Surface geometry inversion of marine CSEM data

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SUMMARY

Traditional minimum-structure style inversion recovers models that are generally smooth due to the incorporation of the model roughness terms in the objective function being minimized. For certain models with a localized anomaly that have a distinct physical property contrast with the surrounding host rocks, such as seafloor massive sulphide (SMS) ore deposits, it is difficult to extract the boundary information of the ore body from the recovered models of minimum-structure inversion. We present a surface geometry inversion (SGI) method which directly inverts for the geometrical information of the ore body's boundary wireframe surface. The objective function of our SGI algorithm only has one data misfit term per geophysical data type. Regularization can be applied but is not required. For this example, we use only a single data misfit term. The minimization of the objective function is an over-determined problem, and we solve it using a global optimization algorithm, namely, the genetic algorithm. We present a synthetic study where we apply our SGI to the inversion of a marine controlled-source electromagnetic (CSEM) dataset. The synthetic model considers realistic bathymetry and the ore body has a complex shape based on a realistic SMS ore body. The surface of the ore body is constructed by connecting a small number of control nodes into triangular facets. We then use a subdivision algorithm to further subdivide the connected facets, which produces a model that has a more serpentine boundary surface although it is still characterized by the original set of control nodes. Constraints can be easily incorporated into the model by fixing certain nodes during the inversion when drilling data are available. In this study, we use our SGI algorithm to invert for the three-dimensional coordinates of these control nodes given a priori physical properties. However, it is possible to invert for physical properties of the ore body simultaneously, although it would increase the nonuniqueness of the inversion significantly. The physical property of the background model is always fixed during the inversion.

We discretize the entire model with unstructured tetrahedral meshes and then calculate the forward response using a finite-element solver. Our SGI algorithm iteratively searches for the best model that can fit the data. We parallelized our SGI using a hybrid MPI+OpenMP technique to speed up the inversion as there could be up to several hundreds of models required to be calculated in each iteration. Our synthetic inversion examples show that the developed SGI could recover models whose shapes are close to those of the true model.

Keywords: Marine CSEM, Seafloor massive sulphide, surface geometry inversion