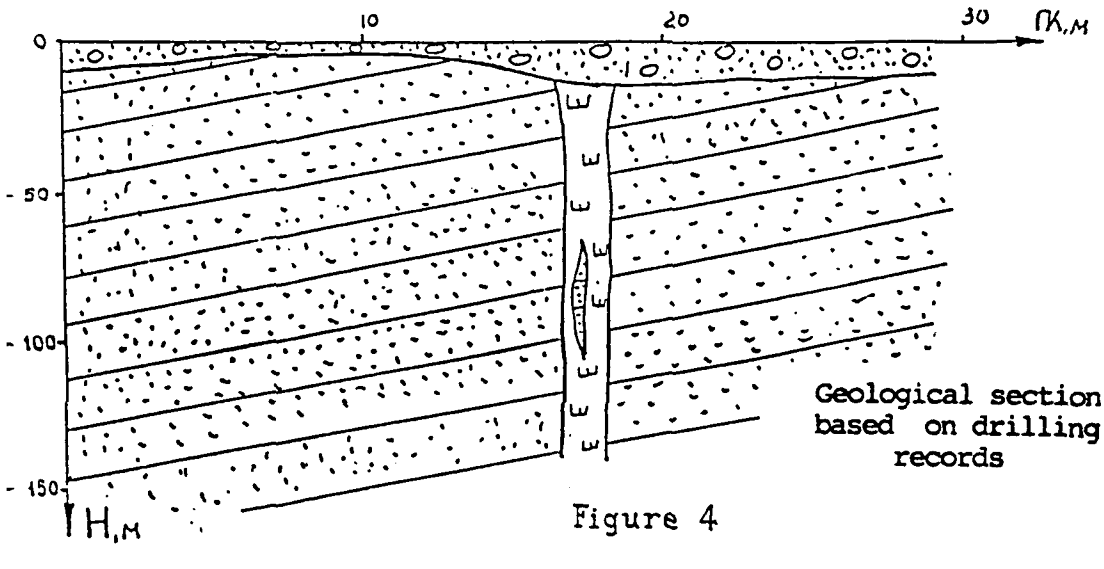
Results of ground magnetic survey in anomaly #20 area
(contour map's fragment)



Scale 1/2500

Delta-Ta magnetic field graph and geological section
along the profile crossing anomaly #20's center





Geological section
based on drilling
records

Figure 4

CONTOUR MAP OF DELTA-Ta MAGNETIC FIELD

Khlebnoe-1 anomaly ground checking area

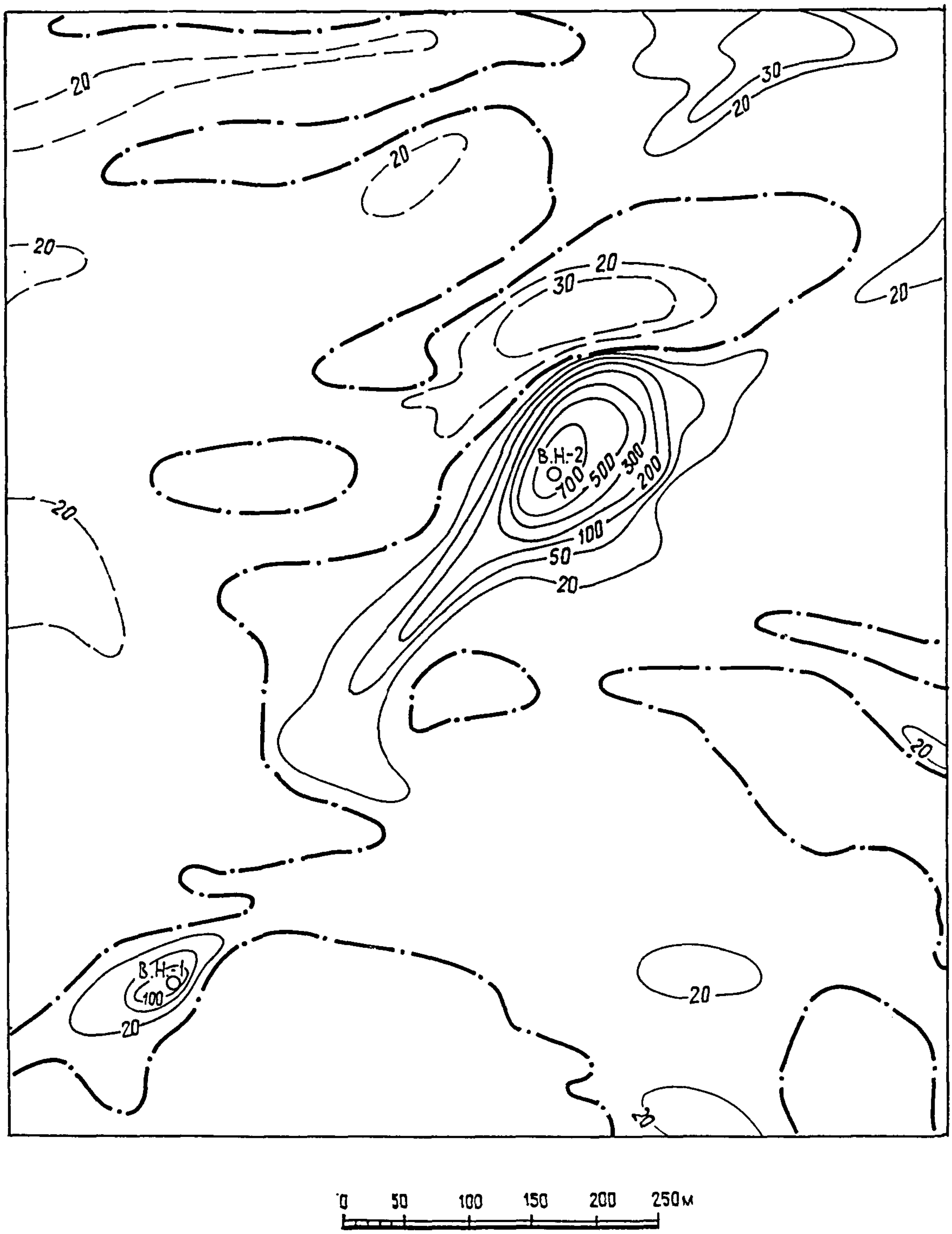


Figure 5

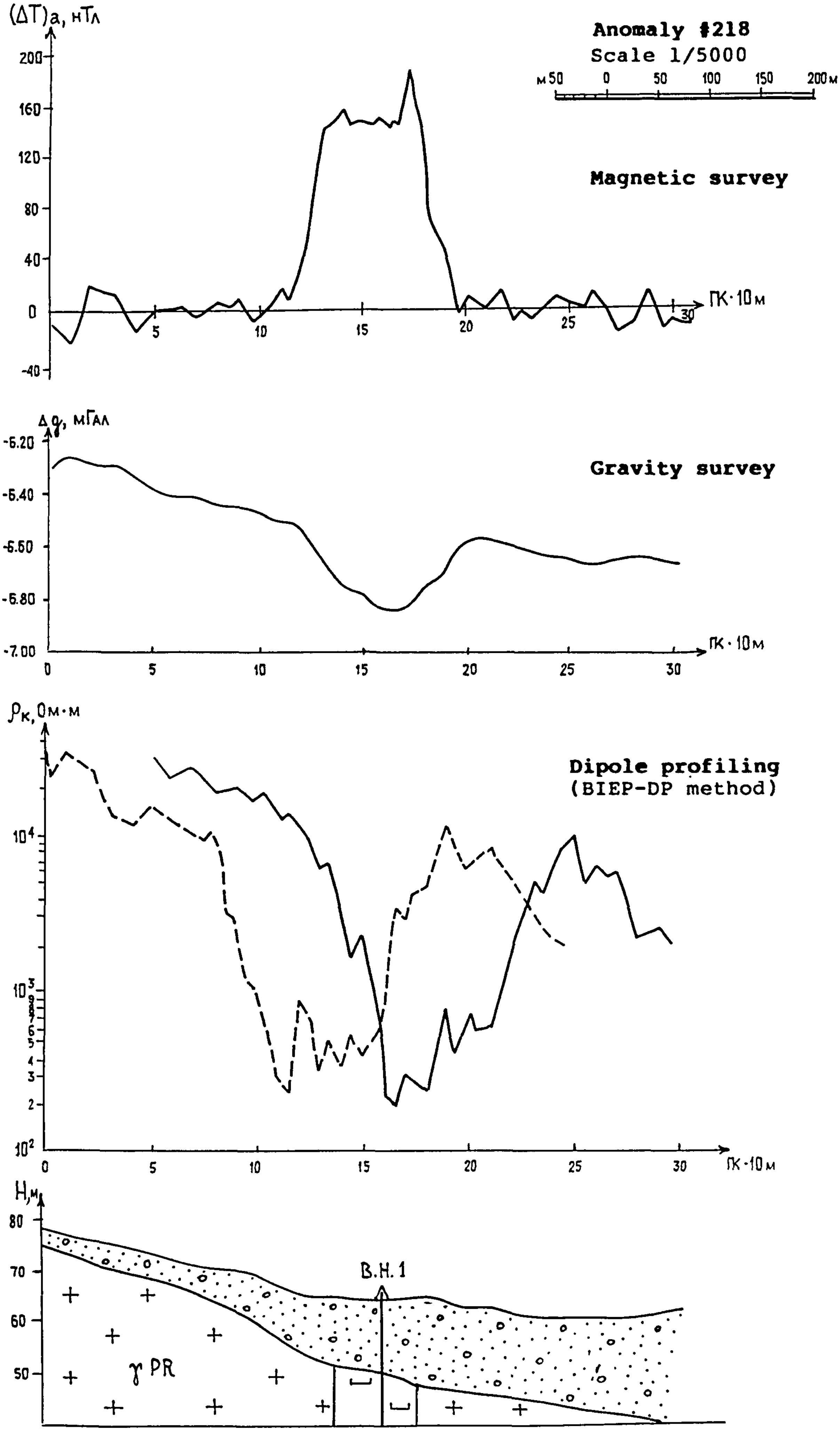

Anomaly #218
Scale 1/5000
м 50 0 50 100 150 200 м
Magnetic survey
(ΔT)a, нТл
200
160
120
80
40
0
-40
5 10 15 20 25 30
ПК·10м
Gravity survey
Δg, мГал
-6.20
-6.40
-6.60
-6.80
-7.00
0 5 10 15 20 25 30
ПК·10м
Dipole profiling
(BIEP-DP method)
ρк, Ом·м
10⁴
10³
9
8
7
6
5
4
3
2
10²
0 5 10 15 20 25 30
ПК·10м
H,м
80
70
60
50
B.H.1
γ PR

Figure 6

CONTOUR MAP OF DELTA-Ta MAGNETIC FIELD

(FRAGMENT)

AIRBORNE GEOPHYSICAL SURVEY, SCALE 1/25,000

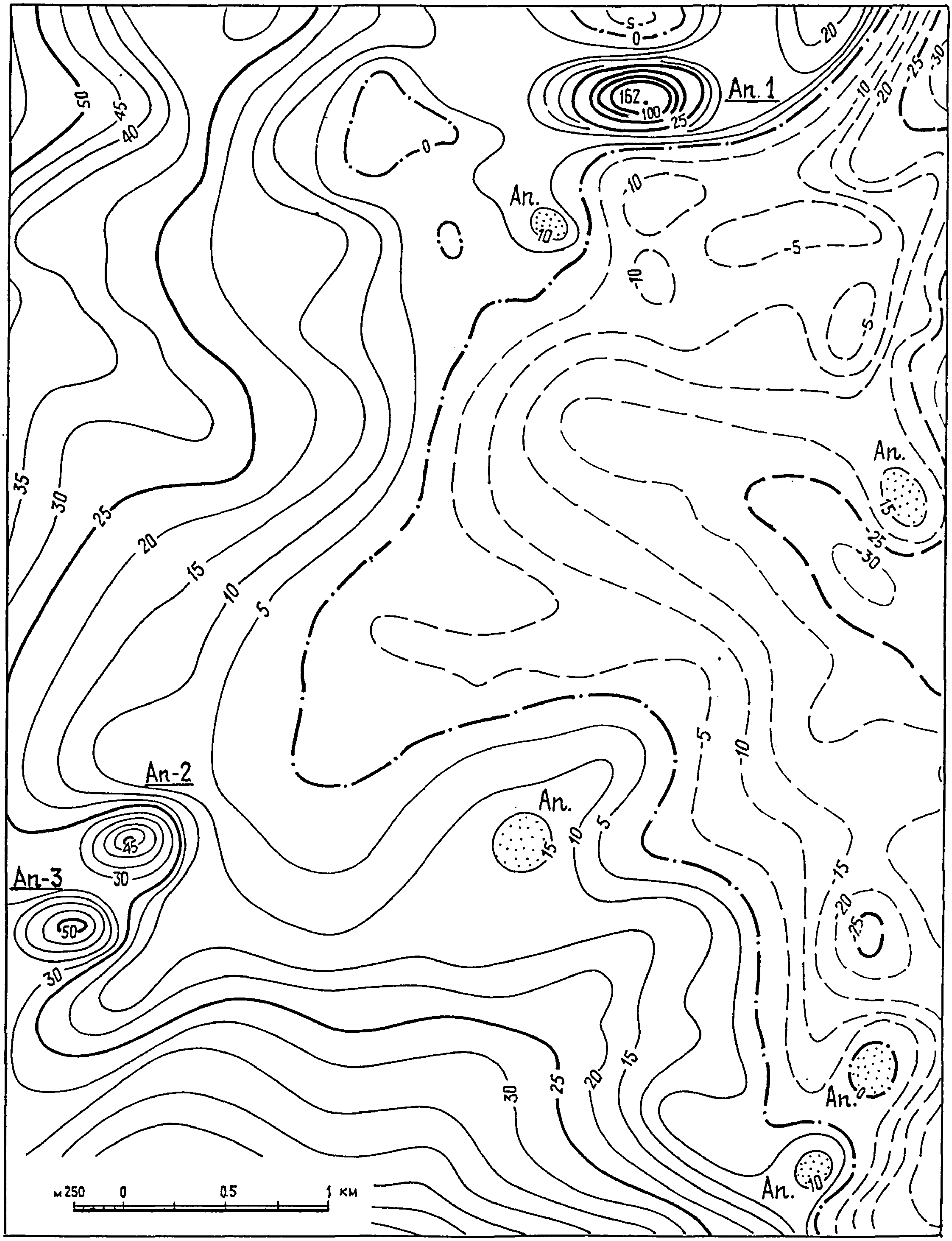


Figure 7

the promising anomalies.

(3) Ground magnetic survey, scale 1/10000 and 1/5000, in the promising areas (after reconnaissance survey only).

(4) Aeromagnetics data field processing and interpretation; choosing an appropriate number, location, and length of gravimetric (electrical) survey profiles in order to sort out magnetic anomalies.

(5) Gravimetric (electrical) measurements on land lines; picking up samples and specimens to be analyzed for physical properties of the rock constituents of an anticipated target body.

(6) Field processing and interpretation of gravimetric (electrical) survey data.

(7) Office processing and jointly performed interpretation of geophysical data; jointly drawn up and formulated advices and hints on a mine/borehole verification and checking.

* * *

2. SURVEY PROCEDURE, DATA PROCESSING AND INTERPRETATION

A combination of ground geophysical operations included magnetic survey, magnetic susceptibility measurements, gravimetric survey and electrical prospecting in the form of BIEP-DP dipole profiling. In all, covered with these operations were 4 airborne magnetic anomaly areas located in the north of Norway.

2.1. Field work

We describe in this section a procedure of reconnaissance and areal surveys in the airborne magnetic anomalous areas that were marked off after the airborne magnetic-EM survey data covering the northern Shuort locality on the scale of 1/25000 (Fig. 8).

As specified in the Contract, field geophysical measurements were carried out on 3 airborne magnetic anomalies which had been supposed to be of a pipe type: the areas of Anomaly-1 and Anomaly-3 were covered by reconnaissance survey, while in Anomaly-1 (Svanvik-1) area areal measureyments on scale 1/10000 were effected. Besides, we did an extra reconnaissance survey of a complex and intense airborne magnetic anomaly in order to acquire the data for making geological interpretation of plentiful similar airborne anomalies recorded over the Shuort area (Anomaly-4).

OVERVIEW MAP OF THE SURVEY AREA

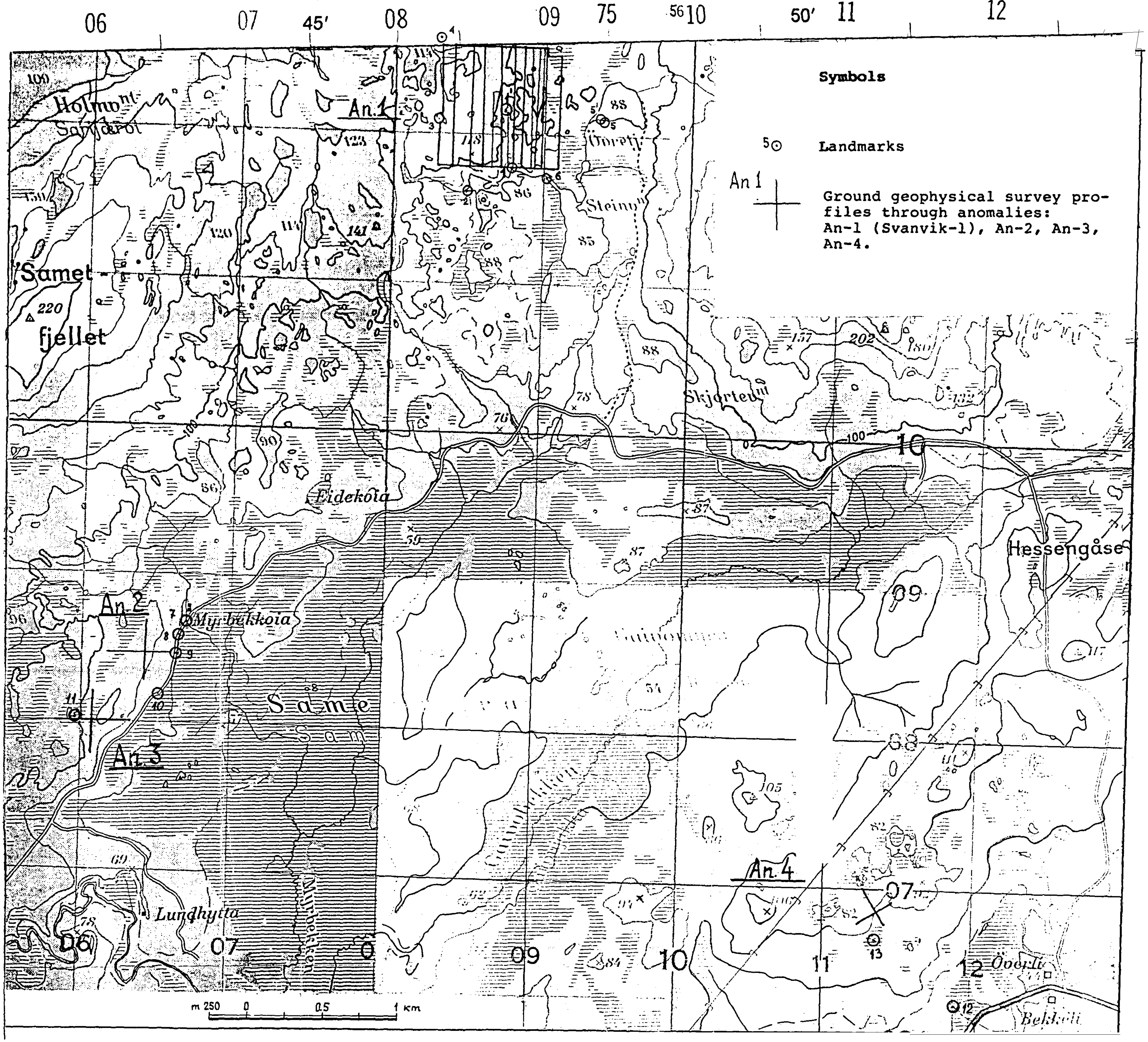


Figure 8

Quantities of field work by operations are given in Table 2 (numerator - line kilometers, denominator - measurements):

Table 2

Area	Magnetics			Magnetic susceptibility	Gravimetric survey	Electrical survey
	Reconnaissance	Areal survey				
		routine	detailed, height varying			
Anomaly-1	1.9 / 142	8.74 / 374	4.4 / 158	7.8 / 742	0.42 / 37	1.71 / 216
Anomaly-2	0.86 / 45	- / -	- / -	0.6 / 31	- / -	- / -
Anomaly-3	1.3 / 139	- / -	- / -	1.14 / 68	- / -	- / -
Anomaly-4	0.6 / 128	- / -	- / -	0.46 / 48	- / -	- / -
Overall quantities	4.66 / 454	8.74 / 374	4.4 / 158	10.0 / 889	0.42 / 37	2.52 / 300

During the field operations 8 samples have been taken from the anomalous areas and their geological description has been made.

2.1.1. Reconnaissance

Reconnaissance survey was conducted with a view to localize the picked airborne anomalies so to say "in situ" and to exclude the anomalies related to man-made or superficial interferences and noises.

Reconnaissance was performed on all airborne anomalies (Anomaly-1,2,3,4) by combined measurements of magnetic field intensity and magnetic susceptibility on two-three traverses across the anomalies' centers with a spacing of 20-10 meters.

As a result of such reconnaissance we could make a tentative conclusion about an origin of airborne anomalies and next steps in their study.

2.1.2. Areal survey

. Subject to areal survey was Anomaly-1 (Svanvik-1) area, although the preceding reconnaissance had failed to prove the "diatreme" origin of this airborne anomaly; on the other hand, the amount of reconnaissance done turned to be too little to give enough information about the anomalous target. That the geophysical surveys in Anomaly-1 area would be effected in compliance with a complete program was agreed upon with Morten Often who, as a Project Manager, inspected the survey area on August 19, 1994.

Following the reconnaissance, the areal survey operations in the already reconnoitered Svanvik-1 anomaly area included:

- Magnetic survey on a 100x20 m grid;
- Detail survey on normal and extra profiles with a 10-5 m spacing;
- Magnetic measurements at varying heights along interpretive profiles with a 10 to 5 meters spacing;

- Magnetic susceptibility measurements along the magnetic survey lines;
- Gravimetric and electrical survey measurements along interpretive profiles with a 20 meters spacing.

Magnetics

A size (800x800 m) of the area was taken on the basis of airborne magnetic survey data, considering the size of the airborne anomaly (recorded on two flight lines) and the results of reconnaissance traverses. Observation grid was 100x20 meters. In all, 9 normal magnetic profiles were laid, observation spacing being always the same (20 meters).

We detected in this area a composite and subtly differentiated magnetic field with its positive anomalies' intensity as high as 2000-3000 nTand even more. To define exact dimensions and a shape of the anomalies spotted in the area, regular measurements were taken along 4 detail survey lines, or profiles, plus extra measurements after every 10-5 meters along the normal profiles.

On profiles 3.5 and 5.5 that cross an extended narrow linear magnetic anomaly, within its most intense interval, the instrument-height-varying magnetic survey measurements were taken with a 5-10 meters spacing, the magnetometer pickup being raised to 0.5 and 2.8 meters above the ground level. In the same observation points measurements with KT-5 susceptimeter were also made.

Magnetic measurements were accompanied by recording the magnetic field variations.

To make the magnetic measurements in the survey area two types of instruments were employed:

- Profile measurements were taken with MMP-203 proton magnetometer (measurement error 1 nT, manufacturer: GEOLOGORAZVEDKA Factory, Russia) and KT-5 susceptimeter (measuring error $0.1x10^{-3}$ of CI units, storage unit (manufacturer: GEOFYZIKA A/S, Brno, Czech Republic);
- Magnetic field variations were measured with MM-60 quantum magnetometer (measurement error 0.1 nT, data recorded on a compact cassette, manufacturer: Russia).

Gravimetric survey

High-precision gravimetric measurements were performed on interpretive profile 5.5 with the view of gaining extra information. Within the gravimetric survey profile, with its overall length being 500 meters (station PK 10-60), elevation difference comes to 15-20 meters and a terrain topography is remarkable for numerous combinations of land microforms. The terrain in the profile strip is woody and partly swampy, but in general the traverse is passable and operating conditions of gravimetric observations can be regarded as good enough.

Gravimetric survey was effected using a datum level, i.e. a point suitable for observations and located at the beginning of the profile (sta. PK 10) was chosen as a fiducial, or a control point, and a recorded value at this reference point was set equal to zero.

To ensure a required accuracy of measurements (not exceeding 0.06 mGal), at each point the duplicated and independent measurements were effected with one and the same high-precision instrument. Also, at each point an elevation of a gravimeter was taken. RMS errors of gravity magnitude measurements at certain points averaged to + 0.03 mGal.

We attained a high accuracy of measurements owing to GNU-KS gravimeter (manufactured by RUDGEOFIZIKA Association, Russia), as well as because of a strict adherence to a rule of maintaining a vibration mode of the instrument, incessant checks over a temperature, and a varying-with-temperature length of runs.

Electrical survey

Our field team performed electrical survey over an already laid-out net of observation points in the area of Anomaly-1 (profiles 3.5 and 5.5) and Anomaly-3 (profile 2) using a BIEP-DP (inductive-EM-field registration) dipole profiling (DP) technique. A primary reason for using that particular method was, for one thing, a small thickness of unconsolidated layers (not exceeding 10-15 meters), and, secondly, because an induced version of EM measurements goes well with a top layer which has a high and varying resistivity.

While doing this survey we made use of a standard DP array with a length of a power line and receiving line being 40 meters and dipole spacing 100 meters (Fig. 9):

Field configuration used in operating ERA unit

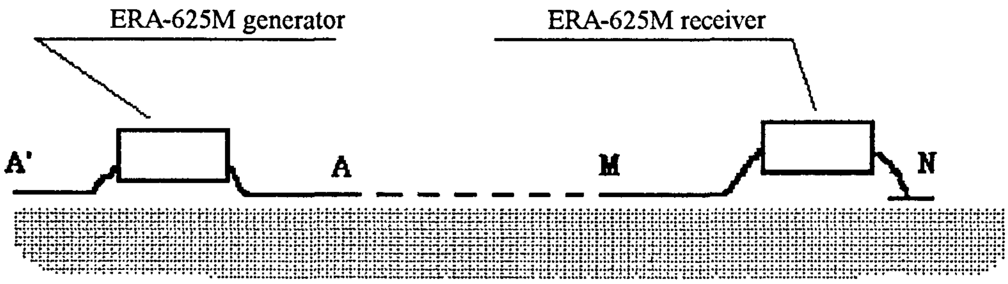


Figure 9

When choosing such spacing consideration was taken of a condition that this distance should exceed 5 to 10 times a thickness of the rocks overlying the target bodies. Mathematical center points of dipoles were taken as the points of grounding, and measuring results were referred to an electrical center of the receiving line, i.e. to a midpoint between the groundings.

On each profile measurements were made every other 20 meters along both a forward and inverse traverses. DP procedure was run with a Russian-made serial set of ERA-625 instrumentation using a frequency of 625 Hz, whereas survey error for repeated measurements was under 6 %.

2.1.3. Topogeodetic survey

The measurements were effected in the areas of reconnaissance and detail geophysical survey in order to:

- lay on terrain a topogeodetic grid of main survey lines and profiles, spacing the observation points, or stations, at 100, 50, 20 and 10 meters;
- mark off on terrain the ends of the main survey lines and anomalies' centers;
- define a plan-view position of landmarks (orienting datum points, or initial signals, for mapping), the ends of the main survey lines and profiles, anomalies' centers, and geophysical measurement points, using the topographic map coordinates;
- construct topographic base maps for the geophysical survey network in a scale range 1/5000-1/10000.

In topogeodetic survey use was made of 1/50000-scale topographic maps and their Xerox copies enlarged to scale 1/25000: these maps were provided by the Customer as per the Contract. What we did not have was a set of maps on a larger scale, and photographs.

In a preliminary stage of preparing to land measurements, the coordinates of airborne anomalies' centers, and their rough outlines, were plotted (using a digital presentation) on the 1/50000-scale topographic maps. Basing on this data a survey pattern, or a frame, of Anomaly-1 detail survey area was chosen and direction off the typical signals towards the centers of airborne anomalies 2, 3, and 4 was preset.

(1) To lay out a topogeodetic net of main survey lines and profiles on terrain and find the coordinates, a lay-out planning and location fixing programs that PGE practices in similar case studies have been used. The following landmarks (OP), easily recognized on the 1/50000-scale topographic map, served as orienting datum points:

for Anomaly-1 OP-1 specific outline of a lake;
for Anomaly-2 OP-7 intersection of a road and a brook;
for Anomaly-3 OP-10 typical road pattern (a sharp bend);
for Anomaly-4 OP-12 intersection of a brook in a marsh with an edge of a forest.

Work included:

- Map measurements of distances and directions from the orienting datum points to the preplanned points;
- Recognition and identification on terrain of those outlines which were picked on the topographic map as initial landmarks: field measurements of distance from these marks to the preplanned survey points;
- Fixing a position of initial preplanned points (frame corners, points at a main survey line or profile) on terrain;
- Laying out the frame and profile lines from a datum point (profile spacing was 100 and 50 meters, whereas observation points on profile were spaced at 20, and at 10 meters for gravimetric and detail survey).

The profile lines were staked with pegs in a preset direction, using a BS-model surveying compass. Distance between observation points (stations) was measured with a tape in one direction only. In case a gradient exceeded 5 degrees a line was subject to correction.

(2) To mark off the geophysical observation points (stations) on profiles and main survey lines, wooden pegs 30-40 cm high were driven into the ground. These were marked with a profile number and observation station serial number.

Likewise the profile observation stations, the frame corners were fixed with the pegs, 30-40 cm high, bearing an inscribed number of anomaly/main survey line/profile. Besides, location of the corner pickets was indicated by notches cut on all 4 sides of a neighbor tree and marked in a aforementioned manner.

(3) To define a plan-view position of the objects chosen for geophysical measurements we first indentified on terrain the outlines of the landmarks shown on the topographic map and then laid down the compass traverses up to the point in question, each traverse including a segment of a profile or main survey line (Fig. 10).

To provide spot elevation data for gravity prospecting survey along profile 5.5 (stations 1.0 and 5.6), trigonometric levelling with a 30"-accuracy 2T-30 theodolite # 70368 was effected. Gradients were measured in one run with a theodolite vertical index disk in a sinistral position (D_S).Position of a zero point (P-zero) was determined right before a survey procedure, in one run and with two positions (dextral/sinistral) of the disk (D_S/D_D), using a formula: P-zero = (D_S + D_D + 180 degrees):2, and amounted to 1.5'. While measuring at the stations (observation points), position of a zero point was regularly checked and zero drift variations never exceeded 1'.

(4) Construction of topographic base maps (Fig. 11,12,13) on the scale of 1/10000 (Anomaly-1,2,3) and 1/5000 (Anomaly-4) was carried out in the office as soon as the field operations had been accomplished. Plotted on the topographic maps were the landmarks, their coordinates being taken from the 1/50000-scale map whereon those landmarks had been drawn as visually recognized and identified on terrain. The frame, profile lines and observation points were drawn up from these plotted landmarks, taking into account the acquired measuring data and picketing with pegs. When using magnetic azimuth measuring data we also took into consideration a total correction for magnetic declination and convergence of meridians for the sake of conversion to grid azimuth in reference to a prime meridian. This total correction amounts to 5 degrees 37 minutes. By these base maps we calculated the coordinates for the frame corners and anomalies' centers (Table 3). Finally, position of Anomaly-1 frame, all profiles (including reconnaissance profiles across Anomaly-2,3,4), anomalies' centers, and landmarks, - these all were plotted on the overview map drawn to scale 1/25000 (Fig. 8).

Basing on trigonometric (geodetic) levelling along interpretive profile 5.5, difference in spot elevations with reference to the datum point (sta. 10) were calculated together with the elevations of those points of gravity prospecting survey whereby a field profile trace was laid.

LAYOUT PLAN OF ANOMALY-1 AREA LOCATION

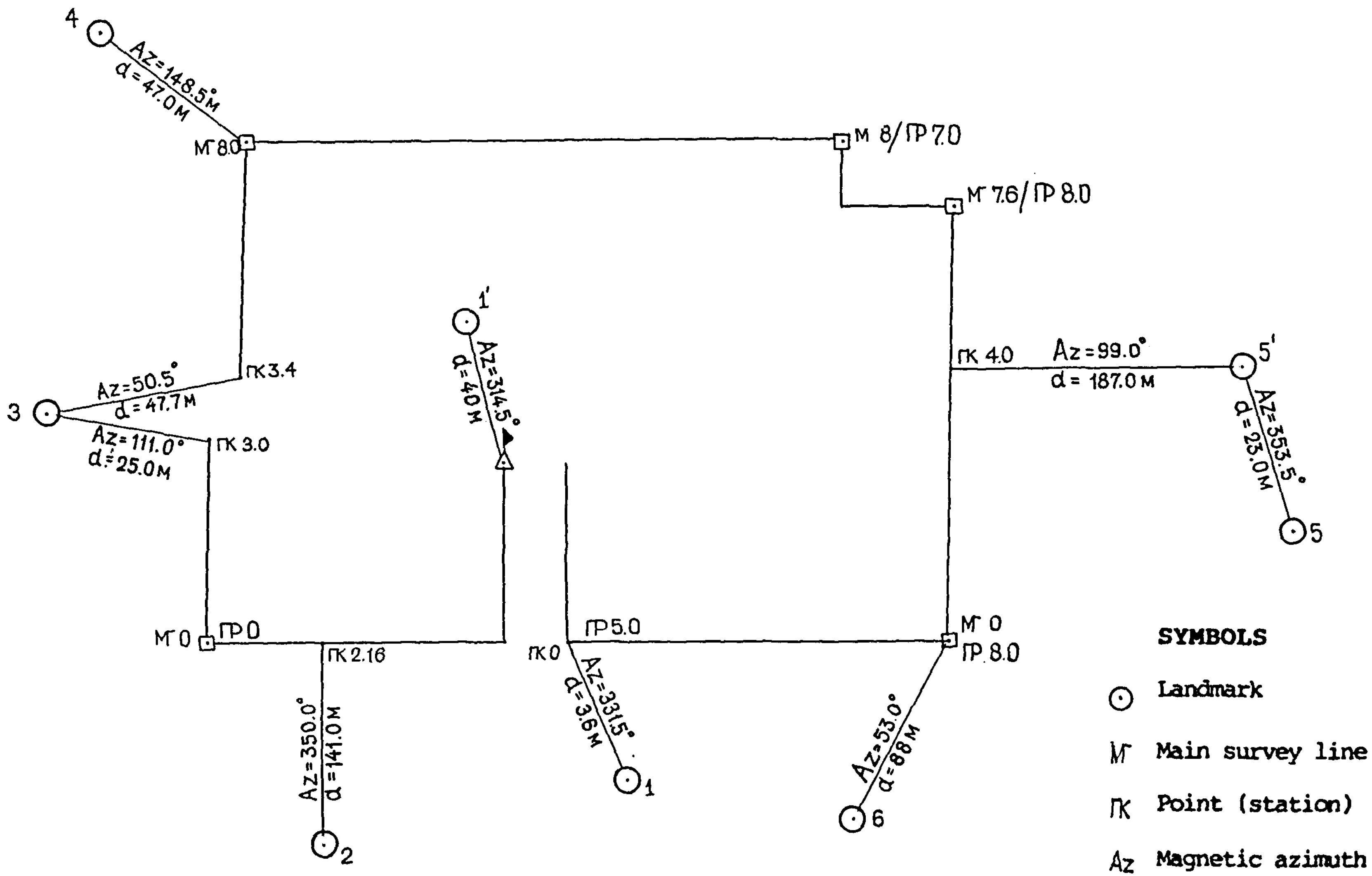


Figure 10

LAYOUT OF ANOMALY-1 (SVANVIK-1) AREA

Scale 1/10 000

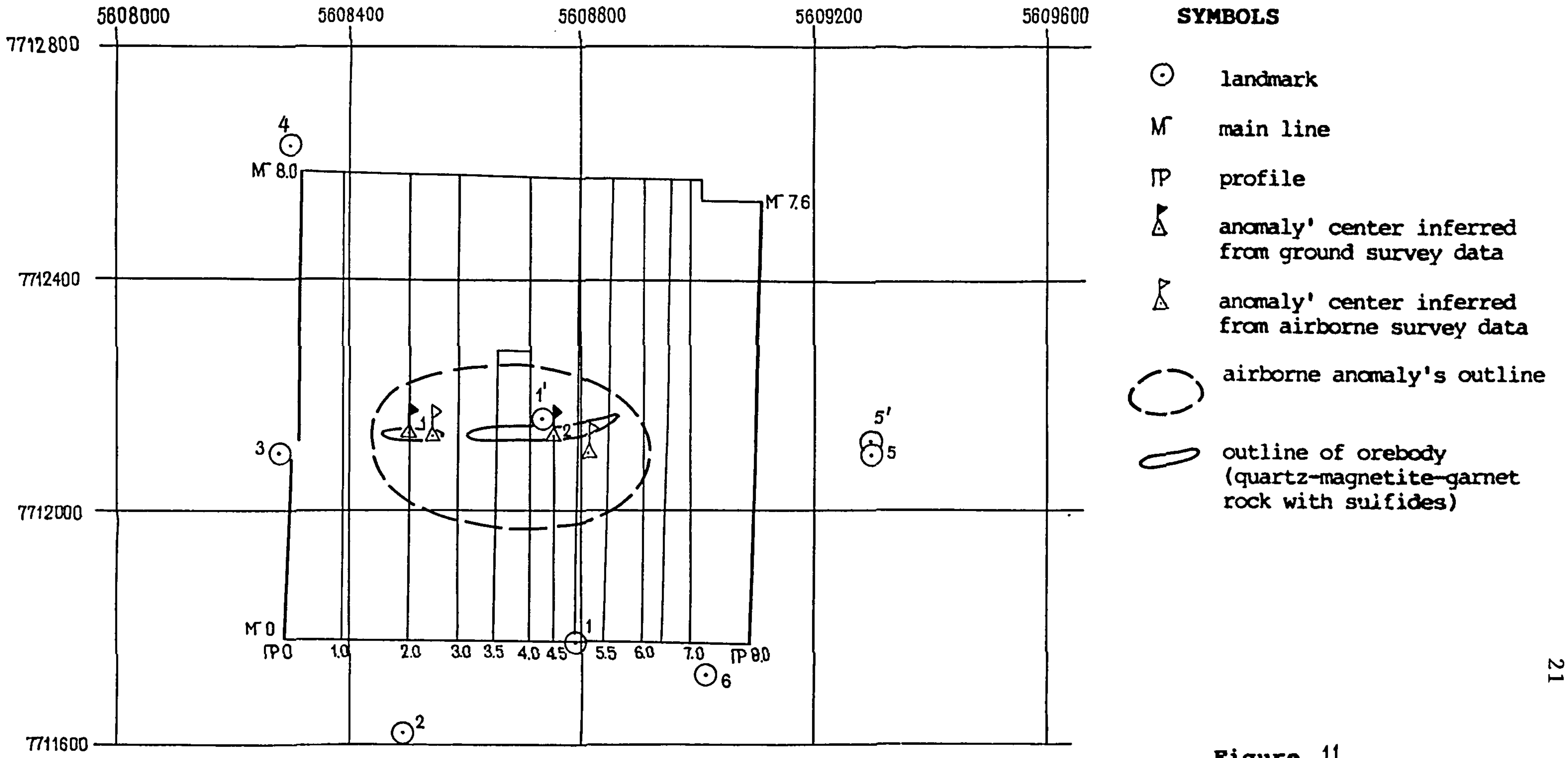
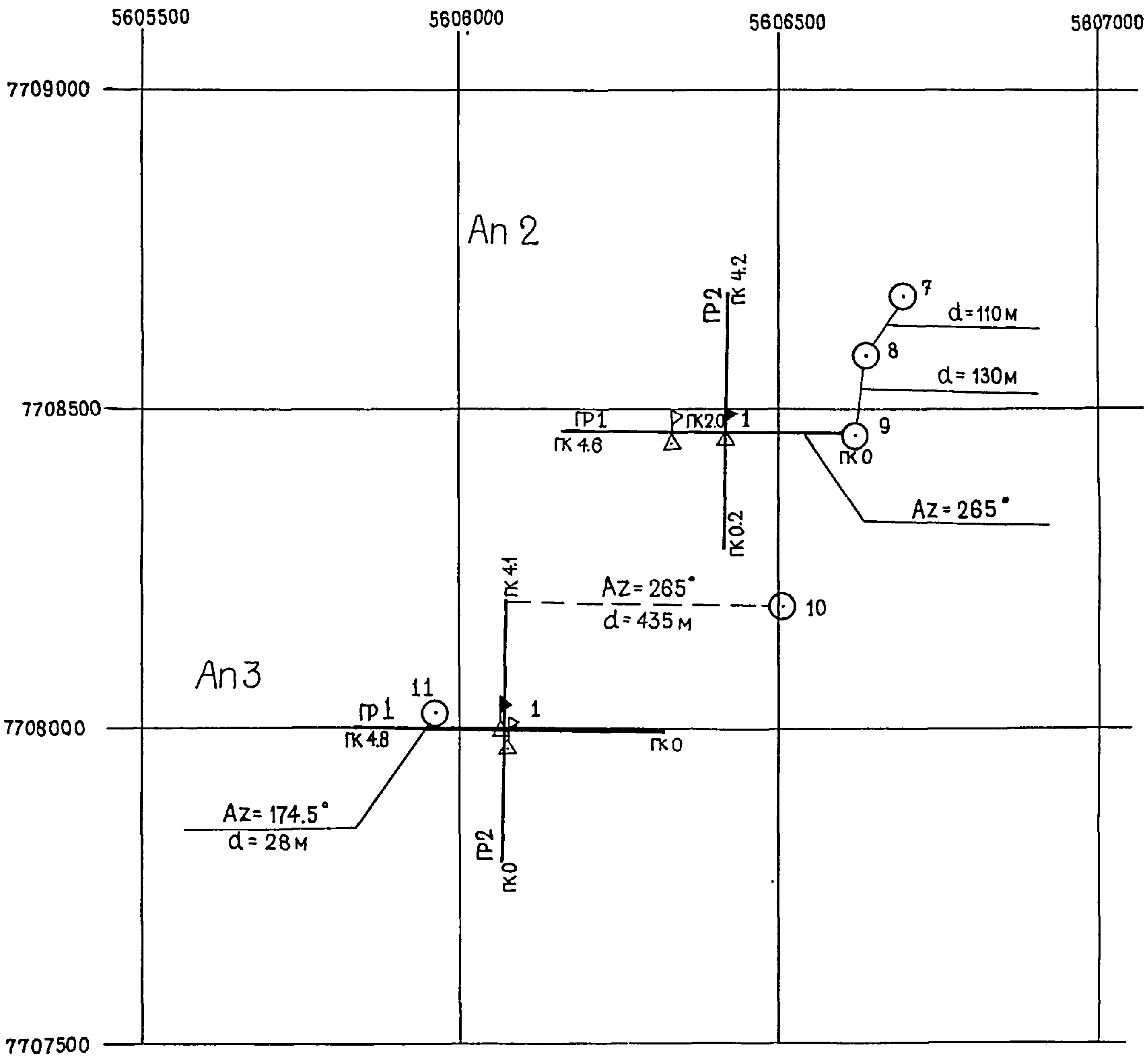


Figure 11

LAYOUT OF ANOMALY-2 AND ANOMALY-3 AREAS (SCALE 1/10,000)



SYMBOLS

ГР profile

ГК point (station)

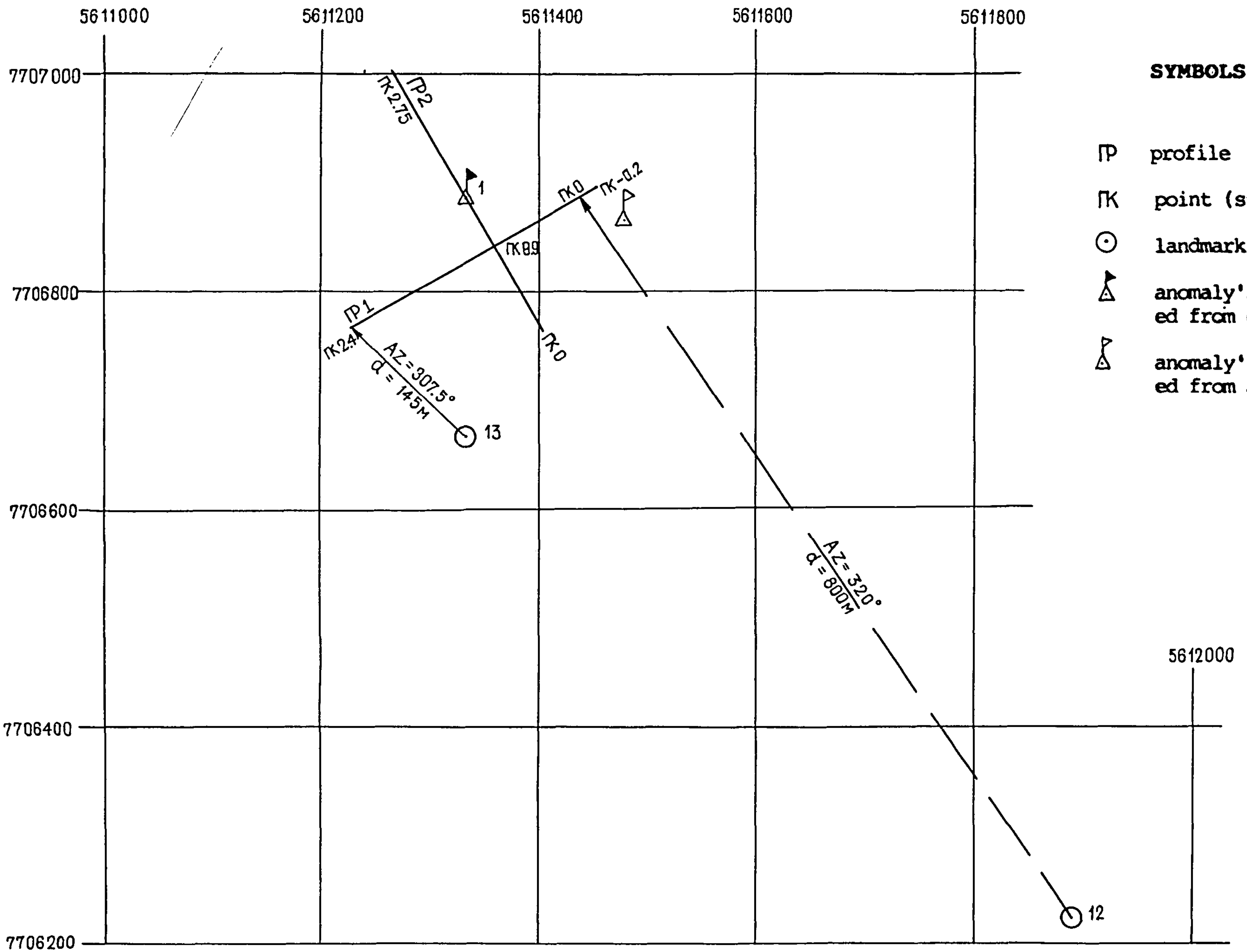
landmark

anomaly's center inferred from ground survey data

anomaly's center inferred from airborne survey data

Figure 12

LAYOUT OF ANOMALY-4 AREA (SCALE 1/5000)



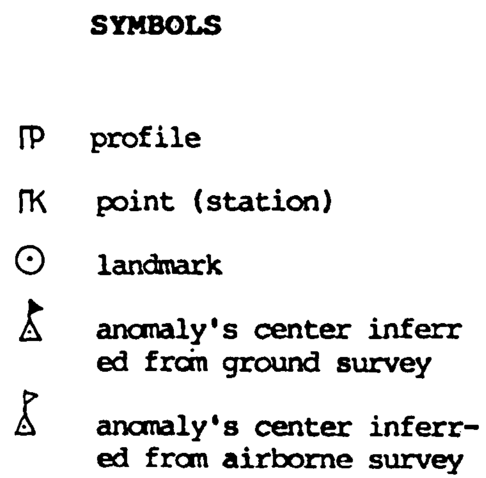


Figure 13

Table 3

LIST OF COORDINATES
OF LANDMARKS AND ANOMALIES' CENTERS

Abbreviations: OP - landmark; M - main survey line; PR - profile; PK - station; Эн - anomaly's center

Anomaly	Point (sta.)	Y (X)	X (Y)	Notes
1	2	3	4	5
Anomaly-1 areal	OP-1	7711775	5608790	
	OP-2	7711617	5608494	
	OP-3	7712096	5608282	
	OP-4	7712630	5608300	
	OP-5'	7712120	5609297	
	OP-5	7712096	5609300	
	OP-6	7711717	5609013	
	OP-1'	7712158	5608732	
	MO/PRO	7711782	5608291	
	M8/PRO	7712583	5608320	
	M8/PK 7.0	7712570	5609010	
	M7.6/PR 8	7712529	5609110	
	M7.6/PK 7.0	7712529	5609010	
	MO PR 8.0	7711769	5609090	
	PR O/PK 3	7712081	5608298	
	Эн 1	7712132	5608503	Acc. to grnd survey
	Эн2	7712130	5608751	
	Эн 1'	7712130	5608545	Acc. to airborne data
	Эн 2'	7712088	5608810	
Anomaly-2 reconnaissance	OP-7	7708675	5606700	
	OP-8	7708580	5606640	
	OP-9	7708455	5606623	
	Эн 1	7708455	5606420	Acc. to grnd survey
	Эн 1'	7708455	5606335	Acc. to airborne data
Anomaly-3 reconnaissance	OP-10	7708190	5606510	
	OP-11	7708020	5605965	
	Эн 1	7707995	5606065	Acc. to grnd survey
	Эн 1'	7707965	5606075	Acc. to airborne data
Anomaly-4 reconnaissance	OP-12	7706225	5611888	
	OP-13	7706665	5611335	
	Эн 1	7706887	5611333	Acc. to grnd survey
	Эн 1'	7706865	5611480	Acc. to airborne data

2.2. Geophysical data processing and interpretation

Data processing operations were conducted in two stages: in the field and in the office.

Field processing comprised: primary calculations done to the raw geophysical log data; entering corrections into measurement data; tying-in the data acquired on different days on control points; construction of graphs and tentative maps using the PC kindly provided by Norwegian colleague Thorleis Lauritzen. The raw data processing results were used to: decide on a locality of interpretive profiles to run straight across the centers of magnetically disturbing targets; make magnetic susceptibility measurements net thicker; choose the sampling location.

Office processing of the ground measurement data was effected in Saint Petersburg on IBM PC/AT in terms of quantitative/qualitative interpretation of the results obtained.

Magnetics

To start with, magnetic data measured at the observation points (magnetic field, coordinates) were entered into PC using an "ad hoc" program. Coming as a result was a file containing the data for all observation points and in such a format that was suitable for subsequent processing. Graphs of individual survey routes were constructed for Anomaly-2,3,4, and Anomaly-1 (Svanvik-1) area was covered by a contour map of delta-Ta magnetic field on the scale of 1/5000 (Fig. 14).

PC was used for the interpretation of magnetic survey data, which consisted in calculating a depth whereat a top edge of a source body occurred, horizontal dimensions of such source body and a depth of its bottom edge (after the results of measurement with a pickup at different heights).

In case of Anomaly-3 area, the results of fitting the delta-Ta magnetic field with the magnetic survey data along profile 2 (Fig. 15) were compared, and a geological/geophysical section along the profile line was drawn up.

Gravimetric survey

A goal of gravimetric survey data processing consisted in: a treatment of the observed gravity field data at the observation stations of profile 5.5; Bouguer reduction (correction for an intermediate layer) and construction of anomalous gravity field graph. Using the delta-g graph we calculated rock density of a source target that caused a gravity anomaly and drew up a density cross-section to be then corrected in view of the magnetic data.

Electrical survey

Office operations comprised calculation of apparent resistivity values based on ac-field measurements and, basing on the constructed graphs, determination of geometric parameters and electrical response of the targets along the lines of interpretive profiles.

In the field 8 samples and specimens were picked in the centers of magnetic anomalies 1, 3 and 4 in order to analyze physical properties and mineral mode of the rocks composing the source target-bodies. Samples were analyzed in the PGE's laboratory and heavy-concentrate/mineralogical laboratory of VSEGEI Institute. Analytical results are listed in Tables 4,5.

In a final stage of the office operations the specialists jointly effected an interpretation of all the data acquired with a view to assessing the potentiality of the measured anomalies.

* * *

Table 4

PHYSICAL PROPERTIES OF ROCK SAMPLES
FROM THE AIRBORNE ANOMALY AREAS IN THE NORTH NORWAY

Sample number	Density g/cm^3	Suscep tibility kappa $x10^{-3}$	Magnetization,remanent, I $x10^{-3}$ A /m	Magnetization,induced, I $x10^{-3}$ A /m	Resistivity Ohmxm	Sampling locality	Sample number in Table 5
An-1							
1-1	3.70	60	7200	23900	3800	PR 4.5 station PK 3.55	1--H
1-2	3.74	73	6700	28900	40	Same	11--H
1-3	3.11	10	1300	4100	16	PR 4.5 station PK 3.6 (15 m to the west)	111--H
1-4	3.74	87	4600	34500	23	PR 4.5 station PK 3.6	-
1-5	2.99	20	500	8300	480	PR 4.5 station PK 3.6 (15 m to the west)	
An-3							
3-1	3.08	7	400	3100	2700	PR 20 station PK1.6 (15 m to the east)	
An-4							
4-1	3.33	220	14000	88000	1800	PR 20 station PK1.25	1Y K
4-2	3.38	234	21000	93000	1360	PR 20 station PK1.5.5	

Table 5

ANALYSIS OF MINERAL MODE OF ROCK SAMPLES AND POLISHED SECTIONS FROM AIRBORNE ANOMALY AREAS IN NORTH NORWAY

Sample number	Thin section	Polished section
I-н	Garnet-quartz ore occurrence Quartz - 80%, almandine - 15%, ore minerals - 5%, light green monoclinic amphibole - .1%, ferroactinolite - .1%, chlorite - .1%, biotite - .1%, orthopyroxene- .1%. Ore minerals, as thin chains of grains, fringe the segregated quartz and garnet.	Pyrite - 3% pyrrhotite - .1% chalcopyrite-.1%
II-н	Quartz-garnet ore occurrence Almandine - 67%, quartz - 25%, ore minerals - 7%, light green amphibole - 1%, chlorite, biotite and ferroactinolite - .1%. Ore minerals fill a space between the garnet and quartz grains, or otherwise cut them.	Magnetite - 15%, pyrrhotite - 2% chalcopyrite- pyrite-melnikovite (greigite) -.1%
III-н	Quartz-magnetite-amphibole-garnet rock Quartz - 35%, almandine - 15%, magnetite - 10%, pyrite - 10%, amphibole - 30%, orthopyroxene, chlorite, biotite, ferroactinolite - .1%. Amphibole (cummingtonite-grunerite) Ng - 1.695 Np - 1.665 c^ Ng - 20 degrees Orthopyroxene Ng - 1.698 Np - 1.686	Magnetite - 17% pyrite - 15% pyrrhotite - 3% chalcopyrite-.1%
IV-к	Schist, mineralized (?) Quartz - 55%, hornblende - 15%, ore minerals - 25%, carbonate - 5%.	Magnetite - 25% limonite - .1% pyrite - .1% chalcopyrite-.1%

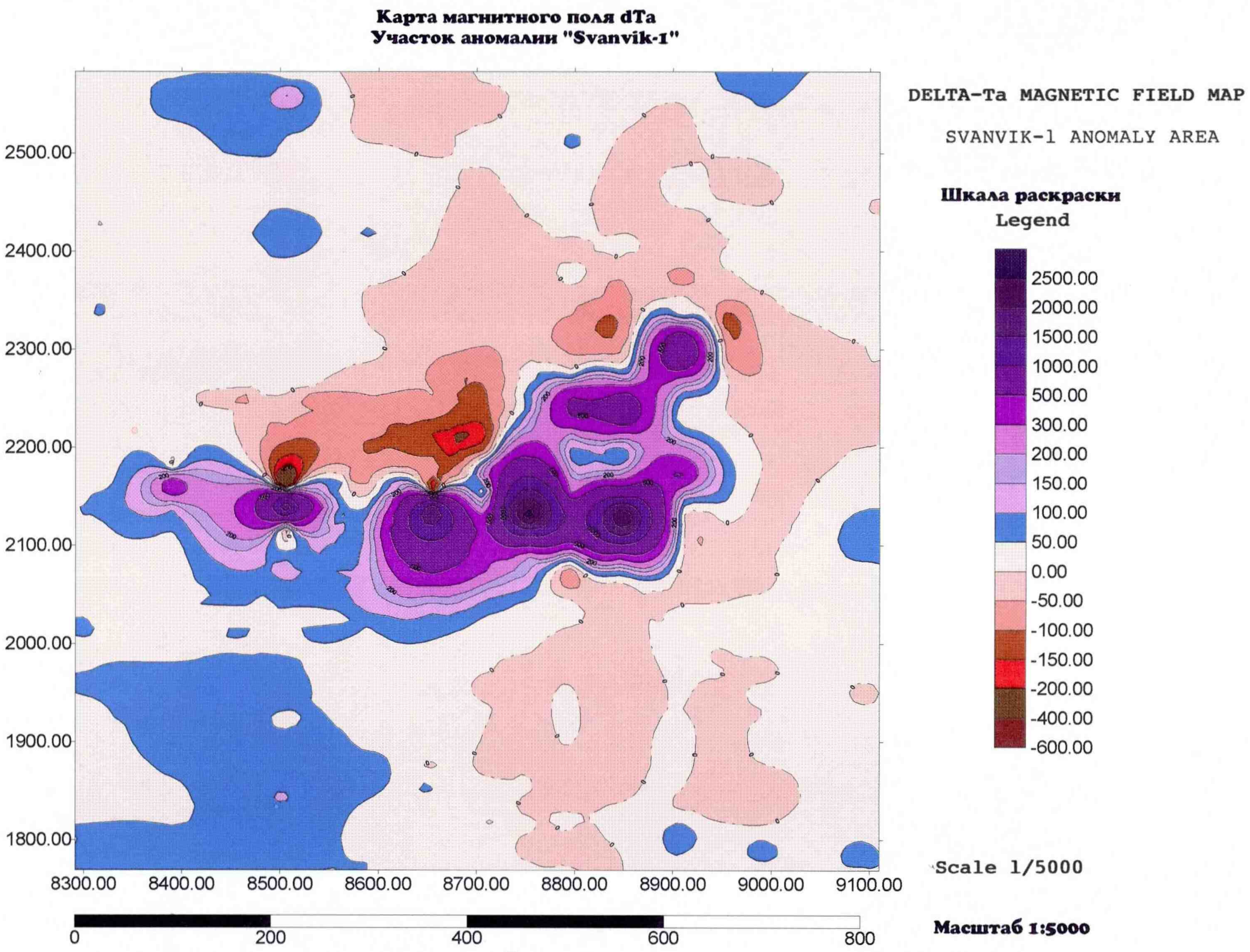
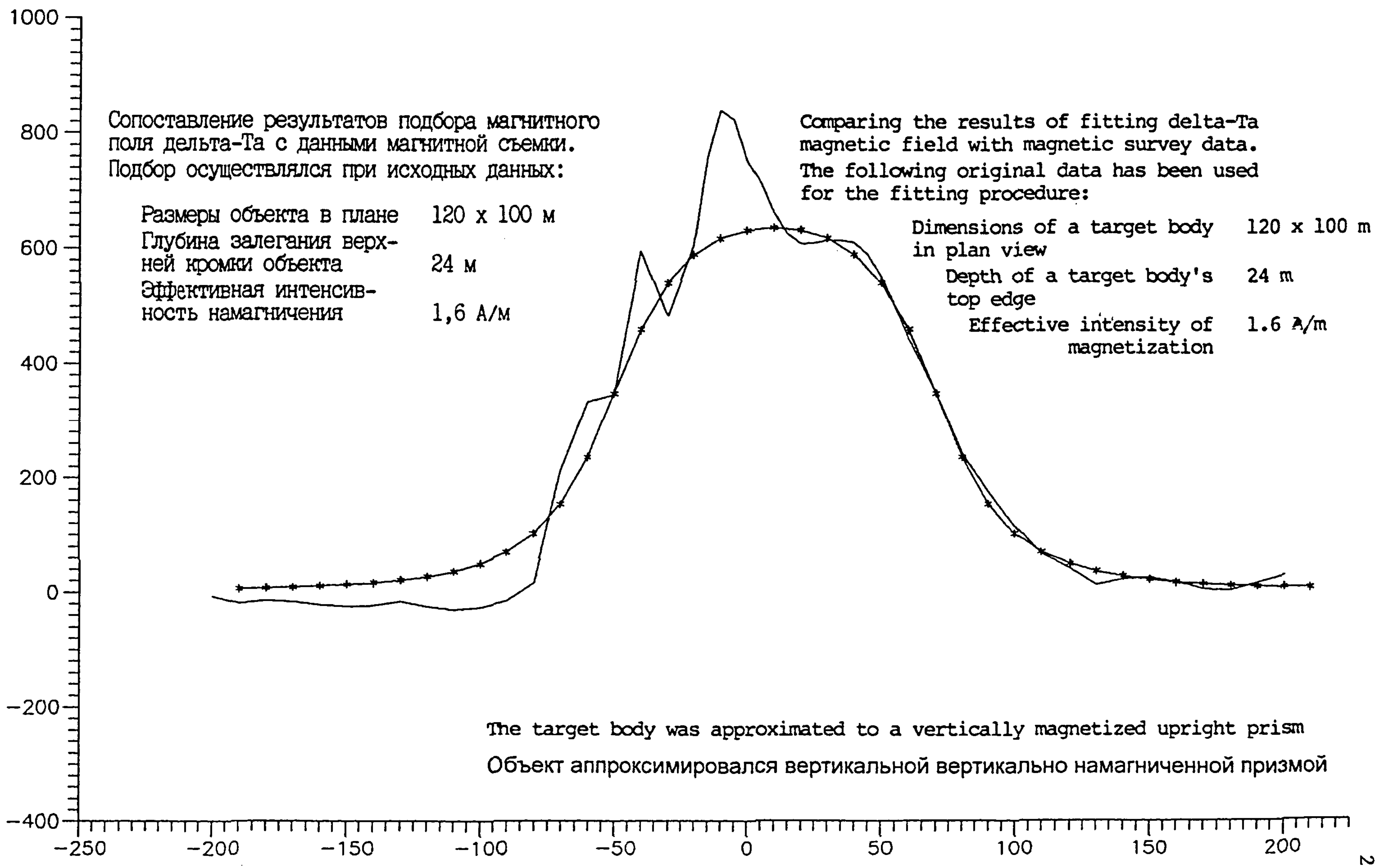

Карта магнитного поля dTa
Участок аномалии "Svanvik-1"
DELTA-Ta MAGNETIC FIELD MAP
SVANVIK-1 ANOMALY AREA
Шкала раскраски
Legend
2500.00
2000.00
1500.00
1000.00
500.00
300.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-400.00
-600.00
Scale 1/5000
Масштаб 1:5000
2500.00
2400.00
2300.00
2200.00
2100.00
2000.00
1900.00
1800.00
8300.00
8400.00
8500.00
8600.00
8700.00
8800.00
8900.00
9000.00
9100.00
0
200
400
600
800

Figure 14



Сопоставление результатов подбора магнитного поля дельта-Та с данными магнитной съемки. Подбор осуществлялся при исходных данных:
Размеры объекта в плане 120 х 100 м
Глубина залегания верхней кромки объекта 24 м
Эффективная интенсивность намагничения 1,6 А/м
Comparing the results of fitting delta-Ta magnetic field with magnetic survey data. The following original data has been used for the fitting procedure:
Dimensions of a target body in plan view 120 x 100 m
Depth of a target body's top edge 24 m
Effective intensity of magnetization 1.6 A/m
The target body was approximated to a vertically magnetized upright prism
Объект аппроксимировался вертикальной вертикально намагниченной призмой
1000
800
600
400
200
0
−200
−400
−250
−200
−150
−100
−50
0
50
100
150
200

Figure 15

3. RESULTS

Ground geophysical measurements were made in the areas where 4 airborne anomalies had been detected, and 3 of which, in particular, had been marked off by airborne magnetics on the scale of 1/25000 as promising for finding the diatremes.

All anomalies are located in the northern end of Shuort territory and are confined to the outcrop areas of granites and granite-gneisses which contain amphibolite bodies varying in size and thickness. Faults striking largely N-E, or in a nearly latitudinal direction, are very common here. The nearest occurrences of kimberlites and kimberlite rock series are encountered in the south of Kola peninsula (Tersky Coast) and in the Middle Finland.

3.1. Anomaly-3 (Fig. 16) is located 1 km SW of Myrbekkoia settlement, within the confines of a swampy saddleback over a hill with a spot elevation of 100 m. Intensity of a positive anomaly is 52 nT, it has a nearly isometric shape and its dimensions along 40 nT contour are 370x240 meters (Fig. 7). On the ground the magnetic anomaly is recorded on two profiles: there, against a low-gradient delta-Ta field one can recognize a pronounced anomaly showing intensity of about 800 nT, its pattern being complicated by few local highs up to 150-200 nT. We figure out the size of this anomaly to be some 80x140 m. Geometry and dimensions can only be approximated, considering a reconnaissance stage of the work performed.

Basing on the results of interpreting (model fitting), we conclude that a theoretical curve over a vertically magnetized upright prism with its overall dimensions being 100x120 m, its top edge's depth h = 24 m and effective intensity of magnetization 1.6 A/m (Fig. 15), corresponds, to a high enough degree of accuracy, to the observed graph of delta-Ta magnetic field on profile 2. The quantitative estimatation proves the magnetic anomaly to be related to a vertically occurring body with its bottom edge going down to over 250 m.

As follows from the magnetic susceptibility measurements, no magnetic rocks are encountered in the anomaly area. The basic rocks (gabbro) outcropping E of the anomaly's outline have their magnetic susceptibility less than 1.12×10^{-3} CI units (mean value of 23 measurements amounts to 0.68×10^{-3} CI units). Particular boulders and fragments of rocks (amphibolites ?) contrasting by their high susceptibility up to 16-20x 10^{-3} CI units are recorded SE of the anomaly's outline.

Electrical survey results on profile 2 leave no doubt in that conductive anomaly corresponds to the magnetic one, and that intersection of forward and inverse transverses corresponds to a position of a disturbing body's center. The conductive anomaly is not high (74 Ohmxm) and a magnitude of apparent resistivity seems to go up to 300 Ohmxm N and S of the anomaly, which is likely to correspond to a higher-resistivity rocks outside the anomalous zone.

With respect to the known volcanic pipes of Kola peninsula, the resistivity of kimberlites and pycrites is placed at a range of 150 to 40 Ohmxm, while for the host granitoid rocks this range changes to 20×10^{2} to 30×10^{3} Ohmxm and to 300-700 Ohmxm for the arenaceous, or sandy, rocks.

That the conductive anomaly coincides with the magnetic anomaly gives us a reason to interpret a magnetically disturbing target as a pipe-like vertical body composed of low-resistivity magnetic rocks.

RESULTS OF GROUND RECONNAISSANCE SURVEY IN ANOMALY-3 AREA (SCALE 1/5000)

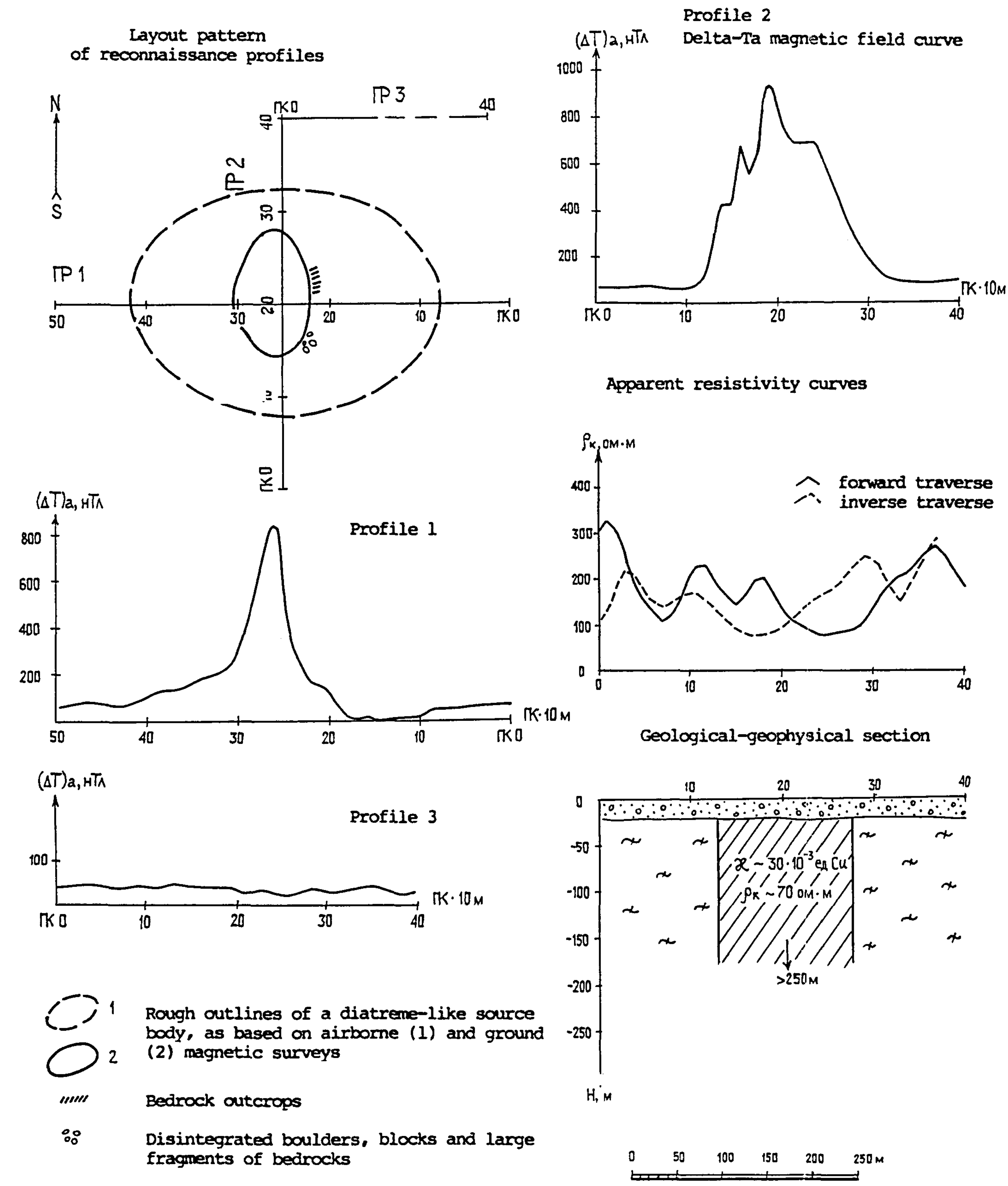


Figure 16

In our opinion, Anomaly-3 looks interesting in terms of prospecting for the volcanic pipes having, probably, a kimberlite composition. To prove its "pipe" origin, we recommend, prior to checking by drilling, to conduct a high-accuracy gravity survey across the magnetic target's center on profiles 1 and 2.

3.2. Anomaly-2 (Fig. 17) is situated 700 m NNE of Anomaly-3 and is confined to a flat top with spot elevation of 100 m. Anomaly intensity is 50 nT, geometry is isometric, dimensions are 200x160 m along a 40 nT contour line (Fig. 7). On the ground, this magnetic anomaly is pinpointed on two profiles so that against a quiet delta-Ta magnetic field a local, somewhat asymmetrical, anomaly with its intensity as much as 1500 nT and a slight low at its SE flank is outstanding. The anomaly is roughly 60 by 100 meters, its shape and size are shown on a figure with no claim to accuracy just because of a reconnaissance stage of area investigations.

According to a delta-Ta graph (profile PR-2), top edge of a source body occurs at a depth interval of 25-30 m, whereas its bottom edge's depth is over 200 m. The body is highly magnetized (up to 300×10^{-3} CI units).

Magnetic susceptibility measurements in the anomaly area show that no magnetic rocks were to be met with, and that measured values for boulders and rock fragments in the exposures do not exceed $0.6\text{-}0.7 \times 10^{-3}$ CI units.

Basing upon the results obtained, one may assume that the local delta-Ta anomaly of a nearly isometric shape is related to a "pipe-like" intrusive body outcropping right under the Quarternary deposits. Should the ground checking of Anomaly-3 yield positive results, it would be reasonable to come back to a geophysical follow-up study of Anomaly-2.

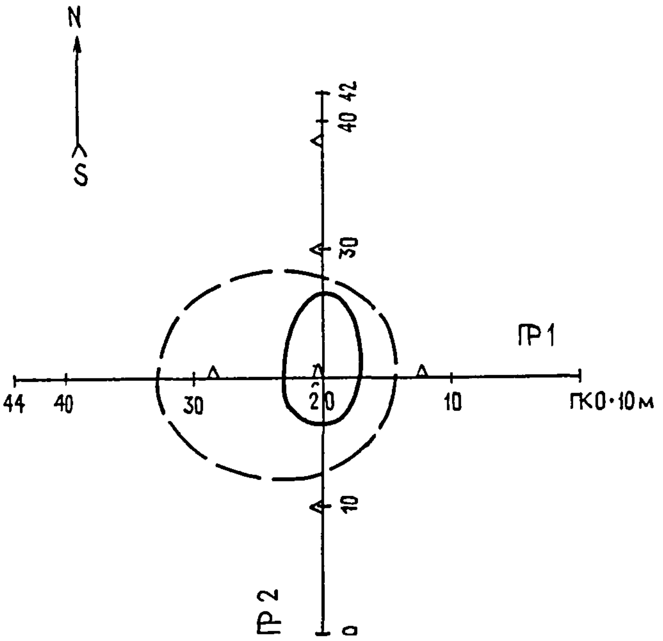
3.3. Anomaly-1 (Svanvik-1) is located 4 km NE of Myrbekkoia settlement. It is spotted there in a caldera-like marshy depression on top of a hill with elevation marks ranging 118-120 m. Detected on two airborne flight lines, this anomaly attains an intensity of 162 nT (flight line # 264), its geometry is ellipsoidal, side-to-side ratio being 2:1, and its dimensions along contour line of 50 nT is 480x250 m (Fig. 7).

Following the reconnaissance and ground verification of airborne anomaly, magnetic survey on scale 1/10000 was made over a prelaid-out net of profiles with a 20-meter spacing (Fig. 11). Ground measurements revealed the airborne magnetic anomaly as a pronounced one approximately of the same size, yet possessing more complex shape and pattern. The low-gradient magnetic field that surrounds the anomaly implies that a magnetically disturbing object occurs among practically nonmagnetic rocks (granites, granite-gneisses) of a basement. A fairly broad and deep delta-Ta magnetic low on a northern side suggests a southward dip of this body (Fig. 14).

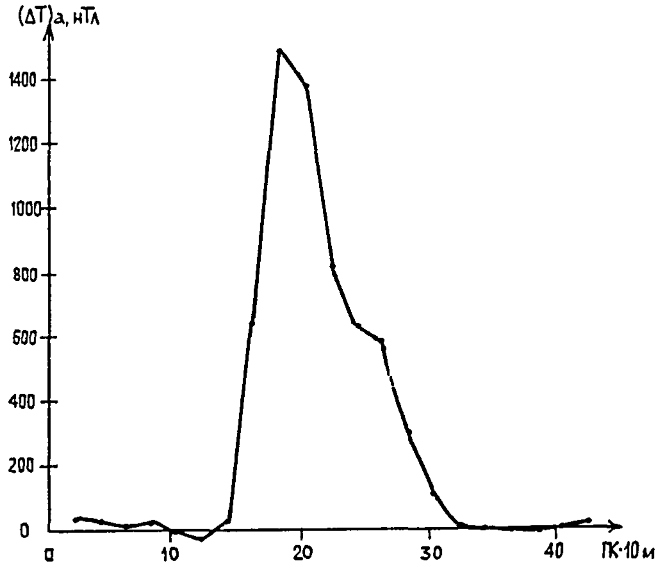
Results of areal survey (100x200 m) served as a basis for detail measurements after each 10-5 m within the particular portions of both the normal profiles and extra profiles spaced at 50 m. A contour map of delta-Ta magnetic field was drawn on the scale of 1/5000, just in view of these measurements, and it shows very well a magnetic field pattern of the area in question (Fig. 18). One can easily identify the contours of a geological body of a complex structure: within this body magnetics, susceptibility and gravity measurements mark off a few minor narrow linear bodies featuring high magnetization and density. We think that a highly intensive positive delta-Ta anomaly that strikes in nearly latitudinal direction for more than 500 m is most interesting (along 2000 nT contour line). Intensity of this anomaly comes to 4500-5700 nT on profile lines 4.0 and 5.5, being maximum of over 6800 nT on profile 4.5

RESULTS OF GROUND RECONNAISSANCE SURVEY IN ANOMALY-2 AREA (SCALE 1/5000)

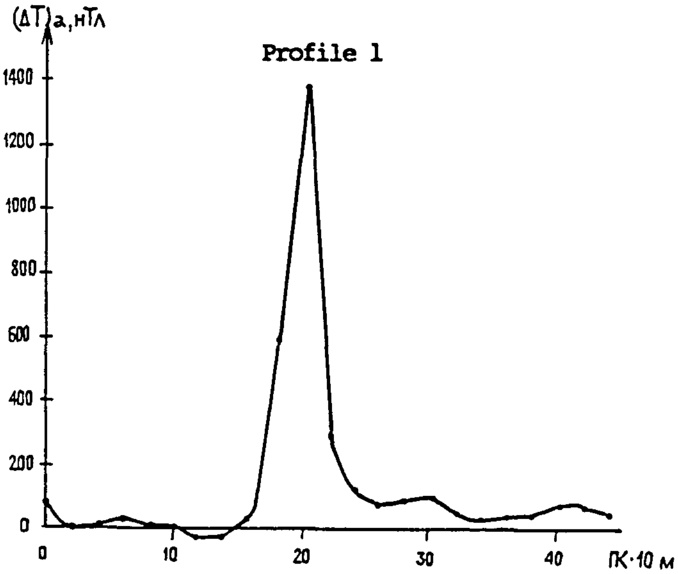
Layout
of reconnaissance profiles



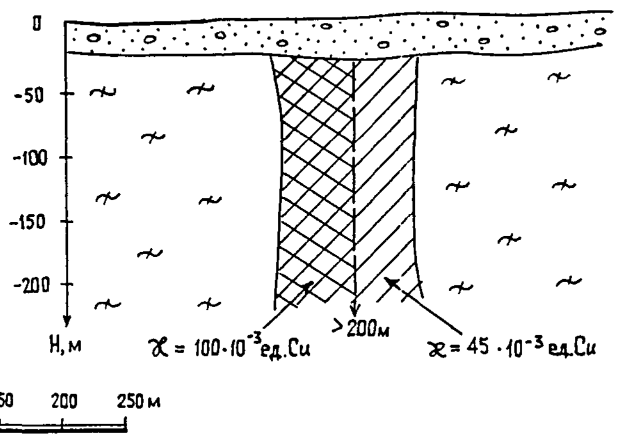
Profile 2

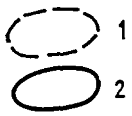


Profile 1



Geological-geophysical section
along profile 2
(based on PC-aided quantitative
interpretation of data)





1 Outlines of a magntically disturbing pipe-like body, as based on airborne (1) and ground(2) magnetic survey
2

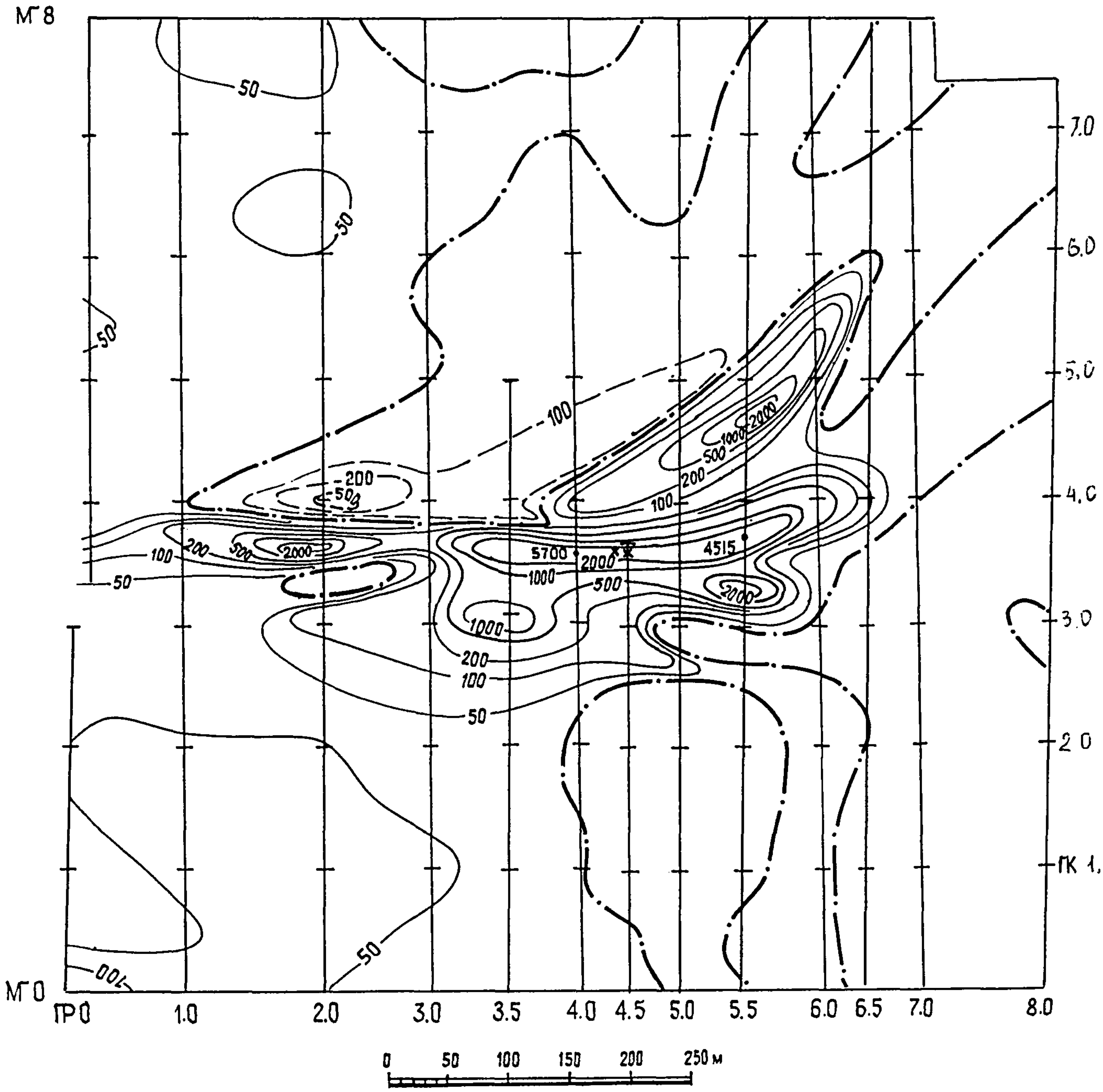
Δ Magnetic susceptibility measurement points

Figure 17

CONTOUR MAP OF DELTA-Ta MAGNETIC FIELD

Svanvik-1 anomaly ground checking area

Total magnetic field reduced by 53,500 nT



x Locality of sampling

Figure 18

(stations 3.55 and 3.6). Again, here, on this anomaly, results of magnetic susceptibility measurements show some of the samples to have this parameter exceeding 150-200x 10^{-3} CI units.

Inasmuch as a location of the local magnetic anomaly utterly coincides with that of the gravity local anomaly, we can figure out the outlines of an orebody with a high magnetization and density, somewhat 400 m long and 10-15 m wide (Fig. 11). Data on physical properties of the ore target rock samples and their mineral composition are given in Tables 4,5.

What came out of the interpretation of geophysical survey data in Svanvik-1 area is shown on interpretive profiles 5.5 and 3.5, where a complete program of survey procedures has been conducted in compliance with the Contract terms (Fig. 19,20). Using several techniques at a time turned out to be effective in this particular case for the purpose of interpreting the magnetic target body, since high values of excess density (more than 0.7-0.9 g/cub.cm) produce quite measurable gravity anomalies and these, together with magnetic and electrical anomalies, enabled to pinpoint an ore object cropping out just beneath the Quarternary sediments (1-6 m) inside a fault zone with a nearly latitudinal trend.

3.4. Anomaly-4 (Fig. 21) is 1.5 km NW of Overli (road # 885). It is confined to a southern slope of a hill with spot elevation marks ranging 100-111 m. Positive airborne anomaly is marked by an intensity of over 250 nT, the accompanying lows amounting to 30-50 nT. The anomaly has a complex configuration, sizing about 600x500 m. It was not regarded as promising for diatreme prospecting and reconnaissance survey was effected within its confines simply to provide data for the interpretation of similar airborne magnetic anomalies in the Shuort area.

On the ground this anomaly is recorded on two profile lines in the form of a complex sign-reversing delta-Ta field with its intensity estimated at several thousands of nT. Particular strictly local anomalies reach +/- 6000-8000 nT and even more, which obscures pretty much a relatively large (2500-3500 nT) anomaly covering an area of 130x220 m. Susceptibility was measured along the ground magnetics profiles. Established was a fact that, with an overall background being about 0.25-1.8x10^{-3} CI units, some bedrocks possess the susceptibility of 418-955x 10^{-3} CI units. As seen from the analysis of physical properties displayed by the relevant bedrock samples (Table 4), the said anomalies of +/- 6000-8000 nT and higher intensity are obviously related to the outcrops of compact and highly magnetic iron ores (iron quartzites ?) containing more than 25% of magnetite. A major magnetic object, with magnetite-bearing rocks at its contacts, occurs at a depth of over 20 m and is probably nothing else than a large body of amphibolites with an abundance of iron.

* * *

RESULTS OF DETAIL SURVEY ALONG INTERPRETIVE PROFILE 5.5 IN ANOMALY-1 (SVANVIK-1) AREA

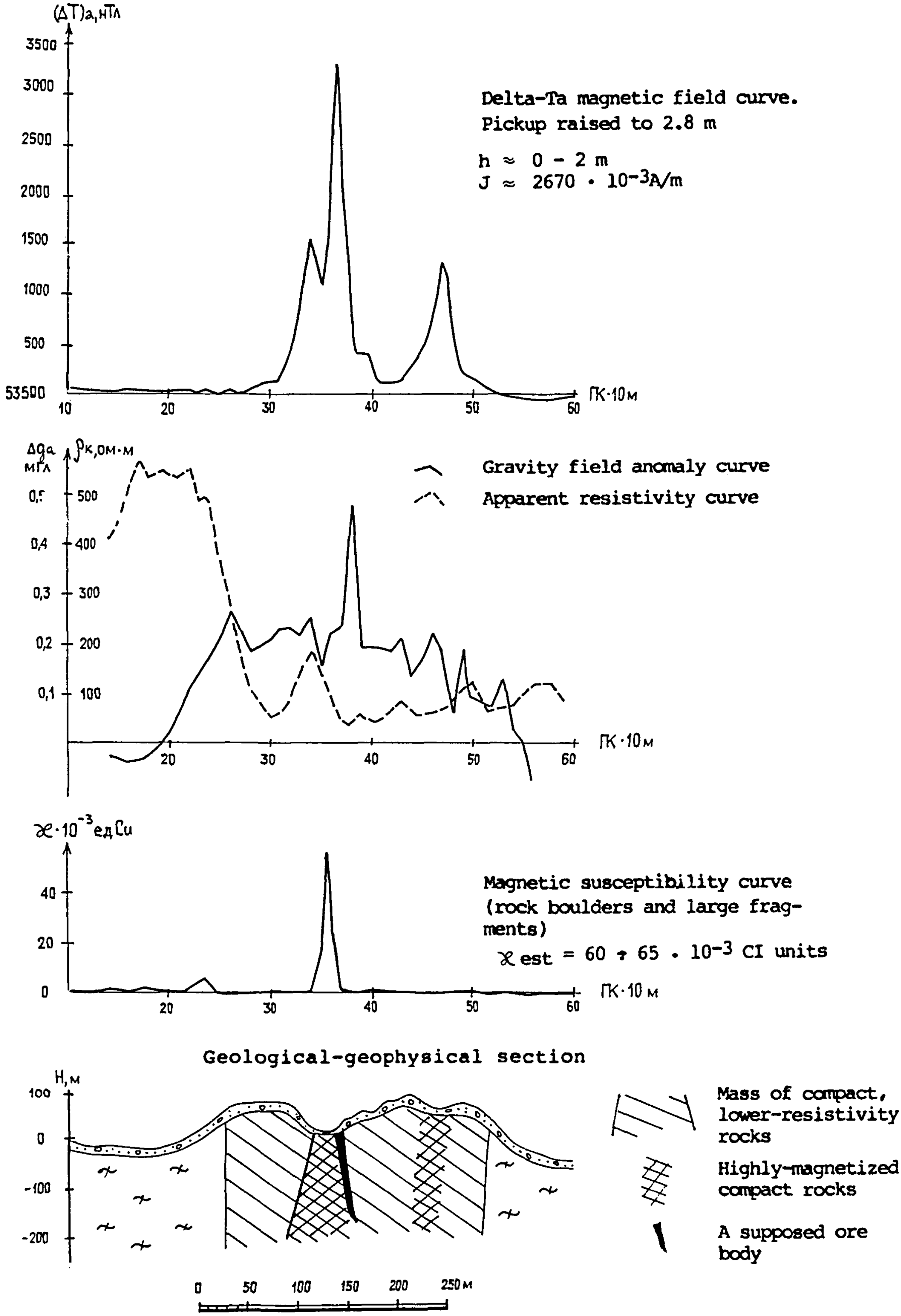


Figure 19

RESULTS OF DETAIL SURVEY ALONG INTERPRETIVE PROFILE 3.5 IN ANOMALY-1 (SVANVIK-1) AREA

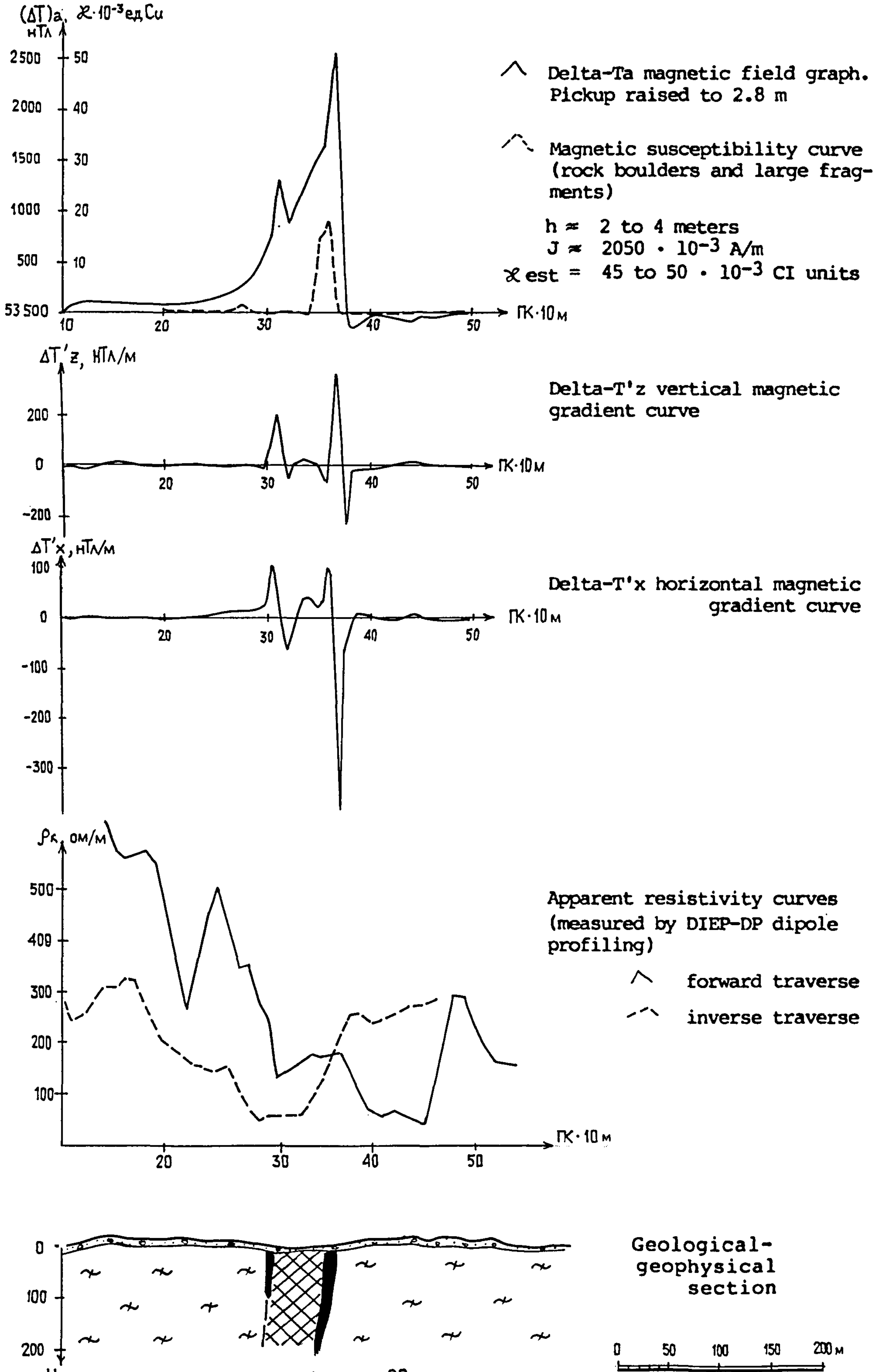
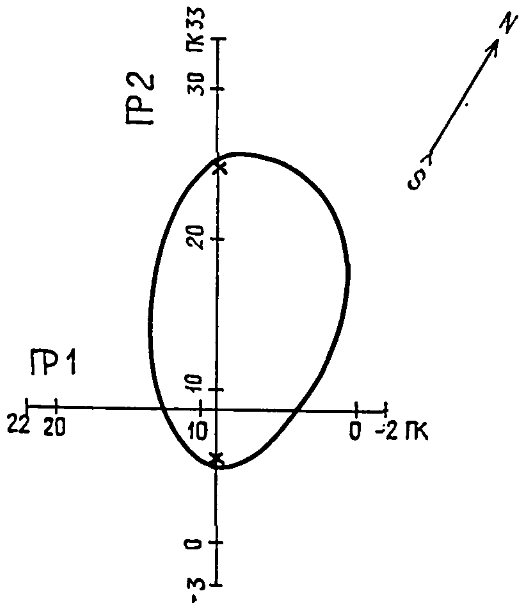


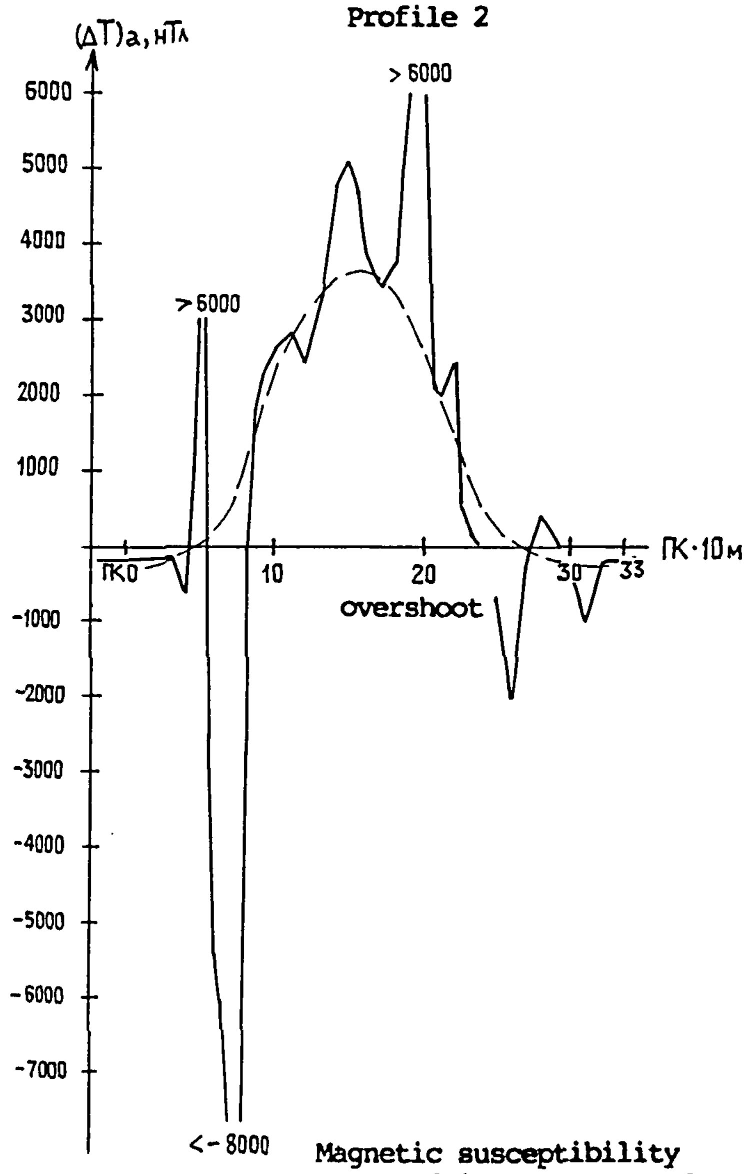
Figure 20

RESULTS OF GROUND RECONNAISSANCE SURVEY IN ANOMALY-4 AREA (SCALE 1/5000)

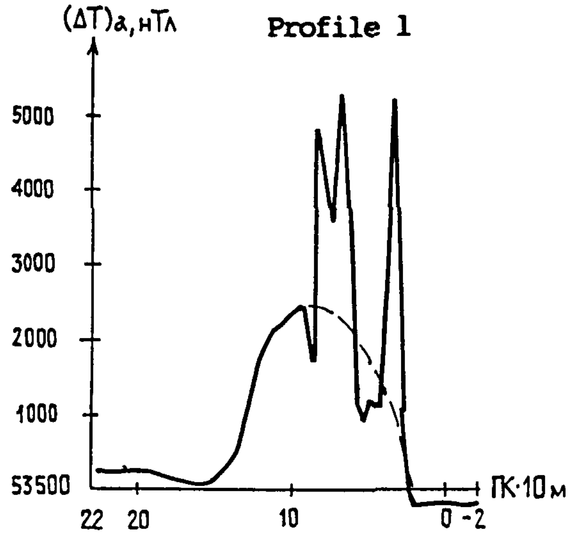
Layout pattern
of reconnaissance profiles

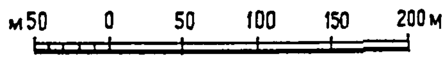


Profile 2



Profile 1





 Rough outlines of a source body according to ground magnetic survey data

 Delta-Ta averaged gradient

× Sampling location

Magnetic susceptibility measured in outcrops and rock samples

Profile, sta. No.	$\varkappa$ 10^{-3} ед.Cu
ГР 1	
ПК 20 - 24	0,25 - 0,75
ПК 19	0,45 - 1,51
ПК 13	136.
ПК 12	1,10 - 3,25
ПК 2	0,15 - 0,65
ГР 2	
ПК 5,5	418. - 955.
ПК 1 5	47,9 - 123
ПК 19	0,3 - 0,71
ПК 23	0. 24 - 3,81
ПК 25	761.- 884.
ПК 30	0,6 - 1,8

Figure 21

CONCLUSIONS

1. Ground geophysical surveys were performed within the confines of 4 airborne anomalies. Three of them, as they were identified on the airborne geophysical map constructed in 1993/94 as a result of the joint airborne geophysical surveys in Pechenga-Pasvik area, were subject to verification, being regarded as promising for finding the diatremes, and stood the proof on the ground to a high degree of precision in coincidence of airborne and ground anomalies' centers.

2. Anomaly-3 is thought to be caused by a pipe-like object. We recommend to make high-precision gravimetric measurements within the anomaly area in order to verify its "pipe" origin.

3. In case the verification in Anomaly-3 area turns out to be positive, we think it be reasonable to turn once again to a geophysical follow-up detail study of Anomaly-2.

4. No proof of that Anomaly-1 (Svanvik-1) was in connection with a pipe-like body came from the ground survey. According to the results of areal surveys on the ground, this airborne anomaly disintegrated into a series of linear highly intensive anomalies, and one of them, traced for more than 400 m, now appears to be promising in terms of finding there a sulfide ore occurrence.

5. Anomaly-4 is interpreted as being related to a large mass of amphibolites betraying high percentage of iron and containing magnetite orebodies.

6. Provided the results of verification check in Anomaly-3 area are positive, we recommend that ground assessment should be done on those local airborne anomalies which we have discriminated in the northern part of the Shuort area.

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FIGURE CAPTIONS

Figure 1 - Contour map of delta-Ta magnetic field, partly shown. Airborne magnetic survey, scale 1/10000.

Figure 2 - Contour map of delta-Tloc magnetic field local anomalies (fragment). Airborne magnetic survey, scale 1/10000.

Figure 3 - Delta-Ta magnetic field graph and geological section along the profile crossing anomaly #7's center. Scale 1/2000.

Figure 4 - Results of ground magnetic survey in anomaly #20 area (contour map's fragment).

Figure 5 - Contour map of delta-Ta magnetic field. Khlebnoe-1 anomaly ground checking area.

Figure 6 - Results of using combined geophysical survey techniques in diatreme prospecting. Anomaly #218.

Figure 7 - Contour map of delta-Ta magnetic field (fragment). Airborne geophysical survey, scale 1/25000.

Figure 8 - Overview map of the survey area.

Figure 9 - Field configuration used in operating ERA unit.

Figure 10 - Layout plan of anomaly-1 area location.

Figure 11 - Layout of anomaly-1 (Svanvik-1) area, scale 1/10000.

Figure 12 - Layout of anomaly-2 and anomaly-3 areas (scale 1/10000).

Figure 13 - Layout of anomaly- 4 area (scale 1/5000).

Figure 14 - Delta-Ta magnetic field map. Svanvik-1 anomaly area (scale 1/5000).

Figure 15 - Comparing the results of fitting delta-Ta magnetic field with magnetic survey data.

Figure 16 - Results of ground reconnaissance survey in anomaly-3 area (scale 1/5000).

Figure 17 - Results of ground reconnaissance survey in anomaly-2 area (scale 1/5000).

Figure 18 - Contour map of delta-Ta magnetic field. Svanvik-1 anomaly ground checking area. Total magnetic field reduced by 53500 nT.

Figure 19 - Results of detail survey along interpretive profile 5.5 in anomaly-1 (Svanvik-1) area.

Figure 20 - Results of detail survey along interpretive profile 3.5 in anomaly-1 (Svanvik-1) area.

Figure 21 - Results of ground reconnaissance survey in anomaly-4 area (scale 1/5000).