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Tittel

Data Acquisition and Processing - Helicopter Geophysical Survey, Skjækerdalen 2006

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Mogaard, Jon Olav	10.05 2006	Sulfidmalm A/S NGU

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Fagområde	Dokument type	Forekomster (forekomst, gruvefelt, undersøkelsesfelt)
Geofysikk		Skjækerdalen nikkelforekomst, Dyrhaugen
Råstoffgruppe Malm/metall	Råstofftype Ni	

Sammendrag, innholdsfortegnelse eller innholdsbeskrivelse

Totalt 620 linjekm geofysikk ble fløyet med 100m linjeavstand med flyhoyde 60m.
EM-system som ble brukt var Hummingbird

CD ligger vedlagt med tekst og kart

NGU Report 2006.041
for
Sulfidmalm A/S

Data Acquisition and Processing –
Helicopter Geophysical Survey,
Skjaekerdalen, 2006
Nord-Troendelag county, Norway

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NGU Report 2006.041

Data Acquisition and Processing – Helicopter Geophysical Survey, Skjaekerdalen, 2006 Nord-Troendelag county, Norway

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Geological Survey of Norway
Geological Survey of Norway
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REPORT

Report no.: 2006.041 | ISSN 0800-3416 | Grading: Confidential until 10.05.2008

Title:
Data Acquisition and Processing - Helicopter Geophysical Survey, Sjaekerdalen, 2006, Nord-Troendelag county, Norway

Authors:
John Olav Mogaard

Client:
A/S Sulfidmalm

County:
Nord-Troendelag

Commune:
Verdal

Map-sheet name (M=1:250.000)
Trondheim

Map-sheet no. and -name (M=1:50.000)
1722 I Vuku

Deposit name and grid-reference
Tveitan 353200, 7082300

Number of pages: 11 Price (NOK):
Map enclosures:

Fieldwork carried out:	Date of report:	Project no.:	Person responsible:
April 2006	10.05.2006	2990.07	Jan S. Rønning

Summary:

In April 2006, a helicopter geophysical survey was carried out over Sjaekerdalen , Nord-Troendelag county. The purpose of the surveys was to provide geophysical information for mineral exploration. The data were collected and processed by the Geological Survey of Norway (NGU). A total of about 670 line-km of electromagnetic (EM) and magnetic data were acquired using a nominal 100-m line spacing. The nominal flying height was 60 m above ground level (AGL), and lines were flown in different alternating directions at headings of 141° and 321° Noise levels were within survey specifications.

All initial processing was carried out on a flight-by-flight basis. Magnetic data, consisting of total field measurements collected by a cesium vapor magnetometer, were corrected by removing diurnal variations as recorded at a magnetic base station in Verdal. EM data were leveled using data from frequent high altitude excursions 300-m AGL. All final processed data were gridded using 25-m cell size. Geophysical maps were produced at a scale of 1:50 000 and are considered as stand alone products.

This report covers aspects of data acquisition and processing.

Keywords: Geofysikk (Geophysics)		Magnetometri (Magnetometry)
Elektromagnetisk måling (Electromagnetic measurements)	Databehandling (Data processing)	Fagrapport (Technical report)

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Map 2006.041-04:	EM stacked profiles 7001 Hz coaxial.
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Map 2006.041-06:	EM stacked profiles 980 Hz coaxial.
Map 2006.041-07:	EM stacked profiles 880 Hz coplanar.
Map 2006.041-08:	EM stacked profiles 34133 Hz coplanar.
Map 2006.041-09:	EM apparent conductivity 7001 Hz coaxial.
Map 2006.041-10:	EM apparent conductivity 6606 Hz horizontal coplanar.

1 INTRODUCTION

As a contract work for AS Sulfidmalm, in April, 2006, a helicopter geophysical survey was carried out over parts of Skjaekerdalen, Nord-Troendelag county. The distances flown (with tie-lines) and areas covered are approx. 750 line-km and 70 km^2. See *fig. 1* for the outline of the area. Magnetic and electromagnetic (HEM) data were collected. The primary objective of the survey was to provide geophysical information for mineral prospecting in the area.

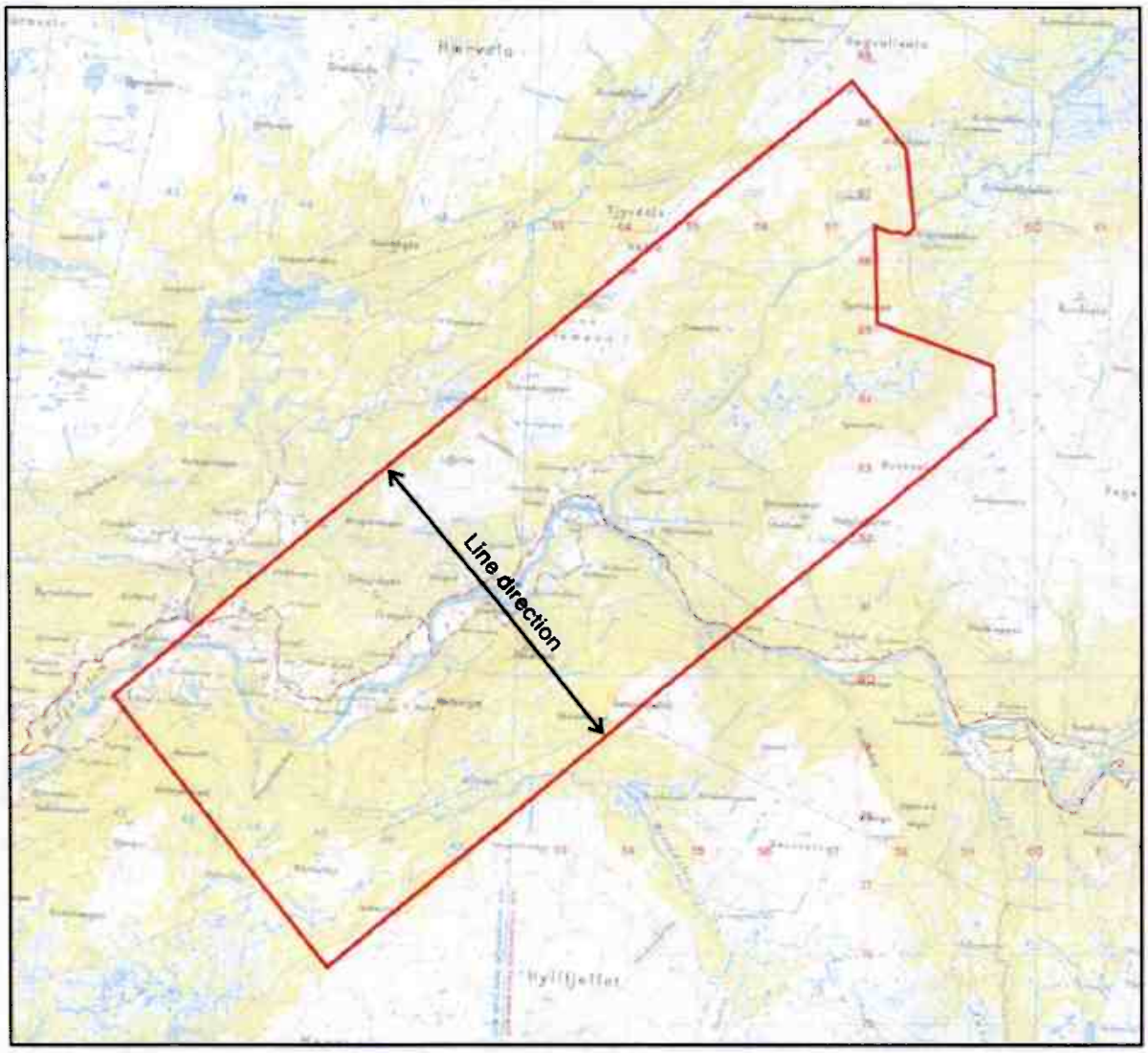

Fig. 1: Outline of the Skjaekerdalen area (flight direction 141/321°).

2 SURVEY VARIABLES AND CONDITIONS

Several conditions may influence on the quality of the geophysical data.

2.1 Weather conditions

Strong wind can increase the noise level of airborne geophysical data. High winds were not frequent during the survey, but were encountered occasionally. No data were acquired during unacceptable wind conditions.

2.2 Topographic conditions

The resolution of geophysical sensors decreases exponentially with flying height. To achieve the greatest possible resolution, the helicopter should be flown as low as is safely possible. The topography in the area are varying from fairly flat to quite steep and it is difficult to keep a constant terrain clearance during flying. The surveys were flown using a helicopter strong enough to climb the hills but in spite of this, data are effected by altitude differences uphill and downhill. As a consequence of this it was very difficulte to drape the terrain with the bird 30 +/- 10 meters above ground as specified in the contract.

2.3 Magnetic conditions

Diurnal changes in the earth's magnetic field affect magnetic data. The base station magnetic field never indicated variations close to the project maximum acceptable values during the survey. Magnetic data quality on all lines used for production is very good.

2.4 EM data conditions

Strong vertical temperature gradients can affect EM leveling because the temperature at the 300-m nulling altitude is different from the temperature at survey altitude (30 m above ground level for the EM sensor). In addition to this, measuring at different altitudes may cause nonlinear drift effects along profiles. Drift effects between nulling points are corrected using standard linear interpolation. EM drift is characterized as low.

The target flying height is 60 meters above ground level. Due to the severe terrain, flying height varied considerably in the present survey. This effected both the magnetic and the electromagnetic datasets.

In general EM signals are high in the area, and producing conductivity maps were fairly simple. The quality of the EM data can be characterized as good.

3 DATA ACQUISITION

The survey aircraft was an Aerospatial Ecureuil AS 350 B-2. Flying speed was approximately 100 km per hour (28 meters per second). Flight lines were flown in directions 141°/321° with a flight line spacing of 100 m . In addition a six tie-lines were measured. The 5-frequency EM system and the magnetometer were enclosed in a 6-m long 'bird' suspended by cable 30m beneath the helicopter.

NGU personnel responsible for data acquisition were John Olav Mogaard and Janus Koziel. Pilots from HELITRANS AS was Jens Fjelnset .

3.1 Magnetic measurements

A Scintrex CS-2 cesium vapor magnetometer was used. The magnetometer resolution is 0.01 nT. Sampling rate is 10 measurements per second (approximately 3 meter spacing).

A Scintrex ENVI-mag proton precession magnetometer was located at the base in Verdal, and was used for base station measurements. The base station magnetometer was synchronized with the Scintrex magnetometer in the helicopter to ensure proper removal of diurnal magnetic changes from the helicopter magnetic measurements. The magnetic total field at the base station was digitally recorded during flights every third second.

3.2 Electromagnetic system

The EM system used was the 5-frequency Hummingbird system made in Canada by Geotech, Ltd. The Hummingbird records data at a sampling rate of 10 measurements per second. It has two coil orientations, vertical coaxial (VCA) and horizontal coplanar (HCP). The VCA coils operate at 980 Hz and 7001 Hz. The HCP coils operate at 880 Hz, 6606 Hz, and 34133 Hz. The transmitter-receiver separation is 6 m for lower frequencies and 4.2 m for 34133 Hz. The manufacturer specified noise level for each frequency is 1-2 ppm.

3.3 Navigation, altimetry, and data logging

The navigation system used is an Ashtech G12, 12 channel receiver. Position accuracy using this system is better than +/- 5 m.

The navigation console is a PNAV 2001 manufactured by the Picodas Group, Ltd. of Canada. Profile line data are entered into the console and are displayed on a left/right-display on the console. The pilot can see his position with respect to these predefined lines and adjust accordingly.

The helicopter is equipped with a King KRA-430 radar altimeter measuring height above ground level. The altimeter data is recorded digitally and altitude is displayed in front of the pilot. The altimeter is accurate to 5 percent of the true flying height. Unfortunately data are strongly affected when flying over dense forest. In these cases, altitude data are adjusted using an interpolating technique.

The data logging system is an integral part of the Hummingbird electromagnetic system, manufactured by Geotech, Ltd. of Canada. Data is recorded both digitally and analog.

4 PROCESSING

The data were processed at the Geological Survey of Norway in Trondheim using Geosoft processing software (Geosoft Oasis Montaj 6.2, 2005).
Obvious inaccuracies in navigation were manually removed from the data. The datum used was WGS84 and the projection was UTM zone 33.

4.1 Standard processing

Total field magnetic data: The data were inspected flight-by-flight and any cultural anomalies were identified and manually removed. A base station correction was applied to each flight using corrections based on the diurnal measurements from the base station magnetometer at the base in Verdal. Finally a time lag of 0.6 sec (6 points) were applied to the basemag-corrected (levelled) magnetic data. Vertical magnetic gradient was calculated from the total magnetic field by applying a first order derivation filter to the data.

EM data: EM data were processed on a flight-by-flight basis. Zero levels and drift control for each frequency were obtained by frequent excursions 300m AGL, usually at the end of every second flight line. A nonlinear filter was applied to all EM data to remove data spikes resulting from sferics. Before levelling, all data were mildly low passed filtered using a 45 m

filter. Noise levels for all frequencies were within an envelope of 2 ppm. Noise levels above 2 ppm occurred near a powerline crossing the area. A huge military radio transmitter located at Rinnleiret, Verdal seemed to affect the 33 khz frequency. A manually levelling on a line by line basis were done for the two frequencies used for apparent resistivity calculation. Magnetic structures having high susceptibility may produce negatively oriented in-phase anomalies. A time lag of 0.5 sec (5 points) were applied to all channels before plotting of maps.

4.2 Map Production

Magnetic maps in scale 1: 50 000, total magnetic field and first vertical derivative, were produced using a grid cell size of 25 x 25 metres. The problems in keeping a correct flying height in parts of the area, created some leveling problems. These were significant on a first version of the contour maps, and were corrected for without ruining the information in the data using median micro-leveling procedures created at the NGU (Mauring & Kihle 2000). The 1D filter radius (along the lines) was 250 m and the 2D filter radius (circular window) was 350 m. The contoured color maps are produced with a shaded relief of the high frequency content. In agreement with the clients representative, magnetic measurements outside the predefined area was kept in the magnetic maps. Flying height and profile separation may be out of specifications and as a result lower data quality.

As a standard, stacked profiles of all EM frequencies in scale 1: 50 000 were produced following standard procedures. Based on quadrature data, apparent resistivity was computed for 6606 Hz coplanar and 7001 Hz coaxial using least squares inversion and a homogeneous half space model (Geosoft 1997). In agreement with the clients representative, conductivity maps were produced using 6606 Hz coplanar and 7001 Hz coaxial frequencies.

5 DATA DELIVERIES

The following stand alone maps in scale 1: 50 000 are produced and delivered to the client as printed maps:

- **Map 2006.041-01:** Flight path.
- **Map 2006.041-02:** Total magnetic field.
- **Map 2006.041-03**: First vertical derivative of magnetic total field.
- **Map 2003.001-04:** EM stacked profiles 7001 Hz coaxial.
- **Map 2006.041-05:** EM stacked profiles 6606 Hz coplanar.
- **Map 2006.041-06:** EM stacked profiles 980 Hz coaxial.
- **Map 2006.041-07:** EM stacked profiles 880 Hz coplanar.
- **Map 2006.041-08:** EM stacked profiles 34133 Hz coplanar.
- **Map 2006.041-09:** EM apparent conductivity 7001 Hz coaxial.
- **Map 2006.041-10:** EM apparent conductivity 6606 Hz coplanar

These maps are also delivered on DVD in Geosoft packed maps format.

Digital magnetic and electromagnetic data in Geosoft XYZ file formats and grid files of these data are delivered on DVD as described in Appendix A.

6 REFERENCES

Geosoft Inc., 2005: OASIS montaj Version 6.2 User Guide, *Geosoft Incorporated, Toronto.*

Geosoft Inc.: 1997: HEM System (Windows®95 & NT™) User Guide, *Geosoft Incorporated*

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

Appendix A: Data delivery formats.

Geosoft XYZ file formats.
Final Delivery on DVD

File: MAGSJAKER.XYZ (including tielines)

x_filt	meters	Final processed x (masked to the extended area polygon)
y_filt	meters	Final processed y (masked to the extended area polygon)
mag_final	nT	Levelled and time-lagged magnetic data (0.5 sec)
mag_final_1D	nT/m	Calculated vertical gradient (first derivative)

File: EMSJAKER.XYZ

x_filt	meters	Final processed x (masked to the area polygon)		
y_filt	meters	Final processed y (masked to the area polygon)		
recnum		Internal record number		
UTCtime		Universal time Hours: Minutes: Seconds. Decimal_seconds		
bird_height_m	meters	Processed radar altimeter data minus 30 meter (bird height)		
IP1_f_L_lag	ppm	Filtered, leveled and lagged	inphase	7001 Hz Coaxial
Q1_f_L_lag	ppm		quadrature	7001 Hz Coaxial
IP2_f_L_lag	ppm		inphase	6606 Hz Coplanar
Q2_f_L_lag	ppm		quadrature	6606 Hz Coplanar
IP3_f_L_lag	ppm		inphase	980 Hz Coaxial
Q3_f_L_lag	ppm		quadrature	980 Hz Coaxial
IP4_f_L_lag	ppm		inphase	880 Hz Coplanar
Q4_f_L_lag	ppm		quadrature	880 Hz Coplanar
IP5_f_L_lag	ppm		inphase	33133 Hz Coplanar
Q5_f_L_lag	ppm		quadrature	33133 Hz Coplanar
cond6606_final	mS-m	Apparent conductivity (6606 Hz coplanar)		
cond7001_final	mS-m	Apparent conductivity (7001 Hz coaxial)		

The following Geosoft grid files are copied to the DVD :

mag_final.grd	Micro levelled magnetic grid (circular median filter) used in map (25 m cell size)
mag_final_1D.grd	Calculated vertical gradient grid used in map based on the final magnetic grid file .
cond6606_final.grd	Final conductivity grid file used in map after micro levelling 6606 Hz coplanar freq. (25 m cell size)
cond7001_final.grd	Final conductivity grid file used in map after micro levelling 7001 Hz coaxial freq. (25 m cell size)

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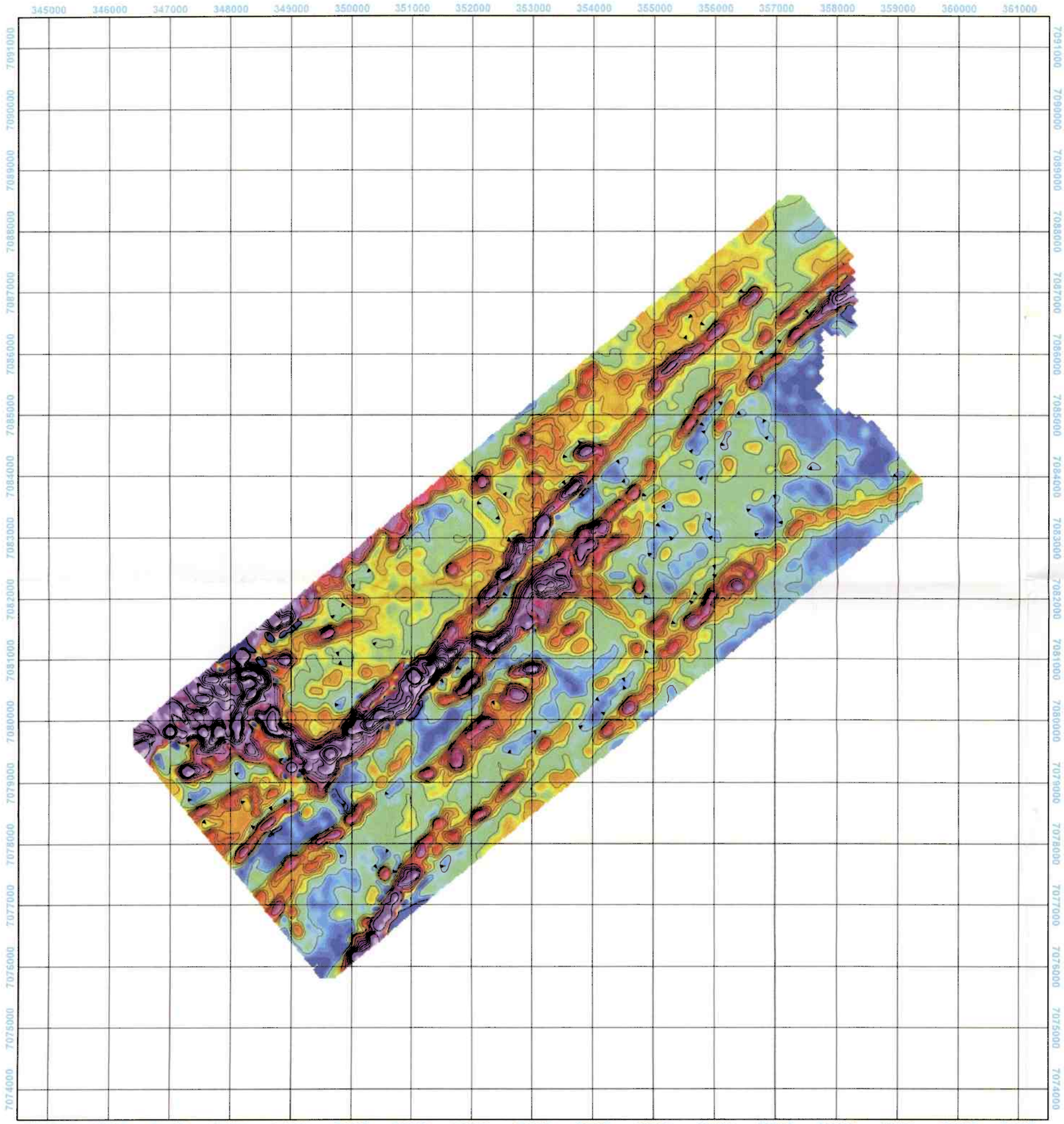
http://www.ngu.no

Trykkerihuset Skipnes, 73 82 63 00



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APPARENT CONDUCTIVITY

Calculated from 6606 horizontal coplanar response.

Contours: given in following intervalls (mS/m)

0.2
1.0
2.0
10.0

Colours - distributed after colourscale.

Sensor elevation - 30 meters.

NAVIGATION

The entire area was covered by GPS navigation.

The nominal flying height above ground level in the area is 60 metres.

A/S SULFIDMALM

EM APPARENT CONDUCTIVITY 6606 Hz H. Coplanar

Colours and contours

Sjækerdalen

Nord-Trøndelag

Drawing: *Mogaard,J.O.*	Date: *APR2006*	Obs: *JOM/JK*
Scale 1:50 000 1000 0 1000 2000 3000 (metres)		Mapsheet (1:50 000): *1722 I Vuku*

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http://www.ngu.no

Drawing no:
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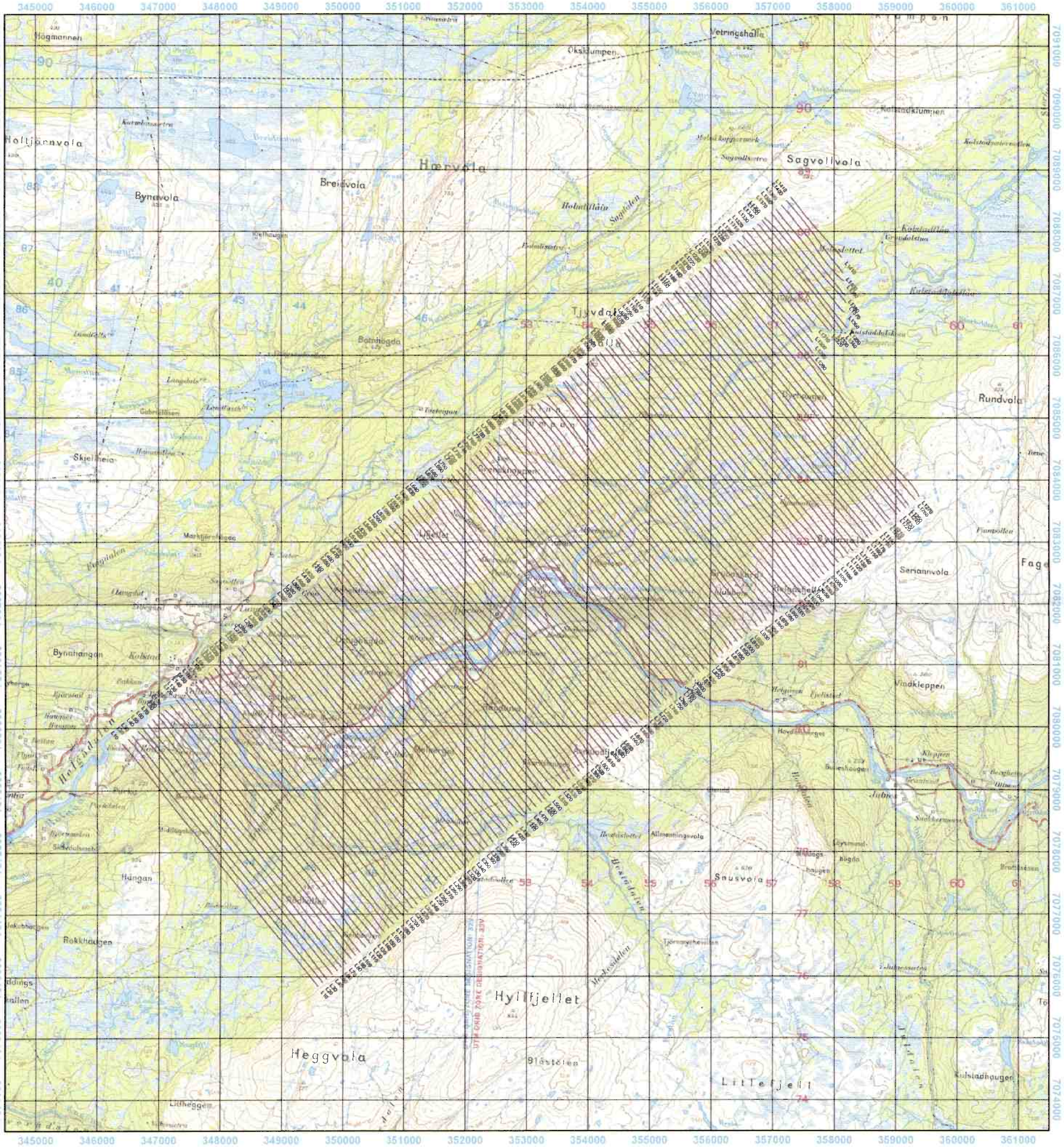

GEODETIC DATUM: WGS84
CONFORM CYLINDERPROJECTION
Numbers in BLUE for UTM coordinates, zone 32N

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NAVIGATION

The entire area was covered by GPS navigation.

The nominal flying height above ground level in the area is 60 metres.

A/S SULFIDMALM

FLIGHTPATH

Sjækerdalen

Nord-Trøndelag

Drawing: *Mogaard,J.O.*	Date: *APR2006*	Obs: *JOM/JK*	
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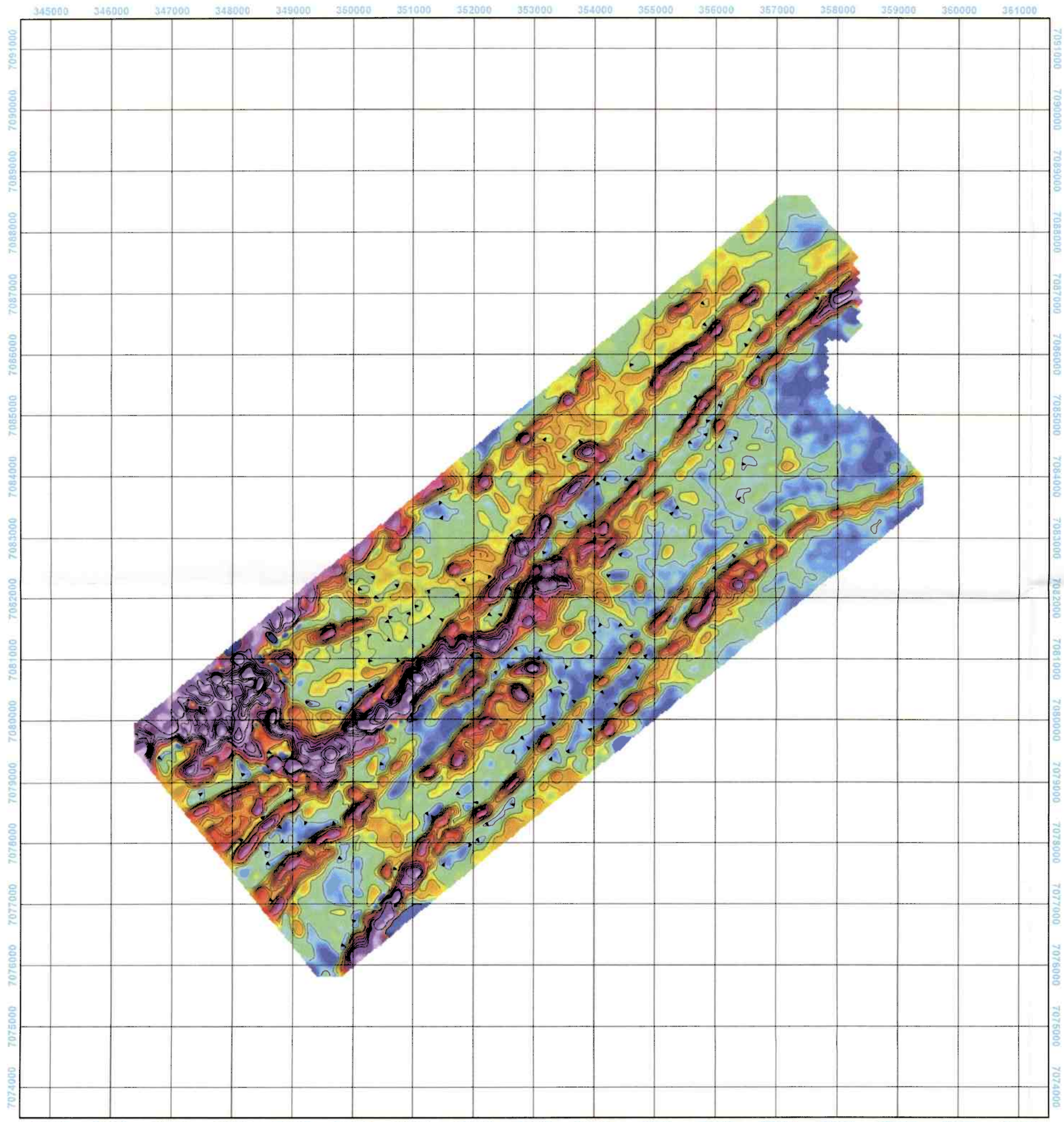
Drawing no: **2006.041-01**



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N

APPARENT CONDUCTIVITY

Calculated from 7001 Hz coaxial response.

Contours: given in following intervalls (mS/m)

0.2
1.0
2.0
10.0

Colours - distributed after colourscale.

Sensor elevation - 30 meters.

NAVIGATION

The entire area was covered by GPS navigation.

The nominal flying height above ground level in the area is 60 metres.

A/S SULFIDMALM

EM APPARENT CONDUCTIVITY 7001 Hz Coaxial

Colours and contours

Sjækerdalen

Nord-Trøndelag

Drawing: *Mogaard,J.O.*	Date: *APR2006*	Obs: *JOM/JK*

Scale 1:50 000

1000 0 1000 2000 3000

(metres)

Mapsheet (1:50 000):

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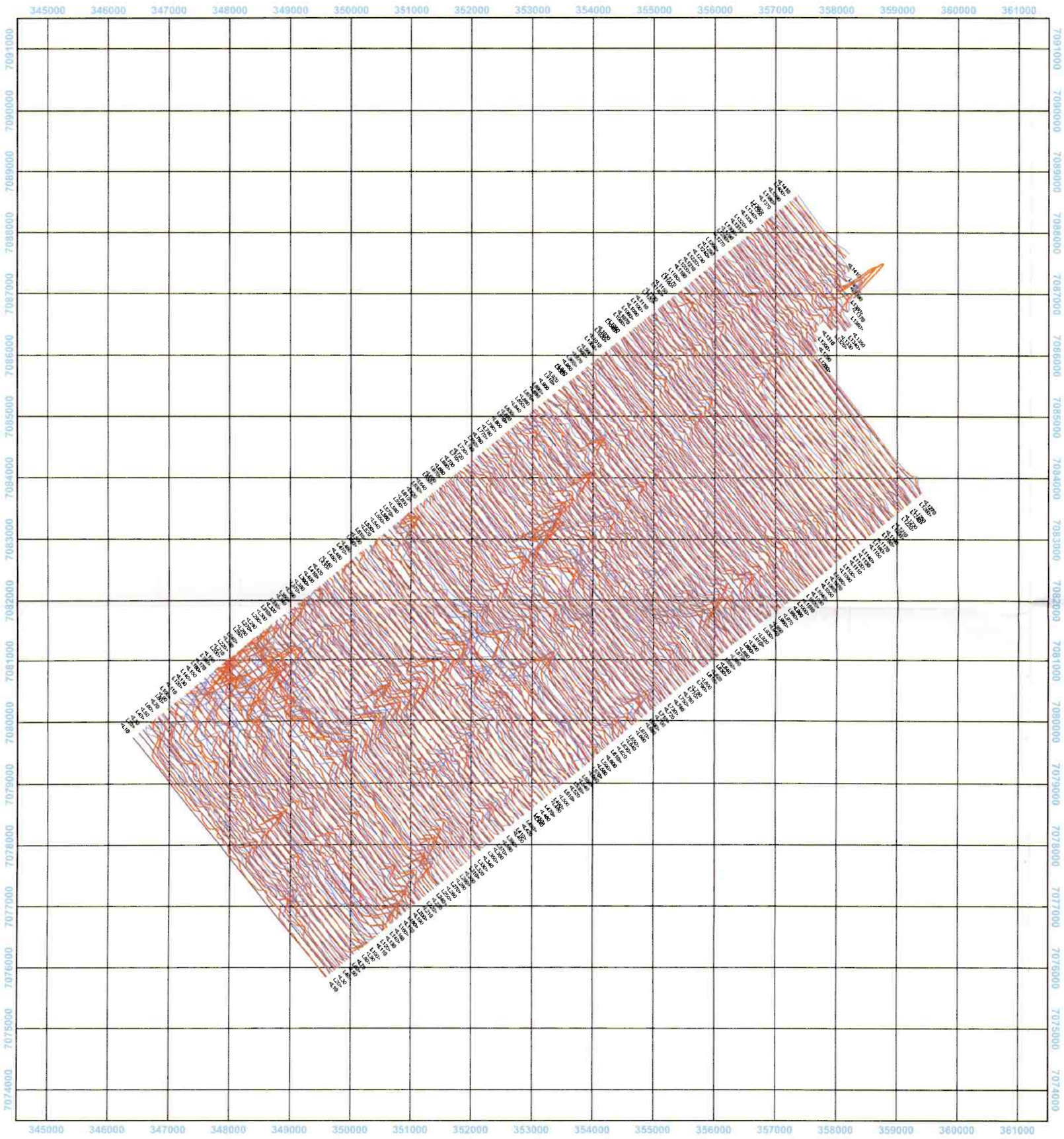
Drawing no:

2006.041-09



GEODETIC DATUM: WGS84
CONFORM CYLINDERPROJECTION
Numbers in BLUE for UTM coordinates, zone 33N

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N

HEM 34133 Hz COPLANAR

Frequency : 34133 Hz (horizontal, coplanarorientation)
Coil spacing : 4.2 m

InPhase
Quad.

Inphase : 20 ppm/mm
Quadrature : 20 ppm/mm

NAVIGATION

The entire area was covered by GPS navigation.

The nominal flying height above ground level in the area is 60 metres.

A/S SULFIDMALM

HEM STACKED PROFILES 34133 Hz COPLANAR

Sjækerdalen

Nord-Trøndelag

Drawing: *Mogaard,J.O.*	Date: *APR2006*	Obs: *JOM/JK*

Scale 1:50 000

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(metres)

Mapsheet (1:50 000):

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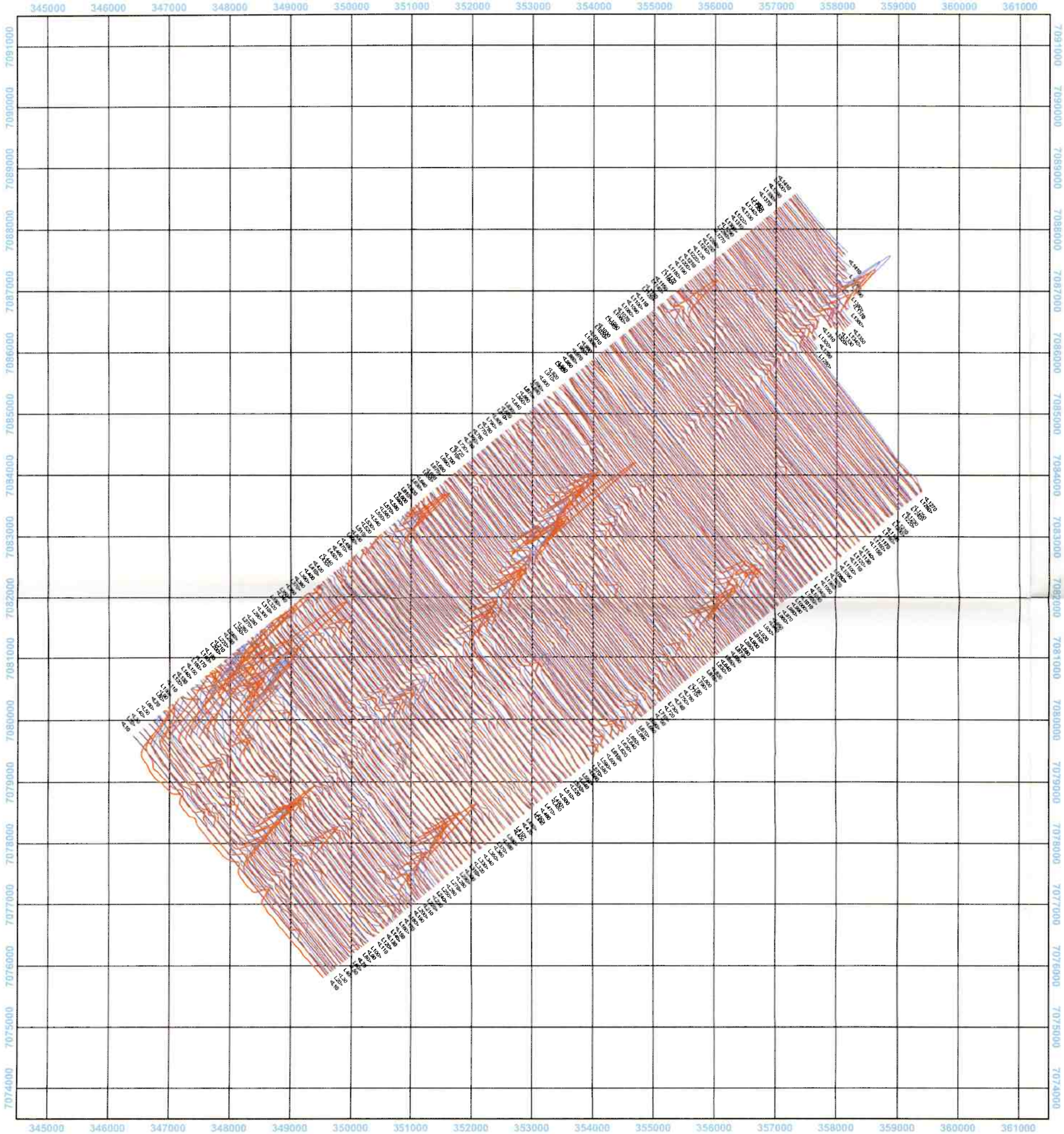

GEODETIC DATUM: WGS84
CONFORM CYLINDERPROJECTION
Numbers in BLUE for UTM coordinates, zone 33N

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Geology for Society since 1858

N

HEM 880 Hz COPLANAR

Frequency : 880 Hz (horizontal, coplanarorientation)
Coil spacing : 6 m

InPhase
Quad.

Inphase : 10 ppm/mm
Quadrature : 10 ppm/mm

NAVIGATION

The entire area was covered by GPS navigation.

The nominal flying height above ground level in the area is 60 metres.

A/S SULFIDMALM

HEM STACKED PROFILES 880 Hz COPLANAR

Sjækerdalen

Nord-Trøndelag

Drawing: *Mogaard,J.O.*	Date: *APR2006*	Obs: *JOM/JK*
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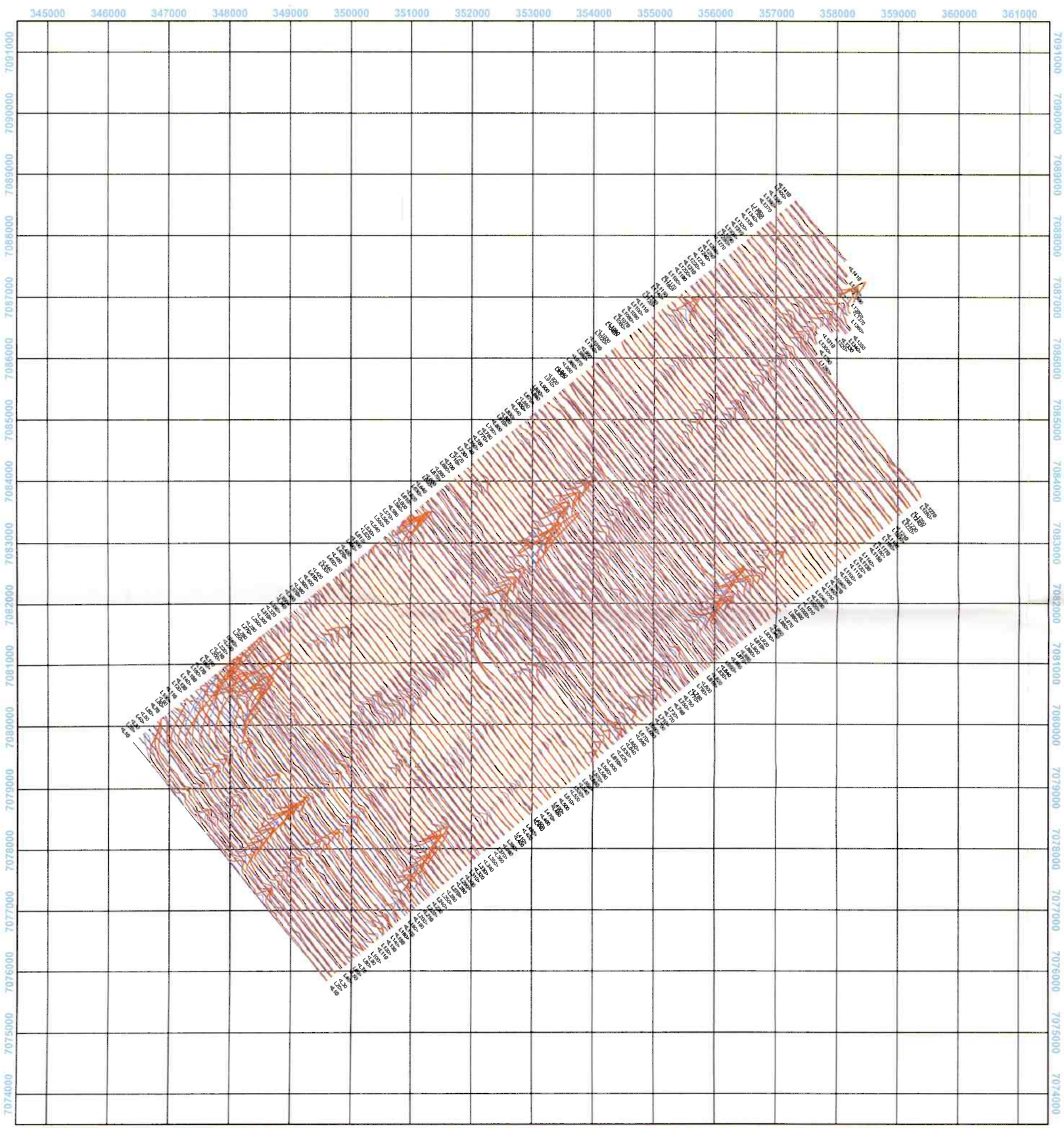

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Numbers in BLUE for UTM coordinates, zone 33N

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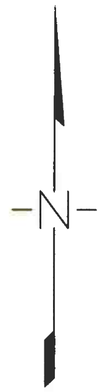

HEM 980 Hz COAXIAL

Frequency : 980 Hz (coaxial orientation)
Coil spacing : 6 m

InPhase
Quad.

Inphase : 5 ppm/mm
Quadrature : 5 ppm/mm

NAVIGATION

The entire area was covered by GPS navigation.

The nominal flying height above ground level in the area is 60 metres.

A/S SULFIDMALM

HEM STACKED PROFILES 980 Hz COAXIAL

Sjækerdalen

Nord-Trøndelag

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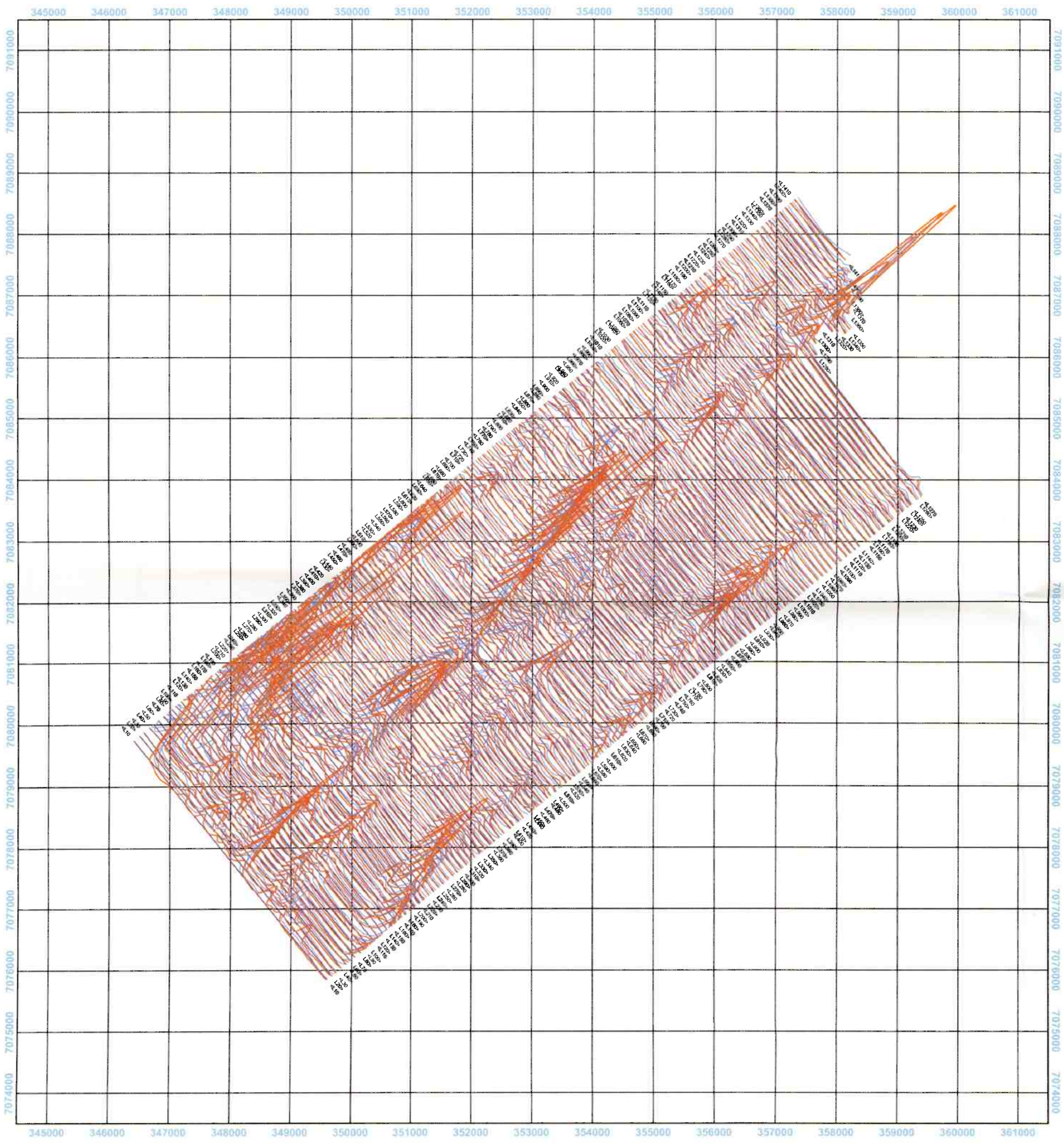

GEODETIC DATUM: WGS84
CONFORM CYLINDERPROJECTION
Numbers in BLUE for UTM coordinates, zone 33N

NGU
Geology for Society since 1858

N

HEM 6606 Hz COPLANAR

Frequency : 6606 Hz (horizontal, coplanarorientation)
Coil spacing : 6 m

InPhase
Quad.

Inphase : 10 ppm/mm
Quadrature : 10 ppm/mm

NAVIGATION

The entire area was covered by GPS navigation.

The nominal flying height above ground level in the area is 60 metres.

A/S SULFIDMALM

HEM STACKED PROFILES 6606 Hz COPLANAR

Sjækerdalen

Nord-Trøndelag

Drawing: *Mogaard,J.O.*	Date: *APR2006*	Obs: *JOM/JK*

Scale 1:50 000

1000 0 1000 2000 3000

(metres)

Mapsheet (1:50 000):

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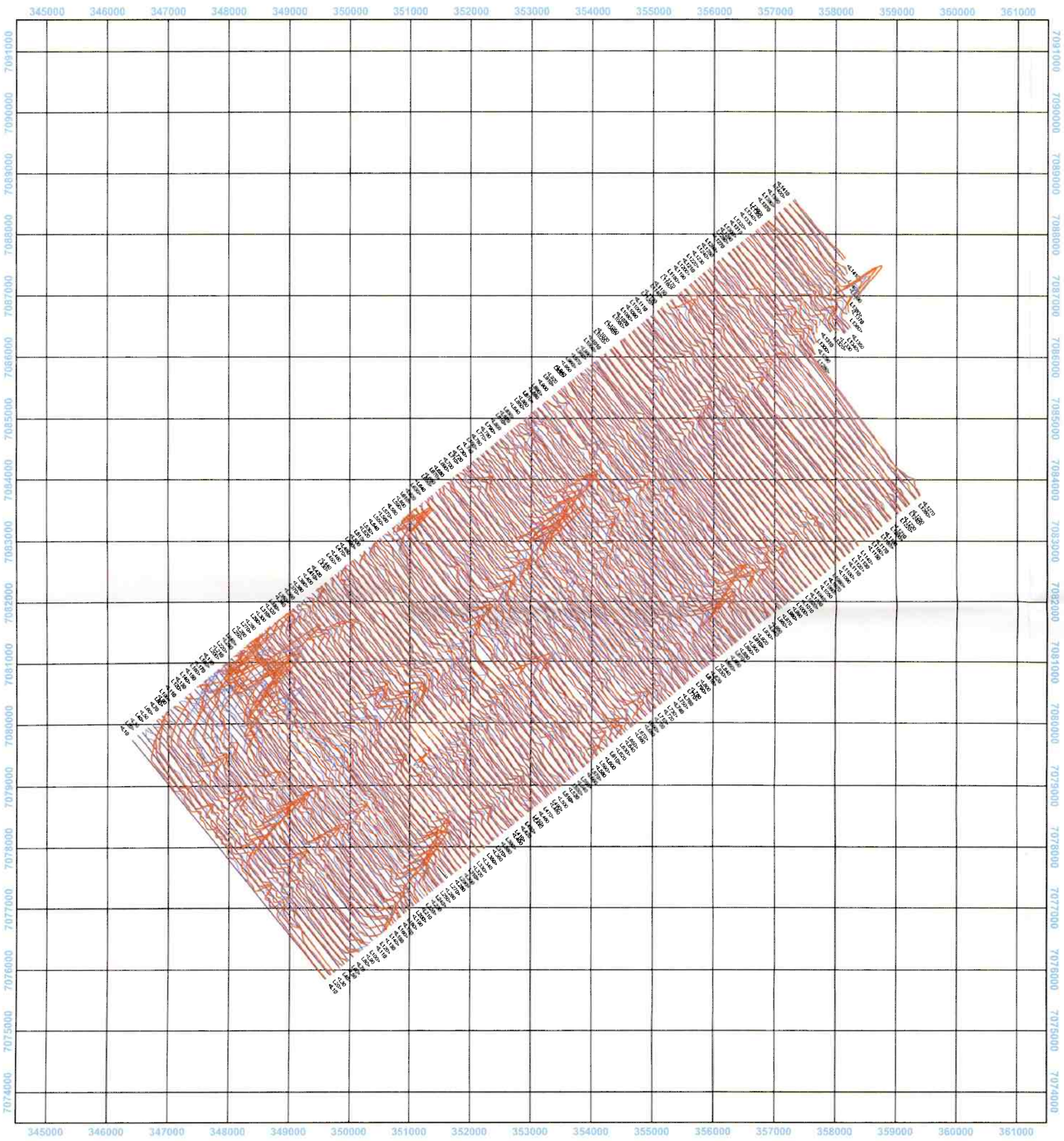
Drawing no:

2006.041-05



GEODETIC DATUM: WGS84
CONFORM CYLINDERPROJECTION
Numbers in BLUE for UTM coordinates, zone 33N

NGU
Geology for Society since 1858

N

HEM 7001 Hz COAXIAL

Frequency : 7001 Hz (coaxial orientation)
Coil spacing : 6 m

InPhase
Quad.

Inphase : 5 ppm/mm
Quadrature : 5 ppm/mm

NAVIGATION

The entire area was covered by GPS navigation.

The nominal flying height above ground level in the area is 60 metres.

A/S SULFIDMALM

HEM STACKED PROFILES 7001 Hz COAXIAL

Sjækerdalen

Nord-Trøndelag

Drawing: *Mogaard,J.O.*	Date: *APR2006*	Obs: *JOM/JK*
Scale 1:50 000 1000 0 1000 2000 3000 (metres)		**Mapsheet (1:50 000):** *1722 I Vuku*

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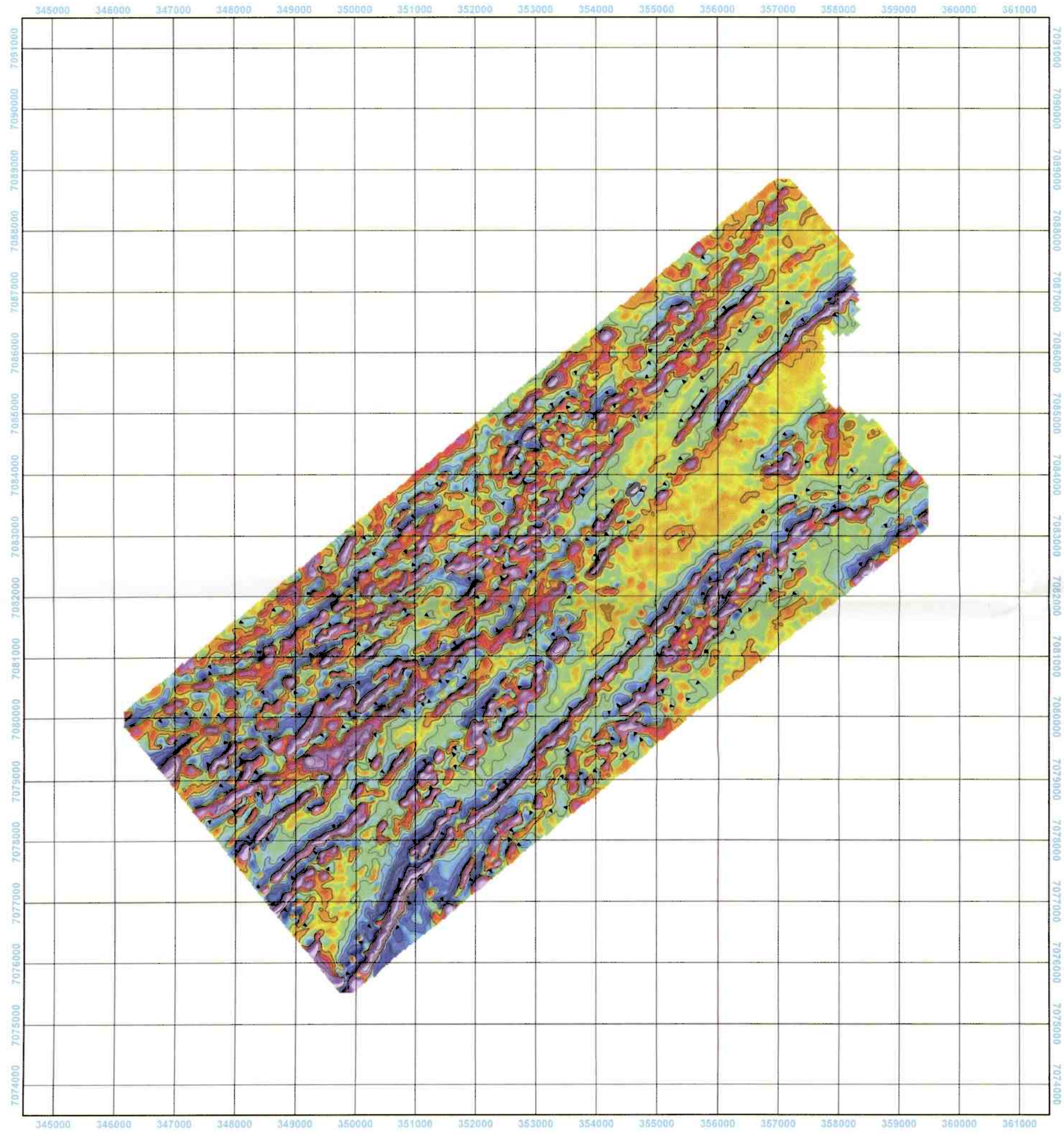
Drawing no:
2006.041-04



GEODETIC DATUM: WGS84
CONFORM CYLINDERPROJECTION
Numbers in BLUE for UTM coordinates, zone 33N

nT/m

-0.4068	-0.2106	-0.1372	-0.0937	-0.0622	-0.0365	-0.0038	0.0599	0.1396	0.2732	0.6992

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CALCULATED VERTICAL GRADIENT

Vertical Magnetic Gradient (in NanoTeslas per meter).
Calculated from the total field magnetics and upward continuated 25 metres.
Contours given in following intervalls:

- 0.1nT/m
- 0.5nT/m
- 1.0nT/m
- 2.0nT/m

Colours - distributed after colourscale.

Cesium high sensitivity magnetometer.
Sensor elevation - 30 metres.

NAVIGATION

The entire area was covered by GPS navigation.

The nominal flying height above ground level in the area is 60 metres.

A/S SULFIDMALM

CALCULATED VERTICAL MAGNETIC GRADIENT

Colours and contours

Sjækerdalen

Nord-Trøndelag

Drawing: *Mogaard,J.O.*	Date: *APR2006*	Obs: *JOM/JK*

Scale 1:50 000

1000 0 1000 2000 3000
(metres)

Mapsheet (1:50 000):
1722 I Vuku

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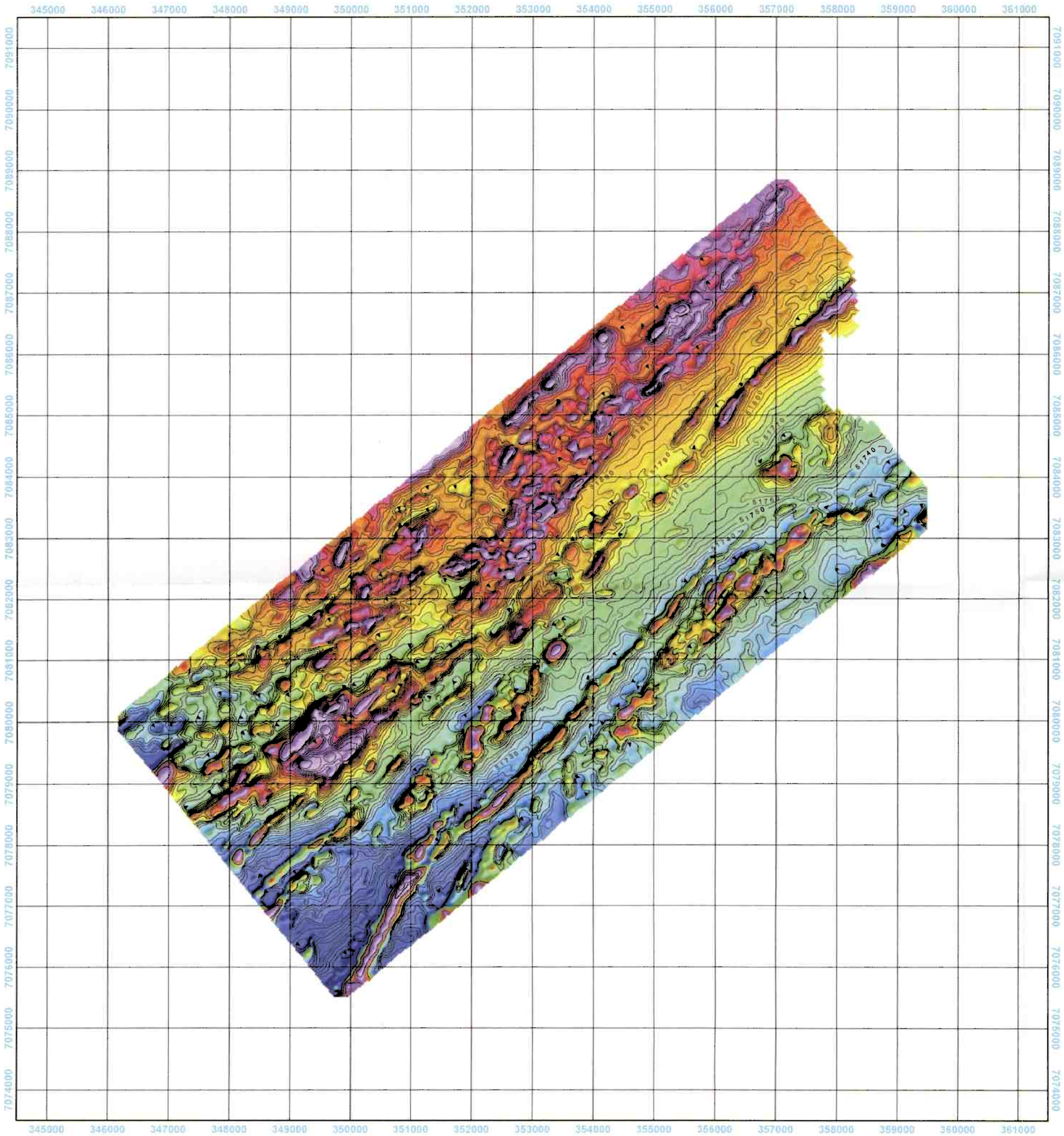
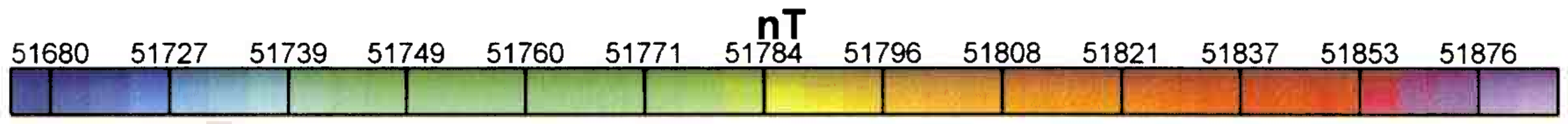
Drawing no:
2006.041-03



GEODETIC DATUM: WGS84
CONFORM CYLINDERPROJECTION
Numbers in BLUE for UTM coordinates, zone 33N



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N

TOTAL MAGNETIC FIELD

The intensity of the total magnetic field is in nanoTesla.

Contours given in following intervalls:

5nT
10nT
100nT
500nT

Colours - distributed after colourscale.

Data are corrected for diurnal variations using a basemagnetometer located in Verdal.

A high sensitivity cesiummagnetometer sensor is used and nominal sensor elevation is 30 metres.

NAVIGATION

The entire area was covered by GPS navigation.

The nominal flying height above ground level in the area is 60 metres.

A/S SULFIDMALM

TOTAL MAGNETIC FIELD
Colours and contours

Sjækerdalen

Nord-Trøndelag

Drawing: Mogaard,J.O.	Date: APR2006	Obs: JOM/JK
Scale 1:50 000 1000 0 1000 2000 3000 (metres)		Mapsheet (1:50 000): 1722 I Vuku

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