NGU Report 2001.068

Data Acquisition and Processing - Helicopter Geophysical Survey, Storsjön, Sweden

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REPORT

Report no.: 2001.068	ISSN 0800-3416	Grading: Open

Title:

Data Acquisition and Processing - Helicopter Geophysical Survey, Storsjön, Sweden

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Map-sheet name (M=1:250.000) Östersund	Map-sheet no. and -name (M=1:50.000) Lunndörrsfjällen 182D Storsjö 182B
Deposit name and grid-reference:	Number of pages: 13 Price (NOK): 130,- Map enclosures:

Fieldwork carried out: 260601 - 300601	Date of report: 09.09.2001	Project no.: 2896.01	Person responsible:

Summary:

In June, 2001, a helicopter geophysical survey was flown over an area in the vicinity of Storsjö, central Sweden. The purpose of the survey was to provide geophysical information for mineral exploration. The data were collected and processed by Geological Survey of Norway (NGU). A combined total of about 1690 line-km of magnetic, very low frequency EM (VLF), and radiometric data were acquired using a nominal 150 m line spacing. The nominal flying height was 60 m above ground level (AGL), and lines were flown in alternating directions at headings of 180° and 360°.

All initial processing was carried out on a flight-by-flight basis. Magnetic total field data were collected using a cesium vapor magnetometer. These data were corrected by removing diurnal variations as recorded at a magnetic base station at the base at Storsjö kapell. VLF data were reduced by removing a first-order polynomial trend along each line. A circular differential median filter was applied to VLF data to remove line errors. Radiometric data were reduced using three-channel processing according to procedures recommended by the International Atomic Energy Association. Noise levels were within survey specifications for magnetic and VLF data. Due to technical installations, the radiometric data were partly influenced by the helicopters fuel content and data quality was seriously reduced.

All final processed data, apart from VLF, were gridded using 45 m square cells. VLF grids have 90 m cells. Geophysical maps were produced at a scale of 1:20 000 and 1:10 000 except for radiometric data (only 1:20000 due to poor data quality). This report covers aspects of data acquisition and processing.

Keywords: Geofysikk (Geophysics)	Radiometri (Radiometrics)	Magnetometri (Magnetometry)
VLF-målinger (VLF-measurements)	Databehandling (Data processing)	
		Fagrapport (Technical report)

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1 INTRODUCTION

In the period 26.06 – 30.06, 2001, a helicopter geophysical survey was flown over an area in the vicinity of Storsjö, central Sweden. The surveyed area is shown in Fig. 1. The original planned survey area was extended to the south to cover the lake Storsjön. The total area covered in the survey is approx. 263 km^2, and the total distance flown is 1690 line-km. Magnetic, radiometric, and very low frequency electromagnetic (VLF) data were collected. The primary objective of the survey was to provide geophysical information for mineral exploration activities.

2 SURVEY VARIABLES AND CONDITIONS

Strong wind can increase the noise level of airborne geophysical data. Strong winds were not frequent during the survey, but were encountered occasionally.

Diurnal changes in the earth's magnetic field affect magnetic data. The base station magnetic field never indicated strong magnetic storm conditions during the survey, hence the magnetic data quality is excellent on all lines.

VLF transmitters are controlled by naval defense authorities for communication with submarines, and their power output cannot be predicted or controlled during a survey. However, during this survey, VLF data quality was generally good.

Radiometric data can be negatively affected by atmospheric radon. In this survey radon contamination did not appear to be significant. However, the technical installation of the sensor influenced the radiometric data quality seriously. In agreement with the client, the crystals were placed the cargo compartment of the helicopter. The helicopter company claimed that fuel tank was placed above, and that it would not influence on the radiometric data. Unfortunately, this was not true, and the data suffers from a saw tooth shape attenuation produced by the actual fuel level in the underlying tank.

The resolution and sensitivity of geophysical measurements decrease exponentially with flying height. To achieve the greatest possible data quality, the aircraft should be flown as low as is safely possible. The target flying height was 60 meters above ground level, and this height was achieved over level terrain. Due to safety precautions, flying heights were somewhat higher over power lines and densely inhabited areas.

3 DATA ACQUISITION

The survey aircraft was an Eurocopter Colibri EC 120B (SE-JME). Flying speed was approximately 140 km per hour (39 meters per second). Flight lines over the survey area were in directions 180°/360°. The radiometric sensors were mounted inside the cargo compartment of the helicopter. VLF sensors were suspended on a cable 7 m beneath the helicopter (53 meters above ground). The magnetometer sensor was enclosed in a 2-m long 'bird' suspended by cable 15 m beneath the helicopter (45 meters above ground).

NGU personal responsible for data acquisition was senior engineer John Olav Mogaard, and the pilot (from Polarflyg AB) was Micke Hällström.

3.1 Magnetic measurements

A Scintrex CS-2 cesium vapor magnetometer was used. The magnetometer resolution is 0.01 nT. Sampling rate was 10 measurements per second, which corresponds to 4 meter station spacing.

A Scintrex MP-3 proton precession magnetometer was placed at the base at Storsjö kapell, and was used for base station measurements. The base station magnetometer was synchronized with the helicopter-borne magnetometer to ensure proper removal of diurnal magnetic changes from the helicopter magnetic measurements. The total magnetic field was digitally recorded during flights at a rate of 15 measurements per minute.

3.2 Radiometric measurements

The radiometric system, purchased from Exploranium, Ltd. of Canada, consists of four sodium iodide (NaI) crystals (model GPX-1024-256) having a total volume of 1024 cubic inches (16.78 liter). The NaI crystals are coupled to a 256 channel Exploranium GR820 gamma ray spectrometer. Registration rate is one per second, giving one record for each 39 meter along the profiles. An upward looking crystal was used in this survey, and can if desired be used to correct for airborne radon contamination. The crystal package is mounted inside the cargo compartment of the helicopter as discussed earlier.

The spectrometer is an energy pulse height analyzer that sorts data into 256 channels according to energy magnitude. Every channel is 0.012 MeV wide. The full 256 channel spectrum was recorded. Windows constructed from selected groups of channels record the contributions of Potassium-40, Bismuth-214 (the daughter product of Uranium-238), and Thallium-208 (the daughter product of Thorium-232). These windows are labeled potassium, uranium, and thorium respectively. A fourth window—the total count window—measures gamma ray energy between 0.4 MeV and 3 MeV.

3.3 VLF-EM system

The VLF measurements were carried out using Totem-2A VLF receivers purchased from Hertz Industries, Ltd. of Canada. The three receivers are mounted orthogonally and measure fields in the direction of the flight line (in-line), normal to the flight direction (orthogonal), and vertical fields. The energy sources for VLF signals are powerful transmitters used by military organizations for communication with submarines. Their frequencies are in the range of 15-30 kHz, depending on the individual transmitter. The VLF receivers are suspended 7 meters beneath the helicopter. Registration rate is five per second, which corresponds to 8 meter station spacing.

Good VLF targets are thin, shallow (a few tens of meters), near vertical conductors which are approximately on a line with one of the monitored VLF transmitters. For this survey, the primary VLF stations monitored were NAA (24 kHz, Cutler, Maine, USA), used for in-line receiver measurements, and GBR (16 kHz, Rugby, England), used for orthogonal receiver measurements. Other stations were used when either of these stations ceased transmission.

3.4 Navigation, altimetry, and data logging

The navigation system used was an Ashtech G12, a 12 channel receiver with an RDS reference receiver connected to a laptop computer. GPS signals are corrected in real time using a correction signal in RDS format from Swedish Radio's P4 transmitter. Differential GPS is calculated using software from Seatex, Trondheim and the data is transferred to the navigation console and data logger. Position accuracy using this system is better than 5 m.

The navigation console was a PNAV 2001 manufactured by the Picodas Group, Ltd. of Canada. Profile line data are entered into the console and the helicopter pilot can see his position with respect to these predefined lines and adjust accordingly.

Flying height above ground level was measured using a King KRA-405 radar altimeter. This was recorded digitally and displayed in front of the pilot. The altimeter is accurate to 5 percent of the true flying height.

The data logging system is an integral part of a Hummingbird electromagnetic system, manufactured by Geotech, Ltd. of Canada. Data is recorded both digitally and analog.

4 PROCESSING

The data were processed at the Geological Survey of Norway in Trondheim using Geosoft processing software (Geosoft 1996). All maps, except VLF maps, were constructed from grids using a 45 m grid cell. The VLF maps used a 90 m grid cell. Obvious inaccuracies in navigation were manually removed from the data. The datum used was RT-90 and the projection used was the Swedish National Projection.

Total field magnetic data: The data were inspected flight-by-flight and any cultural anomalies were identified and manually removed. A base station correction was applied to each flight using corrections based on the diurnal measurements from the base magnetometer located at Storsjön. The magnetic data were gridded without any further filtering.

Radiometric data: The Geosoft radiometric processing package (Geosoft 1995) follows the three channel processing procedure outlined in International Atomic Energy Agency Technical Report No. 323 (IAEA 1991). A narrow non-linear filter was applied to the radiometric data to remove spikes, and a low pass filter was applied to smooth the data slightly prior to further processing. Background radiation levels were estimated by flying background calibration lines over water, usually two per flight, and by analyzing flight lines passing over lakes. After background reduction, the data were corrected for spectral overlap using experimentally determined stripping ratios. The processed data are presented as ground concentrations of the uranium, potassium, and thorium, and as ground level total counts. However, **these numbers are wrong due to earlier discussed installation problems,** and the data should be interpreted bearing this in mind.

VLF-EM data: Along each line of the raw VLF data channels - orthogonal and in-line receivers – a constant base level was estimated and removed, leaving lines containing residual anomalies. A single pass of a Hanning filter was applied to slightly smooth the residual grids. Errors along lines were corrected using a circular, differential median filter (Mauring & Kihle 2000). The maps from the gridded data show VLF anomalies from a receiver orthogonal to the flight direction, and anomalies from the receiver in-line with the flight direction. In general, the maximum of the VLF anomaly should be centered over the conductive structure causing the anomaly.

5 MAPS PRODUCED

Color maps of magnetic and VLF data were produced at a scale of 1:20 000 and 1:10 000 (3 per element), and presented with contours and in shaded relief. Shading is based on fictive illumination at 45° above the horizon from northeast. Radiometric maps (total counts and content of Uranium, Potassium and Thorium) were produced in scale 1:20000 only due to poor data quality. These maps, referenced as below, can be ordered from the Geological Survey of Norway.

Scale: 1:20 000

Map 2001.068-01:	Total magnetic field.
Map 2001.068-02:	First vertical derivative of total magnetic field.
Map 2001.068-03:	VLF, in-line receiver.
Map 2001.068-04:	VLF, orthogonal receiver.
Map 2001.068-05:	Radiometric total counts.
Map 2001.068-06:	Uranium content.
Map 2001.068-07:	Potassium content.
Map 2001.068-08:	Thorium content.

Scale: 1:10 000

Map 2001.068-01, A+B+C:	Total magnetic field.
Map 2001.068-02, A+B+C:	First vertical derivative of total magnetic field.
Map 2001.068-03, A+B+C:	VLF, in-line receiver.
Map 2001.068-04, A+B+C:	VLF, orthogonal receiver.

In this report, maps reduced to scale 1: 71500 are shown in figures 2 through 5 (Total magnetic field, First vertical derivative of total magnetic field, VLF-EM line and orthogonal, respectively).

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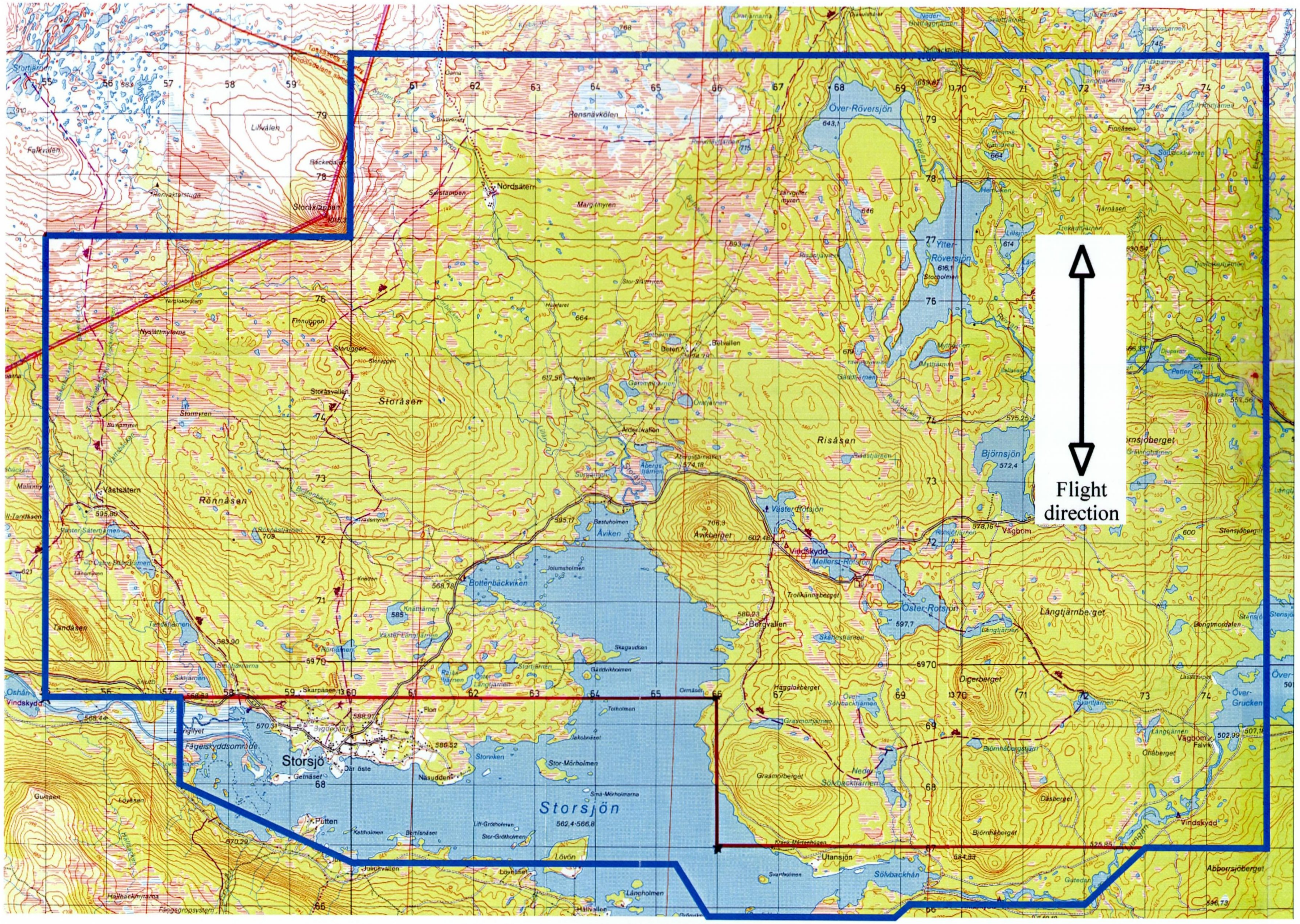

Fig. 1 Extended survey area (blue lines)

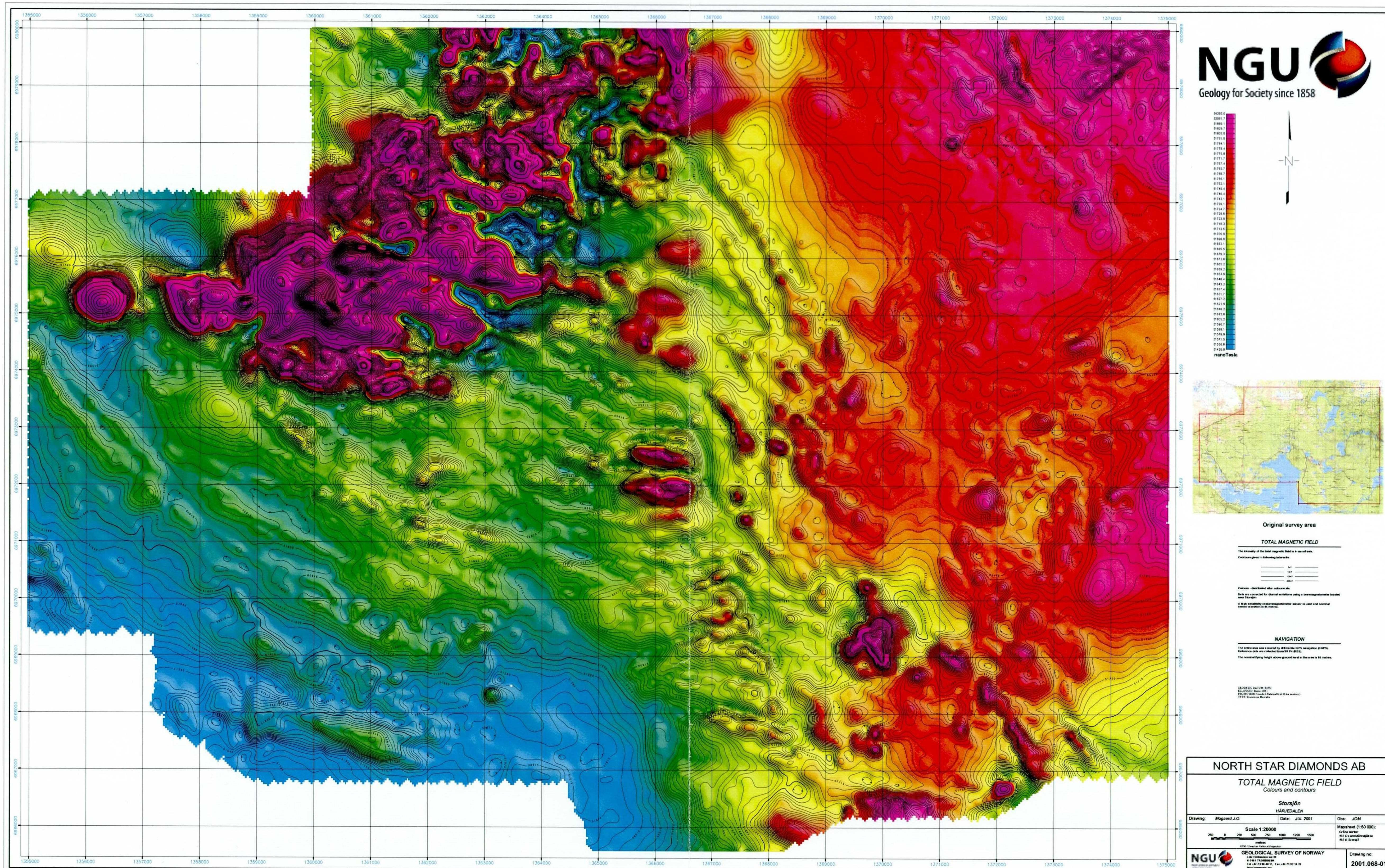

Fig.2 Total magnetic field

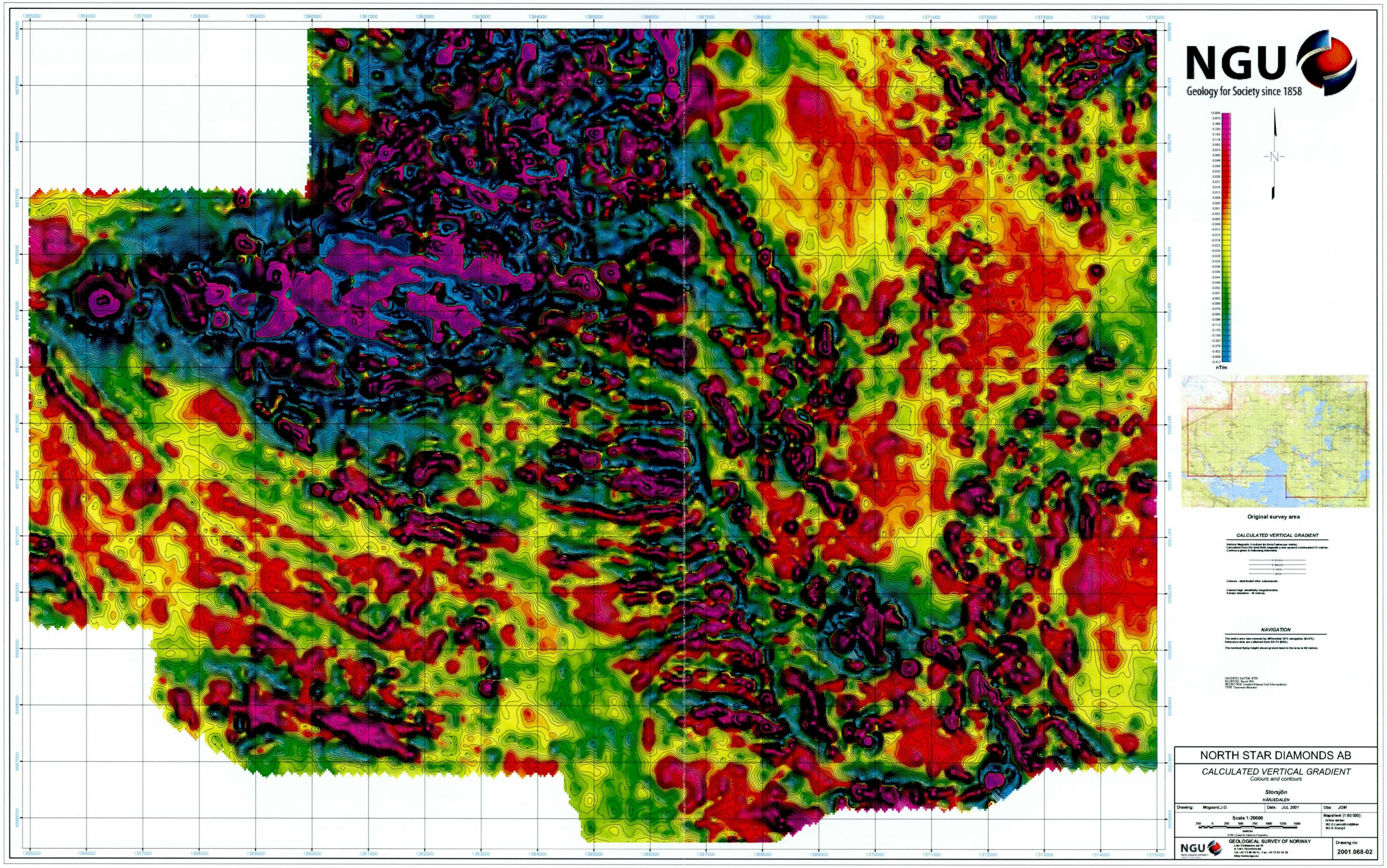

Fig. 3 Calculated Vertical Gradient

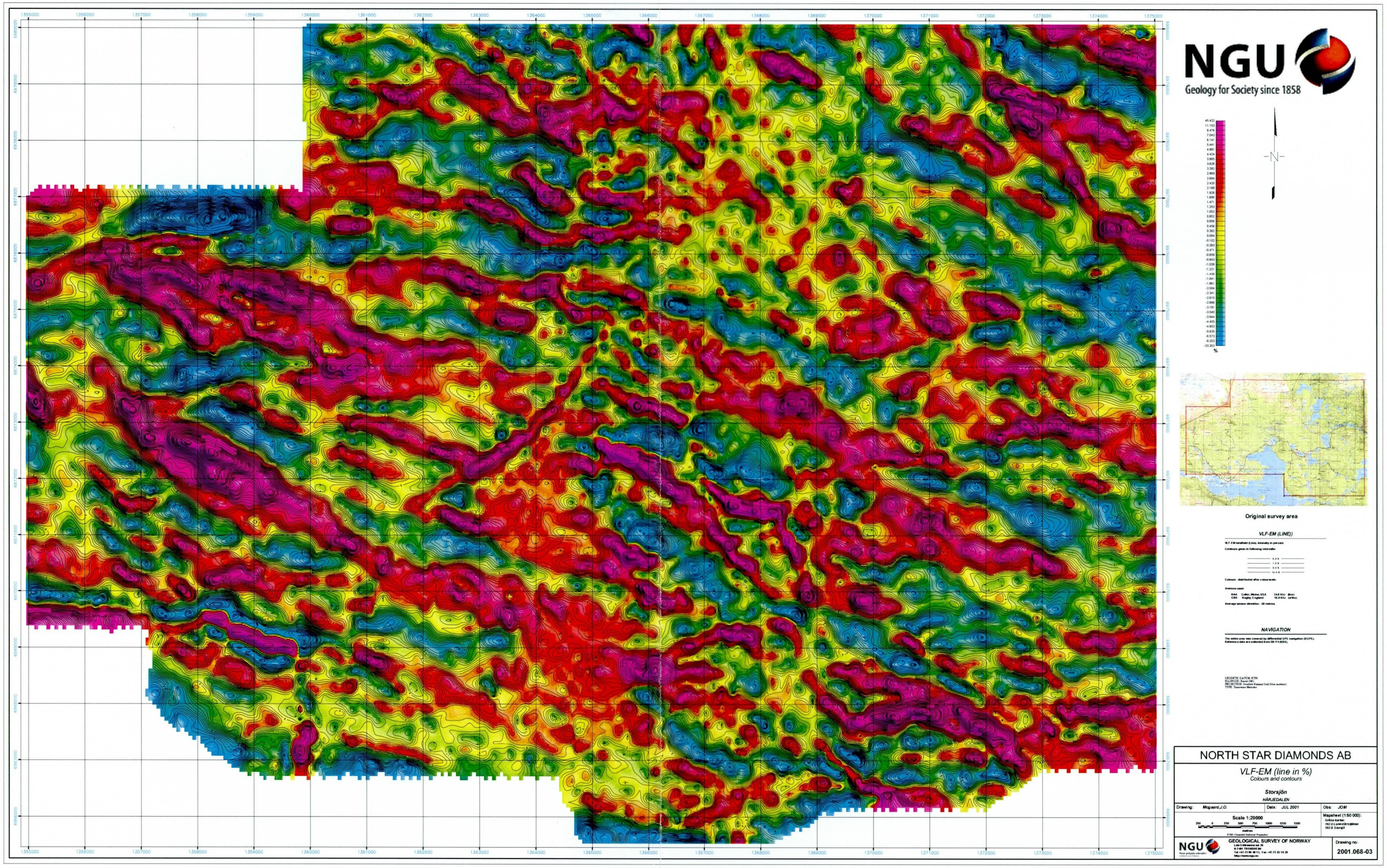

Fig. 4 VLF-EM line

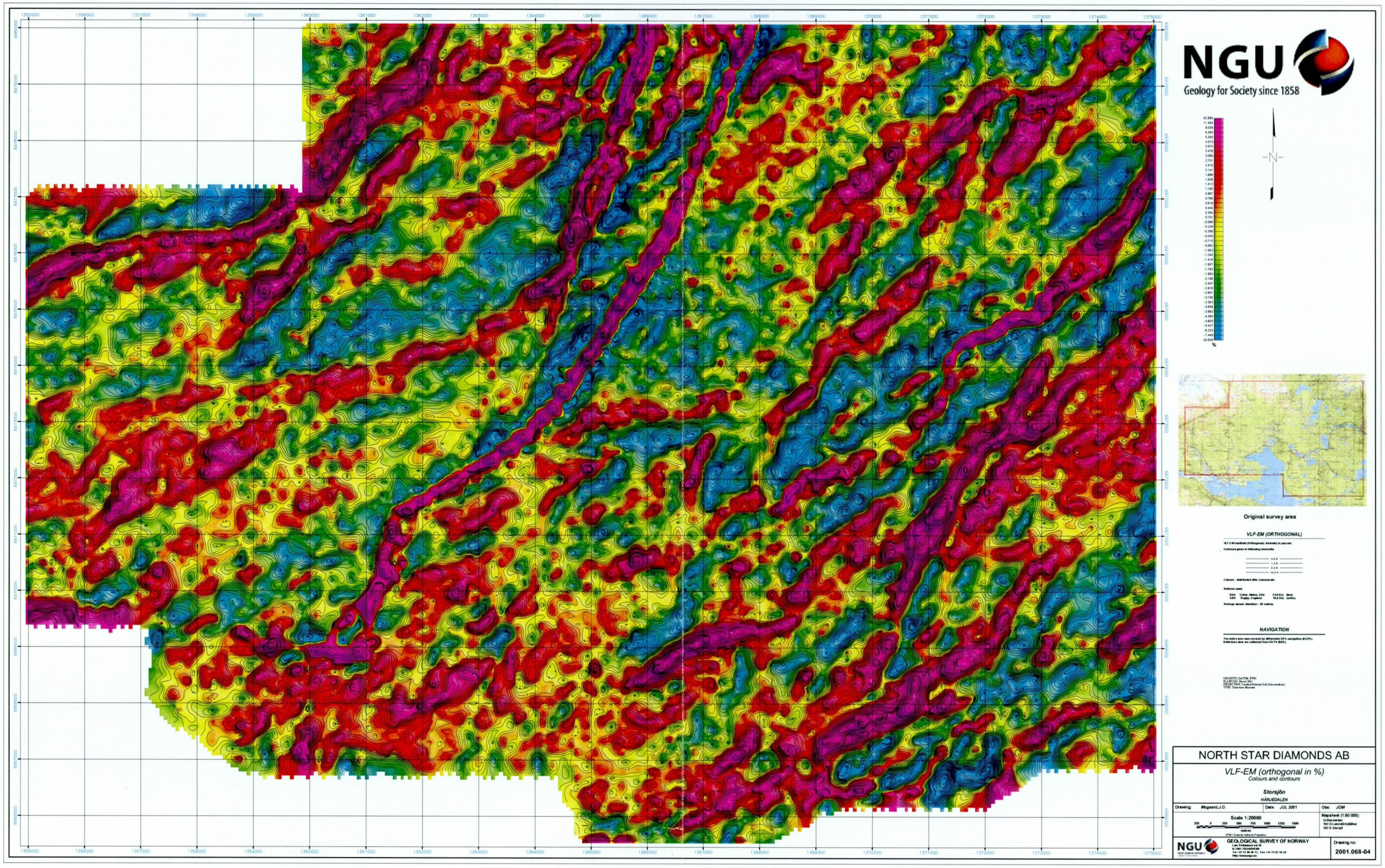

Fig. 5 VLF-EM orthogonal