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Integrating geological constraints into 3D geophysical inversions using unstructured meshes

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The underdetermined geophysical inverse problem is inherently non-unique, requiring additional information to recover geologically interpretable solutions. This additional information commonly includes petrophysical and structural measurements. It can also involve 3D geological Earth models, e.g. ore deposit models commonly created during delineation drilling. Such models typically comprise wireframe surfaces that represent 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. This contrasts with standard rectilinear meshes, on which complicated geological structures are often difficult or impossible to represent adequately without computationally infeasible refinement. 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 geological models.

We are performing minimum-structure-style volumetric inversions that thoroughly discretize the Earth into many mesh cell elements. This approach provides generality and is appropriate in early stages of exploration when little geological knowledge is available. We are also performing fundamentally different inversions that attempt to alter existing wireframe geological models to fit geophysical data. Such an approach is more appropriate in later stages of exploration when enough information is available to generate a sensible geological model and ask specific exploration questions about that model; we can then attempt to find answers using geophysical forward modelling and constrained inversion.

We will present our new numerical methods for performing constrained inversions on unstructured meshes. We will also present a case study that illustrates the careful, iterative process required when performing geologically-constrained inversions.