NGU Report 97.134

Data Acquisition and Processing Report—
Helicopter Survey, Krokskogen

NGU
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Geological Survey of Norway

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REPORT

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Data Acquisition and Processing Report—Helicopter Survey, Krokskogen

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Summary:

During June, 1997, a helicopter geophysical survey was carried out over Krokskogen, an area immediately northwest from Oslo. The purpose of the survey was to provide geophysical information to be used with geological data to help determine the best route for tunneling from Sandvika to Hønefoss. Approximately 900 line-kilometers of radiometric, magnetometric, and electromagnetic data were acquired, covering an area of approximately 180 sq km. The average flying height was 80 m. Nominal line spacing was 200 meters. The data were processed by the Geological Survey of Norway using software developed by Geosoft, Inc. 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 the Eggemoen airfield. Radiometric data were reduced using procedures recommended by the International Atomic Energy Association. Electromagnetic data, measured as parts per million of the primary field with in-phase and quadrature components, were reduced by subtracting an estimated zero level from the beginning of each flight, then correcting for drift under the assumption of linear drift. Very low frequency electromagnetic (VLF) data were processed by subtracting a low passed form of each flight line from the measured data to obtain a residual. It was necessary to apply decorrugation filters to VLF, radiometric, and electromagnetic data sets to remove small line-to-line errors remaining in the processed data. All data were gridded using square cells with 40-m sides. All geophysical maps were produced at a scale of 1:25 000. This report covers aspects of data processing. Interpretation of the geophysical data will be included in a later report, in which will also be included a bedrock geological map of the area.

Keywords: Geofysikk	Radiometri	Magnetometri
Electromagnetisk måling	Databehandling	Fagrapport

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1 INTRODUCTION

In June, 1997, a helicopter geophysical survey was carried out in the vicinity of Krokskogen, an area immediately northwest of Oslo. The radiometric, electromagnetic, magnetic, and very low frequency electromagnetic (VLF) data were collected by personnel from the Geological Survey of Norway. The primary objective of the survey was to provide information on faults, fractures, and other geological features. This information will aid Jernbaneverket personnel in deciding where a railroad tunnel should be built through the area. To this end, approximately 900 line-kilometers of data over an area of approximately 180 sq km were collected using a nominal line spacing of 200 meters.

2 GEOLOGY AND TOPOGRAPHY

Krokskogen lies on the western edge of the Oslo Rift. The eastern half of the area consists of acid-igneous intrusives, often taking the form of ring dikes (Sigmond et al., 1984). Rock types in the eastern area include syenites monzonite, monzodiorite, trachyte, and rhyolite. Brecciated zones having widths of a few hundred meters also occur among the intrusives. Surface exposures on the western half of the Krokskogen area are mainly horizontally layered basaltic igneous extrusives, mostly porphyritic lava flows (rhomb porphyry). Basaltic dikes of varying width can be found among these extrusives.

Topographic relief was not extreme in most of the area. This allowed draped flying over almost the entire area. Where terrain was sufficiently level, a flying height of 60 meters above ground level was achieved. The average flying height for the entire area was 80 meters.

3 ENVIRONMENTAL VARIABLES AND CONDITIONS

Heavy rain and strong wind can increase the noise level of airborne geophysical data. High winds were frequent during the survey, but were not strong enough to cause a flight to be aborted. Rain was encountered on only one flight, but lightning activity from distant thunderstorms caused some noise in the electromagnetic data. Although radiometric data can be degraded by airborne radon and by waterlogged soils, neither of these factors appear to be a problem in this survey. Weather conditions were never caused cancellation of a flight.

Electromagnetic, magnetic, and radiometric data quality was very good on all lines collected. VLF data quality varied considerably because VLF transmitters changed their power or 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.

4 OPERATIONAL VARIABLES AND CONDITIONS

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 average flying height was approximately 80 meters. There were a number of homes in the extreme southeast corner of the survey area, Lommedalen, so for safety reasons this area was flown at a height of about 150 meters. In the extreme north of the map area, a northwest-southeast trending power line caused flight heights to exceed 100 meters. Two of the valleys in the southern and western part of Krokskogen—Djupedalen and Kjaglidalen—were steep walled and forced higher than average flying heights.

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.

5 EQUIPMENT

Aircraft: The survey aircraft was an Areospatiale Ecureuil B-2. Flying speed was approximately 100 km per hour (28 meters per second).

Magnetometer: A Scintrex cesium vapor magnetometer, the MEP 410, was used. The magnetometer resolution is 0.01 nT. Sampling rate was 5 measurements per second. The magnetometer is suspended 15 meters beneath the helicopter.

Magnetic base station magnetometer: A Scintrex MP-3 proton precession magnetometer was located at the Eggemoen airfield, north from Hønefoss. The magnetic field was digitally recorded during flights at a rate of 15 measurements per minute for later use in base station correction of the aerial magnetic data.

Electromagnetic system: The EMEX-2 electromagnetic system is custom-built by the Aerodat Ltd. of Canada. The system uses two transmitter-receiver coil configurations: horizontal coplanar (HCP) and vertical coaxial (VCA). The HCP configuration operates at two frequencies: 32 kHz and 4.3 kHz. The VCA configuration operates at 4.5 kHz and 0.9 kHz. Transmitter-receiver separation is approximately 6.5 meters for all coil pairs. The sampling rate for all frequencies is 10 measurements per second. The coils are encased in a Kevlar bird suspended 30 meters beneath the helicopter. The system measures the in-phase and quadrature components normalized against the primary inducing field. These values are expressed in parts per million of the primary field.

Radiometric system: The radiometric system consists of four 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. No upward looking crystal was used in this survey.

VLF-EM system: The VLF measurements were made with a Hertz Totem-2A VLF receiver. The frequency range is 10-30 kHz. The VLF unit is suspended 7 meters beneath the helicopter. Registration rate is five per second.

Navigation: The survey used satellite navigation with an Ashtech receiver. Real time differential correction was applied to the navigation.

Altimetry: A Collins radar altimeter provided ground clearance information and an on-board barometer provided absolute height above sea level.

6 FIELD OPERATIONS

The center of the survey area is northwest from Oslo and is located less than 10 km from Oslo sentrum. The survey area lies between longitudes 10°17'E and 10°32'E and latitudes 59°56'N and 60°08'N. A total of 900 line-kilometers were flown during the survey. Flight direction was east-west. Typically two flights were flown each day, one in the morning and a second in the afternoon. The airfield used in the survey base, Eggemoen, is located 2.5 kilometers northeast of the town of Hønefoss. The NGU crew flew the survey between 10 June and 16 June, 1997. Flights were conducted only in good weather conditions and when diurnal magnetic variations were sufficiently low. At the beginning and end of each flight, the aircraft ascended to a height of more than 300 meters above ground level in order to establish zero values for the electromagnetic data, to monitor instrument drift, and to measure radiometric background levels. Navigation data were differentially corrected during each flight.

7 PROCESSING

The data were processed by the report authors at the Geological Survey of Norway in Trondheim on Pentium 200 MHz PCs with GEOSOFT processing software (Geosoft, 1996) designed for Windows-NT operating systems. All maps were gridded using a 40-m grid cell size. Obvious inaccuracies in navigation were manually removed from the data. The datum used was WGS-84 in UTM Zone 32. All leveling procedures were conducted flight-by-flight rather than a line-by-line, as this is the most efficient approach and is necessary in the case of the electromagnetic data and the magnetic data. Before gridding, the flights were split into lines and turns were trimmed away.

Total field magnetic data: A narrow nonlinear filter was applied to the raw magnetic data to remove spikes from spherics or other sources. The data were then inspected flight-by-flight and any spikes which were not completely removed by the filter were 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. A lag correction was also applied. The lines were gridded without decorrugation or further smoothing.

Radiometric data: The GEOSOFT radiometric processing package (Geosoft, 1995) follows the procedures outlined in International Atomic Energy Agency Technical Report No. 323 (IAEA, 1991). A livetime channel was recorded. 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 or three per flight, with one at the beginning and another at the end of the flight. After background reduction, the data were corrected for spectral overlap using experimentally determined stripping ratios. The processed data are presented as counts per second of the uranium, potassium, and thorium channels normalized to a height of 60 meters.

Electromagnetic data: The electromagnetic (EM) data consist of in-phase and quadrature measurements recorded as parts per million (ppm) of the free-space electromagnetic response at the receiver coil produced by the transmitter coil. Processing of the EM data was done using Geosoft software (Geosoft, 1997). Data zero levels were determined, and instrument drift corrected. Spikes were removed using a nonlinear filter and the data were low passed. From the leveled data, nomograms were constructed and half-space resistivities were computed for each frequency and coil configuration. A decorrugation filter was applied to the computed resistivity grids. This filter further reduced any residual leveling errors. It should be noted that drift is generally more severe as frequency increases, so drift in the 32 kHz HCP EM system is less well compensated than in the lower frequencies. Furthermore, lower frequencies are more susceptible to power line interference than higher frequencies.

VLF-EM data: The raw VLF data channels were heavily low passed, and the low passed channels were subtracted from the raw VLF data channels to leave the VLF anomaly. The VLF transmitters most often used were JXZ in Helgeland (16 kHz), GBR in Rugby, England (16 kHz), and NAA in Cutler, Maine, USA (24 kHz). The airborne operators have no control over the transmitters. These transmitters were designed for long distance communication with submarines, not geophysical surveys, therefore it is not unusual to find their power reduced or cut off completely during a survey. This occurred at least once during the Krokskogen survey and can be seen as a broad band of random anomalies in the middle of the map showing the VLF orthogonal response.

8 MAPS PRODUCED

All maps were produced at a scale of 1:25 000. All maps were presented in contoured, color, shaded-relief. Shading was from the east—along the flight line direction—and with a sun inclination of 45° above the horizon. The grid cell size for all maps was 40 meters. Flight lines are included on all maps. The following is a list of the maps produced:

Map 97.134-01: Total field magnetic anomaly, base station corrected
Map 97.134-02: Second vertical derivative of total magnetic field anomaly
Map 97.134-03: Resistivity from 4287 Hz horizontal coplanar coil EM
Map 97.134-04: Resistivity from 32165 Hz horizontal coplanar coil EM
Map 97.134-05: Resistivity from 915 Hz vertical coaxial coil EM
Map 97.134-06: Resistivity from 4551 Hz vertical coaxial coil EM
Map 97.134-07: Very low frequency EM—in line sensor
Map 97.134-08: Very low frequency EM—orthogonal sensor
Map 97.134-09: Radiometric total counts
Map 97.134-10: Radiometric potassium
Map 97.134-11: Radiometric thoruim
Map 97.134-12: Radiometric uranium

An interpretation of the data contained in these maps, and a geological bedrock map, will be included in an upcoming report to be written in cooperation with geologists from NGU's Bedrock Geology Section.

9 REFERENCES

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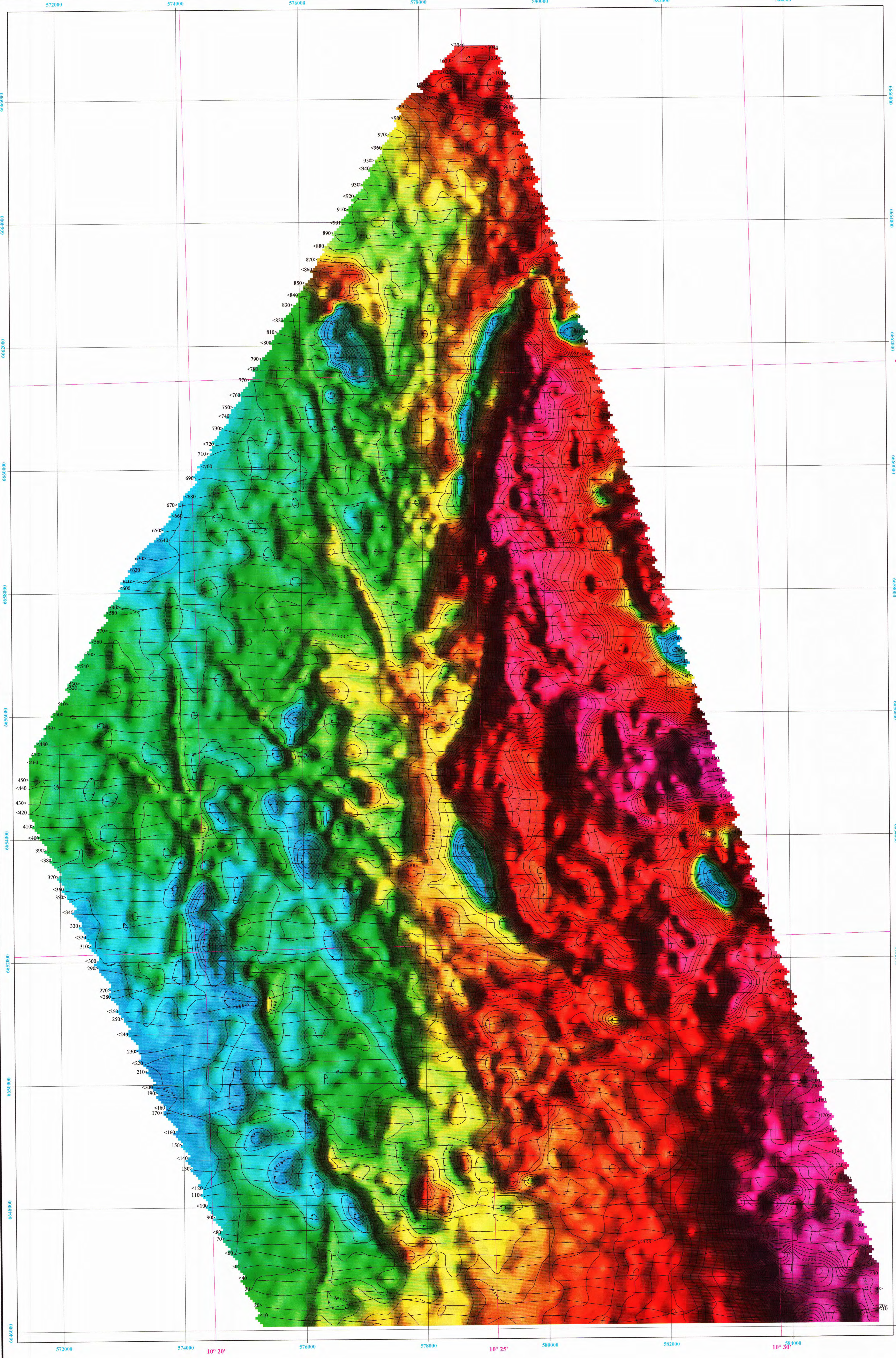

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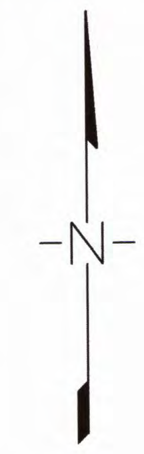
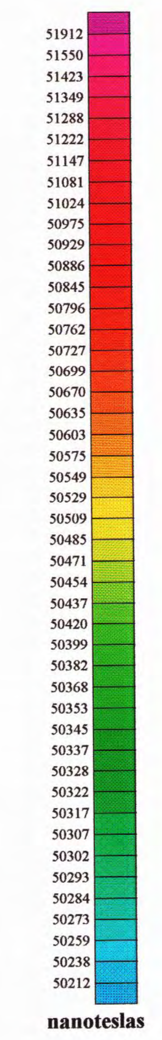




TOTAL MAGNETIC FIELD

Measured total magnetic field with diurnal variation removed.

Illumination is at an inclination of 45 degrees from due East.

Average magnetometer height: 65 m above ground level

Contour intervals: 50, 200, and 1000 nT.

DATUM

Spheriod : WGS 84

Projection: UTM zone 32.

JERNBANEVERKET--SOUTH

TOTAL MAGNETIC FIELD

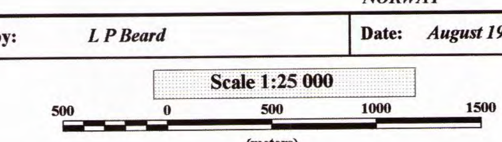
Based on data from an NGU helicopter survey, 1997

KROKSKOGEN

NORWAY

Made by: *L P Beard*	Date: *August 1997*	Oper: *NGU*

Scale 1:25 000



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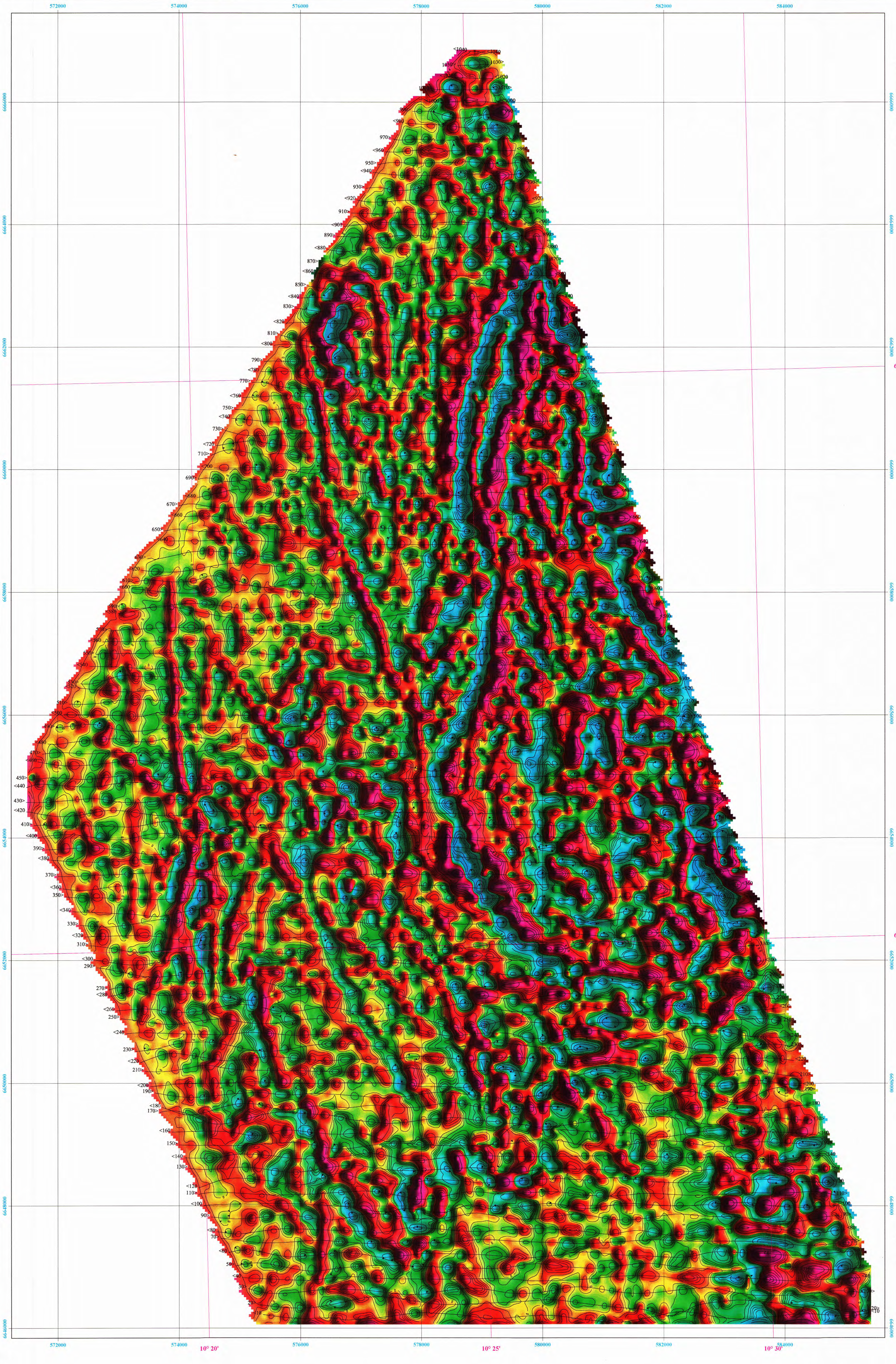

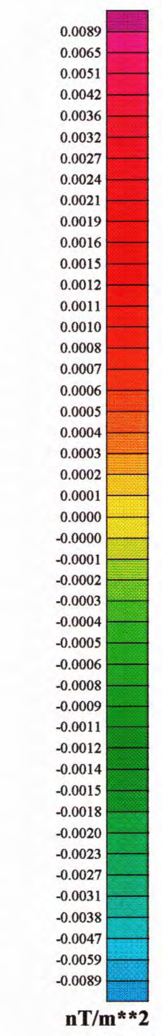

SECOND VERTICAL DERIVATIVE OF TOTAL MAGNETIC FIELD

Second vertical derivative of the measured total magnetic field.

The computed field has been upward continued 50 meters.

Illumination is at an inclination of 45 degrees from due East.

Average magnetometer height: 65 m above ground level

Contour intervals: .0005, .002, .01, .05 nT/m2.**

DATUM

Spheriod : WGS 84

Projection: UTM zone 32.

JERNBANEVERKET--SOUTH

SECOND VERTICAL DERIVATIVE OF TOTAL MAGNETIC FIELD

Based on data from an NGU helicopter survey, 1997

KROKSKOGEN

NORWAY

Made by: *L P Beard*	**Date:** *August 1997*	**Oper:** *NGU*

Scale 1:25 000

500 0 500 1000 1500
(meters)

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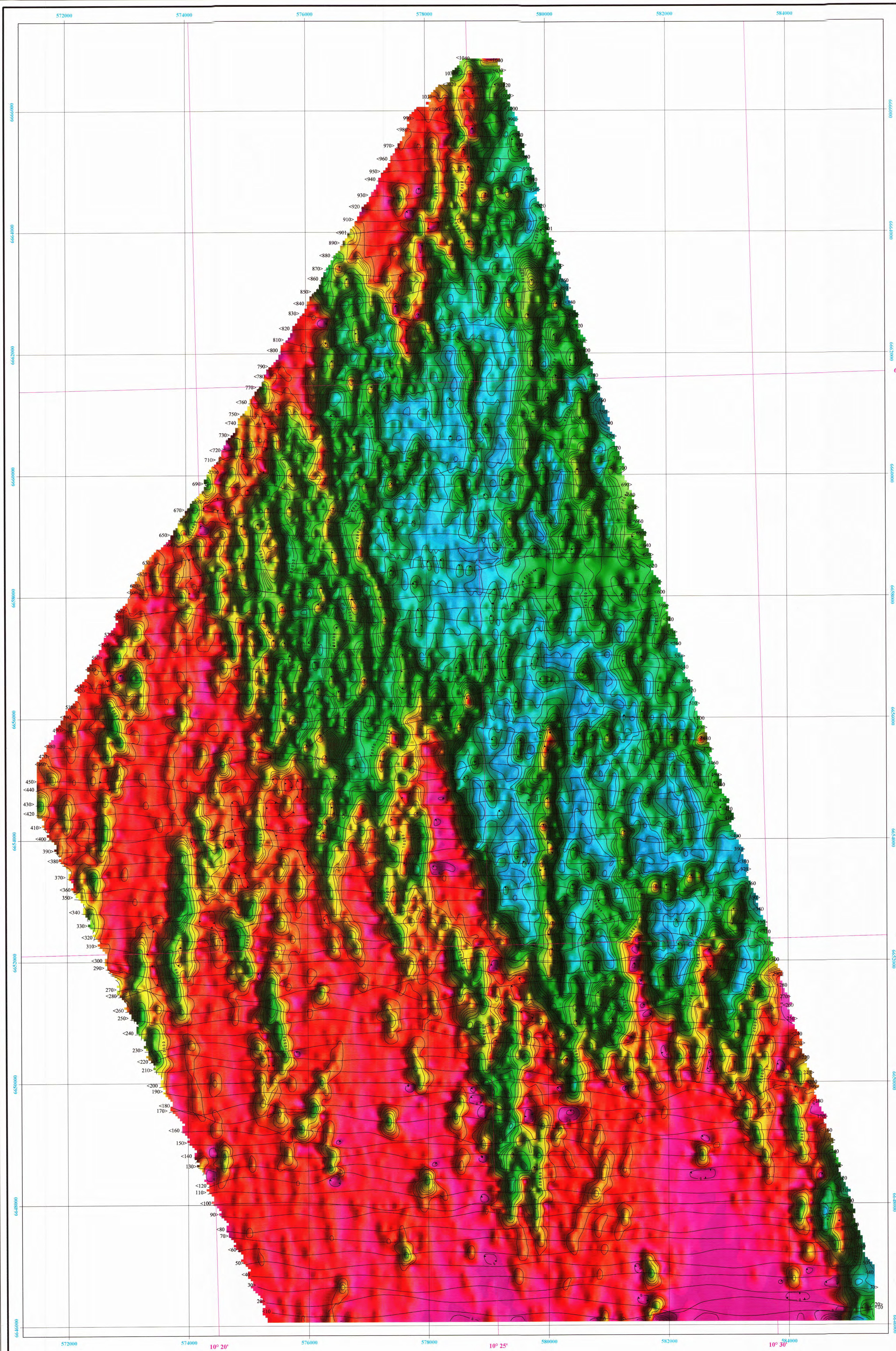

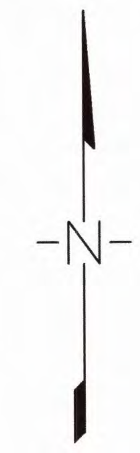

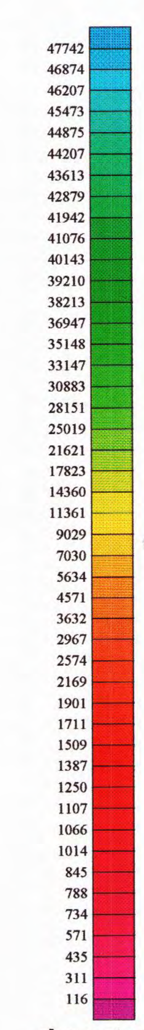

RESISTIVITY-4287 HZ HCP

Half-space resistivity estimated from 4287 Hz horizontal coplanar coil configuration.

Electromagnetic data have been leveled and a decorrugation filter has been applied.

Illumination is at an inclination of 45 degrees from due East.

Average EM sensor height: 50 m above ground level

Contour intervals: 2000, 10000 ohm-m.

DATUM

Spheriod : WGS 84

Projection: UTM zone 32.

JERNBANEVERKET--SOUTH

RESISTIVITY--4287 Hz HCP

Based on data from an NGU helicopter survey, 1997

KROKSKOGEN

NORWAY

Made by: *L P Beard*	Date: *August 1997*	Oper: *NGU*

Scale 1:25 000

500 0 500 1000 1500 (meters)

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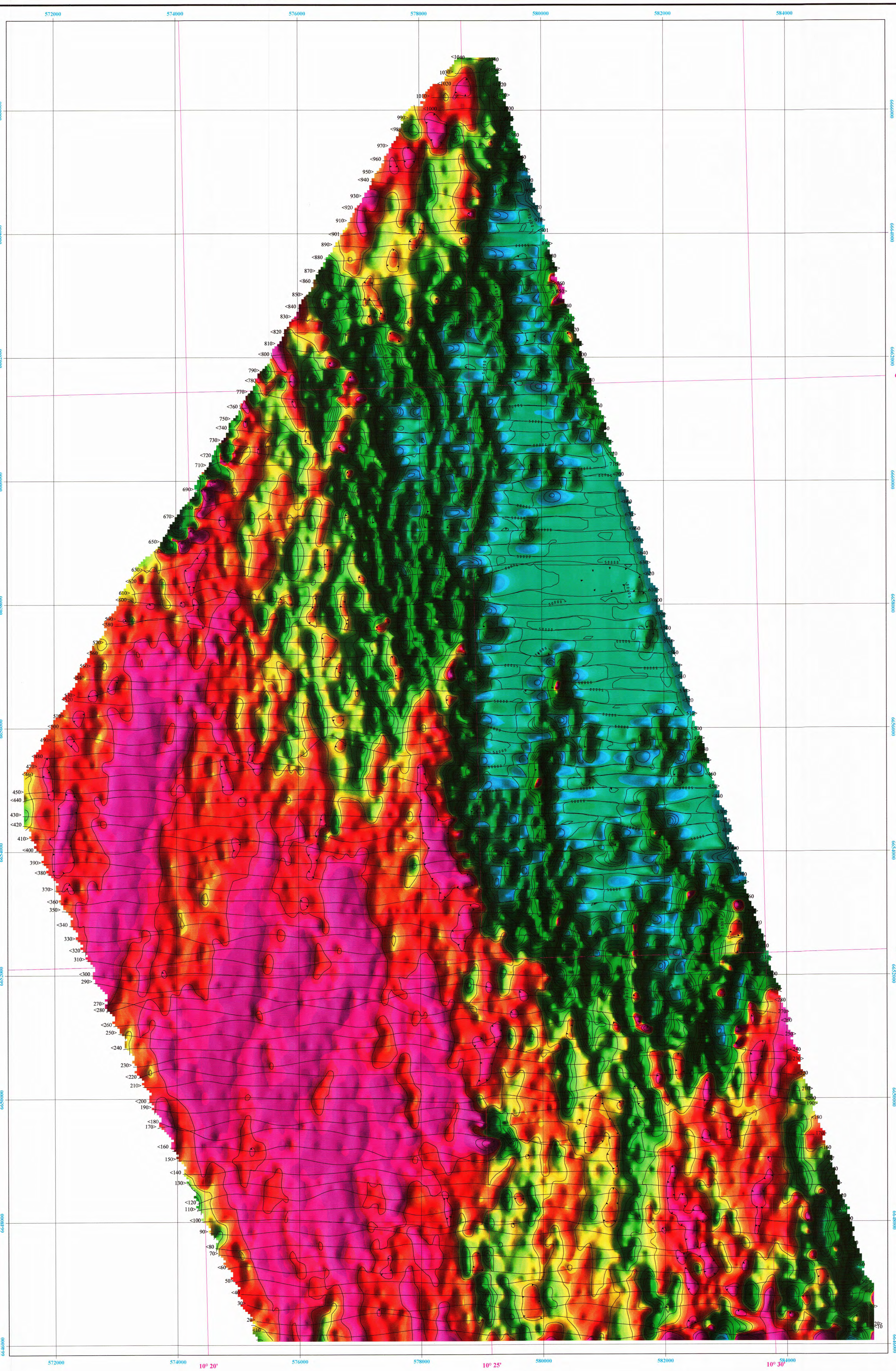

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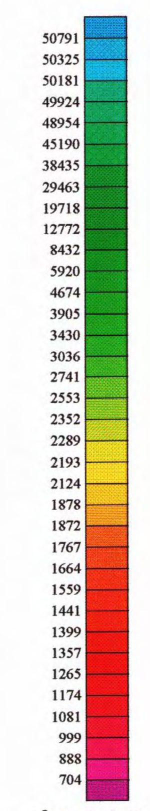

RESISTIVITY-32165 HZ HCP

Half-space resistivity estimated from 32165 Hz horizontal coplanar coil configuration.

Electromagnetic data have been leveled and a decorrugation filter has been applied.

Illumination is at an inclination of 45 degrees from due East.

Average EM sensor height: 50 m above ground level

Contour intervals: 2000, 10000, 50000 ohm-m.

DATUM

Spheriod : WGS 84

Projection: UTM zone 32.

JERNBANEVERKET--SOUTH

RESISTIVITY--32165 Hz HCP

Based on data from an NGU helicopter survey, 1997

KROKSKOGEN

NORWAY

Made by: *L P Beard*	Date: *August 1997*	Oper: *NGU*

Scale 1:25 000

500 0 500 1000 1500

(meters)

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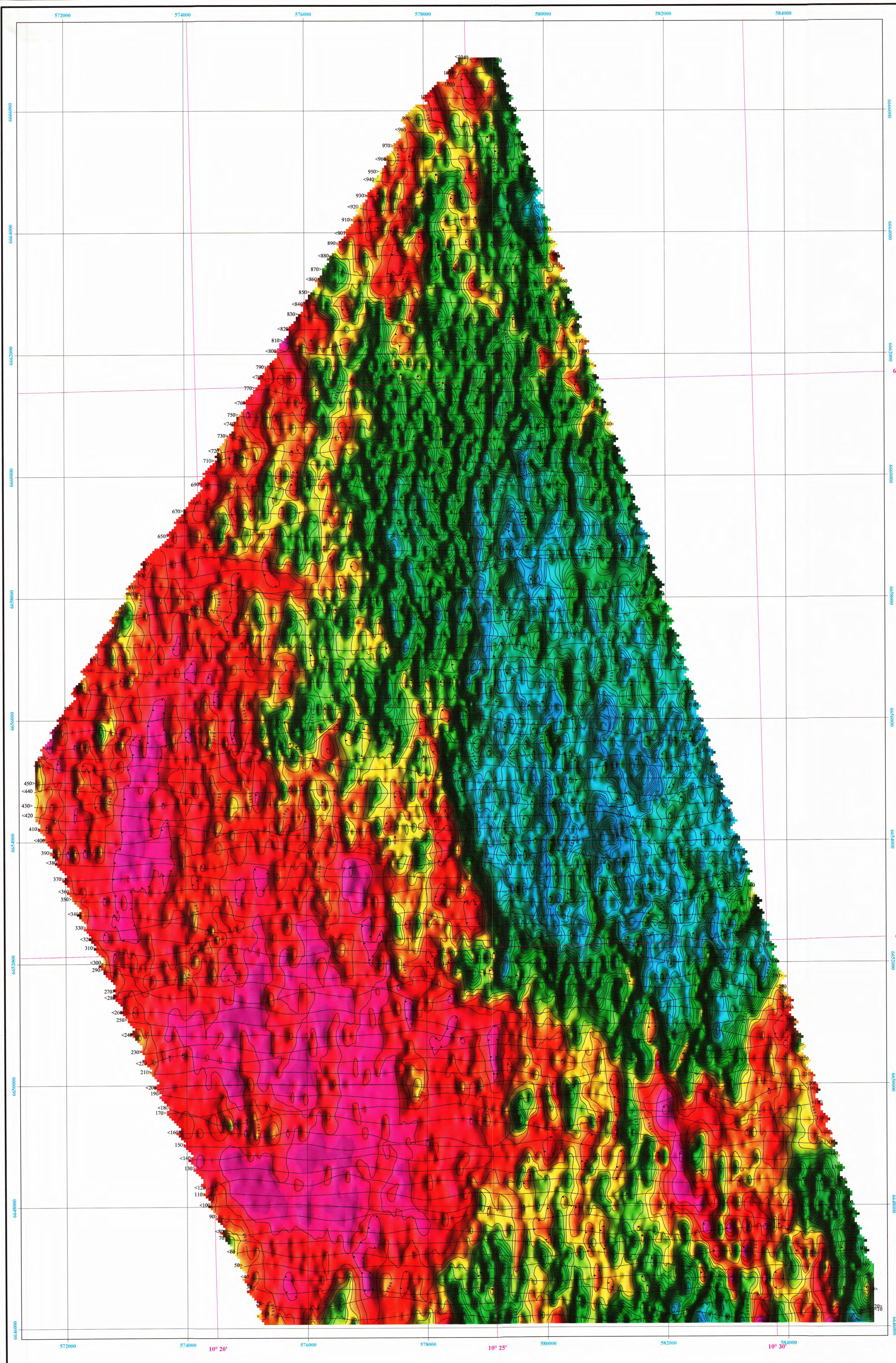

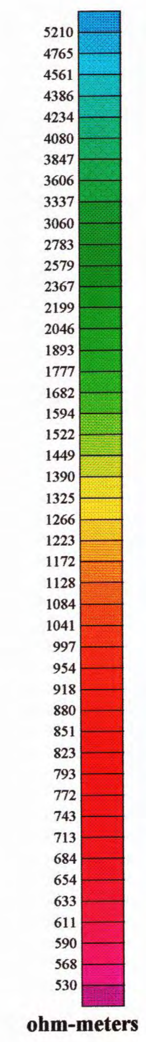

RESISTIVITY-915 HZ VCA

Half-space resistivity estimated from 915 Hz vertical coaxial coil configuration.

Electromagnetic data have been leveled and a decorrugation filter has been applied.

Illumination is at an inclination of 45 degrees from due East.

Average EM sensor height: 50 m above ground level

Contour intervals: 200, 1000 ohm-m.

DATUM

Spheriod : WGS 84

Projection: UTM zone 32.

JERNBANEVERKET--SOUTH

RESISTIVITY--915 Hz VCA

Based on data from an NGU helicopter survey, 1997

KROKSKOGEN

NORWAY

Made by: *L P Beard*	Date: *August 1997*	Oper: *NGU*

Scale 1:25 000

500 0 500 1000 1500 (meters)

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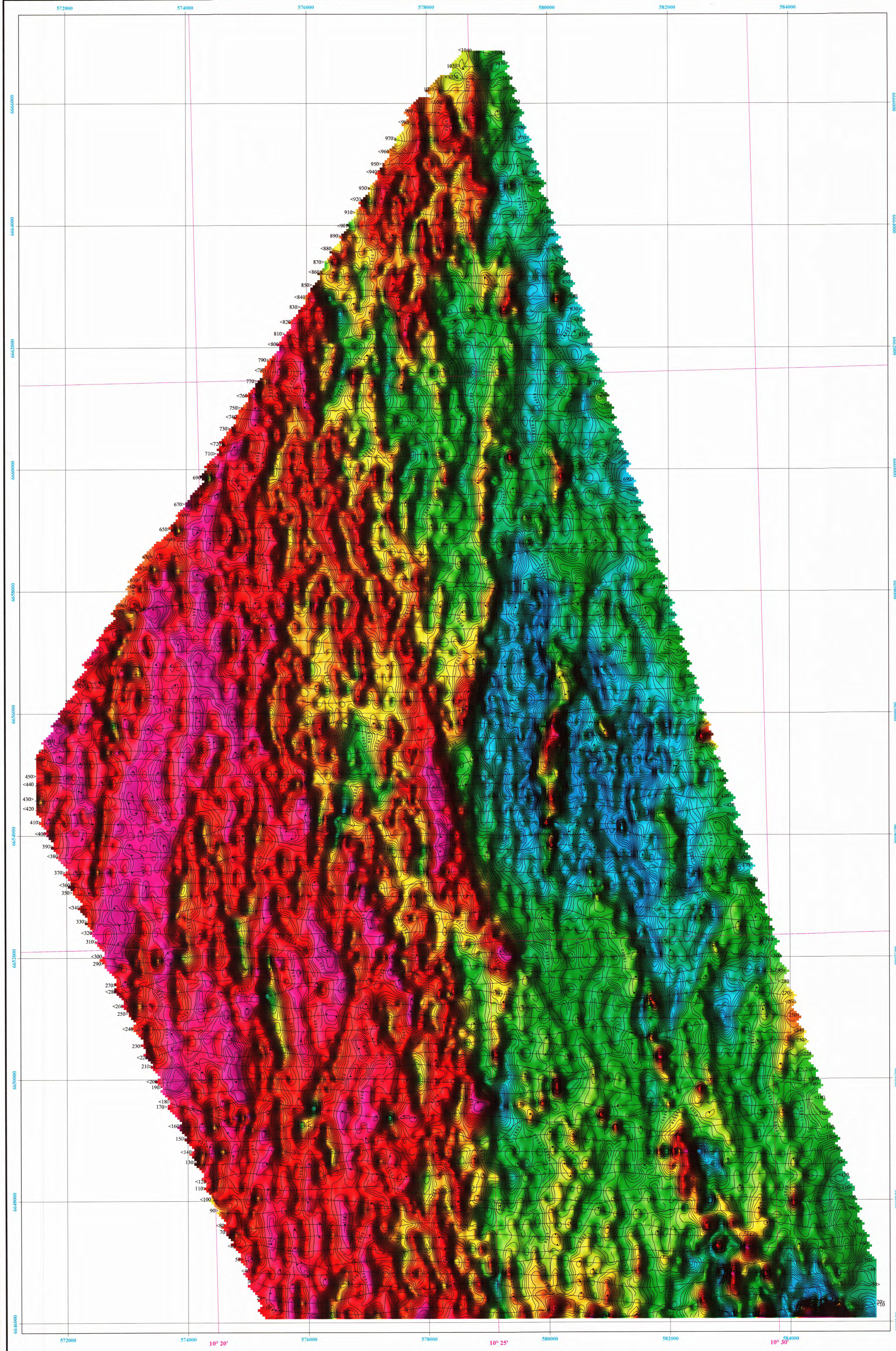

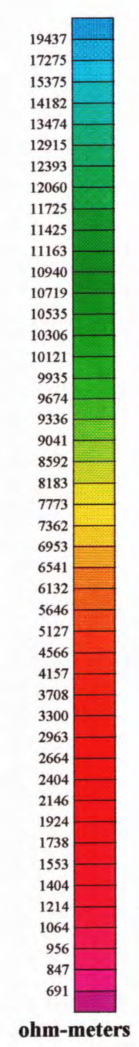

RESISTIVITY-4551 HZ VCA

Half-space resistivity estimated from 4551 Hz vertical coaxial coil configuration.

Electromagnetic data have been leveled and a decorrugation filter has been applied.

Illumination is at an inclination of 45 degrees from due East.

Average EM sensor height: 50 m above ground level

Contour intervals: 20, 100, 500 ohm-m.

DATUM

Spheriod : WGS 84

Projection: UTM zone 32.

JERNBANEVERKET--SOUTH

RESISTIVITY--4551 Hz VCA

Based on data from an NGU helicopter survey, 1997

KROKSKOGEN

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Scale 1:25 000

500 0 500 1000 1500 (meters)

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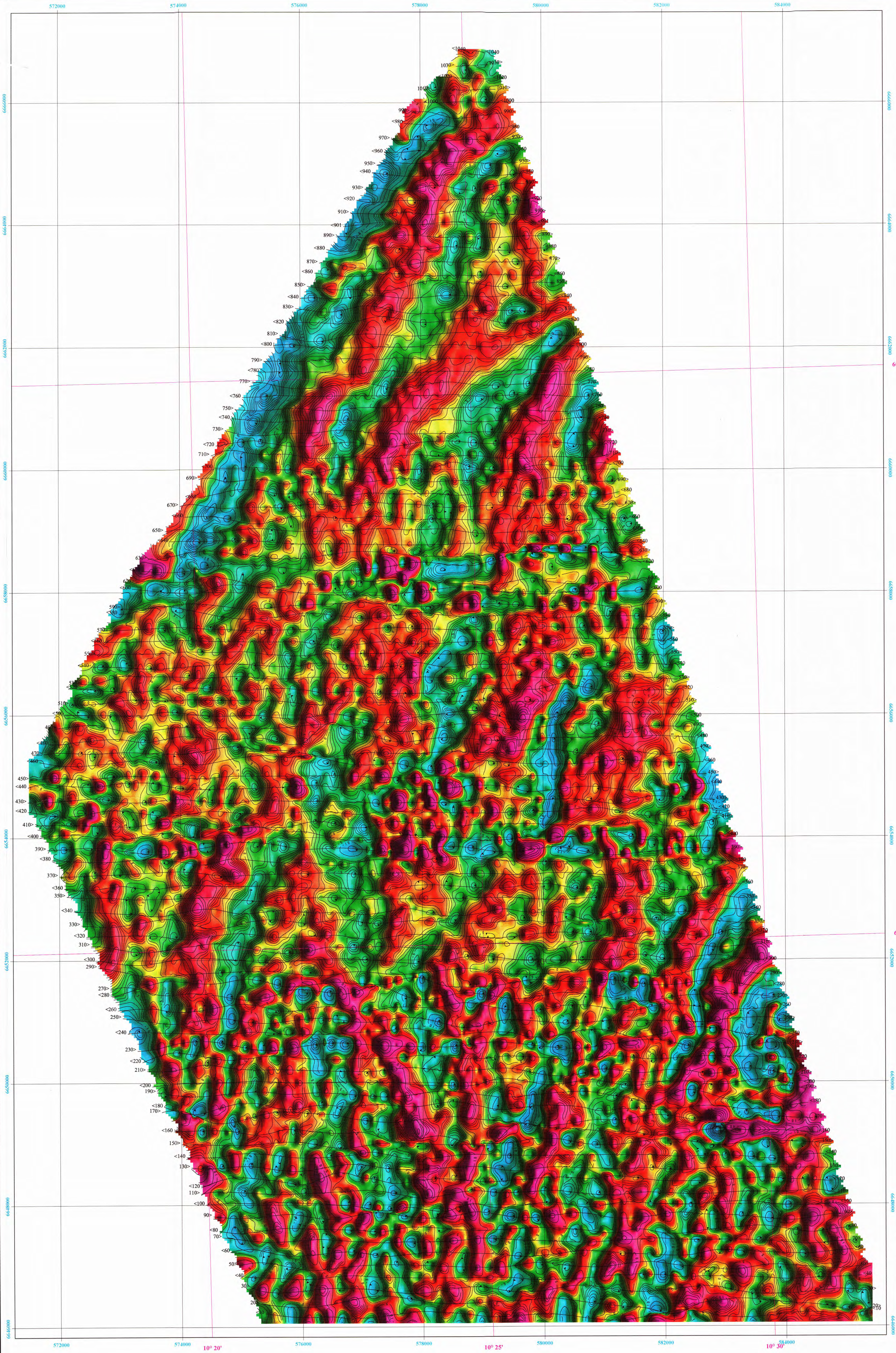

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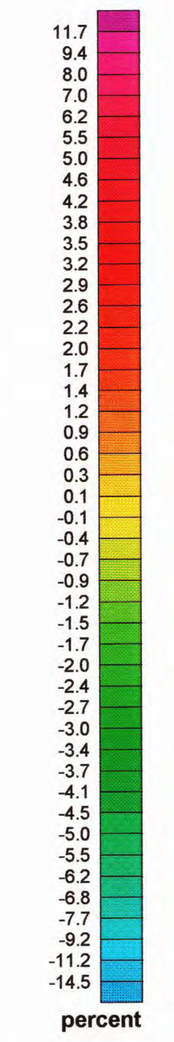

VLF EM--IN LINE RESPONSE

Very low frequency electromagnetic (VLF EM) response from sensor in line with the survey line direction. The sensor measures the percent change in the total field produced by a distant transmitter.

Transmitters used in this survey were JXZ (Helgeland, Norway; 16kHz), GBR (Rugby, England; 16kHz), and NAA (Cutler, Maine, USA; 24kHz).

Illumination is at an inclination of 45 degrees from due East.

Average VLF sensor height: 73 m above ground level

Contour intervals: 1, 5 percent.

DATUM

Spheriod : WGS 84

Projection: UTM zone 32.

JERNBANEVERKET--SOUTH

VLF EM-IN LINE

Based on data from an NGU helicopter survey, 1997

KROKSKOGEN

NORWAY

Made by: *L P Beard*	**Date:** *August 1997*	**Oper:** *NGU*

Scale 1:25 000

500 0 500 1000 1500
(meters)

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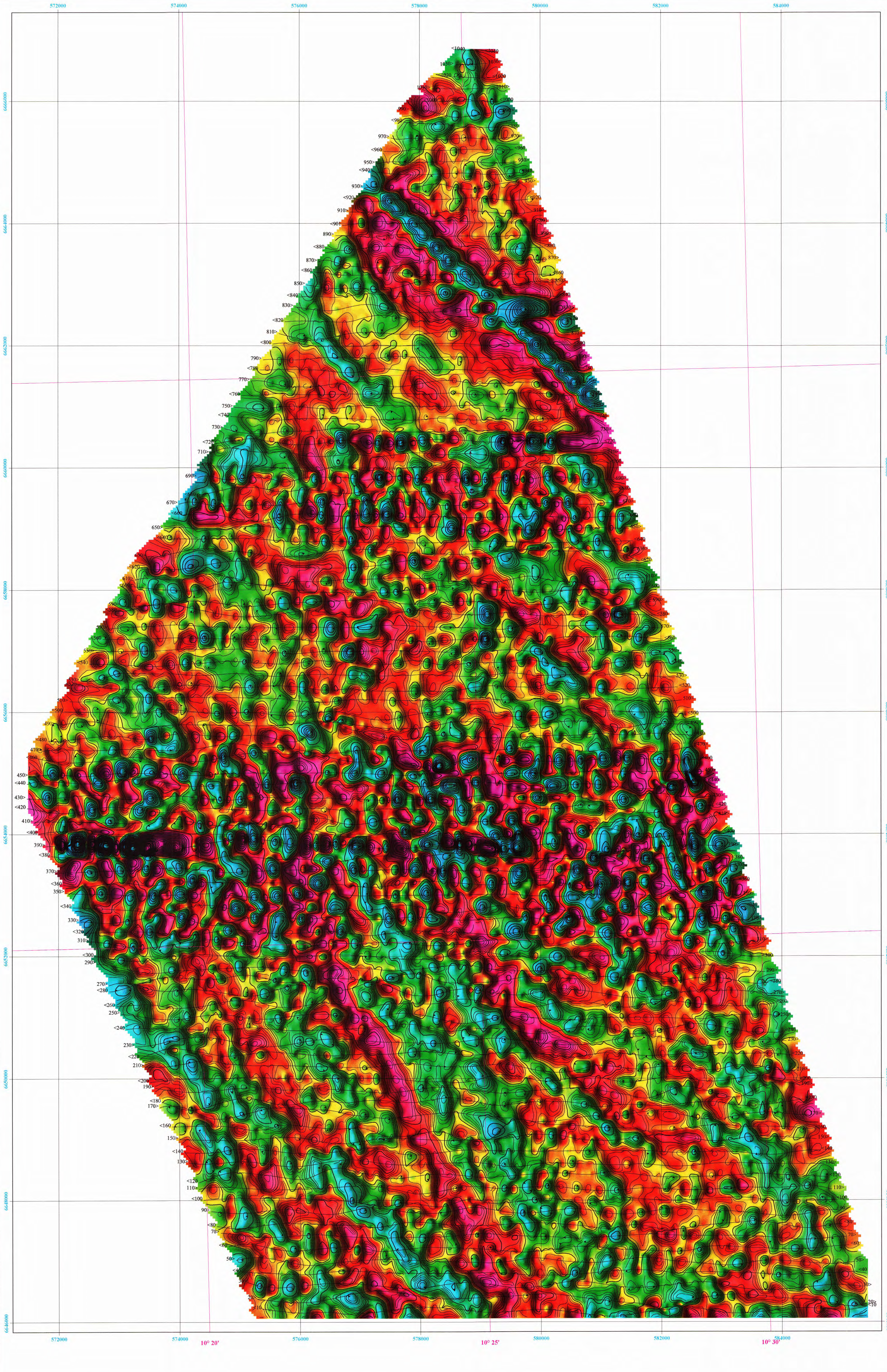

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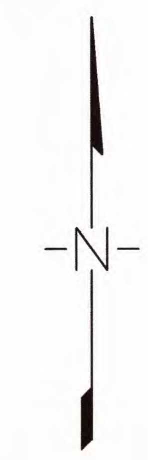
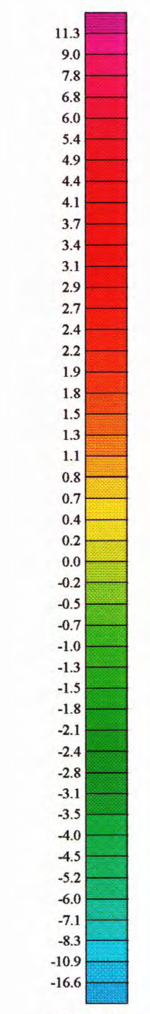




VLF EM--ORTHOGONAL RESPONSE

Very low frequency electromagnetic (VLF EM) response from sensor orthogonal to the survey line direction. The sensor measures the percent change in the total field produced by a distant transmitter.

Transmitters used in this survey were JXZ (Helgeland, Norway; 16kHz), GBR (Rugby, England; 16kHz), and NAA (Cutler, Maine, USA; 24kHz).

Illumination is at an inclination of 45 degrees from due East.

Average VLF sensor height: 73 m above ground level

Contour intervals: 1, 5 percent.

DATUM

Spheriod : WGS 84

Projection: UTM zone 32.

JERNBANEVERKET--SOUTH

VLF EM-ORTHOGONAL

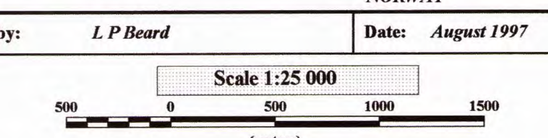
Based on data from an NGU helicopter survey, 1997

KROKSKOGEN

NORWAY

Made by: *L P Beard*	**Date:** *August 1997*	**Oper:** *NGU*

Scale 1:25 000



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GEOLOGICAL SURVEY OF NORWAY

Leiv Eirikssons vei 39

N-7040 TRONDHEIM

Tel 73 90 40 11, Fax 73 92 16 20

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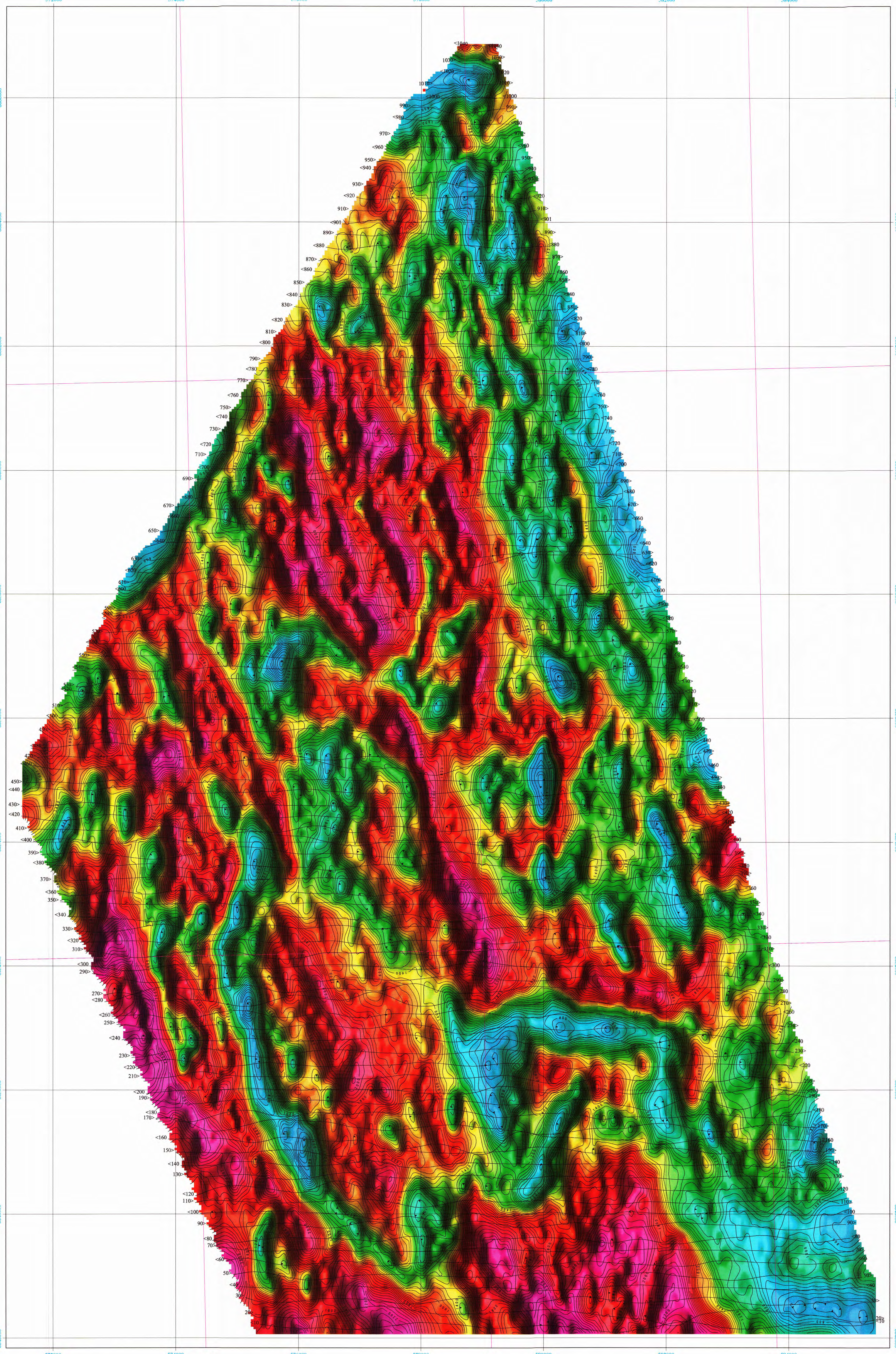

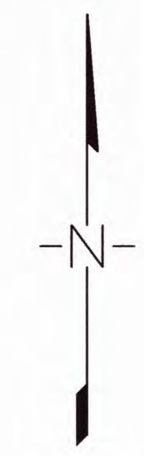

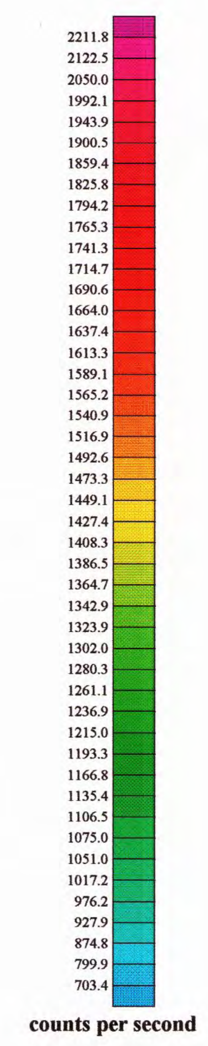

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TOTAL COUNTS

Radiometric total counts per second adjusted to 60 m above ground level.

A decorrugation filter was applied to remove residual leveling inaccuracies.

Illumination is at an inclination of 45 degrees from due East.

Average radiometric sensor height: 80 m above ground level

Contour intervals: 50, 200 cps.

DATUM

Spheriod : WGS 84

Projection: UTM zone 32.

JERNBANEVERKET--SOUTH

RADIOMETRIC TOTAL COUNTS

Based on data from an NGU helicopter survey, 1997

KROKSKOGEN

NORWAY

Made by: *L P Beard*	**Date:** *August 1997*	**Oper:** *NGU*

Scale 1:25 000

500 0 500 1000 1500

(meters)

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Geology for Society since 1858

GEOLOGICAL SURVEY OF NORWAY
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N-7040 TRONDHEIM
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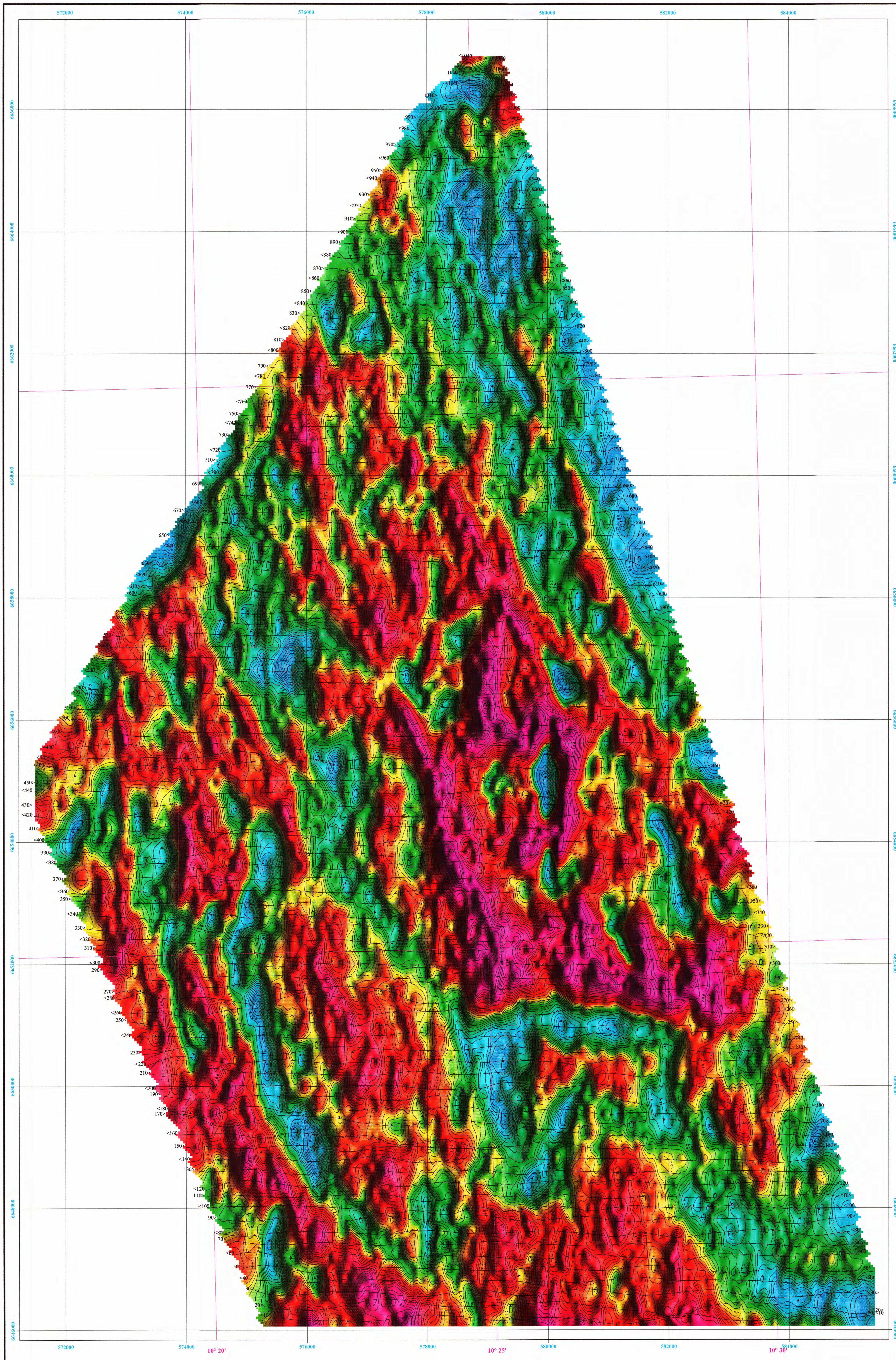
DRAWING:

97-134-09



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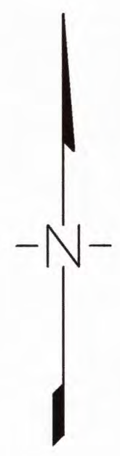

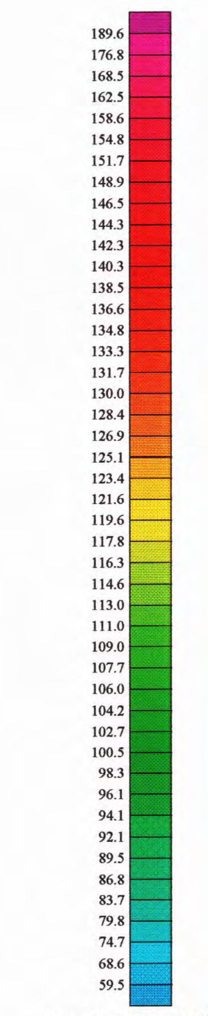

POTASSIUM COUNTS

Radiometric counts per second adjusted to 60 m above ground level--potassium channel.

A decorrugation filter was applied to remove residual leveling inaccuracies.

Illumination is at an inclination of 45 degrees from due East.

Average radiometric sensor height: 80 m above ground level

Contour intervals: 5, 20 cps.

DATUM

Spheriod : WGS 84

Projection: UTM zone 32.

JERNBANEVERKET--SOUTH

RADIOMETRIC COUNTS--POTASSIUM

Based on data from an NGU helicopter survey, 1997

KROKSKOGEN

NORWAY

Made by: *L P Beard*	Date: *August 1997*	Oper: *NGU*

Scale 1:25 000

500 0 500 1000 1500 (meters)

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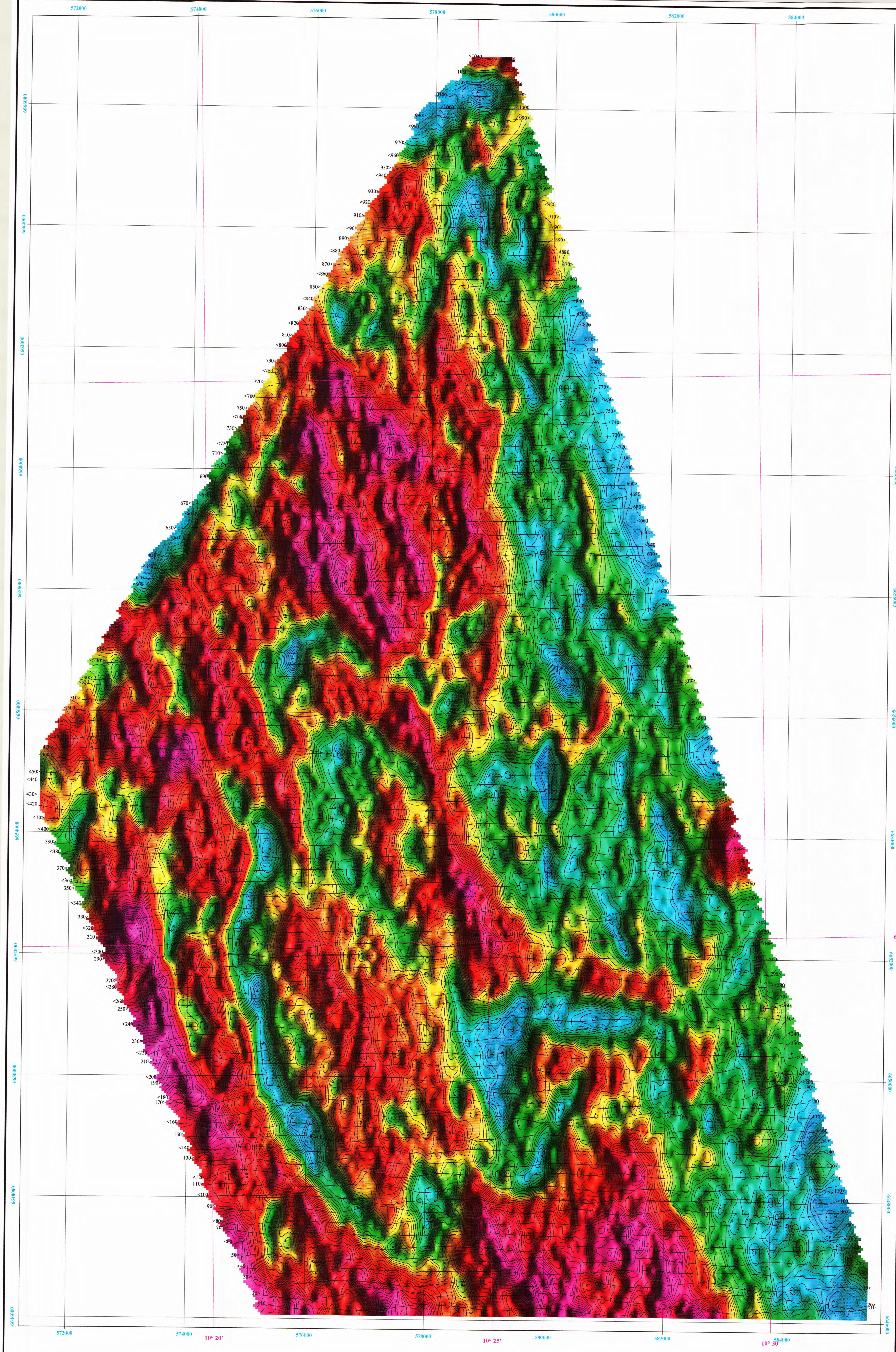

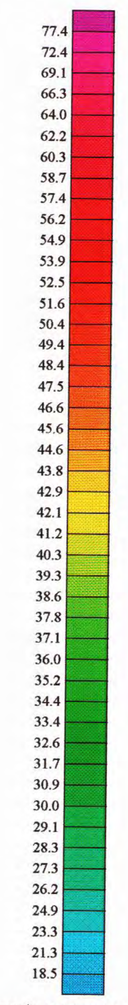

THORIUM COUNTS

Radiometric counts per second adjusted to 60 m above ground level--thorium channel.

A decorrugation filter was applied to remove residual leveling inaccuracies.

Illumination is at an inclination of 45 degrees from due East.

Average radiometric sensor height: 80 m above ground level

Contour intervals: 2, 10 cps.

DATUM

Spheriod : WGS 84

Projection: UTM zone 32.

JERNBANEVERKET--SOUTH

RADIOMETRIC COUNTS--THORIUM

Based on data from an NGU helicopter survey, 1997

KROKSKOGEN

NORWAY

Made by: *L P Beard*	**Date:** *August 1997*	**Oper:** *NGU*
Scale 1:25 000 500 0 500 1000 1500 (meters)		

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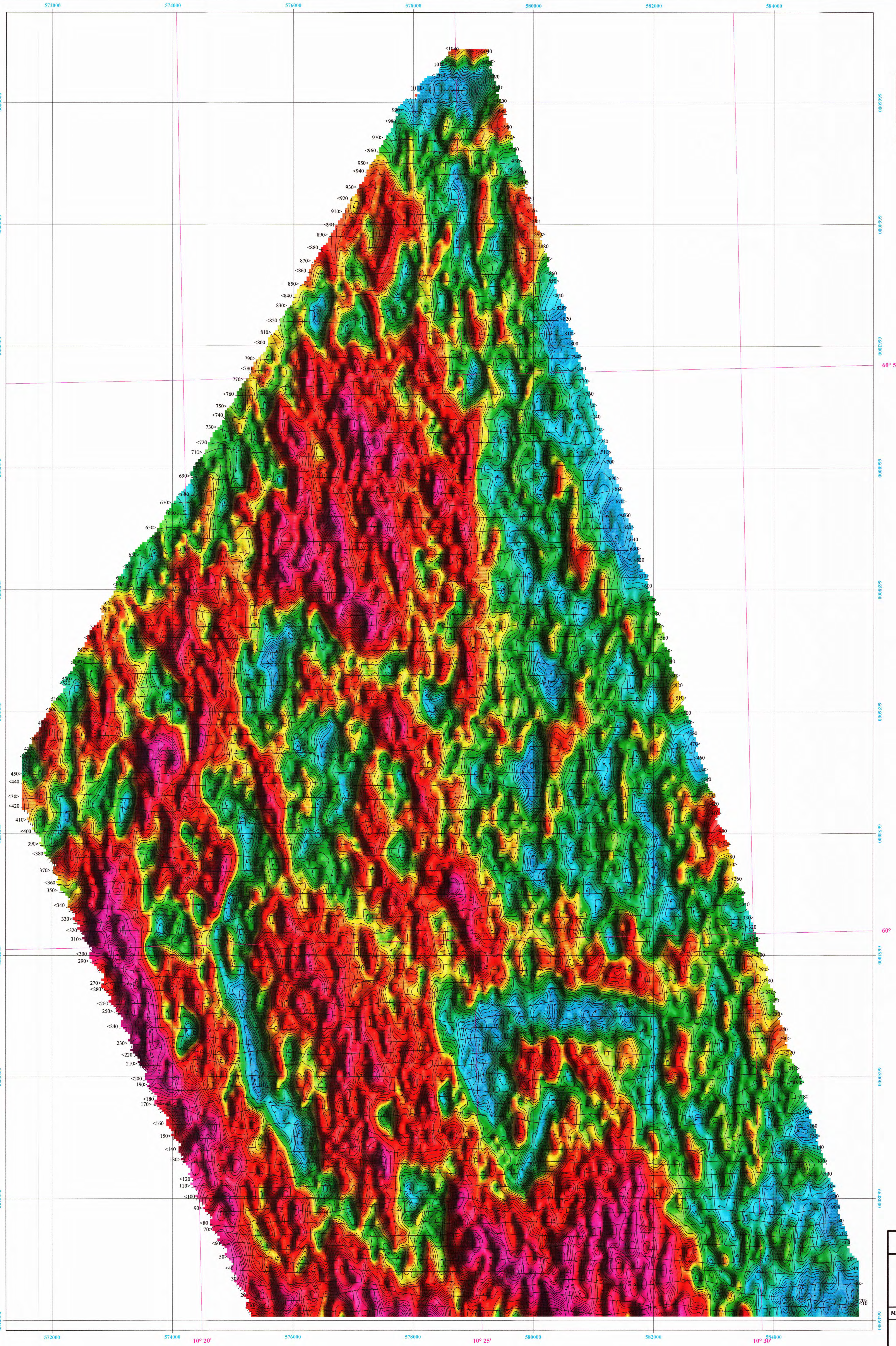

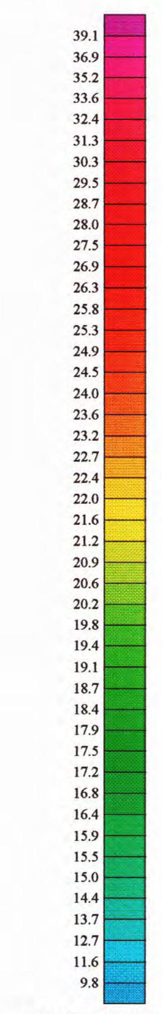

counts per second

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URANIUM COUNTS

Radiometric counts per second adjusted to 60 m above ground level--uranium channel.

A decorrugation filter was applied to remove residual leveling inaccuracies.

Illumination is at an inclination of 45 degrees from due East.

Average radiometric sensor height: 80 m above ground level

Contour intervals: 1, 5, 20 cps.

DATUM

Spheriod : WGS 84

Projection: UTM zone 32.

JERNBANEVERKET--SOUTH

RADIOMETRIC COUNTS--URANIUM

Based on data from an NGU helicopter survey, 1997

KROKSKOGEN

NORWAY

Made by: *L P Beard*	**Date:** *August 1997*	**Oper:** *NGU*

Scale 1:25 000

500 0 500 1000 1500

(meters)

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