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Refining 3D Earth models by unifying geological and geophysical information on unstructured meshes

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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. Incorporation of geological information into inversions is always an iterative process. One begins with the geologists' best guess about the Earth (i.e. the geological model) and the models recovered from geophysical inversion may indicate that the geological model should be changed slightly prior to the next iteration of the procedure. In this way, geological and geophysical data can be combined through inversion and we can move towards the creation of a common Earth model consistent with all the available data. As more information is incorporated, the inherent non-uniqueness of the inverse problem is reduced, yielding a higher potential to resolve deeper features that are less well-constrained by the geophysical data alone.

Geological ore deposit models are commonly created during delineation drilling. The accuracy of these models is crucial when used to determine if a deposit is economic. 3D geological Earth models typically comprise wireframe surfaces that represent the geological contacts between different rock units. The contacts may be known at points from down-hole intersections and surface mapping, and can be interpolated between boreholes and extrapolated outwards. Contacts may also be interpreted from seismic traces. Wireframe surfaces, comprising tessellated triangular facets, are sufficiently flexible to allow the representation of arbitrarily complicated geological structures. These surfaces can be honoured exactly within fully unstructured 3D volumetric tetrahedral meshes. In contrast, geophysical forward modelling and inversion algorithms typically work with rectilinear meshes when parameterizing the subsurface because this simplifies the development of numerical methods. The flexibility of unstructured meshes provides advantages when one needs to incorporate prior information associated with structurally complicated subsurface geometries. Such information can be difficult or impossible to represent adequately on rectilinear meshes, no matter how fine the discretization.

There are some significant challenges involved in working with unstructured meshes for the purposes of geophysical forward and inverse modelling. These include the generation and storage of an unstructured mesh, various book-keeping requirements, developing appropriate numerical matrix operators, and manipulating and visualizing the models. We are developing computational methods and useful software tools to meet these challenges. By working directly with unstructured discretizations of the subsurface in our geophysical inversion methods, we are able to more seamlessly combine geological and geophysical data to push the limits of the geophysical data resolution and produce more accurate ore deposit models.