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A simulation of the measurement of electrical conductivity in randomly generated two-phase rocks.

Eric Mandolesi (1), Max Moorkamp (2), and Alan G. Jones (1)
(1) Dublin Institute for Advanced Studies, Dublin, Ireland (eric@cp.dias.ie), (2) University of Leicester, UK

Geological models of the subsurface require detailed data, often unavailable from direct observation or well logs. Hence imaging the subsurface relies on models obtained by interpretation of geophysical data. Several electromagnetic (EM) geophysical methods focus on the EM properties of rocks and sediments to determine a reliable image of the subsurface, while the same electromagnetic properties are directly measured in laboratories. Often these laboratory measurements return equivocal results that are difficult to reconcile with field observations.

Recently different numerical approaches have been investigated in order to understand the effects of the geometry and continuity of interconnected pathways of conductors on EM field measurements, often restricting the studies to direct current (DC) sources. Bearing in mind the time-varying nature of the natural electromagnetic sources that play a role in field measurements, we numerically simulate the effects of such EM sources on the conductivity measured on the surface of a randomly generated three-dimensional body embedded in a uniform host by using electromagnetic induction equations, thus simulating a magnetotelluric (MT) survey.

A key point in such a simulation is the scalability of the problem: the deeper the target, the longer the period of the EM source is needed. On the other hand, a long period signal ignores small heterogeneous conductors in the target bulk of the material, averaging the different conductivities in a median value.

Since most real rocks are poor conductors, we have modeled a two-phase mixture of rock and interconnected conductive elements (representing melts, saline fluids, sulphidic, carbonitic, or metallic sediments, etc.), randomly generated within the background host. We have compared the results from the simulated measurements with the target rock embedded at different depths with electrical conductivity predicted by both Hashin-Shtrikman (HS) bounds and an updated multi-phase Archie's Law.

Our results demonstrate that neither of these approaches yields robust results, and indeed that the conductivity varies from the lower HS bound at low percentages of the conducting component, to the upper HS bound at high percentages.