

Integrated Analysis of 3D Magnetotelluric and Potential Field Models Using Machine Learning and Petrophysical Information, A Case Study of an Iron Deposit in Northern Sweden

O. Rydman^{1*}, E. Veress¹, M. Yu. Smirnov¹, T. M. Rasmussen¹, T. Bauer¹, N. Juhojuntti²

¹Lulea University of Technology,

²Luossavaara Kirunavaara Aktiebolag,

*Corresponding Author, oskar.rydman@ltu.se

SUMMARY

Simultaneous interpretation of multiple 3D geophysical models presents unique challenges not only in visualization but also in understanding the relationship between the different types of model parameters. Machine learning algorithms allows for unsupervised labeling of the model-space making visualization of geological units of similar characteristics possible. To facilitate this, we have implemented a clustering workflow where 3D geophysical models are clustered and visualized in 3D. In the northern Norrbotten ore district, Sweden, four geophysical datasets have been modelled in 3D. These datasets consist of one magnetotelluric dataset with 63 broadband magnetotelluric measurements (measured during DESMEX project by LTU and partners), one airborne total magnetic intensity dataset and two Bouguer anomaly gravimetric datasets provided by LKAB. Separate 3D inversions of all data sets were performed for the same modelling domain with a multi-resolution grid discretization. The inversions of potential field data used a similar discretization horizontally as for the MT grid but with differing boundary cells and vertical scaling. It was also decided not to merge the two gravimetric surveys leading to two separate 3D density models. In addition, petrophysical measurements of conductivity, density and magnetic susceptibility of rocks in the area has been collected. The petrophysical data and the 3D models of physical parameters were normalized in the same manner to non-dimensional units (standard variables). Then the petrophysical data were clustered/labelled using K-means and the result was compared to geological knowledge. After selecting a reasonable number of clusters, the 3D modelled physical properties were clustered using a Gaussian Mixture model (GMM) which was initialized with the K-mean centroid vectors as the initial means of the Gaussian mixture components. The resulting GMM clusters of the 3D models were then visualized in 3D. These can be compared/interpreted alongside 3D geological models of the area allowing for interpretation of trends in all 3D models simultaneously. We compared the resulting clusters with expected geological/lithological units. Some features are well resolved whereas some clusters are less correlated to known lithological units. Two units hosting mineralization along their contact are identified by the combination of three clusters. Finally, one cluster initialized with a centroid corresponding to measurements of ore intersecting drill-core is either spatially similar to the geological modelled ore body or unrelated to it depending on which density model is used. Therefore, the cluster is interpreted to be related to the ore or a conductive graphite schist located at the boundary of a dense and magnetic greenstone unit.

Keywords: Magnetotellurics, 3D-Modelling, Potential field methods, Petrophysics, Clustering/labelling
