P-03-66

Oskarshamn site investigation

Geophysical measurements for the siting of a deep borehole at Ävrö and for investigations west of CLAB

Carl-Axel Triumf, GeoVista AB

July 2003

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

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Keywords: Simpevarp, Ävrö, CLAB, fracture zones, geophysical survey, magnetometer, slingram.

Contents

1 Introduction

This document reports geophysical measurements in the Simpevarp area carried out in May 2003 and the interpretation of these data. The geophysical survey and the interpretation was carried out by GeoVista AB according to the activity plan AP PS 400-03-027 and the method descriptions for slingram, SKB MD 212.007 and magnetometer, SKB MD 212.004 (SKB internal controlling documents) under the supervision of Leif Stenberg, SKB.

The measurement were carried out at two geophysical survey sites, hereafter named the “Ävrö site” and the “CLAB site”, as seen in Figure 1-1.

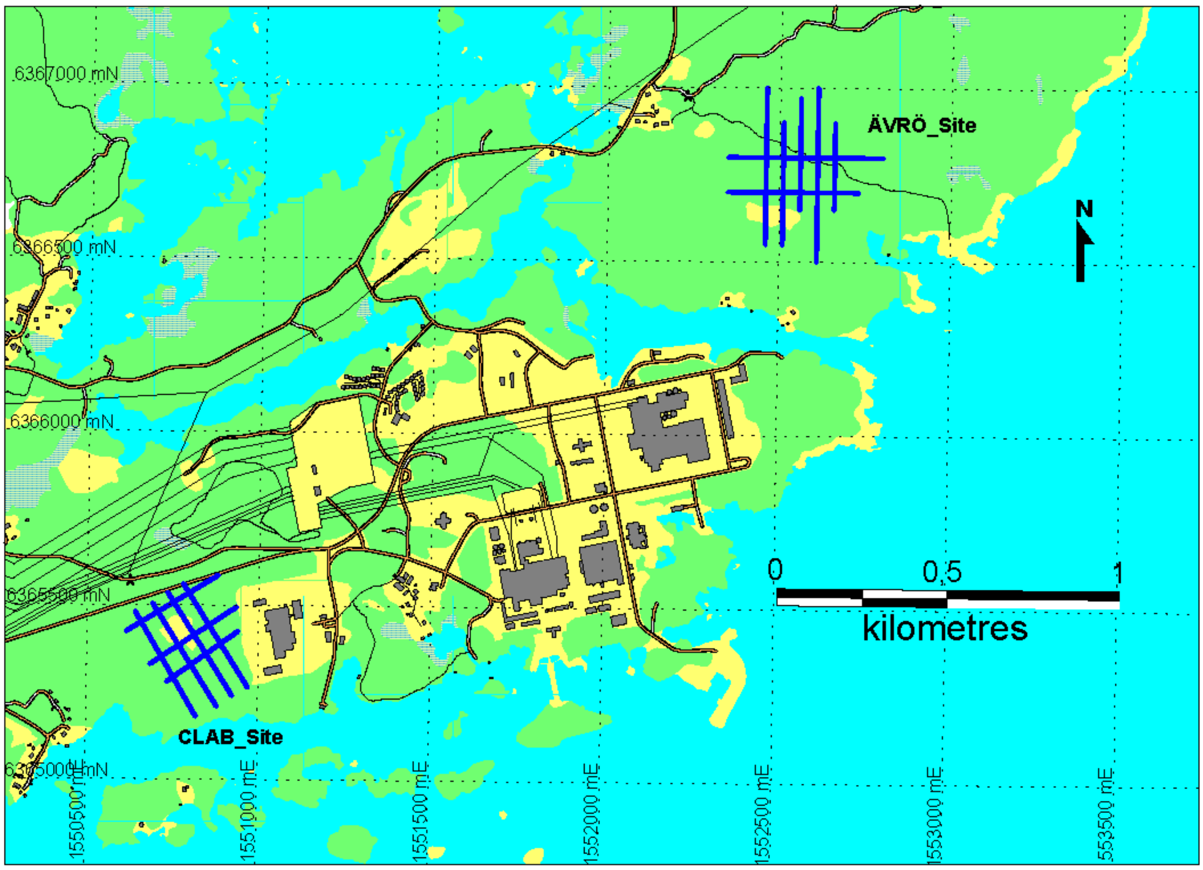

Figure 1-1. *Location of profiles at the Ävrö and CLAB sites.*

2 Objective and scope

The objective of the measurements at Ävrö was to gain knowledge about possible fracture zones for the siting of a planned deep core borehole. At CLAB the objective was to investigate the geometry of fracture zones earlier detected in percussion boreholes and construction works.

At Ävrö in total approximately 2.7 km were measured with a point spacing of 10 m along five profiles in north-south and two profiles in east-west. At CLAB in total approximately 2.3 km were measured with a point spacing of 10 m along four profiles directed in northwest-southeast and three profiles directed in northeast-southwest. The slingram (horisontal loop EM) method with a frequency of 18 kHz and a coil separation of 60 metres and total field magnetometer were used.

3 Methodology

3.1 Location of profiles

The profile locations at Ävrö were planned using airborne geophysical survey data, topography and information from a field excursion. The profile locations at CLAB were planned using mostly older data from earlier site investigations in connection to the construction of CLAB.

Start and end points along the planned profiles, together with intersection points between profiles, were staked in the field by Per-Åke Jureskog, Geocon AB.

The starting point of the profile was used to measure the length with a measuring tape along the profile. When passing a stake placed in the terrain by Geocon, the actual length on the measuring tape was noted by the geophysical field crew. The normal deviation between measured length and the nominal distance to the stake was typically around 0.5–1.5 m.

It is probable that the accuracy of the co-ordinate of the measuring station in RT90 2.5 gon W is better than 5 m in the horizontal plane.

3.2 Daily routines and quality assurance

The slingram system was checked on a daily basis with the aid of a control point which was established in the area.

A base magnetometer was used to record diurnal variations in the magnetic field.

Data were checked every evening by the field crew and then transferred regularly to the GeoVista AB head office in Luleå for further quality control. This included visual inspection of standard plots.

3.3 Measurements

The measurements were carried out with an EMAC Slingram 18 kHz – 60 m and two GEM GSM-19 magnetometres. With both methods the distance between measuring points was 10 m.

During measurements remarks were made about terrain objects which facilitated a control of the locality of profiles.

4 Data processing

Raw data from the measurements were delivered directly after the termination of the field activities. The delivered raw and processed data have been inserted in the database (SICADA) of SKB. The SICADA reference to the present activity is Field note No 67.

4.1 Slingram data

Slingram data were collected and written manually in note books and implemented manually into a computer each day. The data were corrected for drift using measurements at the base station. Linear interpolation was used to estimate the actual drift at a specific time.

4.2 Data of the magnetic total field

Data of the magnetic field measured with the rowing magnetometer were corrected for diurnal variations using the recordings made by the base station magnetometer which sampled the magnetic field every 10th second. Limited editing was applied, with removal of duplicate points etc.

One section at CLAB was measured twice due to disturbances. The latter recording was used in the processing.

5 Results and interpretation

5.1 The Ävrö site

A detailed map over the location of profiles at the Ävrö site is shown in Figure 5-1. Processed data of the magnetic total field anomaly and the response of the slingram system from the profiles at the Ävrö site are shown in Figures 5-2 to 5-8.

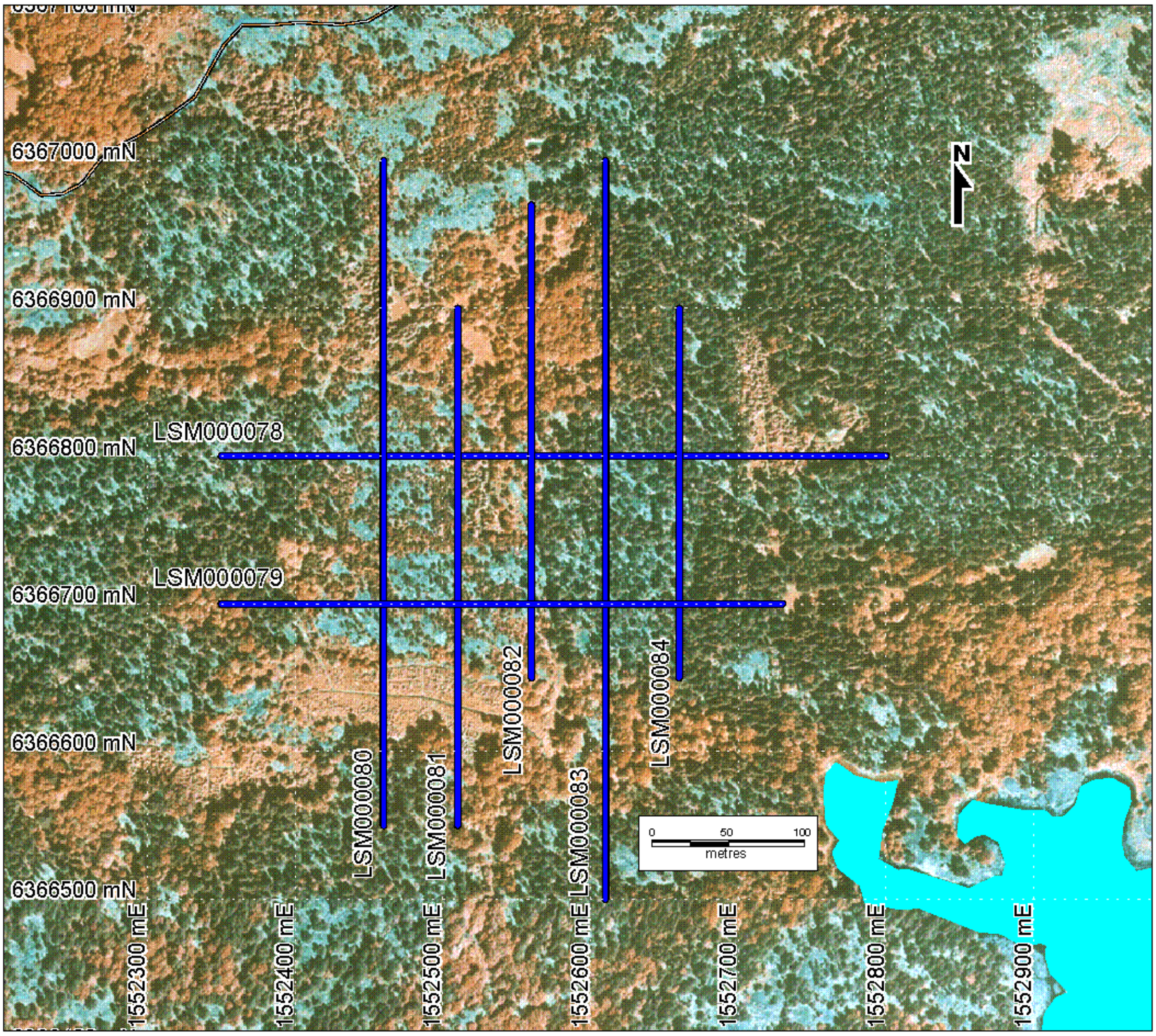

Figure 5-1. *Profiles measured with magnetometer and slingram in May 2003 at the Ävrö site. The total length of the profiles is approximately 2.7 km.*

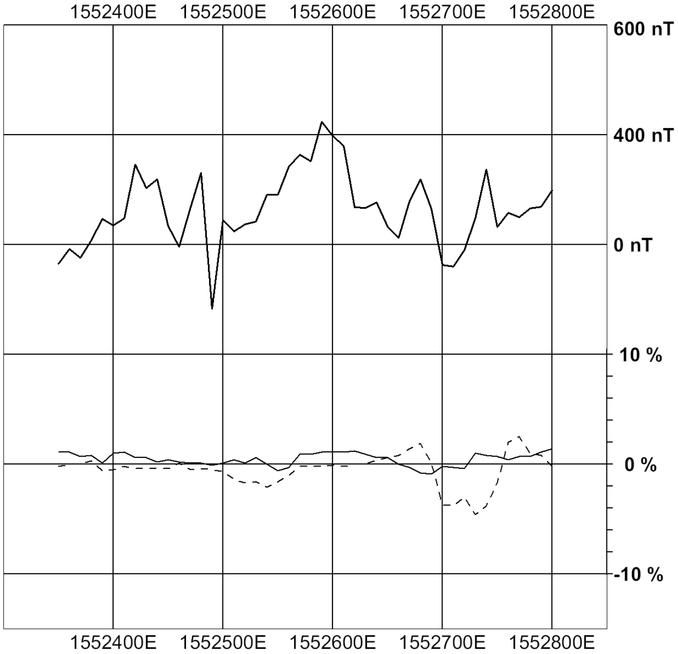

Figure 5-2. *Profile LSM000078 at the Ävrö site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

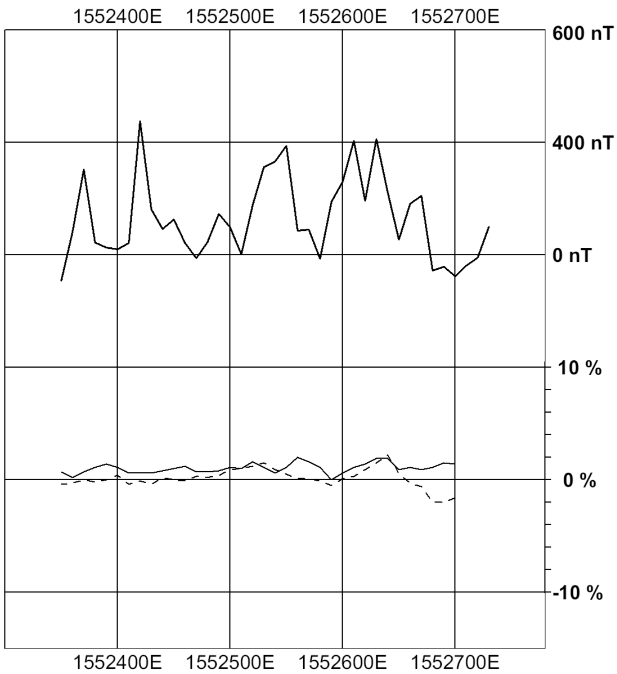

Figure 5-3. *Profile LSM000079 at the Ävrö site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

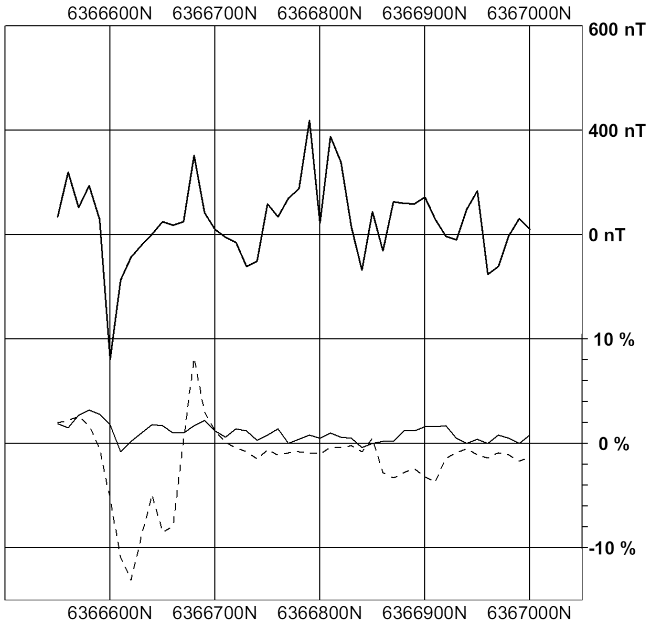

Figure 5-4. *Profile LSM000080 at the Ävrö site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

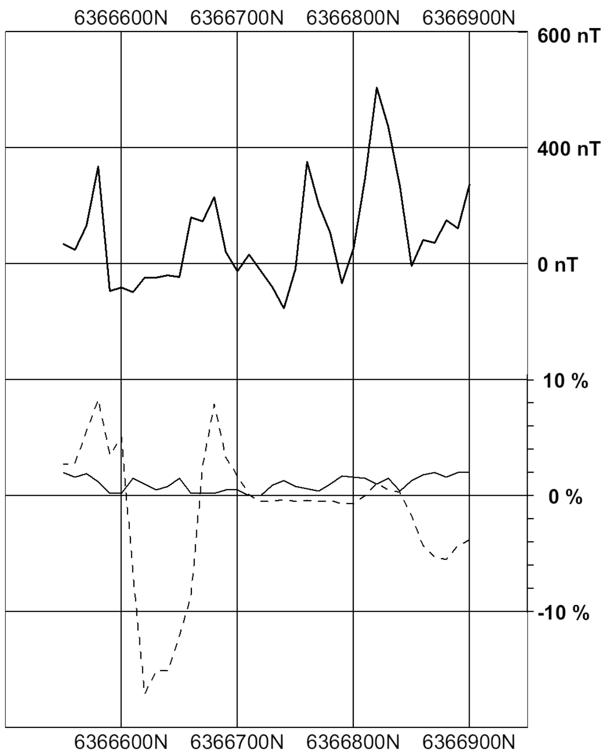

Figure 5-5. *Profile LSM000081 at the Ävrö site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

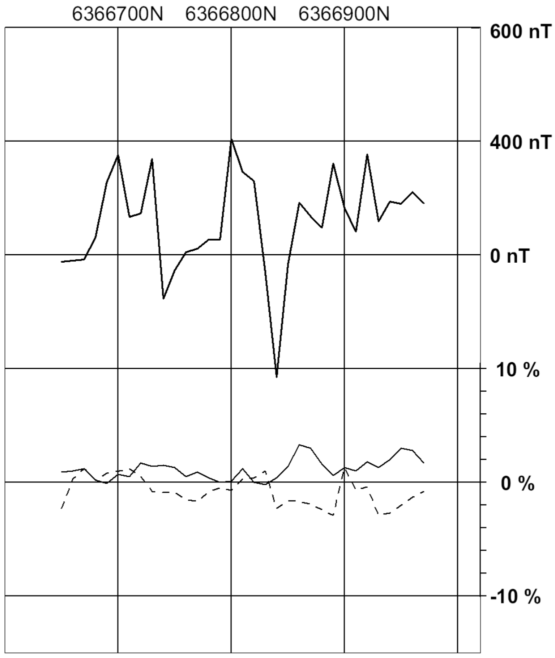

Figure 5-6. *Profile LSM000082 at the Ävrö site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

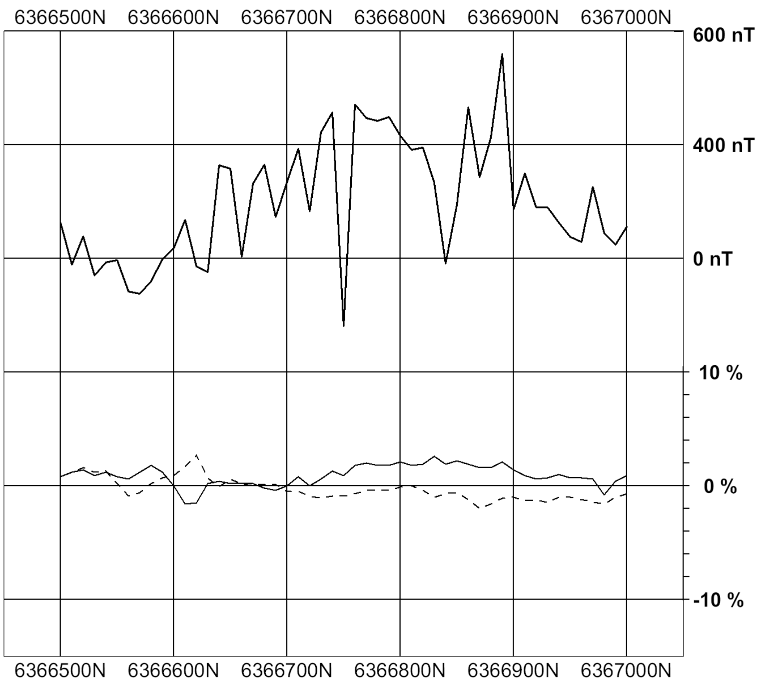

Figure 5-7. *Profile LSM000083 at the Ävrö site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

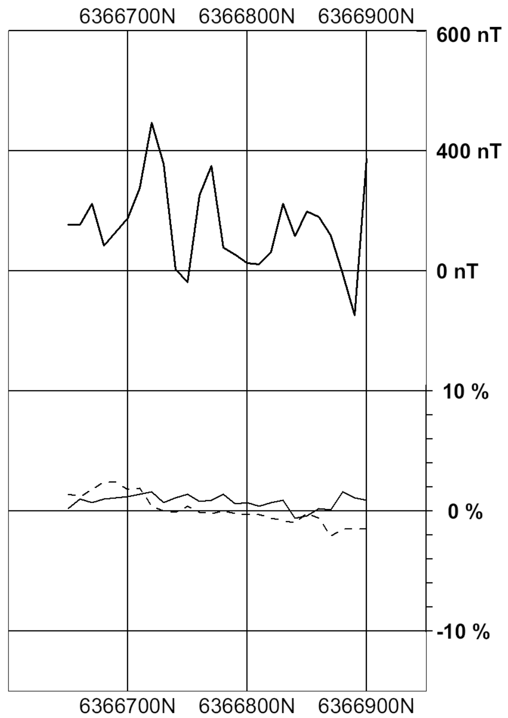

Figure 5-8. *Profile LSM000084 at the Ävrö site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

A map over the magnetic total field anomaly is shown in Figure 5-9. Maps of the slingram In-phase (Real) component and the Out-of-phase (Imaginary) component at the Ävrö site are shown in Figures 5-10 and 5-11 respectively.

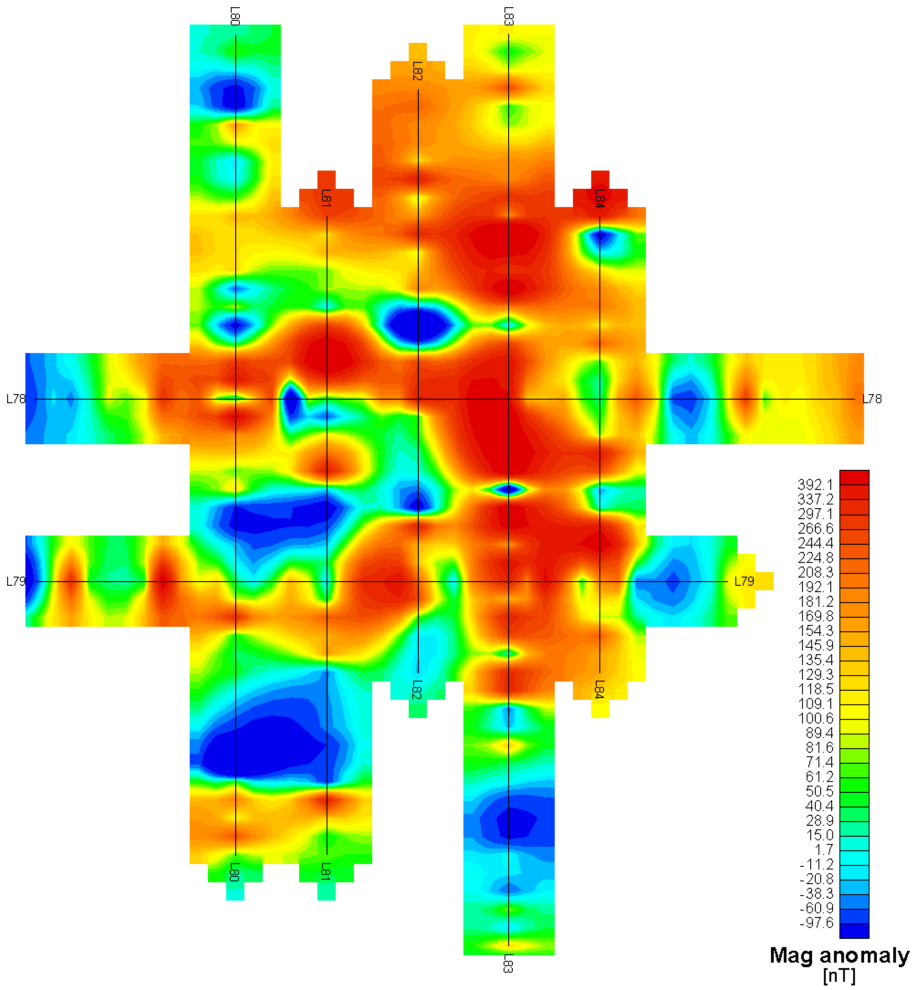

Figure 5-9. *The magnetic total field anomaly at the Ävrö site. The names and locations of measured profiles are also shown on the map. The distance between profiles L80 (LSM0000080) and L81 (LSM000081) is 50 m.*

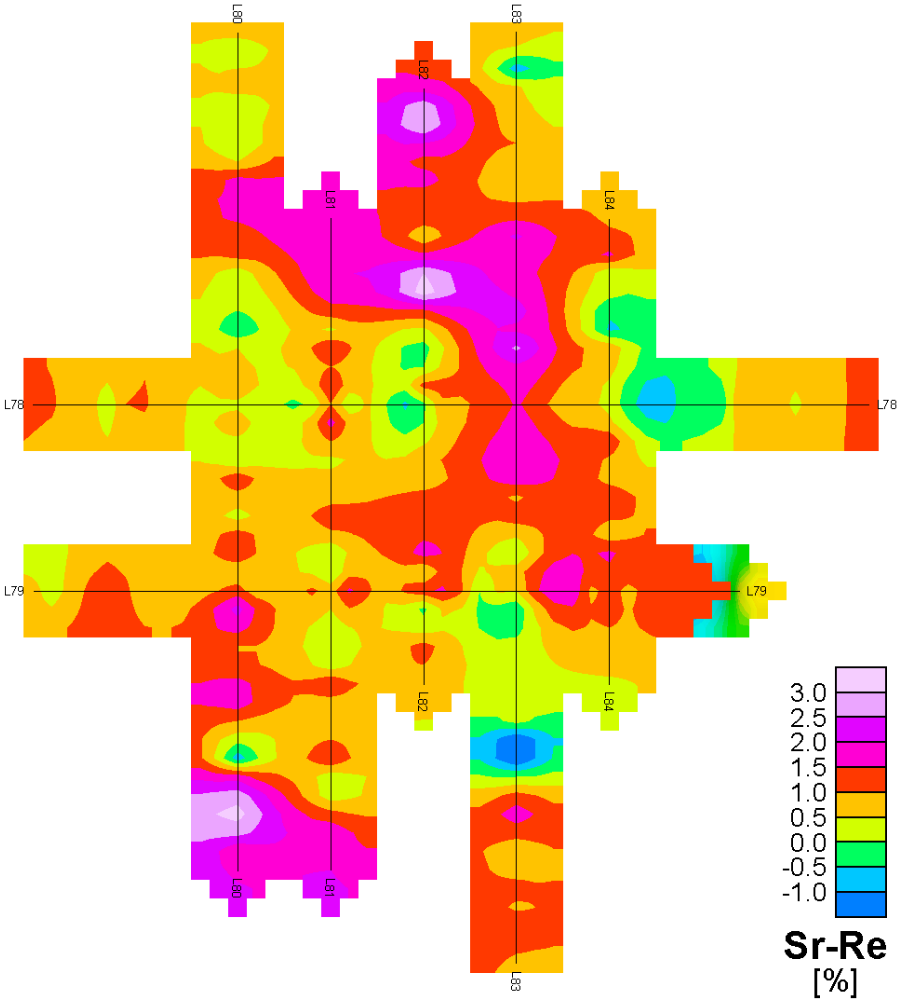

Figure 5-10. *The slingram In-phase (Real) component at the Ävrö site. The names and locations of measured profiles are also shown on the map. The distance between profiles L80 (LSM0000080) and L81 (LSM000081) is 50 m.*

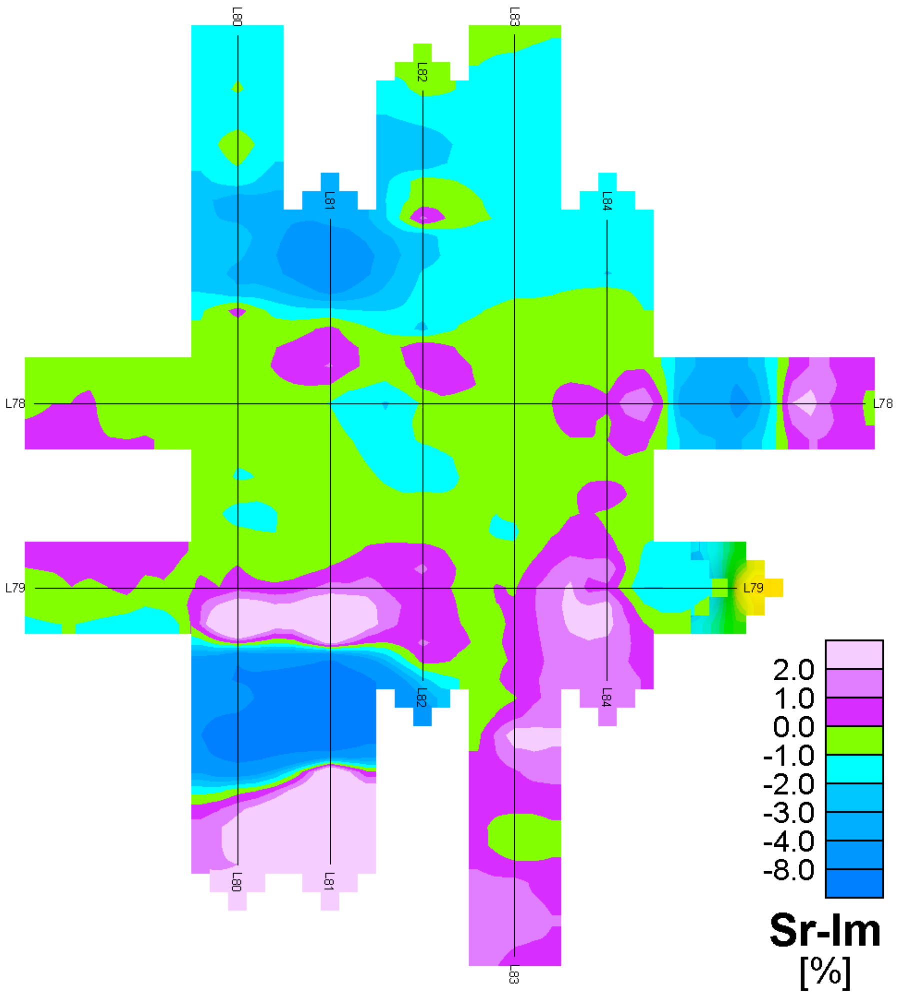

Figure 5-11. *The slingram Out-of-phase (Imaginary) component at the Ävrö site. The names and locations of measured profiles are also shown on the map. The distance between profiles L80 (LSM0000080) and L81 (LSM000081) is 50 m.*

The result of the interpretation is shown in Figure 5-12. As deep core drilling is planned in the area, the main focus of the interpretation has been to localise possible fracture zones which could complicate the initial phase of the drilling.

Slingram data show the existence of a few electrical conductors. They are mostly visible in the out-of-phase component, and are interpreted to be rather weak (low conductances). In the interpretation two levels of anomaly clearness have been distinguished - pronounced and subtle. At the northern, eastern and southern margins of the measured area, three pronounced electrical conductors have been identified which is supported by interpretation of topography data obtained from low altitude airborne photography /Wiklund, 2002/.

To the west the investigated area appears not to be bordered by any significant conductor.

The east-west striking southern pronounced electrical conductor coincides with a magnetic minimum. This anomaly complex is interpreted to be caused by a possible fracture zone with low relative magnetic susceptibility and slightly increased conductivity. The magnetic field has been modelled along profile LSM000080, showing a possible dip between 45–70 degrees of the magnetic anomaly source towards north. The result is supported by the anomaly signature on the slingram survey where a pronounced positive maximum in the out-of-phase component is found at the northern side of the conductor. In the adjacent profile LSM000081 the conductor and the corresponding low magnetic zone appear to be more steeply dipping, possibly almost vertical.

The pronounced conductor at the eastern border of the area is interpreted to be almost vertical.

The dip of the conductor at the northern border of the measured area is difficult to estimate, however the relatively low southern flank maximum on the slingram curve along profile LSM000081 suggests a more or less vertical or possibly northern dip.

In the central area, between the significant conductors, a few subtle conductors are possible to identify. They can be traced to continue into minor lineaments in low altitude airborne photography data /Wiklund, 2002/.

The interpretation indicates that there is an area of approximately 300 m x 200 m between the pronounced anomalies where a bore hole could be sited. In the uppermost 100 metres of the borehole it is probable that the risk is low of direct influence from the possible fracture zones, which are interpreted to border the measured area.

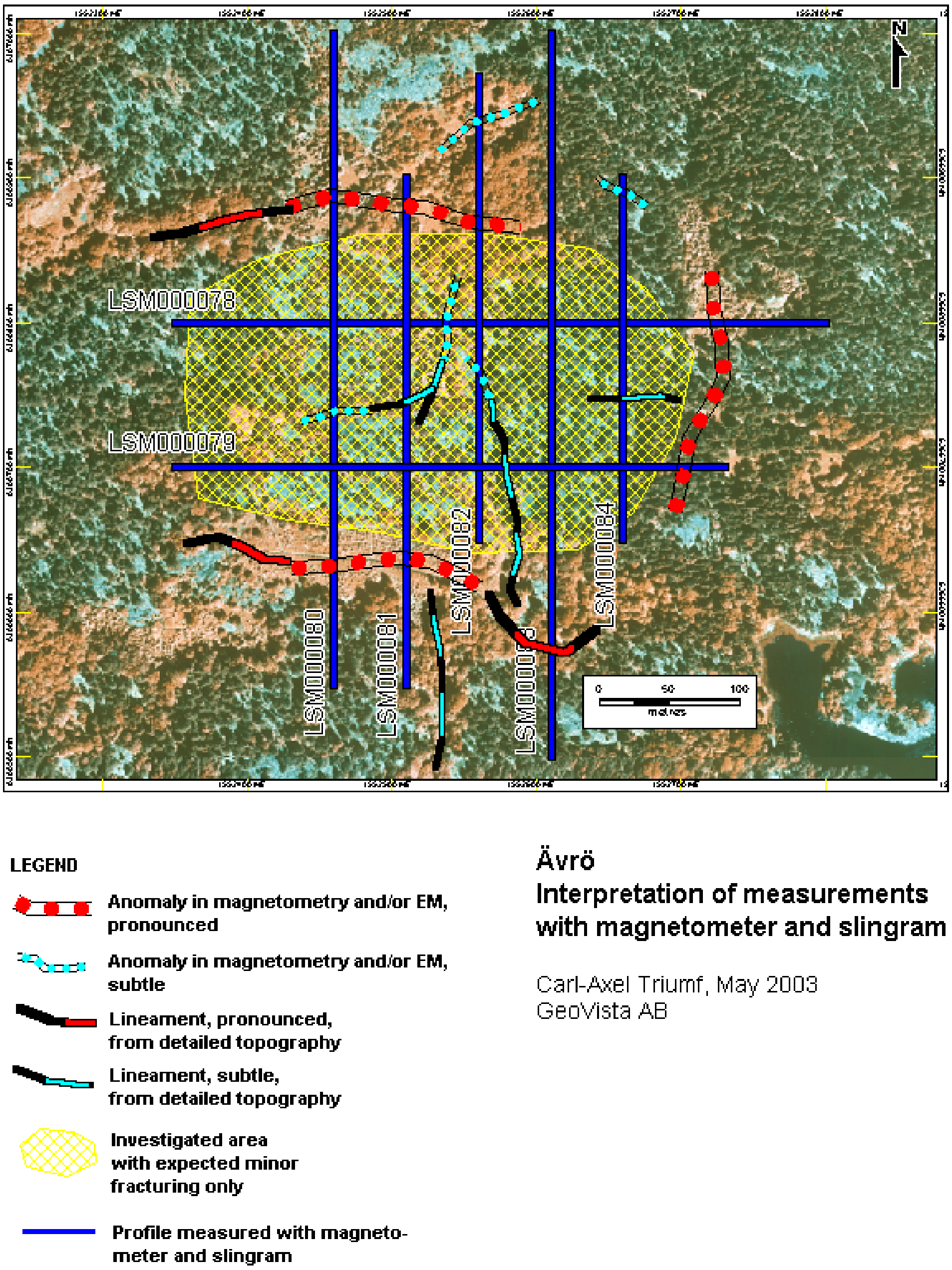

Figure 5-12. *Interpretation of data from the geophysical survey at the Ävrö site together with interpretation of topography data obtained from low altitude airborne photography /Wiklund, 2002/.*

5.2 The CLAB site

A detailed map over the location of profiles at the CLAB site is shown in Figure 5-13.

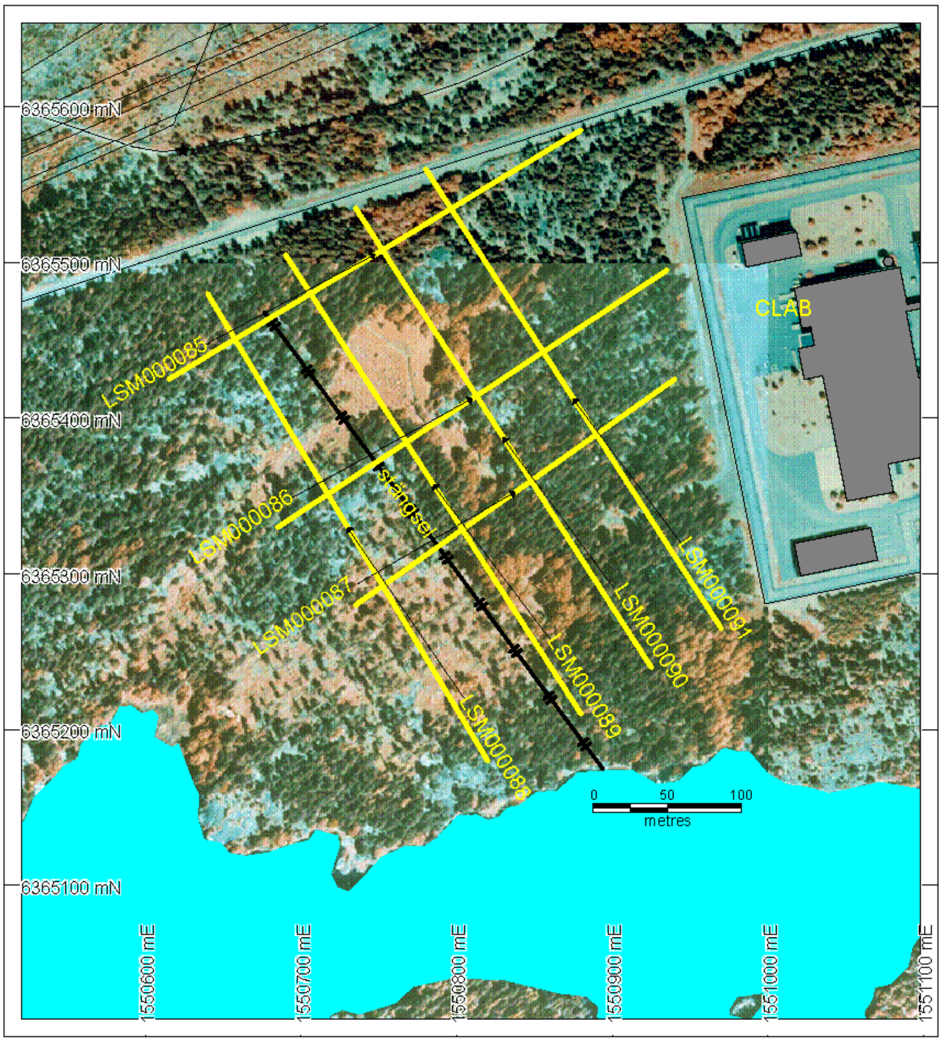

Figure 5-13. *Profiles measured with magnetometer and slingram in May 2003 at the CLAB site. The total length of the profiles is approximately 2.3 km. The black line indicates the position of a fence, which contributed to high noise level.*

Processed data of the magnetic total field anomaly and the response of the slingram system from the profiles at the CLAB site are shown in Figures 5-14 to 5-20. Note that the length scale is given in local co-ordinates along the profile with profile direction given as NE or NW. In general the noise level is quite high in the area. This is indicated by large variations in the response of the slingram system over limited distances. A typical example can be observed in Figure 5-15 where the out-of-phase component of the slingram varies a lot around coordinate 100NE along profile LSM000086. This high noise level occurring irregularly over the entire area prohibits successful EM surveys in the investigated area. The consequence of the high noise level is a less diagnostic survey. A fence has contributed to the noise level, and the effect can be observed in the magnetic anomaly field for example in the Figures 5-14 and 5-15.

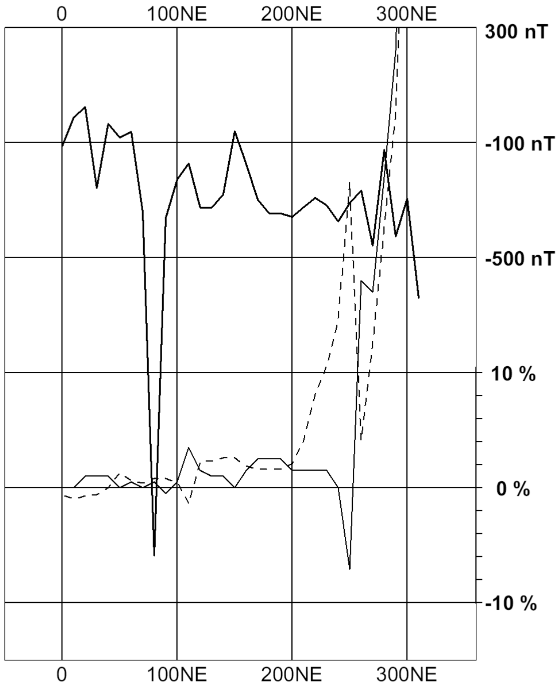

Figure 5-14. *Profile LSM000085 at the CLAB site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

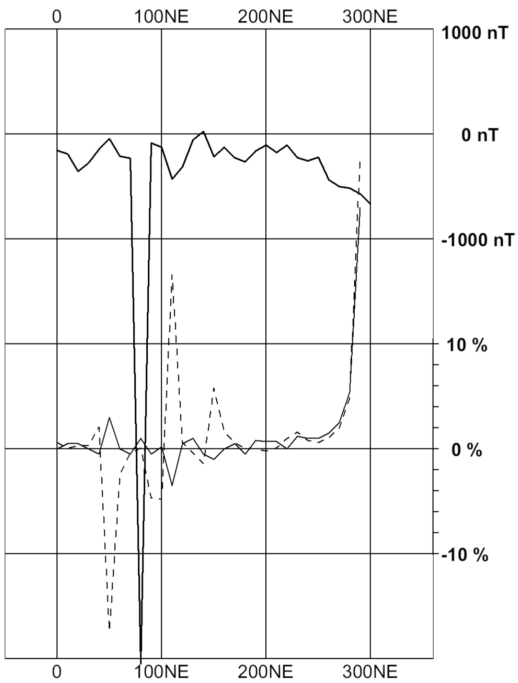

Figure 5-15. *Profile LSM000086 at the CLAB site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

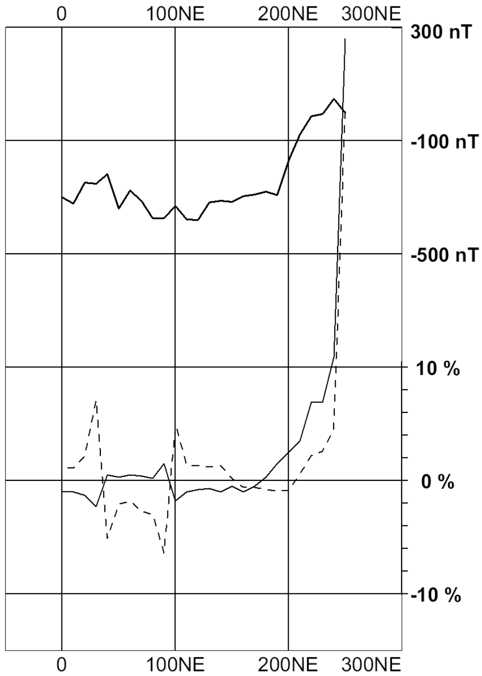

Figure 5-16. *Profile LSM000087 at the CLAB site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

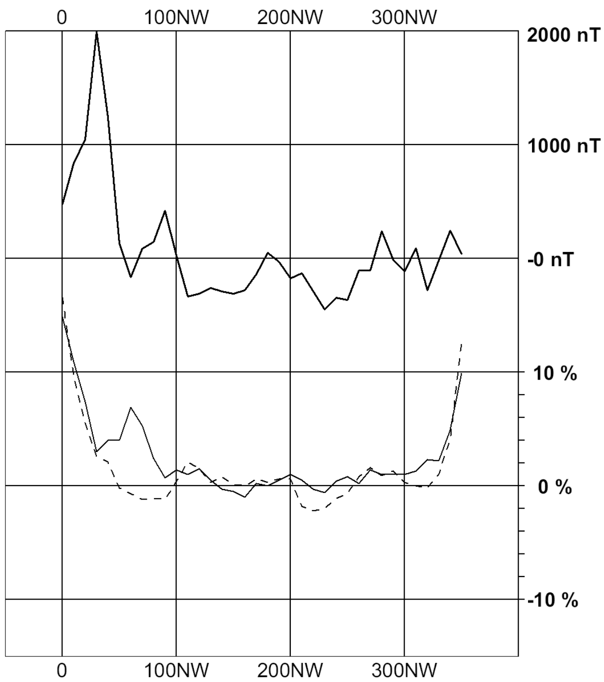

Figure 5-17. *Profile LSM000088 at the CLAB site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

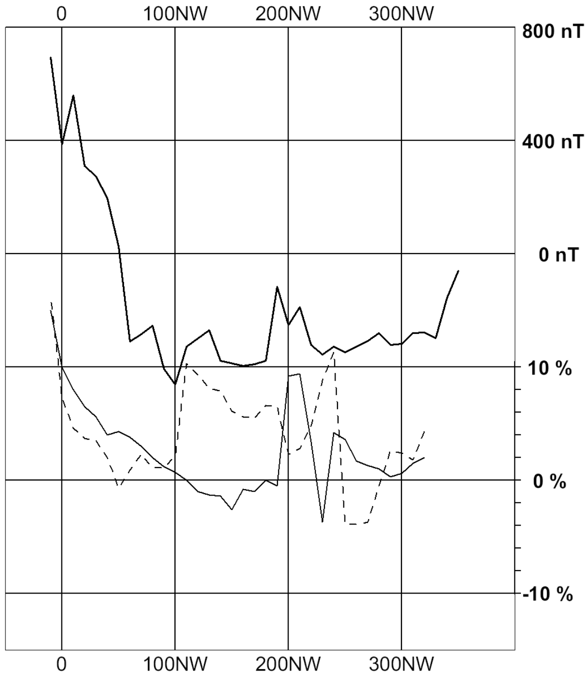

Figure 5-18. *Profile LSM000089 at the CLAB site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

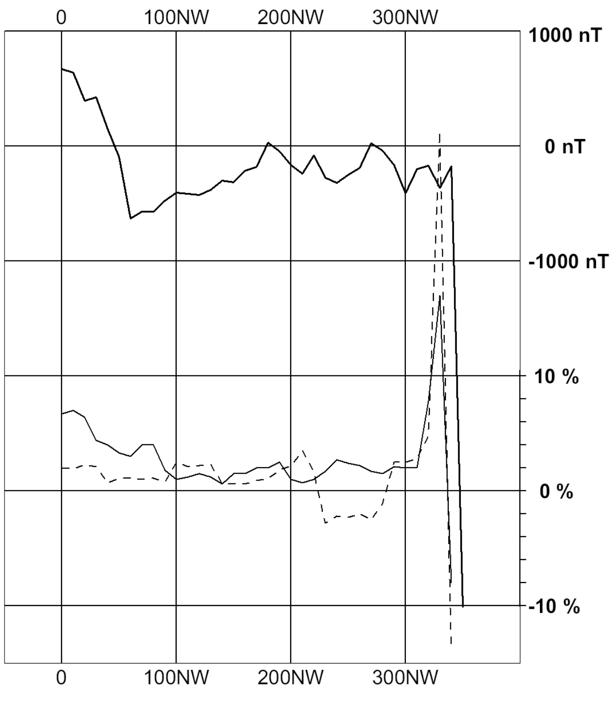

Figure 5-19. *Profile LSM000090 at the CLAB site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

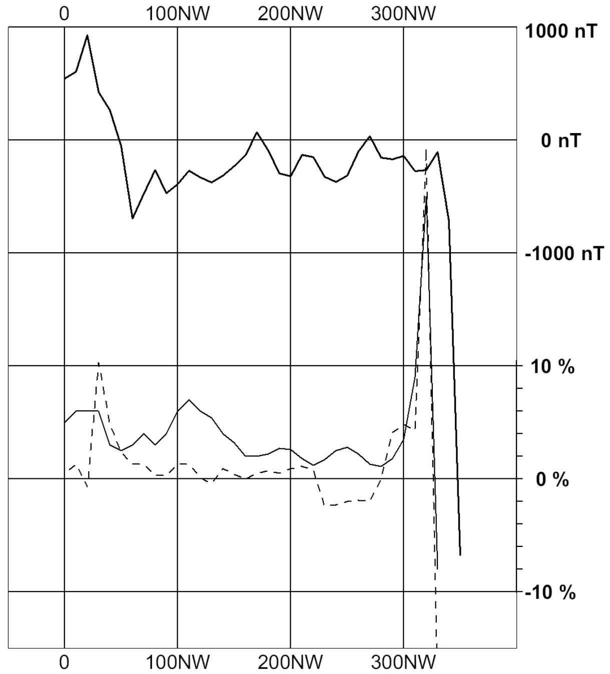

Figure 5-20. *Profile LSM000091 at the CLAB site. The thick line at top shows the magnetic total field anomaly. The thin line below shows the Slingram In-phase component (Real) and the dashed line shows the corresponding Out-of-phase component (Imaginary).*

A map over the magnetic total field anomaly is shown in Figure 5-21. Maps of the slingram In-phase (Real) component and the Out-of-phase (Imaginary) component at the CLAB site are shown in Figures 5-22 and 5-23 respectively.

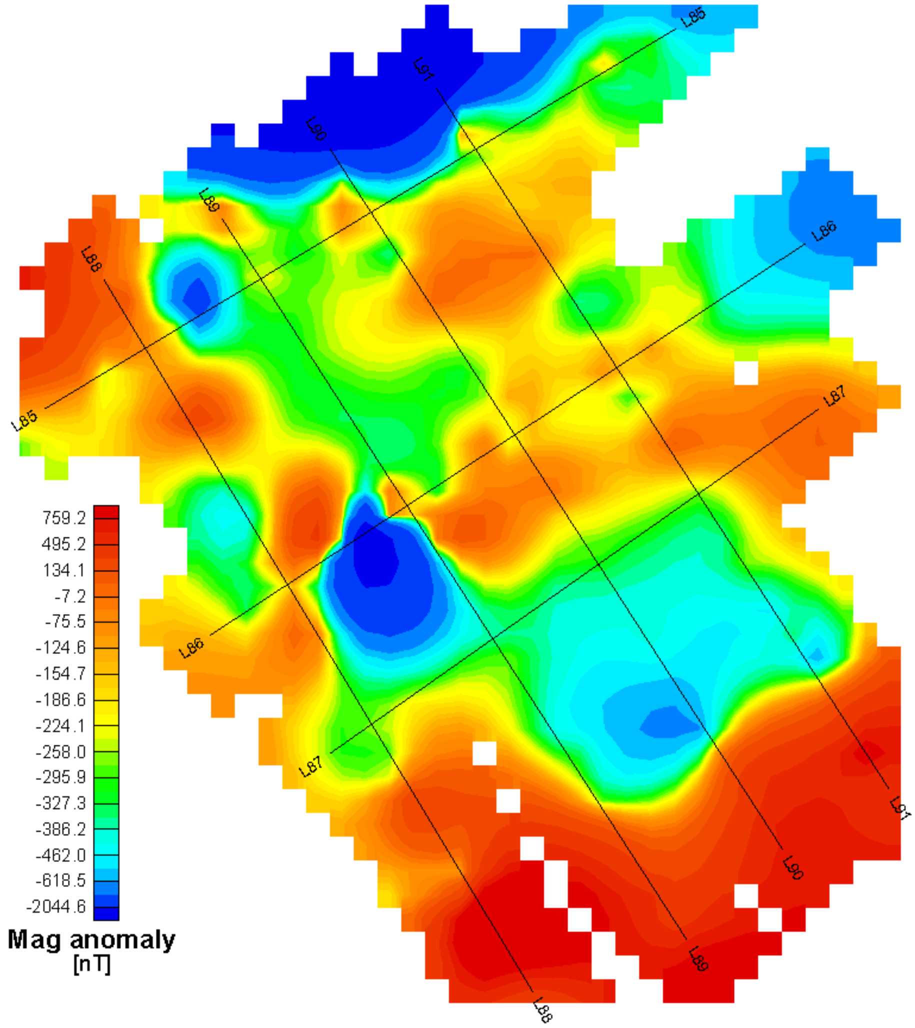

Figure 5-21. *The magnetic total field anomaly at the CLAB site. The names and locations of measured profiles are also shown on the map. The distance between profiles L90 (LSM0000090) and L91 (LSM000091) is 50 m.*

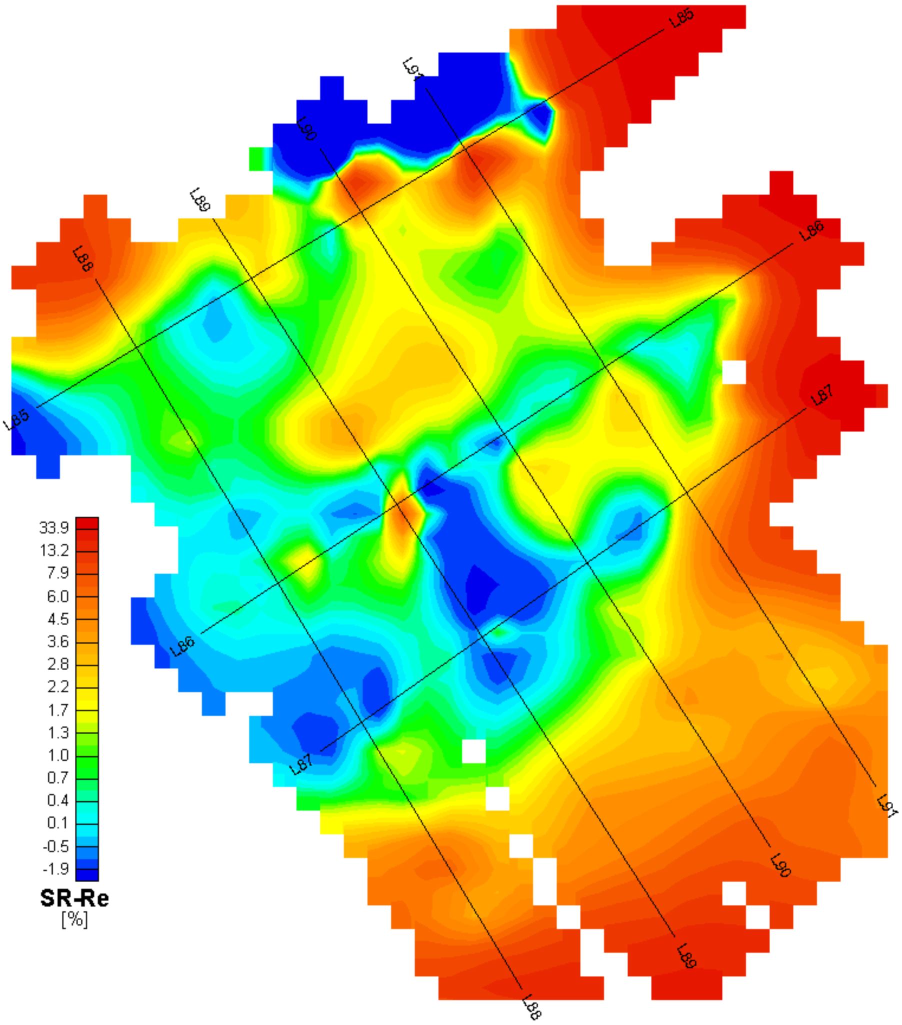

Figure 5-22. *The slingram In-phase (Real) component at the CLAB site. The names and locations of measured profiles are also shown on the map. The distance between profiles L90 (LSM0000090) and L91 (LSM000091) is 50 m.*

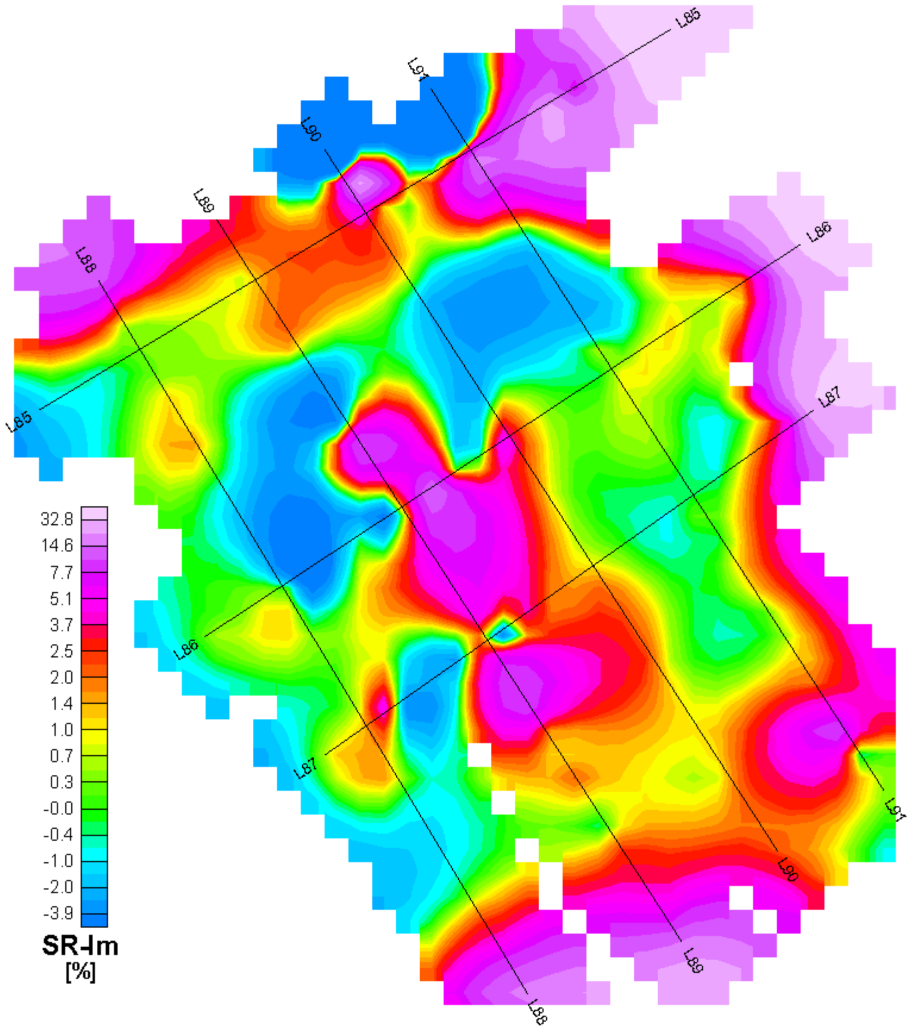

Figure 5-23. *The slingram Out-of-phase (Imaginary) component at the CLAB site. The names and locations of measured profiles are also shown on the map. The distance between profiles L90 (LSM0000090) and L91 (LSM000091) is 50 m.*

The result of the interpretation is shown in Figure 5-24. As mentioned above the noise level in this reported geophysical survey is fairly high in the area. This degrades the significance of the information received from magnetometry and EM. Very limited information has thus been achieved regarding the geometry of possible fracture zones in the area.

A possible fracture zone is however indicated in data from an older refraction seismics survey /Stanfors et al, 1998/ and interpretation of topography data obtained from low altitude airborne photography /Wiklund, 2002/. The structure passes the area in a east-north-eastern direction. EM data and magnetometry indicate the existence of a anomaly source with slightly increased electrical conductivity and low magnetic susceptibility. The conclusion is that the results from the EM and magnetics supports the interpretation of data from refraction seismics and topography, i.e. the existence of a fracture zone. It is however not possible to extract any reliable information regarding the dip of the possible fracture zone from these data.

At the south-eastern border of the survey a pronounced positive magnetic anomaly is indicated. According to geological observations in the area very high magnetic susceptibilities have been recorded on outcrops (up to $15000*10^{-5}$ SI). It is probable that the magnetic anomaly source is to be found among the rock types observed in the area. In this south-eastern part of the measured area, also a pronounced response in the EM system is noted. The quite high levels in the In-phase and Out-of-phase components are interpreted to be caused by saline sea water.

With the exception of the possible fracture zone described above, the geophysical survey with slingram and magnetometer has not brought any further reliable information regarding the geometry of other possible fracture zones in the area. The high noise level recorded in the slingram system indicates that EM is not an effective method at this specific site.

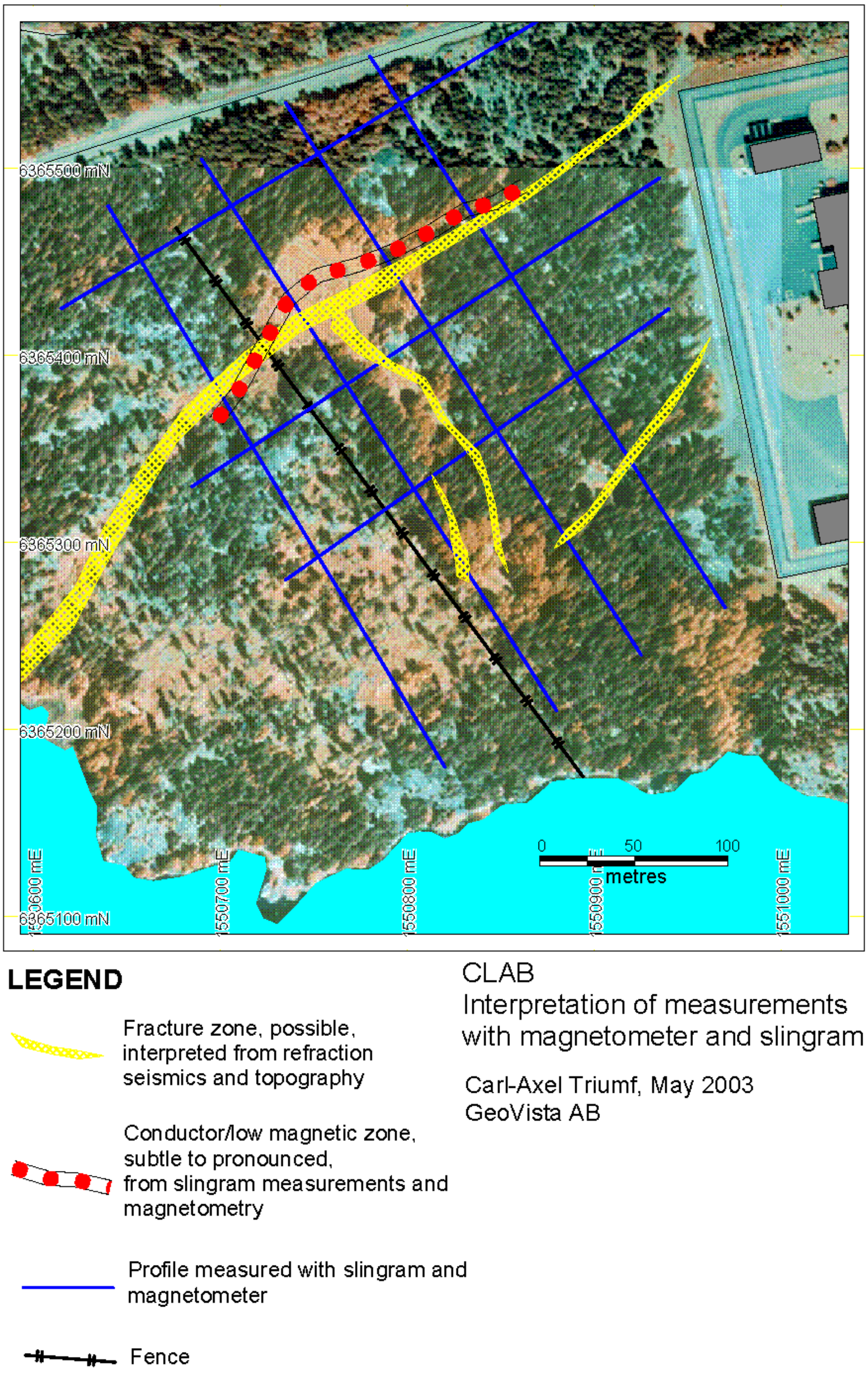

Figure 5-24. *Interpretation of data from the geophysical survey at the CLAB site. Interpretation is made together with interpretation of refraction seismics and information from core drilling performed in the investigations for CLAB2 /Stanfors et al, 1998/ and interpretation of topography data obtained from low altitude airborne photography /Wiklund, 2002/.*

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