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Data Acquisition and Processing - Helicopter Geophysical Surveys, Hurdal

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REPORT

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Data Acquisition and Processing - Helicopter Geophysical Surveys, Hurdal, 2000

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Summary:

In August, 1998 and July, 2000, helicopter geophysical surveys were carried out over an area of about 560 km^2 immediately west of Hurdalssjøen and the Gardemoen airport. The purpose of the surveys was to provide geophysical information for improved geological mapping. The data were collected by Geological Survey of Norway (NGU) personnel and processed at NGU. A combined total of 2780 line-km of VLF, radiometric, and magnetic data were acquired using a nominal 200-m line spacing. Poor performance of the EM system in 1998 yielded unusable EM data, so only the EM data collected in 2000 are reported. These data amount to 1925 line-km. The nominal flying height was 60 m above ground level (AGL), and lines were flown in alternating directions, east-to-west or west-to-east. Noise levels were within survey specifications. All initial processing was carried out on a flight-by-flight basis. Final processing was carried out on all flights combined. Magnetic data, consisting of total field measurements collected by a cesium vapor magnetometer, were leveled by removing diurnal variations as recorded at a magnetic base station at Eggemoen airfield near Hønefoss. Radiometric data were reduced using three-channel processing according to procedures recommended by the International Atomic Energy Agency. VLF data were reduced by removing a first-order base along each line. EM data were levelled using data from frequent high altitude excursions above 300-m AGL. Final processed data were gridded using square cells with 40-m sides. Geophysical maps were produced at a scale of 1:50 000. This report covers aspects of data acquisition and processing.

Keywords: Geofysikk (Geophysics)	Helikoptermåling (Helicopter survey)	Magnetometri (Magnetometry)
Elektromagnetisk måling (Electromagnetics)	Databehandling (Data processing)	Radiometri (Radiometrics)
		Fagrapport (Technical report)

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1 INTRODUCTION

In August, 1998 and July, 2000, helicopter geophysical surveys were carried out in the area west from Hurdalssjøen. The surveyed area lies between longitudes 10°34′ E and 11°05′ E, and latitudes 60°11′ N and 60°27′ N (Fig. 1). The total area covered in the two surveys is approximately 556 km^2. Electromagnetic (EM), radiometric, magnetic, and very low frequency electromagnetic (VLF) data were collected. The northernmost portion of the survey area was covered in 1998. This survey covered 856 line-km and an area of 171 km^2. In the 2000 survey, 1927 line-km were flown over an area of 385 km^2.

The primary objective of the surveys was to provide geophysical information in order to enhance geological mapping. Most of the survey area consists of alkaline to basic intrusive units of the Oslo igneous province, however a small portion of the northwestern corner of the survey area is made up of metasediments—mostly slates and meta-sandstones (Nordgulen, 1999).

2 SURVEY VARIABLES AND CONDITIONS

Strong wind can increase the noise level of airborne geophysical data. High winds were not frequent during the survey, but were encountered occasionally. The quality of the electromagnetic data in the 2000 survey was generally good, although data from some flights suffered interference from electrical storms. EM data from the 1998 survey was of such poor quality because of instrumental difficulties that it was effectively unusable.

Magnetic data quality is excellent on all lines. Diurnal changes in the earth's magnetic field affect magnetic data. The base station magnetic field never indicated a strong magnetic storm.

VLF data quality is generally good. Naval defense authorities control VLF transmitters, and as a result their power output cannot be predicted or controlled during a survey.

Radiometric data can be negatively affected by atmospheric radon. However, in this survey radon did not appear to be prevalent. The quality of the radiometric data is good.

The resolution of geophysical sensors decreases exponentially with sensor height. To achieve the greatest possible resolution, the aircraft should be flown as low as is safely possible. The target height was 60 meters above ground level, and this height was achieved over level terrain. Flying heights were higher over power lines and densely inhabited areas.

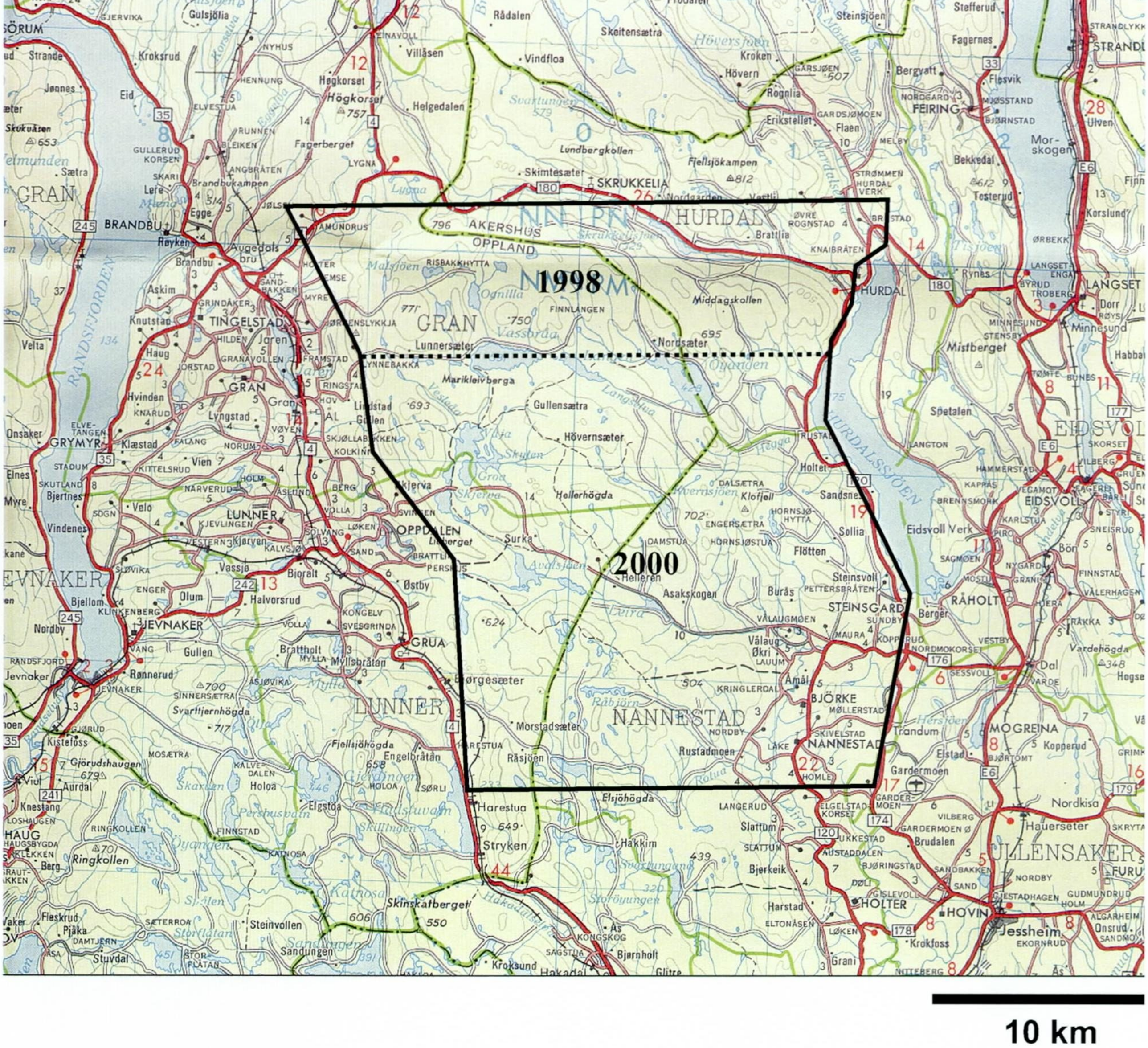

Fig. 1. Location map showing boundaries of the 1998 and 2000 Hurdal surveys. Map is digitized from Blad 5, Vegkart over Norge (Statens Vegvesen, 1977).

3 DATA ACQUISITION

The survey aircraft was an Areospatiale Ecureuil B-1. Flying speed was approximately 100 km per hour (28 meters per second). Flight lines over the survey area were in an east-west direction. The radiometric sensors were mounted immediately beneath the helicopter. VLF sensors were suspended on a cable 10 m beneath the helicopter. The 5-frequency EM system used in the 2000 survey and the magnetometer were enclosed in a 6 m long 'bird' suspended by cable 30 m beneath the helicopter. In the 1998 survey, the magnetometer was located 15 m below the helicopter, outside the EM bird.

NGU personnel responsible for data acquisition were John Mogaard and Janusz Koziel.

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.

A Scintrex MP-3 proton precession magnetometer was located at Eggemoen airfield near Hønefoss, 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 at the base station 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 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. An upward looking crystal was used in this survey, and data from the upward looking crystal can be used if desired to correct for airborne radon contamination. The crystal package is mounted in a frame underneath the helicopter.

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 . Windows constructed from selected groups of channels record the contributions of Potassium-40, Bismuth-214 (a daughter product of Uranium-238), and Thallium-208 (a 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 made with Totem-2A VLF receivers purchased from Hertz Industries, Ltd. of Canada. The three receivers are mounted at right angles 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 various military establishments for communication with submarines. Their frequencies are in the range 15-30 kHz, depending on the individual transmitter. The VLF receivers are suspended 10 meters beneath the helicopter. Registration rate is five per second.

Good VLF targets are shallow (a few 10s of meters), narrow, near-vertical conductors that are on a line with one of the monitored VLF transmitters. For this survey, the primary VLF stations monitored were GBR (16 kHz, Rugby, England), used for in-line receiver measurements, and NAA (24 kHz, Cutler, Maine, USA), used for orthogonal receiver measurements. Other stations were used when either of these stations ceased transmission.

3.4 Electromagnetic system

The EM system used in the 2000 survey was the 5-frequency Hummingbird system made in Canada by Geotech, Ltd. The Hummingbird records data at a sampling rate of 40 measurements per second. It has two coil orientations—vertical coaxial (VCX) and horizontal coplanar (HCP). The VCX coils operate at 980 Hz and 7000 Hz. The HCP coils operate at 880 Hz, 6600 Hz, and 34100 Hz. The transmitter-receiver separation is 6m for all frequencies. Noise levels for the four lowest frequencies are generally under 2 ppm, and are often less than 1 ppm. The noise level of the 34100 Hz coils is usually under 3 ppm.

3.5 Navigation, altimetry, and data logging

The navigation system for the first 12 flights consisted of a Trimble SVeeSix 6 channel GPS receiver and a Seatex DFM-200 RDS reference receiver connected to a laptop computer. From flight 13, an Ashtech G12 12 channel receiver was used. GPS signals are corrected in real time using a correction signal in RDS format from NRK's P2 transmitter. Differential GPS is calculated using software from Seatex, and the data is transferred to the navigation console and data logger. Position accuracy using this system is better than 10m.

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 view the traces. The pilot can see his position with respect to these predefined lines and adjust accordingly.

The helicopter came with a King KRA-430 radar altimeter that measured height above ground level, and was recorded digitally and displayed before the pilot. The altimeter is accurate to 5 percent of the true flying height.

The data logging system is an integral part of the 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) designed for NT operating systems. All maps were gridded using a 40-m grid cell size. GPS data were processed at NGU to improve position accuracy. Obvious inaccuracies in navigation were manually removed from the data. The datum used was WGS-84 in UTM Zone 32 N. All levelling procedures were conducted flight-by-flight rather than a line-by-line, as this is the most efficient approach.

Total field magnetic data: The data were inspected flight-by-flight and any obvious cultural anomalies were identified and manually removed. A correction for diurnal variation was applied to each flight using corrections based on measurements from the base station magnetometer at the Eggemoen airfield. The base station magnetometer showed occasional large excursions over a short time period. These were assumed to be related to the magnetic perturbations of vehicles, most probably passers-by. These excursions were manually excised from the base magnetometer data. A lag correction was applied to the helicopter data. The lines were gridded without further filtering. Although the 1998 survey magnetometer was mounted 15 m higher than the 2000 survey magnetometer, maps made from the combined data sets do not show obvious level differences, and so the 1998 data were not corrected for height differences.

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 nonlinear 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 final processed data are presented as ground concentrations of the potassium (%), uranium (ppm), and thorium (ppm), and as ground level total counts.

Atmospheric radon does not appear to have been a major source of data contamination in any of the flights.

VLF-EM data: Along each line of the raw VLF data channels - orthogonal and in-line receivers – a first order trend was estimated and removed, leaving lines containing residual anomalies. A single pass of a Hanning filter was applied to slightly smooth the residual grids. 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.

EM data: EM data were processed on a flight-by-flight basis. Zero levels and drift control for each frequency were obtained by frequent excursions above 300m AGL, usually at the end of each flight line. A nonlinear filter was applied to all EM data to remove data spikes resulting from atmospheric electrical activity. Before levelling, all data were mildly low passed using a 100 m filter. Noise levels for all frequencies, with the exception of the 34100 Hz data, were usually within an envelope of 1 ppm. Exceptions were high noise levels near powerlines. Levelled in-phase data at all frequencies show a few negative peaks. They occur on multiple frequencies and sometimes along adjacent flight lines. Dikes or other structures having high magnetic susceptibility may produce negatively oriented in-phase anomalies.

5 MAPS PRODUCED

All color maps were produced at a scale of 1:50 000, and presented with contours and in shaded-relief. Shading was from the east at 45° sun inclination above the horizon. The cell size for all map grids was 40 meters. Flight lines are included on all maps. Railroads, roads, powerlines, streams , and lakes are denoted on the maps. Although EM data from the 1998 survey are not shown on the EM profile or conductivity maps, the same base map was used for these data as for the magnetic, VLF, and radiometric maps.

In this report, samples of the data used to create the 1:50 000 Hurdal area maps are shown in Figures 2 through 6 (total magnetic field, 6600 Hz EM conductivity, 880 Hz EM profiles, radiometric total counts, and VLF in line receiver, respectively). The figures are shown in color with shaded relief. Shading has been applied from the east at a 45° sun angle. Color figures show data, but do not include flight line paths, cultural features and landmarks, or contours.

A list of the 16 maps available for order from NGU is given on pages 3 and 4 of this report.

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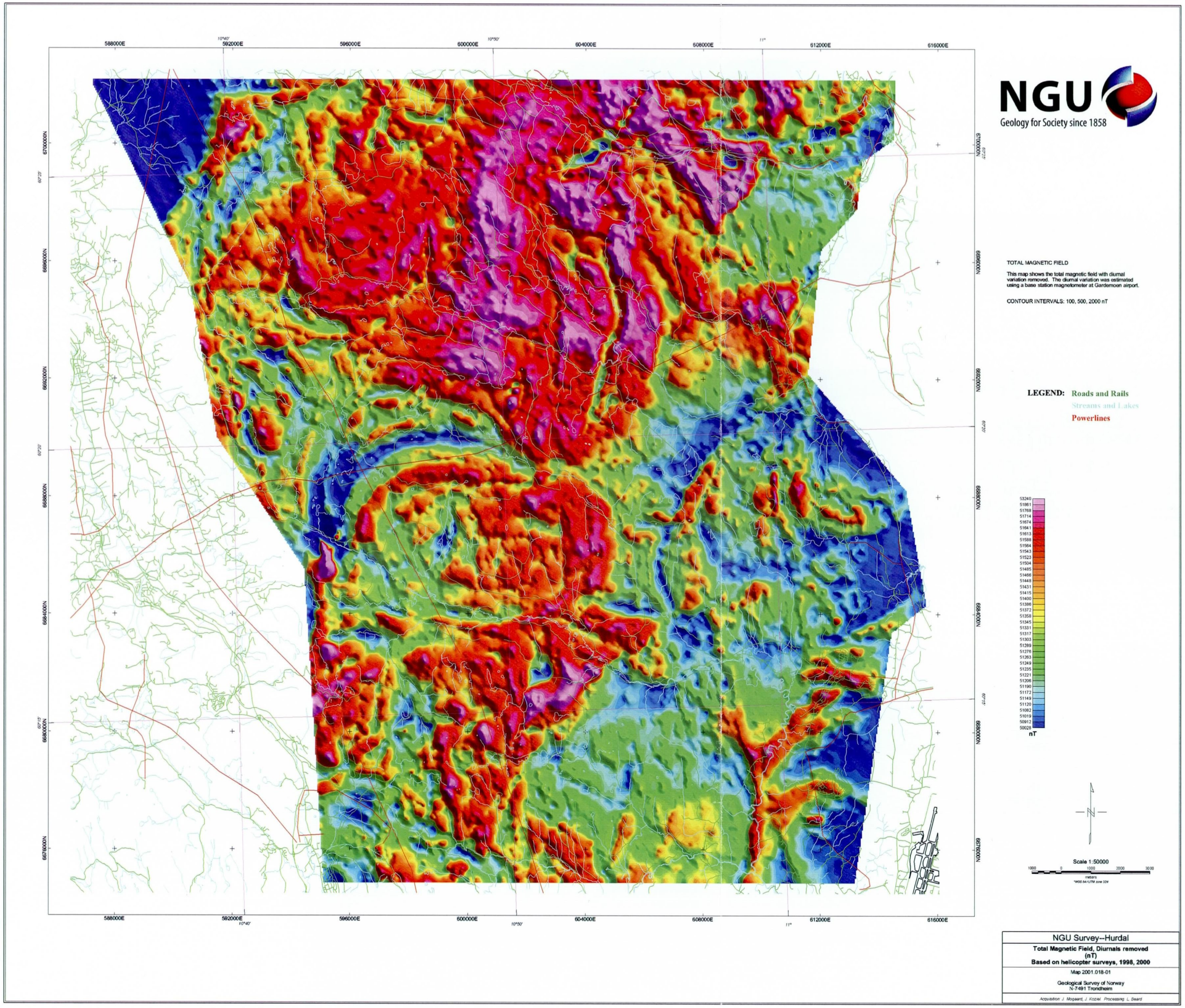

Fig. 2. Map of total magnetic field without contours or flight lines.

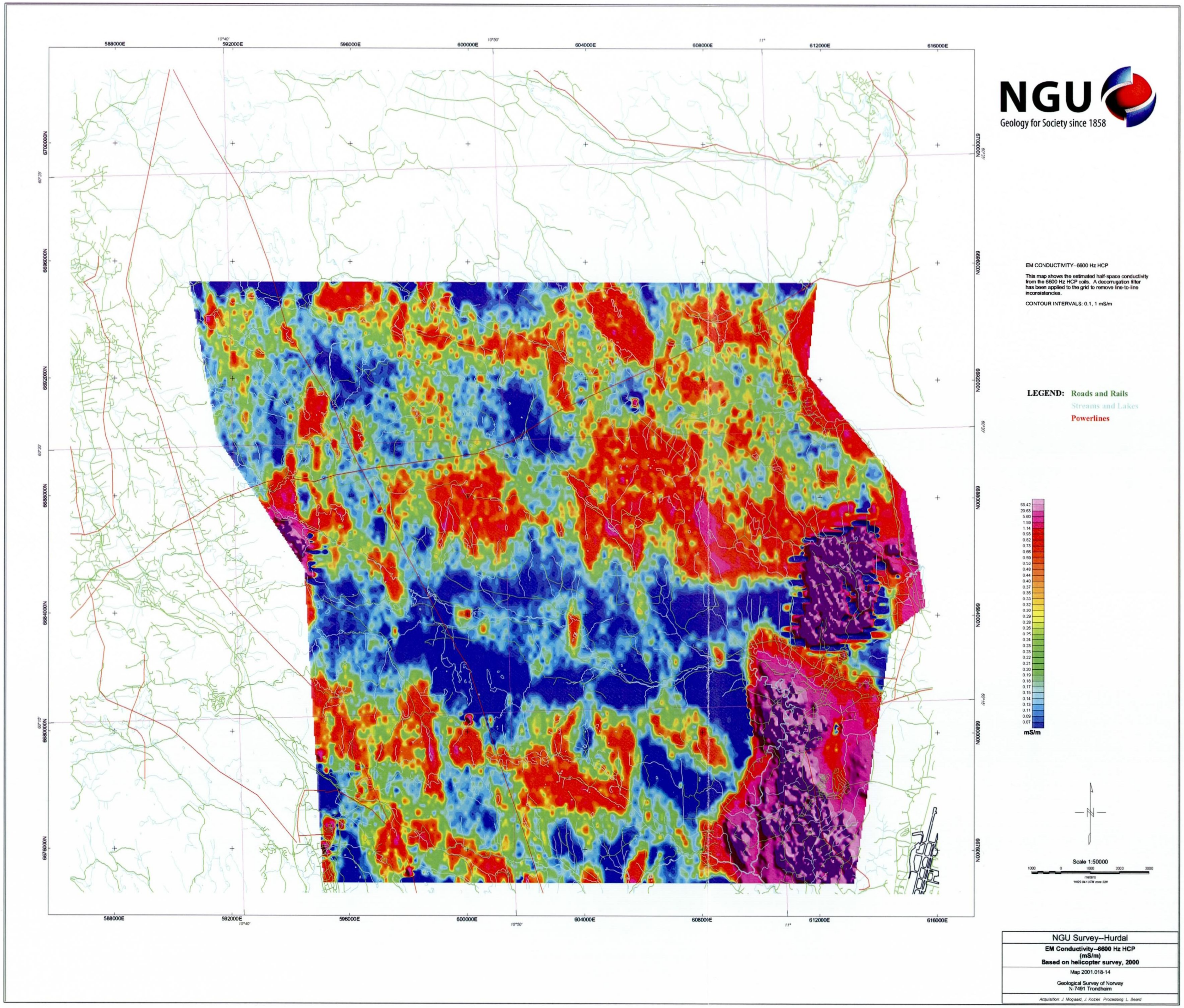

Fig. 3. Map showing EM conductivity from the 6600 Hz horizontal coplanar coils. Flight lines and contours have not been included.

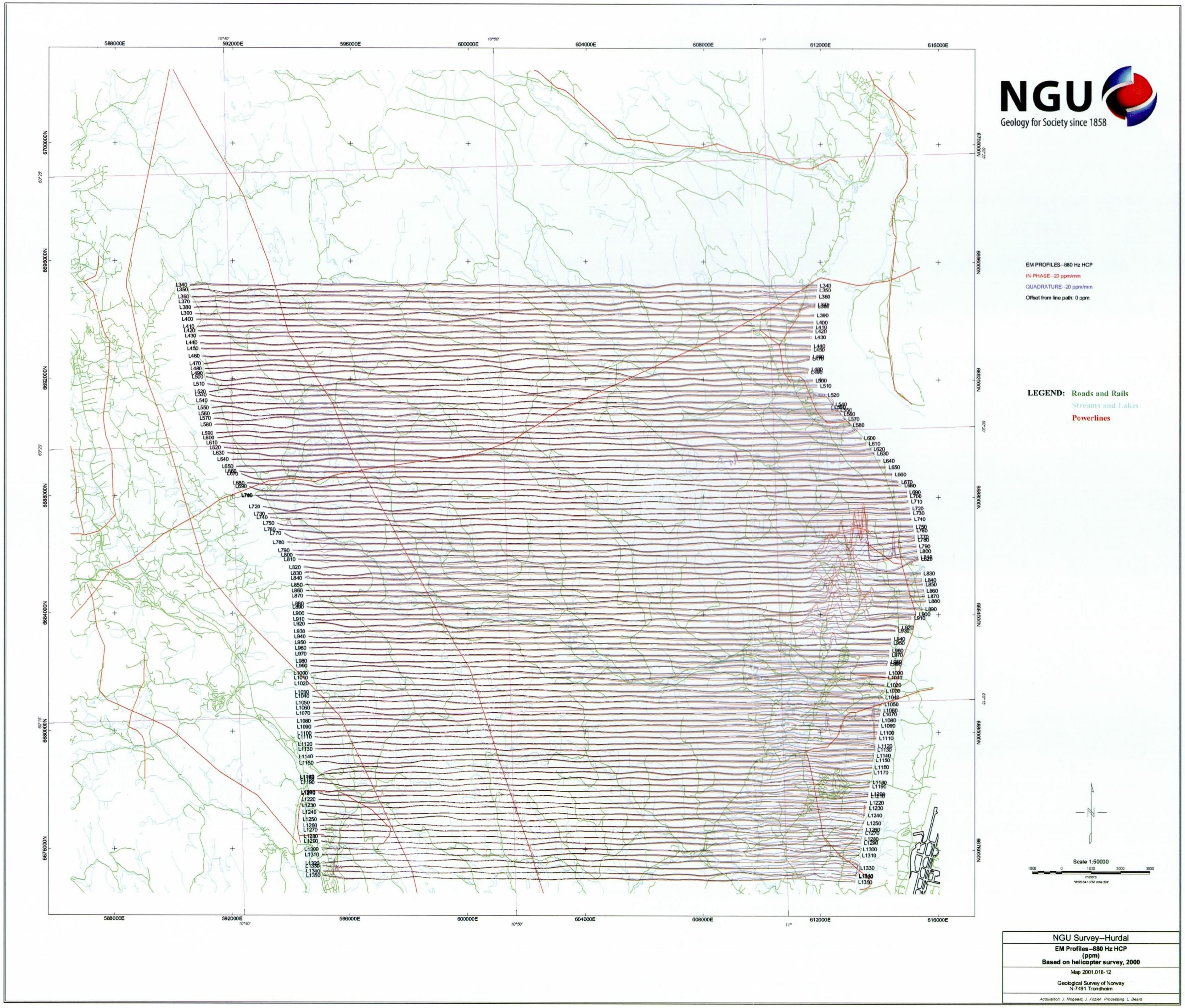

Fig. 4. Profile plot of in-phase and quadrature EM data from the 880 Hz horizontal coplanar coils.

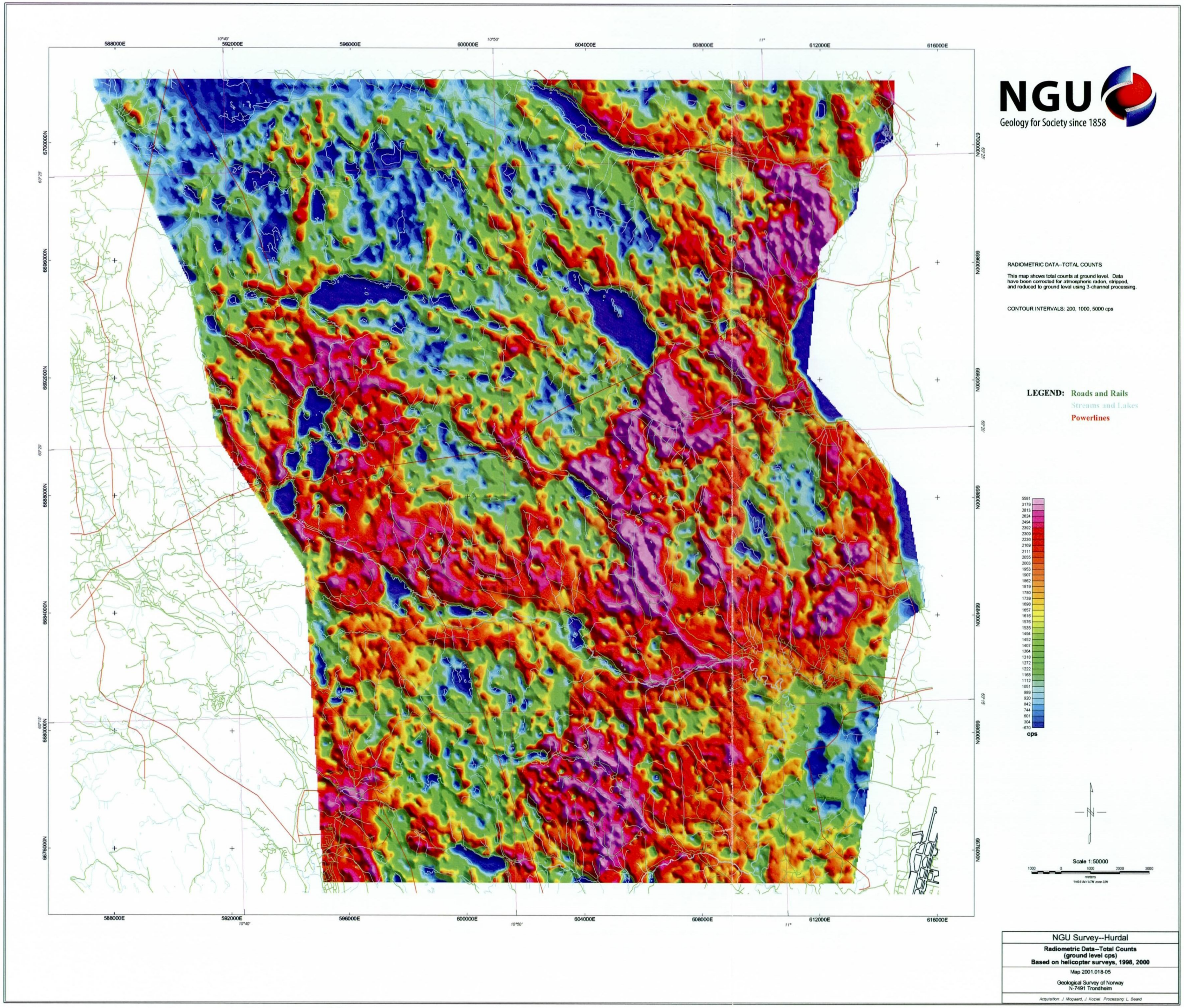

Fig. 5. Sample map of radiometric data. Total count map is shown without contours or flight lines.

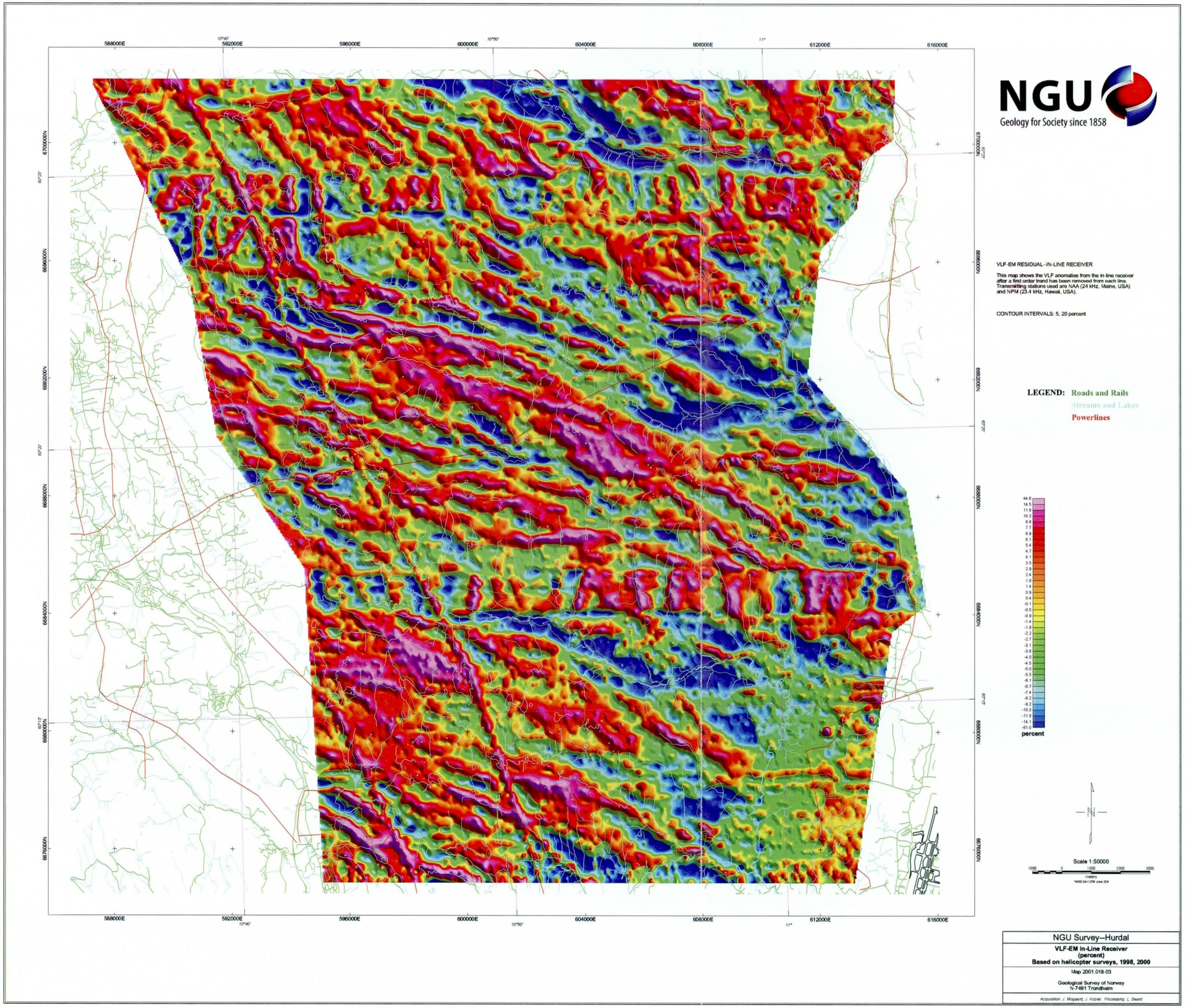

Fig. 6. Map showing VLF response from the in-line receiver. Flight lines and contours have been removed.