NGU Report 2003.070

Røst Basin Aeromagnetic Survey 2003 (RAS-03). Ra 3 aeromagnetic compilation. Data acquisition and processing report

Geological Survey of Norway
N-7441 Trondheim, Norway
Tel.: 47 73 90 40 00
Telefax 47 73 92 16 20

REPORT

Report no.: 2003.070	ISSN 0800-3416	Grading: Confidential to September 2008

Title:
Røst Basin Aeromagnetic Survey 2003 (RAS-03). Ra 3 aeromagnetic compilation. Data acquisition and processing report.

Authors:	Client:
Eirik Mauring , John Olav Mogaard & Odleiv Olesen	OD/Norsk Hydro/Statoil/NGU/BP
County:	Commune:
Map-sheet name (M=1:250.000)	Map-sheet no. and -name (M=1:50.000)
Deposit name and grid-reference:	Number of pages: 20 Price (NOK): Map enclosures: 5

Fieldwork carried out:	Date of report:	Project no.:	Person responsible:
May-July 2003	19/9-2003	3025.00	

Summary:
A high sensitivity aeromagnetic survey (RAS-03) was carried out in an area of c. 41400 km^2 over the Røst Basin offshore Lofoten, Northern Norway. Data processing comprised spike removal and data editing, IGRF correction, loop closure levelling and floating differential median micro-levelling. Four maps were produced for the survey area. One of these shows magnetic total field anomalies after correction for the IGRF of 2000. Two maps show residual magnetic values after application of two different high pass filters. A map showing magnetic analytic signal is also presented. The residual maps after high pass filtering delineate anomalies with amplitudes as low as 0.1-0.2 nT, representing shallow and weak magnetic sources in sedimentary basins.

The report also presents four maps from a compilation of the RAS-03 surveys and three adjacent surveys (LAS-89, NAS-94, VAS-98).

Keywords: Geofysikk	Berggrunnsgeologi	Magnetometri
Kontinentalsokkel		
		Fagrapport

CONTENTS

MAPS (available on request)

1. INTRODUCTION

The report describes the acquisition, processing and map production of magnetic data from the Røst Basin offshore Lofoten, Norway. The survey area is continuous with NGU's NAS-94, LAS-89 and VAS-98 surveys (Olesen & Smethurst 1994, Olesen and Myklebust 1989, Mauring et al. 1999, and Olesen et al. 2002). The areas are shown in Fig. 1. A compilation of these surveys is also presented in this report.

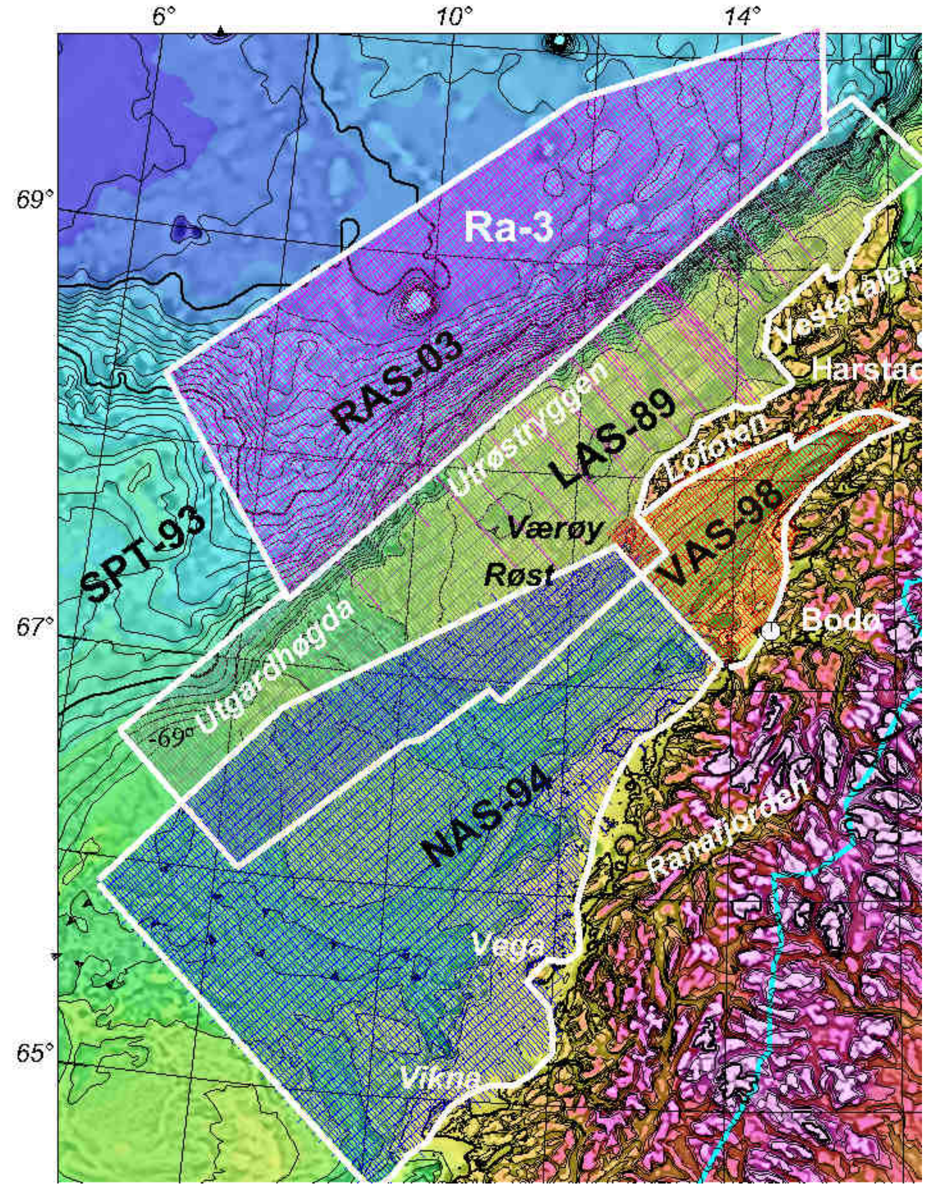


Figure 1. Aeromagnetic survey areas.

Data acquisition was carried out by John Olav Mogaard, Janusz Koziel and Rolf Lynum during the period 27 May to 9 July, 2003. The acquisition period was extended with approximately 10 days due to extraordinary many periods with magnetic disturbances (Fig. 2). Pilots were Ole Thorbjørnsen and Ronny Thorbjørnsen from Fly Taxi Nord in Tromsø.

The area investigated covers c. 41400 km^2. Levelling was performed using a loop closure method by Green (1983). Micro-levelling was carried out using a differential median filtering routine (Mauring & Kihle 2000).

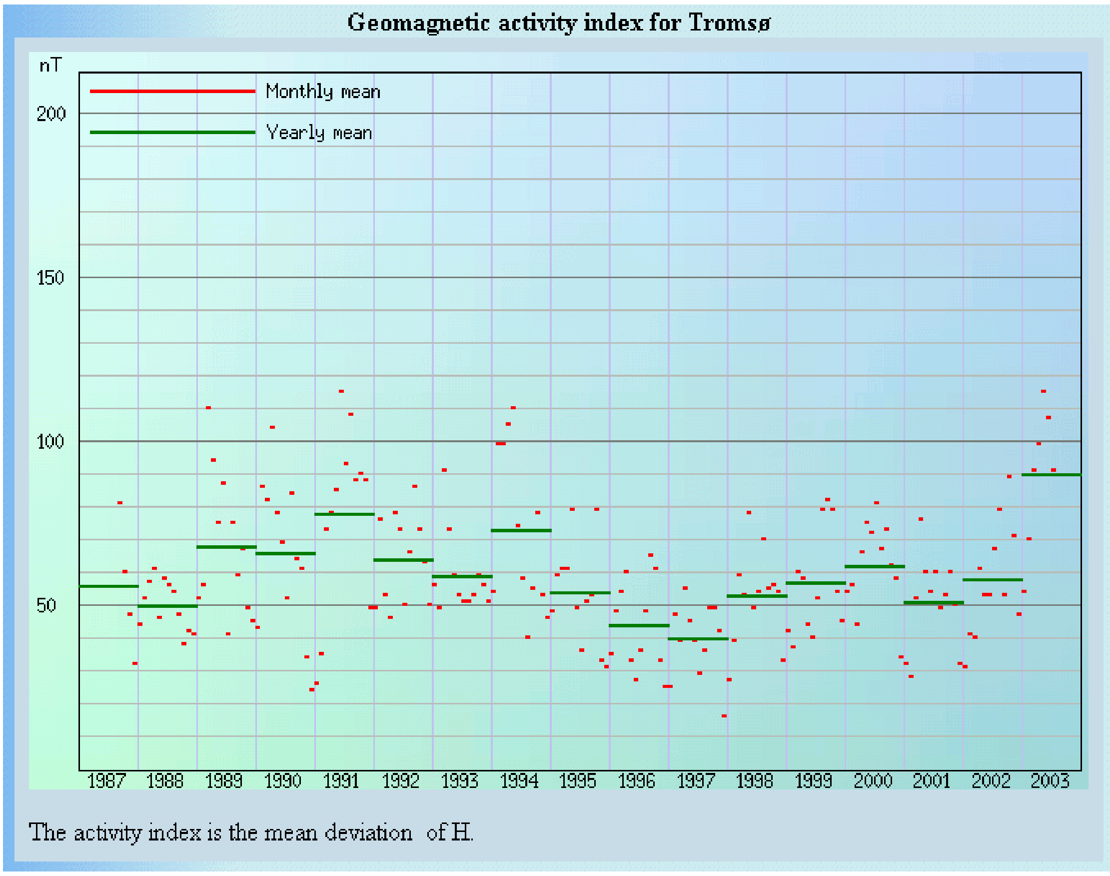


Figure 2. Diagram from the Tromsø Geophysical Observatory (http://www.tgo.uit.no/aix) showing the many magnetic disturbances during the period May-June 2003. May had actually the highest activity during the last 16 years. The survey was planned in January and February when the magnetic activity was moderate.

2. DATA ACQUISITION

The survey was flown using line and tie-line spacings of 2 and 5 km respectively. The line direction was northwest-southeast with orthogonal tie-lines. A total of c. 27840 km was flown covering an area of c. 41400 km^2 during 32 flights. The aircraft altitude was 300 m (1000 feet). The magnetic sensor was towed c. 70 m below and behind the aircraft, giving a sensor altitude of c. 230 m. The flying speed was 225 km/h and magnetic data were sampled at a rate of 5 Hz, giving a spatial sampling interval of 12-14 m along lines. A Piper Chieftain (OY-FTN) from Fly Taxi Nord in Tromsø was hired for data acquisition. Lines and tie-lines are shown in Fig. 3.

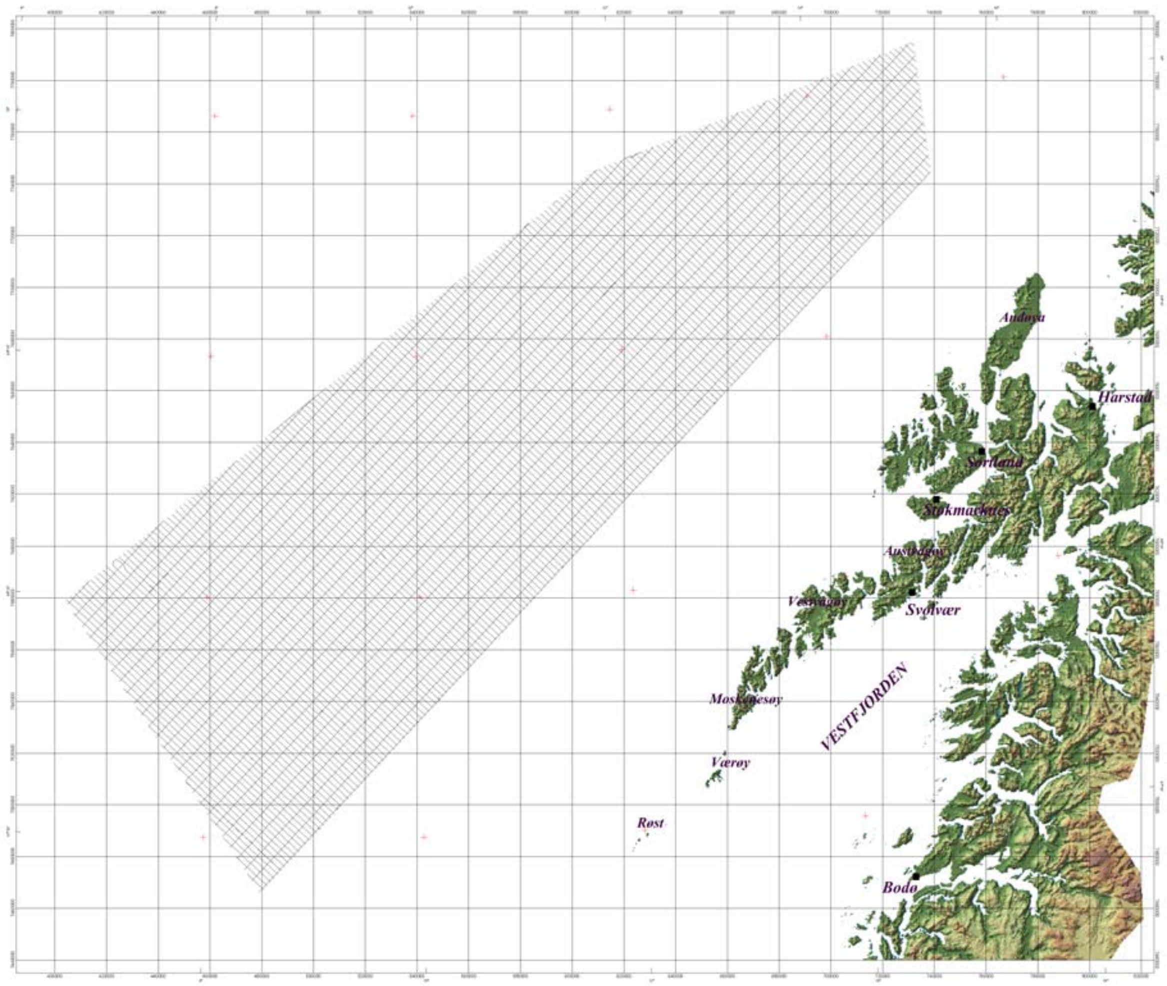


Figure 3: Lines and tie-lines in the RAS-03 survey.

A Scintrex Cesium Vapour MEP 410 high sensitivity magnetometer with a CS-2 sensor was applied in the data acquisition. The noise envelope of the onboard magnetometer was 0.1 nT. Most of the data fell within the limits of ±0.04 nT.

A Scintrex MP-3 and an EnviMAG proton magnetometer was used for recording diurnals at the base station which was located at Svolvær airport. Data from the base magnetometer were used in the planning of flights and to decide which lines should be reflown.

Real time differential GPS navigation was used. The navigation accuracy was better than ±10 m throughout the survey.

The data were classified into four quality groups according to magnetic diurnals:

Class	Criteria	Profile length	Reflown	Final profile length
1	< 10 nT/10 min. linear	12.981 km		12.981 km
2	10 – 30 nT/10 min. linear	9.843 km		9.843 km
3	30 – 50 nT/10 min. linear	3.984 km		3.984 km
4	> 50 nT/10 min. linear	2.502 km	1475 km	1.027 km
Total		29.310 km		27.835 km

3. DATA PROCESSING

Much of the processing was carried out using the OASIS Montaj program system of Geosoft Ltd. Levelling and micro-levelling was performed using software developed at NGU (Mauring & Kihle 2000). The various processing steps are outlined below.

3.1 Importing and editing

Data were imported into an Oasis Montaj database. Spikes were partly removed by non-linear filtering and partly by manual editing. Gaps resulting from removal of spikes were interpolated using Akima spline functions. Due to lower sampling rate of navigation data relative to magnetic data, positions were repeated during acquisition. Repeated positioning data were deleted and linearly interpolated.

3.2 IGRF correction

The International Geomagnetic Reference Field for 2000 (IGRF 2000) was subtracted from the magnetic total field values.

3.3 Use of base magnetometer readings

Data from the base magnetometer cannot be used directly to correct the magnetic readings from the survey area. The most important reason for this is the time shift in the earth magnetic field variations between the survey area and the base station. There is normally a difference in amplitude and frequency of these variations. Data from the base magnetometer were mainly used to assess the quality of individual lines and to make decisions on which lines had to be reflown.

3.4 Levelling

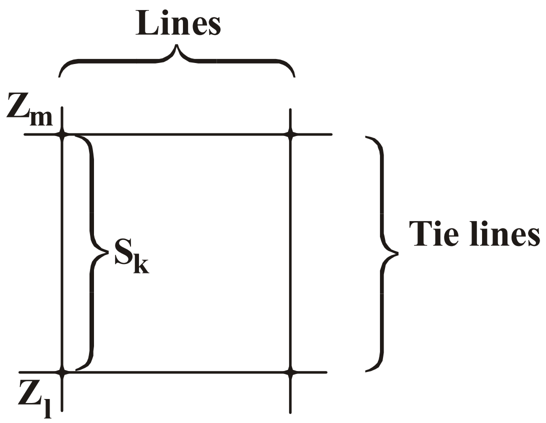


Figure 4. Line/tie line diagram illustrating calculation of the difference between calculated and measured magnetic values.

Levelling was carried out using a loop closure method described by Green (1983). Figure 4 shows two intersecting lines and tie-lines which yield four intersection points. Z_l and Z_m denote calculated magnetic values for the points l and m, and S_k denotes the difference between measured values in points l and m. The difference between calculated and measured values is;

$$(Z_l - Z_m) - S_k = V_k$$

The loop closure method finds the set of Z_i which minimises;

$$\phi = \sum_{k=1}^{N} V_k^2$$

Minimising by differentiation yield N linear equations, one for each intersection. The system of equations has rank 1, which requires manual input of a value at one of the intersection points. The rest of the points are given initial values, e.g. values from the lines. The system of equations can then be solved by Gauss-Seidel iterations (Kreyszig 1979).

3.5 Micro-levelling

After levelling, small levelling errors remained along parts of some profiles. Micro-levelling was therefore performed. This technique is described in Mauring & Kihle (2000). The technique is based on filtering of line data. A floating median filter is applied to each line. For a given line, the 1-D median is determined at each station based on data values within a given distance of the station. In the same way we can find a 2-D median value for a circular area around the station. The difference between the 2-D and 1-D median value is taken to be the micro-levelling error and is added to the magnetic value at that station after smoothing.

For this technique to be used successfully, the regional field must first be removed from the magnetic data. This can be obtained by using the residual after high pass filtering of the magnetic total field. This procedure was performed for the Røst Basin data, using an 8 km Butterworth filter. The 1-D and 2-D filter radii were 5 and 10 km, respectively.

4. Ra 3 COMPILATION

The surveys LAS-89, NAS-94, VAS-98 and RAS-03 were used in this compilation (see Fig. 1). Coordinates for the surveys were converted to a common datum (ED50), and IGRF-corrected data were used for further processing. The lines used in the compilation are shown in Fig. 5. The data were levelled using techniques described in 3.4 and 3.5. The compiled dataset constitute approximately 100 000 profile km.

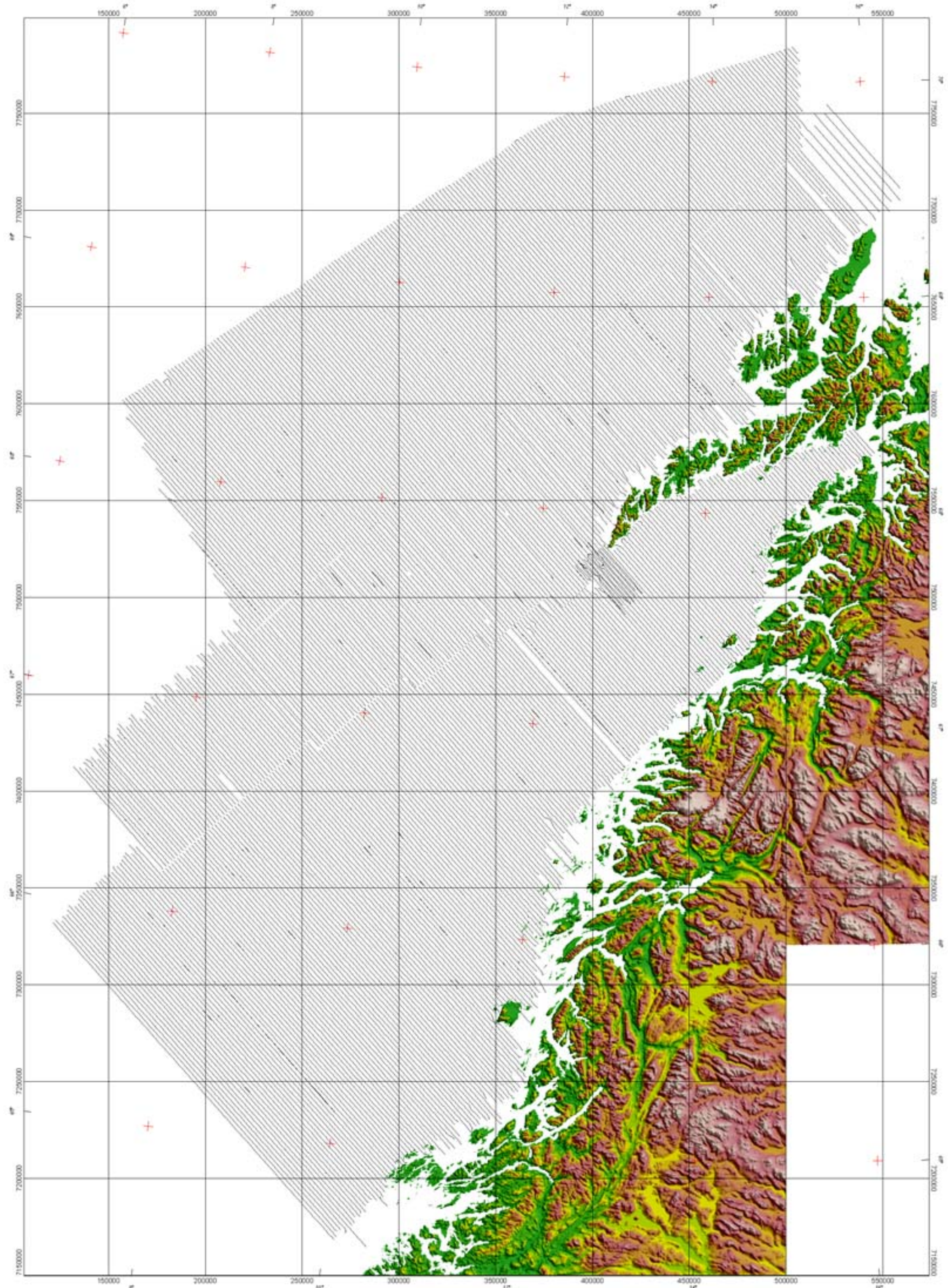


Figure 5: Lines in the Ra 3 compilation

5. DESCRIPTION OF MAPS

The Geosoft OASIS Montaj program system was used in the map production. The maps are presented with shaded relief, with the shadow falling towards the southeast (illumination from the northwest). Presentation of maps with shaded relief enhances lineaments that are oblique to the illumination direction. Colour scale and colour distribution for the data sets have been computed using histogram equalisation. The grids have a cell size of 500 x 500 m^2.

The following maps for the RAS-03 survey are produced (scale 1:500 000);

2003.070-01: Magnetic total field anomaly
2003.070-02: Magnetic analytic signal
2003.070-03: 5 km high pass Gaussian filtered magnetic anomaly
2003.070-04: 15 km high pass Gaussian filtered magnetic anomaly

The following maps for the Ra 3 compilation are produced (scale 1:1 000 000);

2003.070-05: Magnetic total field anomaly
2003.070-06: Magnetic analytic signal
2003.070-07: 5 km high pass Gaussian filtered magnetic anomaly
2003.070-08: 15 km high pass Gaussian filtered magnetic anomaly

The magnetic total field has been upward continued to 100 m before calculation of the analytic signal (total gradient amplitude).

6. CONCLUSIONS

A high sensitivity aeromagnetic survey was carried out in an area of c. 41400 km^2 over the Røst Basin offshore Lofoten, Northern Norway. Data processing comprised spike removal and data editing, IGRF correction, closure loop levelling and floating differental median micro-levelling. Four maps were produced for the survey area. One of these shows magnetic total field anomalies after correction for the IGRF of 2000. Two maps show residual magnetic values after application of two different high pass filters. A map showing magnetic analytic signal is also presented. The residual maps after high pass filtering delineate anomalies with amplitudes as low as 0.1-0.2 nT, representing shallow and weak magnetic sources in sedimentary basins.

The report also presents four maps from a compilation of the RAS-03 surveys and three adjacent surveys (LAS-89, NAS-94, VAS-98).

7. REFERENCES

Green, A.A. 1983: A comparison of adjustment procedures for levelling aeromagnetic survey data. *Geophysics 48,* 745-753.

Kreyszig, E. 1979: Advanced engineering mathematics. *John Wiley & Sons, Inc.*

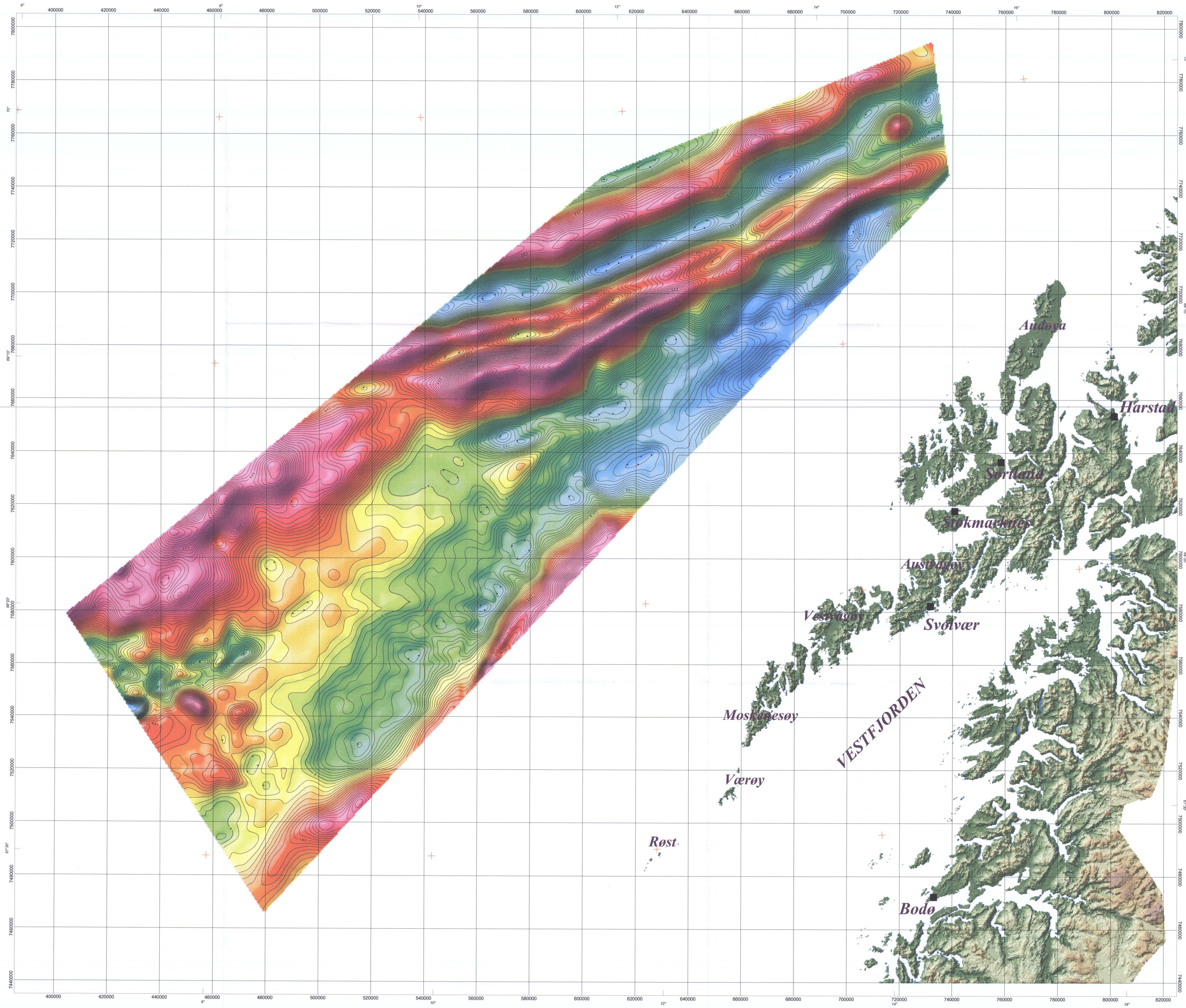
Mauring, E., Smethurst, M.A. & Kihle, O. 1999: Vestfjorden Aeromagnetic Survey 1998. Acquisition and processing report. *NGU Report 99.001,* 23 pp.

Mauring, E. & Kihle, O. 2000: Micro-levelling of aeromagnetic data using a moving differential median filter. *NGU Report 2000.053*, 11 pp.

Olesen, O. & Myklebust, R.1989: LAS-89. Lofoten Aeromagnetic Survey 1989, Interpretation report. *NGU Report 89.168*, 54 pp.

Olesen, O & Smethurst, M.A. 1994: NAS-94 Interpretation Report Part I: Aeromagnetic data. *NGU Report 94.074*, 44 pp.

Olesen, O., Lundin, E., Nordgulen, Ø., Osmundsen, P.T., Skilbrei, J.R., Smethurst, M.A., Solli, A., Bugge, T. & Fichler, C. 2002: Bridging the gap between the Nordland onshore and offshore geology. *Norwegian Journal of Geology 82,* 243-262.



MAGNETIC TOTAL FIELD

The intensity of the magnetic total field is in nanoTesla.

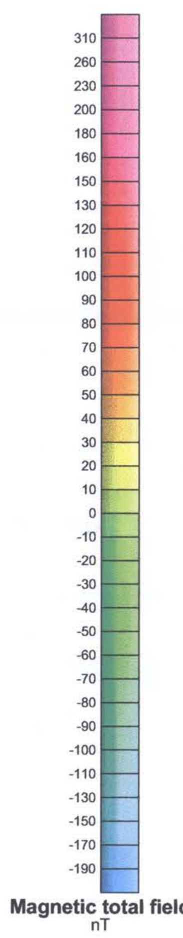
Contours given in following intervals:

10nT

100nT

500nT

Colours - distributed after colourscale.



GEODETIC DATUM: WGS84
CONFORM CYLINDER PROJECTION
UTM coordinates, zone 32

RAS-03

MAGNETIC TOTAL FIELD

RØST BASIN AEROMAGNETIC SURVEY 2003

Draw: Mogaard, J.O. & Mauring, E.	Date: AUGUST 2003	Obs: JOM/JK

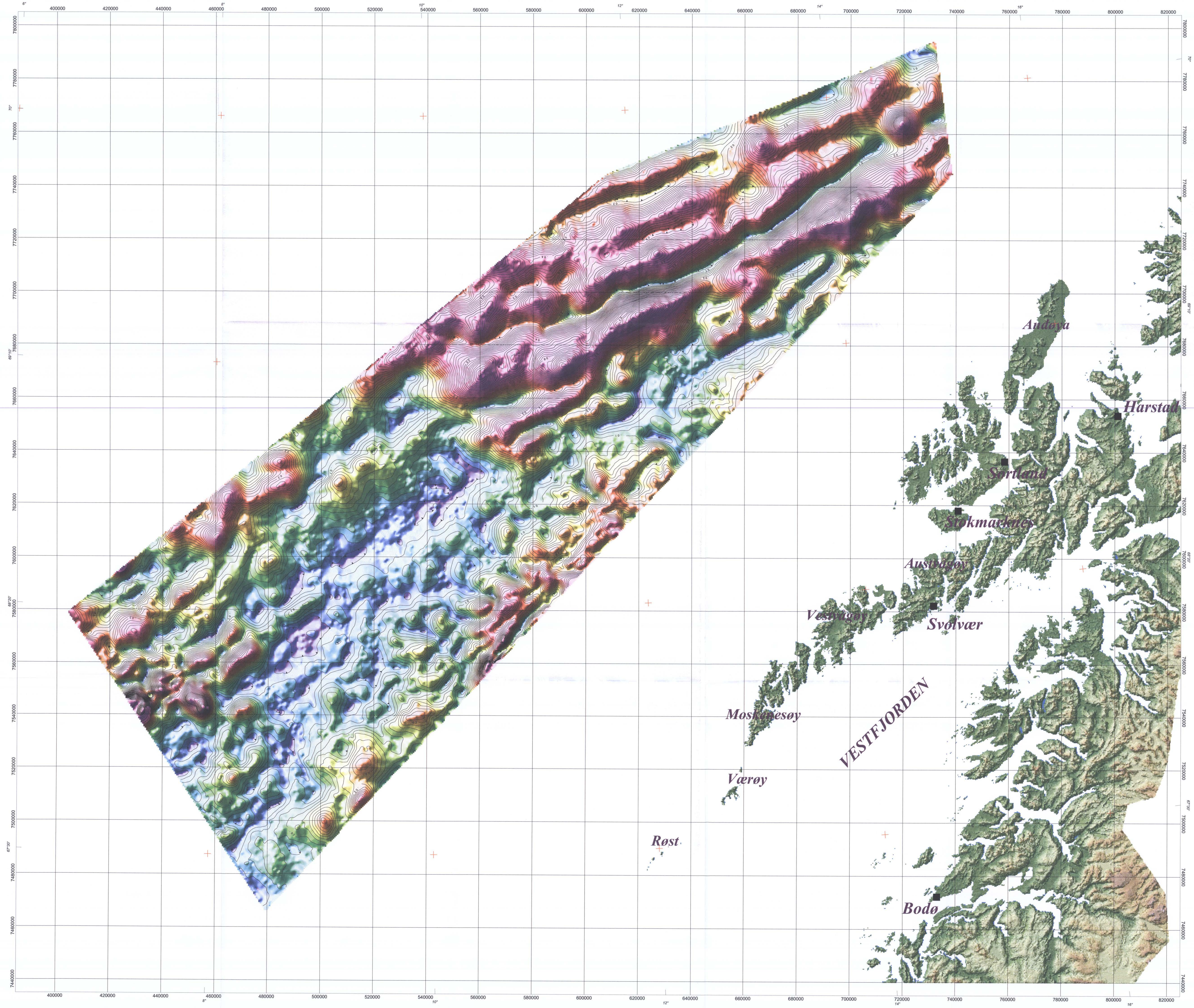
Scale 1:500 000

10000 0 10000 20000 30000

(meters)

GEOLOGICAL SURVEY OF NORWAY
Leiv Eirikssons vei 39
N-7491 TRONDHEIM
Tel +47 73 90 40 11, Fax +47 73 92 16 20
http://www.ngu.no

DRAWING: 2003.070-01

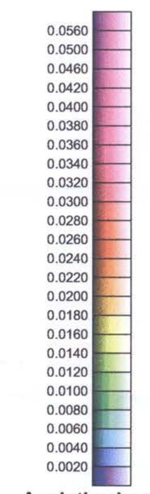


ANALYTIC SIGNAL, UPWARD CONTINUED 100 m

Analytic signal (in nanoTeslas per meter) calculated from magnetic total field, upward continued 100 m. Contours given in following intervals:

0.002 nT/m
0.01 nT/m
0.05 nT/m

Colours - distributed after colourscale.



GEODETIC DATUM: WGS84
CONFORM CYLINDER PROJECTION
UTM coordinates, zone 32

RAS-03

ANALYTIC SIGNAL, UPWARD CONTINUED 100 m

RØST BASIN AEROMAGNETIC SURVEY 2003

Draw: *Mogaard, J.O. & Mauring, E.*	Date: *AUGUST 2003*	Obs: JOM/JK

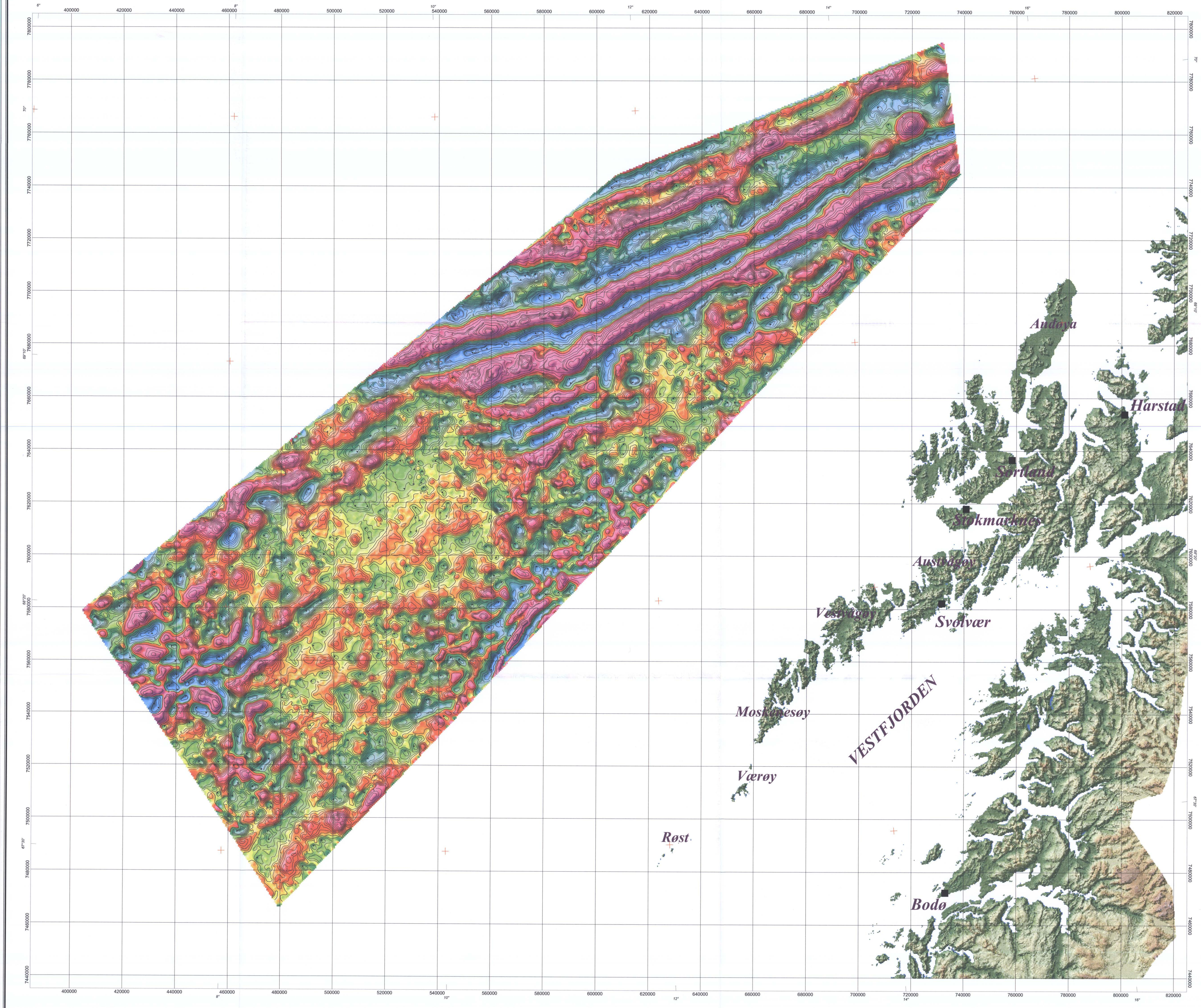
Scale 1:500 000

10000 0 10000 20000 30000

(meters)

GEOLOGICAL SURVEY OF NORWAY
Leiv Eirikssons vei 39
N-7491 TRONDHEIM
Tel +47 73 90 40 11, Fax +47 73 92 16 20
http://www.ngu.no

DRAWING: 2003.070-02



OLJEDIREKTORATET

STATOIL

N

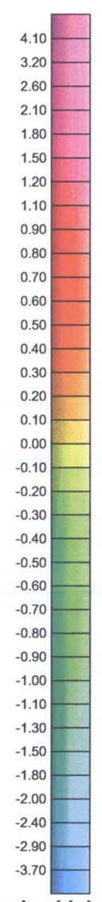
5 KM HIGH PASS GAUSSIAN FILTERED MAG:

5 km high pass Gaussian filtered mag. (in nanoTeslas) calculated from magnetic total field

Contours given in following intervals:

0.1 nT
0.5 nT
2.5 nT

Colours - distributed after colourscale.



5 km Gaussian highpass filter
nT

GEODETIC DATUM: WGS84
CONFORM CYLINDER PROJECTION
UTM coordinates, zone 32

RAS-03

5 KM GAUSSIAN HIGH PASS FILTERED GRID

RØST BASIN AEROMAGNETICS 2003

Draw: *Mogaard, J.O. & Mauring, E.*	Date: *AUGUST 2003*	Obs: JOM/JK
Scale 1:500 000 10000 0 10000 20000 30000 (meters)		

NGU Geology for Society since 1858
GEOLOGICAL SURVEY OF NORWAY
Leiv Eirikssons vei 39
N-7491 TRONDHEIM
Tel +47 73 90 40 11, Fax +47 73 92 16 20
http://www.ngu.no

DRAWING: 2003.070-03

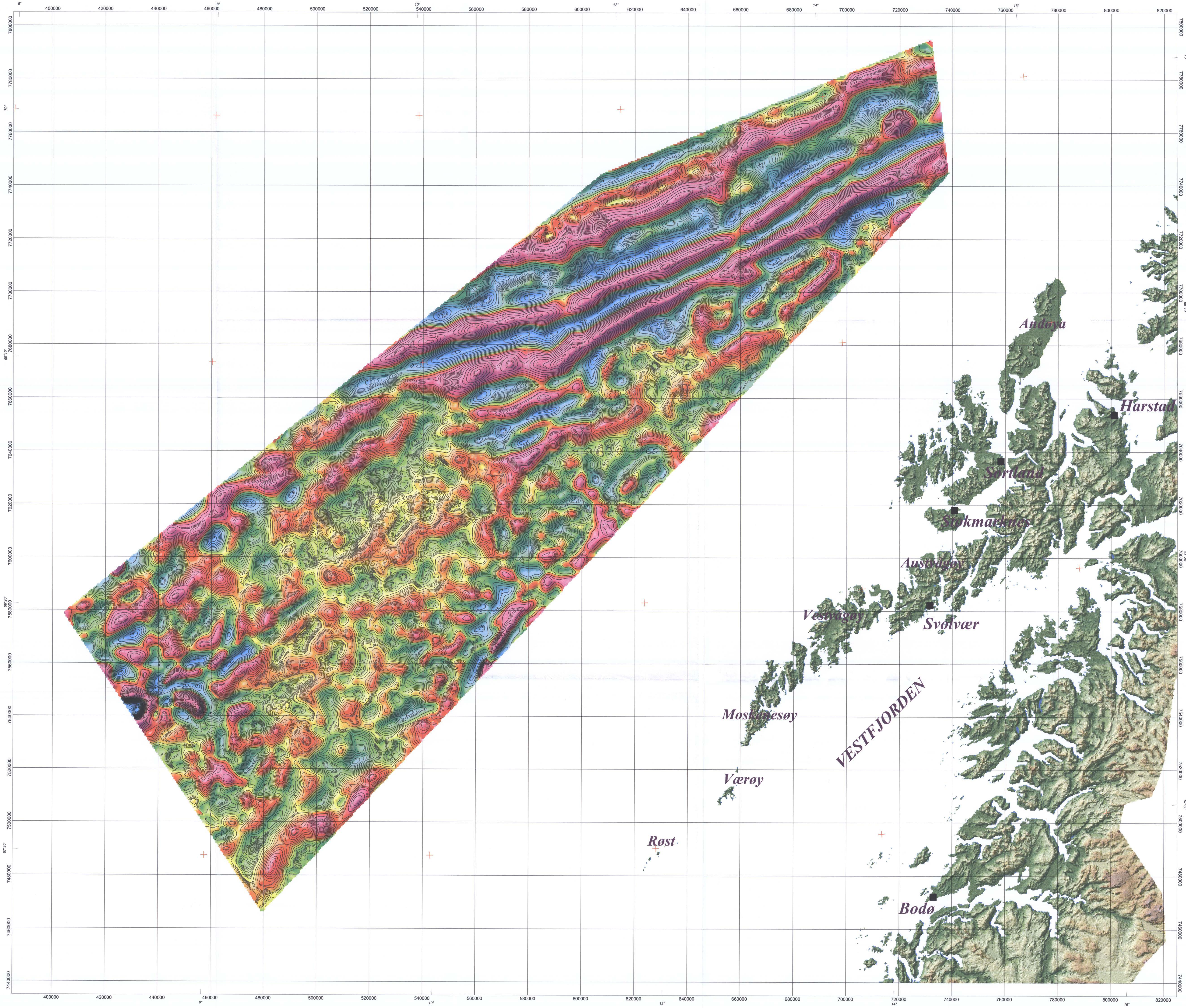
NGU
Geology for Society since 1858

bp

OLJEDIREKTORATET

HYDRO

STATOIL



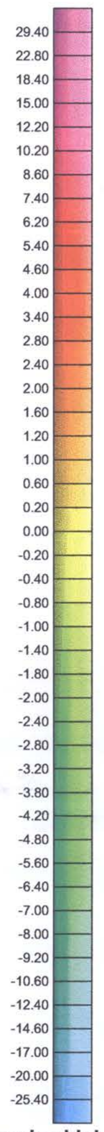
15 KM HIGH PASS GAUSSIAN FILTERED MAG:

15 km high pass Gaussian filtered mag. (in nanoTeslas) calculated from magnetic total field

Contours given in following intervals:

0.2 nT
1.0 nT
5.0 nT

Colours - distributed after colourscale.



15 km Gaussian highpass filter
nT

GEODETIC DATUM: WGS84
CONFORM CYLINDER PROJECTION
UTM coordinates, zone 32

RAS-03

15 KM GAUSSIAN HIGH PASS FILTERED GRID

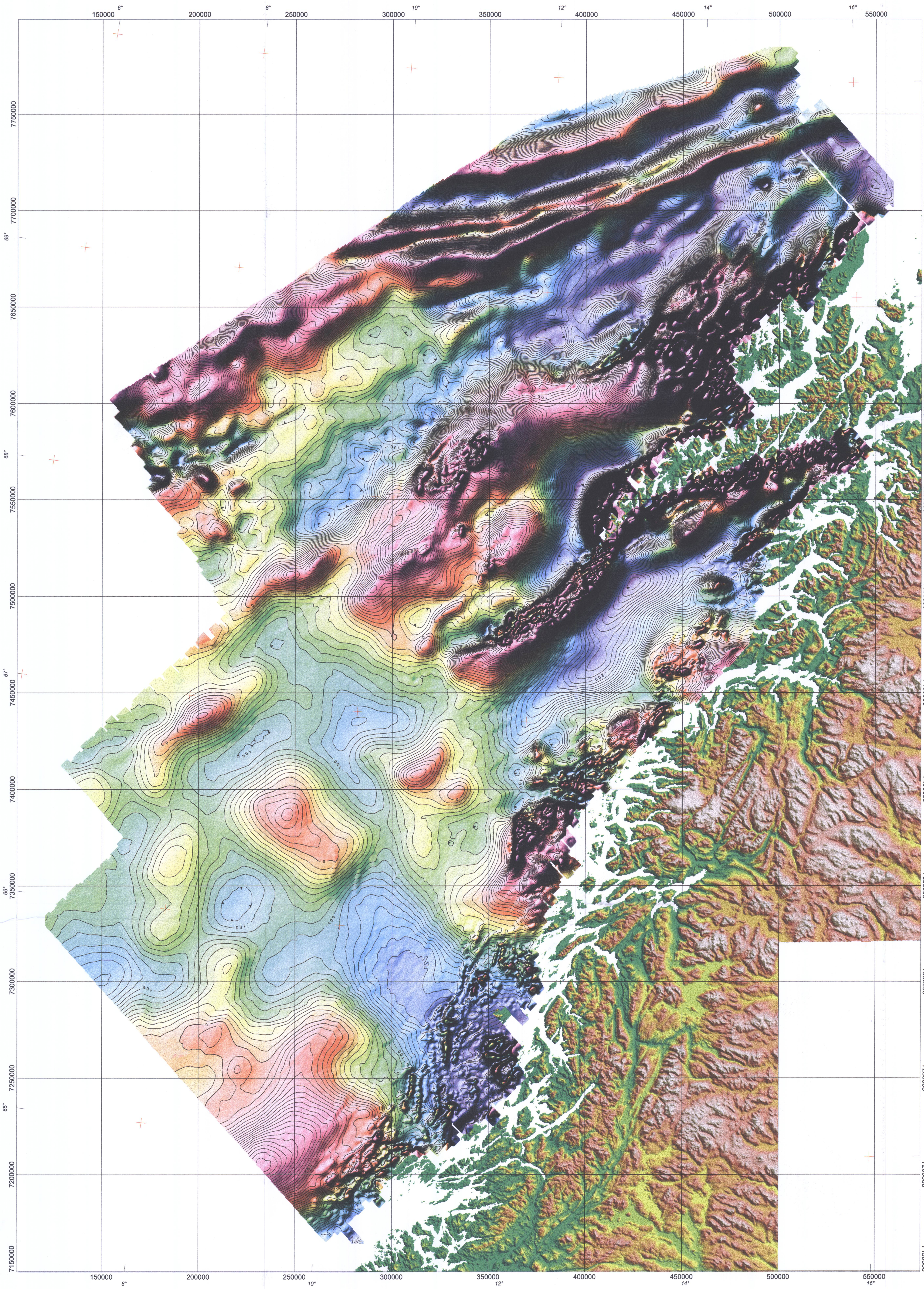
RØST BASIN AEROMAGNETICS 2003

Draw: *Mogaard, J.O. & Mauring, E.*	Date: *AUGUST 2003*	Obs: JOM/JK

Scale 1:500 000
10000 0 10000 20000 30000
(meters)

NGU Geology for Society since 1858
GEOLOGICAL SURVEY OF NORWAY
Leiv Eirikssons vei 39
N-7491 TRONDHEIM
Tel +47 73 90 40 11, Fax +47 73 92 16 20
http://www.ngu.no

DRAWING:
2003.070-04



NGU
Geology for Society since 1858

bp

OLJEDIREKTORATET

HYDRO

STATOIL

MAGNETIC TOTAL FIELD

The intensity of the total magnetic field is in nanoTesla.

Contours given in following intervals:

10nT
100nT
500nT

Colours - distributed after colourscale.

470
300
230
180
160
130
110
90
80
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-200
-220
-240
-280

Magnetic total field
nT

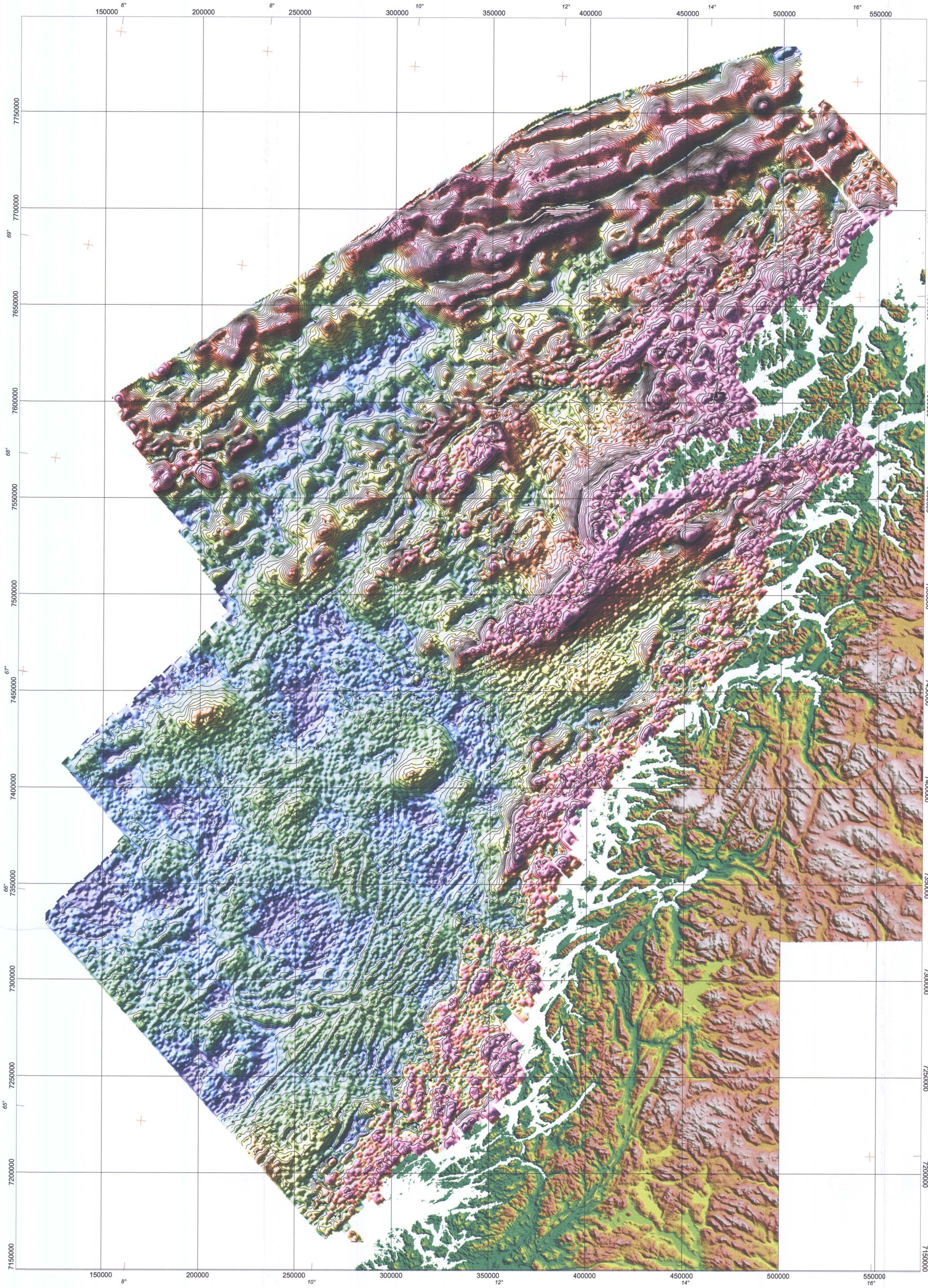
Scale 1:1000000

20000 0 20000 40000 60000

metres

ED50 / UTM zone 33N

Ra 3 COMPILATION		
MAGNETIC TOTAL FIELD ***COMPILATION OF SURVEYS LAS-89, NAS-94, VAS-98, RAS-03***		
Draw: *Mauring, E.*	Date: *AUGUST 2003*	Obs: JOM/JK
NGU Geology for Society since 1858 — GEOLOGICAL SURVEY OF NORWAY, Leiv Eirikssons vei 39, N-7491 TRONDHEIM, Tel +47 73 90 40 11, Fax +47 73 92 16 20, http://www.ngu.no		DRAWING: 2003.070-05



NGU
Geology for Society since 1858

bp

OLJEDIREKTORATET

HYDRO

STATOIL

ANALYTIC SIGNAL

Analytic signal (in NanoTeslas per meter).
Calculated from the total field magnetics.
Contours given in following intervals:

0.002nT/m
0.01nT/m
0.05nT/m

Colours - distributed after colourscale.

0.1790
0.1150
0.0830
0.0650
0.0540
0.0480
0.0430
0.0390
0.0360
0.0330
0.0310
0.0290
0.0270
0.0250
0.0240
0.0220
0.0210
0.0200
0.0190
0.0170
0.0160
0.0150
0.0140
0.0130
0.0120
0.0110
0.0100
0.0090
0.0080
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010

Analytic signal
(nT/m)

Scale 1:1000000

20000 0 20000 40000 60000
metres
ED50 / UTM zone 33N

Ra 3 COMPILATION

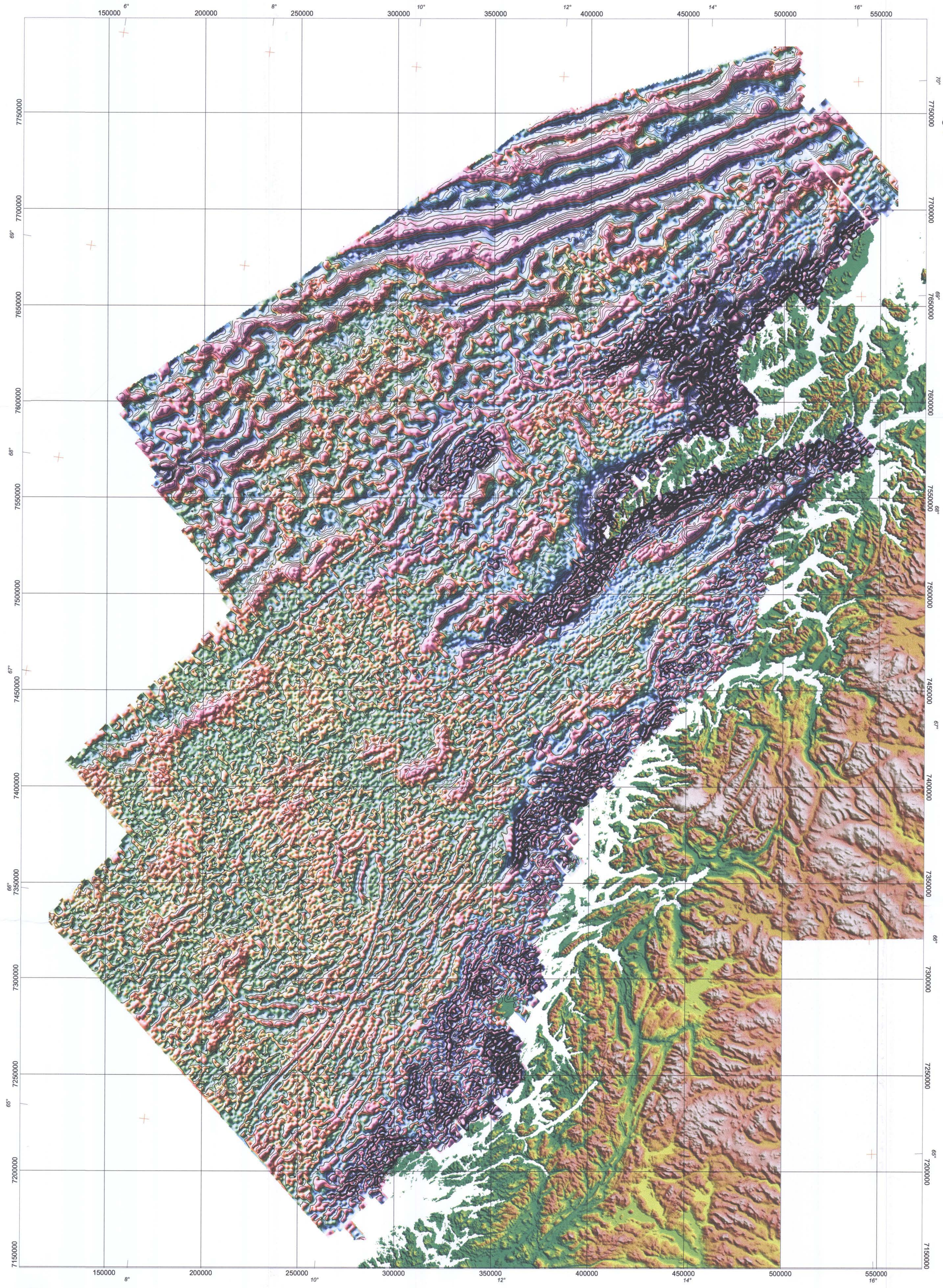
ANALYTIC SIGNAL

COMPILATION OF SURVEYS LAS-89, NAS-94, VAS-98, RAS-03

Draw: *Mauring, E.*	Date: *AUGUST 2003*	Obs: JOM/JK

NGU
Geology for Society since 1858
GEOLOGICAL SURVEY OF NORWAY
Leiv Eirikssons vei 39
N-7491 TRONDHEIM
Tel +47 73 90 40 11, Fax +47 73 92 16 20
http://www.ngu.no

DRAWING:
2003.070-06



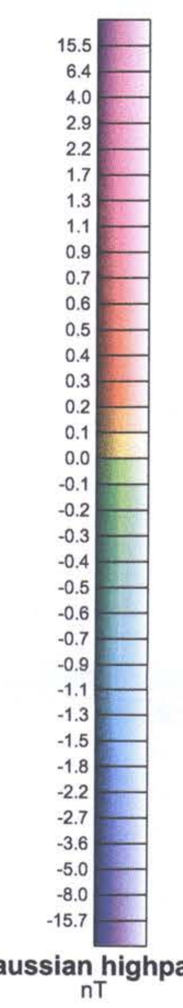
5 KM HIGH PASS FILTERED MAG

5 km high pass Gaussian filtered mag. calculated from magnetic total field.

Contours given in following intervals:

0.1 nT
0.5 nT
2.5 nT

Colours - distributed after colourscale.



5 km Gaussian highpass filter
nT

Scale 1:1000000

20000 0 20000 40000 60000
metres
ED50 / UTM zone 33N

Ra 3 COMPILATION

5 KM GAUSSIAN HIGH PASS FILTERED GRID

COMPILATION OF SURVEYS LAS-89, NAS-94, VAS-98, RAS-03

Draw: *Mauring, E.*	Date: *AUGUST 2003*	Obs: JOM/JK

GEOLOGICAL SURVEY OF NORWAY
Leiv Eirikssons vei 39
N-7491 TRONDHEIM
Tel +47 73 90 40 11, Fax +47 73 92 16 20
http://www.ngu.no

DRAWING: 2003.070-07

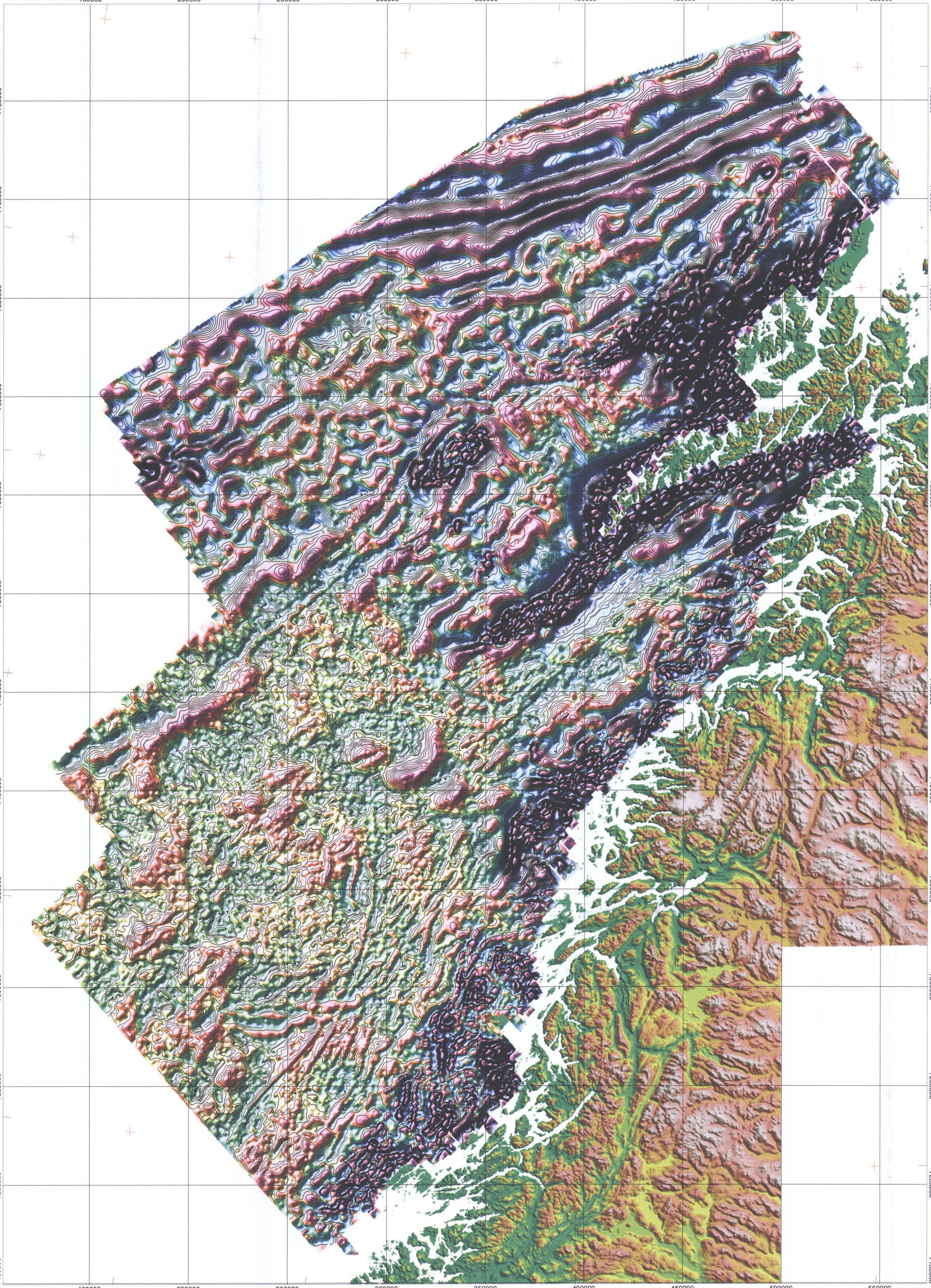
NGU
Geology for Society since 1858

bp

OLJEDIREKTORATET

HYDRO

STATOIL



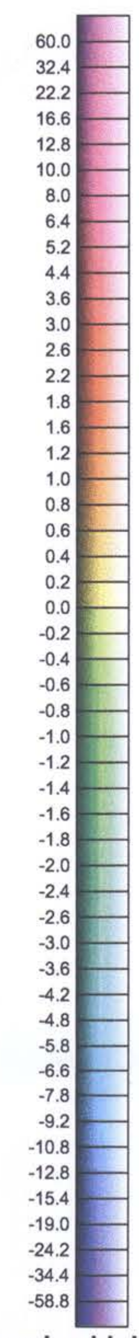
15 KM HIGH PASS FILTERED MAG

15 km high pass Gaussian filtered mag. calculated from magnetic total field.

Contours given in following intervals:

0.2 nT
1.0 nT
5.0 nT

Colours - distributed after colourscale.



15 km Gaussian highpass filter
nT

Scale 1:1000000

20000 0 20000 40000 60000
metres
ED50 / UTM zone 33N

Ra 3 COMPILATION

15 KM GAUSSIAN HIGH PASS FILTERED GRID

COMPILATION OF SURVEYS LAS-89, NAS-94, VAS-98, RAS-03

Draw: *Mauring, E.*	Date: *AUGUST 2003*	Obs: JOM/JK

NGU
Geology for Society since 1858
GEOLOGICAL SURVEY OF NORWAY
Leiv Eirikssons vei 39
N-7491 TRONDHEIM
Tel +47 73 90 40 11, Fax +47 73 92 16 20
http://www.ngu.no

DRAWING:
2003.070-08