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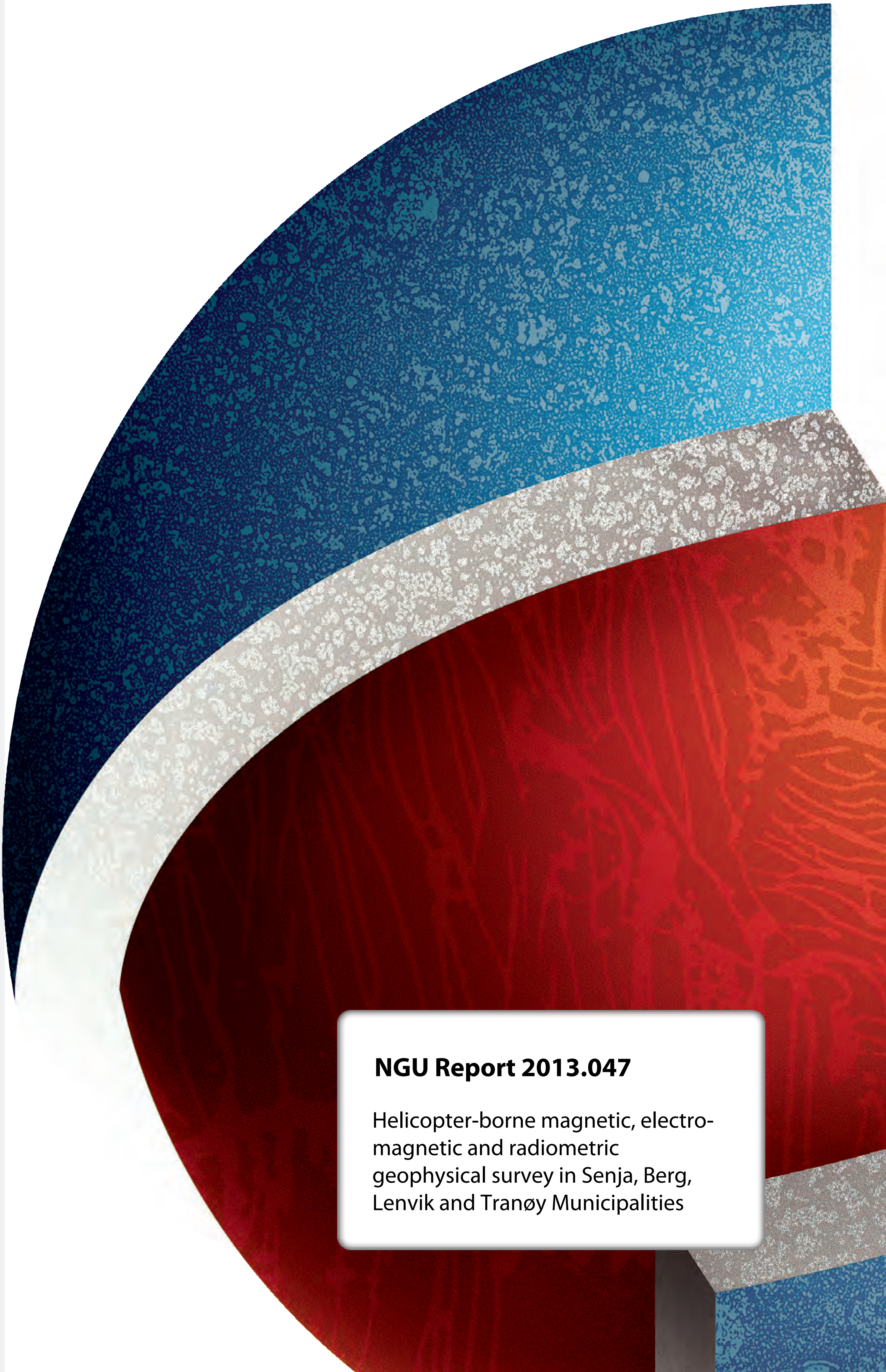

NGU Report 2013.047

Helicopter-borne magnetic, electro-magnetic and radiometric geophysical survey in Senja, Berg, Lenvik and Tranøy Municipalities

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REPORT

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Title:
Helicopter-borne magnetic, electromagnetic and radiometric geophysical survey in the Senja, Berg, Lenvik and Tranøy Municipalities, Troms County.

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Summary:

NGU conducted an airborne geophysical survey at Senja in July-August 2012 and August 2013 as a part of the MINN project. This report describes and documents the acquisition, processing and visualization of recorded datasets. The geophysical survey results reported herein are 5320 line km, covering an area of 1064 km^2.

The NGU modified Geotech Ltd. Hummingbird frequency domain system supplemented by optically pumped Cesium magnetometer and 1024 channels RSX-5 spectrometer was used for data acquisition.

The main part of the survey was flown with 200 m line spacing and lines were oriented at a 55° azimuth in UTM zone 33 W coordinates. The northern part of the survey area was flown with 200 m line spacing and line orientation at 145° due to the extreme rugged terrain. The area around the Skaland and the Trælen graphite mines was flown with 100 m line spacing and line oriented at 125°-160° azimuth.

Collected data were processed at NGU using Geosoft Oasis Montaj software. Raw total magnetic field data were corrected for diurnal variation and levelled using standard micro levelling algorithm.

EM data were filtered and levelled using both automated and manual levelling procedure. Apparent resistivity was calculated from in-phase and quadrature data for each of the five frequencies separately using a homogeneous half space model. Apparent resistivity grids were filtered using 3x3 convolution filter.

Radiometric data were processed using standard procedures recommended by International Atomic Energy Association.

Data were gridded with the cell size of 50 x 50 m and presented as a shaded relief maps at the scale of 1:50 000.

Keywords: Geophysics	Airborne	Magnetic
Electromagnetic	Gamma spectrometry	Radiometric
		Technical report

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1. INTRODUCTION

Recognising the impact that investment in mineral exploration and mining can have on the socio-economic situation of a region, the government of Norway initiated the MINN program (Mineral resources in North Norway). The goal of this program is to enhance the geological information that is relevant to an assessment of the mineral potential of the three northern most counties. The airborne geophysical surveys - helicopter borne and fixed wing- are important integral part of MINN program. The airborne survey results reported herein amount to 5320 line km (1064 km^2) over the Senja island, as shown in Figure 1.

Figure 1: Senja survey area

The objective of the airborne geophysical survey was to obtain a dense high-resolution aero-magnetic, electromagnetic and radiometric data over the survey area. This data is required for the enhancement of a general understanding of the regional geology of the area. In this regard, the data can also be used to map contacts and structural features within the property. It also improves defining the potential of known zones of mineralization, their geological settings, and identifying new areas of interest.

The survey incorporated the use of a Hummingbird™ five-frequency electromagnetic system supplemented by a high-sensitivity caesium magnetometer, gamma-ray spectrometer and radar altimeter. A GPS navigation computer system with flight path indicators ensured accurate positioning of the geophysical data with respect to the World Geodetic System 1984 geodetic datum (WGS-84).

2. SURVEY SPECIFICATIONS

2.1 Airborne Survey Parameters

NGU used a Hummingbird™ electromagnetic and magnetic helicopter survey system designed to obtain low level, slow speed, detailed airborne magnetic and electromagnetic data (Geotech 1997). The system was supplemented by 1024 channel gamma-ray spectrometer which was used to map ground concentrations of U, Th and K.

The airborne survey began on July 31th and suspended on August 19th, 2012. The survey was continued from August 9th to August 23rd, 2013. A helicopter AS350-B2 (B3 in 2013) from the company HeliScan AS was used to tow the bird. The main part of the survey was flown with 200 m line spacing and lines were oriented at a 55° azimuth in UTM zone 33 W coordinates. The northern part of the survey area was flown with 200 m line spacing and line orientation at 145° due to the extreme rugged terrain. The area around the Skaland and the Trælen graphite mines was flown with 100 m line spacing and line oriented at 125°-160° azimuth. This part of the survey was partly financed by *Skaland Graphite as* and previously reported (Rønning et al. 2012). The line paths at the Senja survey is shown in figure 3. In the central part of Senja, no measurements were performed because of restrictions from a reindeer owner.

The magnetic and electromagnetic sensors are housed in a single 7.5 m long bird, which was maintained at an average of 60 m above the topographic surface. A gamma-ray spectrometer installed under the belly of the helicopter registered natural gamma ray radiation simultaneously with the acquisition of magnetic/EM data.

Extreme rugged terrain and abrupt changes in topography affected the aircraft pilot’s ability to ‘drape’ the terrain; therefore the average instrumental height was much higher than the standard survey instrumental height, which is defined as 30 m plus a height of obstacles (trees, power lines etc.).

The ground speed of the aircraft varied from 50 – 130 km/h depending on topography, wind direction and its magnitude. On average the ground speed during measurements is calculated to 65 km/h. Magnetic data were recorded at 0.2 second intervals resulting in approximately 4 m observation point spacing. EM data were recorded at 0.1 second intervals resulting in data with a sample increment of ~2 m along the ground in average. Spectrometry data were recorded every 1 second giving a point spacing of approximately 18 meter. The above parameters are sufficient to obtain details in the data to detect subtle anomalies that may represent mineralization and/or rocks of different lithological and petrophysical composition.

The base magnetometers to monitor diurnal variations in the magnetic field, was located at Finnsnes just ouside the measured area for the eastern part of the survey and at Skaland inside the measured area for the western part. Two magnetometers were used as magnetic base stations. Scintrex Envi-Mag recorded every 3 second was used during 2012 year survey. Gem GSM-19 station magnetometer was used during 2013 year survey and its data were recorded once every 1 second. The CPU clock of the base magnetometer computer was synchronized to the CPU clock of the DAS on a daily basis.

Navigation system uses GPS/GLONASS satellite tracking systems to provide real-time WGS-84 coordinate locations for every second. The accuracy achieved with no differential corrections is reported to be ± 5 m in the horizontal directions. The GPS receiver antenna was mounted externally to the tail tip of the helicopter.

For quality control, the electromagnetic, magnetic and radiometric, altitude and navigation data were monitored on four separate windows in the operator's display during flight while they were recorded in three data ASCII streams to the PC hard disk drive.

2.2 Airborne Survey Instrumentation

Instrument specification is given in Table 1. Frequencies and coil configuration for the Hummingbird EM system is given in Table 2.

Table 1. Instrument Specifications

Instrument	Producer/Model	Accuracy	Sampling frequency/interval
Magnetometer	Scintrex Cs-2	0,002 nT	5 Hz
Base magnetometer	Scintrex Envi GEM GSM-19	0.1 nT 0.1 nT	3 sec (2012) 1 sec (2013)
Electromagnetic	Geotech Hummingbird	1 – 2 ppm	10 Hz
Gamma spectrometer	Radiation Solutions RSX-5	1024 ch's, 16 liters down, 4 liters up	1 Hz
Radar altimeter	Bendix/King KRA 405B	± 3 % 0 – 500 feet ± 5 % 500–2500 feet	1 Hz
Pressure/temperature	Honeywell PPT	± 0,03 % FS	1 Hz
Navigation	Topcon GPS-receiver	± 5 meter	1 Hz
Acquisition system	NGU in house software		

Table 2. Hummingbird electromagnetic system, frequency and coil configurations

Coils:	Frequency	Orientation	Separation
A	7700 Hz	Coaxial	6.20 m
B	6600 Hz	Coplanar	6.20 m
C	980 Hz	Coaxial	6.025 m
D	880 Hz	Coplanar	6.025 m
E	34000 Hz	Coplanar	4.87 m

The electromagnetic, magnetic and radiometric, altitude and navigation data were monitored on the operator's displays during flight while they were recorded to the PC hard disk drive. Spectrometry data were also recorded to internal hard drive of the spectrometer. The data files were transferred to the field workstation via USB flash drive. The raw data files were backed up onto USB flash drive in the field.

2.3 Airborne Survey Logistics Summary

Traverse (survey) line spacing:	200 metres
Traverse line spacing (Northern part):	100 and 200m
Traverse line direction (Southern part):	55° SE-NW
Traverse line direction (Northern part):	125°-160° NW-SE
Nominal aircraft ground speed:	50 - 130 km/h
Average sensor terrain clearance EM+Mag:	60 metres
Average sensor terrain clearance Rad:	90 metres
Sampling rates:	0.2 seconds - magnetometer
	0.1 seconds - electromagnetics
	1.0 second - spectrometer, GPS, altimeter

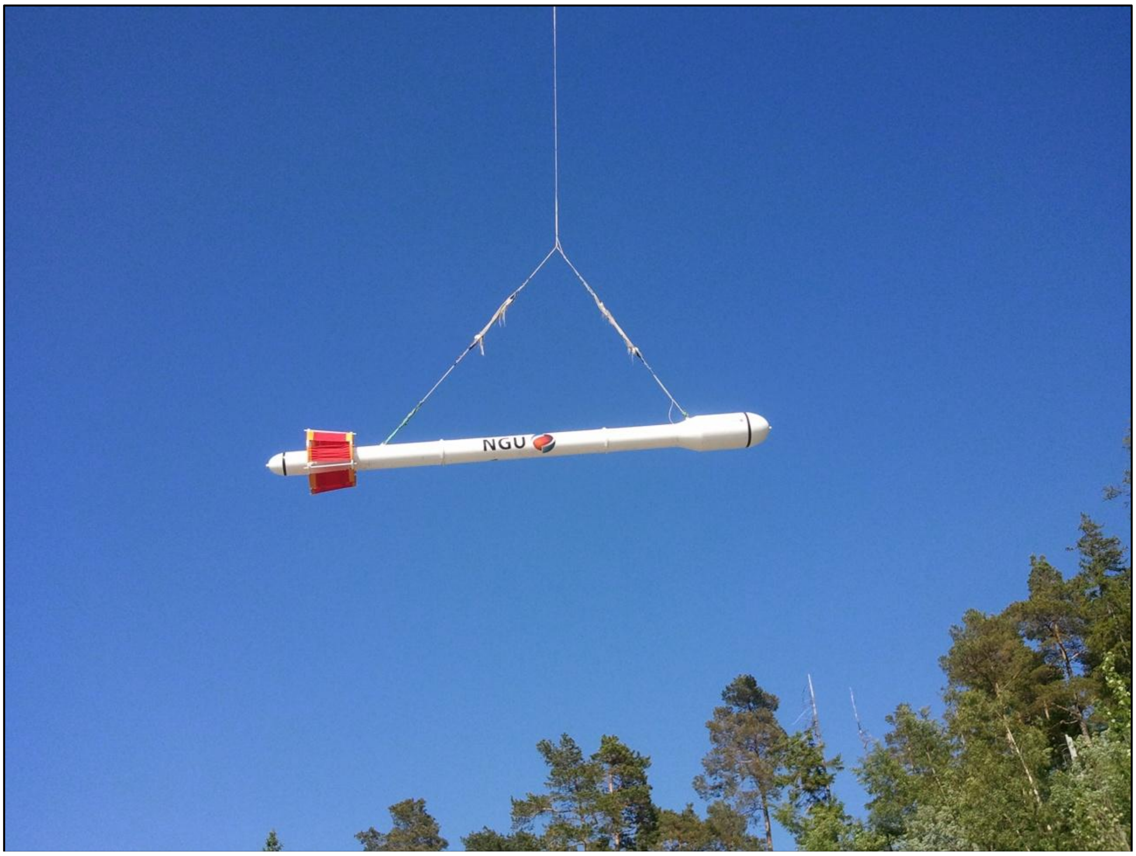

Figure 2: Hummingbird system in air

3. DATA PROCESSING AND PRESENTATION

All data were processed by Alexei Rodionov (AR Geoconsulting Ltd., Canada) in Calgary. The ASCII data files were loaded into three separate Oasis Montaj databases. All three datasets were processed consequently according to processing flow charts shown in Appendix A1, A2 and A3.

3.1 Total Field Magnetic Data

At the first stage the magnetic data were visually inspected and spikes were removed manually. Non-linear filter was also applied to airborne raw data to eliminate short-period spikes. Then the data from basemag station were imported in magnetic database using the standard Oasis magbase.gx module. Diurnal variation channel was also inspected for spikes and these were removed manually if necessary. Typically, several corrections have to be applied to magnetic data before gridding - heading correction, lag correction and diurnal correction.

Diurnal Corrections

The temporal fluctuations in the magnetic field of the earth affect the total magnetic field readings recorded during the airborne survey. This is commonly referred to as the magnetic diurnal variation. These fluctuations can be effectively removed from the airborne magnetic dataset by using a stationary reference magnetometer that records the magnetic field of the earth simultaneously with the airborne sensor. Magnetic diurnals were within the standard NGU specifications during the entire survey (Rønning 2013).

Diurnal variations were measured with GEM GSM-19 and Scintrex Envi magnetometers. The base station computer clock was synchronized with the DAS clock on a daily basis. The recorded data are merged with the airborne data and the diurnal correction is applied according to equation (1).

$$\mathbf{B}_{Tc} = \mathbf{B}_T + \left(\overline{B}_B - \mathbf{B}_B\right), \qquad (1)$$

Where:

$\mathbf{B}_{Tc}$ = Corrected airborne total field readings

$\mathbf{B}_T$ = Airborne total field readings

$\overline{B}_B$ = Average datum base level

$\mathbf{B}_B$ = Base station readings

Corrections for Lag and heading

Neither a lag nor cloverleaf tests were performed before the survey. According to previous reports the lag between logged magnetic data and the corresponding navigational data was 1-2 fids. Translated to a distance it would be no more than 5-7 m - the value comparable with the precision of GPS. A heading error for a towed system is usually either very small or non-existent. So no lag and heading corrections were applied.

Magnetic data gridding and presentation

Before gridding, flight data were split by lines. For the purposes of data presentation and interpretation the total field magnetic data are gridded with a cell size of 50 m, which represents one quarter of the 200 m average line spacing. A micro levelling technique was applied to the magnetic data to remove small line-to-line levelling errors and 3x3 convolution filter was passed over the final grid to smooth the grid image.

Note. Part of magnetic data from flight 36, lines 1870-1940 (South-west of Skaland, see lack of data in resistivity maps) was lost due to problems with bird electronics and data were interpolated.

The Vertical Gradient and the Tilt Derivative of the total magnetic field was calculated from the resulting total magnetic field map. These signals transform the shape of the magnetic anomaly from any magnetic inclination to positive body-centred anomaly and it's widely utilized for mapping of structures.

3.2 Electromagnetic Data

The DAS computer records both an in-phase and a quadrature value for each of the five coil sets of the electromagnetic system. Instrumental noise and drift should be removed before computation of an apparent resistivity.

Instrumental noise

In-phase and quadrature data were filtered with 3-5 fids non-linear filter to eliminate spheric spikes which were represented as irregular spikes of large amplitude in records. Simultaneously, the 90-120 fids low-pass filter was also applied to suppress instrumental and cultural noise. Due to problems in electronics of EM system in 2013, the internal noise was higher than standard 1-2 ppm and reached 3-5 ppm on 880, 980, 6600 HZ in-phase and quadrature data and up to 15 ppm on 34000 Hz . Low pass filter was not able to supress the noise completely due to irregular nature of noise and the quality of data is suffered partly from low signal/noise ratio. Due to this, 880 Hz In phase component of the EM data is not presented in the published data.

Instrument Drift

In order to remove the effects of instrument drift caused by gradual temperature variations in the transmitting and receiving circuits, background responses are recorded during each flight. To obtain a background level the bird is raised to an altitude of approximately 1200 ft above the topographic surface so that no electromagnetic responses from the ground are present in the recorded traces. The EM traces observed at this altitude correspond to a background (zero) level of the system. If these background levels are recorded at 20-30 minute intervals, then the drift of the system (assumed to be linear) can be removed from the data by resetting these points to the initial zero level of the system. The drift must be removed on a flight-by-flight basis, before any further processing is carried out. Geosoft HEM module was used for applying drift correction. Residual instrumental drift, usually small, but often non-linear, was manually removed on line-to-line basis.

Apparent resistivity calculation and presentation

When levelling of the EM data was complete, apparent resistivity was calculated from in-phase and quadrature EM components using a homogeneous half space model of the Earth (Geosoft HEM module). Due to the low signal to noise level for the 880 Hz In phase component, resistivity for this frequency was calculated from the quadrature component only. Threshold of 3 ppm was set for inversion of 34000 Hz data, 2 ppm for 6600, 7000, 880 and 1 ppm for 980 Hz. Due to low signal/noise ratio, the resolution of EM survey in high resistivity area was also very low that is especially noticeable on 880 and 980 Hz resistivity maps.

Secondary electromagnetic field decays rapidly with the distance (height of the sensors) – as $z^{-2} - z^{-5}$ depending on the shape of the conductors and, at certain height, signals from the ground sources become comparable with instrumental noise. Levelling errors or precision of levelling can lead sometimes to appearance of artificial resistivity anomalies when data were collected at high instrumental altitude. Application of threshold allows excluding such data from an apparent resistivity calculation, though not completely. It's particularly noticeable in low frequencies datasets. Resistivity data were visually inspected; artificial anomalies associated with high altitude measurements were manually removed.

Data, recorded at the height above 100 m (90 m for 980 Hz) in resistive areas, were considered as non-reliable and removed from gridding. Remaining resistivity data were gridded with a cell size 50 m and 3x3 convolution filter was applied to smooth resistivity grids.

Note. Part of EM data from flight 36, lines 1910-1940 (in the western part of the surveyed area) are absent due to problems with bird electronics.

3.3 Radiometric data

In processing of the airborne gamma ray spectrometry data, live time corrected U, Th and K were corrected for the aircraft and cosmic background (e.g. Grasty et al. 1991; IAEA 2003). The upward detector method, as discussed in IAEA (2003), was applied to remove the effects of radon in the air below and around the helicopter. Window stripping was used to isolate count rates from the individual radio-nuclides K, U and Th (IAEA, 2003). The topography in the region was rough, and the sensor was not always at a constant altitude. Stripped window counts were therefore corrected for variations in flying height to a constant height of 60 m. Data, recorded at the height above 150 m were considered as non-reliable and removed from processing. Finally, count rates were converted to effective ground element concentrations using calibration values derived from calibration pads at the Geological Survey of Norway in Trondheim. A list of the parameters used in the processing scheme is given in Appendix A3. For further reading regarding standard processing of airborne radiometric data, we recommend the publication from Minty et al. (1997).

Quality of the radiometric data was within standard NGU specifications (Rønning 2013) except for a few short line segments where data were lost due to lack of GPS-signal.

4. PRODUCTS

Processed digital data from the survey are presented as:

1. Three Geosoft XYZ files:
   Senja_Mag.xyz, Senja_EM.xyz, Senja_Rad.xyz

2. Coloured maps (jpg) at the scale 1:50000 available from NGU on request.

3. Georeferenced tiff-files (Geo-Tiff).

Table 3: Maps in scale 1:50000 available from NGU on request.

Map #	Name
2013.047-01	Total magnetic field
2013.047-02	Magnetic Vertical Derivative
2013.047-03	Magnetic Tilt Derivative
2013.047-04	Apparent resistivity, Frequency 34000 Hz, coplanar coils
2013.047-05	Apparent resistivity, Frequency 6600 Hz, coplanar coils
2013.047-06	Apparent resistivity, Frequency 880 Hz, coplanar coils
2013.047-07	Apparent resistivity, Frequency 7000 Hz, coaxial coils
2013.047-08	Apparent resistivity, Frequency 980 Hz, coaxial coils
2013.047-09	Uranium ground concentration
2013.047-10	Thorium ground concentration
2013.047-11	Potassium ground concentration
2013.047-12	Radiometric Ternary Map

Downscaled images of the maps are shown on figures 4 to 15. Data and maps are available from www.ngu.no.

5. REFERENCES

Geotech 1997: Hummingbird Electromagnetic System. User manual. Geotech Ltd. October 1997

Grasty, R.L., Holman, P.B. & Blanchard 1991: Transportable Calibration pads for ground and airborne Gamma-ray Spectrometers. Geological Survey of Canada. Paper 90-23. 62 pp.

IAEA 2003: Guidelines for radioelement mapping using gamma ray spectrometry data. IAEA-TECDOC-1363, Vienna, Austria. 173 pp.

Minty, B.R.S., Luyendyk, A.P.J. and Brodie, R.C. 1997: Calibration and data processing for gamma-ray spectrometry. AGSO – Journal of Australian Geology & Geophysics. 17(2). 51-62.

Naudy, H. and Dreyer, H. 1968: Non-linear filtering applied to aeromagnetic profiles. Geophysical Prospecting. 16(2). 171-178.

Rønning, J.S., Rodionov, A., Ofstad, F. & Lynum, R. 2012: Elektromagnetiske, magnetiske, og radiometriske målinger fra helikopter i området Skaland - Trælen på Senja. NGU Rapport 2012.061 (30pp, In Norwegian).

Rønning, J.S. 2013: NGUs helikoptermålinger. Plan for sikring og kontroll av datakvalitet. NGU Intern rapport 2013.001, (38 sider).

Appendix A1: Flow chart of magnetic processing

Meaning of parameters is described in the referenced literature.

Processing flow:

- Quality control.
- Visual inspection of airborne data and manual spike removal
- Import magbase data to Geosoft database
- Inspection of magbase data and removal of spikes
- Correction of data for diurnal variation
- Splitting flight data by lines
- Gridding
- Microlevelling
- 3x3 convolution filter

Appendix A2: Flow chart of EM processing

Meaning of parameters is described in the referenced literature.

Processing flow:

- Filtering of in-phase and quadrature channels with low pass filters
- Automated leveling
- Quality control
- Visual inspection of data.
- Splitting flight data by lines
- Manual removal of remaining part of instrumental drift
- Calculation of an apparent resistivity using both - in-phase and quadrature channels
- Gridding
- 3x3 convolution filter

Appendix A3: Flow chart of radiometry processing

Underlined processing stages are not only applied to the K, U and Th window, but also to the total.
Meaning of parameters is described in the referenced literature.

Processing flow:

- Quality control
- Airborne and cosmic correction (IAEA, 2003)
  Used parameters: (determined by high altitude calibration flights near Langoya in July 2013)

  Aircraft background counts:

K window	7
U window	0.9
Th window	0.9
Uup window	0
Total counts	36

  Cosmic background counts (normalized to unit counts in the cosmic window):

K window	0.0617
U window	0.0454
Uup window	0.0423
Th window	0.0647
Total counts	1.0379

- Radon correction using upward detector method (IAEA, 2003)
  Used parameters (determined from survey data over water and land):

a_u: 0.3048	$b_{u:}$ 0.5941
a_K:0.9525	b_K: 2.2398
a_T: 0.0635	b_T: 0.2371
$a_{Tc:}$ 16.119	$b_{Tc:}$ 8.0586
a_1: 0.01320	a_2: 0.05054

- Stripping correction (IAEA, 2003)
  Used parameters (determined from measurements on calibrations pads at the NGU on May 6 2013):

a	0.049524
b	-0.00169
g	-0.00131
alpha	0.29698
beta	0.47138
gamma	0.82905

- <u>Height correction to a height of 60 m</u>
  Used parameters (determined by high altitude calibration flights near Langoya in July 2013):
  Attenuation factors in 1/m:

  K: -0.001634
  U: -0.00777
  Th: -0.0088
  Total counts: -0.01148

- Converting counts at 60 m heights to element concentration on the ground
  Used parameters (determined from measurements on calibrations pads at the NGU on May 6 2013):
  Sensitivity (elements concentrations per count)::

  K: 0.007545 %/counts
  U: 0.088909 ppm/counts
  Th: 0.151433 ppm/counts

- <u>Microlevelling using Geosoft menu and smoothening by a convolution filtering</u>
  Used parameters for microlevelling:

De-corrugation cutoff wavelength:	800 m
Cell size for gridding:	200 m
Naudy (1968) Filter length:	800 m

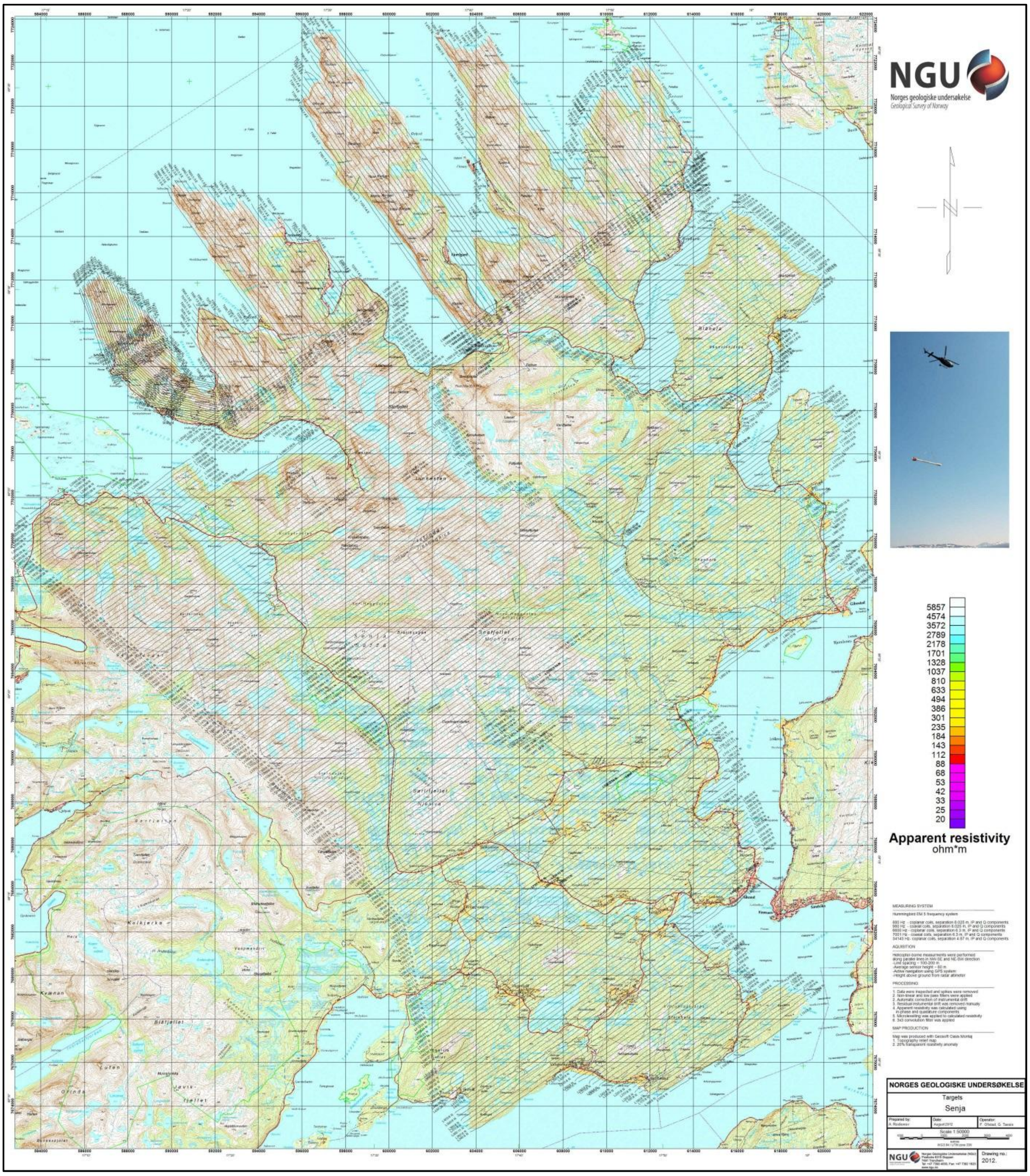

Figure 3: Senja survey area with flight path

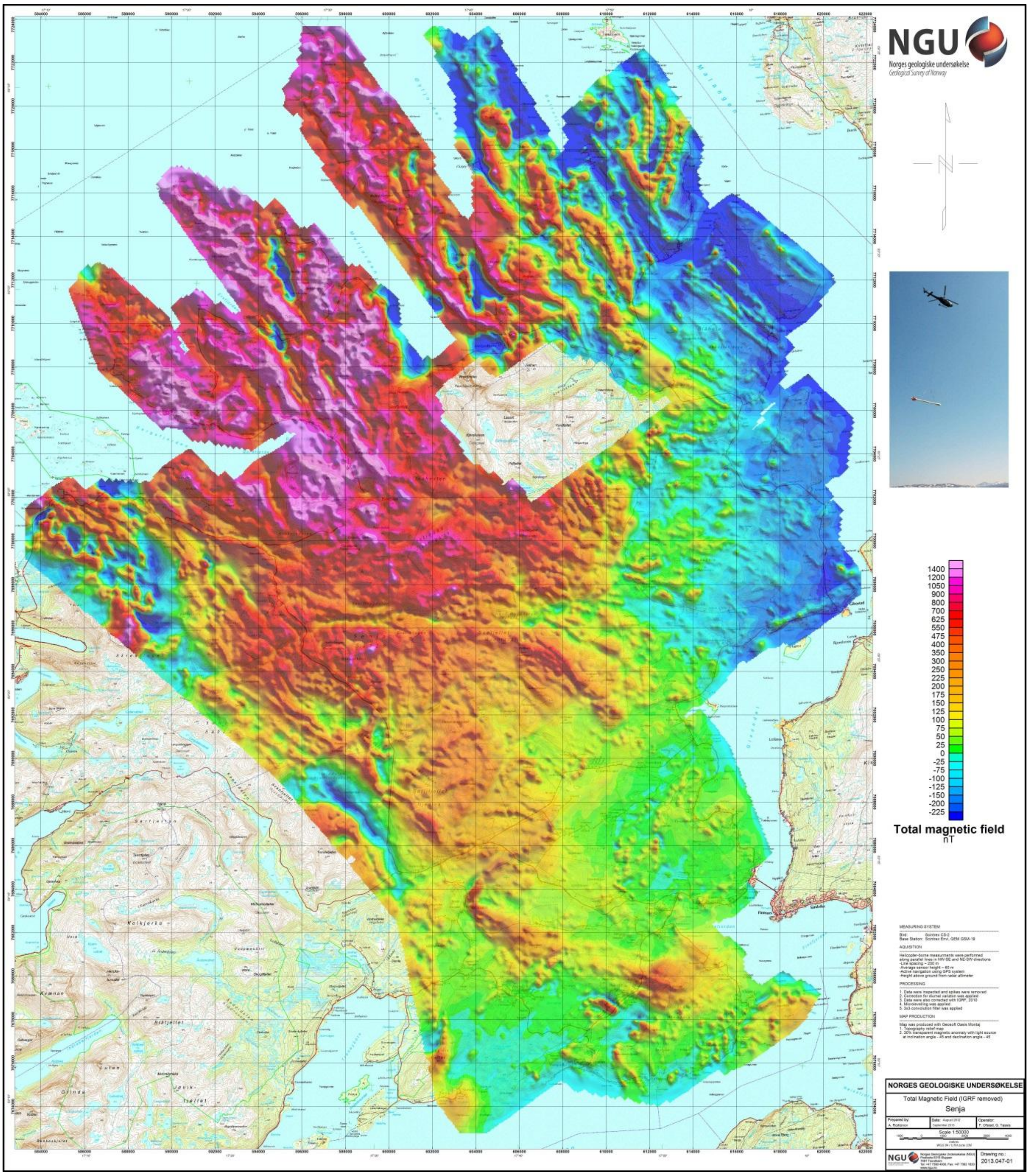

Figure 4: Total Magnetic Field

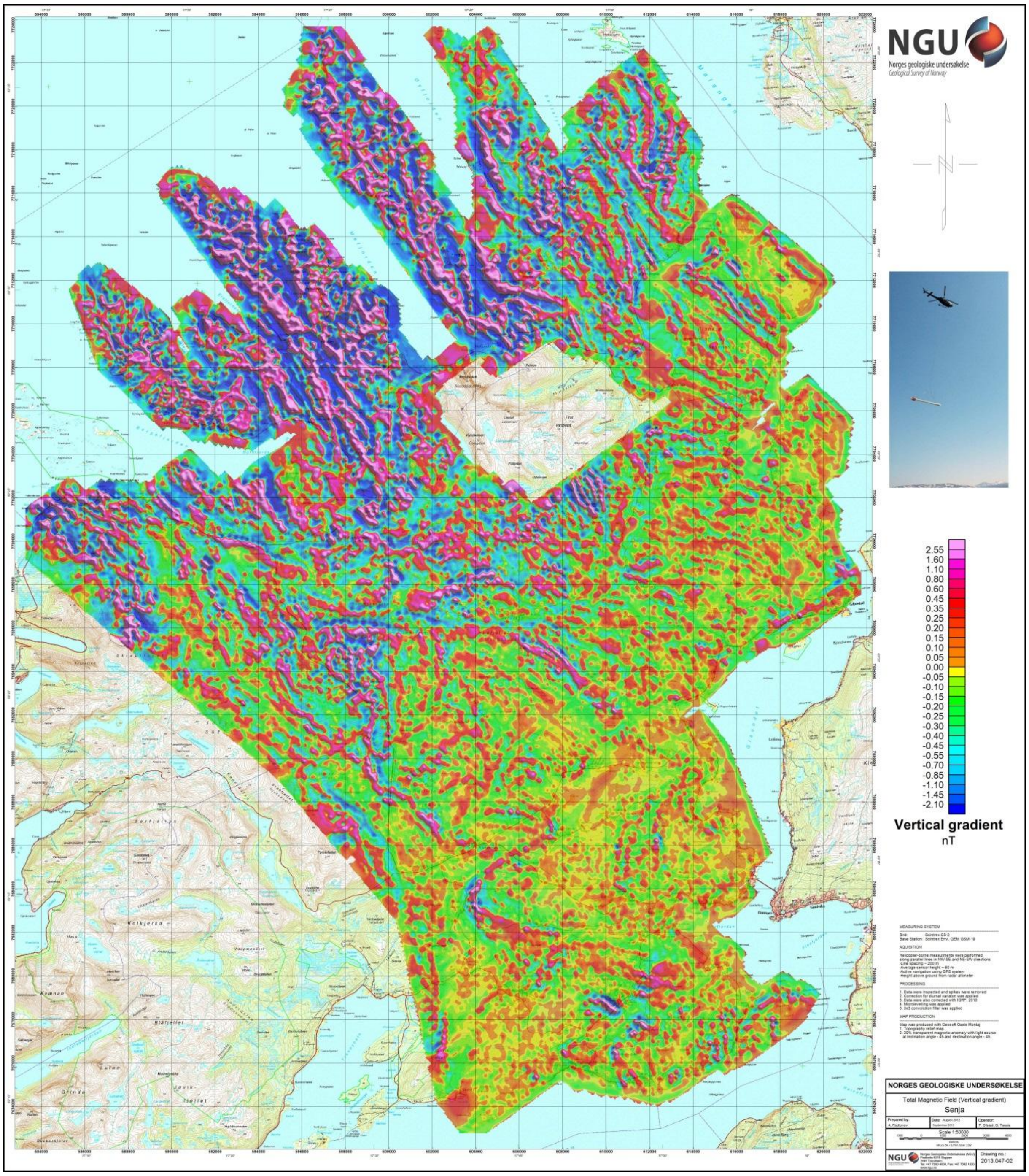

Figure 5: Magnetic Vertical Derivative

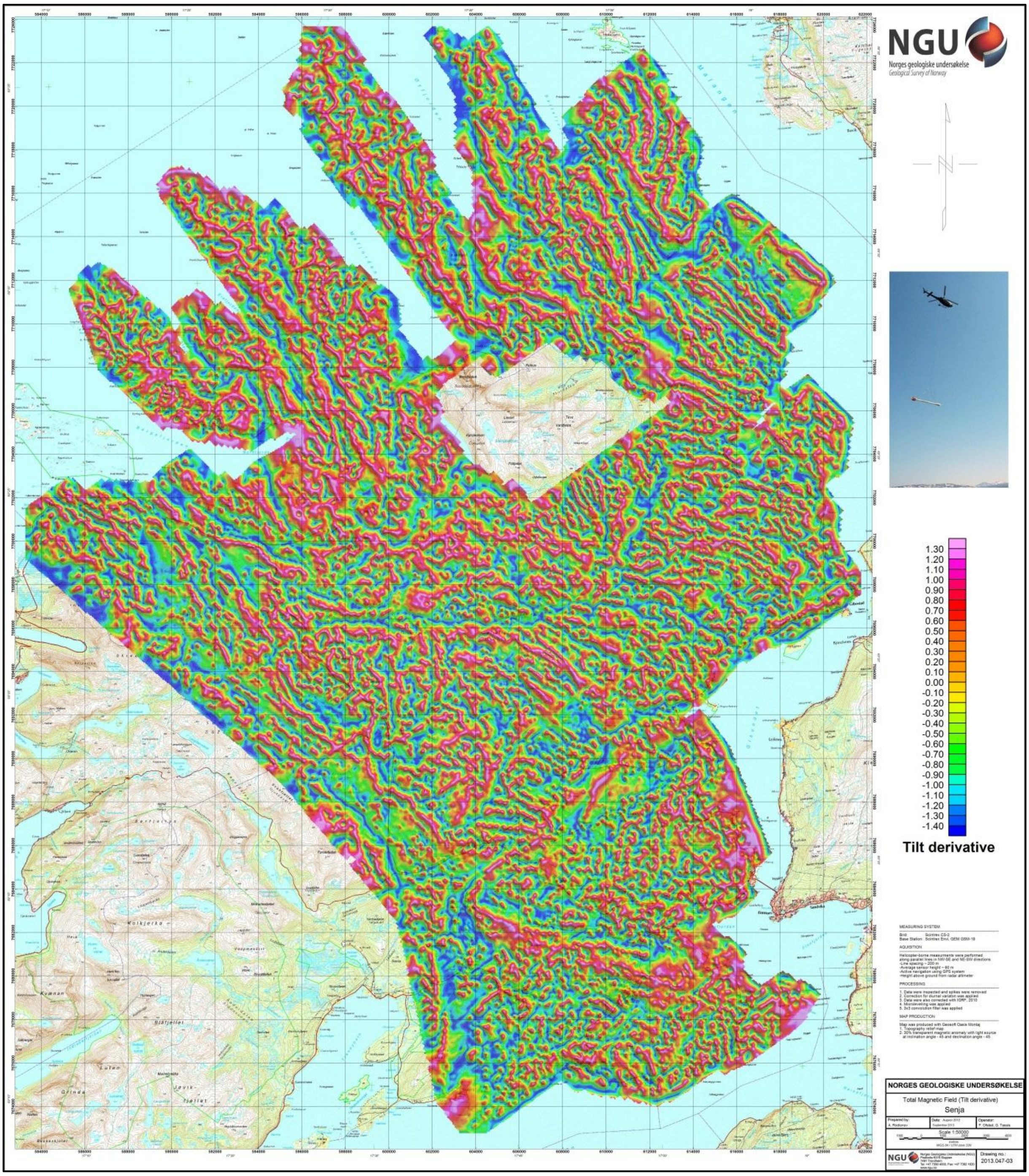

Figure 6: Magnetic Tilt Derivative

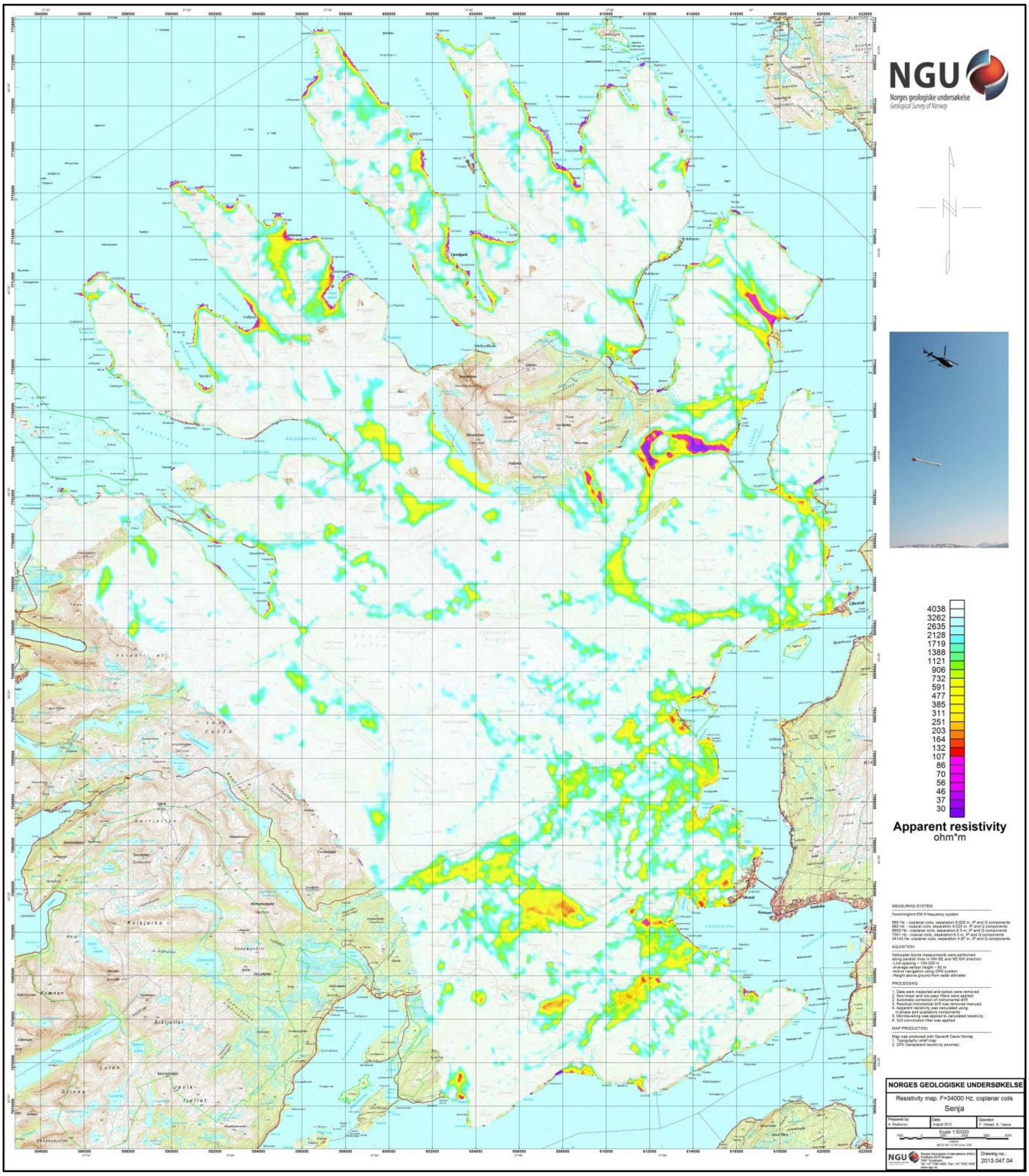

Figure 7: Apparent resistivity. Frequency 34000 Hz, Coplanar coils

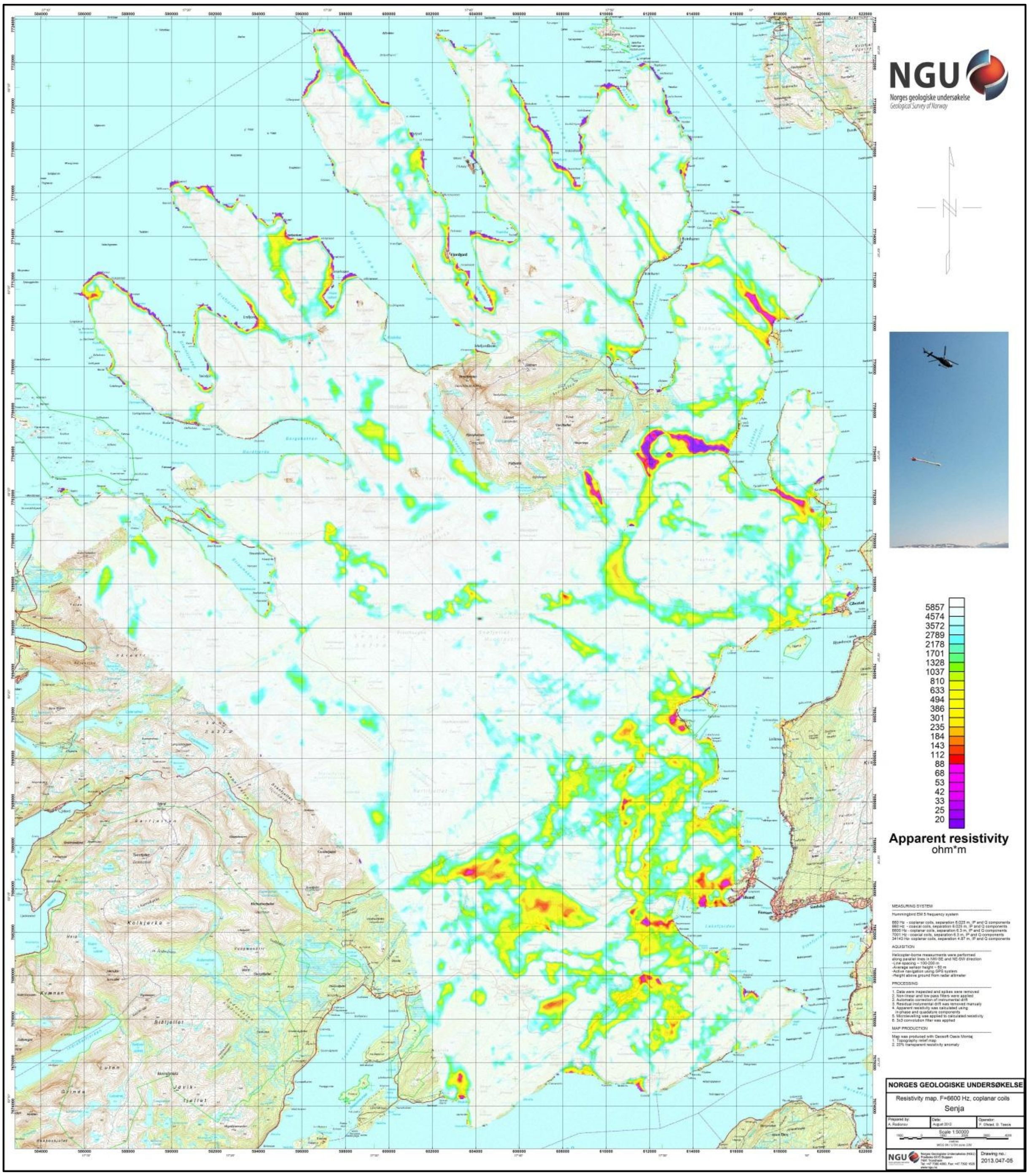

Figure 8: Apparent resistivity. Frequency 6600 Hz, Coplanar coils

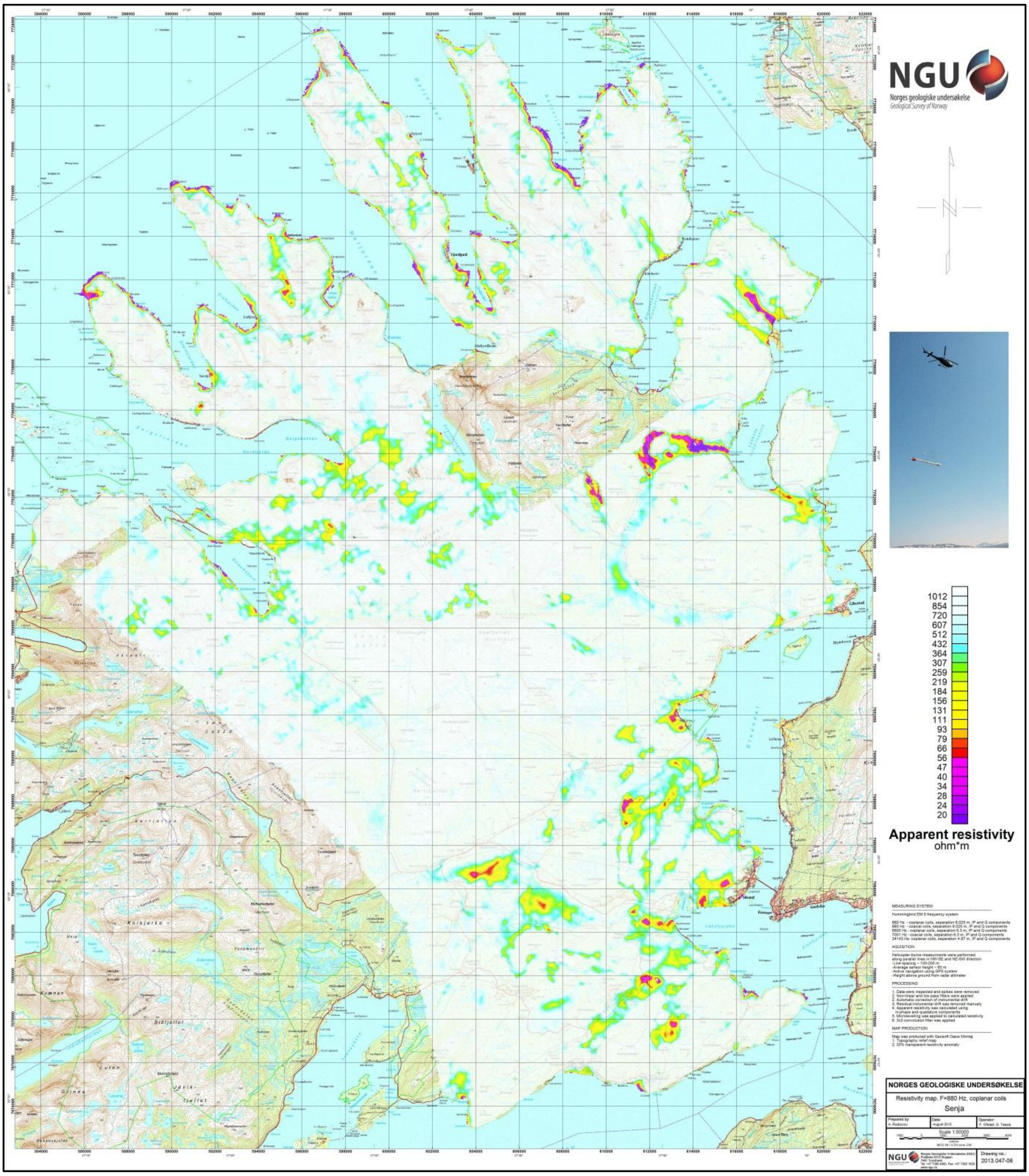

Figure 9: Apparent resistivity. Frequency 880 Hz, coplanar coils

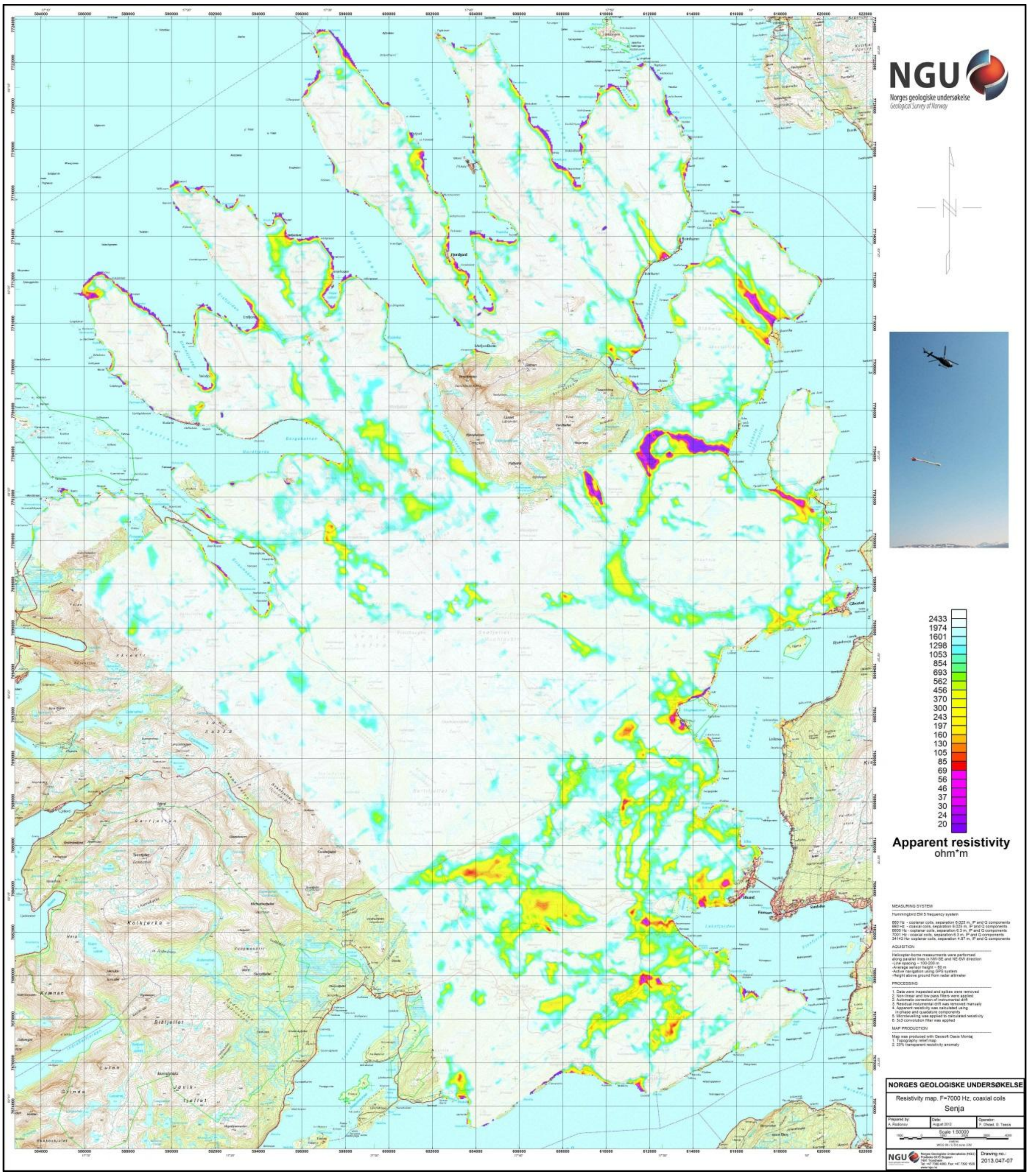

Figure 10: Apparent resistivity. Frequency 7000 Hz, Coaxial coils

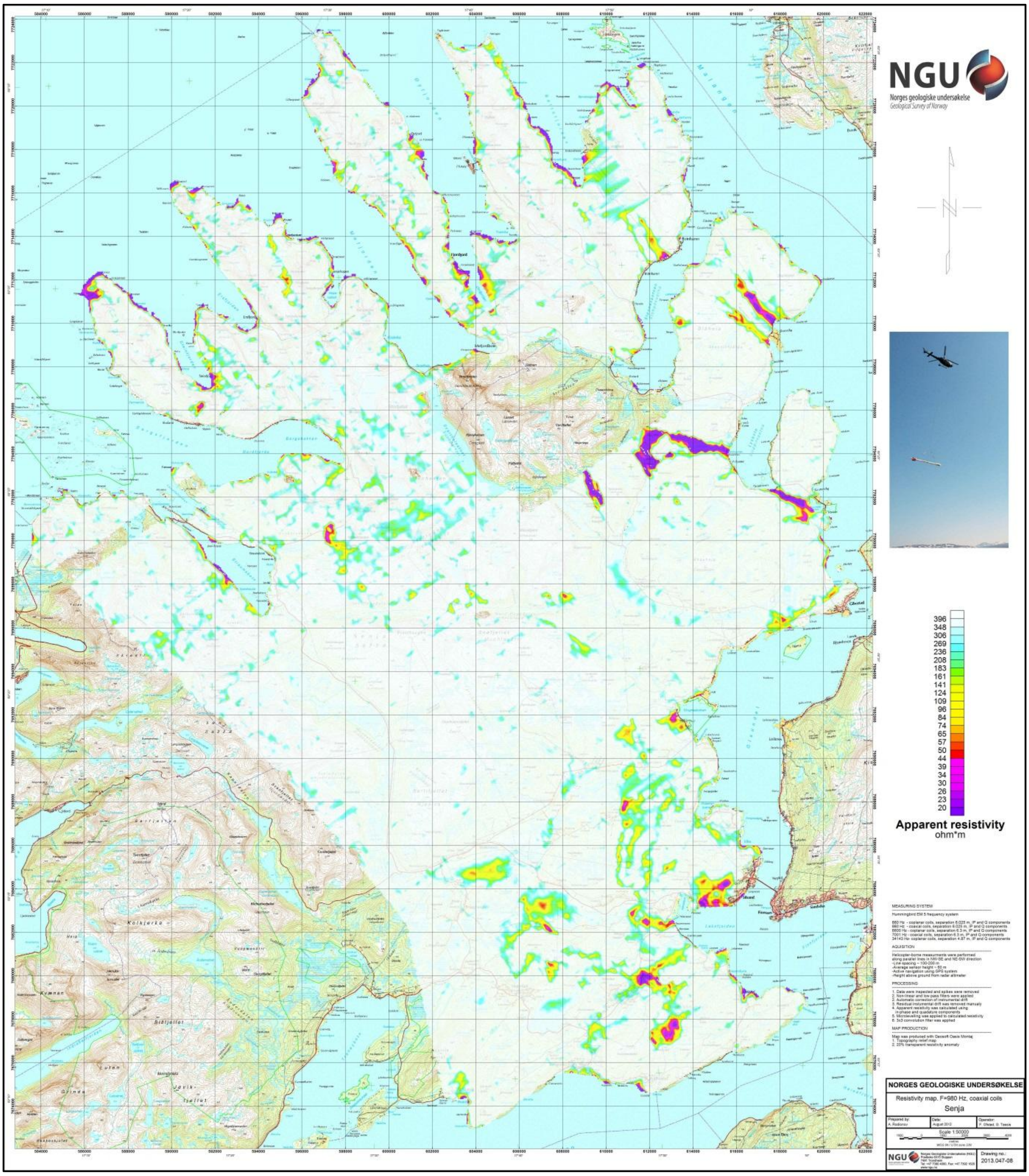

Figure 11: In-phase and quadrature responses. Frequency 980 Hz, Coaxial coils

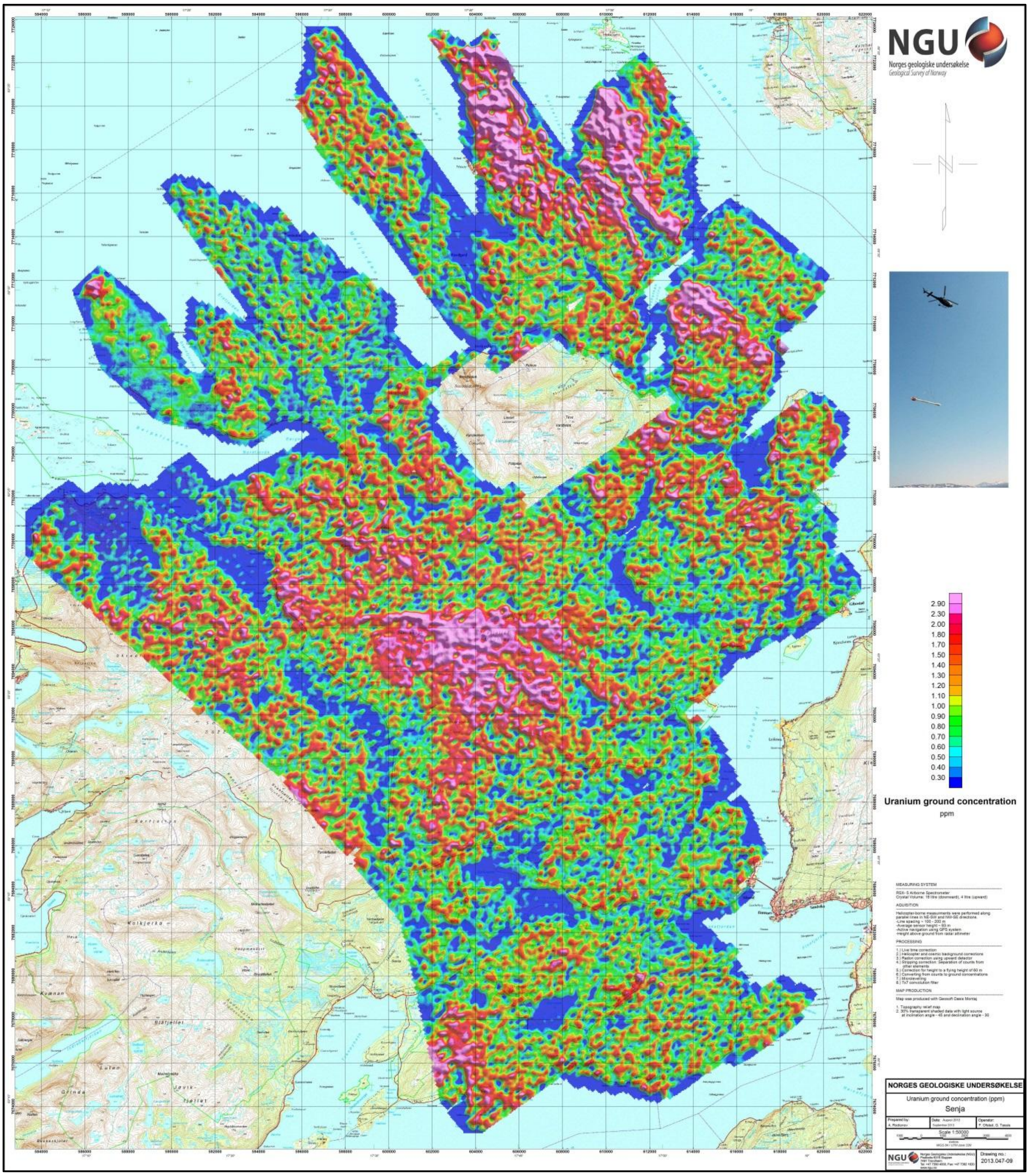

Figure 12: Uranium ground concentration

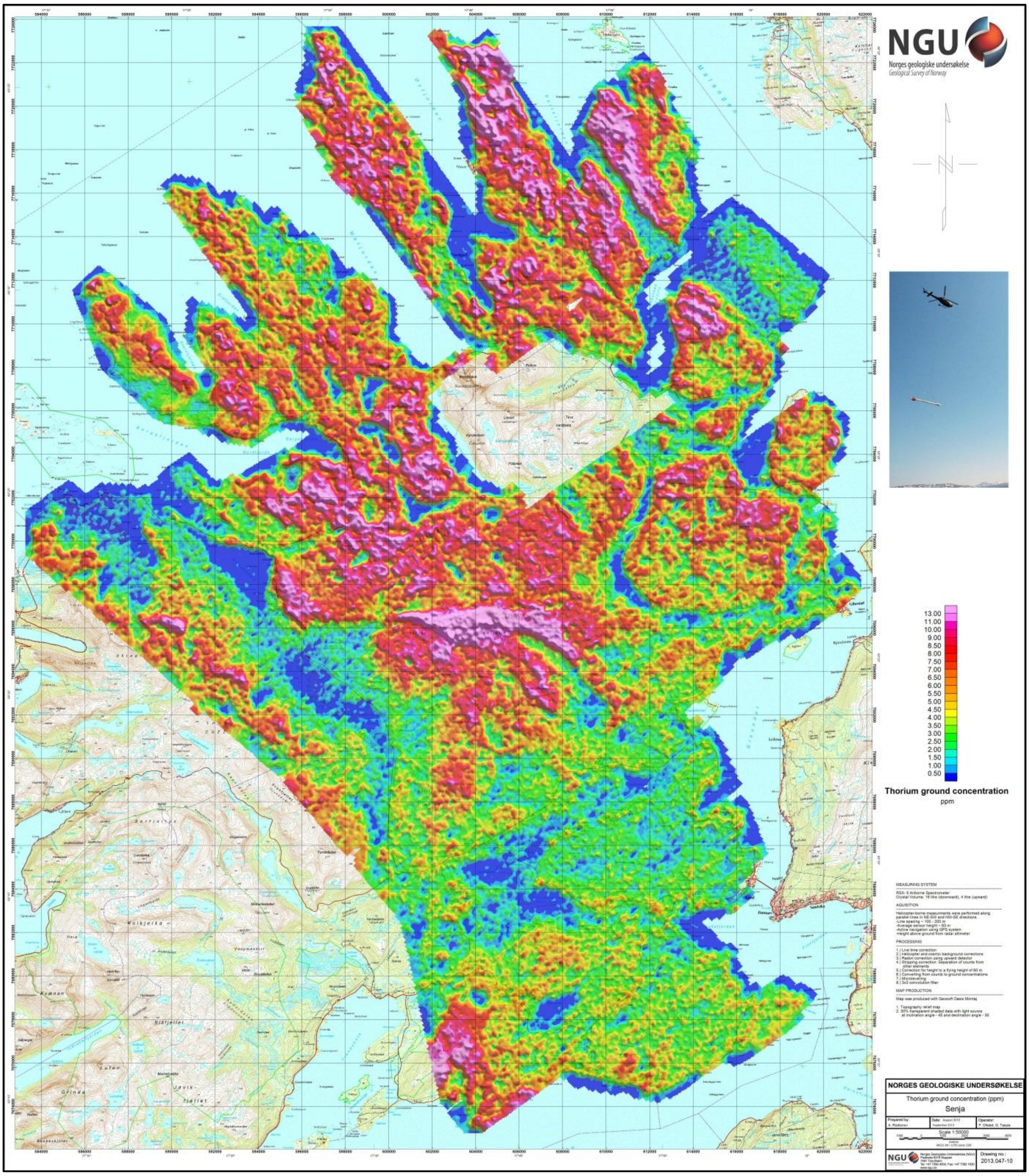

Figure 13: Thorium ground concentration

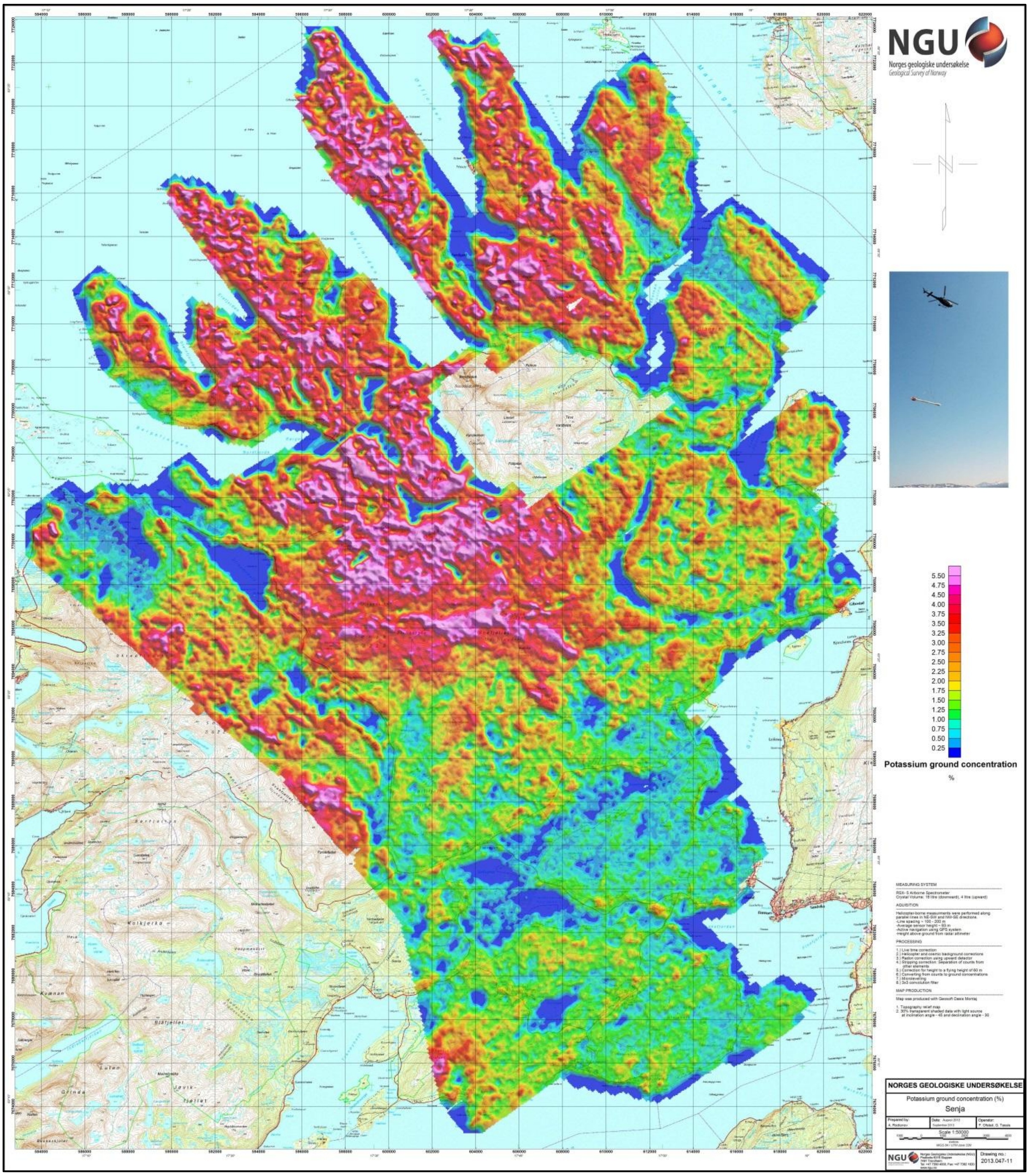

Figure 14: Potassium ground concentration

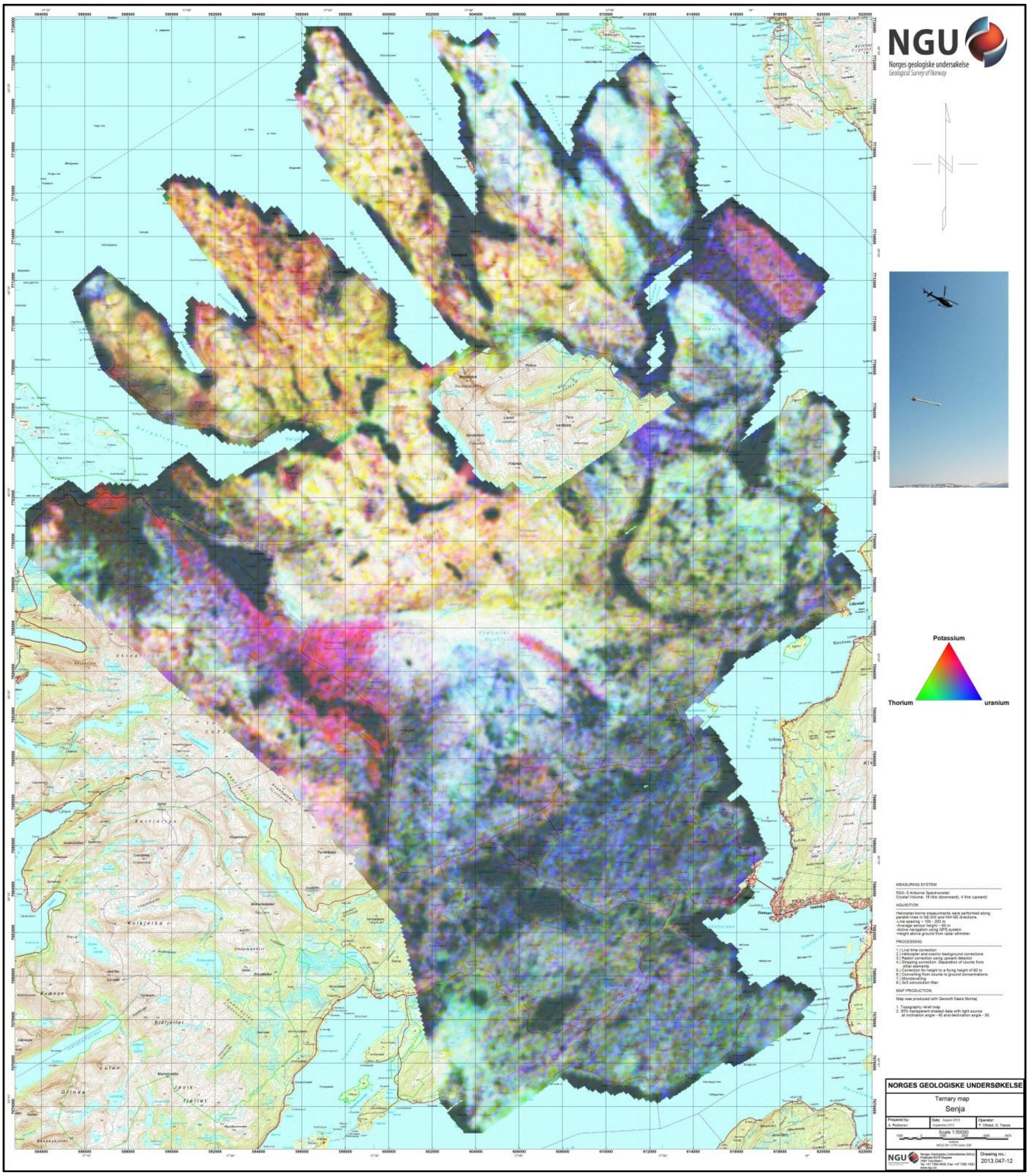

Figure 15: Radiometric Ternary map

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