AMT survey in the Outokumpu ore Belt, Eastern Finland

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Geological background

The Outokumpu ore belt (Fig. 1) comprises Paleoroterozoic turbiditic deep-water sediments enclosing fault-bound ophiolitic slices composed dominantly of serpentinites derived from oceanic upper mantle peridotites. These together form the allochthonous Outokumpu suite that was emplaced onto the Karelian Craton margin during the early stages of the Svecofennian Orogeny. The area which has been over 100 years among the most important mining regions in Finland is still supporting active mining and exploration. The main prospectivity is for polymetallic (Cu-Co-Zn-Ni-Ag-Au) sulfide ores that are hosted by carbonate, calc-silicate and quartz rocks fringing serpentinite bodies embedded in extensive formations of electrically conductive iron sulfide and graphite-bearing black schists that are showing no geochemical vectors to the ores (e.g. Peltonen et al., 2008).

AMT measurements

The presence of conductive schists makes electromagnetic exploration of the sulfide ores challenging. However, the detection of the black schists at depth would be useful in locating new environments with potential for the serpentinites and prospective Outokumpu rock assemblage.

Audiomagnetotelluric (AMT) data has been collected in 2012 – 2014 to image subsurface conductivity structure of the belt (Fig. 1). The measurements are a part of a larger collaborative project that aims at developing methods, skills and concepts for deep exploration using the Outokumpu Belt as an example and to carry out methodological and comparative study on concepts and technologies for deep exploration (up to 2 km). AMT data were acquired along five profiles transecting several key-features, including the Miihkali serpentinite, Archean Sotkuma gneiss window and the area SE from the Outokumpu mine. Altogether 91 sites were measured with the site spacing of 300 m–2 km. AMT data (f = 1 - 10 000 Hz) were acquired during daytime whereas night-recordings enabled to obtain data at the frequency range of 0.01 – 10 000 Hz. Measurements were done using two Metronix 24bit ADU-07e broadband electromagnetic acquisition systems. Robust remote reference processing yielded mostly good data quality, particularly for data recorded during night-time.

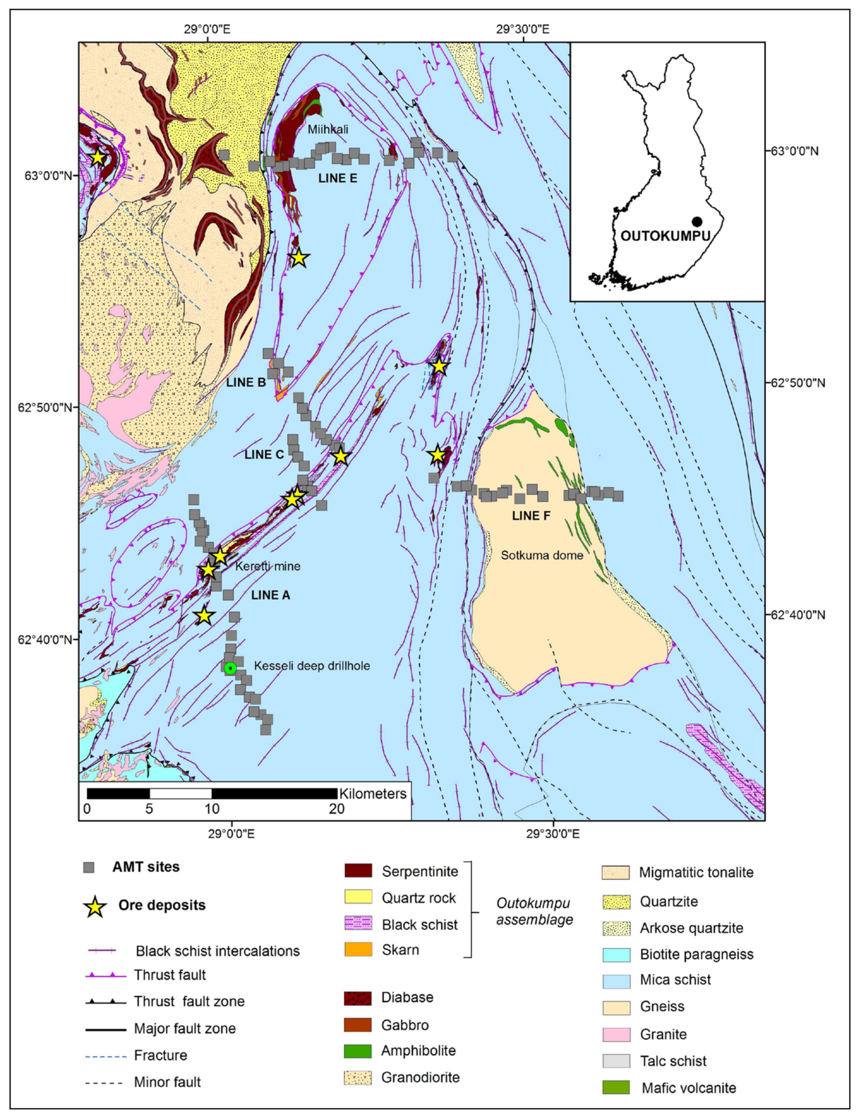

Figure 1. AMT sites on the Geological map of the study area. Bedrock map (Bedrock of Finland – DigiKP).

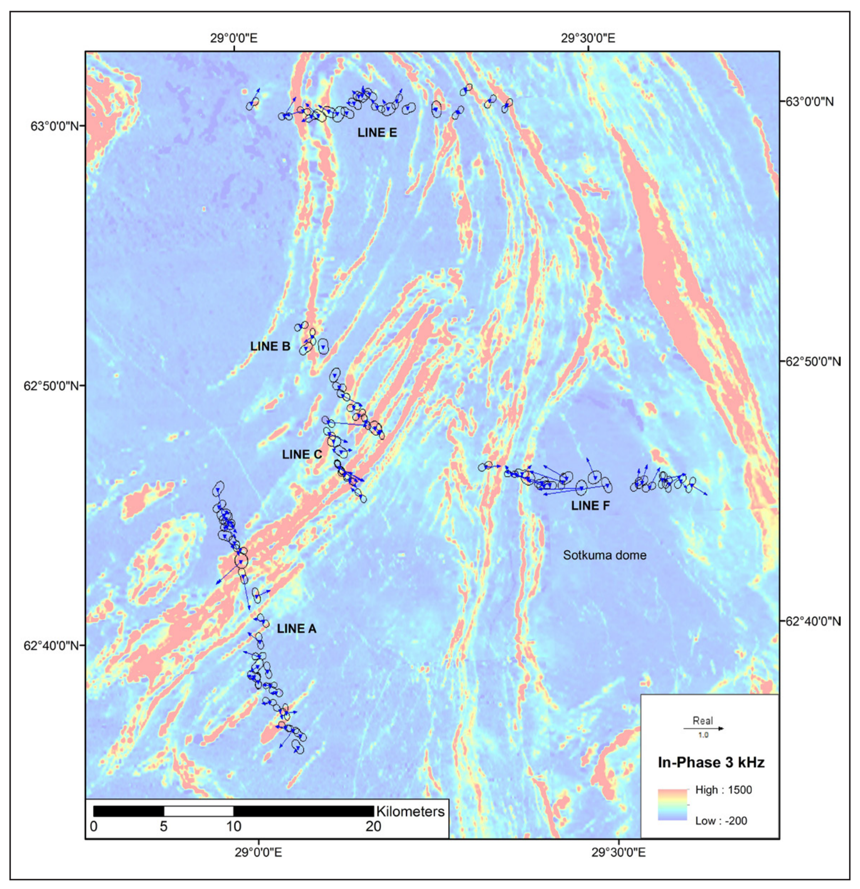

Figure 2. AMT sites on the airborne EM map. Red colours show good conductors. Impedance polar diagrams and induction vectors are also shown (f = 40 Hz).

References

Bedrock of Finland – DigiKP. Digital map database [Electronic resource]. Espoo: Geological Survey of Finland [accessed 10.10.2014]. Version 1.0. Available at: http://www.geo.fi/en/bedrock.html

Peltonen, P., Kontinen, A., Huhma, H. and Kuronen, U. 2008. Outokumpu revisited: New mineral deposit model for the mantle peridotite-associated Cu-Co-Zn-Ni-Ag-Au sulphide deposits: Ore Geology Reviews, 33, no. 3–4, 559–617.

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2-D Inversion

The survey area is favorable for 2-D modeling as it is characterized by thin, laterally extensive conductors indicated by airborne electromagnetic data (Fig 2). Two-dimensional inversion was done jointly for TE, TM- and Tipper data using the inversion code by Rodi and Mackie (2001). Inversion results are shown for three profiles in Figures 3 (a-c). Results show dipping and sub-horizontal conductors southeast of the Outokumpu town. One c. 1 km deep sub-horizontal conductor is verified by a drill hole located approximately 8 km from the town at Kesseli (Fig. 3a). Gently eastwards dipping conductor was detected in the Miihkali serpentinite area (Fig. 3b). Conductors are absent in the uppermost 6 km below the Sotkuma gneisses (Fig. 3c).

In addition to AMT, high resolution seismic and airborne ZTEM surveys have been recently carried out in the study area. Figure 4 shows 2-D AMT inversion model and 300 Ωm isosurface obtained from 3-D inversion airborne ZTEM data.

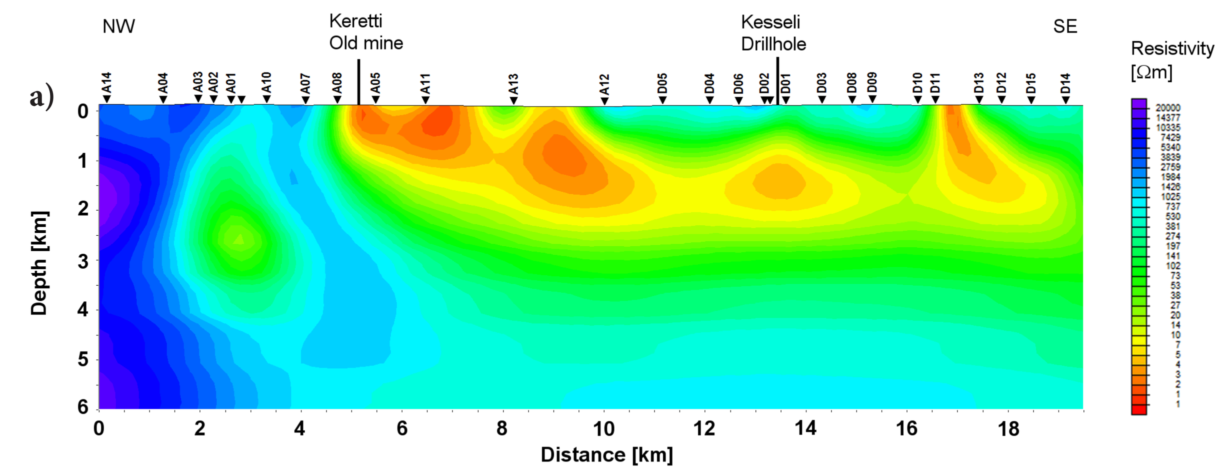

Figure 3 a) 2-D inversion model (Line A), RMS = 3.1. View from South-west.

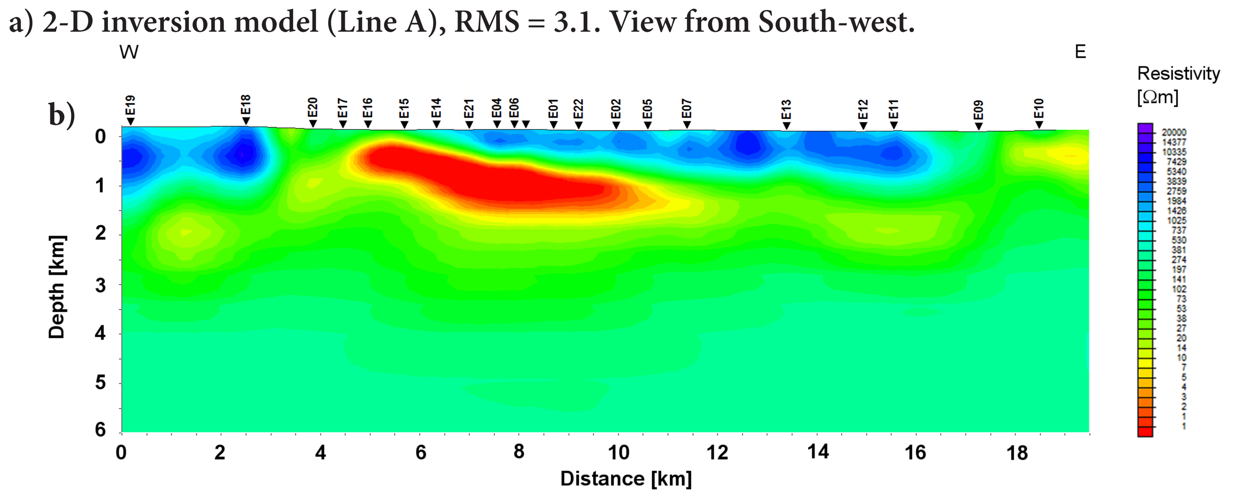

Figure 3 b) 2-D inversion model (line E), RMS = 3.3 View from South.

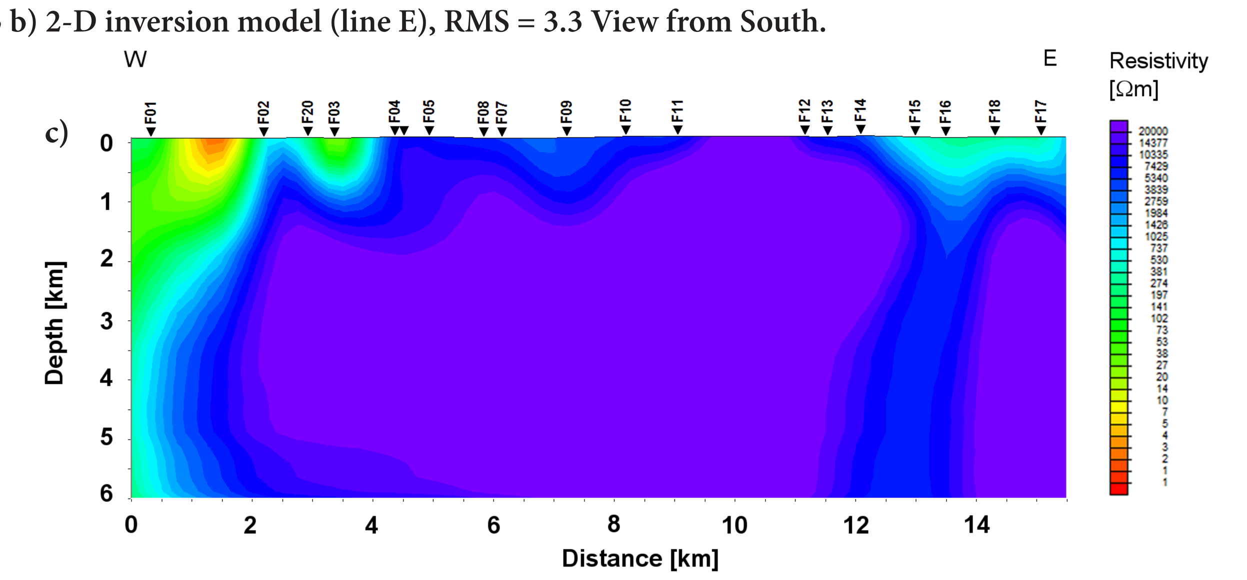

Figure 3 c) 2-D inversion model (line F), RMS = 3.4. View from South.

Discussion

ZTEM is capable to measure large areas in a short period. However, additional AMT soundings are useful as full impedance tensor and much larger frequency band are obtained. Our results infer (Fig. 4) that AMT detects sub-horizontal conductors more reliably than ZTEM. Only one EM component, Hz, is measured in ZTEM, which is unfortunately insensitive to sub-horizontal conductivity structures (i.e. Hz = 0 in 1-D case).

Different hypotheses have been presented on the nature of the Sotkuma dome area (Fig 3(c)) including thin (~ 2 km) thrust sheet with underlying conductive zone. AMT results show a thick (> 6 km) and resistive structure at the Sotkuma dome, which consequently represents rather a thick uplifted fault block than a thin thrust sheet of the Archaean basement rocks.

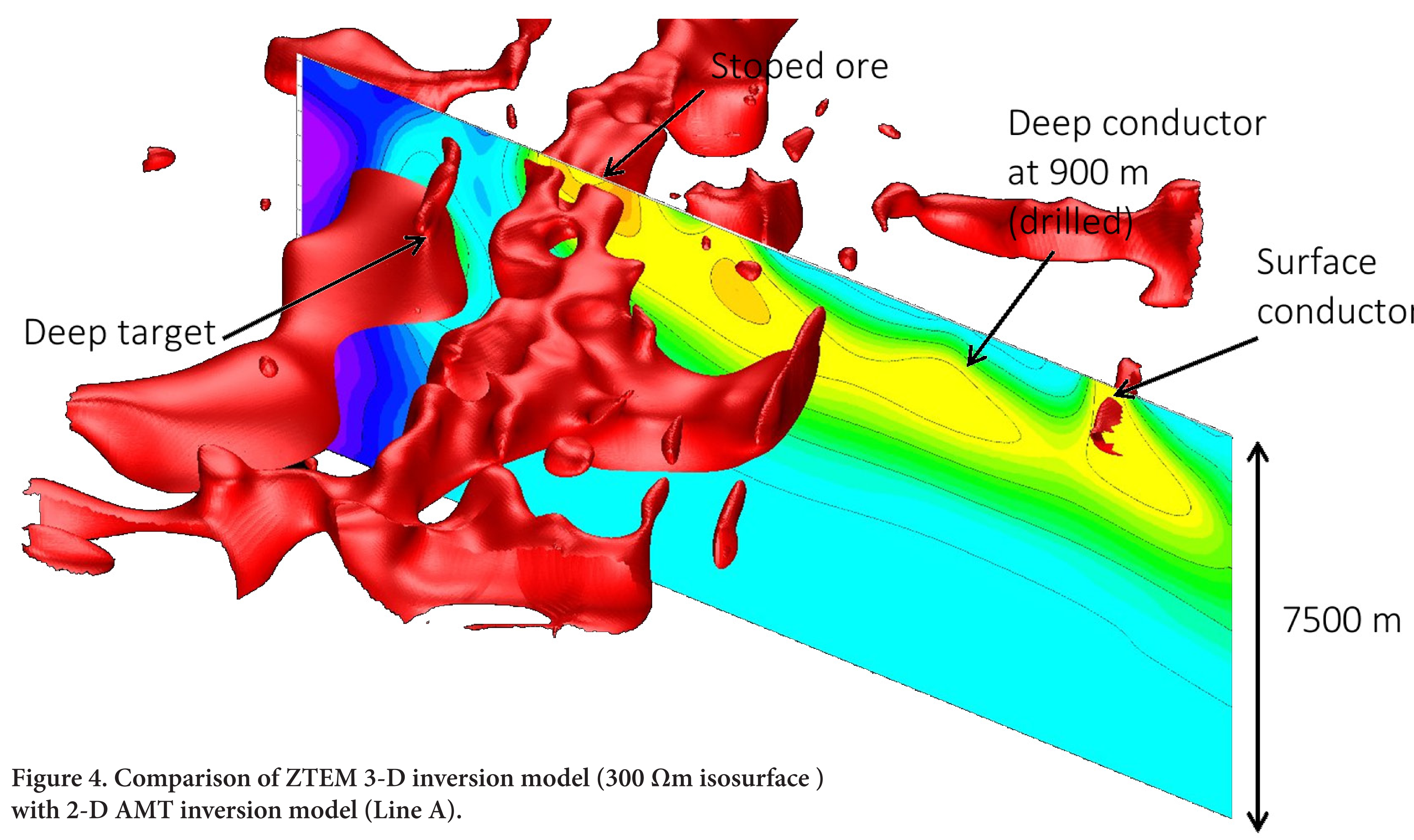

Figure 4. Comparison of ZTEM 3-D inversion model (300 Ωm isosurface) with 2-D AMT inversion model (Line A).

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