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# Uncertainty reduction of gravity and magnetic inversion through the integration of petrophysical constraints and geological data

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We introduce and test a workflow that integrates petrophysical constraints and geological data in geophysical inversion to decrease the uncertainty and non-uniqueness of the results. We show that the integration of geological information and petrophysical constraints in geophysical inversion can improve inversion results in terms of both uncertainty reduction and resolution. This workflow uses statistical petrophysical properties to constrain the values retrieved by the geophysical inversion and geological prior information to decrease the effect of non-uniqueness. Surface geological data are used to generate geological models as a source of geometrical prior information. Petrophysical measurements are used to derive the statistical laws used for the petrophysical constraints. We integrate the different sources of information in a Bayesian framework, which will take into account these states of information. This permits us to quantify the posterior state of knowledge, the reduction of the uncertainty and to calculate the influence of prior information.

To quantify the influence of petrophysical constraints and geological data we compare results obtained with several levels of constraints. We start by inverting data without petrophysical constraints and geological prior information. Then, we add petrophysical constraints before using geological prior information.

The results of the inversion are characterized using fixed-point statistics. Various indicators such as model and data misfits, resolution matrices and statistical fit to the petrophysical data are calculated. The resolution matrices are used to plot sensitivity maps. We calculate the posterior covariance matrices to estimate the uncertainty of the model.

This workflow was first tested using very simple synthetic datasets before using a subset of the Mansfield area data (Victoria, Australia). The geological model is derived from geological field data. We simulate petrophysical properties based on field measurements and standard values obtained from the literature. Finally, we ran the different inversions on gravity and magnetic data generated using this model.

As a result, the use of petrophysical constraints permits us to retrieve sharper boundaries while prior structural information from geology on the shallow lithologies permits to retrieve the contacts more accurately. The integration of the different constraints provides a better-resolved model, with reduced uncertainties such as improved posterior covariance and resolution matrices. The analysis of the sensitivity to and resolution indicators using geological a priori information and petrophysical constraints shows complementarity between the resolution matrices. Moreover, the comparison of the posterior covariance matrices (diagonal and non-diagonal elements) shows that when geological prior information and petrophysical constraints are used together higher values coincide with poorly resolved lithologies. This is not always the case when either only geological prior information or no constraints are used. However, the improvement of the inversion results due to the constraints and prior information are more pronounced on gravity inversion than on magnetic inversion.