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3-D Seismic surveying in the Otway Basin

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ABSTRACT

The Tilbooroo seismic survey, recorded in early 1993, is the first 3-D survey acquired in the Otway Basin. It was preceded by an extensive study to optimise acquisition parameters in a cost-effective manner. This survey followed-up the minor oil recovery from fractured basement intersected by the exploration well Sawpit-1 and forms part of an integrated geological and geophysical analysis of the structural history of the Sawpit area. Evaluation of this fracture play requires accurate prediction of the orientation and intensity of the basement fault and fracture pattern.

The 3-D data, sampled at a spacing of 15 m inline by 30 m crossline, are acquired over a 44 km² area. Land use is mainly pasture land, but also extends into the Coonawarra vineyards. There were numerous obstacles - swamps, fences, buildings, no-access areas, vineyards - that challenged ingenuity in the planning, acquisition and processing stages of the survey. The 3-D seismic data are acquired at less than one quarter of the fold and twice the group interval of 2-D data, yet have a vastly superior signal-to-noise ratio. Confident interpretation of the basement fault pattern, combined with structural analysis of fault attributes and knowledge of the present day stress field, indicates the basement fracture play would be best evaluated by a deviated well with a southwest azimuth.

Keywords: 3-D Seismic Survey, Otway Basin, 3-D acquisition parameters, 3-D migration parameters, 3-D data quality, fracture reservoir, basement.

INTRODUCTION

The Tilbooroo 3-D survey is acquired onshore across the Sawpit structure in South Australian permit PEL 27 (see Moriarty et al., 1995 for location figure). It is about 15 km northeast of the Katnook gas field. In 1992 the exploration well Sawpit-1 had as the primary target sandstones on the upthrown side of the prominent Sawpit Fault (Moriarty et al., 1995). The well was subsequently deepened and recovered a minor amount of oil (1.5 BBL) from fractured basement, opening up an exciting new play for the basin (Moriarty et al., 1995). The selection of acquisition parameters for this, the first 3-D seismic survey recorded in the Otway Basin, was based on research that took place over one year. The aim was to record high definition seismic data that imaged fault planes while minimising costs in an environment that had many surface obstacles.

Prediction of basement fracture orientation and intensity requires accurate imaging of basement fault attributes (including dip, vertical displacement and heave) followed by structural analysis to predict the principal axes of strain. Basement faulting patterns cannot be imaged to the necessary accuracy on 2-D seismic data because of ambiguity in correlating fault trends and seismic sideswipe. An example of sideswipe on 2-D migrated data is shown in Figure 1. On the right-hand-end of the dip line (92S-02) at the basement horizon there is a 100 ms band of high amplitude reflectors (2.0 - 2.1 s), whereas on the strike line (OO91-08) there is a 300 ms band (1.8 - 2.1 s) at the intersection of these lines. The sideswipe on the strike line is from basement on the upthrown side of the Sawpit Fault. Furthermore, sideswipe occurs on the 2-D dip line where we see at least two positions, separated by 250 m, for the Sawpit Fault. Thus there is little confidence in basement structural interpretation in the Sawpit area using 2-D seismic data. The position of the basement in the crestal region is uncertain on the 2-D data. Only 3-D seismic migration can remove sideswipe and determine the large and small scale faulting orientations required for the detailed structural analysis.

METHOD

Field Parameters Optimisation

The area covered by the 3-D survey is to the northeast of the town of Penola comprising mainly farmland together with a number of permanent swamps (Figure 2). It was intended that spread would be laid through the swamps using marsh phones where the swamps were less than about one metre deep. Recording through the Coonawarra vineyards in the survey's western area provided a challenge, given the limited source access points. Other difficulties included working around several areas of no access because of quarantined paddocks (foot-rot sheep) and an expensive hybrid-seed crop.

As Bee et al. (1994) indicated, the planning stage of a 3-D survey is probably the most time consuming, yet important,

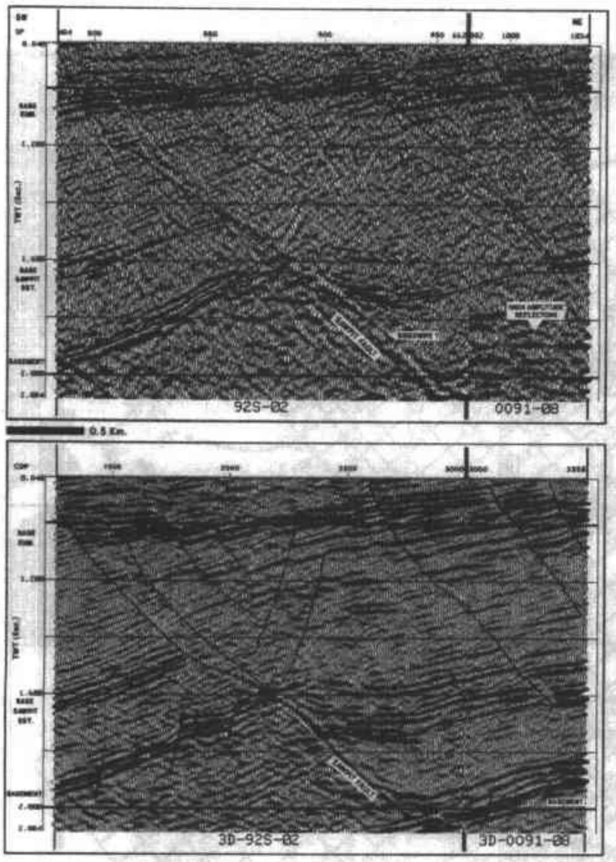

Fig. 1. Migrated seismic data intersecting on the downthrown side of the Sawpit Fault - 2-D data in the upper figure, 3-D equivalent traverse in the lower figure. Note the 2-D data have sideswipe; 3-D data have superior imaging of faulting and reflector geometry. The 2-D fold is 120, 3-D fold is 24.

stage. The design of acquisition parameters of the Tilbooroo seismic survey extended to consideration of many factors (Table 1) that could alter acquisition cost and data quality. Deciding the 3-D parameters was a challenging process, given there were no other 3-D surveys in the basin and that 2-D acquisition parameters of other operators were quite different (Moriarty, 1992).

Typically 2-D data have been recorded in the Sawpit area using a 240 channel system. However, recording 3-D data would require swaths of several receiver lines - typically four or six. If the same group interval used for 2-D acquisition were to be used, then the total number of channels required for 3-D acquisition would be 960 (4-line swath) or 1440 (6-line swath). Recognising that this large number of channels was impractical, the search began for acquisition parameters that would deliver the required data quality at an affordable price.

The 2-D seismic data in the Sawpit area have 120-fold 15 m group interval acquisition with one vibroseis sweep at each station (Table 2). These parameters achieve good data quality for the sub-horizontal sedimentary reflectors and fairly good definition of the steeply dipping fault planes (Moriarty, 1992). Mapping of fault plane reflections is critical for the definition of Otway Basin plays since many rely on fault seal.

The primary target of the Tilbooroo 3-D survey is the zone between 1.0 to 2.0 s, particularly the band of high amplitude reflectors near basement. Estimates using 2-D migrated seismic data and well velocity information indicates a 15° maximum dip for the sedimentary reflectors. Fault planes have 20-50° dips in the sedimentary section below 1.0 second (Figure 1) and are near vertical in the overlying section.

Recognising that a 3-D survey is designed such that spatial and temporal aliasing do not occur during processing, spatial sampling consideration at the basement level indicates for appropriate highest frequency (70 Hz) and RMS velocity (3,000 m/s), a 30 m group interval theoretically record dips up to 50° without aliasing (Lansley and Gonzalez, 1992). This spatial aliasing limit is difficult to accurately quantify since high frequency signal attenuation depends not only on dip magnitude but also on dip azimuth, bin dimension along azimuth of steepest dip and trace distribution within the bin (Lansley and Gonzalez, 1992). Thus theoretical predictions should be checked against actual data. A 2-D seismic line (15 m group interval 120-fold) was reprocessed to migration stage to simulate larger group intervals and/or lower fold, after appropriate summation or decimation of field records (Table 3). All data simulating 30 m group interval acquisition in this paper have interpolated traces post migration to maintain the same CMP spacing as 15 m acquisition.

A migrated comparison between 15 m and simulated 30 m group interval acquisition is shown in Figure 3. The 15 m group interval data exhibit somewhat superior imaging of the fault planes, although the 30 m data are adequate. Moriarty (1992) attributed improved data quality of these 2-D data to small group interval (15 m compared with 25 m) and high fold (120 compared with 60). It is now believed, after conducting these processing tests, that fold is the major control of data quality, provided the group interval does not exceed about 30 m. Thus a 30 m group interval was chosen for the 3-D survey, since use of a smaller group interval would significantly increase acquisition time, channels and cost.

With respect to the temporal requirement to avoid aliasing, a 4 ms sample rate is theoretically adequate for frequencies up to 125 Hz. In practice it is desirable to have at least three samples per cycle for the highest frequency, because of system uncertainties (Brown, 1991). This safety margin means 4 ms sampling is adequate for frequencies to 83 Hz. Highest frequencies recorded in the 0.0-1.0 s zone approach 100 Hz, decreasing to 60-70 Hz by 2.0 s. Given the extra effort put into imaging and processing these data and recognition that a 2 ms sample rate would be required for the migration (see later), the data were acquired with a 2 ms sample rate. This sample rate did not affect survey acquisition speed.

A major control on data quality is acquisition fold. The overall magnitude of the fold is considered to affect the signal-to-noise (S/N) ratio, the ability to determine accurately stacking velocities, consistency of reflection character for stratigraphic work and residual static computations. To investigate the effect of fold on data quality, processing trials (20- to 60-fold)