Constrained Potential Field Inversion for Oil & Gas Applications

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Abstract

Potential field data interpretation often plays a role in oil and gas applications at the basin scale or where seismic reflection methods have poor resolution. Two important applications are estimating the shape and depth extent of base of salt using gravity data and estimating basement structure and geology using magnetic data. In both cases, significant physical rock property contrasts support the use of potential field methods. The most common approaches to these problems focus on grid processing (depth-to-source, etc.) or 2D/2.5D forward modelling using analytical responses of prismatic bodies. Although insightful, these methods usually do not take into account all available geological and petrophysical information and results are not easily transferable into a 3D earth model for use by explorationists or engineers.

Inversion methods provide a more robust and quantitative solution. They are more readily automated, often quicker, and available in 3D. Nevertheless, the processof potential field inversion by which one defines a 3D earth model that is consistent with measured data is non-unique. Thus an infinite number of 3D models are in principle consistent with measured data. The main problemetic task is to choose one that can be best interpreted in geological terms. The use of geological and petrophysical constraints, derived from well markers, seismic data interpretation, and wireline logging, provide the means to select a 3D earth model that is in agreement with key information.

To make the most of *a priori* geological and petrophysical knowledge it is essential that an inversion algorithm be integrated with a 3D earth modelling platform and have internal mechanisms to make use of such constraints. Over ten years of research in this field has resulted in the emergence of a class of proven technology. 3D potential field inversion software (such as *mag3d* and *grav3d* from the University of British Columbia Geophysical Inversion Facility and *VPmg* from Fullagar Geophysics Pty. Ltd.) have been linked to *Gocad*, one of the main 3D earth modelling platforms. Together they provide an integrated solution for the application of constrained potential fields data inversion for oil and gas applications.

As an example of this approach, we present a case study using gravity data inversion as a tool to define the base of a salt dome using a synthetic 3D earth model and its modeled gravity signature. The typical stratigraphy of some of the world's largest oil and gas reservoirs includes the presence of salt diapirs, and defining the shape of salt domes has great exploration value. Because the seismic velocity of salt is generally slower than its host rocks, imaging the base of salt domes is challenging with seismic reflection. Because of the density contrast typically associated with salt features their shape can often be reconstructed with 3D gravity inversion.

For this study a 3D sub-surface model including a complex (multi-Z) salt feature was constructed and embedded in a sedimentary sequence characterized by an increasing density gradient with depth. The synthetic gravity response of the sub-surface model was forward modelled, simulating a marine survey. Conventional surface or marine 3D seismic surveys are effective at imaging the top of a salt feature, providing important geometric constraints for the inversion. Host rock densities can be estimated from seismic velocities as a petrophysical constraint. The top of salt geometry, a hard geological constraint, is thus fixed and not allowed to move during the inversion. The base of salt is deformed until its gravity response fits the measured data within a defined misfit range. The deformation also takes into account how the host density gradient is either compressed or stereteched. The result of the constrained gravity inversion is a salt geometry consistent with the seismic data interpretation and the measured gravity data.

In this case study we demonstrate that 3D constrained potential field data inversion can be used as a tool to complement seismic data interpretation and provide an image of the base of salt that can later be used as a starting earth model to refine the final seismic image as part of an iterative depth migration process. This is but one of several application areas in which quantitative inversion of potential field data can yield value far beyond traditional processing and interpretation methods.

References

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