Creating 3-D Earth models that unify geological and geophysical information

P.G. Lelièvre, C.G. Farquharson, and C.A. Hurich
Department of Earth Sciences, Memorial University of Newfoundland, St. John's, Newfoundland and Labrador A1B 3X5, Canada <plelievre@mun.ca>

Earth models used for mineral exploration or other subsurface investigations should be consistent with all available geological and geophysical information. Geophysical inversion provides the means to integrate geological information, geophysical survey data, and physical property measurements taken on rock samples. Inversion is a computational process that recovers models of the subsurface that could have given rise to measured geophysical data while maintaining consistency with the geological knowledge available.

Throughout the development of a mineral exploration site, subsurface models are developed based on available data and subsequent interpretations. Geological contacts are often known at points from drill-hole intersections and/or outcrop observations. The contacts can be interpolated or extrapolated throughout the subsurface volume of interest. Such 3-D geological models are typically created on unstructured wireframe meshes, which are sufficiently flexible to allow the representation of arbitrarily complicated subsurface structures. However, geophysical forward modelling and inversion algorithms typically work with regular rectilinear meshes when parameterizing the subsurface because this simplifies the development of numerical methods.

3-D rectilinear meshes are comprised of regular brick-shaped cells, tightly fitted together in three dimensions. The relevant rock type or physical properties are assumed to be uniform within each cell but possibly different from one cell

Atlantic Geology, 2011, Volume 47, Number 1

to the next, creating pixelated models. Such meshes will always be incompatible with wireframe geological models, regardless of how fine a discretization is used. To address this incompatibility unstructured tetrahedral meshes are used in the geophysical forward modelling and inversion techniques. On these meshes arbitrarily complicated features can be represented and it is therefore possible to have geological and geophysical models that are, in essence, the same Earth model. Geophysical modelling software is being developed using unstructured tetrahedral meshes for seismic travel-time, gravity, and electromagnetic data. A suite of tools necessary for creating a volumetric tetrahedral discretization of geological models containing triangulated surfaces is also being developed, and these techniques allow for the incorporation of a large amount of geological information.