Complex resistivity inversion using controlled source electromagnetic data

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In some Earth materials, induced polarization (IP) phenomena are occurring when an electric perturbation is applied. These mechanisms are described by a frequency dependent complex resistivity. The study of relaxation model parameters describing these phenomena allows to access indirectly to several properties of interest of the underground, as properties linked to the pore space geometry, fluid content or presence and discrimination of disseminated metallic particles. Nevertheless, complex resistivity is usually studied using electrical method with a direct current hypothesis, neglecting by the way electromagnetic induction that can occurs in the data. Thus, strong limitations appear to recover a complex resistivity image as EM induction increase with frequencies and larger offset.

We implemented a frequency dependent complex resistivity in POLYEM3D, a 3D finite-difference modelling and inversion code for controlled-source electromagnetic data (CSEM) in order to fully recover IP information contained in EM data. CSEM method is a resistivity imaging technique using multi-frequency electromagnetic signals fully taking into account EM induction with larger investigation depth. Following a preliminary sensitivity study, a multi-stages inversion strategy was defined to undertake the multi-parameters problem. Furthermore, to manage the increasing number of parameters, a second order polynomial parametrization is used to describe frequency variation of complex resistivity.

We show through 1D synthetic data inversions and preliminary 3D results that we are able to recover a complex resistivity and its frequency variation from CSEM data in the IP/EM coupling domain, when IP signals are sufficiently large compared to EM induction. Our inversion strategy allows then to access to IP parameters of the medium in an extended frequency domain as well as for greater depth of investigation. A 3D CSEM survey was undertaken in December 2020 on the former mining site of La Porte-Aux-Moines (Côtes-d’Armor, France) presenting strong IP responses, to validate our inversion method for a 3D in-situ dataset.