MobileMT: Depth of investigation and forward modeling

ABSTRACT

MobileMT is the next generation of a natural-field airborne EM technology. Diagrams of predicted effective depth of investigation in the **MobileMT** frequency range are given using an expression based on the skin depth concept. Forward modeling exercises results are illustrated for different geoelectrical situations with **MobileMT** effective depth of investigation estimation.

PREDICTION OF EFFECTIVE DEPTH OF INVESTIGATION

Actual **MobileMT** depth of investigation (DOI) is controlled by complex relations between factors combined into two groups: External and internal. Correspondingly:

1) natural signal strength, earth resistivity and geoelectrical structure complexity, man-made EM noise;

2) instrument accuracy and sensitivity, frequency range measurement, noise level of the survey data and the system design.

Approximate and rapid estimation of the ***effective depth*** of EM field penetration can be done based on the relationship with the ***"skin depth"*** parameter which is the depth at which the EM field is reduced to $1/e$, or 37% of its value at the surface (Spies, 1989). Approximate frequency-domain (or MT) ***skin depth*** can be estimated based on the formula (Spies, 1989):

$$\delta_{FD} = \sqrt{\frac{2}{\sigma\mu_0\omega}} \qquad (1)$$

where: σ is conductivity in S/m; μ_0 is magnetic permeability in H/m; and ω is angular frequency ($=2\pi f$, where f is frequency in Hz).

For a non-magnetic environment, when $\mu = \mu_0 = 4\pi \times 10^{-7}$ H/m, the formula (1) can be transformed into a more simple form:

$$\delta_{FD} \approx 503 * \sqrt{\frac{\rho}{f}} \qquad (2)$$

where: ρ is resistivity in Ohm·m ($=1/\sigma$).

There are several approaches of direct transformation from observed EM data to inferred resistivity and depth (resistivity-depth imaging). The techniques are based on the relationship between the ***skin depth*** parameter and the ***effective depth*** of EM field penetration. Two approximate depth transformations commonly used in magnetotellurics are known as the Bostick and Niblett Sayn-Wittgenstein transforms (Spies, 1989). The ***effective depth*** of penetration (h) for these transformations is estimated directly from the Cogniard apparent resistivity $\rho_a(\omega)$:

$$h = \sqrt{\frac{\rho_a(\omega)}{\omega\mu_0}} \qquad (3)$$

which, for a homogeneous half space, is 71% of the ***skin depth*** given by equations (1) (Spies, 1989) and (2), accordingly.

Thereafter, in order to estimate the **MobileMT** ***effective depth of investigation***, we use the next approximation:

$$h \approx 357 * \sqrt{\frac{\rho_a}{f}} \qquad (4)$$

Below is the calculated estimation of **MobileMT** effective DOI, using equation (4), in resistivity ranges of: 1-50,000 Ohm·m (top, with logarithmic resistivity scale) and 1-100 Ohm·m (bottom, linear resistivity scale) in the specified range of **MobileMT** frequencies (**Figure 1**).

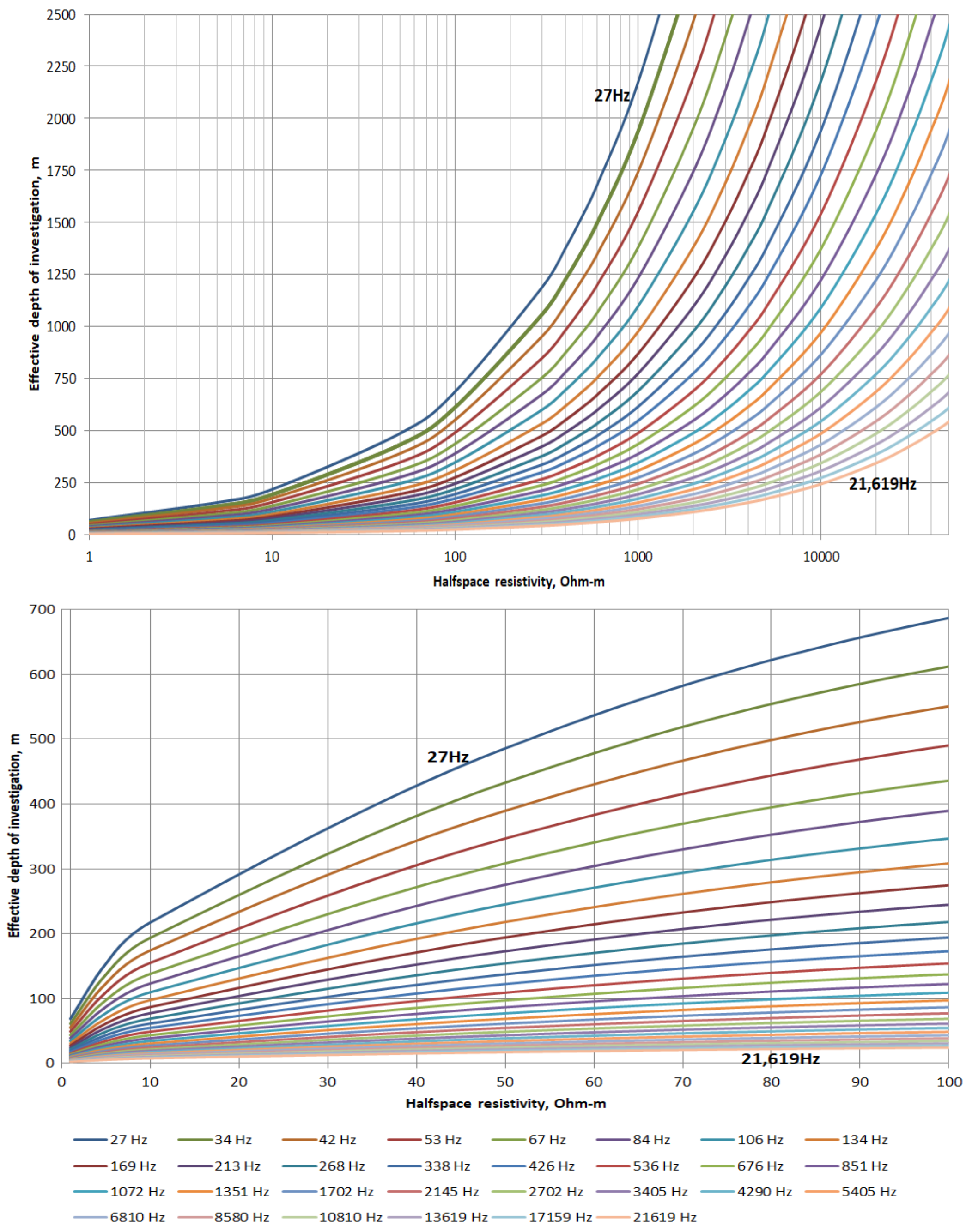


Figure 1 Diagrams of effective depth of investigation in the MobileMT frequency range and windows.

MobileMT FORWARD MODELING

Forward modeling is a useful tool for the estimation of the potential of a method and its equipment and their capability in geological characterization and exploration tasks solving.

We present three scenarios – a shallow VMS target in a resistive environment, a deep VMS target in a resistive environment, and a porphyry structure in a conductive environment.

Forward modeling and inversions are done with 2D MT OCCAM (v.3, EM Lab, 2006) software to obtain **MobileMT** synthetic forward apparent conductivity data and invert the calculated data into a resistivity section. The 2D OCCAM smooth model inversion is the result of an implementation of the general Occam procedure of Constable, et al. (1987) extended to 2D by deGroot-Hedlin and Constable (1990).

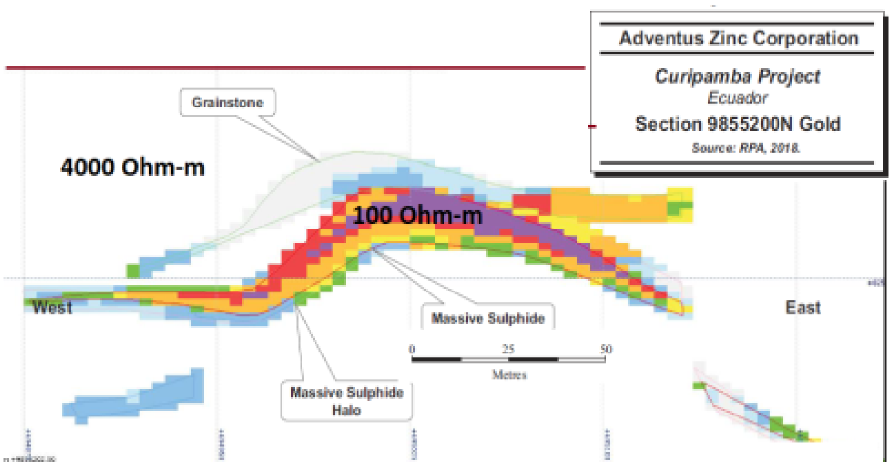
The 2D MT forward calculations in the code are carried out with the code of Wannamaker, et al (1987) using reciprocity to calculate the Jacobian (de Lugao and Wannamaker, 1996).

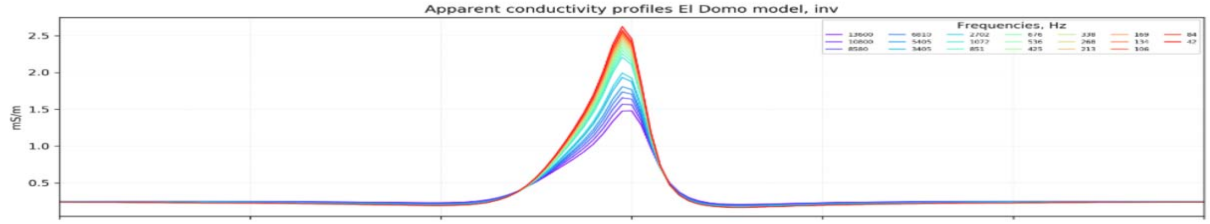
The **MobileMT** forward modeling results are presented in the next profiles and sections (from top to bottom):

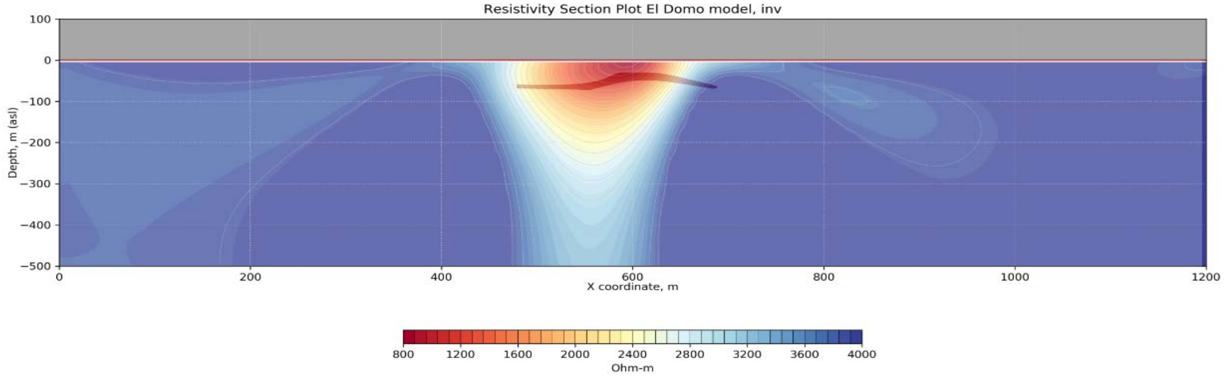
1) synthetic **MobileMT** apparent conductivity profiles from the two-dimensional model for TM mode (response);
2) resistivity section as a result of the calculated response 2D inversion with the transparent synthetic model;
3) Pseudosections (X-log10(Frequency)) of the **MobileMT** apparent resistivity data;
4) **MobileMT** apparent resistivity sections with Effective Depth estimated for each frequency in accordance with equation (4).

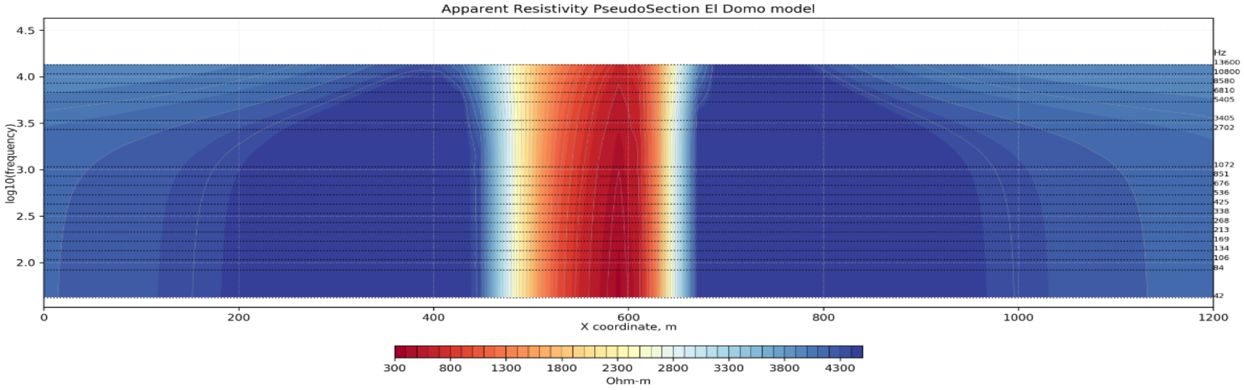
Case I. El Domo polymetallic Cu-Au deposit (Ecuador).

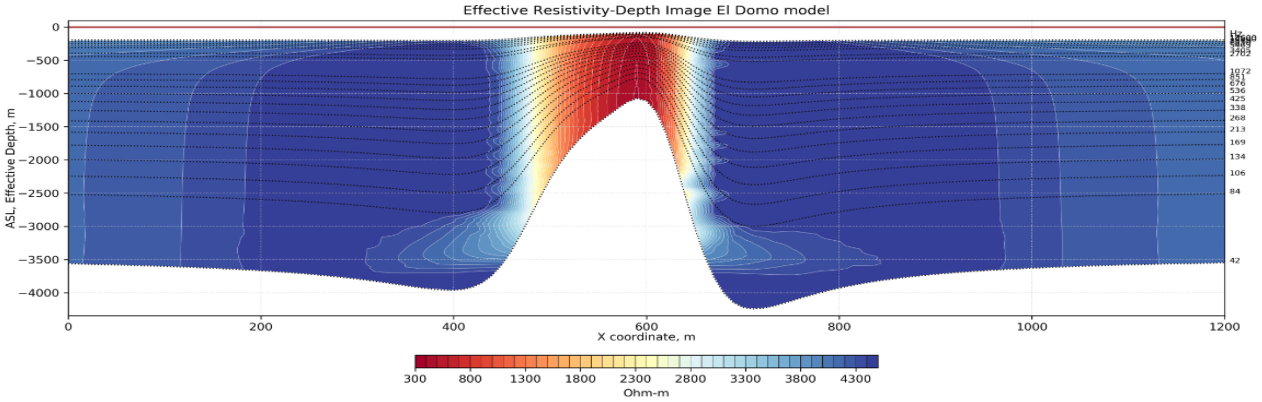
The deposit is identified as a stratiform and largely stratabound horizon of semi-massive to massive sulphide mineralization with an overlying zone of brecciated/fragmented sulphide fragments (Weierhäuser, 2018).



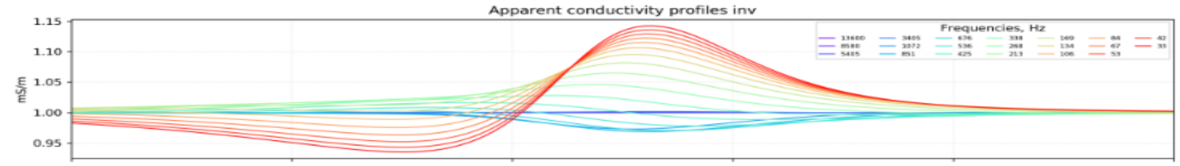

Apparent conductivity profiles El Domo model, inv
Frequencies, Hz
13600
10800
8580
6810
5405
3405
2702
1072
851
676
536
425
338
268
213
169
134
106
84
42
mS/m
2.5
2.0
1.5
1.0
0.5

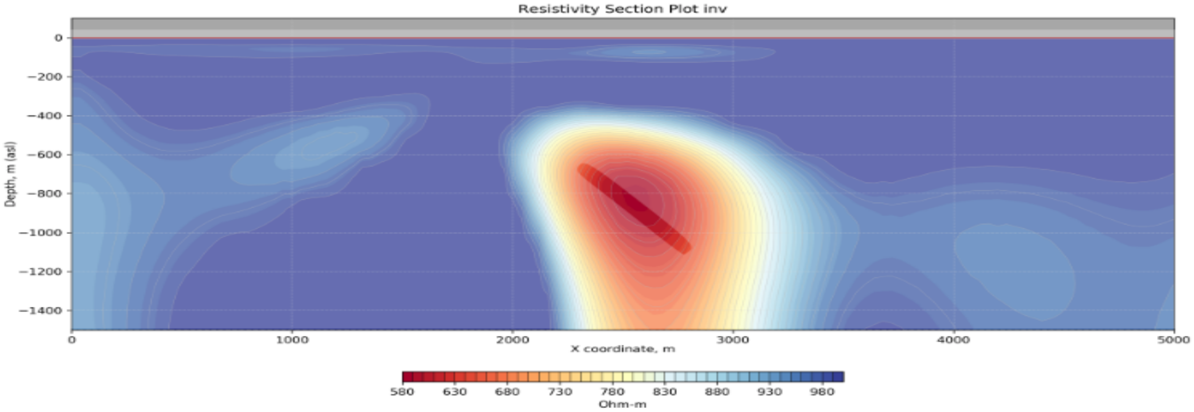

Resistivity Section Plot El Domo model, inv
Depth, m (asl)
100
0
−100
−200
−300
−400
−500
0
200
400
600
800
1000
1200
X coordinate, m
800
1200
1600
2000
2400
2800
3200
3600
4000
Ohm-m

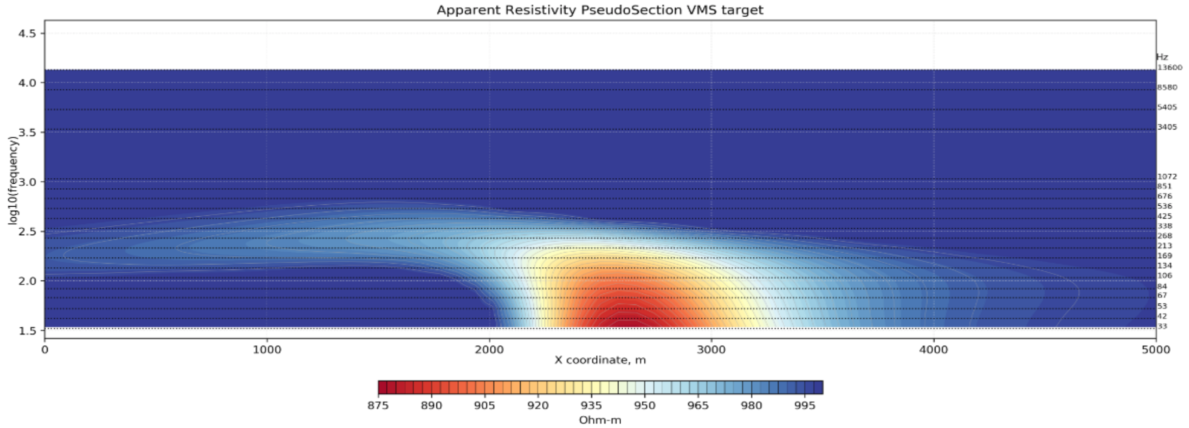

Apparent Resistivity PseudoSection El Domo model
log10(frequency)
4.5
4.0
3.5
3.0
2.5
2.0
Hz
13600
10800
8580
6810
5405
3405
2702
1072
851
676
536
425
338
268
213
169
134
106
84
42
0
200
400
600
800
1000
1200
X coordinate, m
300
800
1300
1800
2300
2800
3300
3800
4300
Ohm-m

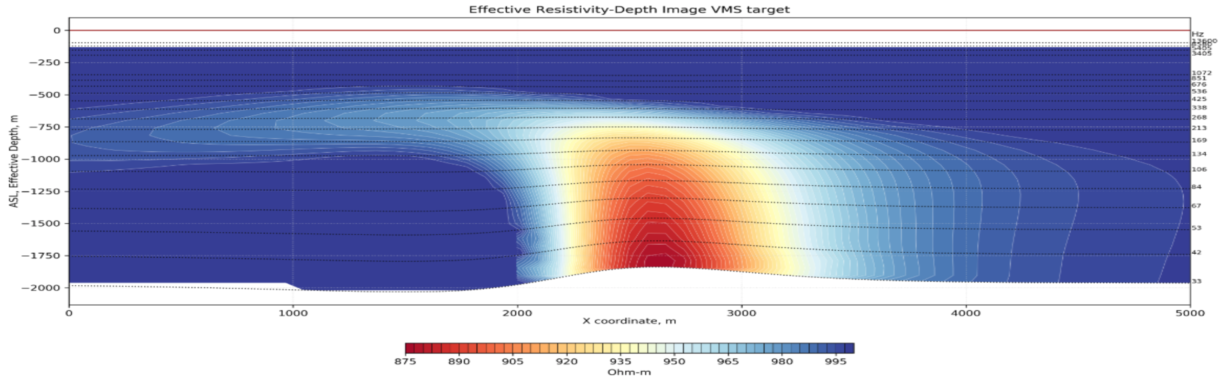

Effective Resistivity-Depth Image El Domo model
ASL, Effective Depth, m
0
−500
−1000
−1500
−2000
−2500
−3000
−3500
−4000
Hz
13600
10800
8580
6810
5405
3405
2702
1072
851
676
536
425
338
268
213
169
134
106
84
42
0
200
400
600
800
1000
1200
X coordinate, m
300
800
1300
1800
2300
2800
3300
3800
4300
Ohm-m

Case II. Deep conductor (>600 m depth), 1 Ohm·m in 1000 Ohm·m host. Flin-Flon belt VMS model.

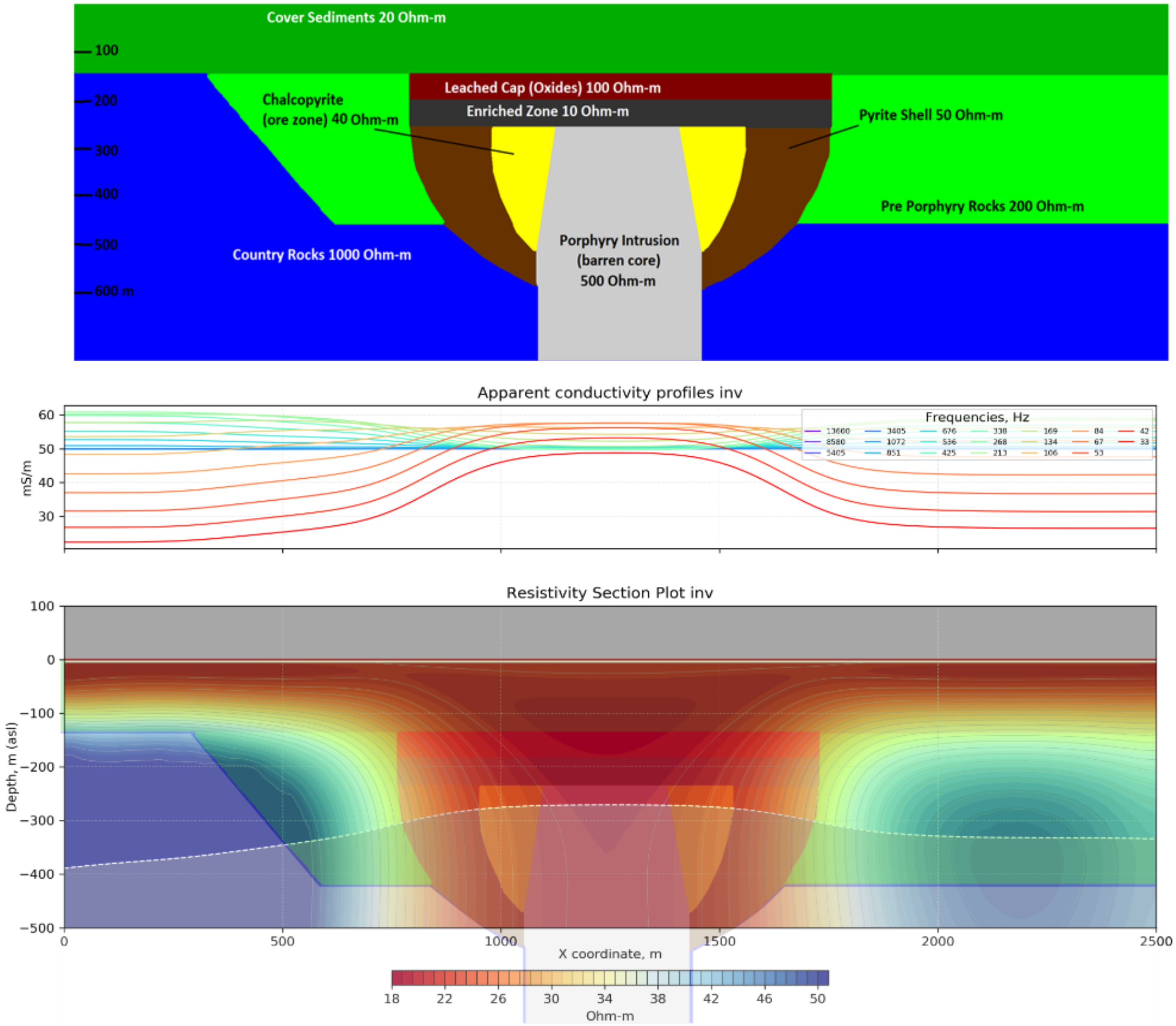


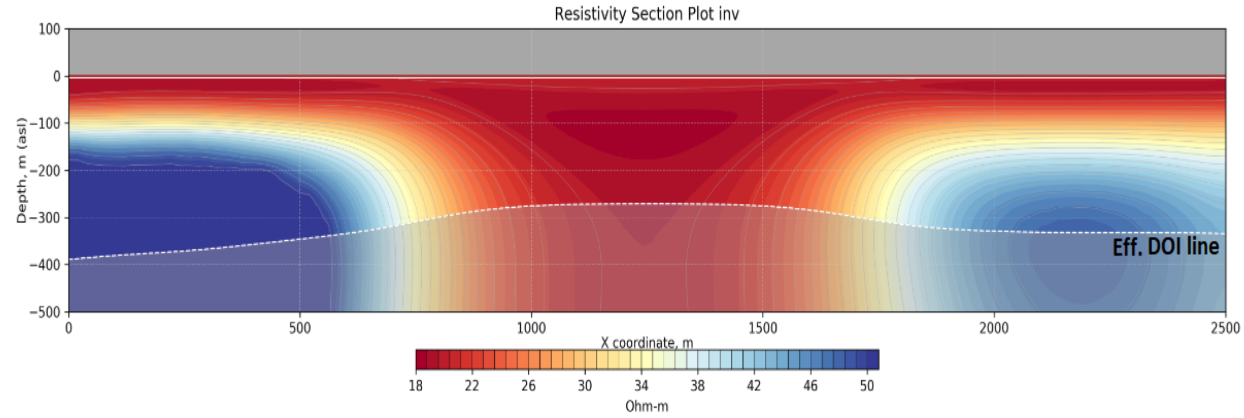


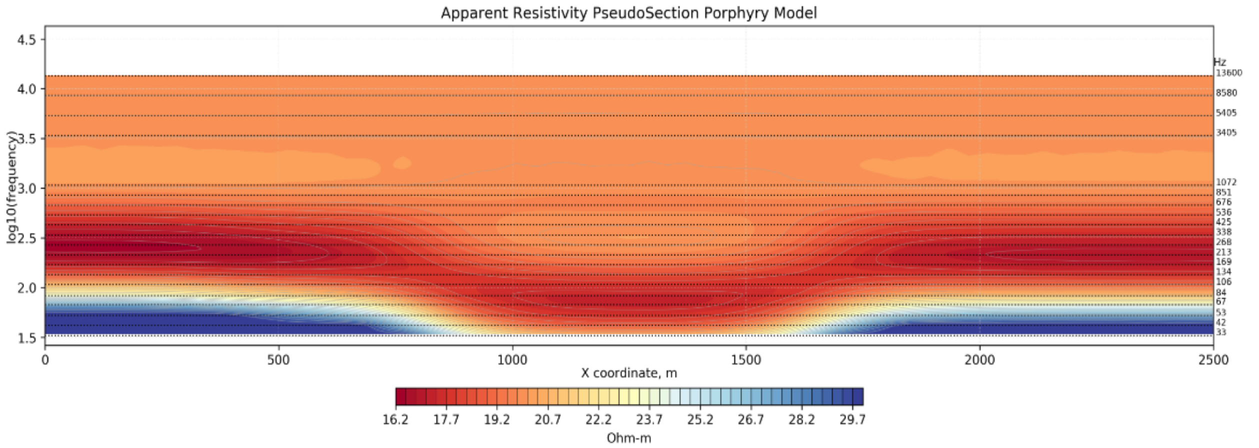


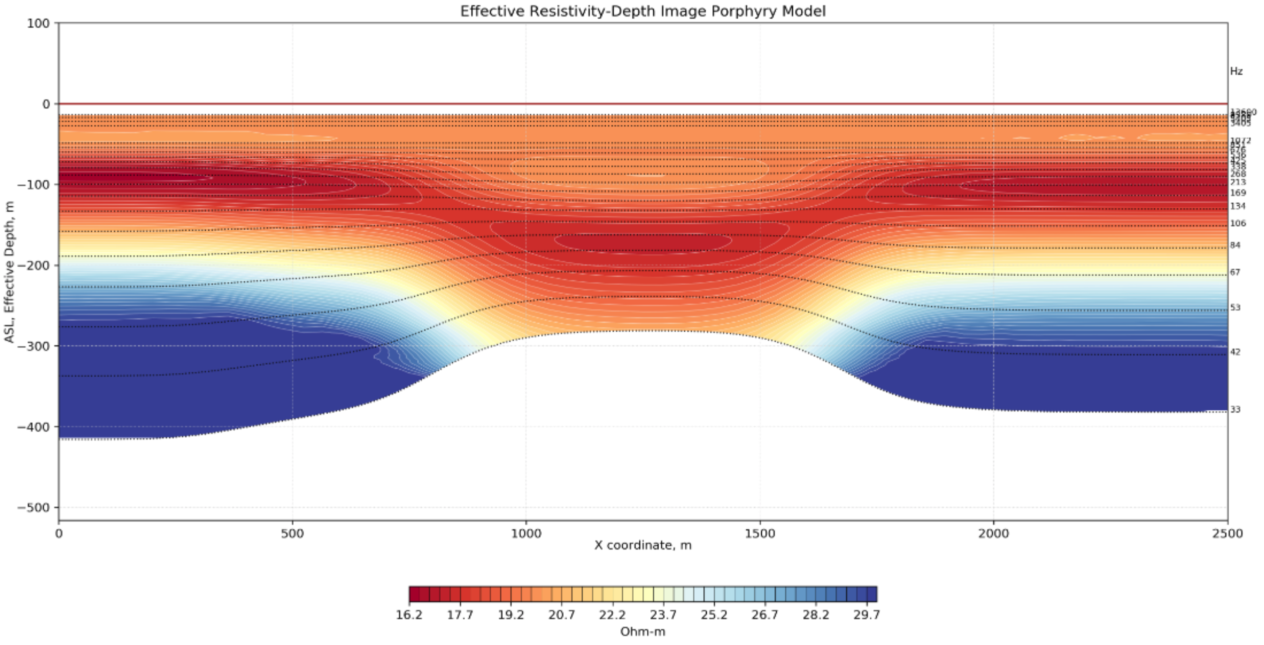


Case III. The simplified porphyry model with inherent physical properties (resistivity) was constructed based on known geological information (Emond et. al. 2006).




Resistivity Section Plot inv


Apparent Resistivity PseudoSection Porphyry Model


Effective Resistivity-Depth Image Porphyry Model

CONCLUSION

Effective depth of investigation in application to selected **MobileMT** measurement frequencies has been quantified in the wide range of possible resistivities of various geological environments. The depth ranges presented in the forward modeling studies are considered to be resolved for the geoelectrical conditions because the response of these models is well within the **MobileMT** instrumental bandwidth. As the depth of investigation estimation and forward modeling studies shows, **MobileMT** airborne EM technology has great abilities in wide geoelectrical conditions including presence of thick conductive overburden and in detecting both shallow and deep conductors.

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