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# VLF-R and magnetic surveys at the Asentolampi and Isokangas targets, Portimojärvi, Ranua

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Abstract

A total on four roughly 1.5 km long VLF-R and magnetic ground profiles were surveyed at Asentolampi and Isokangas targets in Portimojärvi, Ranua, in June 2008. The purpose of the surveys was to investigate the electric conductivity of the ground as well as to check if the reflections met in a GPR survey at Asentolampi were visible in VLF-R.

Keywords
VLF-R surveys, magnetic surveys, Asentolampi, Isokangas, Ranua

Geographical area
Finland, Lapland Province, Ranua Commune, Portimojärvi, Asentolampi, Isokangas

Map sheet
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Raportin nimi
VLF-R and magnetic surveys at the Asentolampi and Isokangas targets, Portimojärvi, Ranua
[=VLF-R- ja magneettisia mittauksia Ranuan Portimojärven Asentolammella ja Isokankaalla]

Tiivistelmä
Ranuan Portimojärven Asentolammella ja Isokankaalla mitattiin kesäkuussa 2008 yhteensä neljä n. 1.5 km pituista VLF-R- ja magneettista maanpintaprofiilia. Tarkoituksena oli tutkia kohteiden maankamaran sähkönjohtavuutta sekä tarkistaa näkyvätkö Asentolammen kohteella tehtyjen maatutkaluotausten heijasteet VLF-R-mittauksessa.

Asiasanat (kohde, menetelmät jne.)
VLF-R-mittaukset, magneettiset mittaukset, Asentolampi, Isokangas, Ranua

Maantieteellinen alue (maa, lääni, kunta, kylä, esiintymä)
Suomi, Lapin lääni, Ranua, Portimojärvi, Asentolampi, Isokangas

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3524 06

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Tilaaja Tapio Hyysalo, Areva Resources Finland Oy. Tilauksessa on noudatettu puitesopimusta Dnro K129/53/2004 vuodelle 2008.

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## Contents

## 1 REFERENCE

This study is based on the preliminary working plan and offer (12.12.2007), and the discussions between the stuff of AREVA Resources Finland Oy (ARF) and the Geological Survey of Finland (GTK) in 2008, and followed order (order number 0821; 23.5.2008). The order is a part of skeleton agreement (dnro K129/53/2004) between ARF and GTK in 2008. The study was carried out under GTK's project FinU1 (1901006). The purpose of the study was to check if the electrical structures met in the GPR profiles were detectable by the electromagnetic VLF-R method.

## 2 STUDY AREA

Study area is situated on the northeastern side of the Portimojärvi village, Ranua, southern Lapland. The general name of the target is Asentolampi and it consists of two sub-targets, Asentolampi and Isokangas, both on map sheet 3524 06.

## 3 METHODS AND THE AIM OF THE STUDY

The VLF resistivity (VLF-R for short) method uses the electromagnetic field of a distant radio transmitter to detect changes of resistivity of the ground to depths of a few tens of meters. As the method utilizes both magnetic and electric components of the electromagnetic field, the apparent resistivity of the ground can be determined. Another outputted quantity is the depth to the conducting layer. As the distance to the transmitter is typically up to thousands of kilometres, the primary field in the survey area is uniform and no edge effects cause problems.

The VLF transmitter used at Asentolampi was DHO38 at the frequency on 23800 Hz which is located in Germany near the Dutch border. The distance from Asentolampi to the transmitter is ~2000 km and the direction is ~225$^{o}$. The distance satisfies easily plane wave requirements. The optimal direction of the transmitter for good anomalies to develop would be the same as the direction of geological strike. In this case the strike differs some 40$^{o}$ from the station direction. Yet the anomalies are well developed and their flanks are quite steep.

The equipment used was Geonics EM-16R. This is a light weight and flexible unit. The electric field is measured with two electrodes that are set 10 meters apart in a line towards the transmitter. Readings are typically taken every ten meters, and a two man team can measure up to 400 points a day. Measurement accuracy of phase angle is 2$^{o}$ and of apparent resistivity 10 %.

The magnetic field was measured with a GSM8-proton magnetometer. Nominal measurement accuracy is 1 nT. Magnetic base station near the survey area recorded diurnal variations.

Coordinates were determined by a Garmin GPS 12 XL. The accuracy is ±2 m. Magnetic and VLF-R readings were taken at the same footsteps.

The aim of the measurements was to check if the structures detected in the GPR surveys (Sarala, 2008) were visible in the VLF-R profiles and if other interesting structures appeared. If VLF-R proves to give promising results, a mapping of a larger area can be justified. The magnetic field mapping is a commonly measured component as one of the VLF-R measurement persons can record it without extra effort and cost.

## 4 FIELD WORK

The field work was done by a two man team, Antero Saastamoinen and Veikko Ojuva on the 4.-5.6.2008. Both have an experience of more than twenty years in VLF-R and magnetic field mapping. The coordinates and lengths of the profiles are given in Table 1.

Table 1. VLF-R and magnetic profiles at Asentolampi.

| Prof # | $x_{begin}$ | $y_{begin}$ | $x_{end}$ | $y_{end}$ | Length | Points |
|---|---|---|---|---|---|---|
| | (m) | (m) | (m) | (m) | (m) | (-) |
| 1 | 3476410 | 7339080 | 3477763 | 7338566 | 1440 | 145 |
| 2 | 3478317 | 7337648 | 3477154 | 7336893 | 1390 | 140 |
| 3 | 3483891 | 7331254 | 3484942 | 7330321 | 1400 | 141 |
| 4 | 3485138 | 7331213 | 3483891 | 7331207 | 1250 | 126 |
| | | | | Total | 5480 | 552 |

The magnetic base station was set up at the coordinates x3466926 y7340190. During the two days, the maximum and minimum readings differed by 16 nT.

The primary VLF-R signal was well audible and the anomalies could be measured reliably. Ground was dry and not even the locations marked with “swamp” were moist. This means that the depth extent of the VLF-R survey is several tens of meters; probably up to 100 m. There were neither electric power lines nor any other cultural sources to cause disturbances.

The measured profiles have been drawn on airborne electromagnetic quadrature component maps in appendix 1.

## 5 INTERPRETATION OF VLF-R DATA

The data recorded on the four profiles have been plotted in appendices 2 - 5. At the top in each page there is the airborne quadrature component as parts per million. The data points have been sampled from the maps in appendix 1. The second blue graph is the VLF-R apparent resistivity in logarithmic scale as Ohm-meters. Maximum value for apparent resistivity in EM 16R is 30000 Ωm and minimum 10 Ωm. Phase angle is shown with red color and it is given as degrees. Minimum value for phase angle is $0^o$ and maximum $90^o$. $45^o$ is the important value that separates resistive structures ($0^o$ - $45^o$) from conductive structures ($45^o$ - $90^o$) below the uppermost layer. If the recorders have logged swamps along the profile, there is a mark of this on the phase angle graph. At the bottom there is the magnetic total intensity field.

One readily notes that the apparent resistivities are quite high along most parts of the profiles. Depth penetration of a VLF signal for this kind of resistivities is more than 100 m. Together with the very low phase angles this implies that there are no notable conductors within the first hundreds on depth meters. The very low phase angles are in accordance with the high resistivities suggesting that the ground resistivity grows downwards. The swamps seem not correlate with apparent resistivity enough to be responsible for the few conductivity anomalies. It seems that most of the anomalies have their sources in the hard bedrock.

There is only one anomaly that is caused by a good conductor, the one on profile 4 at 800 - 900 m. This kind of anomalies are usually caused by sulfide occurrences or by graphite bearing schists. As there is no magnetic anomaly at the spot, magnetite-poor sulphides or schists are both possible.

The magnetic field does not show remarkable anomalies suggesting that there is no magnetite present. Only on profile 2 the magnetic field is anomalous. On the airborne magnetic map there is a long zone of anomalies with profile 2 running along the strike of the anomaly crest. It is not pos-sible to estimate dip or other parameters of the source of the anomaly, but the airborne map shows that the dip may be close to vertical. On all the other profiles anomalies are very weak.

Appendix 6 shows the results of a 1-D interpretation of the VLF-R profiles. The model consists of two layers and their resistivities. The bottom layer thickness is infinite. As the phase angle along the measured profiles is very low, a 1-D assumption dictates that the resistivity of the second layer must be higher that that of the first layer. As the measured apparent resistivity is very high, thousands of Ohm-meters, the second layer resistivity must be even higher. In the figures in appendix 6 the color bar indicates the logarithm of the relevant resistivities. Dark blue colors represent the resistive bedrock the depth of which varies but along profiles 2 and 3 is only a couple of meters. Above this the greenish color represents the soil the resistivity of which is some hundreds of Ohm-meters. The 1-D interpretation suggests that most of the measured apparent resistivity variation reflects resistivity variation in the overburden or its depth variation. The interpretation program 2LAYINV has been written by Markku Pirttijärvi (Pirttijärvi, 2006).

The 1-D two layer model is not always the best model. If the ground consists of more than two layers and if the resistivities are very high, all or many of the layers have their own contributions to the measured anomaly, and the simple modeling result will inevitably be wrong. Three dimensional structures cause their own contributions thus complicating the situation. For this reason it is customary to have a qualitative look at the VLF-R maps.

In the appendices 2 - 5 the topmost graph represents the airborne data and one can see that every time when the airborne data shows a local maximum, there is a corresponding low in VLF-R apparent resistivity. So the two electromagnetic measurements are in agreement. The red areas in the two airborne maps in appendix 1 are outputs of conductors in the overburden or in the bedrock. Depth to the structures may be several tens of meters. One notes that the VLF-R resistivity conductor anomalies are all parts of large areal red areas. It is possible that the airborne anomalies are caused by surficial overburden conductors, but it is not probable. At least the VLF-R anomaly on profile 4 seems to be caused by a bedrock conductor, and the corresponding airborne anomaly is a part of a large anomaly structure. If the reason for the peak on profile 4 is in the overburden, a good quality clay is needed to develop it.

## 6 CONCLUSIONS

It is not easy to compare GPR and VLF-R data because of several reasons. The minimum size of the blocks that can be separated from background in GPR is of the order of 0.5 meters. Smaller structures have their contribution to the image but are easily lost into the background and noise. For VLF-R the corresponding size can be estimated to be >10 m. A GPR image consists of many vertical soundings that, when combined, produce a section of the reflecting structures of the ground. For VLF-R there are only two measured components the variation of which along the profile is considered. In effect, GPR is a sounding method and VLF-R is a profiling or mapping method. The depth penetration of GPR in a resistive environment is up to 20 m whereas for VLF-R it is more that 100 m. All the structures within this distance produce their own contribution to the data. One great difference lies in the basic principles of the methods. The physical property behind GPR is dielectricity while for VLF-R it is specific resistivity. Water has high dielectric constant and the same water reduces the specific resistivity of most earth materials. This is the reason why some structures sometimes are visible in both methods. Still, sometimes the introduction of water does not reduce the resistivity of the ground enough to make it detectable by electromagnetic methods.

The depths of the bedrock are close to the same for both methods. Small features visible in the GPR images are not easy to distinguish from the VLF-R data. The response of poor conductors in shallow depths may be beyond the reach of VLF-R. VLF-R suits best for large scale mapping when occasional measuring points with their measuring errors are scaled out.

Magnetic field in the area is not anomalous. Only a couple of magnetized zones, possibly diabases are visible. This means that there are no magnetite bearing rocks are in the area.

Appendix 7 presents the airborne quadrature component map between Asentolampi and Isokangas. The surveyed VLF-R profiles are added on the map. There are several conductive zoned running from NNW to SSE. It would be interesting to check the nature of the conductors. From geophysical point of view, the three most probable sources are magnetite-poor sulphides, clays, and graphite bearing schists.

## 7 REFERENCES

**Pirttijärvi, Markku 2006. 2LAYINV**, Laterally constrained two-layer inversion of VLF-R measurements, User's guide, Version 1.0a. OYGF/M/2006/1, University of Oulu, Department of Physical Sciences, Division of Geophysics, 12 p.

**Sarala, Pertti 2008.** Ground Penetrating Radar Survey in the Asentolampi target, Portimojärvi, Ranua. Geological Survey of Finland, report P31.4/2008/23, 11 p., 1 app., DataCD.

## 8 APPENDICES

Appendix 1. Location of profiles 1 - 4 on airborne quadrature component map
Appendix 2. VLF-R and magnetic graphs from profile 1
Appendix 3. VLF-R and magnetic graphs from profile 2
Appendix 4. VLF-R and magnetic graphs from profile 3
Appendix 5. VLF-R and magnetic graphs from profile 4
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Appendix 7. Airborne quadrature component map from the Asentolampi - Isokangas area

## 9 CONTENTS OF THE CD-ROM

pdf
  pdf-format report from the Asentolampi - Isokangas area surveys

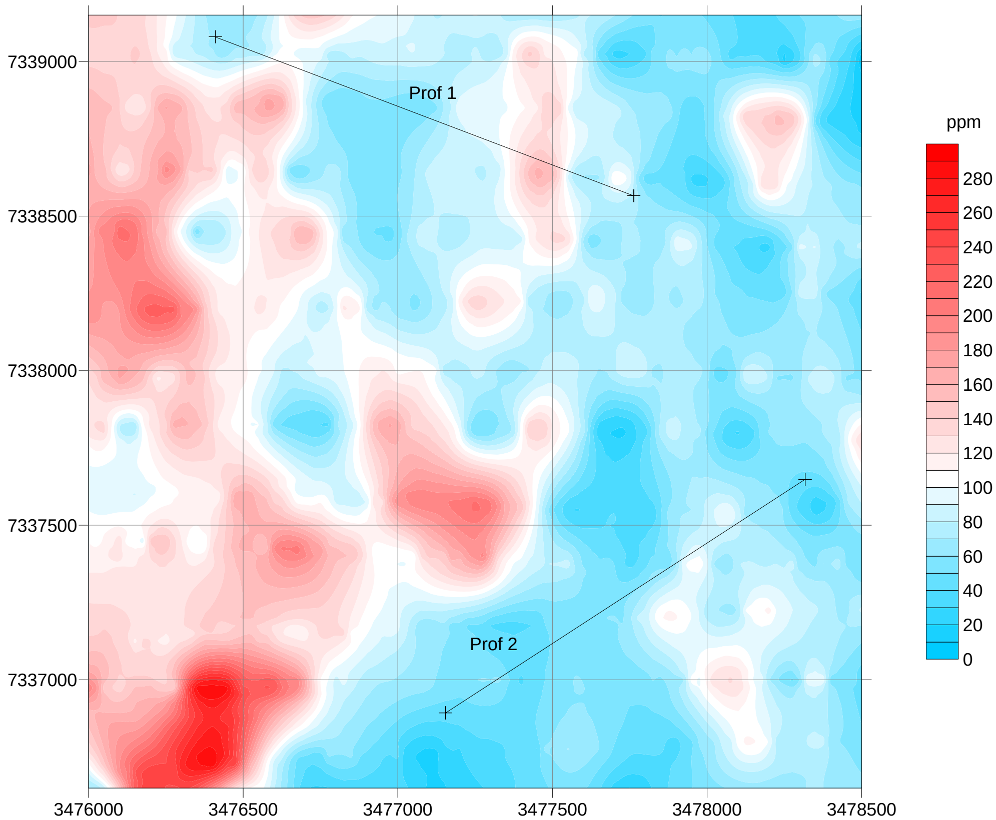
ptc
  original ptc-data files
    A: VLF-R
    B: magnetic
    C: magnetic base station

dxf
  magnetic, VLF-R phase angle and VLF-R apparent resistivity files in ArcMap format
  readme-files contain information on scaling the dxf-files

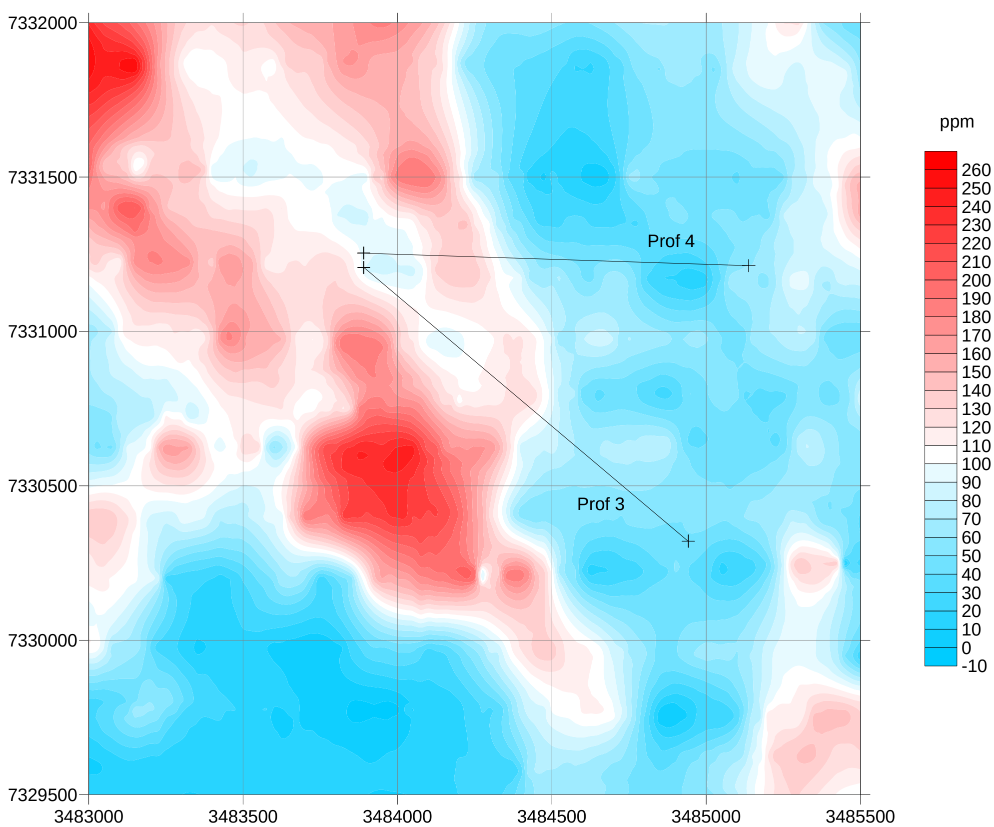
xyz
  field data in geosoft xyz-format

Asentolampi

Appendix 1.




Isokangas



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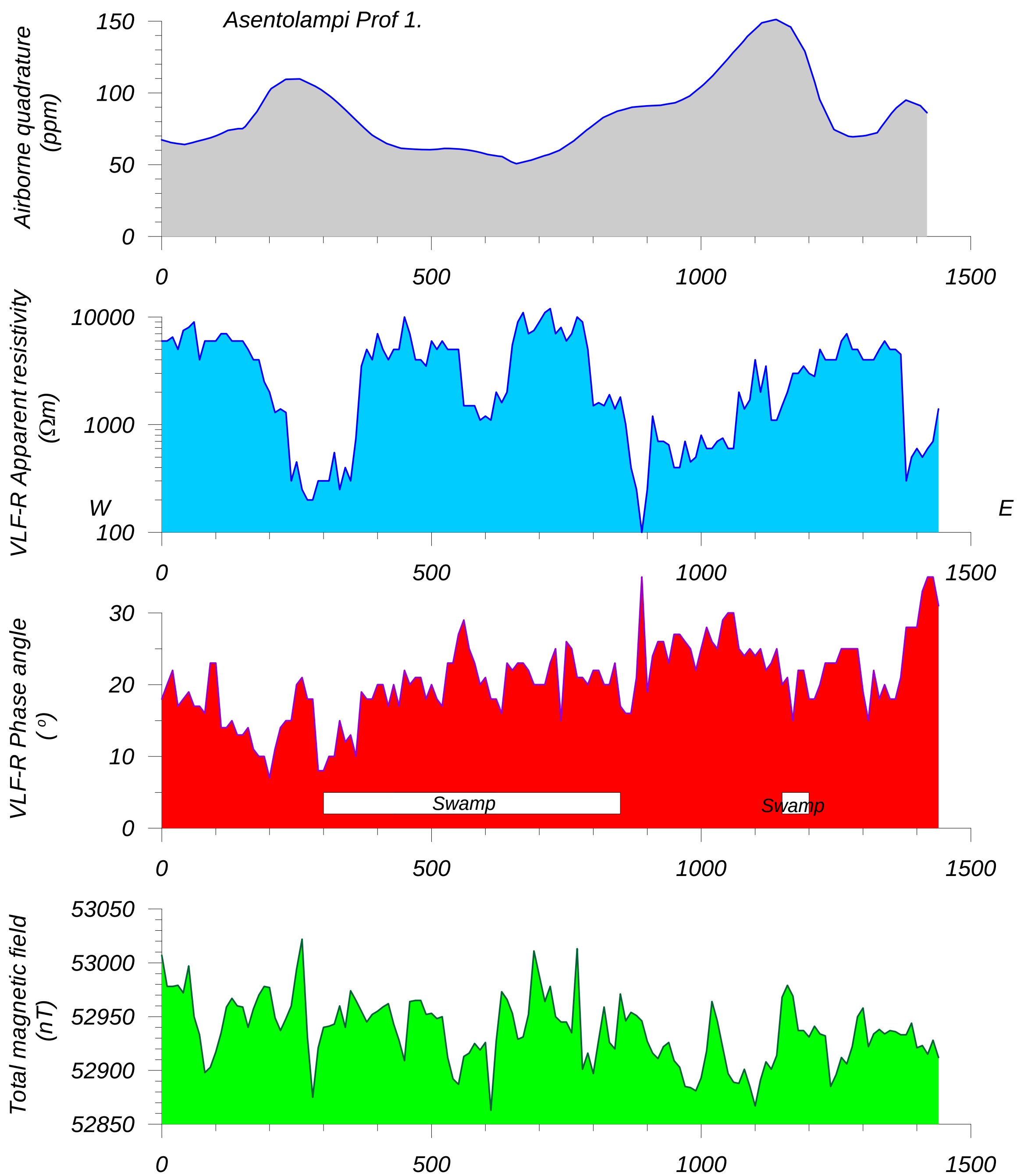
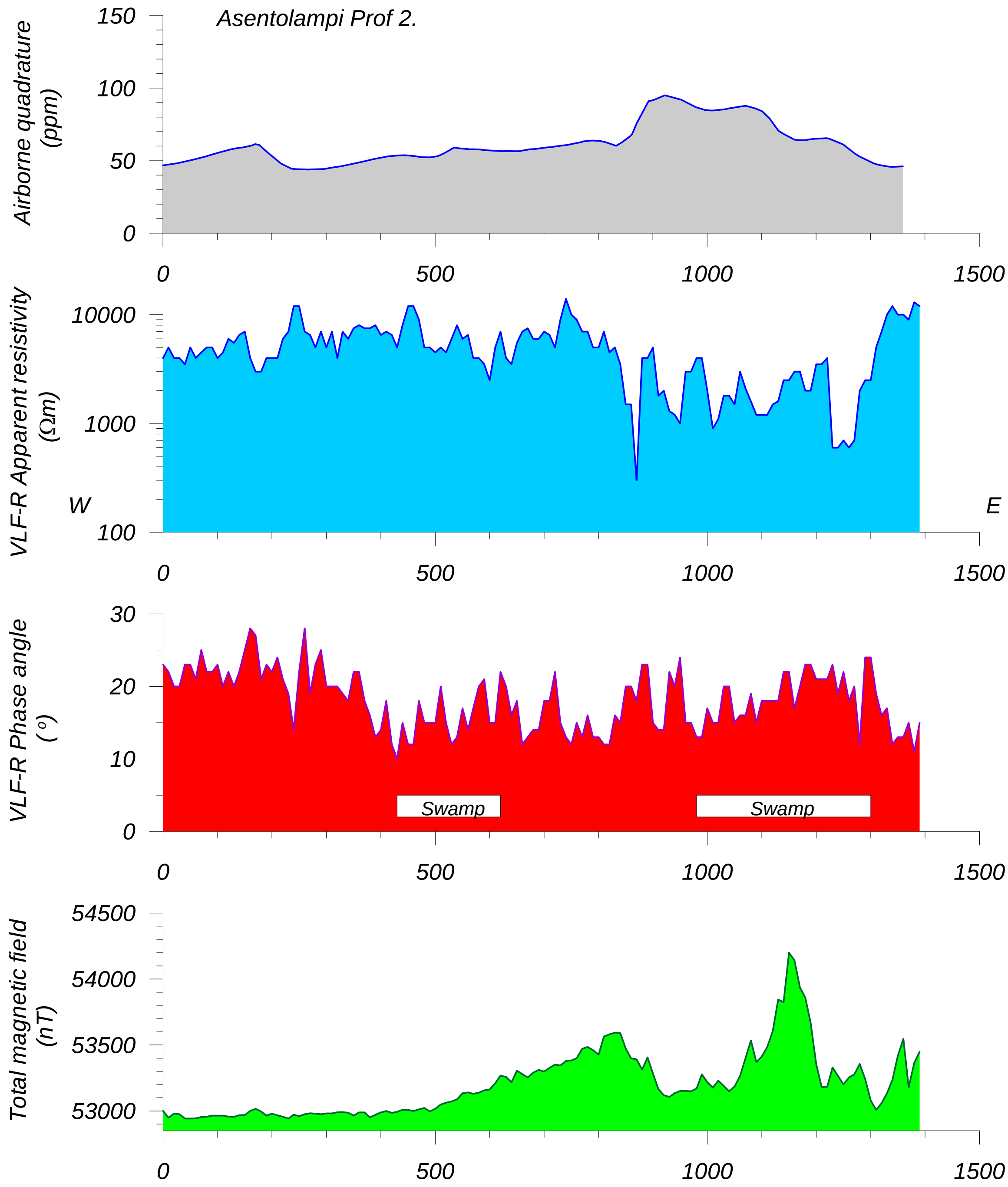
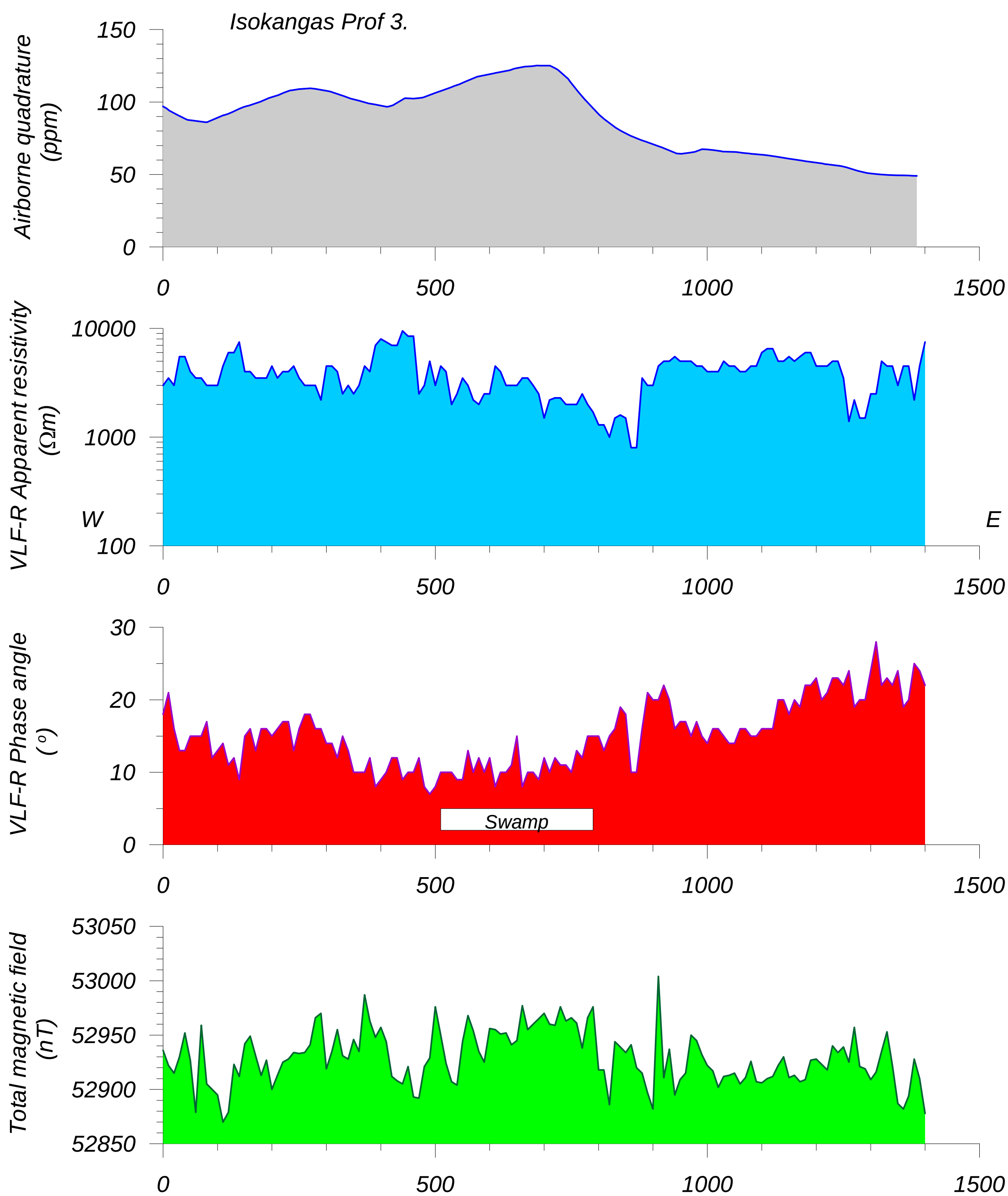


Asentolampi Prof 1.
Airborne quadrature (ppm)
150
100
50
0
0
500
1000
1500
VLF-R Apparent resistivity (Ωm)
10000
1000
100
W
E
0
500
1000
1500
VLF-R Phase angle (°)
30
20
10
0
Swamp
Swamp
0
500
1000
1500
Total magnetic field (nT)
53050
53000
52950
52900
52850
0
500
1000
1500

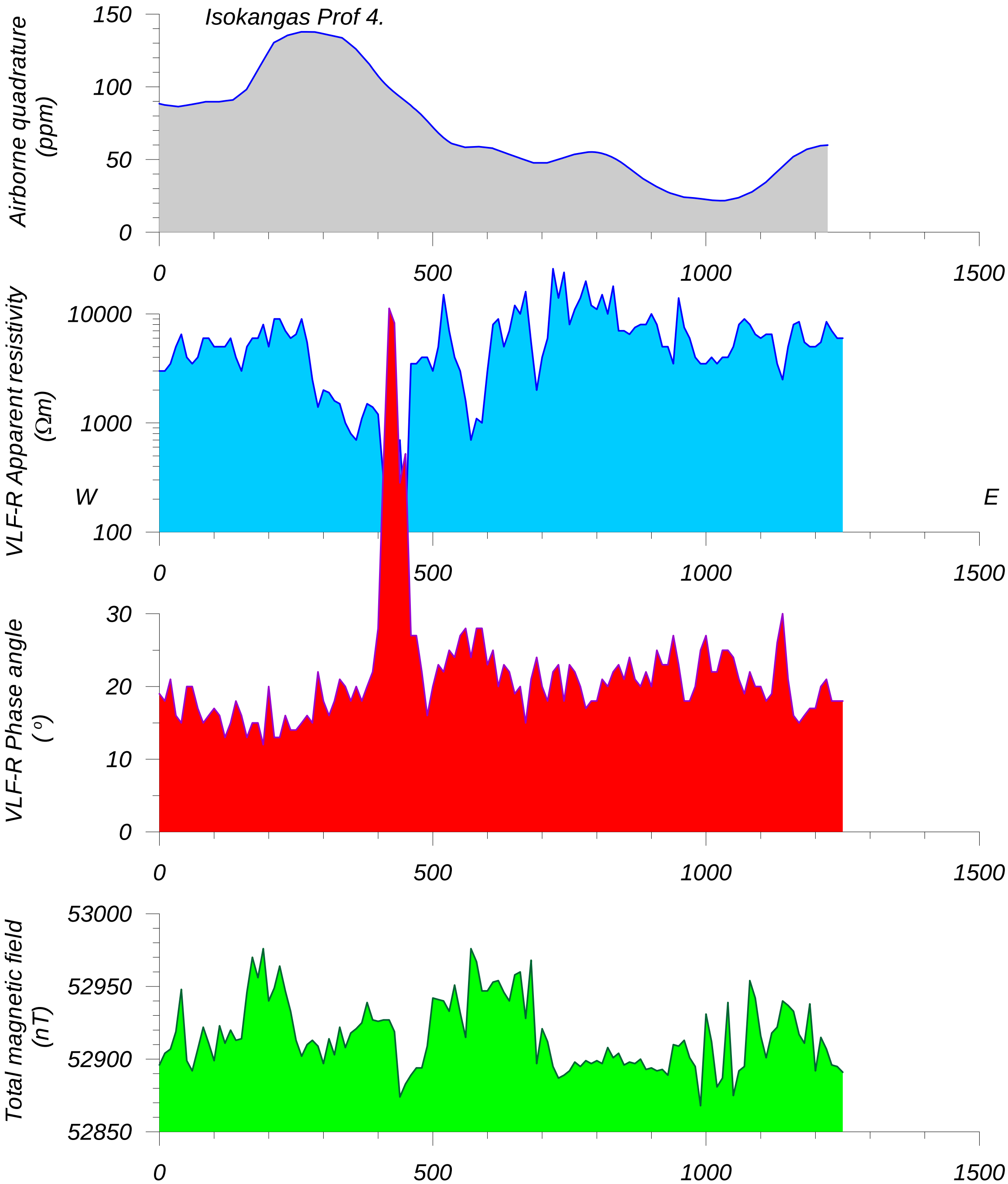
Appendix 3.



Asentolampi Prof 2.
Airborne quadrature (ppm)
150
100
50
0
0
500
1000
1500
VLF-R Apparent resistivity (Ωm)
10000
1000
100
W
E
0
500
1000
1500
VLF-R Phase angle (°)
30
20
10
0
Swamp
Swamp
0
500
1000
1500
Total magnetic field (nT)
54500
54000
53500
53000
0
500
1000
1500


Isokangas Prof 3.
Airborne quadrature (ppm)
150
100
50
0
0
500
1000
1500
VLF-R Apparent resistivity (Ωm)
10000
1000
100
W
E
0
500
1000
1500
VLF-R Phase angle (°)
30
20
10
0
Swamp
0
500
1000
1500
Total magnetic field (nT)
53050
53000
52950
52900
52850
0
500
1000
1500

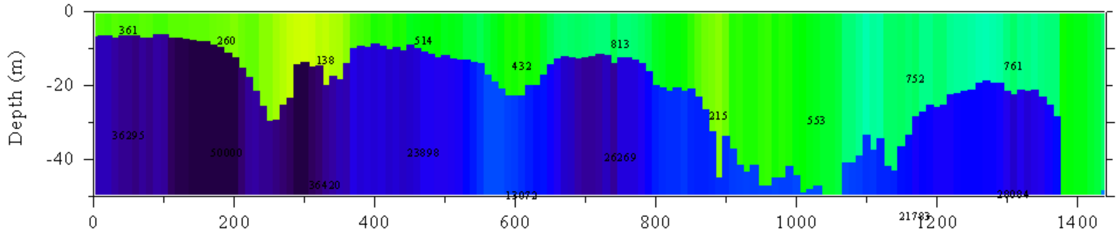
Appendix 5.



Isokangas Prof 4.
Airborne quadrature (ppm)
150
100
50
0
0
500
1000
1500
VLF-R Apparent resistivity (Ωm)
10000
1000
100
W
E
VLF-R Phase angle (°)
30
20
10
0
Total magnetic field (nT)
53000
52950
52900
52850

Appendix 6.

Prof 1.

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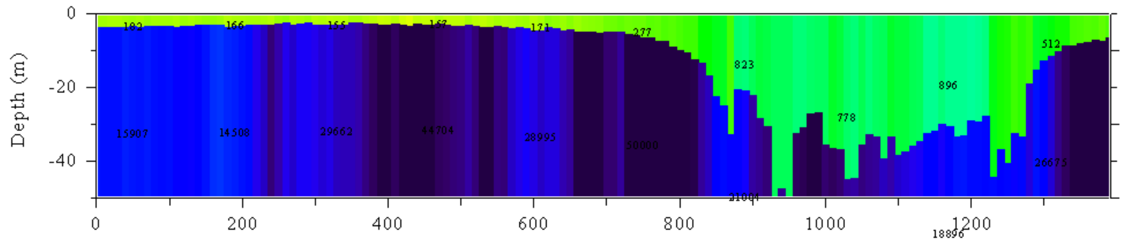


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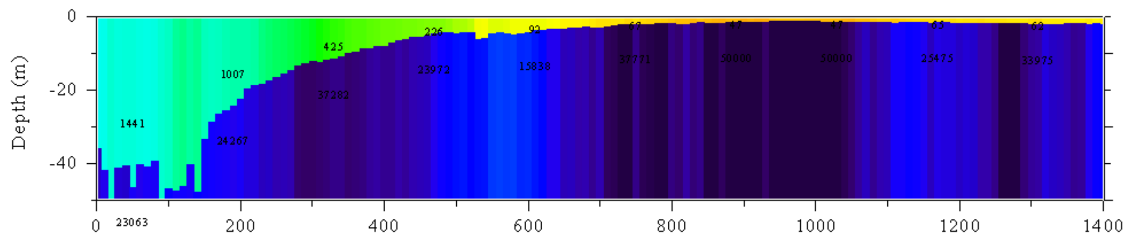


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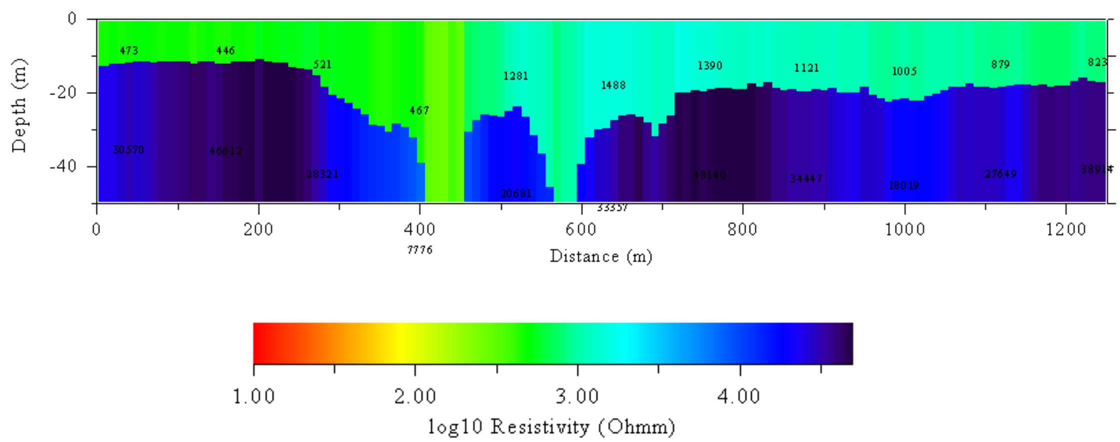

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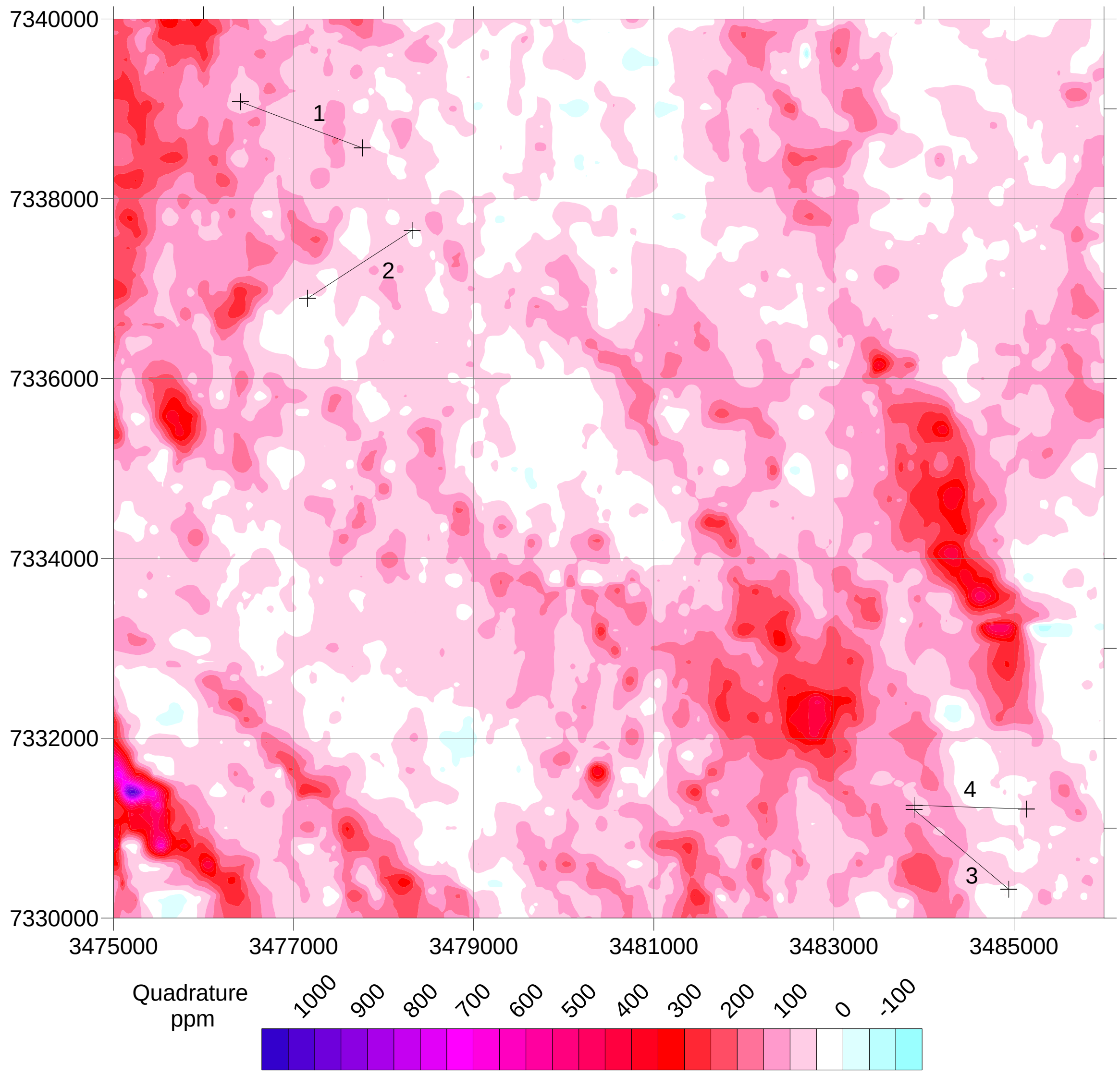

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3481000
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1
2
3
4
Quadrature
ppm
1000
900
800
700
600
500
400
300
200
100
0
-100