NGU REPORT 2015.003

Helicopter-borne magnetic and radiometric geophysical survey in Dividalen, Målselv municipality, Troms county

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REPORT

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Title:
Helicopter-borne magnetic and radiometric geophysical survey in Dividalen, Målselv municipality, Troms County.

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NGU

County: Troms	**Municipality:** Målselv
Map-sheet name (M=1:250.000) NARVIK and TROMS	**Map-sheet no. and -name (M=1:50.000)** 1532 I Dividalen, 1533 II Tamokdalen
Deposit name and grid-reference: UTM 33W – 680000 E and 7650000 N	**Number of pages:** 25 **Price (NOK):** 80,- **Map enclosures:**

Fieldwork carried out: Sept 2013, Oct 2014	**Date of report:** February 20th 2015	**Project no.:** 342900	**Person responsible:** Jan S. Rønning

Summary:

NGU conducted an airborne magnetic and radiometric survey in the Dividalen area in September 2013 and October 2014 as a part of the MINN project (Mineral resources in Northern Norway).

This report describes and documents the acquisition, processing and visualization of recorded datasets. The geophysical survey results reported herein are 2014 line km, covering an area of 403 km^2.

A Scintrex CS-3 magnetometer in a towed bird and a 1024 channels RSX-5 spectrometer installed under the helicopter belly was used for data acquisition.

The survey was flown with 200 m line spacing, line direction 28^o (NNE to SSW) and average speed 83 km/h. The average terrain clearance was 75 m for the bird and 90 m for the spectrometer.

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.

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	Radiometric
		Technical Report

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1. INTRODUCTION

The government of Norway initiated in 2011 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 northernmost counties. The airborne geophysical surveys are part of MINN program.

The helicopter survey results reported herein amount to 2014 line km (403 km^2) over the Dividalen survey area, mainly in Målselv municipality, about 50 km east of Setermoen and Bardufoss, as shown in Figure 1.

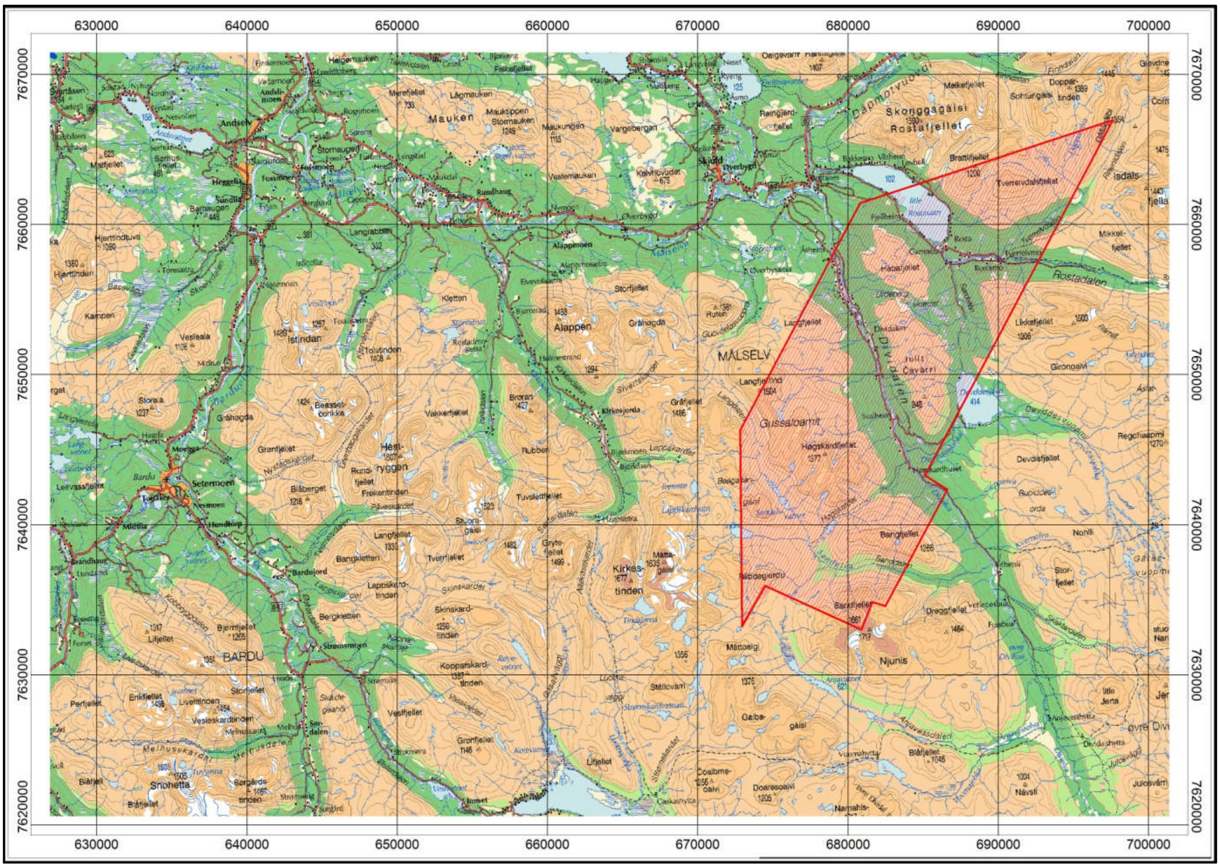

Figure 1: Dividalen survey area in Målselv municipality in Troms County.

The objective of the airborne geophysical survey was to obtain a dense high-resolution aero-magnetic and radiometric data set over the survey area. This data set 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 area. 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 high-sensitivity Cesium 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 helicopter survey system designed to obtain high detailed airborne magnetic data. The system was supplemented by one 1024 channel gamma-ray spectrometer with 16 litres downward and 4 litres upward crystal volume, which was used to map ground concentrations of Uranium, Thorium and Potassium.

The survey started September 23rd, and ended September 30th 2013, d.t weather conditions. One additional flight was made October 6th 2014 to complete the area. A Eurocopter AS350-B2 from HeliScan AS was used during the survey (Figure 2). The survey lines were spaced 200 m apart, and oriented at a 28° azimuth in UTM zone 33W. Instrument operation was performed by Heliscan employees.

The magnetic sensor was housed in a single 1.8 meters long bird, which was flown at a constant altitude above the topographic surface. The Radiation Solutions RSX-5 gamma-ray spectrometer was installed under the belly of the helicopter, registering natural gamma ray radiation simultaneously with the acquisition of magnetic data.

Figure 2: Pilots with Mag bird in front of the helicopter used in survey. (P1)

Rugged terrain and abrupt changes in topography affected the pilot's ability to 'drape' the terrain; therefore there are positive and negative variations in sensor height with respect to the standard height, which is defined as 60 m plus a height of obstacles (trees, power lines). The average survey height for the magnetometer was 75 m, and 90 m for the spectrometer.

The ground speed of the aircraft varied from 60 – 120 km/h depending on topography, wind direction and its magnitude. On average the ground speed during the whole survey was calculated to 83 km/h. Magnetic data were recorded at 0.2 second intervals resulting in approximately 4.6 meters point spacing. Spectrometry data was recorded every 1 second giving an average point spacing of 23 meters.

A base magnetometer to monitor diurnal variations in the magnetic field was located at Jutulstad, 3 km south of Øverbygd, at UTM 33W: 7659800 N, 670350 E. For the last flight, the base magnetometer was positioned near Setermoen, at UTM 33W: 7641800 N, 636800 E. The GEM GSM-19 station magnetometer data were recorded once every 3 seconds. The CPU clock of the base magnetometer is synchronized to UTC time through the built-in GPS receiver.

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 cabin roof of the helicopter.

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

2.2 Airborne Survey Instrumentation

Table 1: Instrument Specifications

Instrument	Producer / Model	Accuracy / Sensitivity	Sampling freq / interval
Magnetometer	Scintrex Cs-3	2.5 nT / 0.002 nT	5 Hz
Base magnetometer	GEM GSM-19	0.1 nT	3 s
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 ft ± 5 % 500-2500 ft	1 Hz
Pressure/temperature	Honeywell PPT	± 0,03 % FS	1 Hz
Navigation	Topcon GPS-receiver	± 5 meter	1 Hz
Nav recording system	NGU custom software	0.01 m	1 Hz

The 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 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 direction:	28° NNE-SSW
Nominal aircraft ground speed:	60 - 120 km/h
Average sensor terrain clearance Mag:	75 metres
Average sensor terrain clearance Rad:	90 metres

3. DATA PROCESSING AND PRESENTATION

All data were processed by Frode Ofstad and Alexandros Stampolidis at NGU. The ASCII data files were loaded into separate Oasis Montaj databases. The datasets were processed consequently according to processing flow charts shown in Appendix A1 and A3.

3.1 Total Field Magnetic Data

At the first stage the magnetic data were visually inspected and spikes were removed manually. A two-fiducial lag filter and a non-linear filter were applied to eliminate short-period spikes. Then the data from basemag station were imported into the magnetic database. Diurnal variation channel was also inspected for spikes and spikes were removed manually. Typically, several corrections have to be applied to magnetic data before gridding – i.e. heading, lag and diurnal correction, in addition to a few special processing steps necessary for this survey.

Pendulum noise problems

The small wing area of the bird and the relative low flight speed during parts of the survey caused the bird to swing with a pendulum effect. The 15 m rope gave this pendulum motion a period time of about 7.5 seconds. The effect of the swinging motion was clearly visible in the magnetic data and made it necessary to apply a special filter in order to reduce the noise that was prominent in parts of the survey. This was achieved using a Matlab code developed by Alexandros Stampolidis. Please see description of this method in Appendix A2. This step was applied before the diurnal corrections described below.

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 a GEM GSM-19 base magnetometer. The base station computer clock was continuously synchronized with GPS time. 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

The average datum base level ($\overline{B}_B$) was set to 53800 nT for the 2013 part of the survey, and 53200 nT for the 2014 flight.

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 less than 10 m - the value comparable with the precision of GPS. A heading error for a towed system is usually either very small or non-existent.

Magnetic data processing, gridding and presentation

The total field magnetic anomaly data ($\mathbf{B}_{TA}$) were calculated from the diurnal corrected data ($\mathbf{B}_{Tc}$) after subtracting the IGRF for the surveyed area calculated for the data period (eq.2)

$$\mathbf{B}_{TA} = \mathbf{B}_{Tc} - IGRF \qquad (2)$$

The total field anomaly data were split in lines and then gridded using a minimum curvature method with a grid cell size of 50 meters. To remove small line-to-line levelling errors that were detected on the gridded magnetic anomaly data, the Geosoft Microlevelling technique was applied on the flight line based magnetic database. Then, the microlevelled channel was gridded using again a minimum curvature method with 50 m grid cell size.

The processing steps of magnetic data presented so far were performed on point basis. The following steps are performed on grid basis. The Horizontal and Vertical Gradient along with the Tilt Derivative of the total magnetic anomaly were calculated from the microlevelled total magnetic anomaly grid. The magnitude of the horizontal gradient was calculated according to equation (3)

$$HG = \sqrt{\left(\frac{\partial B_{TA}}{\partial x}\right)^2 + \left(\frac{\partial B_{TA}}{\partial y}\right)^2} \qquad (3)$$

where $\mathbf{B}_{TA}$ is the microlevelled field. The vertical gradient (VG) was calculated by applying a vertical derivative convolution filter to the microlevelled $\mathbf{B}_{TA}$ field. The Tilt Derivative (TD) was calculated according to the equation (4)

$$\text{TD} = \text{atan(VG/HG)} \qquad (4)$$

Magnetic data gridding and presentation

Before final gridding, a micro levelling technique was applied to the magnetic data to remove small line-to-line levelling errors and a convolution filter was passed over the final grid to smooth the grid image.

Vertical Gradient, Horizontal Gradient and Tilt Derivative of the total magnetic field were 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. A list of the produced maps is shown in Table 3.

3.2 Radiometric data

Airborne gamma-ray spectrometry measures the abundance of Potassium (K), Thorium (eTh), and Uranium (eU) in rocks and weathered materials by detecting gamma-rays emitted due to the natural radioelement decay of these elements. The data analysis method is based on the IAEA recommended method for U, Th and K (International Atomic Energy Agency, 1991). A short description of the individual processing steps of that methodology as adopted by NGU is given bellow.

Energy windows

The Gamma-ray spectra were initially reduced into standard energy windows corresponding to the individual radio-nuclides K, U and Th. Figure 3 shows an example of a Gamma-ray spectrum and the corresponding energy windows.

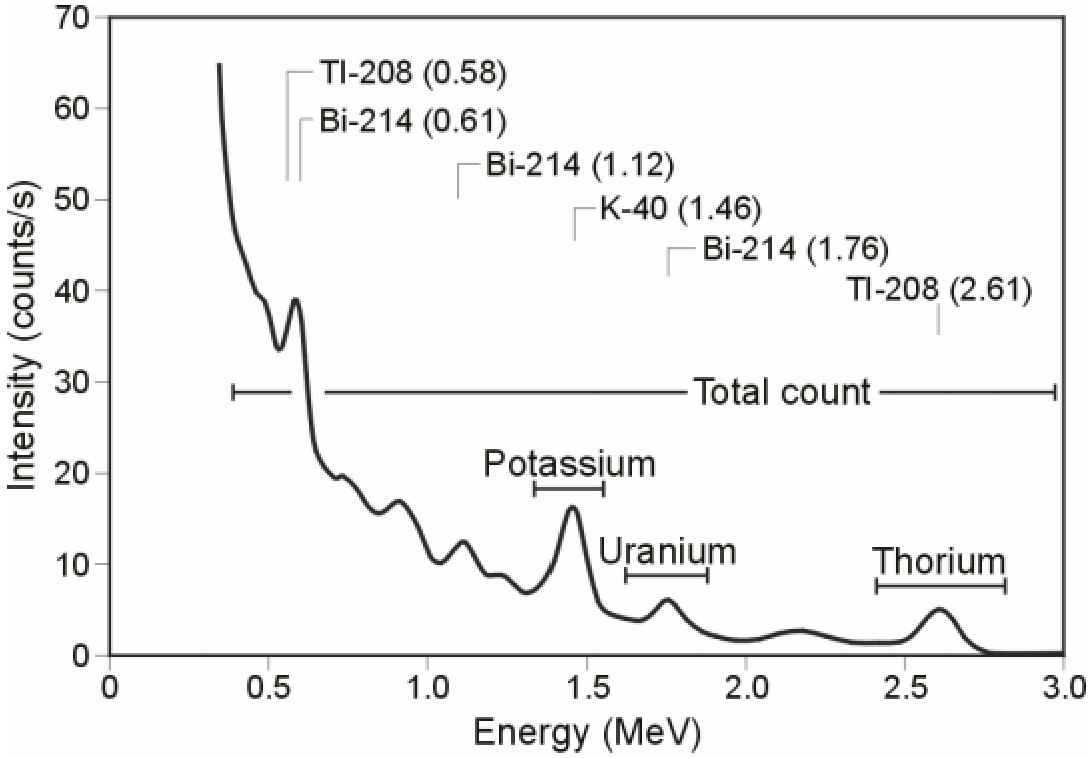

Figure 3: Gamma-ray spectrum with K, Th, U and Total count windows

The RSX-5 is a 1024 channel system with a four downward looking and one upward looking detector, with a total crystal volume of 16 liters downward and 4 liters upward for cosmic corrections. The Gamma-ray spectrum from 0 eV to over 3000 keV is divided into 1024 channels, where each channel has a 3.0 keV range. Table 2 shows the channels and energies that were used for the reduction of the spectrum.

Table 2: Specified channel windows for the RSX-5 system used in survey

Gamma-ray Spectrum	Cosmic	Total count	Potassium	Uranium	Thorium
Down	1022	134-934	454-521	551-617	801-934
Up	1022			551-617	
Energy, keV	>3000	407-2807	1367-1568	1658-1856	2408-2807
Peak, keV			1460	1765	2614
Peak channel			486	586	872

Live Time correction

The data were corrected for live time. “Live time” is an expression of the relative period of time the instrument was able to register new pulses per sample interval. On the other hand “dead time” is an expression of the relative period of time the system was unable to register new pulses per sample interval. The relation between “dead” and “live time” is given by the equation (5)

$$\text{“Live time”} = \text{“Real time”} - \text{“Dead time”} \qquad (5)$$

where the “real time” or “acquisition time” is the elapsed time over which the spectrum is accumulated.

The live time correction is applied to the total count, Potassium, Uranium, Thorium, upward Uranium and cosmic channels. The formula used to apply the correction is as follows:

$$C_{LT} = C_{RAW} \cdot \frac{1000000}{Live\ Time} \qquad (6)$$

where C_{LT} is the live time corrected channel in counts per second, C_{RAW} is the raw channel data in counts per second and Live Time is in microseconds.

Cosmic and aircraft correction

Background radiation resulting from cosmic rays and aircraft contamination was removed from the Total Count, Potassium, Uranium, Thorium and upward Uranium channels using the following formula:

$$C_{CA} = C_{LT} - (a_c + b_c \cdot C_{Cos}) \qquad (7)$$

where C_{CA} is the cosmic and aircraft corrected channel, C_{LT} is the live time corrected channel a_c is the aircraft background for this channel, b_c is the cosmic stripping coefficient for this channel and C_{Cos} is the low pass filtered cosmic channel.

Radon correction

The upward detector method, as discussed in IAEA (1991), was applied to remove the effects of the atmospheric radon in the air below and around the helicopter. Usages of over-water measurements where there is no contribution from the ground, enabled the calculation of the coefficients a_c and b_c of the linear equations that relate the cosmic corrected counts per second of Uranium channel with total count, Potassium, Thorium and Uranium upward channels over water. Data over-land was used in conjunction with data over-water to calculate the a_1 and a_2 coefficients used in equation (8) for the determination of the Radon component in the downward uranium window:

$$Radon_U = \frac{Uup_{CA} - a_1 \cdot U_{CA} - a_2 \cdot Th_{CA} + a_2 \cdot b_{Th} - b_U}{a_U - a_1 - a_2 \cdot a_{Th}} \qquad (8)$$

where $Radon_U$ is the radon component in the downward uranium window, Uup_{CA} is the filtered upward uranium, U_{CA} is the filtered Uranium, Th_{CA} is the filtered Thorium, a_1, a_2, a_U and a_{Th} are proportional factors and b_U an b_{Th} are constants determined experimentally.

The effects of Radon in the downward Uranium are removed by simply subtracting $Radon_U$ from U_{CA}. The effects of radon in the other channels are removed using the following formula:

$$C_{RC} = C_{CA} - (a_C \cdot Radon_U + b_C) \quad (9)$$

where C_{RC} is the Radon corrected channel, C_{CA} is the cosmic and aircraft corrected channel, $Radon_U$ is the Radon component in the downward uranium window, a_c is the proportionality factor and b_c is the constant determined experimentally for this channel from over-water data.

Compton Stripping

Potassium-, Uranium- and Thorium- Radon corrected channels are subjected to spectral overlap correction. Compton scattered gamma rays in the radio-nuclides energy windows were corrected by window stripping using Compton stripping coefficients determined from measurements on calibrations pads at the Geological Survey of Norway in Trondheim (for values see Appendix A3).

The stripping corrections are given by the following formulas:

$$A_1 = 1 - (g \cdot \gamma) - (\mathrm{a} \cdot \alpha) + (\mathrm{a} \cdot g \cdot \beta) - (b \cdot \beta) + (b \cdot \alpha \cdot \gamma) \quad (10)$$

$$U_{ST} = \frac{Th_{RC} \cdot ((g \cdot \beta) - \alpha) + U_{RC} \cdot (1 - b \cdot \beta) + K_{RC} \cdot ((b \cdot \alpha) - g)}{A_1} \quad (11)$$

$$Th_{ST} = \frac{Th_{RC} \cdot (1 - (g \cdot \gamma)) + U_{RC} \cdot (b \cdot \gamma - \mathrm{a}) + K_{RC} \cdot ((\mathrm{a} \cdot g) - b)}{A_1} \quad (12)$$

$$K_{ST} = \frac{Th_{RC} \cdot ((\alpha \cdot \gamma) - \beta) + U_{RC} \cdot ((\mathrm{a} \cdot \beta) - \gamma) + K_{RC} \cdot (1 - (\mathrm{a} \cdot \alpha))}{A_1} \quad (13)$$

where U_{RC}, Th_{RC}, K_{RC} are the radon corrected Uranium, Thorium and Potassium, a, b, g, α, β, γ are Compton stripping coefficients.

Reduction to Standard Temperature and Pressure

The radar altimeter data were converted to effective height (H_{STP}) using the acquired temperature and pressure data, according to the expression:

$$H_{STP} = H \cdot \frac{273.15}{T + 273.15} \cdot \frac{P}{1013.25} \quad (14)$$

where H is the smoothed observed radar altitude in meters, T is the measured air temperature in degrees Celsius and P is the measured barometric pressure in millibars.

Height correction

Variations caused by changes in the aircraft altitude relative to the ground corrected to a nominal height of 60 m. Data recorded at the height above 150 m were considered as non-reliable and removed from processing. Total count, Uranium, Thorium and Potassium stripped channels were subjected to height correction according to the equation:

$$C_{60m} = C_{ST} \cdot e^{C_{ht} \cdot (60 - H_{STP})} \quad (15)$$

where C_{ST} is the stripped corrected channel, C_{ht} is the height attenuation factor for that channel and H_{STP} is the effective height.

Conversion to ground concentrations
Finally, corrected count rates were converted to ground element concentrations using calibration values from calibration pads at NGU in Trondheim (for values see Appendix A3). The corrected data provide an estimate of the apparent surface concentrations of Potassium, Uranium and Thorium (K, eU and eTh).

Potassium concentration is expressed as a percentage, equivalent Uranium and Thorium as parts per million. Uranium and Thorium are described as "equivalent" since their presence is inferred from gamma-ray radiation from daughter elements (^{214}Bi for Uranium, ^{208}Tl for Thorium). The concentration of the elements is calculated according to the following expressions:

$$C_{CONC} = C_{60m} / C_{SENS\_60m} \quad (16)$$

where C_{60m} is the height corrected channel, C_{SENS_60m} is experimentally determined sensitivity reduced to the nominal height (60m).

Spectrometry data gridding and presentation
Gamma-rays from Potassium, Thorium and Uranium emanate from the uppermost 30 to 40 centimetres of soil and rock in the crust (Minty, 1997). Variations in the concentrations of these radio-elements largely related to changes in the mineralogy and geochemistry of the Earth's surface.

The calculated ground concentrations of the three main natural radio-elements Potassium, Thorium and Uranium were microlevelled to remove small line-to-line levelling errors, as in the case of the magnetic data, and then gridded using a minimum curvature method with a grid cell size of 50 meters.

Special radiometric processing challenges
The initial Radon correction coefficients chosen for this area did not level the whole data set properly. The changes in conditions and lack of water bodies caused challenges during processing. To compensate for this, the radon corrected levels of U, Th, K and TC for the 2014 flight was reduced by 20%, based on average levels for the different isotopes after cosmic correction. This brought the radon corrected values to the same average level for the whole survey.

To achieve the uniform concentration values, the correction coefficients from the nearby areas of Gratangen and Sørreisa, completed just days before the 2014 flight, were used to level the whole data set. These coefficients were far better at compensating for the variation in Radon influence which was not present in the statistics from the local Radon background data from the 2013 flights.

The quality of the radiometric data was within standard NGU specifications (Rønning 2013), except for one half line where the radiometric data is missing completely due to system error; line 2570, south end of line. The one line of missing radiometry data is not visible in the maps because the gridding process will interpolate the area.

A list of the maps is shown in Table 3. A list of the parameters used in the processing schemes is given in Appendix A3. For further reading regarding standard processing of airborne radiometric data, we recommend the publication from Minty et al. (1997).

4. PRODUCTS

Processed digital data from the survey are presented as:

1. Geosoft XYZ files: Dividalen_Mag.xyz, Dividalen_Rad.xyz.

2. Coloured maps (jpg) at the scale 1:50.000 available from NGU on request.

3. Geo-referenced tiff files (Geo-tiff).

Table 3: Maps in scale 1:50.000 available from NGU on request.

Map #	Name	Figure No
2015.003-01	Total magnetic field	5
2015.003-02	Magnetic Vertical Derivative	6
2015.003-03	Magnetic Horizontal Derivative	7
2015.003-04	Magnetic Tilt Derivative	8
2015.003-05	Uranium ground concentration	9
2015.003-06	Thorium ground concentration	10
2015.003-07	Potassium ground concentration	11
2015.003-08	Radiometric Ternary Map	12
2015.003-09	Radiometric Total Counts	13

Downscaled images of the listed maps are shown in Figures 5 to 13.

5. REFERENCES

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.

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Geosoft 2010: Montaj MAGMAP Filtering, 2D-Frequency Domain Processing of Potential Field Data, Extension for Oasis Montaj v 7.1, Geosoft Corporation

P1: Photo by Mari Nymoen, Telen Newspaper, Notodden

Appendix A1: Description 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 basemag data to Geosoft database
- Inspection of basemag data and removal of spikes
- Special Matlab Gauss-filter for removal of 7.5 sec pendulum noise
- Correction of data for diurnal variation
- Splitting flight data by lines
- Gridding
- Micro-leveling
- 3x3 Convolution filter

Appendix A2: Description of the Special Matlab filtering step

The Matlab code is being used to filter the “pendulum effect” periodic noise on the magnetic data. The data are filtered by calling a built-in convolution routine called “conv” that convolves the input data vector with a vector that has coefficients of Gaussian lowpass filter at a certain frequency (Freq.1).

If the differences between the input and the filtered data are above a predefined threshold, this part of the data is reprocessed be employing a less severe filter (Freq.2) on the input data. Again a threshold is applied on the differences between the input and the filtered data and in this case if the differences are above the threshold then the input data are retained for that part on the final filtered dataset.

These steps enable us to preserve the amplitudes of strong anomalies in the data, which would be lost otherwise by typical convolution or Fourier filtering. The cutoff frequency that were used were Freq.1=0.04Hz and Freq.2=0.09Hz.

Appendix A3: Description of radiometry processing

Most of the survey was performed in the autumn of 2013, with just one flight in 2014. This caused problems in the final processing steps, as the 2013 flights were done in 0-2 °C, and the 2014 flight was done in 10-12 °C. The temperature difference gave different levels of Radon in the air, thus giving some variations in the final concentration levels of the radiometric isotopes.

Also, the data from the two lakes in the area gave limited amounts of Radon correction statistics, and some snow falling during the survey gave larger than normal variations in the conditions. Also the 2014 flight was done in higher temperature with a different spectrometer. All these factors caused challenges in the processing.

To compensate for the change in conditions, it was decided to reduce the Radon corrected isotope levels for the 2014 flight by 20% and to use the correction coefficients from nearby area Gratangen and Sørreisa, which was flown prior to the last flight. This proved to be the best way to compensate for the problems caused by changes in conditions, lack of statistical data and change of spectrometer, and made the final concentration levels consistent for the whole survey.

Underlined processing stages are applied to the K, U, Th and TC windows.
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 flights at Frosta, May 2013)

Aircraft background counts:	
K window	5.36
U window	1.43
Th window	0
Uup window	0.7
Total counts	42.73

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

K window	0.0570
U window	0.0467
Uup window	0.0448
Th window	0.0643
Total counts	1.0317

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

a_u:	0.05243	$b_{u:}$	0.22111
a_{Th}:	0.04872	b_{Th}:	0.6176
a_K:	0.79998	b_K:	0.30094
a_{Tc}:	12.76538	b_{Tc}:	0
a_1:	0.027804	a_2:	0.063093

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

a	0.046856
b	0
g	0
alpha	0.30346
beta	0.47993
gamma	0.82316

- <u>Height correction to a height of 60 m</u>
  Used parameters (determined by high altitude calibration flights at Frosta, Jan 2014):
  Attenuation factors in 1/m:

K:	-0.009523
U:	-0.006687
Th:	-0.007394
TC:	-0.00773

- Converting counts at 60 m heights to element concentration on the ground
  Used parameters (determined from measurements on calibrations pads at NGU, May 2013):

  Sensitivity (elements concentrations per count):

K:	0.007458	%/counts
U:	0.08773	ppm/counts
Th:	0.15666	ppm/counts

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

De-corrugation cutoff wavelength:	2000 m
Cell size for gridding:	50 m
Naudy (1968) Filter length:	800 m

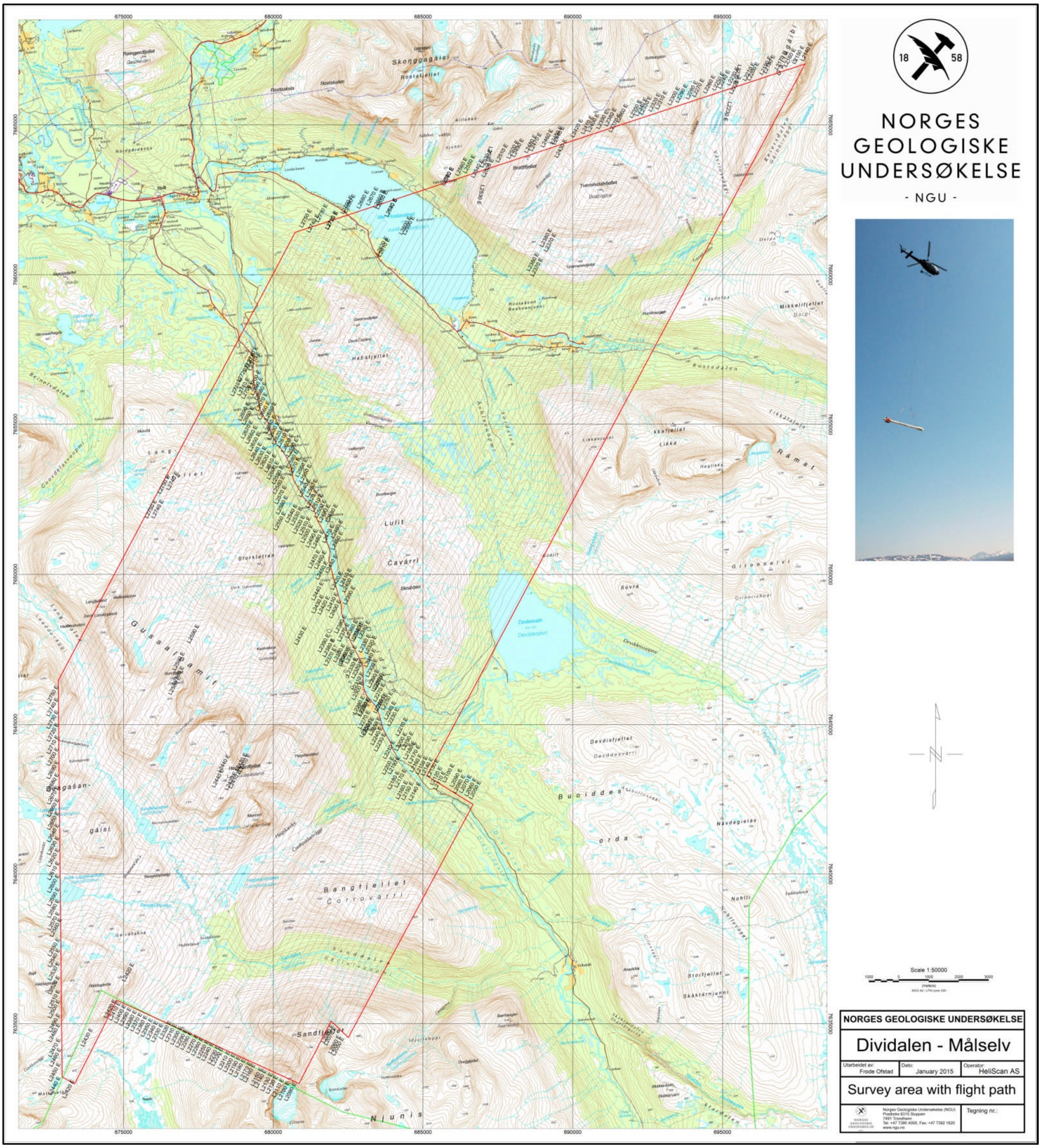

Figure 4: Dividalen survey area with flight path

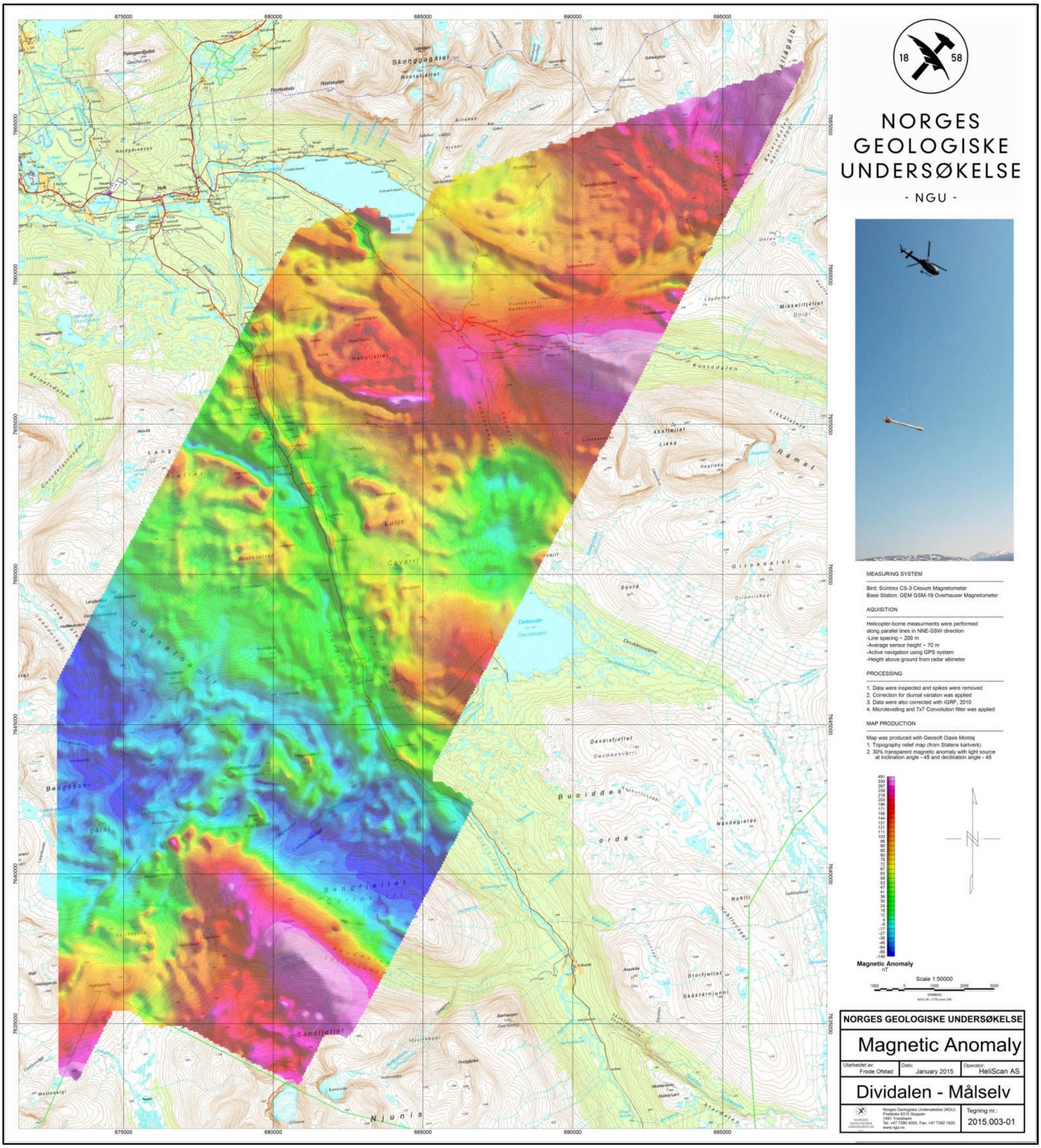

Figure 5: Total Magnetic Field Anomaly

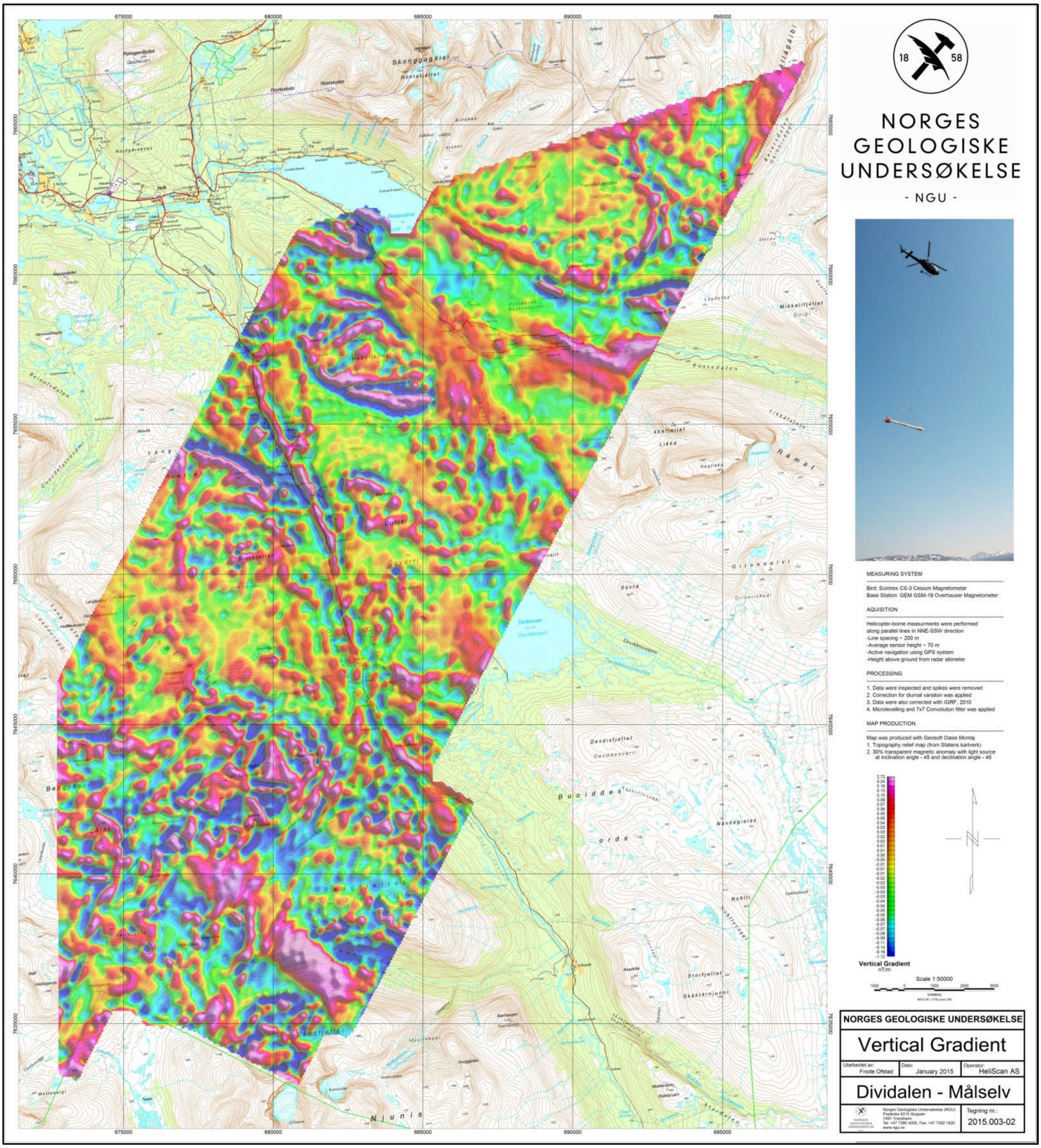

Figure 6: Magnetic Vertical Gradient

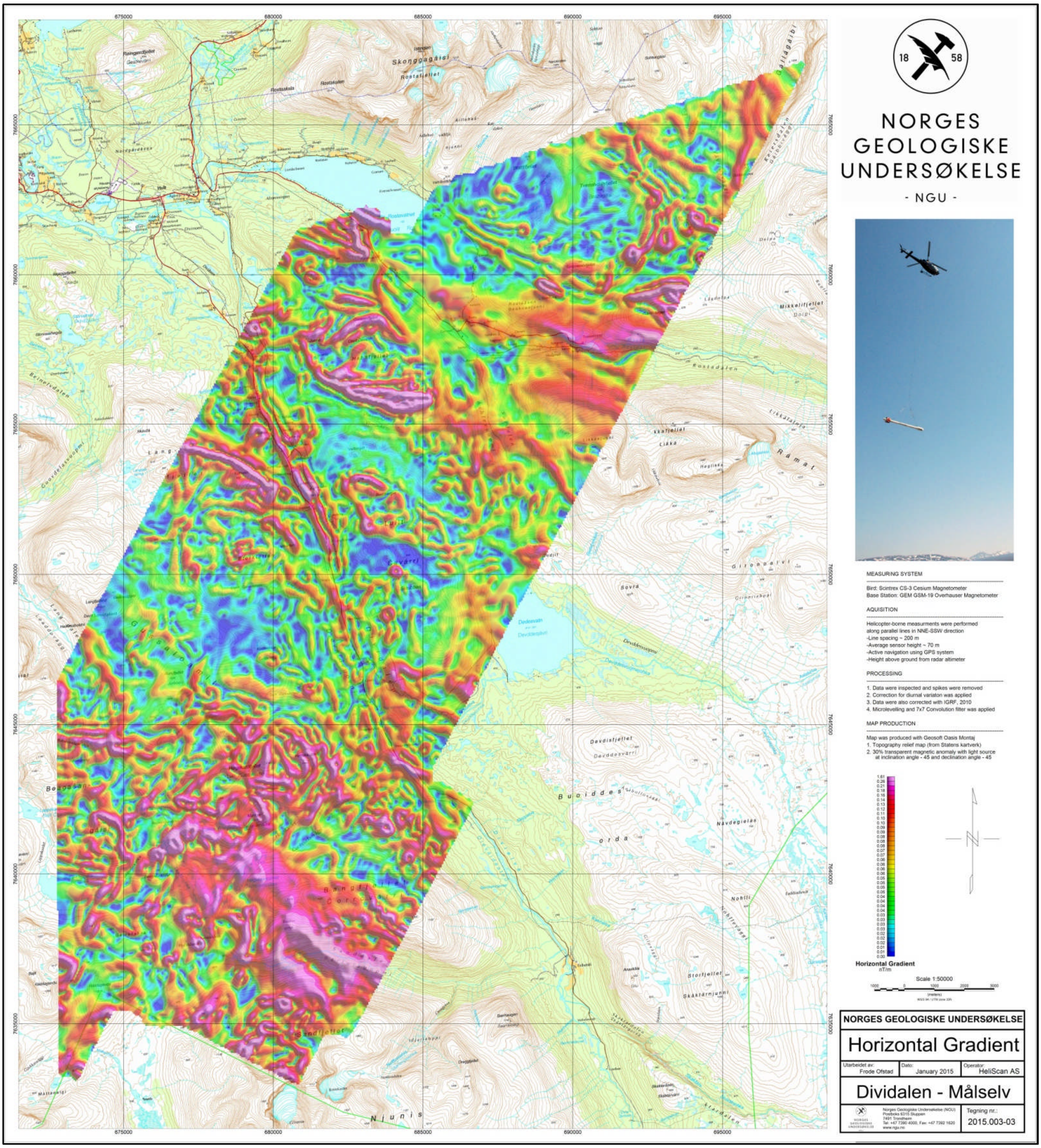

Figure 7: Magnetic Horizontal Gradient

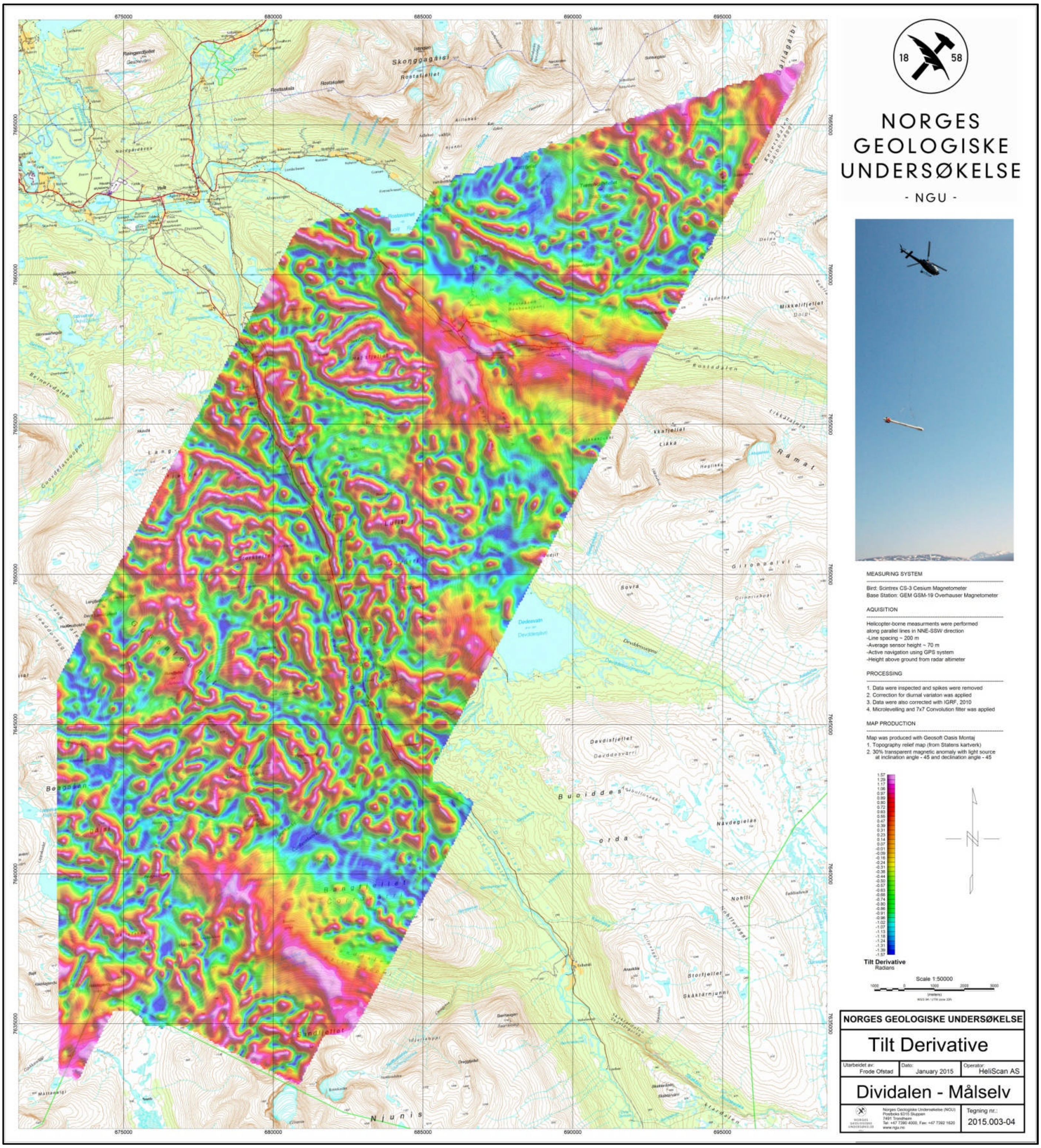

Figure 8: Magnetic Tilt Derivative

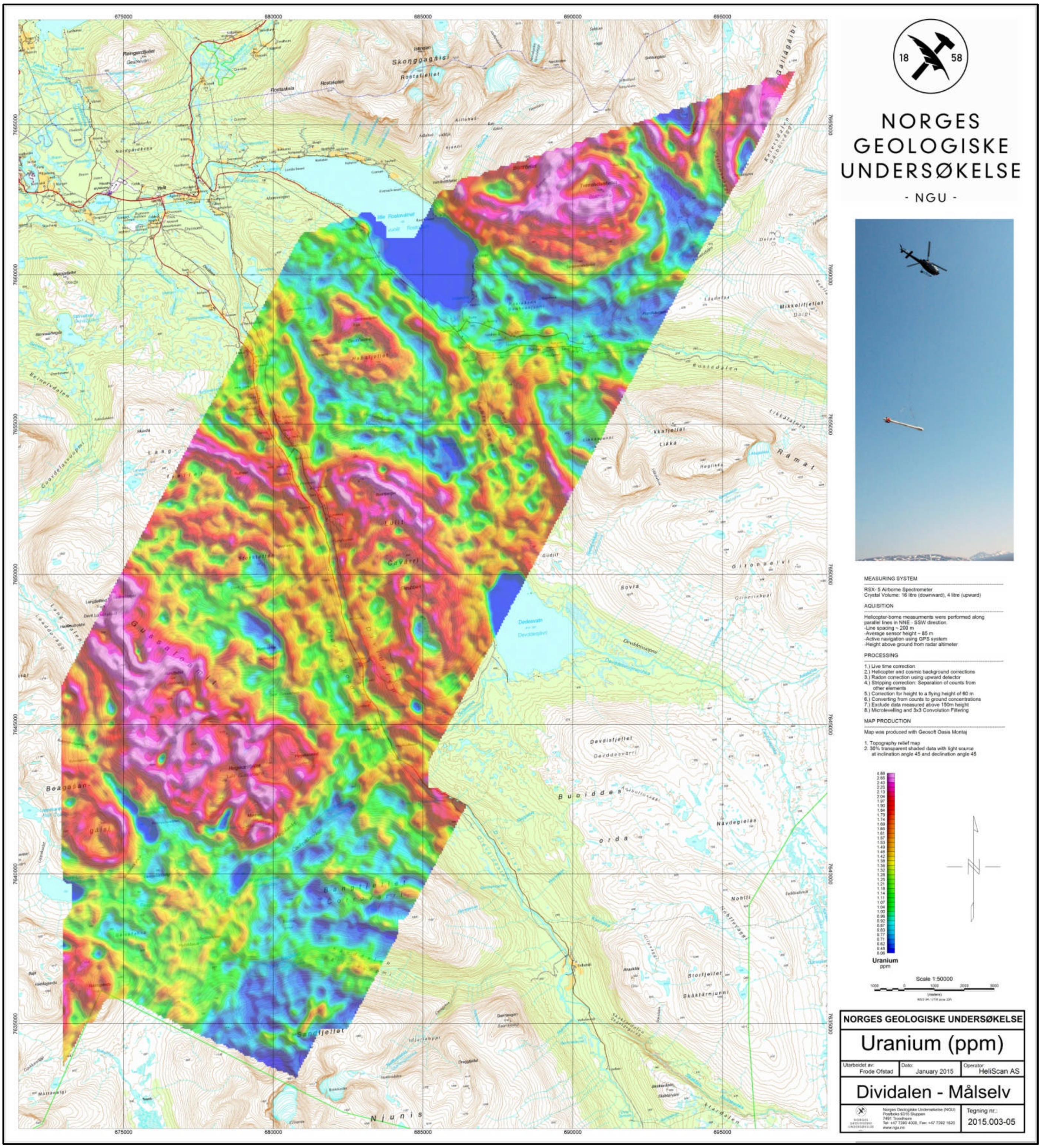

Figure 9: Uranium Ground Concentration

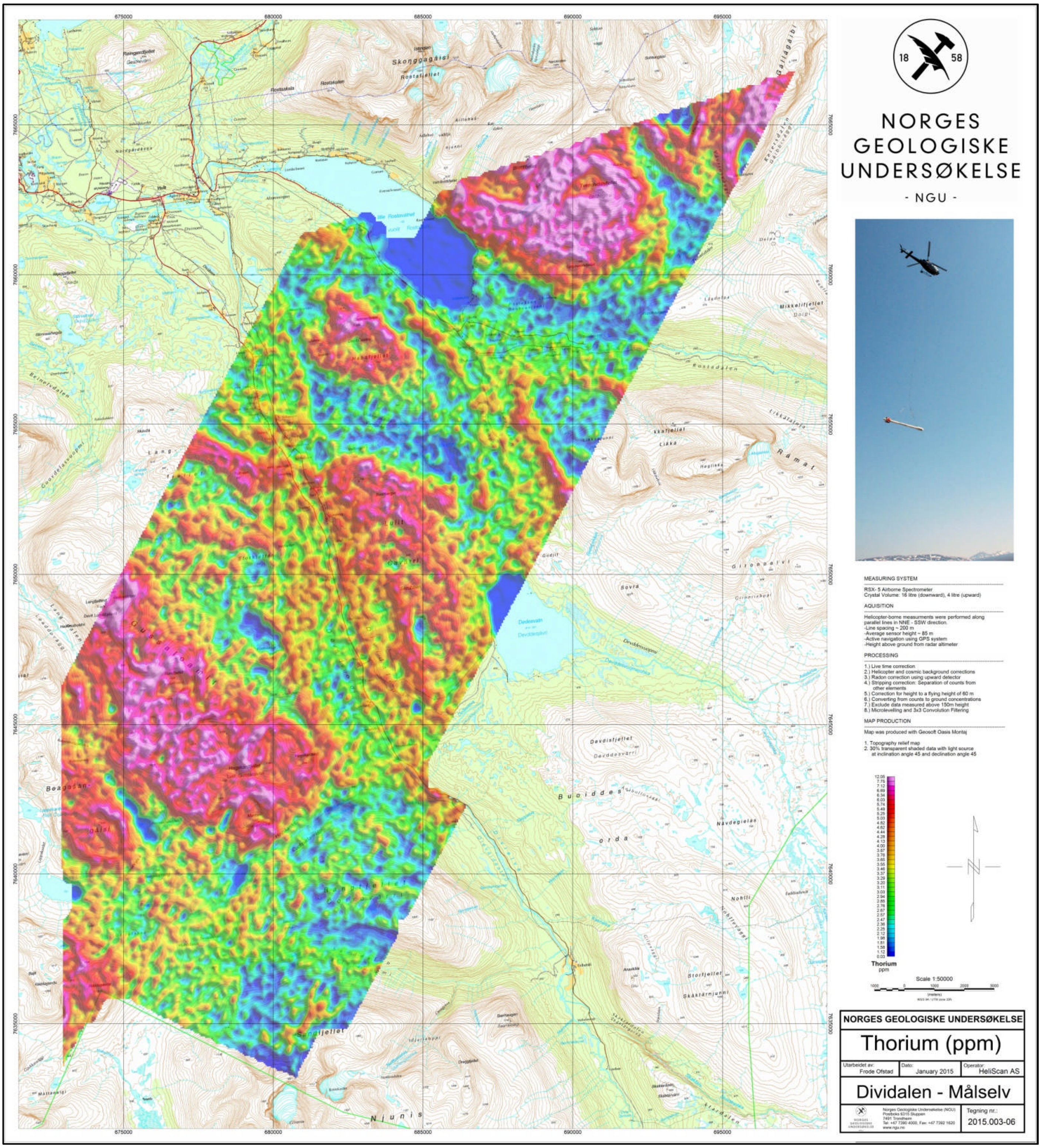

Figure 10: Thorium Ground Concentration

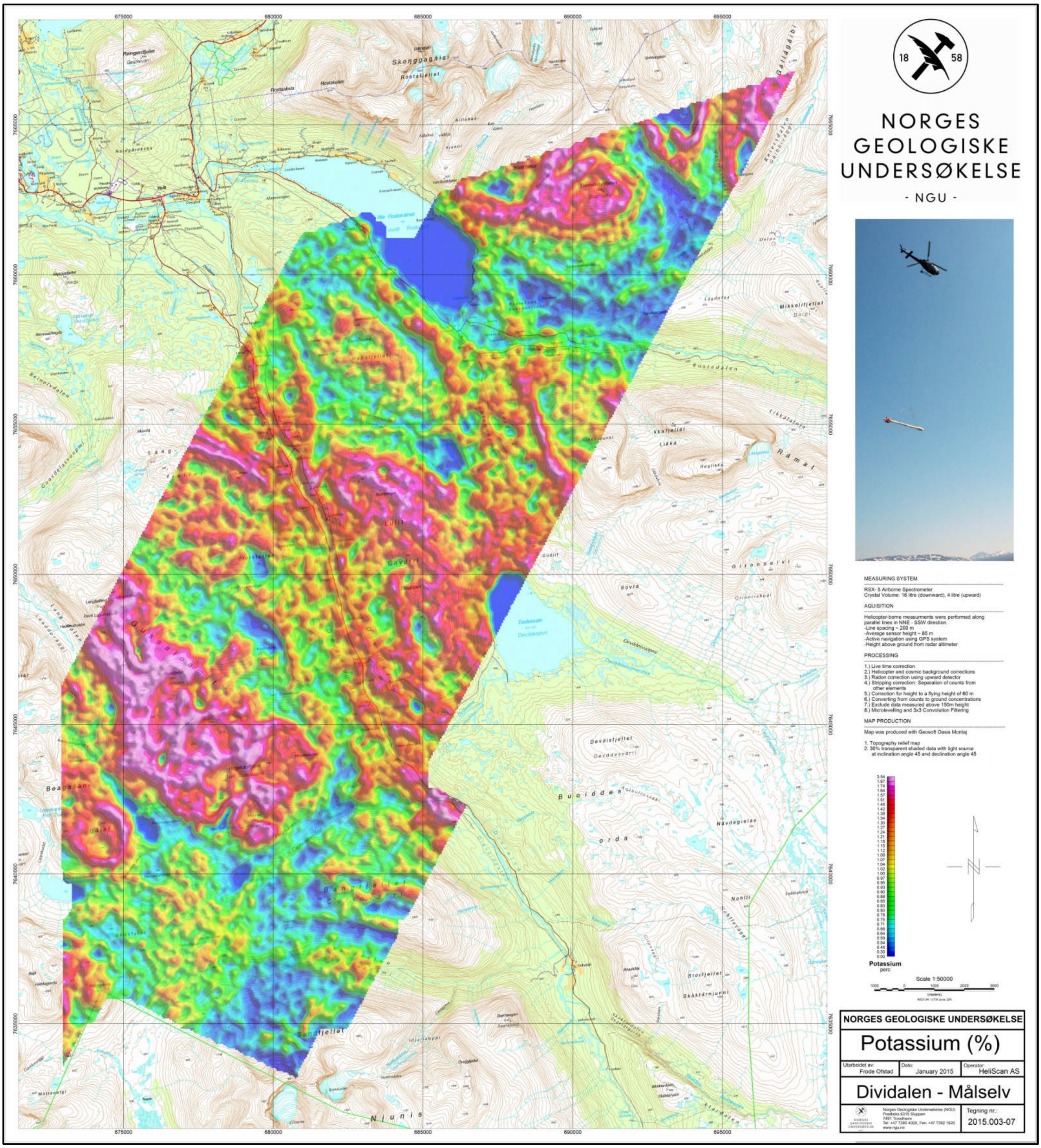

Figure 11: Potassium Ground Concentration

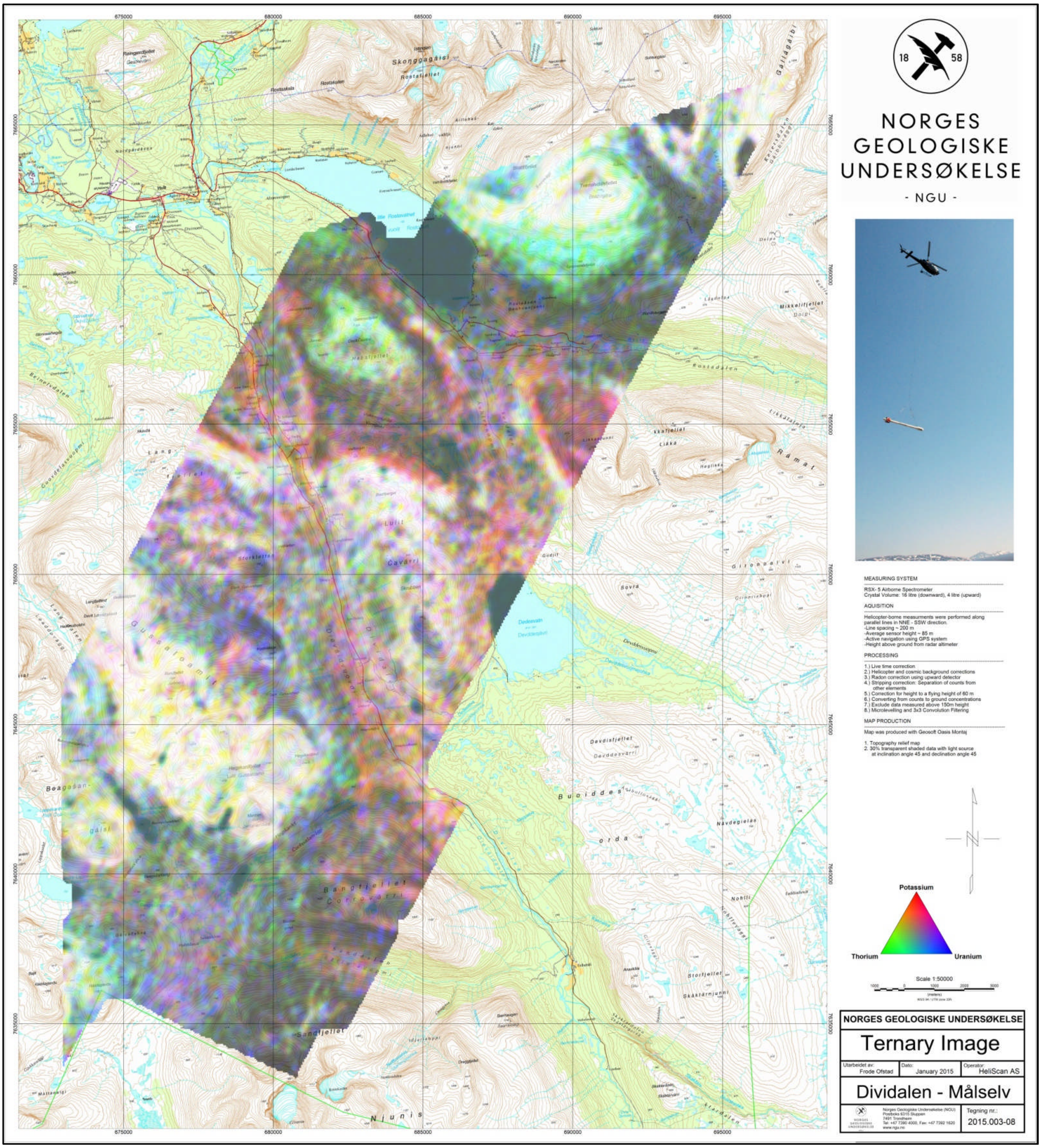

Figure 12: Ternary Image of Radiation Concentrations

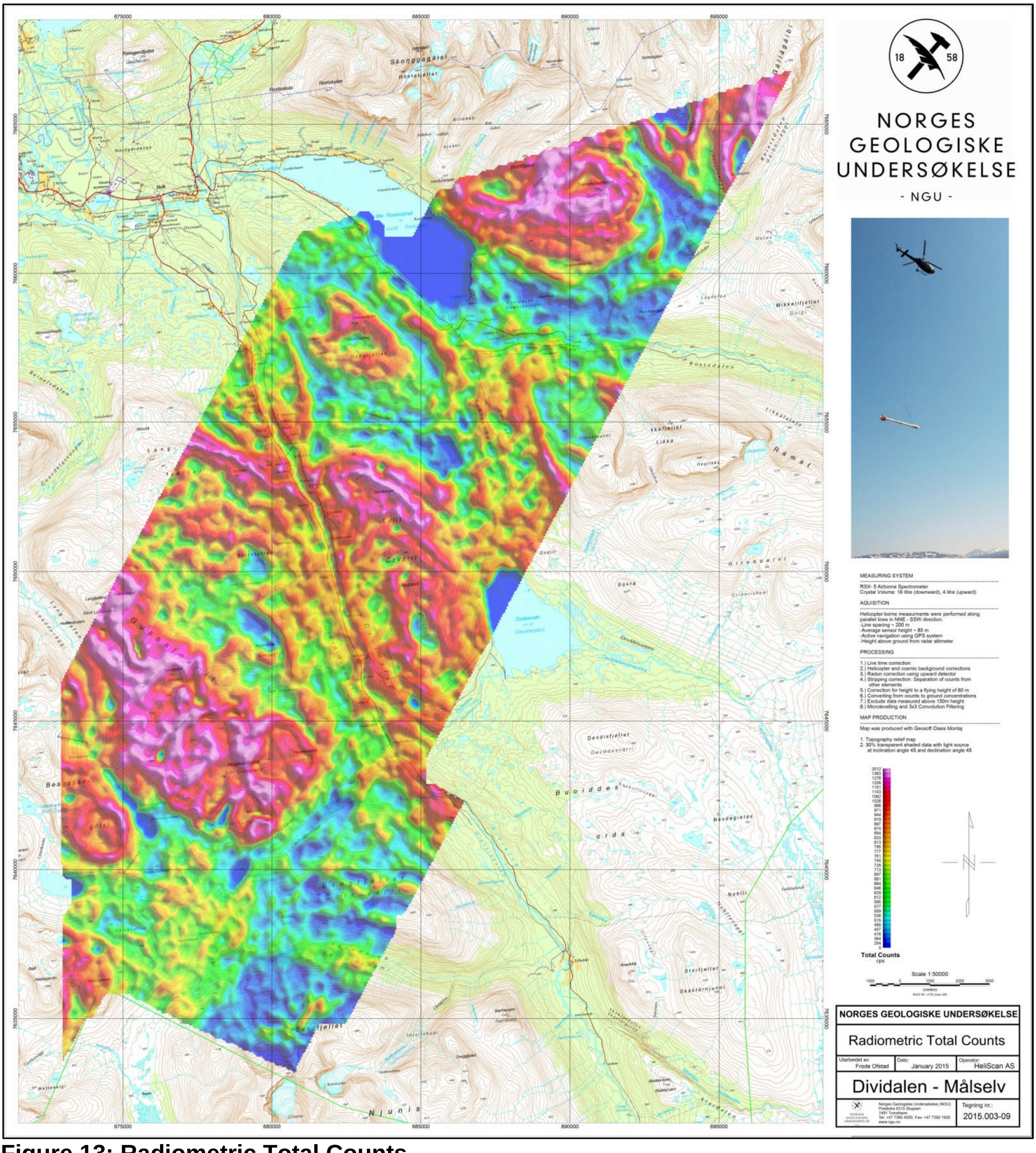

Figure 13: Radiometric Total Counts

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