Inversion 2005 – yesterday, today, and tomorrow

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General Definition of Inversion

In this discussion, inversion is defined as a procedure for obtaining models which adequately describe geophysical data sets. Observations show the effects of rock properties on physical phenomena such as seismic wave propagation. Since geophysical inversion allows us to extract geological model information from these data, the procedure is of interest to geoscientists.

The inversion process for seismic data is closely related to forward modeling and a comparison between the two procedures is described by Lines and Newrick (2004). In the case of reflection seismology, forward modeling uses some version of the wave equation to synthesize the earth's response for a given set of model parameters. Inversion or "inverse modeling" process uses a "reverse" procedure to that of forward modeling. For a given data set, inversion seeks to define a geologic model, which agrees with the observations (ref. Lines and Treitel, 1984). Inherent in the inversion process is an attempt to estimate rock property parameters which allow model responses to fit the available data. Hence, the choice of an appropriate model is important for inversion as for forward modeling, and the geophysicist should always be concerned with the physical basis of the inversion model. Even assuming that our modeling choice has been correctly made, numerous problems still remain. According to Jackson (1972), inversion is the "interpretation of inaccurate, insufficient, and inconsistent data".

Cooperative Inversion

Generally speaking, our model of the Earth is improved with the use of more information. Although this truth would seem to be self evident, it is often ignored by many geophysicists who equate geophysics with seismology, while focusing only on with seismic data alone. In addition to seismic data, we should try to constrain and enhance our models with available well log data, potential field data, electrical surveys, cores and formation tops. Such data will generally enhance subsurface descriptions of the earth's interior. The cooperative inversion of several data types was illustrated in a case history by Lines et al. (1988). Also, Doug Oldenburg and his students have successfully investigated cooperative inversion with seismic, electrical, and potential field methods. The integration of information through cooperative inversion is now becoming especially important in the case of reservoir characterization. Neural networks have proven to be a worthwhile instrument for integrating information in such problems and this was well illustrated by Russell (2004).

Inversion With a Grain of Salt

We should realize that our inversion solutions are *estimates* of Earth models and that all geophysical inversions are inherently nonunique. The title of this section is based on sensitivity analysis of ambiguity as investigated with Sven Treitel, Tad Ulrych, John Scales, Jon Downton, and other colleagues. It is important not only to estimate a model whose response matches the data but to quantify the uncertainty of our solution. One of the favorite vehicles for describing this uncertainty makes use of Bayes' Theorem. Bayesian solutions were described lucidly by Downton (2005) for the analysis of AVO as an inversion problem. Although we might not formally use Bayes in our inversion, we should always judge the probability of our solutions, at least in heuristic terms.

Inversion and Processing – What are the Connections?

It might be claimed that many "processing steps" represent forms of inversion. Migration has been described as "structural inversion". One can also make the argument that the use of prestack depth migration in velocity analysis provides an inversion method. Full waveform inversion has been related to migration by Tarantola (1984). Deconvolution can be couched in terms of linear inverse theory (Treitel and Lines, 1982). Recently, some of the biggest advances have come through replacing conventional AVO processing by AVO inversion, as illustrated by Downton (2005).

The Future of Inversion and Reservoir Characterization – Bring in the Engineers

Most of the activities of a geophysical inverter revolve around attempts to fit geophysical data with models. However, complete reservoir characterization involves the integration of geology, geophysics, and reservoir engineering. It is important to match the production history of the reservoir. The “new inversion” will involve linkages between reservoir production models and geophysical models. This new form of “cooperative inversion” should produce enhanced oil recovery. Steps in this direction have been implemented by Zou (2005). The future years of inversion will involve attempts to describe the changing physical properties of the reservoir by matching geological, geophysical and engineering data.

Summary

No single talk can cover all of the topics of inversion. This talk represents the author’s own views about the past, present, and future of geophysical inversion in a general sense. It is based on the present and past experiences with colleagues and students over the last 3 decades, with predictions of the role of inversion in decades to come.

References

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