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Oskarshamn site investigation

QC-report concerning helicopter borne geophysics at Simpevarp, Oskarshamn, Sweden

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August 2003

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Contents

1 Introduction

Helicopterborne geophysical measurements have been performed in the Simpevarp area on behalf of SKB during September and October 2002. A method description (SKB internal controlling document SKB MD 211.002) describes specifications for calibrations, tests and data quality for the survey. The Norwegian Geological Survey (NGU) was the contractor for the survey. Details concerning data tests and calibration routines were presented by NGU in an activity specific quality assurance plan (QAP). Peter Walker (Geophysical Algorithms, Canada) was subcontracted by NGU to carry out data processing and quality control.

It is common that the client contracts independent quality controllers (QC) during large surveys like the present one. In this case, QC has signed for work carried out and in cases where they have found that the data quality has not been up to specifications, ordered reflights. The Swedish Geological Survey through Sören Byström and Peter Hagthorpe has been QC for navigation, magnetometry and spectrometry, whereas GeoVista AB through Hans Thunehed has been QC for electromagnetic measurements. QC has also assisted SKB about priorities between data coverage and reflights (see below). It should however be pointed out that the contractor has had the full responsibility for data quality through the entire production chain to the final delivery of data.

Results from calibrations, tests and quality controls performed by NGU can be found in pre-survey and a post-survey report that are included in NGU's survey report /Rønning et al, 2003/.

2 Activity

The time frame available for the survey was limited due to environmental impact and community relations issues. This resulted in lack of time at the end of the available survey period. It was still possible to get full data coverage.

3 Quality control

Comments regarding quality control performed by QC persons follow below for the different methods. Results are also shown in Figures 3-1 to 3-8 and in Table 3-2.

3.1 Navigation

Differential GPS and a radar altimeter were used for navigation. Some survey lines were not up to specifications regarding line separation and altitude. Some of these were due to the pilot's decision regarding flight safety and some were due to sudden wind changes. Most of the areas with to high survey altitude were where the pilot has ascended over the major power lines. The data were approved since the deviations did not seem to affect data quality in a serious way. The area around the power plant and four areas in the north with duck ponds have been excluded in the statistics below regarding data coverage since they were unavailable for surveying. The nominal data coverage is shown in red in Figure 3-1.

The control of navigation data has resulted in the following statistics for north-south survey lines:

Line separation not up to specifications: 3%,
Altitude not up to specifications: 17%,
Data coverage: 100% of nominal.

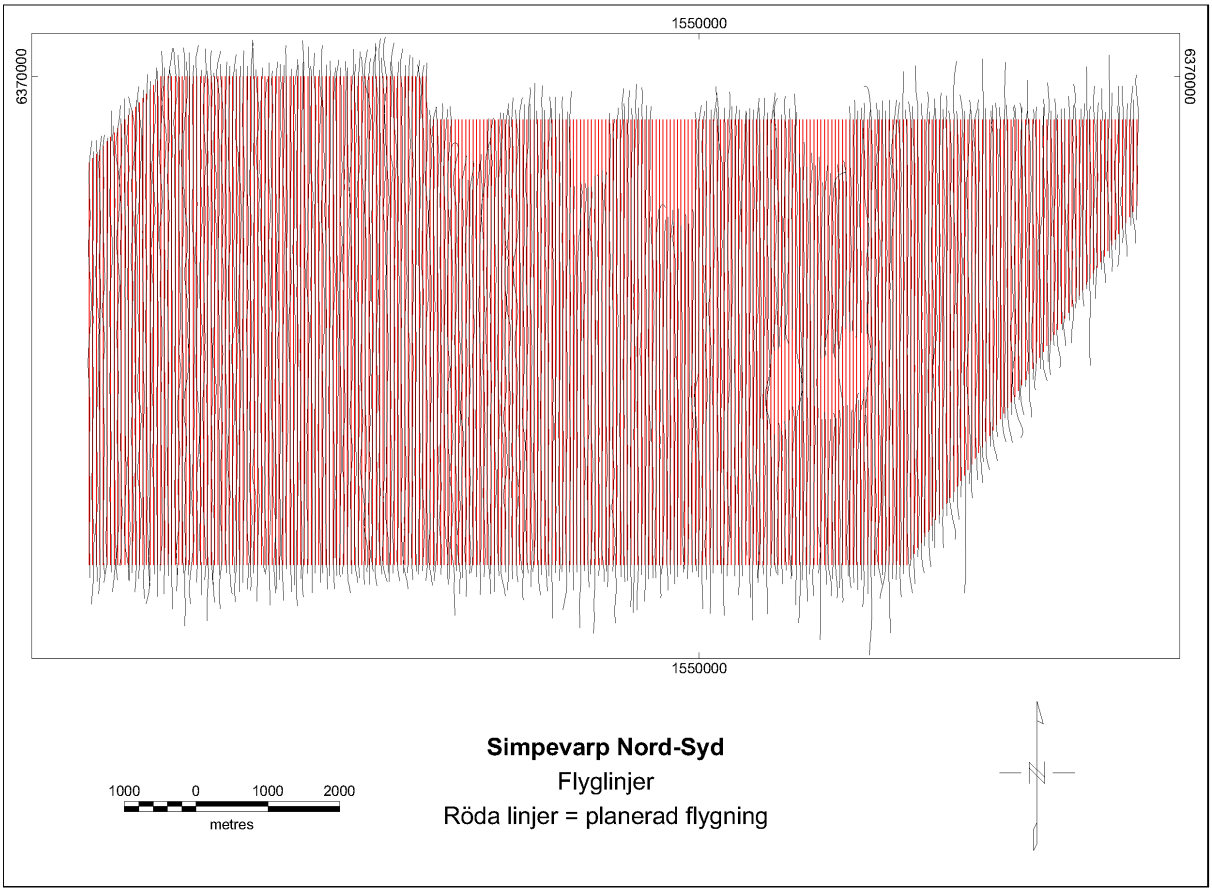

Figure 3-1. *Data coverage, north-south survey lines. The red lines indicate nominal coverage whereas black lines indicate actual coverage.*

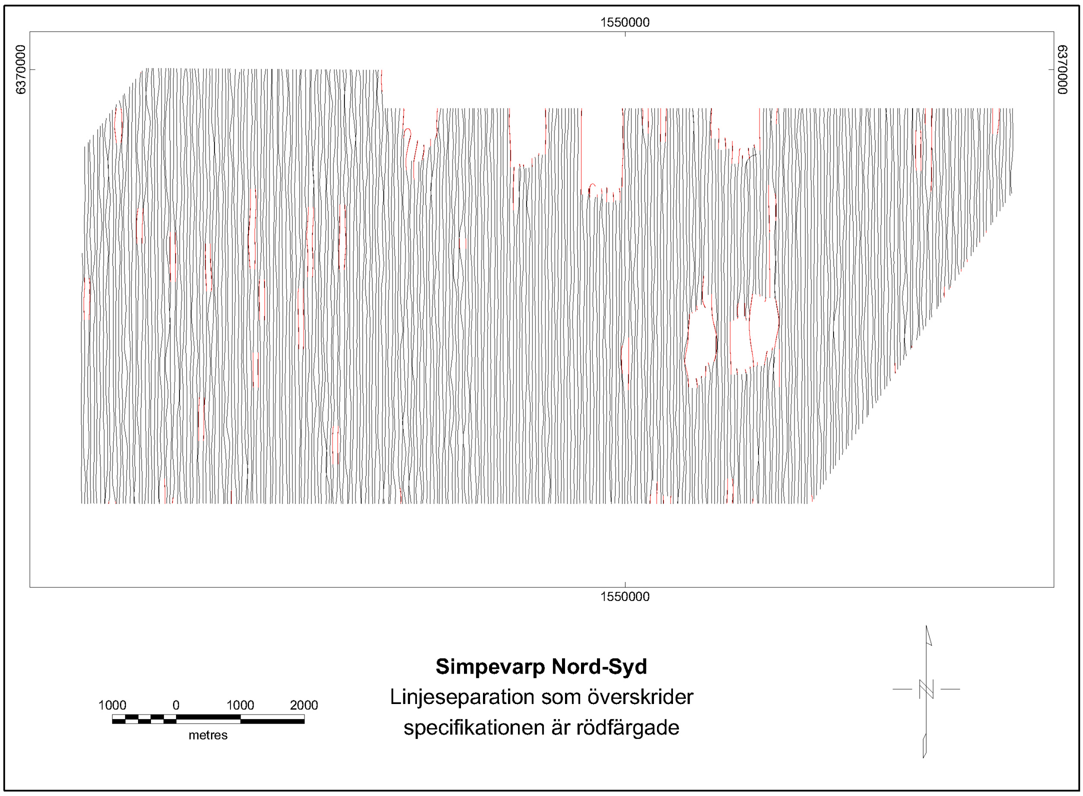

Figure 3-2. Lines marked with red are those where line separation is out of specification for the north-south survey lines.

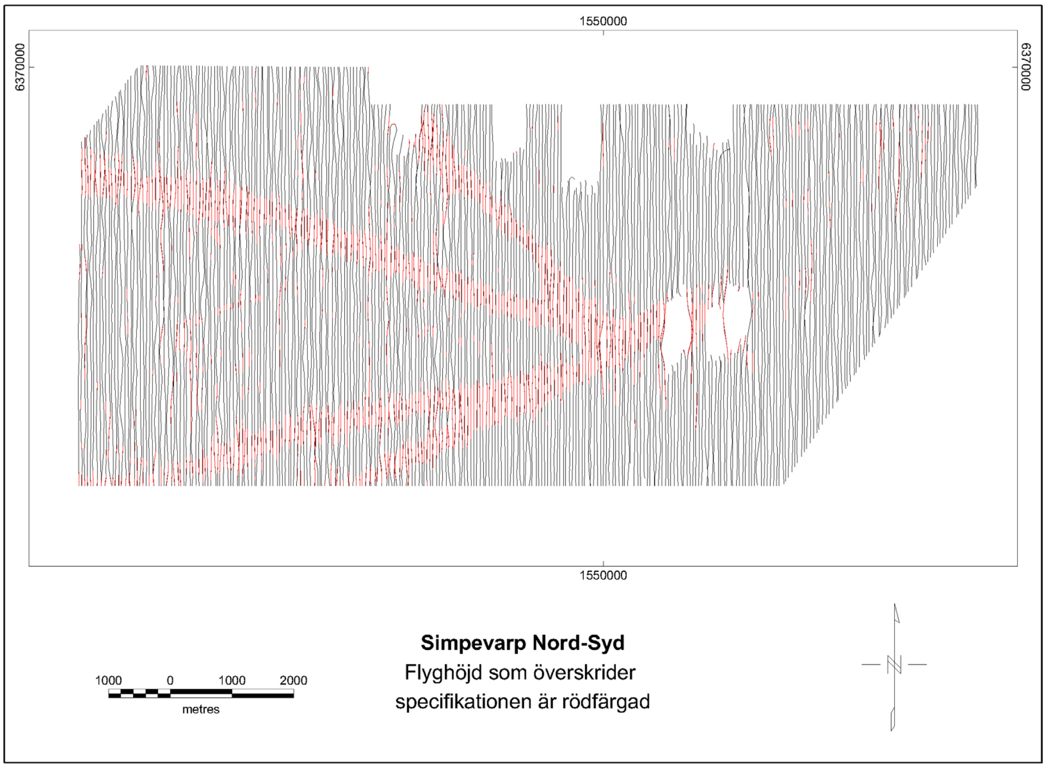

Figure 3-3. Lines marked with red are those where flight altitude is out of specification for the north-south survey.

The control of navigation data has resulted in the following statistics for east-west tie lines:

Line separation not up to specifications: 1%,
Altitude not up to specifications: 19%,
Data coverage: 100% of nominal

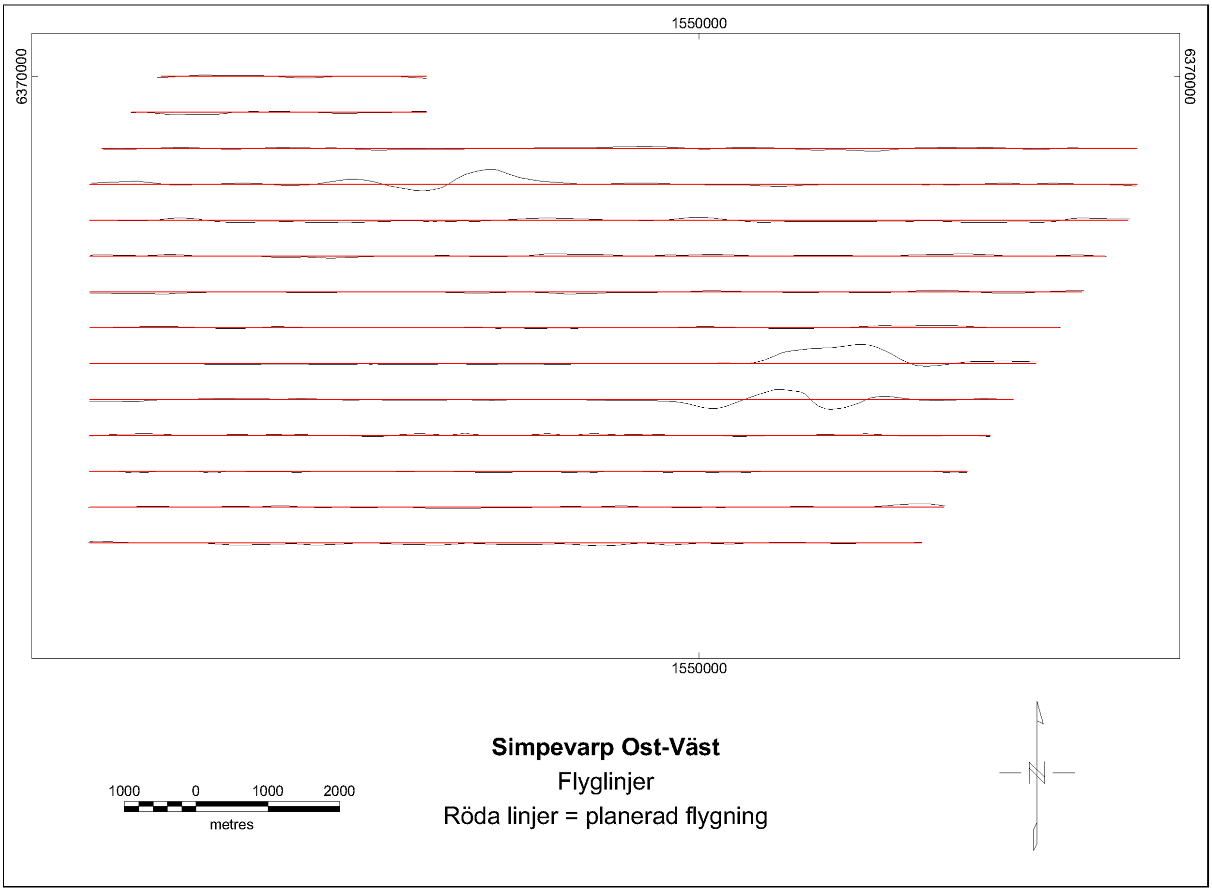

Figure 3-4. *Data coverage, east-west tie lines. The red lines indicate nominal coverage whereas black lines indicate actual coverage.*

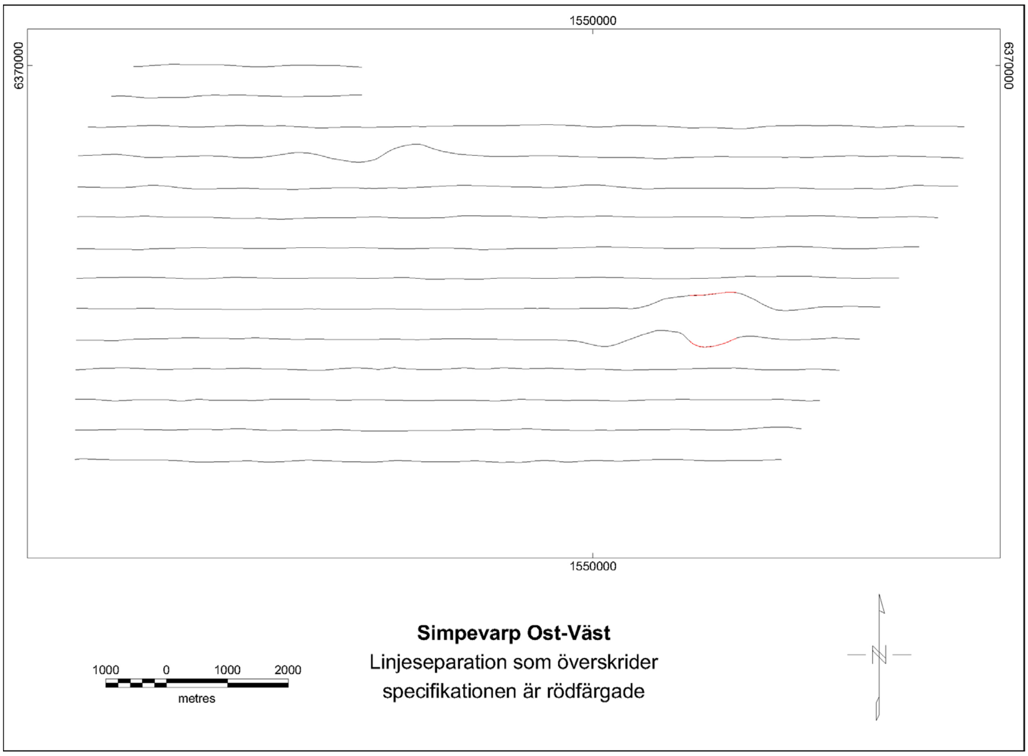

Figure 3-5. *Lines marked with red are those where line separation is out of specification for the east-west tie lines.*

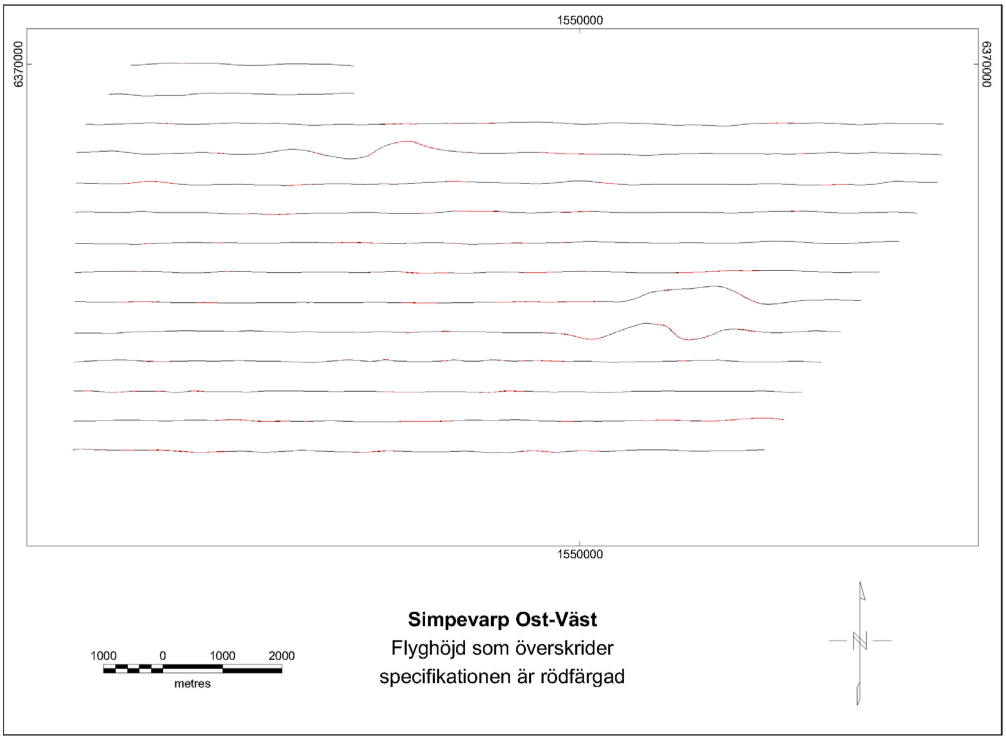

Figure 3-6. *Lines marked with red are those where flight altitude is out of specification for the east-west tie lines.*

3.2 Magnetometry

Magnetic measurements can be used to map lithological units. The magnetic properties of rocks mainly depend upon grades of the magnetic mineral magnetite.

The instrument that has been used, an optically pumped magnetometer, can be regarded as without drift or scale errors, at least for practical purposes.

The quality of the survey is within the specifications in the method description. However, gridded data displays stripes due to irregular levelling differences between lines. The problem seems to be correlated to variations in altitude at some places but not others. There is also a dependence with flight direction but the problem cannot be removed with lag or heading corrections.

Figures 3-7 and 3-8 show the result of the quality control of the magnetic survey and of diurnal variations.

Some notes about the result of the quality control of the magnetic data:

- An area around the power plant could not be surveyed due to security reasons (see section 3.1) and four areas with duck ponds along the northern border of the area were also excluded from surveying
- A problem with synchronisation of the clocks in the data logging system resulted in an unacceptable uncertainty in the position of the survey points. This problem was later corrected by the contractor and the data in the final delivery are within specifications.

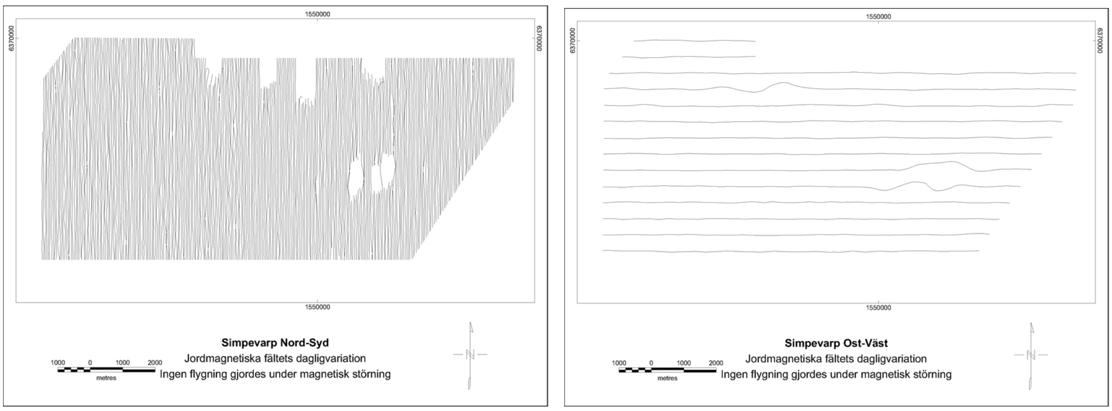

Figure 3-7. *Quality control of diurnal variations. All lines are within specifications (black).*

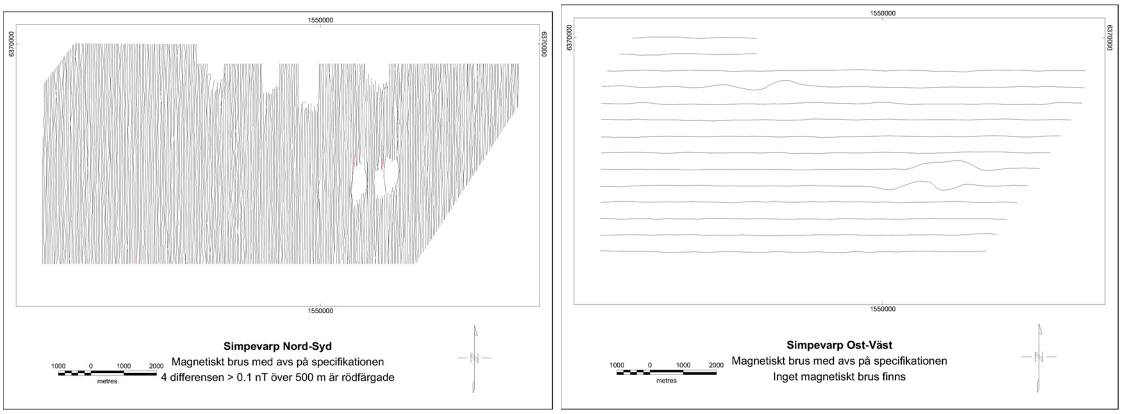

Figure 3-8. *Quality control of magnetometer noise. All lines are within specifications (black).*

3.3 Spectrometry

Radiometric information is useful for geological mapping since it gives information about the grades of the elements potassium, thorium and uranium. The depth of investigation is however only 10 to 20 cm since γ-rays cannot penetrate any thicker layers of rock or soil.

The radiometric measurements in the Simpevarp area fulfilled the requirements in the method description. Parameters have been checked by taking random samples without any remarks.

3.4 Electromagnetic measurements

Electromagnetic data should be possible to use for identification of lineaments and for inversion to a layered model. Of these two applications the latter puts harder demands on data quality. Problems with data quality can be due to random noise and to drift in the base level, gain and phase of the measurement system. The drift is usually not correlated between different measurement frequencies. Disturbances can also be due to power lines, radio transmitters and other installations. The method description specifies random noise levels and maximum drift estimated from readings at ground effect free altitude (minimum 300 metres).

The contractor prior to mobilisation to the survey area has tested the stability and noise level. Documentation from these tests can be found in a pre-survey report /Appendix A in Rønning et al, 2003/. The stability of the phase can also be checked since a test line was flown over an artificial anomaly source (cable loop) for every flight. A selection of the test lines have been visually inspected and compared without remarks.

The electromagnetic data from Simpevarp were affected by cultural noise sources. The effect was high amplitude noise in the vicinity of the major power lines. The data from the preceding survey at Forsmark showed frequent and irregular level shifts in the data for two of the frequencies (7 kHz coaxial coils, 34 kHz coplanar coils). This effect has only occurred sporadically in Simpevarp e.g. during flight 8. Additionally, more or less permanent level shifts have occurred during flight 1 and 3.

The external noise sources made it difficult to estimate random noise due to the measurement system. A thorough test of random noise was performed on data from the preceding Forsmark survey. Therefore only random tests have been performed on data from the Simpevarp survey. No tested data set, not severely affected by external sources, showed noise levels that were out of specifications.

During inversion of electromagnetic data it is essential that the zero levels of the data are correctly defined. This is particularly important in highly resistive terrains as the signal strength is expected to be low. Before the survey commenced, NGU pointed out that the specifications in the method description might be difficult to live up to regarding level drift. An agreement was made that data could be approved even if the formal specifications were not met on the condition that the drift was linear or possible to fit to e.g. a low-order polynomial with small residuals.

Some control about instrument drift can also be gained from measurements over large, continuous areas of high resistivity or when the helicopter has raised to higher altitude during approach to a new line. However, at least for some of the measured components it seems clear that there is a systematic altitude dependence on the zero level. This has e.g. the effect that there will be a bias in the data after corrections for instrument drift. This bias must be corrected for before any inversion of the data is attempted.

Whether the data meets the specifications in the method description or not is shown on a flight by flight basis in Table 3-2. The channel labels for electromagnetic data are shown in Table 3-1. The two highest frequencies with co-planar coils are shown individually whereas the quadrature components for the other three components have been grouped. The quality control of the in-phase components for those three frequencies is not shown in the table since they will have a very small impact on inversion of the data.

Reflights have been ordered in those cases where the instrument drift not can be estimated accurately with the help of high altitude readings. The lines in question are listed in Table 3-2.

3.5 VLF

VLF-measurements have been performed with those transmitters presently available. No special quality control has been performed on VLF-data since this method was of lower priority. Data coverage was good for the GBR-transmitter (inline) and the NAA-transmitter (ortho). However, other transmitters had to be used for some flights.

Table 3-1. Channel labels for electromagnetic data.

Channel	Frequency (Hz)	Coil orientation	Coil separation (m)	Component
IP1	7001	coaxial	6	In-phase
Q1	7001	coaxial	6	Quadrature
IP2	6606	Hor. coplanar	6	In-phase
Q2	6606	Hor. coplanar	6	Quadrature
IP3	980	coaxial	6	In-phase
Q3	980	coaxial	6	Quadrature
IP4	880	Hor. coplanar	6	In-phase
Q4	880	Hor. coplanar	6	Quadrature
IP5	34133	Hor. coplanar	4.2	In-phase
Q5	34133	Hor. coplanar	4.2	Quadrature

Table 3-2. Table showing if level drift is within specifications on a flight by flight basis. An estimation has also been made whether drift corrections can be made with sufficient accuracy even if formal specifications are not met. This is possible if the drift has been linear or gently varying. The two rightmost columns shows which profiles where reflights were ordered. The corresponding cells are marked with yellow colour. (N = No, not approved, Y = Yes, approved, ? = close to specification or difficult to estimate).

QC EM-data Simpevarp 2002, SKB

Flight	Drift Q5 within spec	Drift Q2 within spec	Drift Q5 linear	Drift Q2 linear	Drift IP5 within spec	Drift IP5 linear	Drift IP2 within spec	Drift IP2 linear	Drift Q1,3,4 within spec	Drift Q1,3,4 linear	Reflight recommended	Reason/Comment
1	N	Y	Y?	Y	Y	Y	Y	Y	N	Y		Level shift in IP1/Q1
2	N	Y	Y	Y	N	Y	N	Y	Y	Y		
3	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Line 110, 120, 130, 140, 150	Non-linear drift Q5 and level shifts in Q5/IP5/Q1/IP1
4	Y	Y	N	Y	N	Y	Y	Y	Y	Y	290, 300, 310, 320, 330	
5	N	Y	Y	Y	N	Y	Y	Y	N	N		
6	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		
7	N	Y	Y	Y	Y	Y	Y	Y	N	Y		Aborted flight
8	N	Y	Y	Y	Y	Y	Y	Y	Y	Y		Q5/IP5/Q1/IP1 noise
9	N	Y	Y	Y	N	Y	Y	Y	Y	Y		
10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		
12	N	Y	Y?	Y	Y	Y	Y	Y	Y	Y		
13	N	Y	Y?	Y	Y	Y	Y	Y	N	Y	2080, 2090, 2100, 2110, 2120, 2130	
14	N	Y	Y	Y	N	Y	N	Y	Y	Y		
15	N	Y	N	Y	Y	Y	N	Y	Y	Y	2540, 2550, 2560, 2570, 2580	
16	N	Y	Y?	Y	N	Y	Y	Y	Y	Y		
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		No EM-data acquired
18	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Reflights

References

Rønning H J S, Kihle O, Mogaard J O, Walker P, 2003.
Helicopter borne geophysics at Simpevarp, Oskarshamn, Sweden. SKB P-03-25.