The migration of the model data to effect a satisfactory match with observed data revealed some interesting algorithmic and parametric sensitivities of various migration implementations.

Inversion Studies

Inferences on subsurface structure and velocities can be derived using the dynamic properties as well as the kinematic properties of seismic data. Line 80–06 (Fig. 4) was chosen for SEISLOG inversion because the lateral extent of the reef on this near crestal line provides the best opportunity for the wavefront 'healing' which is a prerequisite for successful inversion. The inversion revealed that the velocities throughout the reef core are consistent with good porosity; lower velocities (higher porosities) on the south-west flank of the reef suggest that this flank was subjected to the higher energy wave action. An interesting result of the Seislog inversion is the strong indication of an approximate 1000 ft (305 m) thick volcano-clastic section beneath the ~2000 ft (610 m) thick reef section. The distribution of volcano-clastics, being much thicker on the flanks (e.g. at Sentry Bank No. 1), appears to be consistent with the form of a classic sedimentary apron, and is not clearly resolved on the conventional seismic data.

Conclusions

Three independent studies described in this paper provide consistent evidence to support the interpretation of the Sentry Bank Reef prospect as a viable exploration target. The totality of geophysical data strongly supports the assignment to the reef of the requisite volume and porosity for a very large reserves capacity. It is anticipated that the interpretation will be tested by the drill before this paper is presented.

Reference

Musgrave, A. W. (1961)—'Wavefront charts and three-dimensional migrations', *Geophysics* **26(6),** 738–753.

MAP MIGRATION AND 3D MODELLING IN A COMPLEX VELOCITY MEDIUM

D. J. Kirkham and D. J. Muscatello

Introduction

Many structures cannot be adequately migrated by two-dimensional methods unless the orientation of seismic lines is such that every line is effectively a dip line. This is rarely the case, and on steep sided structures such as salt domes or pinnacle reefs, severe misties will probably exist after two-dimensional migration, making mapping impossible. One solution is to shoot a 3D survey, but this is expensive and the migration algorithm will have to be chosen carefully if dips significantly greater than 50 or 60 degrees are involved. A quicker and cheaper approach is to migrate a time map. However, several questions must be answered before assessing the validity of the results. In particular, how sensitive is the migration to the input velocity model and how detrimental to the final result is the omission of multi-valued points, such as bow-ties?

In order to answer these questions it was decided firstly to design a depth model which would prove a strong test, then to perform an inverse migration on this model, and finally to migrate the resultant time map using different velocity fields and different subsets of the inversely migrated data. As a means of achieving this, a program known as DISSECTOR was developed to perform an inverse migration on a single surface and present the results as a set of separate intersecting surfaces, thereby representing three-dimensional bow-ties, diffractions, etc. The theory behind DISSECTOR is not discussed in detail in this paper, but examples of its application are shown.

The Model

It is known that events migrate more both with increasing dip and with increasing depth. A model was chosen, therefore, which included reasonably steep dips well below a two-way time of 1 second. It was also designed to contain points of inflexion which would generate three-dimensional bow-ties when inversely migrated, and hence test the importance of including these when running a migration. The 'Mexican Hat' structure shown in Figs 1 and 2 was considered to be appropriate, with dips of almost 70 degrees occurring at approximately 1.5 seconds. Four horizontal layers with gradually increasing interval velocities formed an overburden immediately above the crest. The symmetry of the model was felt to be an advantage as it simplified the analysis and allowed conclusions to be drawn which were also valid in a two-dimensional context. In addition, the structure approximated a natural feature such as a salt dome or a pinnacle reef, both of which are prime targets for map migration.

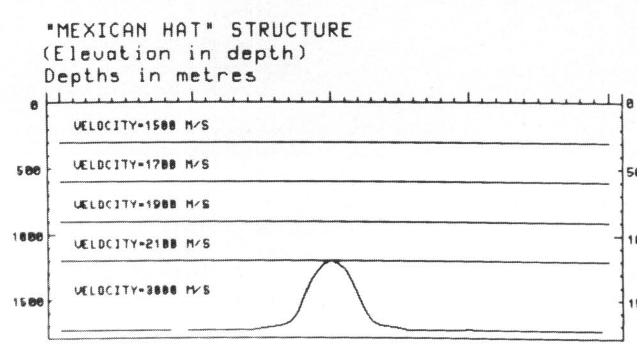

FIGURE 1
Elevation of 'Mexican Hat' structure (in depth).

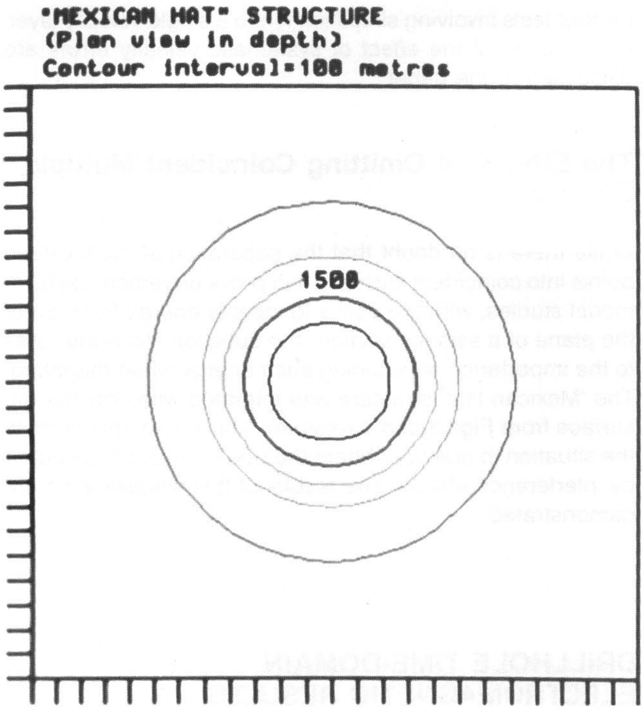

FIGURE 2
Contour map of 'Mexican Hat' structure (in depth).

The Migration Technique

Both migration (forward) and modelling with DISSECTOR (inverse) use a ray-tracing technique on gridded data. The initial depth model is therefore first gridded. Each grid square is divided into two triangles, and rays are traced from the mid-points of each triangle through successive velocity boundaries. In the case of migration, each layer must be migrated in turn, starting with the shallowest. The migration of deeper boundaries is then accomplished by tracing rays through those layers which have already been migrated. For inverse migration, vertical incidence rays are traced upwards from the surface of interest through all the overlying interfaces. In each case, the end points of the rays are regridded. This becomes more complex after inverse migration, however, as multi-valued points are likely to occur. DISSECTOR incorporates a method of gridding all the points as a series of separate surfaces in order to describe this phenomenon three-dimensionally. The results of inversely migrating the 'Mexican Hat' structure are seen in Figs 3 and 4. Three surfaces are obtained. Two form a 'mortar board' — i.e. a horizontal plane with a hole in the middle abutting a partial anticline, while the third is an anticline passing through the crest of the original structure, intersecting the plane and eventually meeting the base of the 'mortar board' to form a circular three-dimensional bow-tie. Fig. 4 is a vertical cross-section taken through the middle of the structure.

The Sensitivity of Migration to Velocity

In order to avoid erroneous conclusions derived from the accuracy limitations of the migration technique, it was first necessary to remigrate the modelled data using the correct

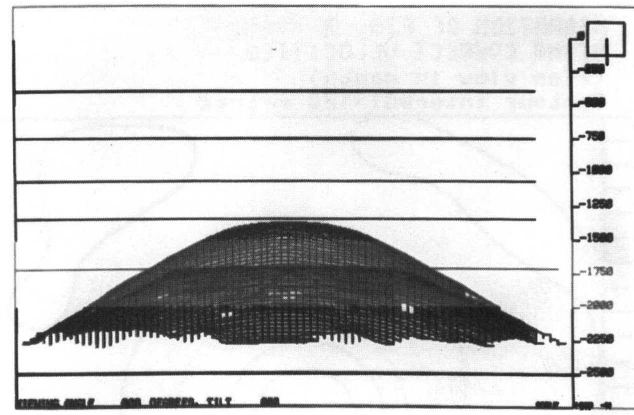

FIGURE 3
Isometric of 'Mexican Hat' structure after inverse migration (in time).

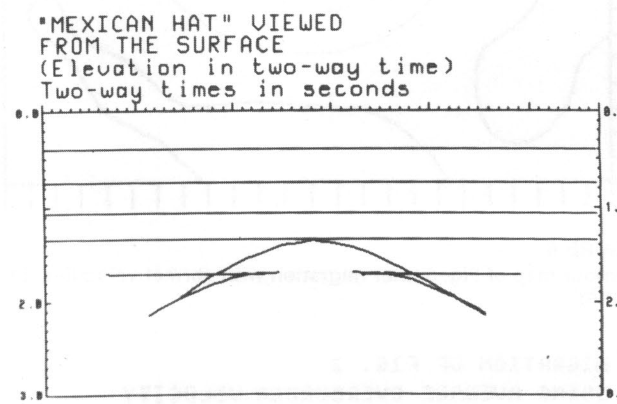

FIGURE 4
Vertical cross-section through the middle of Fig. 3 (in time).

velocity field, and determine the differences from the original model. Fig. 5 shows a contour map after the double operation and can be compared with Fig. 2. In the region of maximum dip down to the point of maximum curvature at the base of the structure, the error was nowhere more than 30 metres, or 2 percent of the total depth. At the crest of the structure, the error was only 20 metres or approximately 1.7 percent. The greatest differences were visible at a radius of about 600 metres from the crest, where the original model was horizontal. The maximum error was approximately 130 metres, or 7.5 percent. However, this appeared to be the result of gridding edge effects on the two bow-tie surfaces, which caused a disproportionate effect on the subsequent migration. Steps are being taken to remedy this, but in any case the main region of interest was inside this zone.

The first variation of the velocity field to be tested was a simplification of the horizontal overburden layers above the top of the structure. An average velocity of 1783 metres/second was used from the surface to the crest of the structure when performing the final migration. In many instances, inadequate information exists to quantify the shallow interval velocities accurately, and this test was designed to evaluate how important this knowledge is in a case where the velocities are increasing with depth. Fig. 6 shows the result of the migration using the simplified velocities. The errors involved were almost identical to those observed when the correct velocities were

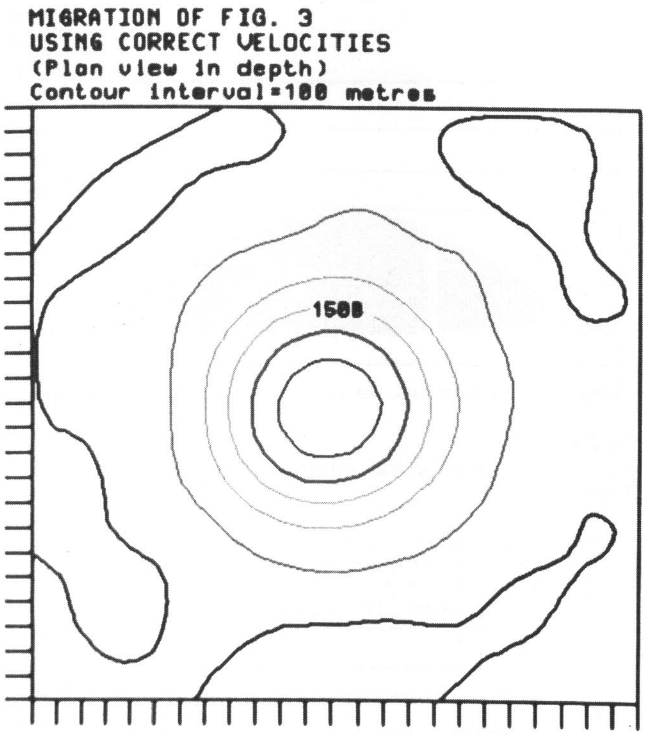

FIGURE 5
Contour map of Fig. 3 after migration with correct velocities (in depth).

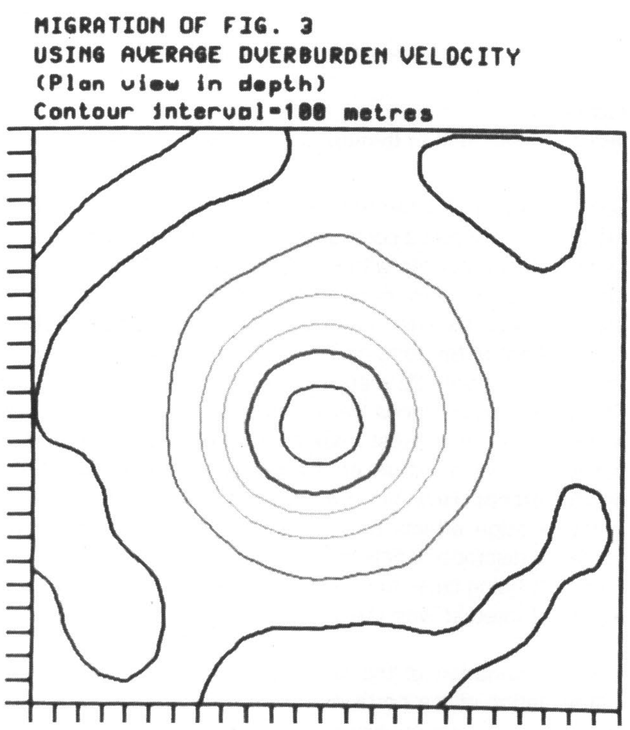

FIGURE 6
Contour map of Fig. 3 after migration with average overburden velocity (in depth).

used, with the biggest difference occurring at the crest. In this case, the error had been increased to 50 metres, or 4.2 percent, apparently because of a slight overmigration.

Further tests involving simplification to a single velocity layer, and a study of the effect of systematic velocity errors are discussed in the paper.

The Effects of Omitting Coincident Multiple Surfaces

While there is no doubt that the separation of multi-valued points into coincident surfaces can prove extremely useful in model studies, with the ability to identify energy from out of the plane of a seismic section, the question still remains as to the importance of including such energy when migrating. The 'Mexican Hat' structure was migrated with only the top surface from Figs 3 and 4 retained. This could approximate the situation in practice, where the bow-tie may be obscured by interference effects. The results of this simplification are demonstrated.

DRILLHOLE TIME-DOMAIN ELECTROMAGNETIC RESULTS

R. Kneebone, R. Parums, A. Smelic & L. Thomas

Physical model results are useful both as typical examples to aid in interpretation and also as controls on numerical or analytical model predictions. We present here some results of simple physical modelling of the SIROTEM downhole time-domain electromagnetic (DHEM) system which have been obtained over the last few years. More examples, and more discussion, are included in unpublished Reports of University of Melbourne Honours Projects by Parums, Kneebone, and Smelic.

The following main lines of modelling have been pursued, as examples show. To date, all modelling has been carried out with an axial sensor in a borehole dipping at 45 or 60 degrees and simple metal targets, at a spatial scale of 1:1000. A SIROTEM field system has been used for data acquisition, so that there is no time scaling, and results shown have been corrected for power scaling.

We have produced a suite of responses for a simple conductive slab in free space (air). Fig. 1 is an example; the target is a copper slab, representing a target 300 m square with a conductance of approximately 120 S, symmetrically placed with respect to the borehole. The cartoon at the top of the figure is a scaled section in the plane of the borehole. The responses plotted show the variation with depth of selected SIROTEM channels.

The responses found confirm the numerical results of programs such as PLATE, and also verify predictions on the behaviour of the anomalous field with time. For instance, Fig. 2 shows how the field crossover positions in the borehole