INTEGRATED GEOPHYSICS CORPORATION

FOOTNOTES
ON INTERPRETATION

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Two Dimensional Structural Modeling with Potential Field Data

Two-dimensional (2D) structural modeling of integrated geology and potential field data provides a powerful interpretation tool.

1. In a forward mode, the modeled integration of gravity and/or magnetic data with seismic data and real or postulated geology provides a visual demonstration of a best-fit solution to a given geologic problem. In a negative but also important sense, the forward modeling could instead demonstrate that the postulated geology is incompatible with the potential field data.

If the input model geometry is well-constrained, the gravity/magnetic fit of the model can predict (or confirm) probable formation density and magnetization, and hence gross formation lithology (e.g., whether clastic, salt, carbonate, volcanic). Even where the geometry is more loosely constrained, forward modeling can be used to select the best of alternative local structural configurations.

2. In an inverse mode, where little so-called "hard" data is available for geometric constraint, 2D gravity/magnetic modeling provides a visual demonstration of geologically-reasonable structural interpretations (in cross section form) which also fit the potential field data. Good estimates or measurements of formation density---as would be common in salt provinces---and basement density/magnetization reduce the ambiguity and range of solutions for a probable structural configuration.

Both modes of modeling are widely used throughout the exploration community to display a proposed solution and the degree to which the solution fits both geologic probability and all the input data.

An Example of 2D Structural Modeling for Fault Interpretation

The problem

Several fields in the U.S. Rocky Mountain region produce hydrocarbons from sediments trapped under and/or against overthrusted basement. The area of potential reservoir closure under the overhanging basement block is related to the fault geometry: a low-angle thrust usually provides the most closure. However, closure can be difficult to evaluate from seismic data because the basement overhang may cause velocity anomalies which distort apparent relief of the reservoir formation. Definition of the geometry of fault plane and underlying formations is therefore critical to development of a viable prospect.

One of IGC's clients needed to know whether their acreage block had favorable fault geometry for a proposed prospect. Published geologic maps of the prospect area show a large basement outcrop flanked by a normal fault system to the northeast and a major thrust fault system to the southwest. A second, smaller, basement outcrop lies immediately southwest of the large outcrop. A single southwest-northeast 2D seismic line (Fig. 1) shot in the 1980's crosses the prospect area and both outcrops. It provides good quality data in the sedimentary basin southwest of the outcrops, but does not image the basement clearly. The seismic data loses resolution as it approaches the thrust system, and the northeast-dipping thrusts in front of the outcrop can be interpreted on seismic as either high-angle or low-angle faults. A proper evaluation of prospect quality was therefore dependent on a seismic fault interpretation which could be supported by the potential field data and an integrated 2D structural model.

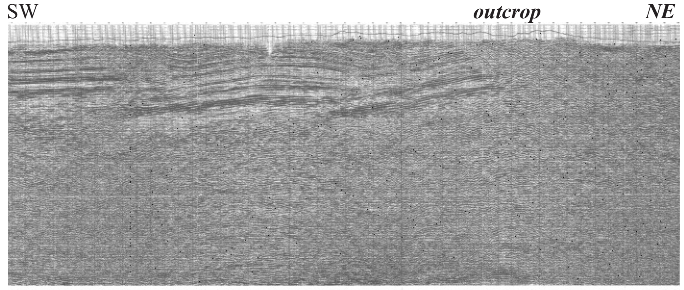

Figure 1. Seismic Line

The solution

IIGC recommended collection of closely spaced (1/8 mile) gravity data to provide high resolution coverage along the track of the 1980's seismic line. The detailed gravity line data was then merged with regional coverage to confirm the dominant gravity trends. Acquisition of a block of high-quality aeromagnetic data in the interpretation area was also recommended. IGC calculated magnetic depth estimates and mapped them to provide configuration and depth of the primary basement terrane, plus any buried crystalline thrust slices. IGC also acquired and plotted formation densities measured from well surveys in the area to constrain the gravity effect of the modeled sedimentary section. Since the modeling process is based on linear distance and depth, well and seismic stacking velocities were used to convert the seismic horizons from time to depth.

Client interpretation of the shallower seismic time horizons, plus the outcrop data, provided key geometric and geologic constraints for a 2D structural model along the seismic profile. Magnetic depth estimates provided constraints for basement depth and geometry. Numerous iterations, varying either density, magnetization or geometry, were tested to improve the data fit for each model. A low-angle fault thrust solution was finally determined to give the best-fit result. A high-angle fault model, and one using a homogeneous basement terrane, were also interpreted for comparison. The comparison confirmed IGC's choice of low-angle faulting as the best solution.

Low-angle overthrust model (Fig. 2)

This 2D model (Fig. 2) honors all the known geologic and seismic constraints plus the magnetic depth estimates. An inhomogeneous basement terrane of varied density and magnetization blocks is required but all assumed rock parameter values fall within accepted guidelines. The contact zones between basement blocks appear related to both basement and sedimentary structure.

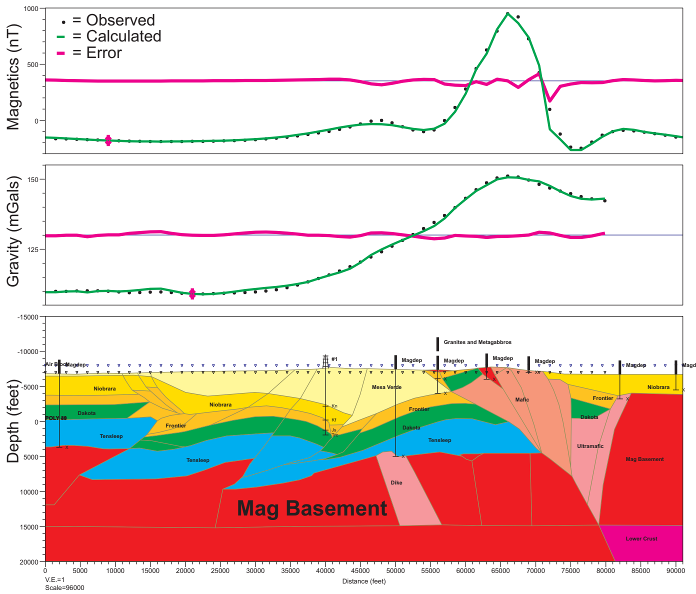

Figure 2. Low-angle overthrust

IGC's modeling demonstrates that the low-angle fault solution provides an excellent fit between observed and calculated gravity and magnetics. The magenta error traces show a maximum difference of 28.4 nT between observed and calculated magnetics, and 0.6 mGal between observed and calculated gravity. The modeled geology is similar to that of other mountain front thrust structures in the region; some of those structures are more fully documented by both seismic and subthrust well data. IGC's low-angle 2D model supports the interpretation of a significant area and thickness of sedimentary section under the basement outcrop. It also indicates Frontier-Dakota-Tensleep structural closure in the seismic "no reflector" zone under the basement overhang.

The integrated interpretation illustrated by this 2D model provides strong support for the client's prospect concept.

High-angle fault model (Fig.3)

This 2D model (Fig. 3) similarly honors all known data constraints and also requires an inhomogeneous basement terrane. However, despite IGC's iteration of basement block densities and magnetization under the outcrop area while still maintaining the high-angle fault geometry, the gravity/magnetic profile fit is poorer than that of the low-angle fault model (Fig. 2). The error traces show a difference of 59.3 nT for the magnetics and 0.9 mGal for the gravity. The inferred basement geology of the uplift, while otherwise reasonable, is not typical for the region. Because of its greater computation error range and its lower geologic probability, this model does not provide the best integrated solution. It does not provide favorable support for the client's proposed prospect since potential reservoir area would be limited and the seal would be questionable. Such a prospect would be high risk.

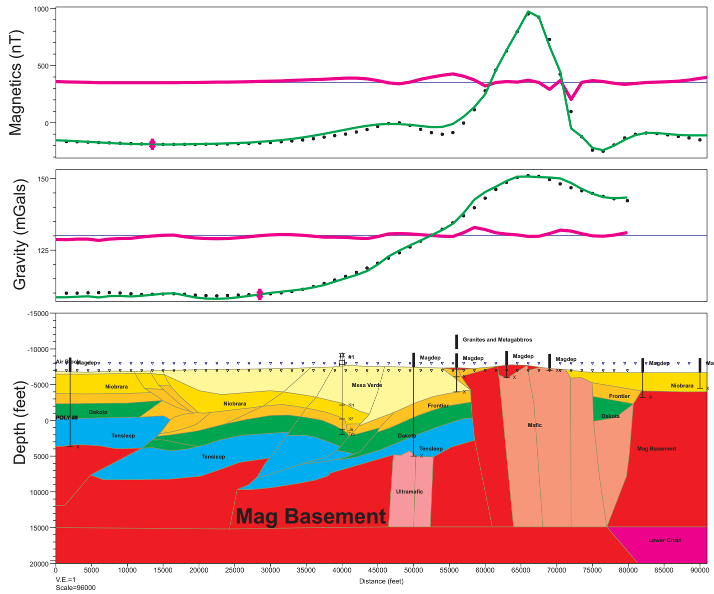

Figure 3. High-angle fault

Homogeneous basement terrane model

Some published 2D model interpretations employ a simple, homogeneous basement terrane. Such models are usually made because of modeling software limitations or lack of geologic constraints. As a test, IGC made a homogeneous terrane model (not illustrated) along the seismic profile. The potential field data fit required a model with a thick, high-density mafic basement core under the outcrop area. The core must be flanked by massive volumes of high-density nonmagnetic material (e.g., Tensleep carbonates). The geologic concepts required for this model are unrealistic and the model was never considered as a possible solution. However, the model does caution that an adequate potential field fit can sometimes be achieved even if no reasonable limitations are placed on the geologic conclusions.

Summary

The thrust fault modeling presented here is only one example illustrating the interpretation power of 2D structural modeling. The method provides a visual demonstration of the successful integration of gravity and magnetics with other data sets and can test various possible geologic scenarios for appropriate solutions. The more data constraints applied to the model, the more unique the final best-fit solution. In this case, IGC applied multiple constraints and used numerous iterations of other variables before recommending a low-angle thrust scenario. The final interpretation, with the degree of data fit and the assumed geology well-illustrated, are then available for client evaluation.

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