The integration of seismic and well log data: a new concept in reservoir description

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Most reservoir descriptions are performed today as ‘after the fact’ studies. That is, they are usually employed to describe various parameters of the reservoir after the last well has been drilled. This post-mortem approach has many valid applications but coming at or near the end of field development many opportunities may have been missed.

The development of borehole seismic techniques provides an opportunity to give a Reservoir Description Study (RDS), a completely new operation concept. The use of the vertical seismic profile as the missing link between surface seismic data and standard multi-well log analysis makes it possible to describe the reservoir in the initial stages of field development and, in fact, to guide that development by determining the optimum placement of each well.

In this paper, the feasibility of using seismic data to enhance present reservoir description capabilities is studied. The case history consists of an 11-well field in North Texas, though all the methodology and many of the conclusions are valid for many Australian prospects.

A map view of the 11-well field is shown in Fig. 1. The eight bold dots represent more recent wells where very comprehensive logging programs were run and the other three dots represent older wells with limited electric log data. The three seismic lines crossing the prospect are also shown.

The deficiencies of the original reservoir mapping are illustrated in Fig. 2. This shows a contour map of the top of the reservoir formation. The indicated structural high is to the southeast of the northeast–southwest drilling trend. It will later be shown that this trend is spurious and is a bias due to the linear distribution of seven of the wells.

A VSP was recorded in one of the recent wells located on one of the seismic lines. It should be pointed out that the VSP data did not suffer from many of the disadvantages that were noted for the surface seismic. The downhole recording of the VSP ensures that a downgoing wavefield will be recorded, including the direct wavelet. Knowing the amplitude and phase spectra of the direct downgoing wavelet allows the VSP upgoing wavefield to be deconvolved in a deterministic manner. Since the downhole recording positions are known, the VSP can be calibrated in depth as well as in transit time. Migration effects are minimized by the fact that the recording positions are very close to the reflectors.

A comparison was made between the VSP trace, computer-generated well log interpretations of the subsurface lithology and the surface seismic. This led to the conclusion that the surface seismic data mismatch with both the VSP and well logs could be explained by use of an improper deconvolution technique.

The surface seismic was then reprocessed using an inverse filter derived from the VSP trace. Figure 3 shows the section before and after the reprocessing. Note the enhanced perception of continuity in the reprocessed section. It can also be shown that the reprocessed traces in the vicinity of the

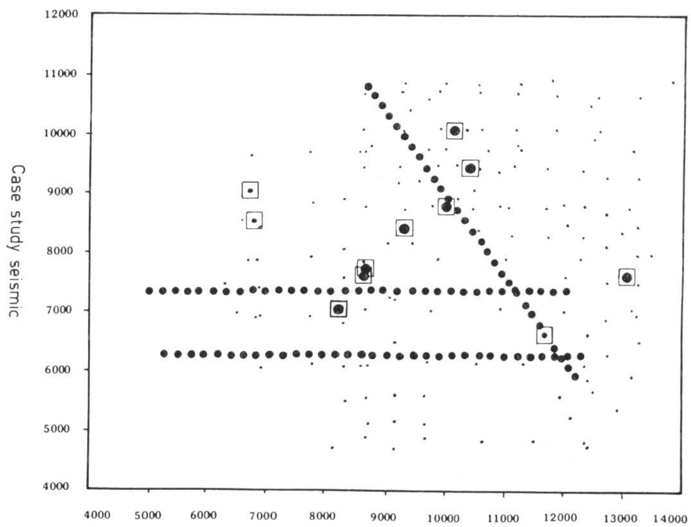

Fig. 1 Well locations and seismic lines.

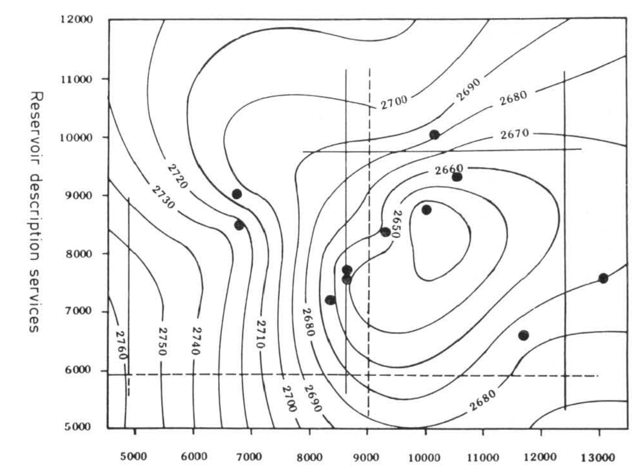

Fig. 2 Top of reservoir from logs only.

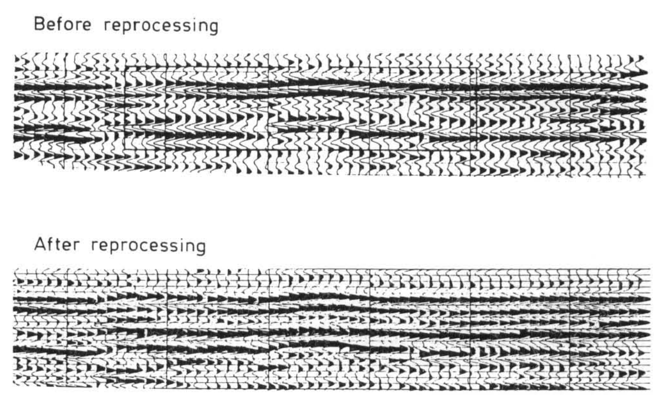

Fig. 3 Seismic line before and after VSP reprocessing.

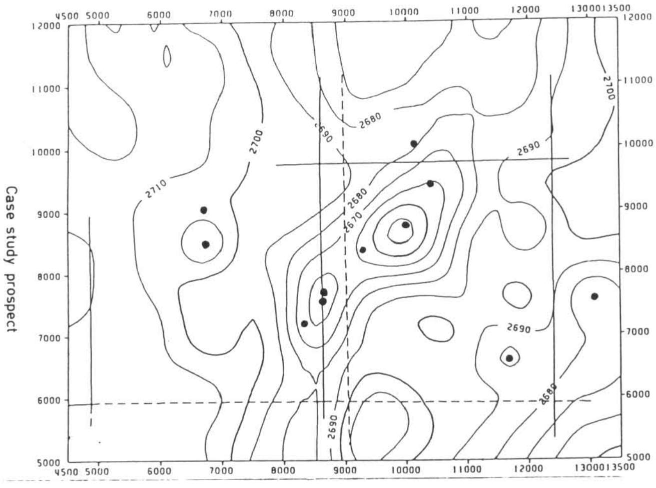

Fig. 4 Top of reservoir from logs and seismic.

wellbore are almost identical, in phase and amplitude to the VSP traces.

Recall that Fig. 1 is a contour map of the top of the reservoir formation as determined from log data only. In Fig. 4 the top of the reservoir formation as determined from the reprocessed (or calibrated) surface seismic data is displayed. Two-way transit times from the seismic data have been converted to depths from the transit time–depth relation observed at the wells. The combined seismic-log map not only shows much greater resolution in terms of the shape of the anomaly, but also indicates that the structural high is along the line of the wells and not to the south-east as indicated by the log map.

The following conclusions can be reached:

(1) It is feasible to combine seismic and well log data to produce a reservoir description that is superior to using either data set alone.

(2) The VSP can provide the missing link between the petrophysical properties in the borehole and the surface seismic data.

(3) The linking of the surface seismic sections to borehole answers should allow a Reservoir Description Study to be involved in the initial stages of field development.

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Interpretation of satellite magnetometer data

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Introduction

The MAGSAT satellite mission (Langel *et al.* 1982) obtained vector magnetic field measurements at altitudes ranging from 350 to 500 km above the earth's surface for a period of 7 months from November 1979 to June 1980. The satellite flew in a sun-synchronous near-polar orbit to achieve maximum coverage over the earth's surface and to minimize the effects of rapidly time-varying magnetic fields. The isolation of the crustal source anomaly components has proved to be a complex task involving the development of new geomagnetic field modelling techniques, improved methods for accounting for time-varying components and interactive techniques for critically selecting optimal data sets (Johnson & Dampney 1983).

Geomagnetic field sources

The magnetic field measured at satellite altitudes is a combination of effects due to several sources. The main field is due to electrical currents flowing in the outer core of the earth. This is normally modelled as a spherical harmonic sequence, up to at least order 13 (the transition between core and crustal field wavelengths), with linear coefficients to account for time variations of the order of a decade. More rapid time variation components arise from electrical current systems in the ionosphere and the magnetosphere. The former effects are very large near to auroral latitudes whereas the latter are quietest for dawn–dusk orbits. Field models are now available for the duration of the MAGSAT mission which adequately describe the main field plus the time varying components. MAGSAT data now dominates the International Geomagnetic Reference Field Models (Peddie & Fabiano 1982).

The remainder of the satellite observed magnetic field appears to come from the crust of the earth, where the temperatures lie below the Curie point for magnetic minerals.

The relative amplitudes of the anomalies from the various sources, when observed at satellite altitudes, demand that careful attention be paid to the problems of correctly separating the various effects. The vexing problem of separating the core and crustal anomaly fields remains essentially unsolved and is deserving of continued research.

Crustal-source anomaly map

Figure 1 shows a map of the crustal-source magnetic field superimposed on a map of the Solid Geology of Australia (Bureau of Mineral Resources 1979). The data set is obtained from the global anomaly map (Langel, Phillips & Horner 1982) which presented averages of the scalar magnetic field, taken over 2° × 2° latitude/longitude bins and over all elevations, after field model and linear trends have been removed. This data set was filtered by frequency domain techniques to remove high frequency effects due to between-orbit differences and along-orbit noise (Johnson *et al.* 1984). Both the global map and the filtered Australian map show extensions of