A Long-offset seismic reflection and refraction study of the Gippsland and Bass Basins from onshore recording of a marine air-gun source

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Abstract

Seismic refraction data were obtained for the Bass and Gippsland Basins during the 1988 cruise of the BMR research vessell "Rig Seismic". Seismic recorders were deployed on land by BMR and Monash University to record long-offset wide-angle reflection and refraction data using the ship's air-guns as the energy source. Preliminary results have now been obtained from these data providing information on deep crustal structure related to the basin formation. Two crustal layers have been detected with velocities of 4.5 km/s increasing to 7.4 km/s (unreversed) at depths exceeding 20 km.

Additional data have now been obtained over a traverse length of 170 km to provide constraints on the deep structure of Bass Strait and the Lachlan Fold Belt in Victoria and Tasmania.

Key words: Detachment models, Bass/Gippsland basins, seismic reflection, refraction, air-gun arrays

Introduction

Models involving lithosphere stretching have been proposed (eg McKenzie 1978, Wernicke 1985) to explain the evolution of sedimentary basins characterised by thinning, rifting, and subsidence of the total crustal section. Similar models may be appropriate to the Bass and Gippsland Basins in Australia.

However the diagnostic detachment faults are difficult to recognise using conventional seismic reflection profiles.

Interpretations may be improved by generating data in traverses normal to the postulated transfer faults which divide the extending terrane into uniform compartments (Etheridge *et al* 1985).

Longer reflection profiles were obtained for the Bass and Gippsland Basins by the Bureau of Mineral Resources in 1989.

A dual air-gun array totalling 3200 cubic inches was deployed in an attempt to penetrate to the presumed zones of detachment. This survey was designed primarily to obtain reflection data but Jokat and Flueh (1987) have demonstrated that seismic refraction profiles can be obtained with the same source. Costs are substantially reduced and data densities are sufficient for detailed structural analysis.

Normally charges exceeding 1 tonne of TNT equivalent are required for long range seismic refraction surveys; at least two orders of magnitude greater than the power of the BMR air-gun array. Consequently feasibility studies were considered essential to demonstrate suitable signal/noise ratios prior to more detailed surveys. Excellent results were obtained using a standard air-gun source deployed on industrial surveys in Bass Strait justifying the current project.

Survey Procedure

Three digital recorders were deployed by Monash University, and six analogue recorders were deployed by BMR. One recorder was installed on Deal Island to provide reversals for the other sites located near Orbost, Seaspray and Wilson's Promontory (Figure 1). The firing rate for the air-gun and ship's speed were selected to give a shot interval of 50 metres offering considerable potential for signal processing and data redundancy.

Survey configurations were selected to obtain reversed refraction profiles over a 200 km section of the Gippsland basin. The extensional model proposed for the Gippsland Basin divides the basin into compartments bounded by northeast/southwest transfer faults. The main refraction lines were oriented parallel to the transfer faults each sampling a single compartment. Recorders were also deployed off these

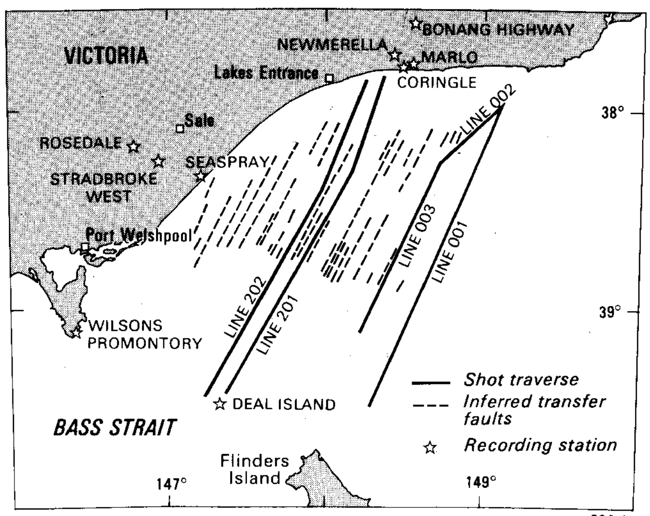

FIGURE 1
Survey location in Bass Strait with seismic refraction profiles consistent with transfer faults predicted by detachment model.

lines and were run continuously throughout the cruise, so a wide range of offsets and azimuths across the basin were recorded.

Two major refraction lines were selected to provide a traverse across the Gippsland Basin from Deal Island to the Victorian coast near Orbost. They were separated by about 10 km and ran either side of an inferred major transfer fault zone. These lines were shot without coincident reflection profiling; other lines which were run for the acquisition of reflection data were also recorded by the land stations. Some of these were located within the eastern Bass Basin.

Data Analysis

Charges exceeding 1 tonne of TNT equivalent are usually required for long range seismic refraction studies (eg Finlayson *et al* 1979). The air-gun sources available for the Bass Basin Survey were smaller by at least two orders of magnitude. Jokat and Flueh (1987) have demonstrated the advantages of the tau-p technique in these circumstances.

They applied a three-trace local slant stack giving an improved section for data obtained in Sweden. However single phases may be subject to smearing and superior results may be obtained using velocity filters.

All original records are substantially obscured by noise. A typical trace is illustrated in Figure 2. This record is dominated by a low period background swell but the air-gun generates regular pulses of higher frequency. Consequently digital filtering can be used to separate signals for interpretation. An equivalent result would be obtained by limiting the response of the sensor. The resulting record section for a representative group of shots is shown in Figure 3.

A complete record section has not yet been prepared.

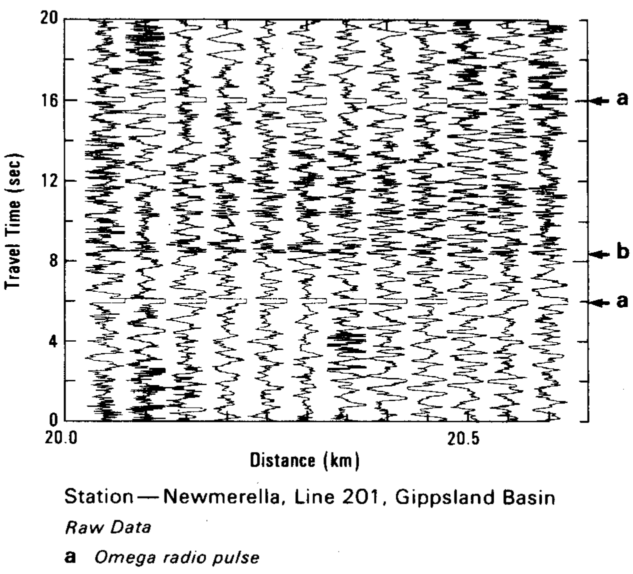

FIGURE 2
Raw seismic refraction section obtained at Newmerella using air-gun arrays with digital recorder (50 samples/second) operating with pass band 1-100 hz.

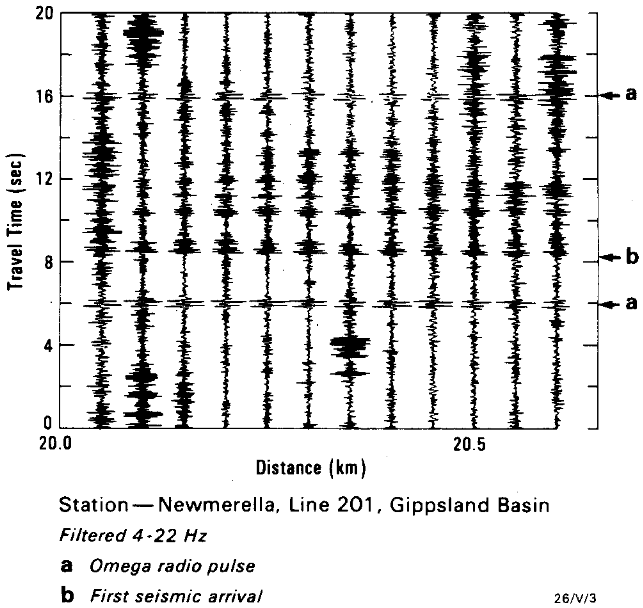

FIGURE 3
Seismic refraction records obtained at Newmerella after digital filtering to exclude background noise (below 4 hz).

However initial estimates for the first arrivals at one station have been obtained for calculations of velocity.

These data are presented as a time/distance plot in Figure 4.

Two layers are indicated with velocities of 4.5 and 7.4 km/s.

The critical distance for these two layers is of the order of 90 km indicating an upper layer thickness exceeding 20 km.

There is an offset in the deeper segment possibly indicating basement structure. However navigational errors must be assessed before this preliminary interpretation can be verified.

Conclusions

Noise levels in the Bass Strait are much higher than those experienced in the Swedish fiords. Furthermore seismic surveys are complicated by significant attenuation of the signal by the thick sedimentary pile in the basins (including coals).

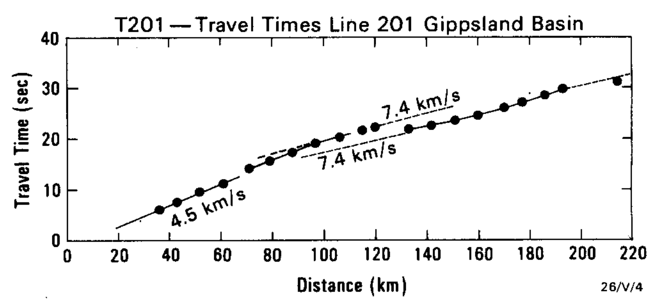

FIGURE 4
Preliminary travel-time plot for first arrival data obtained from air-gun arrays in Bass Strait. Apparent velocities consistent with results from BUMP (Underwood 1969) complicated by offset indicating departures from 1D layered structure.

However, the close shot spacing and large number of shots recorded at each recording site provide an excellent opportunity for developing processing/stacking procedures designed to enhance the data.

Preliminary interpretations are consistent with previous results obtained in Victoria and Tasmania. Using data from the Bass Strait Upper Mantle Project (BUMP) Underwood (1969) obtained Pn velocities in the range 7.83–7.88 km/s at depths of 25–37 km. Velocities in the surface layers were poorly constrained but values in the range 6.0–6.1 km/s were assumed for a granitic basement. Velocities of 4.0 km/s were observed over the minor sand/shale and greywacke sequences.

Gibson *et al* (1981) have adopted a model consistent with the BUMP data for interpretations of data obtained from seismic arrays in Victoria (VIC4A). They proposed a major discontinuity at depths close to 17 km corresponding to the base of the tectonically thickened Palaeozoic sequences (C. Wilson, pers comm). However similar results can be obtained with more complex models and intermediate velocities observed elsewhere in the Lachlan Fold Belt may persist to depths of 41–50 km (Finlayson and McCracken, 1981).

Acknowledgements

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