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Data Acquisition and Processing - Helicopter Geophysical Survey, Røros, 1999

NGU
Norges geologiske undersøkelse
Geological Survey of Norway

Geological Survey of Norway
Leiv Eirikssons vei 39
N-7491 Trondheim, Norway
Tel.: 47 73 90 40 11
Telefax 47 73 92 16 20

REPORT

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Data Acquisition and Processing - Helicopter Geophysical Survey, Røros, 1999

Authors: Les P. Beard, John Olav Mogaard	Client: Mindex AS, NGU
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Summary:

In August and September, 1999, a helicopter geophysical survey was carried out over and area of about 1240 km^2 immediately north from the town of Røros. The purpose of the survey was to provide geophysical information for mineral exploration activities. The data were collected by Geological Survey of Norway (NGU) personnel and processed at NGU. A combined total of 6200 line-km of electromagnetic (EM), very low frequency EM (VLF), radiometric, and magnetic data were acquired using a nominal 200-m line spacing. 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 an airfield near Røros. Radiometric data were reduced using three-channel processing according to procedures recommended by the International Atomic Energy Association. VLF data were reduced by removing a linear trend along each line. EM data were leveled using data from frequent high altitude excursions above 300-m AGL. Final processed data were gridded using square cells with 50-m sides. Geophysical maps were produced at a scale of 1:50 000. This report covers aspects of data acquisition and processing.

Keywords: Geofysikk	Radiometri	Magnetometri
Elektromagnetisk måling	Databehandling	Fagrapport

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1 INTRODUCTION

In August and September, 1999, a helicopter geophysical surveys were carried out in the vicinity of Røros, Sør-Trøndelag. The surveyed area lies between longitudes 11°13′ E and 11°58′ E, and latitudes 62°37′ N and 62°57′ N (Fig. 1). The total area covered in the three surveys is approximately 1200 km^2. Electromagnetic (EM), radiometric, magnetic, and very low frequency electromagnetic (VLF) data were collected.

The primary objective of the surveys was to provide geophysical information in order to enhance mineral exploration in the area. Most of the survey area consists of metasediments intruded by gabbros (Nilsen and Wolff, 1989). Rocks of igneous origin—gabbros, tuffs, greenstones, and trondhjemites (alkalai-feldspar granites)— are found in the northwest portion of the survey area. Exposures of economic minerals are common throughout both the metasedimentary and the igneous units.

2 SURVEY VARIABLES AND CONDITIONS

Strong wind can increase the noise level of airborne geophysical data. High winds were frequent during the survey, and on two occasions caused flights to be aborted.

Magnetic data quality was excellent good on all lines. Diurnal changes in the earth's magnetic field affect magnetic data. The base station magnetic field never indicated a magnetic storm severe enough to degrade the aerial magnetic data.

VLF data quality was generally good, but varied because VLF transmitters switched off completely at times during the survey. These transmitters are controlled by naval defense authorities for submarine communication, and their power output cannot be predicted or controlled during a survey.

The resolution of geophysical sensors decrease exponentially with flying 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.

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 survey area were in an east-west

Figure 1. Area outlined in black shows the helicopter survey area. East-west width of southern section of area is 37 km.

direction. A few tie lines were flown north-south. The radiometric sensors were mounted immediately beneath the helicopter. VLF sensors were suspended on a cable 10m beneath the helicopter. The 5-frequency EM system and the magnetometer were enclosed in a 6-m long 'bird' suspended by cable 30-m beneath the helicopter.

NGU personnel responsible for data acquisition were John Mogaard and Oddvar Blokkum.

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 an airfield near Røros, 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 4 measurements per second.

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 an Exploranium GR820 gamma ray spectrometer. Registration rate is one per second. An upward looking crystal was used in this survey. 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 (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 made with 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 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), linear conductors which 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 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 880 Hz and 7000 Hz. The HCP coils operate at 980 Hz, 6600 Hz, and 34000 Hz. The transmitter-receiver separation is 6m for all frequencies. The manufacturer claims noise levels of 1-2 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 50-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 leveling 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 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 at the airport. 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 curious 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.

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 processed data are presented as ground concentrations of the uranium, potassium, and thorium, and as ground level total counts.

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

VLF-EM data: Along each line of the raw VLF data channels - orthogonal and in-line receivers – a linear 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.

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 sferics. Before levelling, all data were mildly low passed using a 100-m filter.

Noise levels for all frequencies, with the exception of the 880 Hz data, were usually within an envelope of 1 ppm. Exceptions were high noise levels near powerlines and an area of about 4 km^2 immediately south from Aursunden (centered at UTM 632000E, 6952000N). The source of the noise is unknown but may be a result of leakage into the earth from electrical lines in the area. It is particularly prominent on 980-Hz and 880-Hz data. 880 Hz data appear noisier than the other frequencies, having a noise envelope of 1.5 to 2 ppm over most of the survey area. Profile maps made from the 880 Hz data have been low passed using a 300-m filter. 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 grid cell size for all maps was 50 meters. Flight lines are included on all maps. Railroads, roads, powerlines, streams , and lakes are denoted on the maps.

In this report, samples of the data used to create the 1:50 000 Røros area maps are shown in Figures 2 through 6 (total magnetic field, 980 Hz EM conductivity, 34000 Hz EM profiles, radiometric total counts, and VLF in-line, 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 14 maps available for order from NGU is shown on page 3 of this report.

6 REFERENCES

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Nilsen, O. and Wolff, F.C., 1989. Geologisk kart over Norge, bergrunnskart Røros og Sveg— 1:250 000: Norges geologiske undersøkelse.

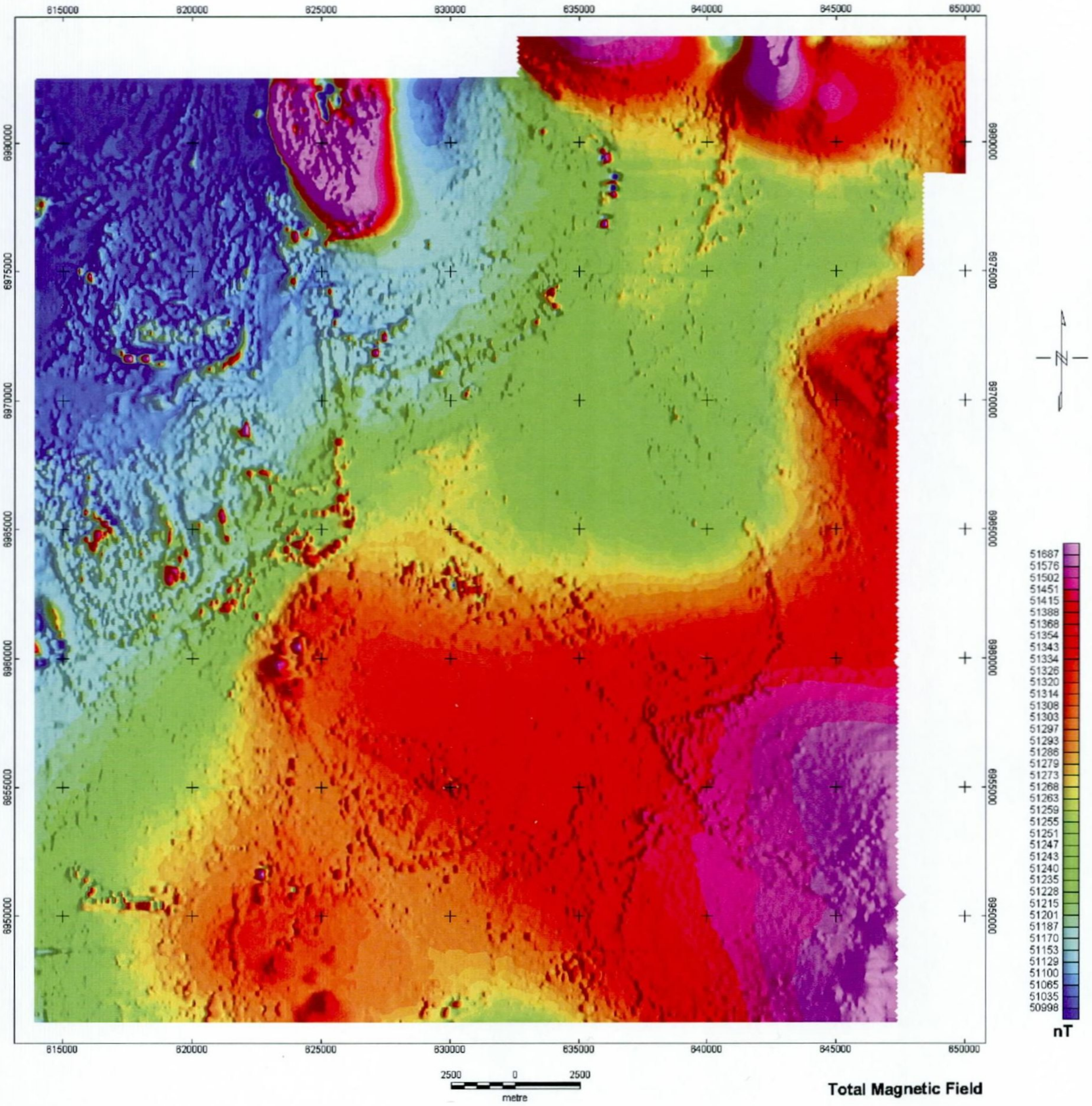

Figure 2. Total magnetic field with diurnals removed.

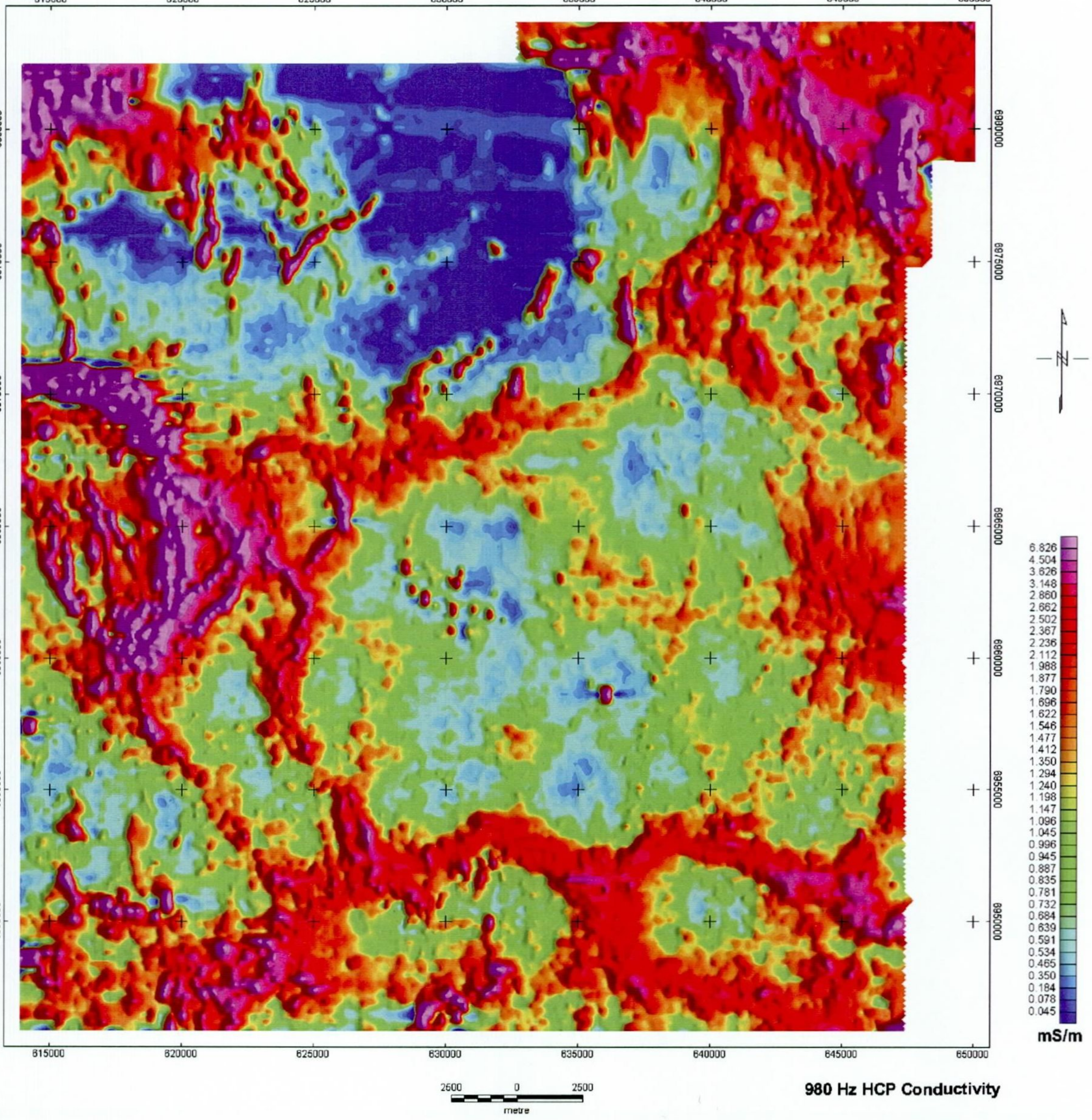

Figure 3. EM conductivity- 980 Hz HCP.

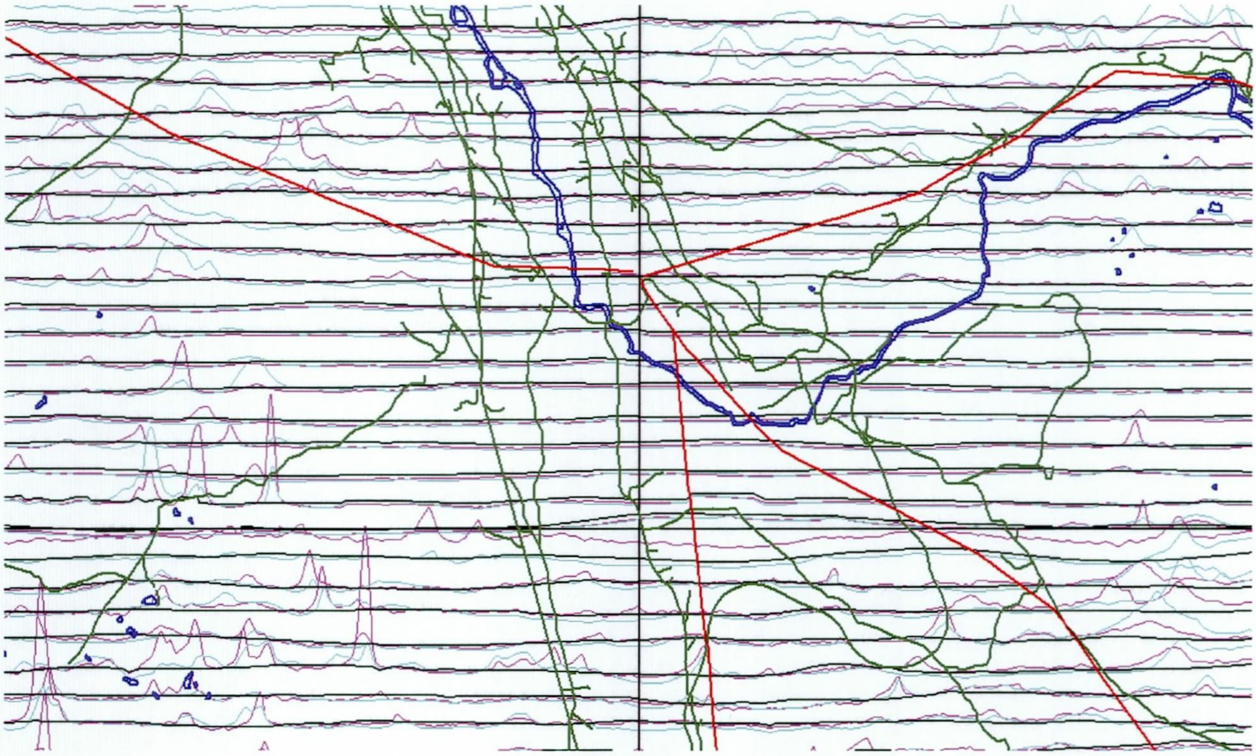

Figure 3. Sample of profiles from 34 kHz EM data. Line spacing-- 200m. In-phase--magenta. Quadrature--cyan. Powerlines, streams, and roads in red, blue, and green, respectively.

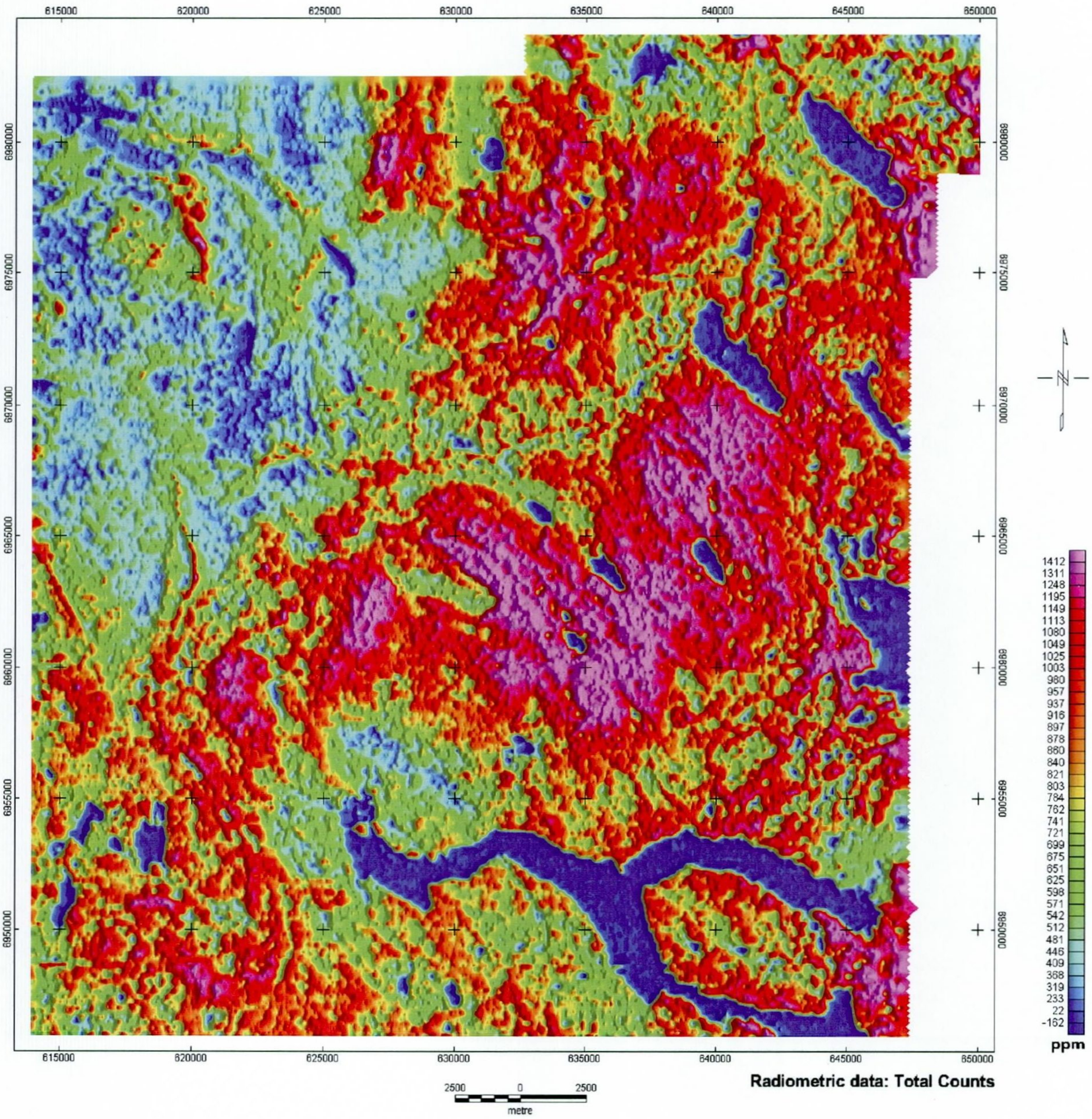

Figure 5. Radiometric data showing total counts.

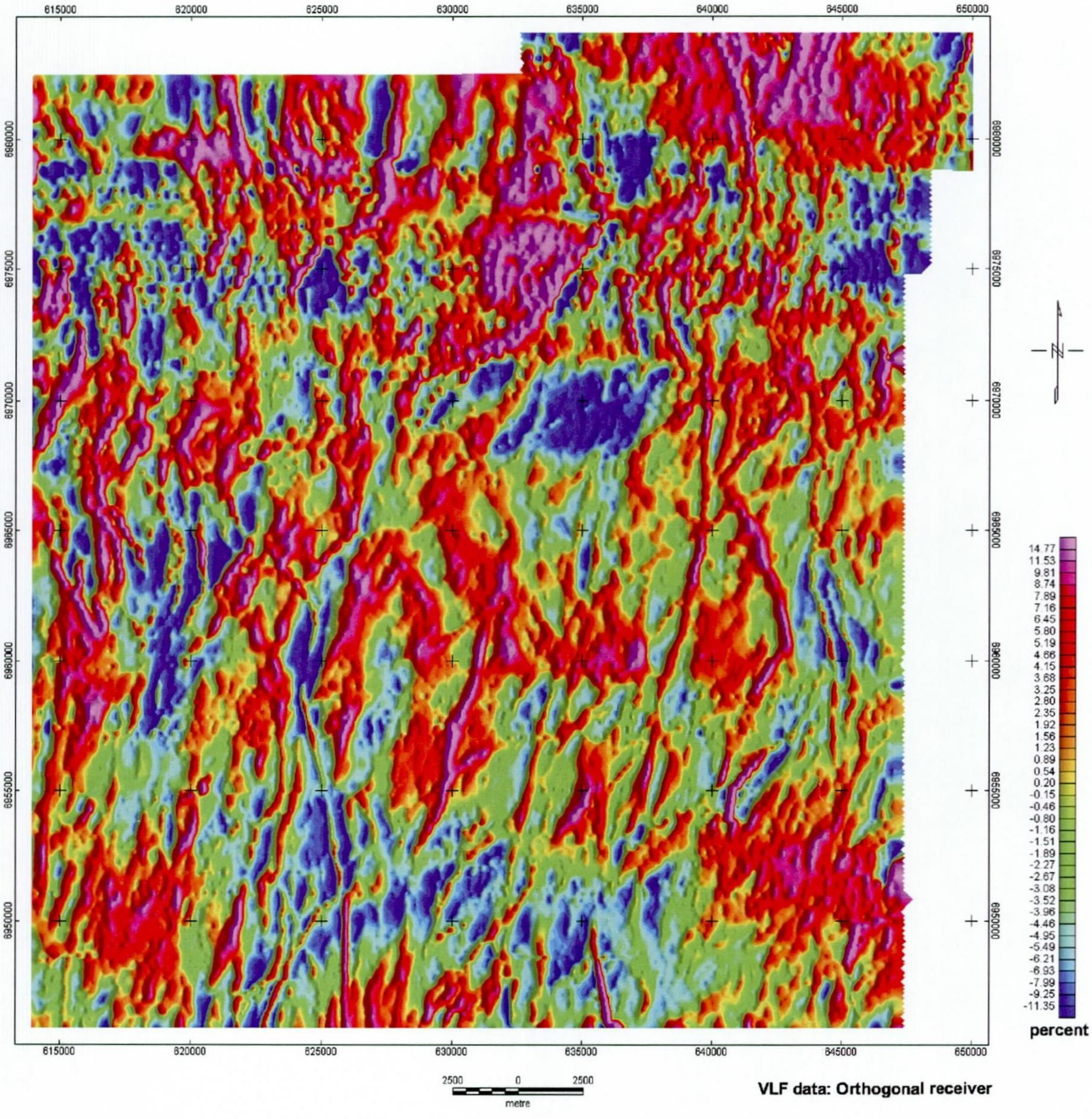

Figure 6. VLF data: Receiver oriented orthogonal to flight direction.