NGU Rapport 91.256

Helicopter geophysical survey in Finnmark, 1991

NORGES GEOLOGISKE UNDERSØKELSE

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RAPPORT

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Tittel:

Helicopter geophysical survey in Finnmark, 1991

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Fylke: Finnmark	**Kommune:** Kautokeino
Kartbladnavn (M. 1:250 000) Nordreisa og Enontekiø	**Kartbladnr. og -navn (M. 1:50 000)** 1832 I Siebe 1833 II Kautokeino
Forekomstens navn og koordinater:	**Sidetall:** 12 **Pris:** **Kartbilag:** 12+(60)

Feltarbeid utført:	Rapportdato:	Prosjektnr.:	Seksjonssjef:
17.-27.09.91	31.12.1991	61.2577.00	[signature]

Sammendrag:

This report contains the results from helicopter geophysical measurements over 2 areas flown near Kautokeino in 1991 for Outokumpu Finnmines Oy. The areas are named Cabardasjåkka and Reidnjajavri, with 1649 line kilometers flown in the first area and 801 line kilometers flown in the second. Aircraft altitude was approximately 200 feet and the line spacing was set at a nominal 50 meters.

Field operations and data processing were completed by NGU. Results are presented as coloured contour maps and stacked electromagnetic profiles. All map products were produced at NGU at scales of 1:10.000 and 1:20.000 scales, with stacked profiles being produced at 1:10.000 scale only.

2 copies of this report each containing 12 colour maps (A3) and 60 colour maps at scales of 1:10.000 and 1:20.000 have been made for Outokumpu Finnmines Oy.

Extra colour maps at scales 1:10.000 and 1:20.000 can be ordered from NGU.

Emneord	Magnetometri	VLF-målinger
Geofysikk	Radiometri	
Helikoptermålinger	Elektromagnetisk måling	Fagrapport

Table of Contents

Enclosed A3 sized maps at 1:40000 approximate scale

General

AREA: A helicopterborne geophysical survey was undertaken by the Norwegian Geological Survey (NGU) on behalf of Outokumpo Finnmines Oy over two areas in the Kautokaino area in Finnmark Fylke, Norway. The survey was flown during September, 1991, and consisted of a total of 2450 line kilometers. 1649 line kilometers were completed in the Cabardasjåkka area, which lies just north of Kautakaino, and 801 line kilometers were completed in the Reidnjajavri area which lies approximately 25 kilometers to the south. Line spacing was nominally 50 meters, but additional lines were flown at a nominal 500 meter spacing to connect the Reidnjajavri area with a similar survey previously flown during 1989. This survey is described in NGU report 89.143.

EQUIPMENT: Equipment operated in the survey included a four-frequency electromagnetic system, a helium optical pumped magnetometer, a VLF-EM system, a radiometric system, a video camera for flightline tracking, a radar altimeter and a radio navigation system. All data were recorded both in digital and in analogue form, with positioning data stored on video film as well as being recorded by the navigator in flight.

PURPOSE: The purpose of the survey was to locate structures favourable for gold mineralization. The gold mineralization is believed to be associated with breaks in graphitic conductors which can be identified through resistivity highs. These breaks are caused by oxidation of the graphite, and are therefore often associated with magnetic lows which result from the oxidation of magnetite into hematite.

SURFACE GEOLOGY: In both areas, bedrock is poorly exposed and is covered by overburden with localized swampy areas.

Operational Aspects of the Survey

CABARDASJÅKKA AREA: In the Cabardasjåkka area, the survey was completed in 9 flights between the dates Sep. 17 and Sep. 24, 1991. Lines were flown east-west at a nominal line spacing of 50 meters. See figure 1 for an overview of the area.

REIDNJAJAVRI AREA: The Reidnjajavri area was completed in 5 flights between Sep. 25 and Sep. 27, 1991. Two line orientations with a nominal spacing of 50 meters were employed to form an inverted "L" shaped grid with a common area of overlap. In the northern area, the lines were oriented north-south, and in the south the orientation was east-west. An additional series of north-south trending lines parallel to the northern section of this area were flown at a 500 meter line spacing free of charge by NGU for Outokumpu Finnmines OY. See figure 2 for an overview of the area.

TIE LINES: In addition to profile data, tie lines were flown to assist in levelling the magnetic data should there be problems with the magnetic basestation. These data were not required to level the magnetic data.

BASESTATION: A magnetic basestation was operated so diurnal changes in the magnetic field could be removed from magnetic profile data.

BACKGROUND LINES: Background lines, to monitor instrumental drift in the electromagnetic system, were flown at 20 minute intervals. To reduce instrumental drift, the electromagnetic system was left on continuously so the electronic components would remain warm and so have stable electronic properties.

PERSONNEL: The following personnel participated in the survey:

J. Mogård	Senior Engineer	(NGU)
O. Blokkum	Engineer	(NGU)
L. Huus	Pilot / aircraft engineer	

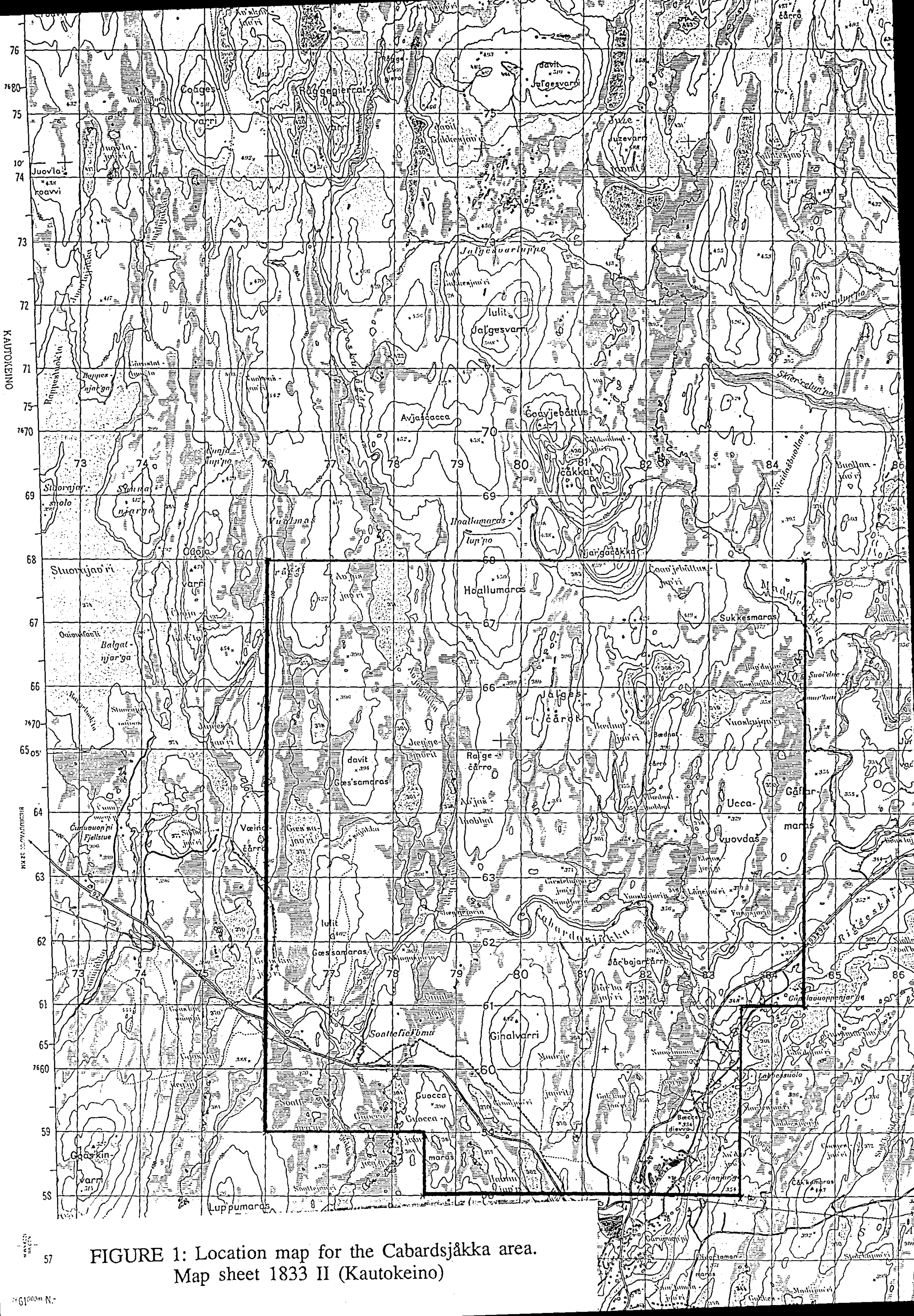

FIGURE 1: Location map for the Cabardsjåkka area.
Map sheet 1833 II (Kautokeino)

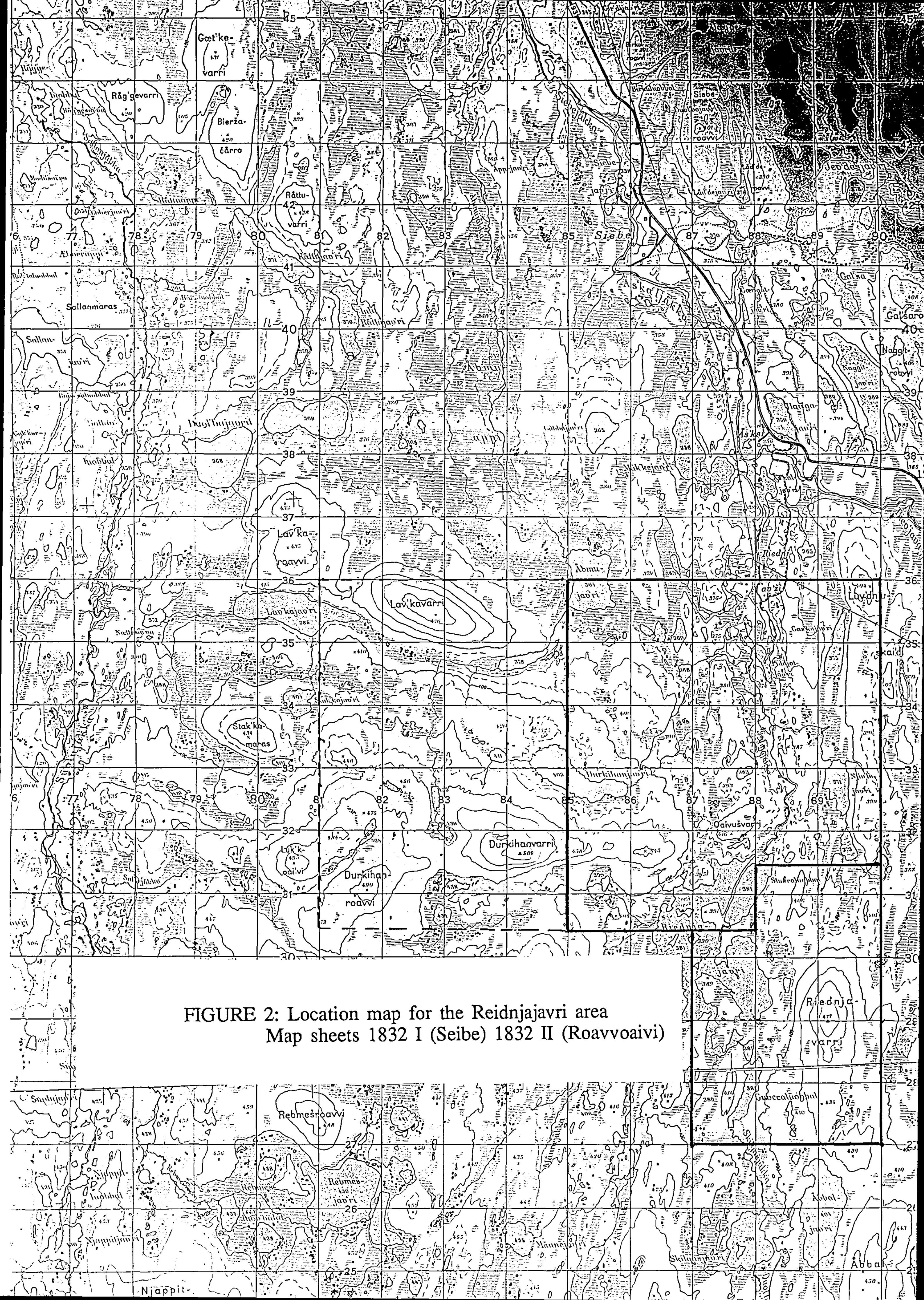

FIGURE 2: Location map for the Reidnjajavri area
Map sheets 1832 I (Seibe) 1832 II (Roavvoaivi)

Processing

MAP SHEETS: Data from both areas were processed at 1:10000 and 1:20000 scales, apart from EM profiles which were processed only at 1:10000 scale. Because of the size of the maps at 1:10000 scale, both areas were divided into two parts (a north part and a south part) and these parts were plotted as separate, but overlapping maps. A total of three copies of each map therefore exist for each area: 2 at 1:10000 scale and one at 1:20000 scale.

In addition, profiles of the data flown at 500 meter line spacing were plotted on the 1:20000 scale maps of the Reidnjajavi area, where such profile data existed. (Eg: For values computed from grids, such as the calculated magnetic vertical gradient, magnetic shadows, and the averaged VLF fields, no profile data exist.) Rather than producing profiles of electromagnetic data plotted on the flight lines as originally specified in the contract, stacked electromagnetic profiles were produced at 1:10000 scale. The stacked profile format was selected over line profiles due to their superiority for interpreting electromagnetic data.

MAP PRODUCTS: The following products were produced at 1:10000 and 1:20000 scales as coloured and contoured maps for both areas. A total of 6 maps exist for each of the following: 2 at 20000 scale (1 for each area) and 4 at 10000 scale (2 for each area):

01	Flight lines, topography and time
02	Total magnetic field
02S	Total magnetic field shadow
03	Calculated magnetic vertical gradient
04	900 Hertz coaxial apparent resistivity
05	4200 Hertz coplanar apparent resistivity
06	Total radiometric count
07	Averaged inline and orthogonal VLF field
07L	VLF inline field
07O	VLF orthogonal field

All of these maps are available from NGU on request. Selected copies of these maps have been reproduced in colour in A3 size (approximately 1:40000 scale), and are included in this report. (See the listing following the table of contents.)

COMMENTS:

Note that for product 1 at 1:10000 scale, topography was not plotted. On these maps flight times are plotted to provide a base so that structures interpreted from the stacked electromagnetic profiles can be transferred to maps at 1:10000 scale.

The magnetic shadow maps were produced using three different illumination directions. The blue shadows were cast from a source located to the north, the red shadows from a source to the east and the yellow shadows from a vertical source.

Where the in-phase response is negative due to the presence of magnetite, the apparent resistivity is calculated assuming a bird height of 30 meters with the quadrature response alone. Where magnetite is present, the inphase response will be more depressed than if it were absent: This means that the apparent resistivity where magnetite is present will be higher than where it is absent -- all other factors being the same.

Note that during some parts of the survey, snow was present in certain areas. Snow absorbs gamma radiation which can lead to apparent lows in the spectrometric data. This can be checked using videotape.

Aircraft and Equipment

AIRCRAFT: The survey was flown using an Aerospatiale Ecureuil B-2 provided by Helikoptertjeneste A/S, based in Kinsarvik, Norway. Installation of the geophysical and ancilliary equipment was done by NGU in Trondheim. Base for operations in the Kautokaino area was on a small knoll outside Kautokaino near an installation operated by the Norwegian Department of Defence.

ELECTROMAGNETIC SYSTEM: Electromagnetic measurements were made using a four-frequency electromagnetic system manufactured by Aerodat, Ltd. of Mississauga, Canada. The system employs two coil pairs which operate at 932 and 4568 Hertz in the coplanar mode, and two pairs which operate at 4175 and 34165 Hertz in the coaxial mode. Transmitter and receiver coils for each frequency are separated by approximately 7 meters, and are mounted inside a kevlar "bird" with a total length of approximately 8 meters. The system measures the inphase and quadrature responses at each frequency 10 times per second, which corresponds to approximately a 3 meter interval over the ground at a flight speed of 100 kilometers/hour. The bird is suspended approximately 30 meters below the helicopter. Output of the system is in parts per million of the primary field at the receiver coils.

VLF-EM SYSTEM: VLF-EM measurements were made with a Herz Totem-2A VLF system. The system measures the field strength radiated from transmitters in the 15 to 30 KHz range which are operated by various national governments. The system provides total field and vertical quadrature measurements of the fields from two such stations. The sensor was towed in a bird located approximately 10 meters below the helicopter.

MAGNETOMETER: Magnetic measurements were made with a Scintrex split beam optically pumped helium magnetometer coupled to a digital signal processor. Magnetic data are recorded 10 times per second and the sensor is located approximately 15 meters below the helicopter.

MAGNETIC BASE STATION: Diurnal variations in the magnetic field were recorded with a Scintrex MP-3 magentometer located at the base of helicopter operations. Data were recorded digitally on a personal computer and in analogue form on a thermal chart recorder. Clocks in the base station and the data acquisition system were synchronized prior to each flight to ensure diurnal effects could be accurately removed from the magnetic profile data.

RADIOMETRICS: Radiometric measurements were recorded with a 1024 cubic inch crystal volume detector which was coupled to a Geometrics gamma-ray spectrometer system. The system consists of 4 crystals which are continuously stabilized by a micro-processor controlled spectrum stabilization package.

DATA ACQUISITION SYSTEM: Data were acquired by a DAS-8 data acquisition system manufactured by RMS Instruments Ltd. Data were recorded both digitally on a 40 Mbyte tape and in real time with a thermal graphic printer. Digital data were subsequently transferred to VAXes at NGU for processing and map production.

RADIO NAVIGATION: The survey was flown using a Motorola line of sight radar system with a positioning accuracy of approximately 5 meters. The system provided real time output of the position of the helicopter which assisted the pilot in keeping the helicopter on-line. A total of three transponders were used to overcome shadowing effects which can result from variations in topography.

FLIGHT PATH VIDEO: As a backup to the radio naviagation system, a video camera was mounted in the helicopter so the position of the helicopter could be recovered in case the radio navigation system failed. Time and manual fiducials are superimposed on ground imagery to assist the correlation of the video with digitally recorded data. Video proved to be unnecessary for recovering the position of the aircraft.

RADAR ALTIMETER: A King KRA-10A radar altimeter was mounted in the helicopter to provide ground clearance information to an accuracy of 5%. The primary use of the radar altimeter as an aid for maintaining constant ground clearance.

General Interpretive Considerations

ELECTROMAGNETIC:

The Aerodat four frequency system utilizes two different coil geometries. Both the coaxial and the coplanar coil configurations are operated at two widely separated frequencies. One horizontal coplanar coil pair is operated at a frequency similar to one of the frequencies operated by one of the vertical coaxial coil pairs. Thus both coil pairs have a similar sensitivities to conductive structure buried at the same depth. Any difference in response between the two is therefore due to differential coupling of the vertical coaxial field and the horizontal coplanar field to structures in the ground. By examining the difference in the coplanar and the coaxial anomalies, the shape of the conductor responsible for the anomaly can by interpreted.

For a given conductive body, the phase response of the body (or the ratio of the quadrature to the inphase response) increases with the conductivity and dimensions of the body. A small phase response indicates a weakly conductive and or small body, but the size of the body can also be deduced from the strike and length extent of the body. The dependence of the response on phase is shown quantitatively for a non-magnetic, vertical halfplane model in the accompanying phasor diagram. The specific response for a given body will depend on the geometric properties of the causative body.

The phasor diagram presented in figure 3 illustrates the response of a vertical halfplane model to excitation by coaxial coils directly over the top of the conductor. Such a model was used to assist the interpretation of the electromagnetic data acquired in the survey, and the conductance of selected anomalies is presented on various maps produced from this survey. One must be careful when using the values presented: bear in mind that they are only valid for a vertical halfplane sitting in a resistive medium. Attributes of the body that can adversely affect the interpreted conductance are its dip, limited strike extent, variations in it conductivity and/or thickness (heterogeneity) and magnetic susceptibility. Also bear in mind that the response of a body can be significantly modified by adjacent bodies, so where anomalies are clustered, caution is also required.

Sulphides: Massive sulphide mineralization generally produces a strong electromagnetic response. To produce a strong response, the electrically conductive mineralization must be connected. Where mineralizeation is disseminated, the response will generally be weak, even though a large fraction of the rock is mineralized.

Gold: Gold mineralization is usually present is such small quantities that it produces little or no electromagnetic response on its own. Rather, the targets when looking for gold should be either the response of associated mineralization or of host geologic structures.

GEOMETRICAL INFORMATION: Geometrical information about the conductor can often be interpreted from the shape of the profile. The change in the profile shape is related to changes in inductive coupling between the transmitter, target and the receiver.

Thin conductor: In the case of a thin, steeply dippping sheet-like conductor, the coaxial coil pair will yield a symmetric peak over the conductor. The coplanar coil pair will on the other hand, be null coupled directly over the sheet with side lobes to each side.

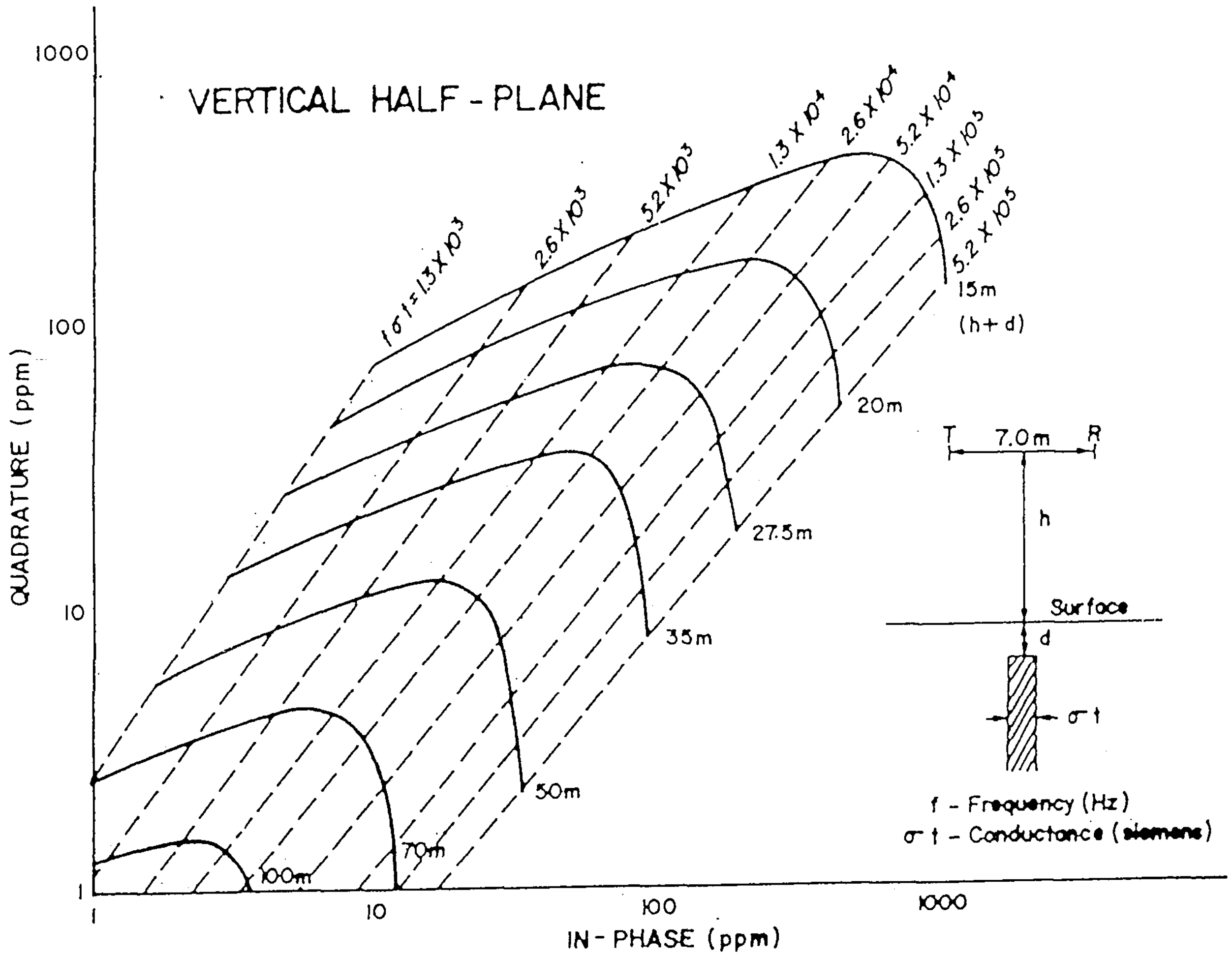

FIGURE 3: Phasor diagram showing EM responses

Thick conductor: When the conductor is thick, current can be induced in any direction in the body and it is not possible to produce a null coupled configuration. As a result, the minimum associated with null coupling to a thin conductor diminishes, and when the conductor is thick enough, it vanishes completely.

Massive conductor: When the conductor is massive, such as in the case of a spherrical conductor, both the coaxial and coplanar coils will display a single peak. The coplanar response will have an amplitude of upto eight time the coaxial response.

Overburden: Where the response is a result of overburden, the coplanar response is generally four times greater than the coaxial response. When the edge of the overburden is sharply defined, edge effects will appear in the coaxial coils as a peak over the sharp conductivity contrast.

MAGNETICS:

Magnetite is the most common magnetic mineral, and the total magnetic field generally is a reliable indicator of the amount of magnetite present. EM anomalies with magnetic correlations can be caused by a sulphide deposit if the mineralization contains pyrrhotite or the sulphides are associated with magnetite. However, coincident EM and magnetic anomalies are often associated with graphite and magnetite.

VLF:

The VLF-EM method uses signals from powerful military radio transmitters as primary signals. The magnetic field associated with the primary field is elliptically polarized in the vicinity of electrical conductors. The Herz Totem 2a receiver uses three orthogonal coils to measure the total field and the vertical quadrature components of the polarization ellipse from two stations.

The relatively high frequency of VLF (15 to 25 kilohertz) and the distance of the transmitters from the survey area permits currents to be induced in large conductors with fairly low conductance. For this reason, disconneted sulphide ores have produced measurable VLF signals. For the same reason, poor conductors such as sheared contacts, breccia zones, narrow faults, alteration zones and porous flow tops normally produce VLF anomalies, so the method has application in geological mapping.

For the VLF method to be the most sensitive to a conductor, the conductor should be aligned along the axis lying between the survey area and the VLF transmitter. Sensitivity of the method to a conductor diminishes as the angle between the conductor ans this axis increases to 90 degrees.

The total field VLF response will be a maximum over the conductor, and if the conductor is dipping, the response will strongly favor the upper edge of the conductor. The vertical quadrature component over steeply dipping sheet-like conductors will be a cross-over type response, with the cross-over at the upper edge of the conductor.

OUTOKUMPU FINNMINES OY
FLYLINJER OG TOPOGRAFI
CABARDASJÅKKA
FINNMARK FYLKE
SCALE
0 660 1320 2640 1 MILE
0 200 400 1000 2000 METRES
NORGES GEOLOGISKE UNDERSØKELSE
Leiv Eirikssons vei 39
N-7040 TRONDHEIM
TEL 07 - 90 40 11
DATO: SEP 91
TEGNING NR:
91.256-01A
KARTBLAD NR:
1833 II KAUTOKEINO
EM Anomalier
Ledningsevne X tykkelse (mhos)
0 - 1
1 - 2
2 - 4
4 - 8
8 - 15
15 - 30
> 30
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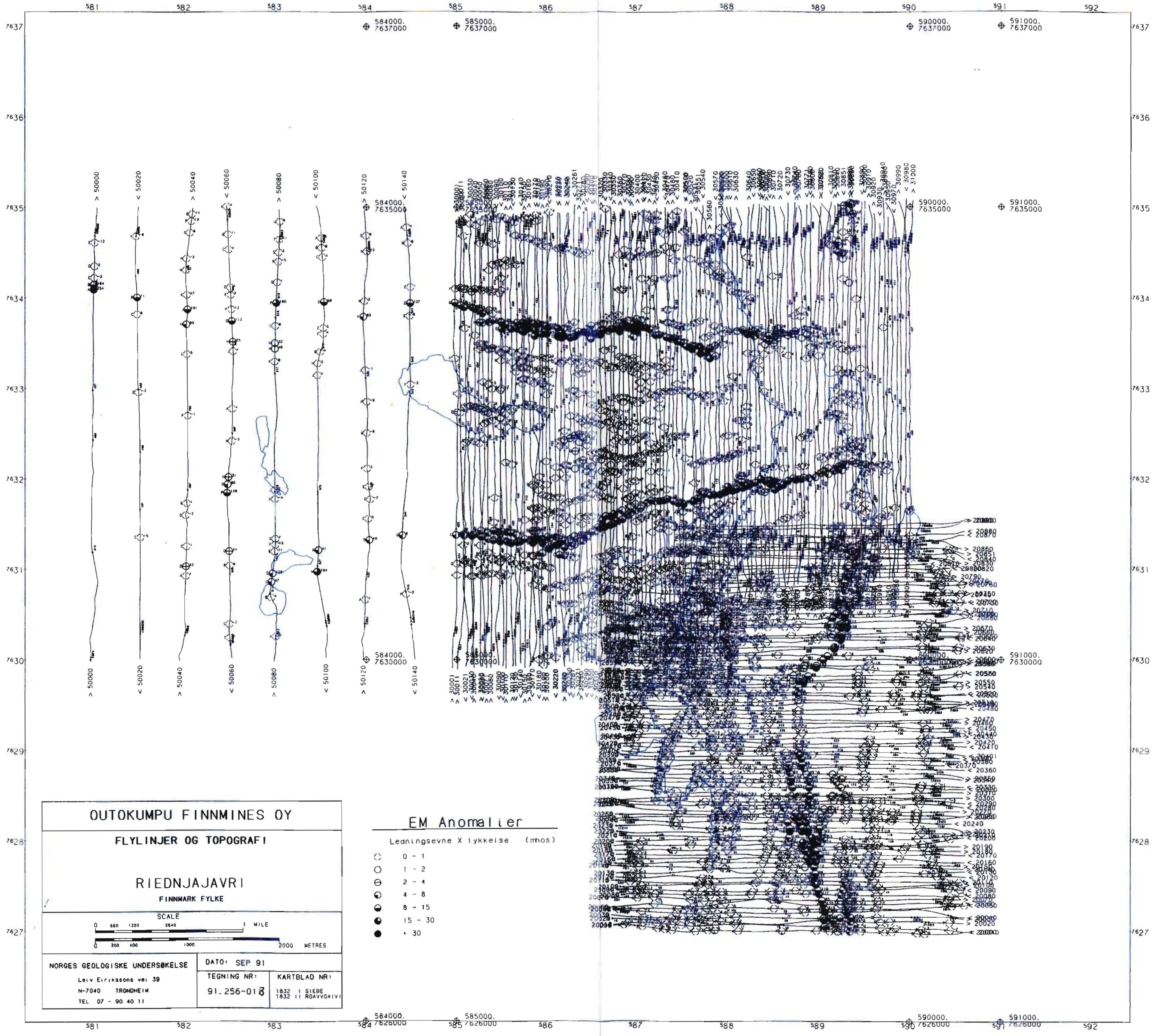
OUTOKUMPU FINNMINES OY
FLYLINJER OG TOPOGRAFI
RIEDNJAJAVRI
FINNMARK FYLKE
SCALE
0 660 1320 2640 1 MILE
0 200 400 1000 2000 METRES
NORGES GEOLOGISKE UNDERSØKELSE
Leiv Eirikssons vei 39
N-7040 TRONDHEIM
TEL 07 - 90 40 11
DATO: SEP 91
TEGNING NR:
91.256-018
KARTBLAD NR:
1832 I SIEBE
1832 II ROAVVOAIVI
EM Anomalier
Ledningsevne X tykkelse (mhos)
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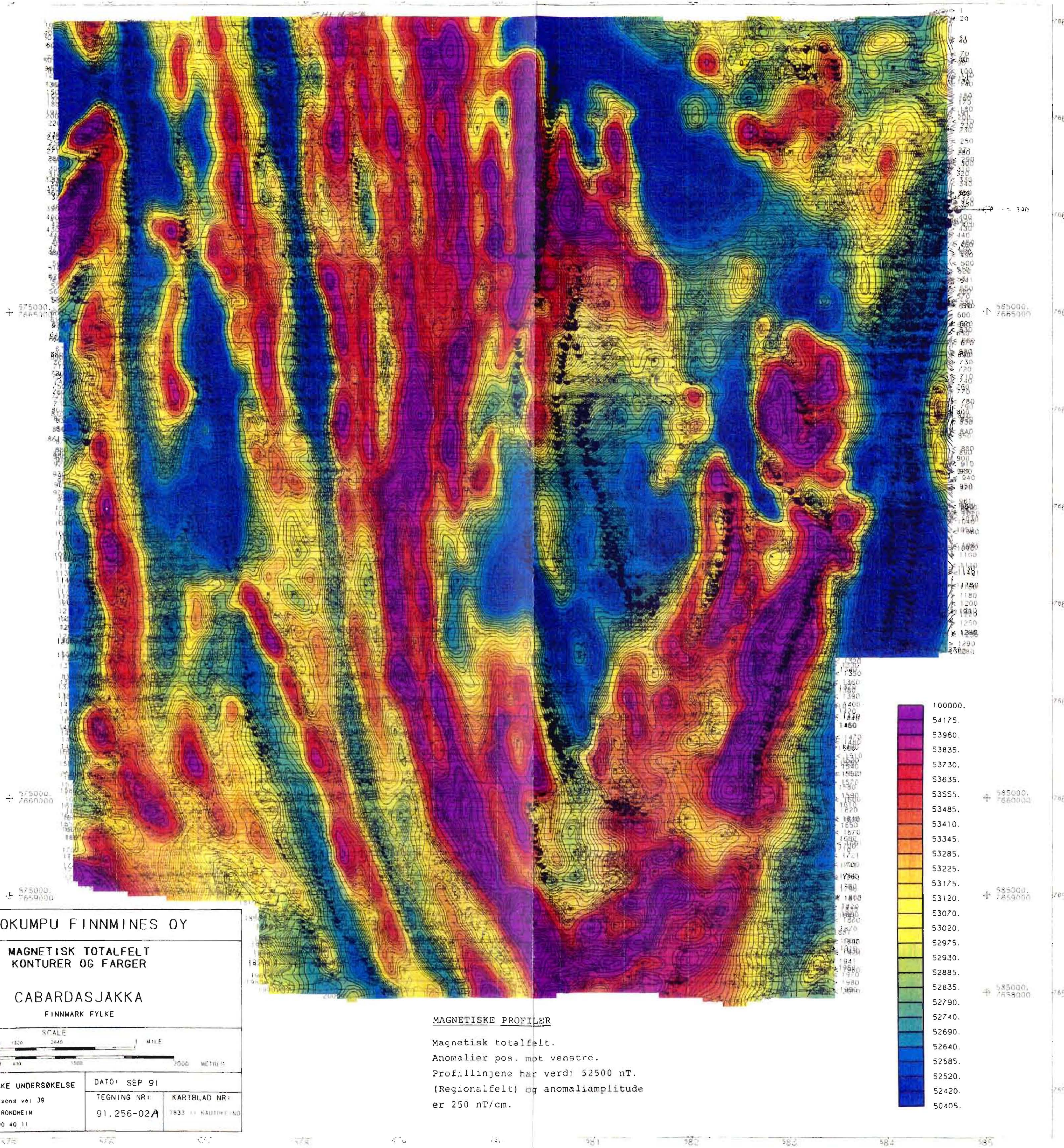

OUTOKUMPU FINNMINES OY

MAGNETISK TOTALFELT KONTURER OG FARGER

CABARDASJAKKA

FINNMARK FYLKE

SCALE

0 660 1320 2640 1 MILE

0 200 400 1000 2000 METRES

NORGES GEOLOGISKE UNDERSØKELSE Leiv Eirikssons vei 39 N-7040 TRONDHEIM TEL 07 - 90 40 11	DATO: SEP 91	
	TEGNING NR: 91.256-02A	KARTBLAD NR: 1833 II KAUTOKEINO

MAGNETISKE PROFILER

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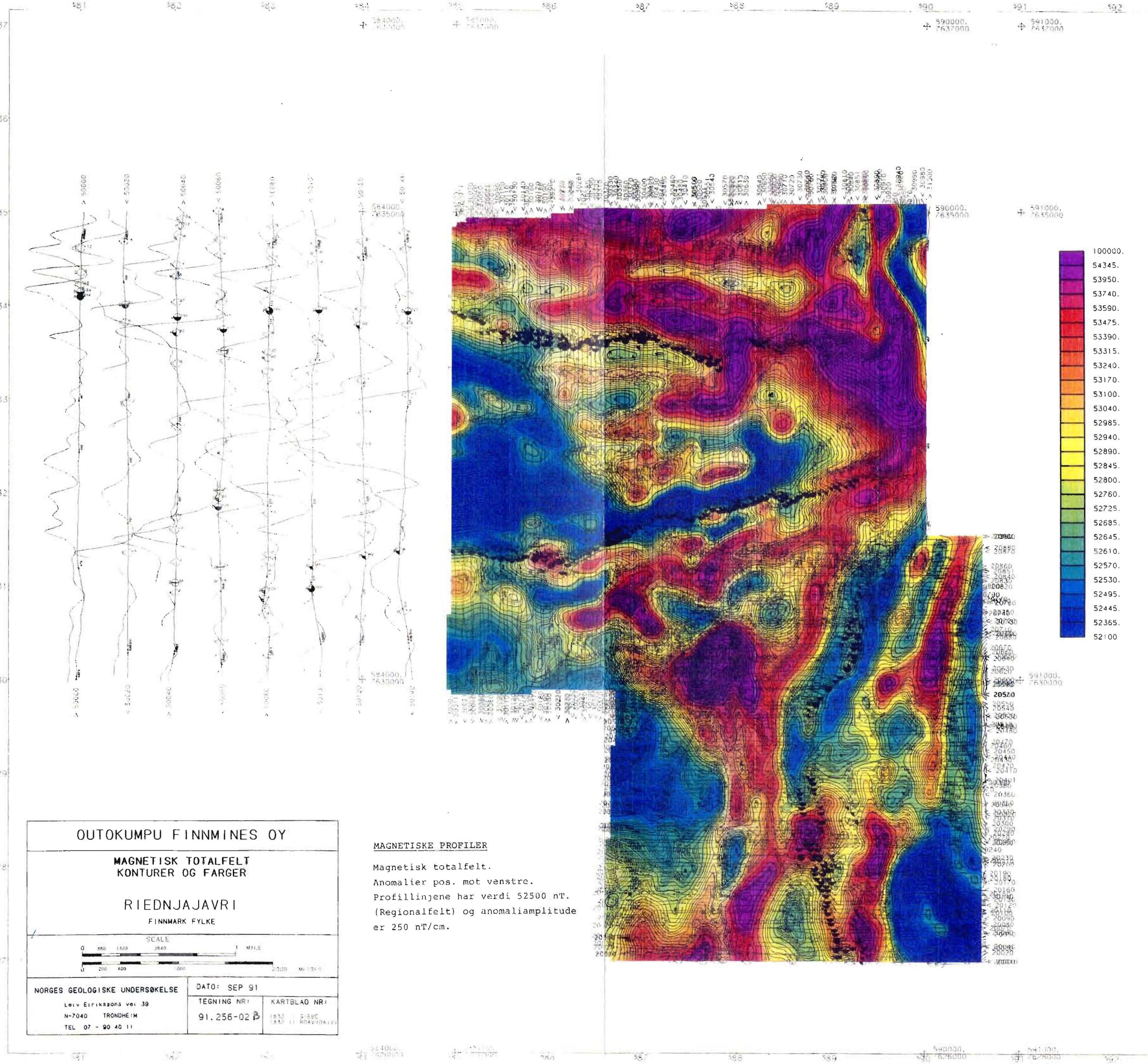
Anomalier pos. mot venstre.
Profillinjene har verdi 52500 nT.
(Regionalfelt) og anomaliamplitude
er 250 nT/cm.



OUTOKUMPU FINNMINES OY
MAGNETISK TOTALFELT
KONTURER OG FARGER
RIEDNJAJAVRI
FINNMARK FYLKE
SCALE
1 MILE
METRES
NORGES GEOLOGISKE UNDERSØKELSE
Leiv Eirikssons vei 39
N-7040 TRONDHEIM
TEL 07 - 90 40 11
DATO: SEP 91
TEGNING NR:
91.256-02 B
KARTBLAD NR:
MAGNETISKE PROFILER
Magnetisk totalfelt.
Anomalier pos. mot venstre.
Profillinjene har verdi 52500 nT.
(Regionalfelt) og anomaliamplitude
er 250 nT/cm.
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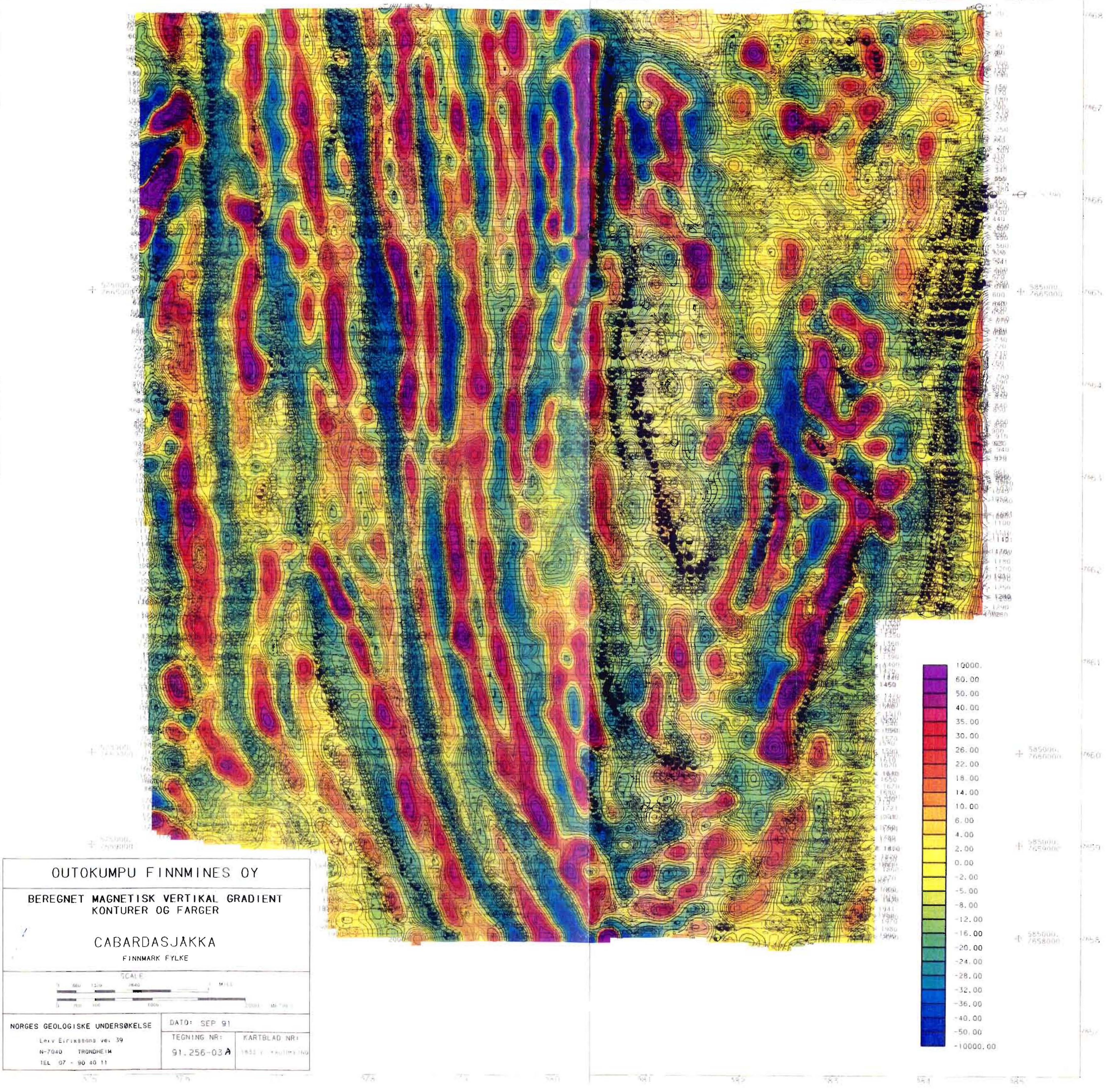
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KONTURER OG FARGER
CABARDASJAKKA
FINNMARK FYLKE
SCALE
NORGES GEOLOGISKE UNDERSØKELSE
Leiv Eirikssons vei 39
N-7040 TRONDHEIM
TEL 07 - 90 40 11
DATO: SEP 91
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91.256-03A
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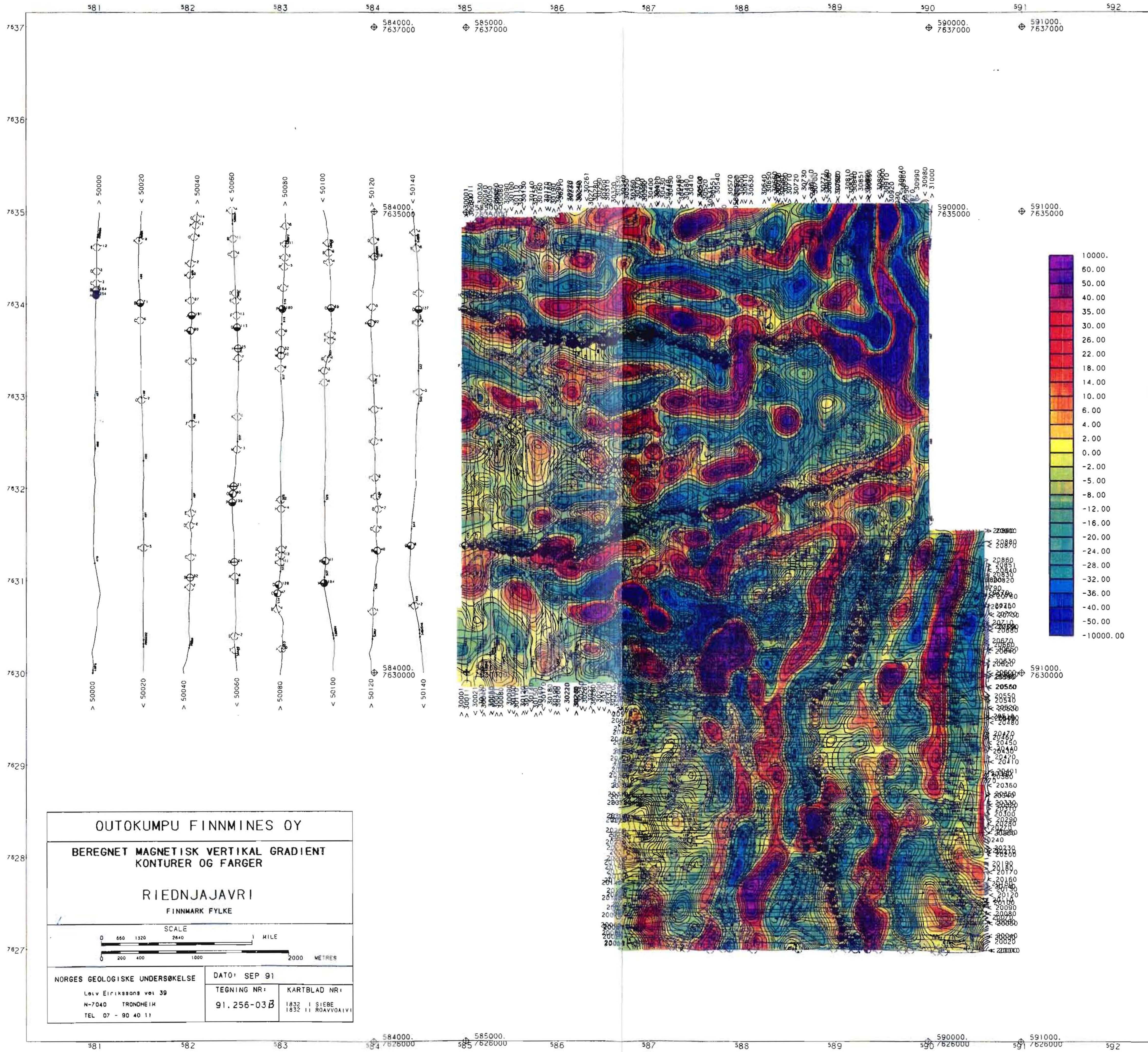
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KONTURER OG FARGER
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FINNMARK FYLKE
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0 200 400 1000 2000 METRES
NORGES GEOLOGISKE UNDERSØKELSE
Leiv Eirikssons vei 39
N-7040 TRONDHEIM
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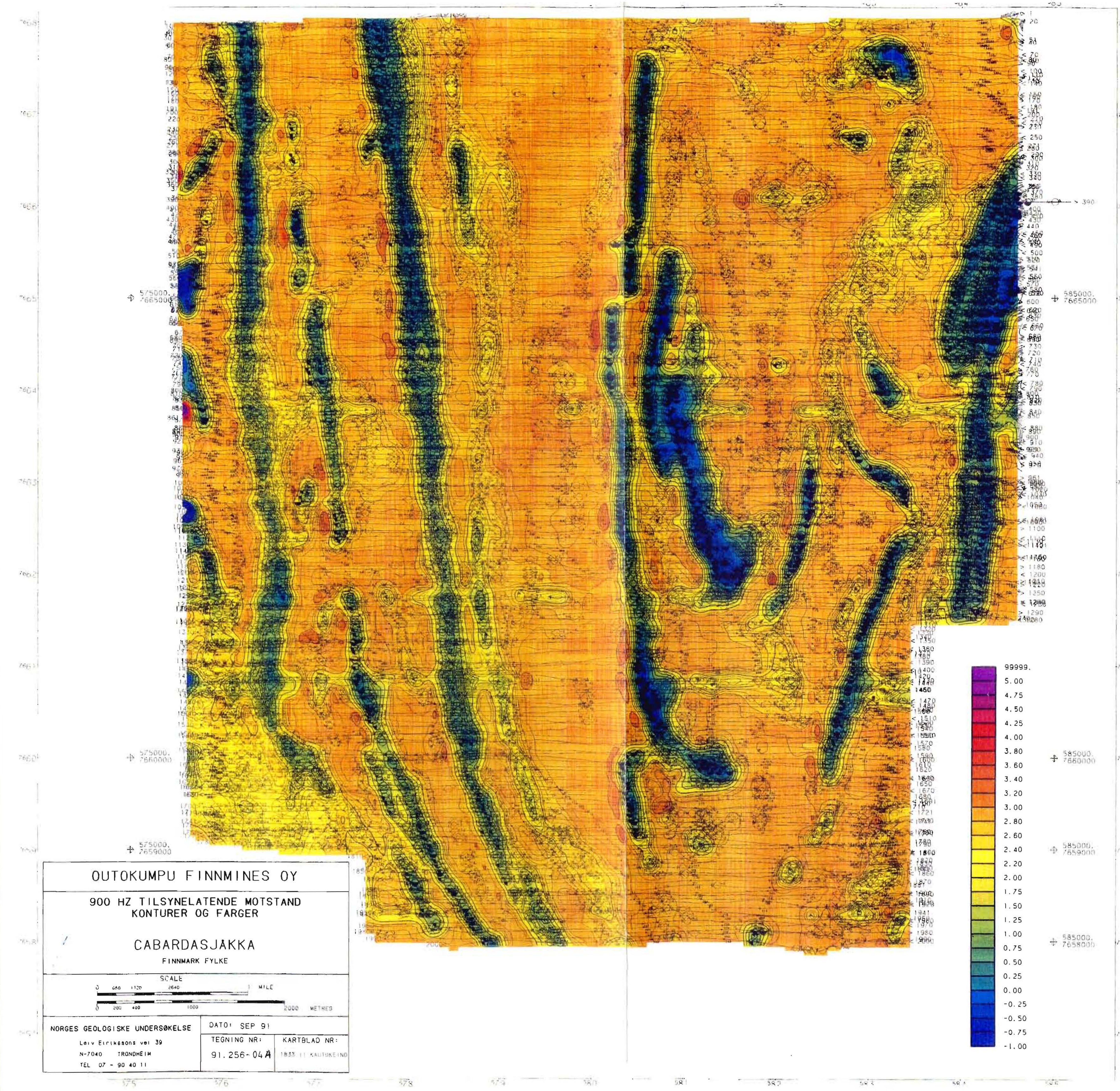

OUTOKUMPU FINNMINES OY
900 HZ TILSYNELATENDE MOTSTAND
KONTURER OG FARGER
CABARDASJÅKKA
FINNMARK FYLKE
SCALE
0 660 1320 2640 1 MILE
0 200 400 1000 2000 METRES
NORGES GEOLOGISKE UNDERSØKELSE
Leiv Eirikssons vei 39
N-7040 TRONDHEIM
TEL 07 - 90 40 11
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TEGNING NR:
91.256-04A
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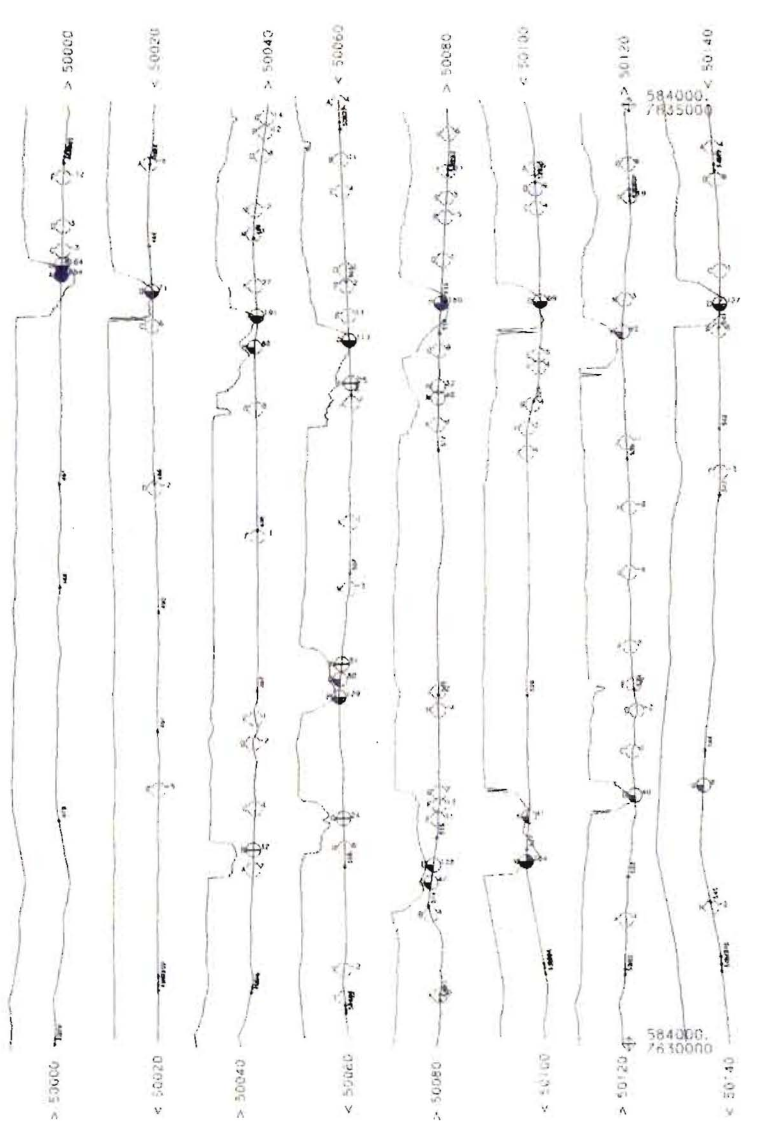
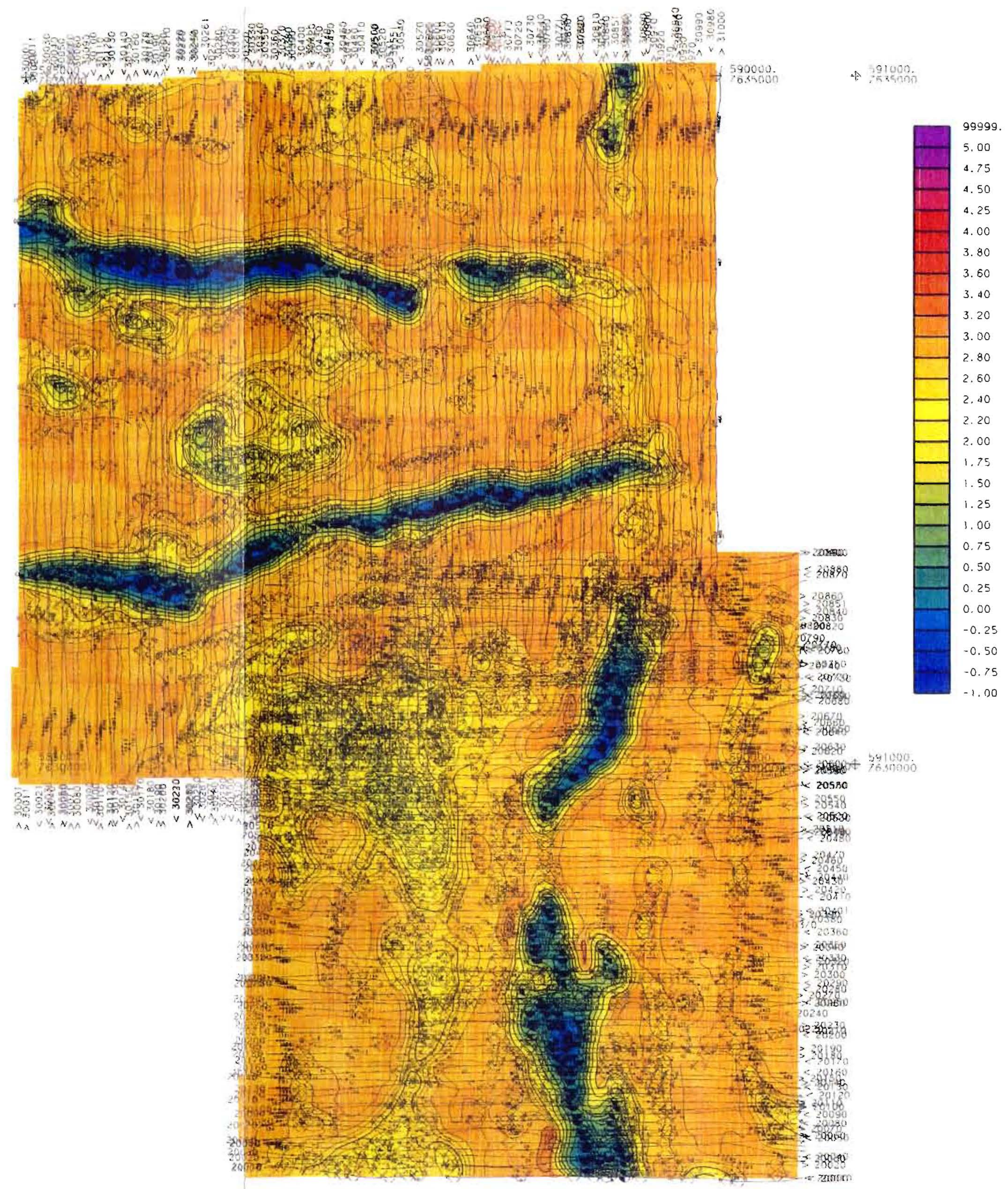




Profiler med kalkulert tilsynelatende motstand. Logaritmisk skala (2.5/cm), positiv amplitude mot venstre.

OUTOKUMPU FINNMINES OY

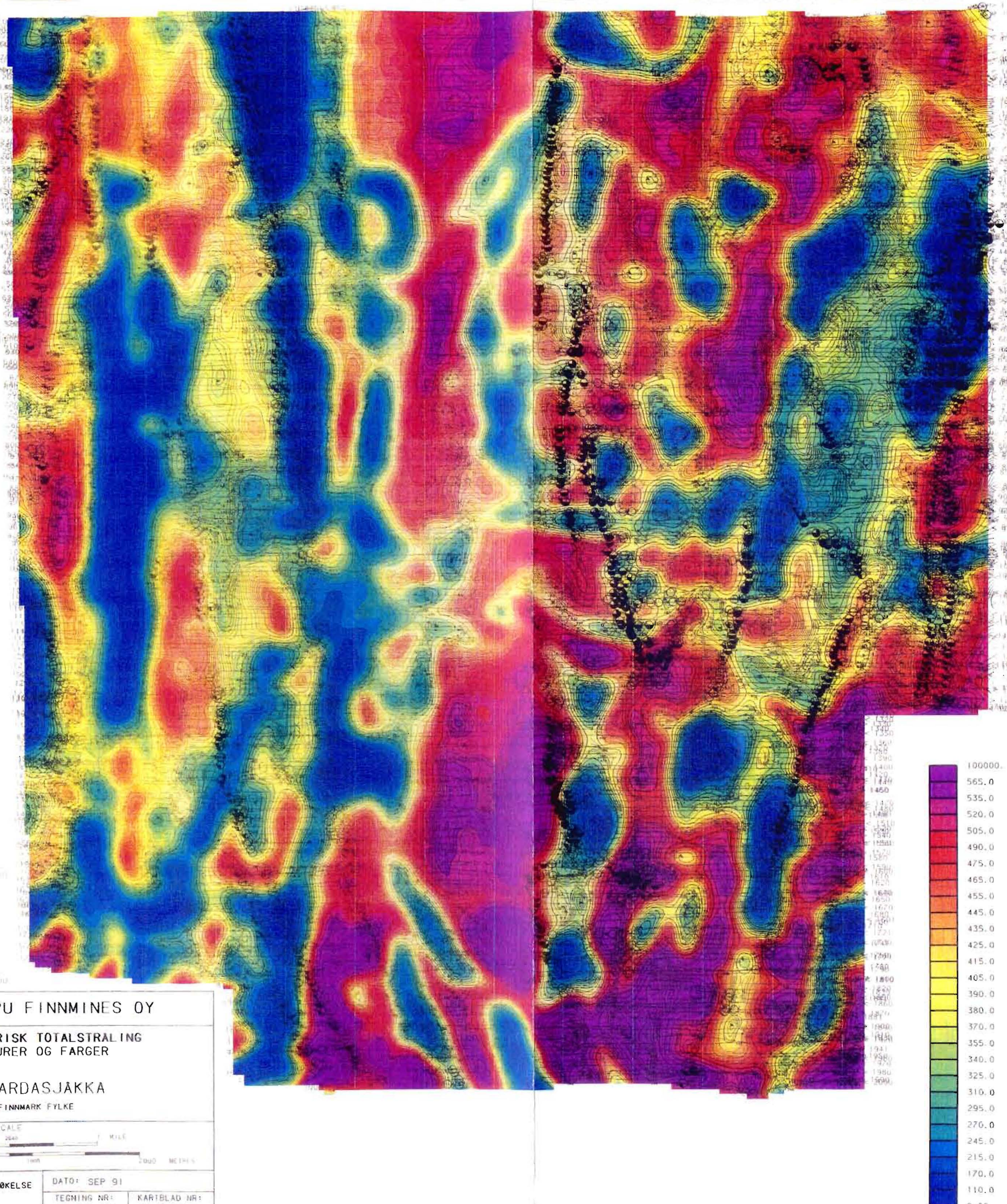
900 HZ TILSYNELATENDE MOTSTAND KONTURER OG FARGER

RIEDNJAJAVRI

FINNMARK FYLKE

SCALE

NORGES GEOLOGISKE UNDERSØKELSE Leiv Eirikssons vei 39 N-7040 TRONDHEIM TEL 07 - 90 40 11	DATO: SEP 91 TEGNING NR: 91.256-04B	KARTBLAD NR: 1832 I SIERI 1832 II ROAVVOAIVI



OUTOKUMPU FINNMINES OY

RADIOMETRISK TOTALSTRALING
KONTURER OG FARGER

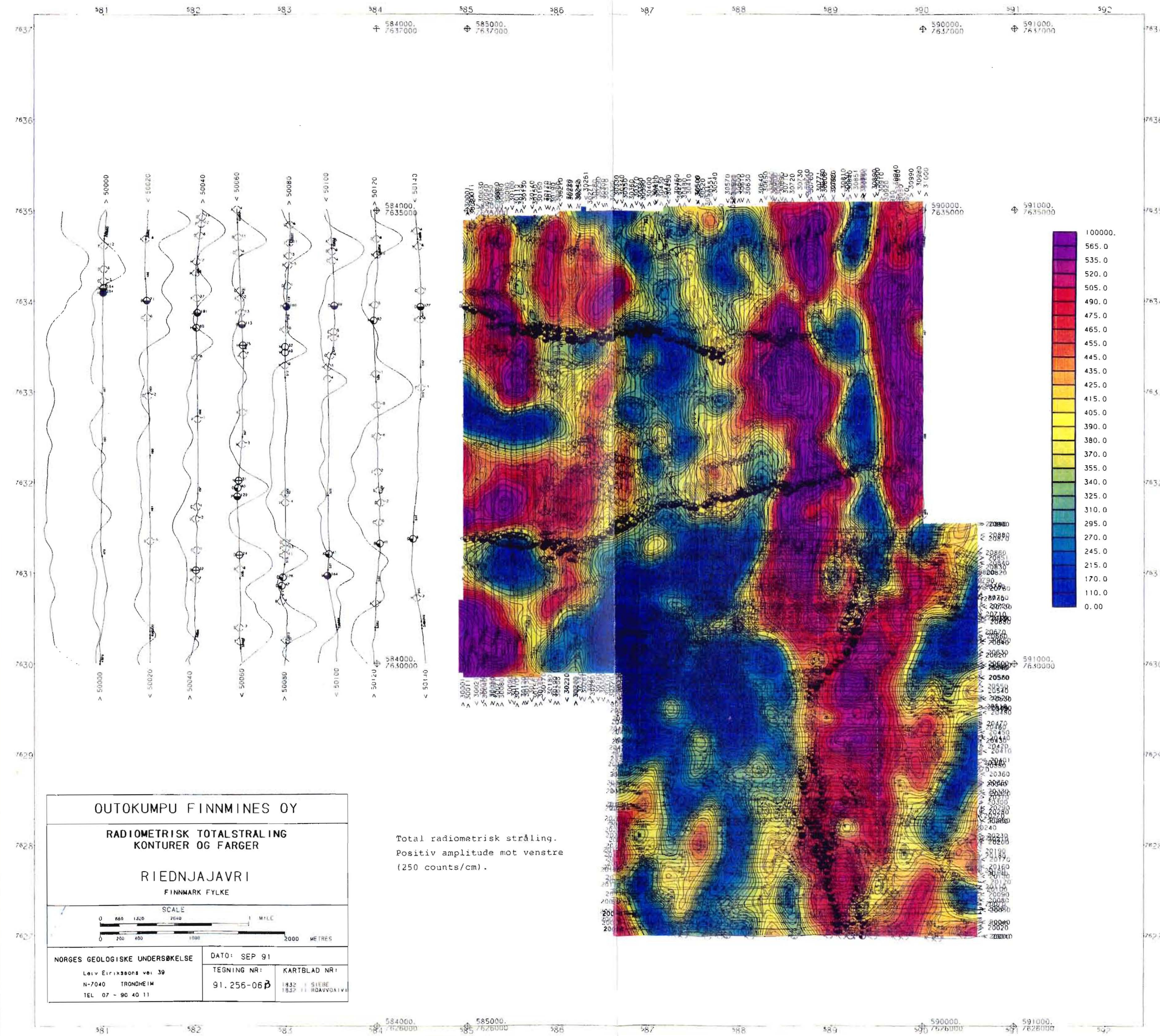
CABARDASJÅKKA

FINNMARK FYLKE

SCALE

2000 METRES

NORGES GEOLOGISKE UNDERSØKELSE	DATO: SEP 91	
Leiv Eirikssons vei 39 N-7040 TRONDHEIM TEL 07 - 90 40 11	TEGNING NR: 91.256-06A	KARTBLAD NR:



Total radiometrisk stråling.
Positiv amplitude mot venstre
(250 counts/cm).

OUTOKUMPU FINNMINES OY		
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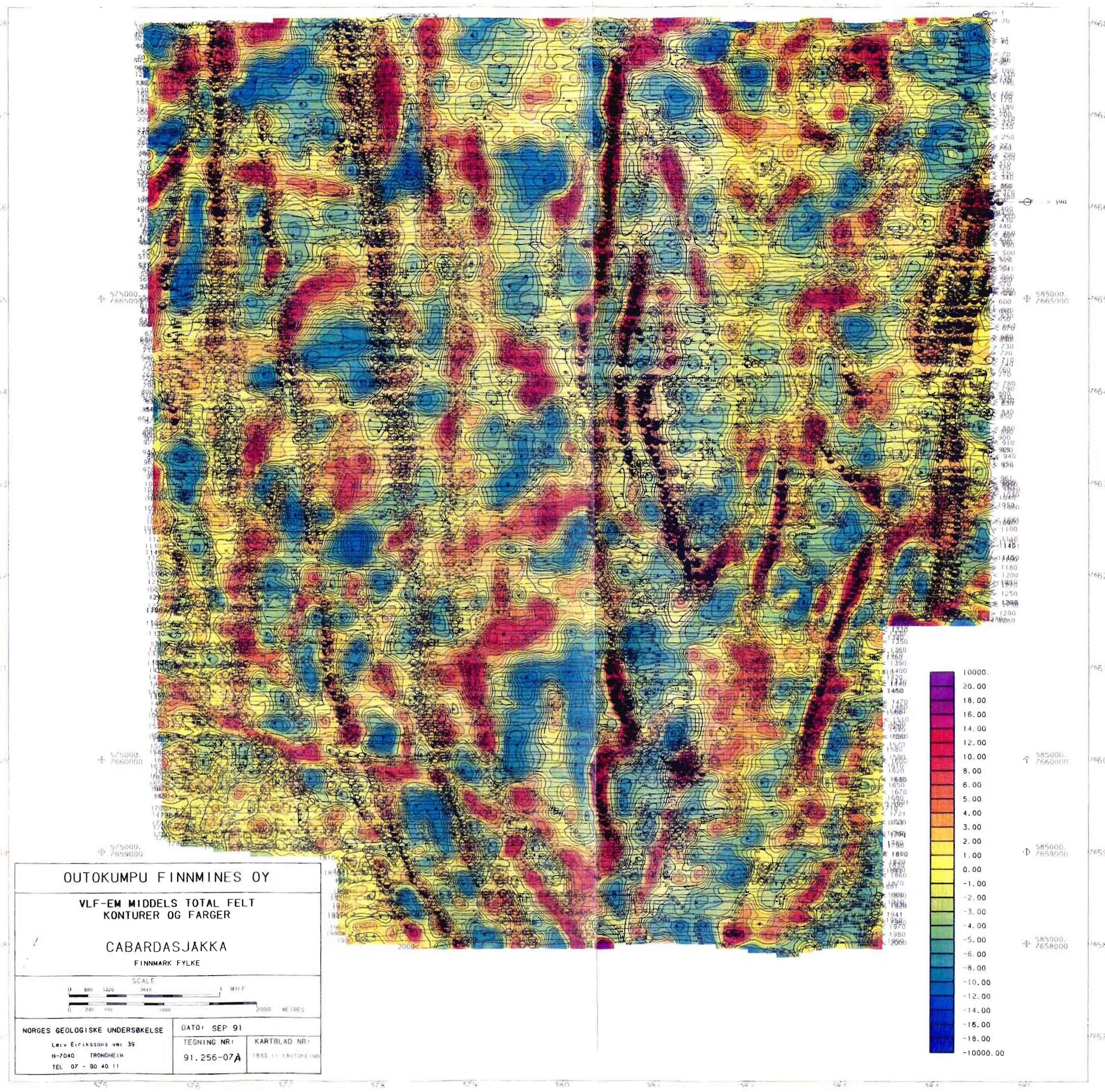
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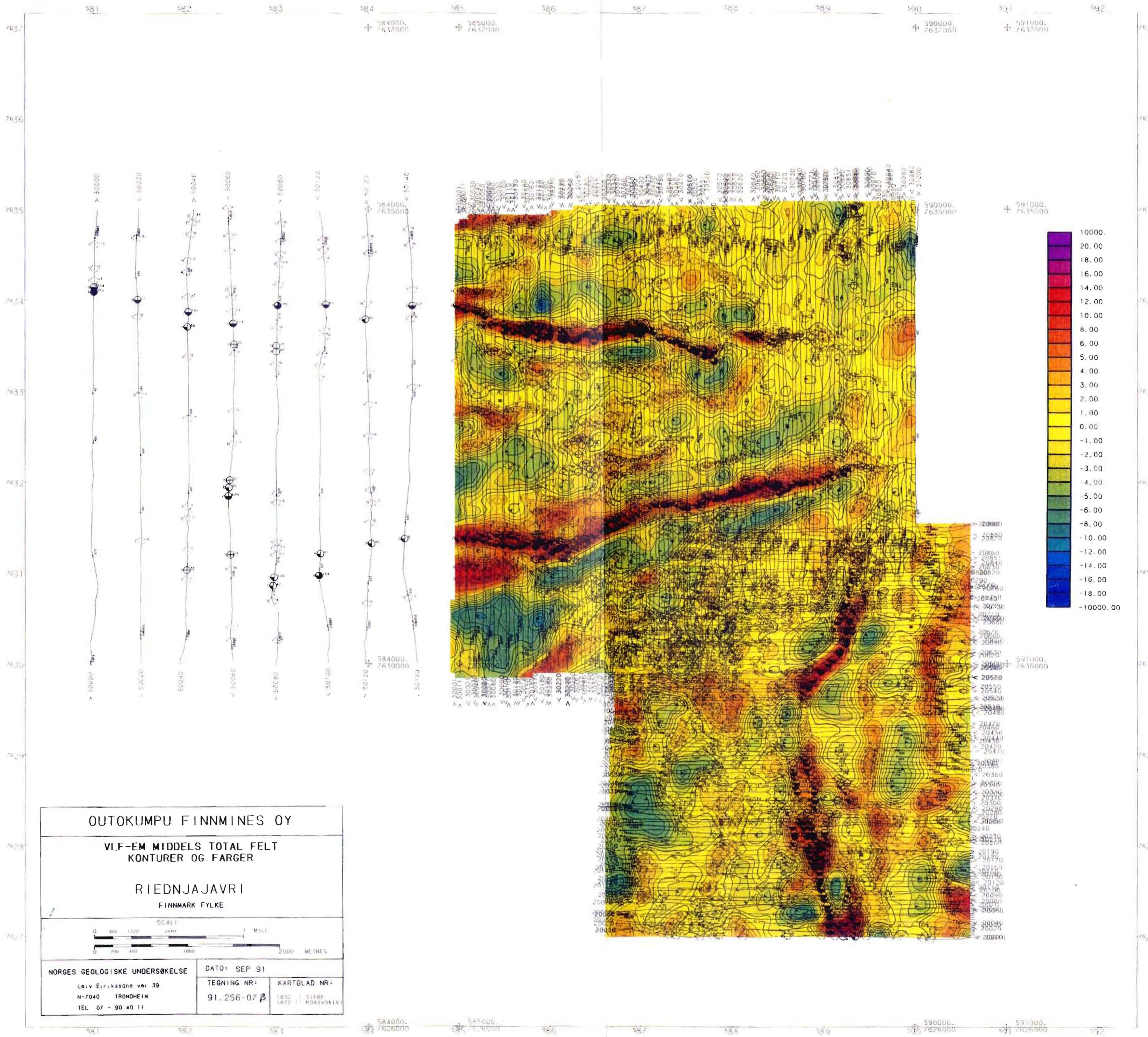
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RIEDNJAJAVRI
FINNMARK FYLKE
SCALE
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NORGES GEOLOGISKE UNDERSØKELSE
Leiv Eirikssons vei 39
N-7040 TRONDHEIM
TEL 07 - 90 40 11
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