AGCRC Wide-Angle Seismic Profiling across the Broken Hill Block and Eastern Lachlan Fold Belt 1997: Operations Report

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Abstract

During the period June-July, 1997, wide-angle seismic data were acquired along profiles across two areas of NSW as part of the program of the Australian Geodynamics Cooperative Research Centre (AGCRC[1]) to investigate major mineral provinces throughout Australia.

The two areas were:

- The Broken Hill Block
- The Eastern Lachlan Orogen in the Orange/Bathurst area

The first profile crossed the Broken Hill Block in western NSW in a northwest-southeast orientation and was 342 km long. It was designed to determine the velocity structure of the crust beneath this important mineral province, to investigate the source of the extensive amphobolite dyke complex in the Broken Hill region, and to probe whether there was a significant difference in the crustal structure underlying the Tasman Line. A secondary objective was to test whether the subsurface geology of the the Broken Hill region is analogous to that under the Mt Isa region of Queensland.

The second profile was 364 km long and aligned north-south along the Molong-Wyangala Structural Zone in the Eastern Lachlan Orogen, centred on the Orange/Bathurst region. This profile was designed to investigate the nature of the Lachlan Transverse Zone, an east-southeast oriented structural feature crossing the Molong-Wanagla Structural Zone about its mid-point which seems to have controlled gold mineralisation in the volcanic belts within the Eastern Lachlan Orogen.

For the surveys, ninety Seismic Group Recorders (SGRs) were borrowed from the IRIS[2] research organisation in USA through the US Geological Survey, Menlo Park, California. The instruments were deployed along the two profiles and recorded wide-angle seismic arrivals from the six shots spaced along each profile.

This record describes the seismic field operations associated with this AGCRC research program and the retrieval and archiving of the data collected. These data will form the basis for future interpretations of the geological structures in the two areas surveyed.

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[1] *AGCRC : Australian Geodynamics Co-operative Research Centre - Established by the Australian Government to develop a better understanding of links between geodynamic processes applying to Australia and the formation of world-class ore deposits (see http://www.ned.dem.csiro.au/AGCRC).*

[2] *IRIS : Incorporated Research Institutions for Seismology - A group of about ninety US universities and national institutions funded by the National Science Foundation to engage in seismic research both in USA and worldwide (see http://www.iris.washington.edu/HQ/HQ.htm).*

Introduction

Crustal scale wide-angle (refraction) seismic programs provide the only geophysical tool which gives accurate information on the seismic wavespeed (or seismic velocity) and hence an indication of the composition of rocks beyond the reach of the drilling bit. Combining crustal-scale seismic reflection and refraction programs is a logical approach which provides complimentary information on the structure and composition of the crust beneath mineral provinces. As an example, the recent combined reflection/refraction seismic work across the Mt Isa Block (Goncharov et al., 1997) provided a new model of the structure of the basement and suggested the importance of mid-crustal mafic bodies in controlling and focusing the mineralisation in that region.

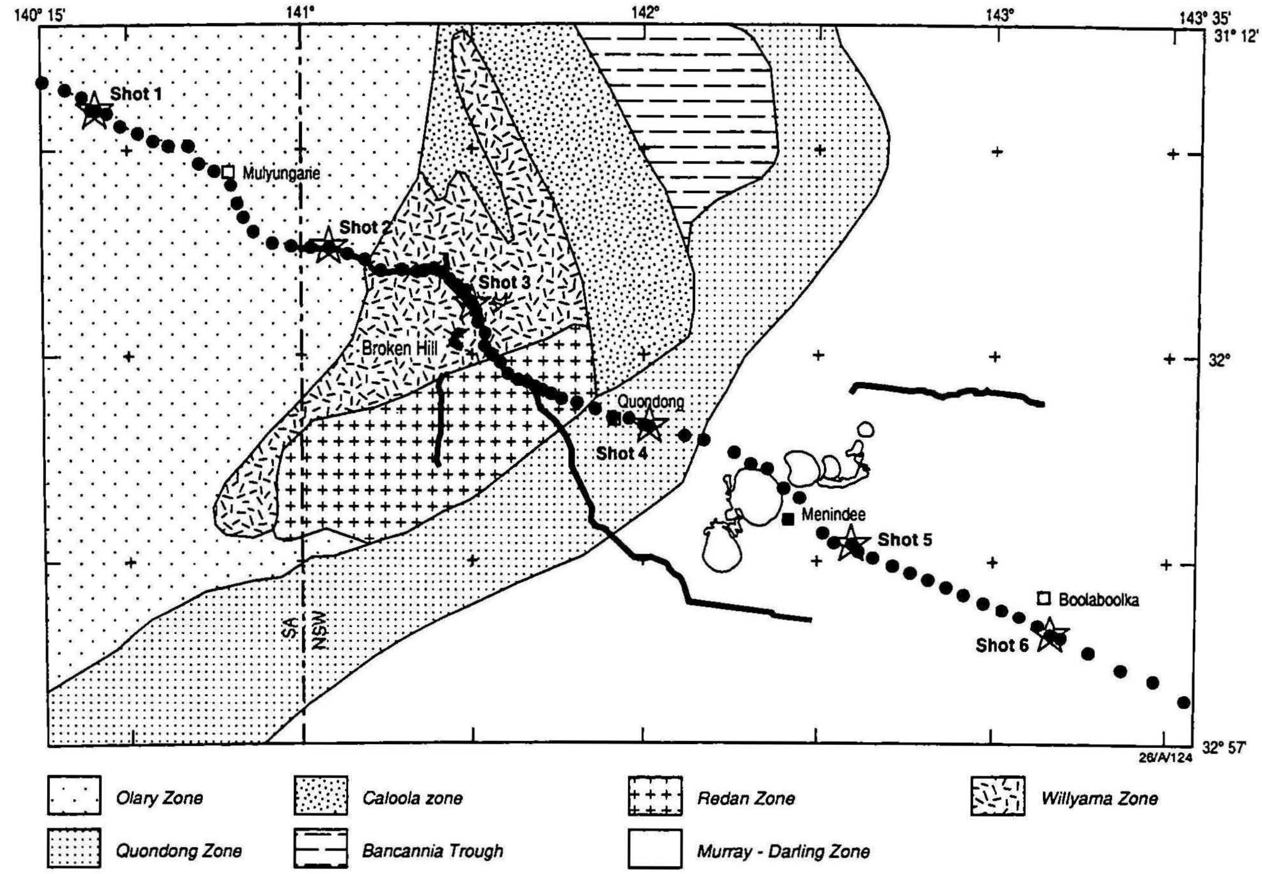


Figure 1. Location map of the Broken Hill profile showing the position of the SGR recorders (dots) and the six shot sites (stars) for the refraction profile. The seismic reflection lines are indicated as solid lines.

In 1997 the AGSO North Australian Basins Resource Evaluation (NABRE) project had planned to combine both reflection and refraction profiling across the Batten Fault Zone in the McArthur Basin, Northern Territory. For this AGSO program, a loan of ninety SGR seismic recorders had been arranged with the US Geological Survey and Stanford University.

In March 1997 it became clear that, because of financial restrictions, the AGSO NABRE seismic program would not proceed. However, by this time the ninety Seismic Group Recorders (SGRs) had already been shipped from the United States to Brisbane. The opportunity to use these recorders was therefore accepted by the Australian Geodynamics Cooperative Research Centre (AGCRC), and a program was formulated to investigate the crustal structure beneath the world clss orebodies of the Broken Hill Block and the Eastern Lachlan Orogen to test specific geological models.

Wide-Angle Seismic Survey Design

The same philosophy was applied to the design of the wide-angle seismic survey work for both the Broken Hill area and the Eastern Lachlan Orogen. The primary target for both surveys was the velocity structure of the crust in the depth range of 0 - 50 km, i.e. a crustal scale investigation. To adequately investigate this range of depth and develop a velocity model of the whole crust, shot-receiver offsets in excess of 300 km are required.

The profiles in both the Broken Hill area and the Eastern Lachlan Orogen both exceeded 340 km in length, and were orientated perpendicular to the target structure. Although no line preparation was undertaken for either survey, both profiles were designed to be as straight as available roads and access allowed.

As no AGSO staff had prior experience with the programming or deployment of the SGR instruments, Brian Laird, a consultant was contracted to train AGSO staff in the use of the SGR instruments and to ensure their successful deployment and recovery in the refraction acquisition program. Brian had previously worked for the USGS and had extensive experience with the use of the SGR instruments.

The SGRs were deployed as a linear array along each profile. The recorder spacing was varied along the profile, with stations concentrated in the vicinity of the target at a station spacing of around 2.5 km, and with station spacing extending out to 10 km near the ends of the profile. One or two SGRs were deployed within 100 m of each shot site to provide shot timing information.

Shot holes for the refraction blasts were pre-drilled and loaded before deployment of the SGR instruments. Shots were pattern drilled, with each shothole usually being 20-40 m deep and loaded with 50-250 kg of ICI "Breaker" explosive packaged as 5 kg "sausages". In shallow shot holes the shotweight loaded in each hole was sometimes as low as 15 kg. Two or three priming charges (2 kg ICI Powergell seismic explosive) were normally loaded in each shothole. Shothole separation was about 10 m; hole diameter was either 4.5 inches or 5.5 inches. On each profile, six shots were detonated electrically during specific time windows programmed into all the SGRs using a master clock (see Appendix 6). These six shots were recorded by the whole seismic array. Nominal shot sizes were three tonnes of explosive for the sites near both ends of the profiles and one tonne for the four intermediate shot sites.

Broken Hill Profile

Overview

The Broken Hill refraction seismic survey was part of a multidisciplinary study of the structure and evolution of the Broken Hill region in western NSW. The aim of this seismic survey was to produce a velocity map of the crust beneath the Broken Hill Block and the Tasman Line that would delineate the structure beneath and adjacent to the inlier, and complement the information obtained from the seismic reflection survey work (Fomin et al., 1998). In particular, the refraction survey aimed to map the depth extent and form of mafic bodies that were believed to have sourced the extensive amphibolite sills within the Thorndale Gneiss. It was postulated that mafic bodies may have had a causal role in the formation of the Broken Hill deposit. Another objective of the survey was to investigate the structure of the crust underlying the Tasman Line, which is a geological boundary representing the eastern limit of Precambrian outcrop.

The investigation also aimed to test the applicability of geological models developed for the Mt Isa region (Drummond et al., in press) to the Broken Hill Block. Interpretation of a refraction profile recorded along the Mt Isa seismic transect identified two high velocity lens-shaped bodies in the middle and lower crust. The seismic velocities within these bodies (in excess of 7 km s^{-1}) indicated that they are most likely mafic to ultramafic in composition (Drummond et al., 1998). These bodies are interpreted either as thrust slices or igneous intrusions. The relationship of these high-velocity bodies to the Mt Isa mineralisation is still controversial.

Geology

The Broken Hill region lies just inboard of the late Neoproterozoic continental rift margin and comprises rocks of the Willyama Supergroup, a varied sequence of Palaeoproterozoic sediments and minor felsic volcanic rocks metamorphosed up to the granulite facies (Willis et al., 1983; Stevens et al., 1988).

Figure 1 shows a location map of the wide-angle profile in which the geology has been simplified into seven zones defined on the basis of the geophysical signature and the mapped geology. At the northwestern end of the profile, the Olary zone is characterised in the TMI image by a variable signature and the Proterozoic geology is largely obscured by a veneer of Cretaceous to Cenozoic sediments. East of the Mundi Mundi Fault, the Willyama zone is characterised by a relatively subdued magnetic signature, apart from a series of dykes with a prominent magnetic expression. The total thickness of the Willyama Supergroup has been estimated at approximately 7-11 km (Stevens et al., 1988). The Redan Zone is characterised by a strong magnetic signature. Glen et al. (1977) proposed that the Redan Zone forms an older basement to the Willyama Supergroup rocks, however, Willis et al. (1983) correlated the rocks of the Redan Zone to the base of the Willyama Supergroup. North of the profile, the Willyama Supergroup is unconformably overlain by sediments of the late Neoproterozoic Adelaidean succession (the Caloola Zone). The Quondong zone is a belt of predominantly Cambrian rocks which abuts the eastern edge of the Redan Zone and the Bancannia Trough (farther north), and is characterised by a strong negative anomaly in the TMI image. The Murray-Darling Zone at the SE end of the profile is magnetically quiet and characterised by large negative Bouguer gravity anomalies associated with a series of Cambrian to Devonian troughs.

Structure

Structural models for the Broken Hill region range from those of Laing et al., (1978), Marjoribanks et al., (1980) who interpreted the structure in terms of a series of refolded nappes, to White et al (1995) who reinterpreted the Broken Hill Block as a series of SE verging thrust packages. Recently Gibson et al., (1998) have interpreted reflection seismic data in terms of strike slip and reverse slip movement on southeast dipping structures, with evidence for the preservation of an earlier extensional geometry of unknown age.

Targets

The targets for the wide-angle seismic profiling were as follows:

- Velocity structure of the crust beneath the Broken Hill Block at a scale suitable for correlation with regional geological mapping.
- Possible sources of the mafic dykes
- Lateral velocity variations within the crust across the Tasman Line

Seismic Survey Operations

The Broken Hill traverse was a 342 km NW-SE transect that followed the alignment of the existing AGSO seismic line 1A west-northwest of Broken Hill and follows the railway line southeast of Broken Hill (Figure 1). Seventy seven SGR recorders were used to record six shots spaced along the traverse. The proposed station spacing of the SGR recorders was approximately 2 km over the inlier and between 5 to 10 km elsewhere.

In April 1997, the recording equipment, which had been shipped to Brisbane in preparation for the NABRE refraction survey, was re-directed to Broken Hill. Drilling of the shot holes commenced after completion of the seismic reflection work, and proved to be the rate limiting step.

The ambient night temperature in the Broken Hill region at that time of year was below 0° C, and below the operational specification of the SGR instruments. On arrival at the camp, Brian Laird ran one of the SGR instruments overnight (above ground) in the sub-zero temperatures, and the failure of this instrument indicated that overnight temperatures were below the successful operating range of the SGR instruments. Another test with the SGR buried suggested that burying the SGR's would improve the success rate. Consequently the decision was made to bury the SGR instruments at all recording sites in an attempt to maintain their temperature within specifications. This naturally slowed deployment of the instruments.

All timing of the SGR recorders was relative to a master clock (#10) which was set approximately (±2 s) to Universal Time (UT). Two slave-clocks were accurately synchronised to this master clock (#10) for backup. These master clocks, which had thermostatically controlled crystal oscillators, were assumed to have no appreciable drift. For refraction surveys, the determination of the relative timing of the arrivals after the shot instance is of prime importance. The clocks in the individual SGR units were synchronised with the master clocks before deployment and their drift measured relative to the master clocks upon recovery. This drift was assumed to be linear during the time of deployment and a correction for this drift applied during the translation of seismic data files to SEGY format.

For the Broken Hill survey it was not possible to precisely determine the offset of the master clock from UT, so the absolute time (UT) of the Broken Hill shots is only known to an accuracy of ±2 s. For refraction surveys the travel time of the seismic waves relative to the shot time is the important measurement. Therefore it is only necessary to relate all recorder clock times to the master clock and thus determine relative seismic travel times.

The SGR units were programmed with 80 second recording windows, designed to commence 5 seconds before the time of shot detonation. No variation of the record-start-time with offset was used, and all instruments commenced recording simultaneously (assuming no clock drift). The recording units were deployed over two days by four teams of two, each deploying around 22 instruments. On Friday 20 June, the six shots were successfully detonated within the six recording windows (Appendix 2). Appendix 3 details the locations of the SGR instruments.

The SGR instruments were recovered over a period of two days and the clock drift recorded onto the tape. Appendix 4 outlines the success rate of the instruments.

The AGSO Sercel reflection seismic acquisition system was deployed at the Shot 5 site along the highway east of Broken Hill (Appendix 6). Four of the refraction shots were recorded on the Sercel - 120 channel at 60 m group interval - giving a detailed 7.14 km array at 2 ms sample rate with 40 second record time. The number of samples in these long records exceeds the capacity of the short integer in the SEGY header which stores the number of samples, providing difficulty in transcribing these shot records. Appendix 7 details the station locations for the Sercel recording.

After recovery of the SGR instruments, seven diagnosed as faulty were returned to Canberra for servicing. Five of these faults were found to be related to battery problems as the batteries had not been recharged in Australia prior to deployment. Two problems were more serious, and without SGR test equipment it was not possible in the available time to rectify the problems with the two instruments with more serious faults.

East Lachlan Profile

Overview

The Ordovician volcanics in the Eastern Lachlan Orogen host significant gold and copper porphyry-style deposits, and recently these have become the main mineral exploration target in NSW. Gold mineralisation within these Ordovician volcanic belts appears to have been controlled by a set of east-southeast trending lineaments; in particular the Lachlan Transverse Zone (Glenn, 1979). The seismic refraction profile in the East Lachlan Orogen was designed to investigate the nature of this Lachlan Transverse Zone, which may have provided major fluid migration pathways for mineralisation.

Geology

Although there is agreement that the Lachlan Orogen of eastern Gondwanaland developed into continental crust during the early Palaeozoic, there is still debate about how it evolved and what forms the substrate to the exposed rocks. Glen (1997) describes the Lachlan Orogen as forming at a convergent continental margin from mid-Cambrian to Early Silurian times, before being subjected to back-arc extension, felsic volcanism, and granite emplacement until the Late Devonian. Using recent geochemical data, Glen (1997) favours an intra-oceanic island arc setting for the Ordovician volcanics of the Lachlan Orogen resting on a Cambrian oceanic crust and related to west dipping subduction of the palaeo-Pacific plate beneath eastern Gondwanaland.

VandenBerg & Stewart (1992) indicate that four belts of Ordovician volcanics are recognised, but the belts are thought to have been originally connected. They favour hot-spot volcanism as the mechanism for the volcanics. Wyborn (1992), using geochemical arguments, prefers a model involving delayed heating, melting and thinning of a sub-continental lithosphere. Gray et al. (1997) envisage southwest-Pacific-type subduction processes acting on an oceanic crust adjacent to the Gondwana continental margin.

In the Eastern Belt of the Lachlan Orogen, Glen (1992) describes the major structures in terms of "thin skinned" tectonics, with surface contractional faults flattening into upper crustal detachments at about 4 km depth, but also with some deeper level thrusts to about 10-14 km. Below these depths, however, Glen (1992) speculated (to accommodate evidence from granite source rock geochemistry) that the middle and lower crust of the Eastern Lachlan Belt comprise an underthrust Precambrian(??) slab about 30 km thick. Ideas on the lower crustal composition and history of this region are still evolving.

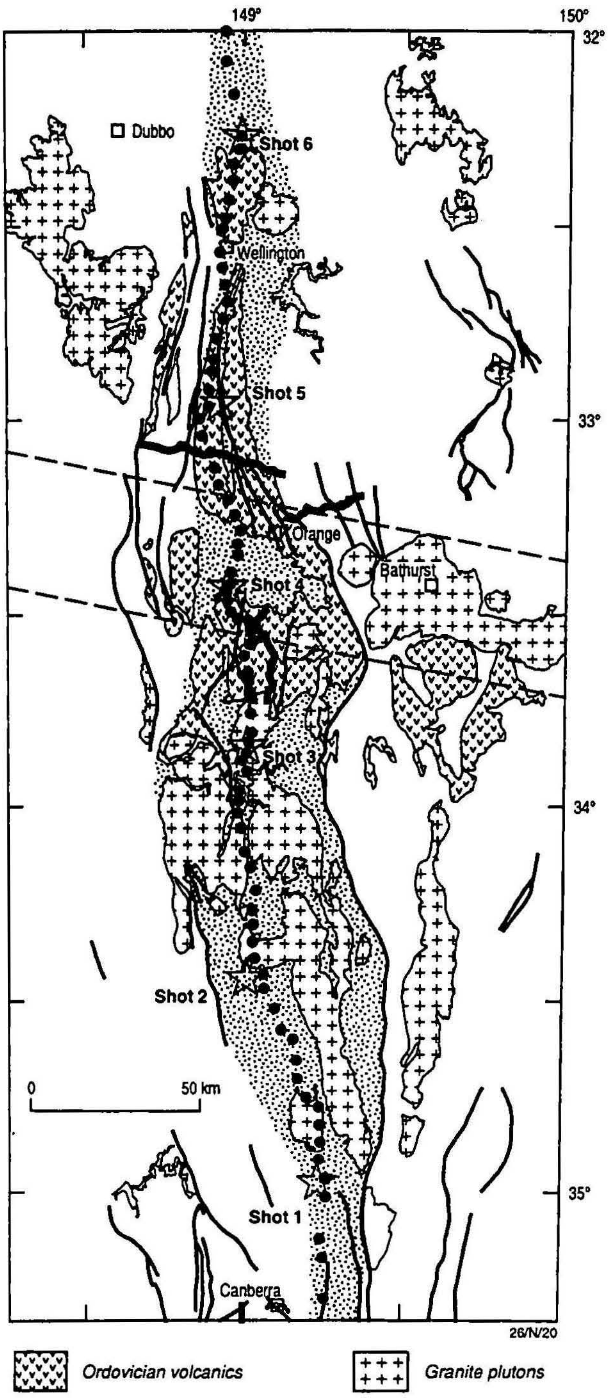


Figure 2. Simplified geology of the Molong-Wyangala Structural Zone and location of wide-angle seismic profile (dots) and shot sites (stars). Also shown in thick line are the locations of three 1997 seismic reflection profiles.

Structural Elements

In the Orange-Bathurst region there are three belts of Ordovician volcanics and Glen (1997) interprets these three present-day belts as being relics of a single large belt that has been subjected to extensional thinning, thrusting and strike-slip faulting. Glen & Wyborn (1997) have drawn attention to west-northwest oriented structures across the region that form what they call the Lachlan Transverse Zone (LTZ). This zone is regarded as being a crustal-scale tear/fault/accommodation zone controlling deformation in the region and it is inferred to be the locus of large mineralised intrusive/volcanic complexes along its length, known to host some world-class porphyry copper and gold orebodies.

Targets

In the Eastern Lachlan Orogen the targets for the wide-angle seismic profiling were:

- Crustal velocity structure along the Molong-Wyangala Structural Zone (Scheibner, 1996) of the East Lachlan Orogen at a scale compatible with regional geological mapping.
- Differences in crustal velocity structure across the Lachlan Transverse Zone that bisects the Molong-Wyangala Structural Zone at about its mid point.

Seismic Survey Operations

The wide-angle profile in the Eastern Lachlan orogen extended 364 km from Ballimore (near Dubbo) in the north to near Canberra in the south. It was located along the Molong-Wyangala Structural Zone (Scheibner, 1996) to investigate the nature of features north and south of the ESE-WNW trending Lachlan Transverse Zone (Figure 2).

Because of the sub-zero overnight temperatures, the SGR instruments were buried during deployment to maintain the instrument temperature within operational specifications, slowing deployment of the instruments. The batteries of the SGR units were fully charged before deployment, and this is believed to have resulted in the better success rate of the SGR instruments during the East Lachlan survey.

As with the Broken Hill survey, shot hole drilling and shot-loading were the rate limiting steps during survey operations. Due to operational restraints, the instrument deployment was done on Thursday and Friday, 3 and 4 July, but the shots could not be detonated until Monday 7 July, so the time between deployment and recovery (around 6 days) was greater than desirable or normal practice. This longer deployment period meant greater clock drift, and possible greater error in the assumption of linear clock drift between deployment and recovery.

On Monday 7 July, all shots were successfully detonated within the recording windows. Appendix 2 details the shot times and locations. Shot 5 was detonated in two parts because of shothole/wiring problems. The main portion of the loaded shot (890 kg) was detonated at 11:22 EST and the remaining portion (110 kg) was detonated at 11:52, in the backup time window.

Most of the SGR instruments were recovered on Monday 7 or Tuesday 8 July, with only two instruments recovered on Wednesday 9 July. All the instruments deployed at the southern end of the profile were taken back to AGSO for recording the clock drift using Master Clock #3. Unfortunately, this master clock had been tampered with during transport to Canberra, and another delay of 1.226 seconds introduced. This additional delay was corrected during clock drift correction and transcription to SEGY format at the USGS office in Menlo Park, California.

Data Retrieval and Quality

The SGR data cartridges were shipped back to the USGS in Menlo Park, California, and the data transcribed by Brian Laird into SEGY format with the clock drift corrections applied. The data were recorded at 2 ms sampling rate, so that the total number of samples in the 80 second records exceeded the capacity of the short integer in the SEGY header to record the number of samples per trace. Thus these SEGY data from the Eastern Lachlan were also resampled to 6 ms sampling rate, which allowed the use of standard SEGY programs to handle the data. Both the 2 ms and the 6ms data were shipped to AGSO on 9-track tapes.

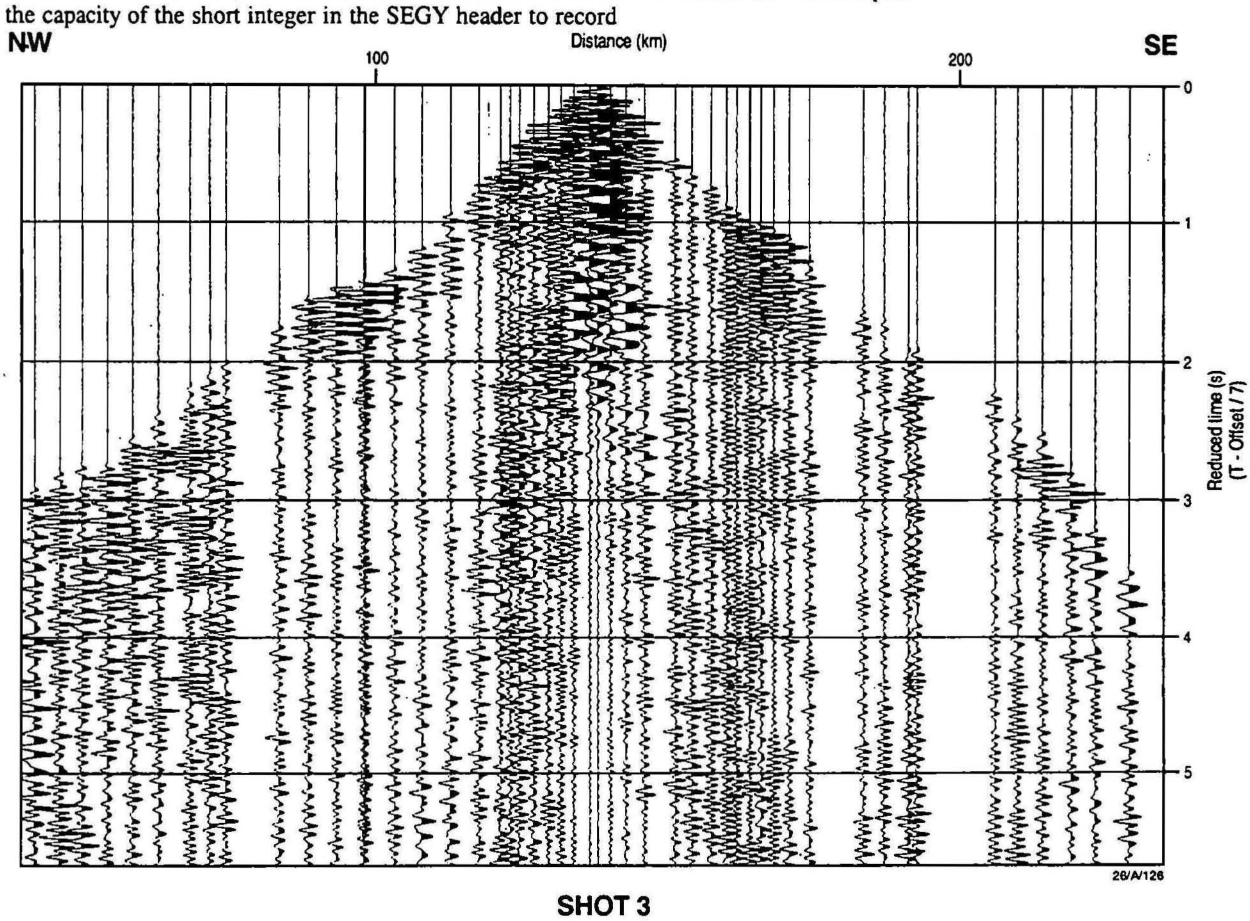


Figure 3. An example of the Pg1 arrivals from shot 3 detonated north of Broken Hill recorded across the Broken Hill Block. These Pg1 arrivals show little delay time, indicating the presence of basement rocks with a P-velocity near 5.9 km s^{-1} near the surface.

Appendix 4 details the operational success of the SGRs. During both the Broken Hill and Eastern Lachlan surveys, six of the SGRs were not deployed because of failures with the recorders during the programming phase. Of the 84 remaining instruments deployed for the Broken Hill survey, seven units failed totally (no shots recorded) and three units did not record all shots. Of the 84 instruments deployed for the Eastern Lachlan survey, two units failed totally, and six recorders did not record all shots. Undoubtedly the cold weather and sub-zero overnight temperatures took a significant toll. The better performance of the SGR recorders during the Eastern Lachlan survey is thought to be attributable to fully recharged batteries. For the Broken Hill survey, the batteries were fully charged in the US, but not recharged in Australia.

Data from the Broken Hill survey showed good signal-to-noise (S/N) for the crustal phases, but poor S/N for the Pn phase, particularly for shots 1 and 2. Figure 3 shows the Pg1 arrivals from shot 3 detonated about 8 km north of Broken Hill. In figure 4 the Pg1 arrivals for shot 5 detonated about 20 km east of Menindee show a large intercept time and prominent delays associated with near-surface low-velocity Darling Basin sediments.

Data from the Lachlan survey was considerably noisier than data from the Broken Hill survey, in part because of wind noise, but also because the Lachlan profile was aligned along busy roads. Future surveys could benefit from adopting the procedure of the USGS of detonating refraction shots during the night when both wind and cultural noise are at a minimum. Figure 5 shows the seismic record section from shot 6 at the northern end of the East Lachlan profile, on which some of the P-wave seismic phases have been identified and interpreted

Figures 7 to 12 show the reduced travel time plots of the arrivals from the Broken Hill survey, and Leven et al. (1998) have interpreted these data and derived a P-wavespeed crustal model of the Broken Hill region.

Figures 13 to 18 show the reduced travel time plots of the arrivals from the Lachlan survey, and Finlayson et al. (1998) presented a preliminary interpretation of these data for the Eastern Lachlan region around Orange.

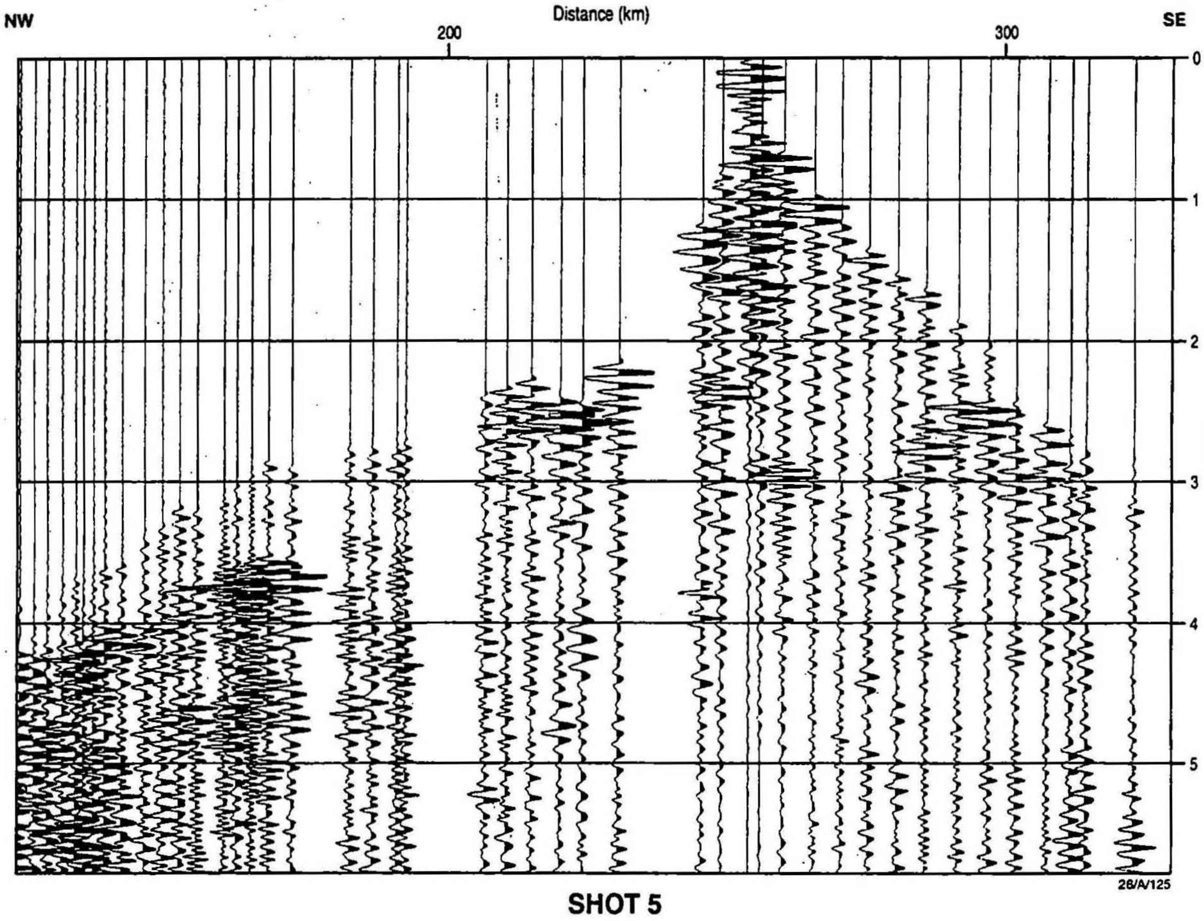


Figure 4. An example of the Pg1 arrivals from shot 5 of the Broken Hill survey detonated east of Menindee. These Pg1 arrivals show a significant delay time, indicating the presence of near-surface low-velocity rocks. The striking asymmetry of the Pg1 arrivals indicates rapidly changing geometry of this low-velocity zone which corresponds to the Menindee Trough.

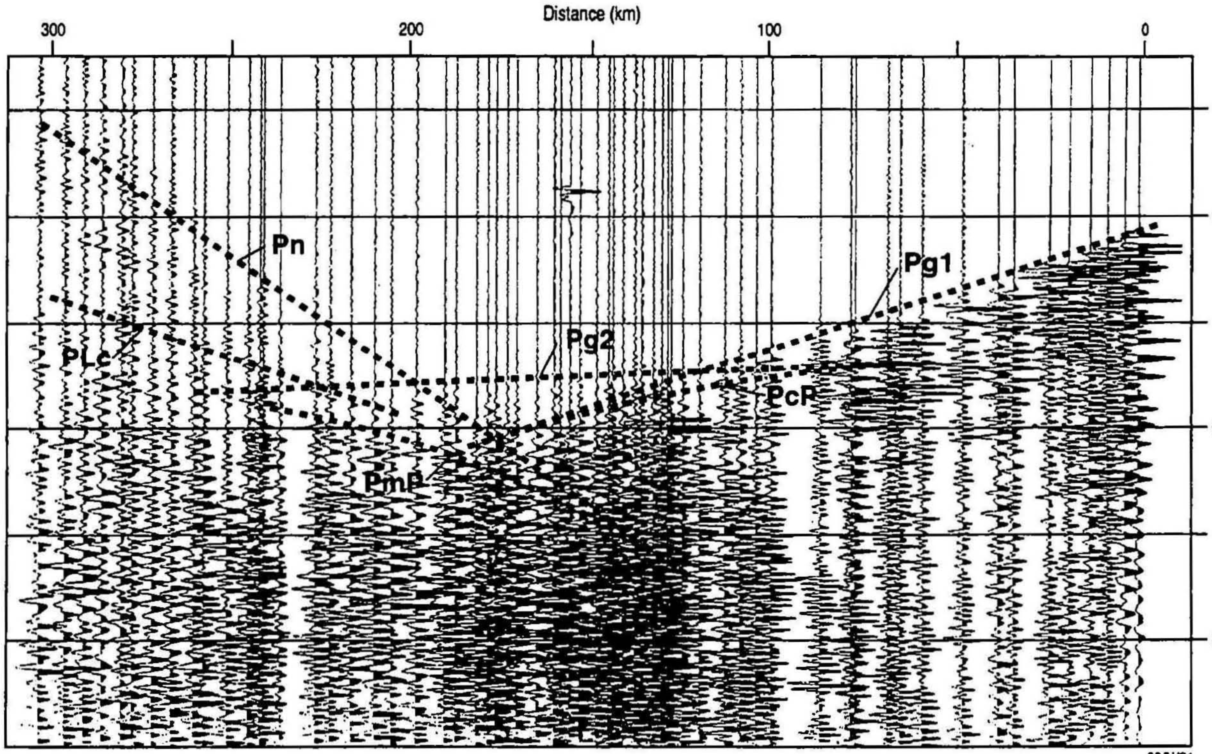


Figure 5. Wide-angle seismic record section (reduced travel time) from Shot 6 at the northern end of the East Lachlan profile and some of the P-wave seismic phases identified and interpreted.

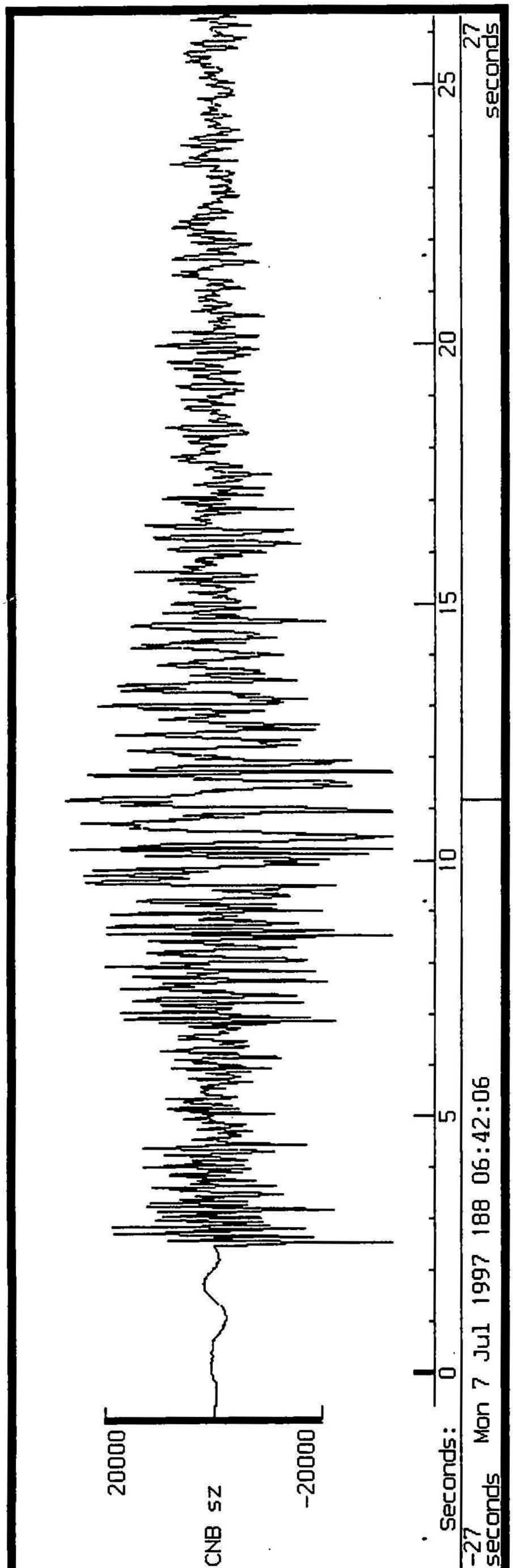
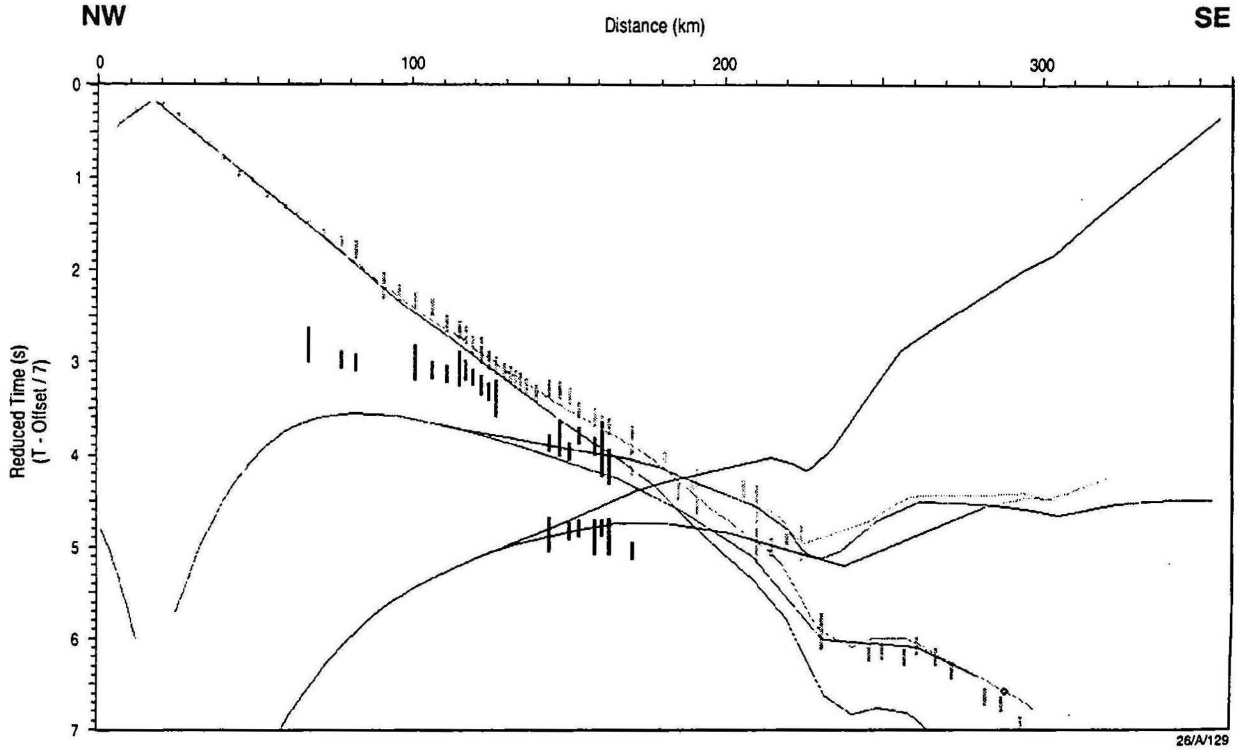


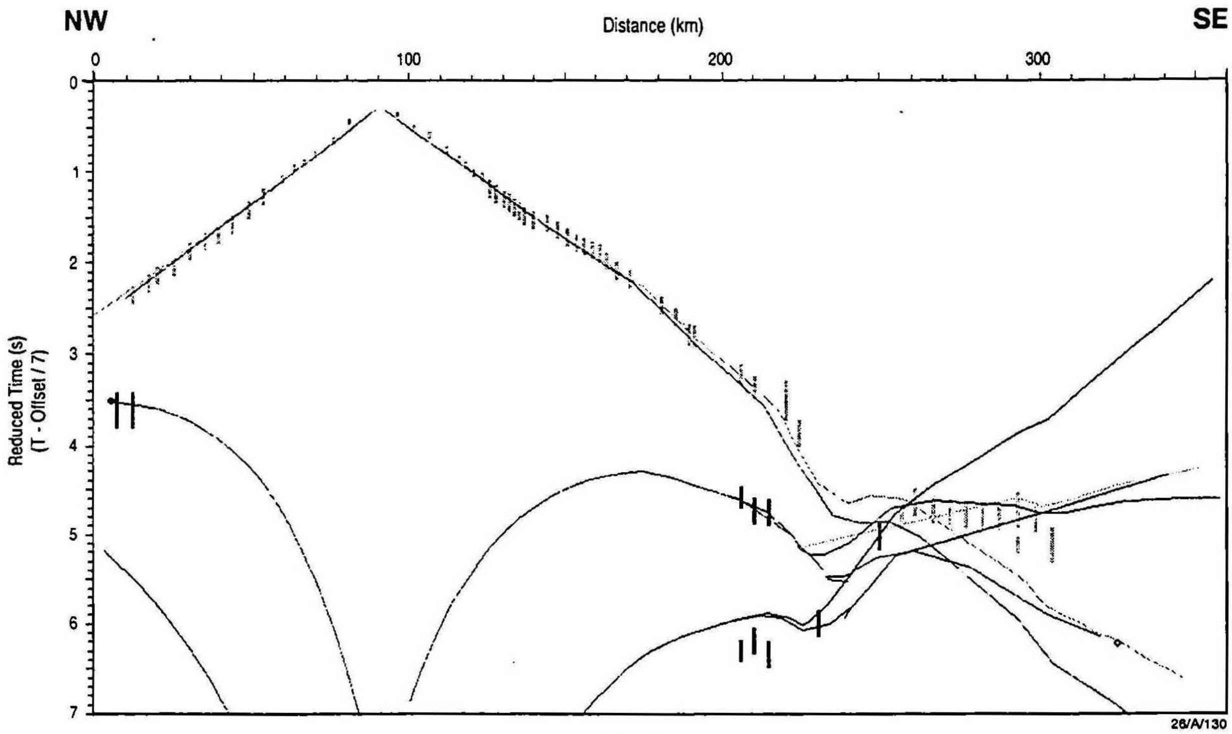
Figure 6. Record of Shot 1 from the East Lachlan Survey recorded at the Canberra Observatory.

The shots detonated during the East Lachlan survey were recorded on the permanent southeast Australian seismic network as part of its regular earthquake monitoring. Figure 6 shows the P and S arrivals from Shot 1 recorded on the Canberra seismic station. Because these shots could be used to improve the earthquake location programs, the absolute time of these shots was determined by calibrating the master clock to Universal Time (UT). Master Clock #10 was measured to be 494 ms slow relative to UT. The absolute time of the shots in the East Lachlan survey could be determined to an estimated accuracy of ±50 ms, and these times are tabled in Appendix 2. Figure 6 shows a relatively prominent S-wave arrival around 4 s after the P arrival. In the case of the Broken Hill survey, the data show no clear evidence for S-wave arrivals.



SHOT 1

Figure 7. Reduced travel time plot of arrivals from Shot 1 along the Broken Hill Profile.



SHOT 2

Figure 8. Reduced travel time plot of arrivals from Shot 2 along the Broken Hill Profile.

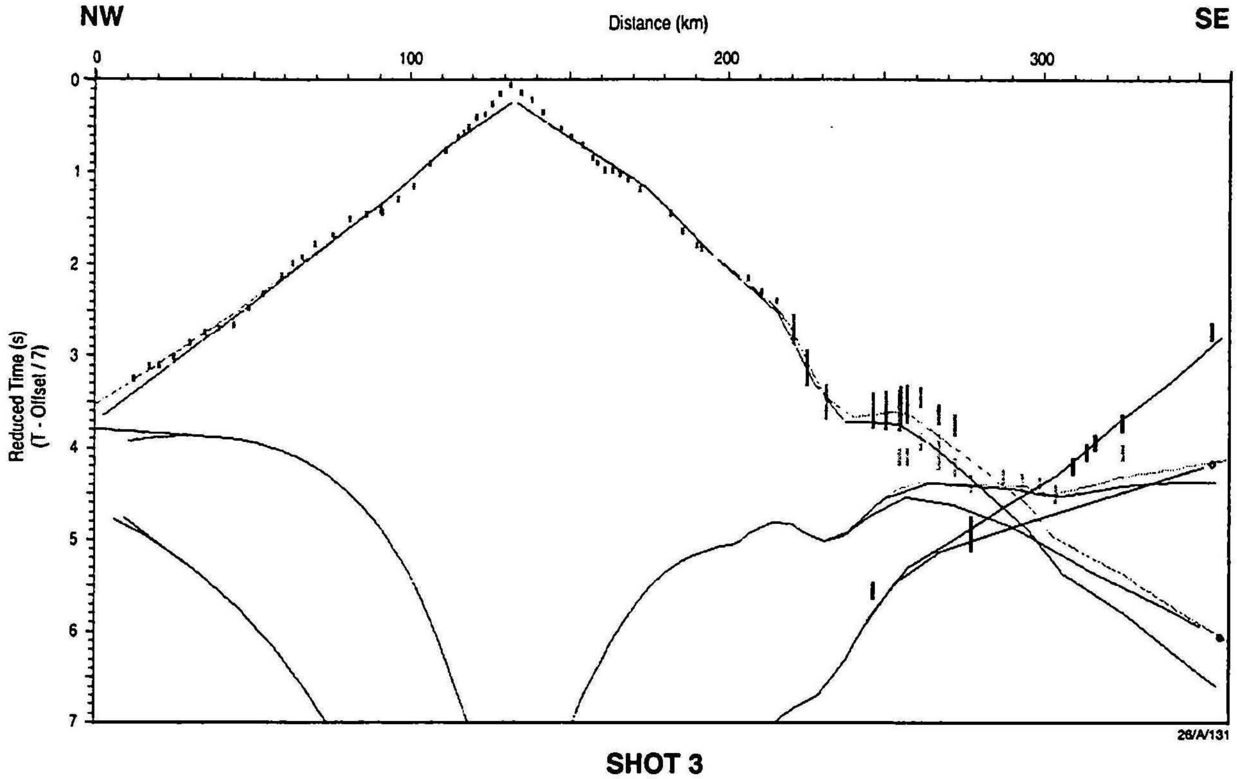


Figure 9. Reduced travel time plot of arrivals from Shot 3 along the Broken Hill Profile.

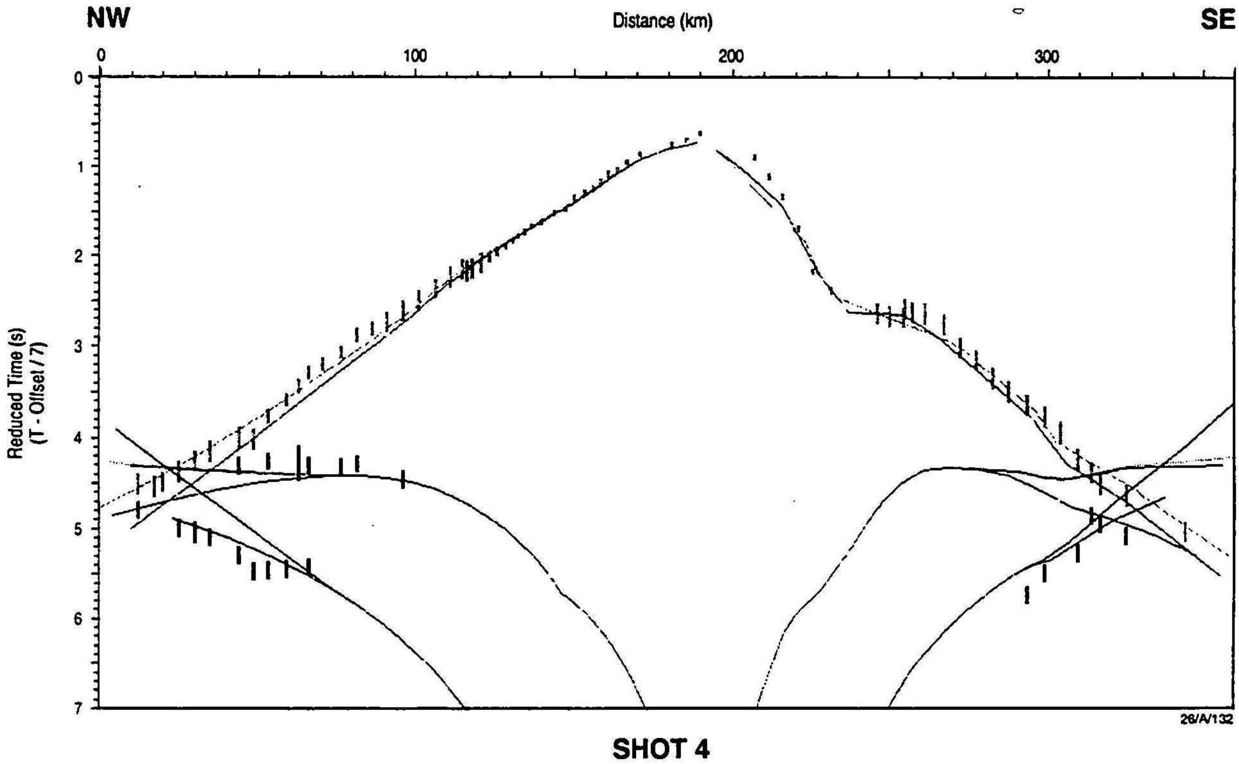
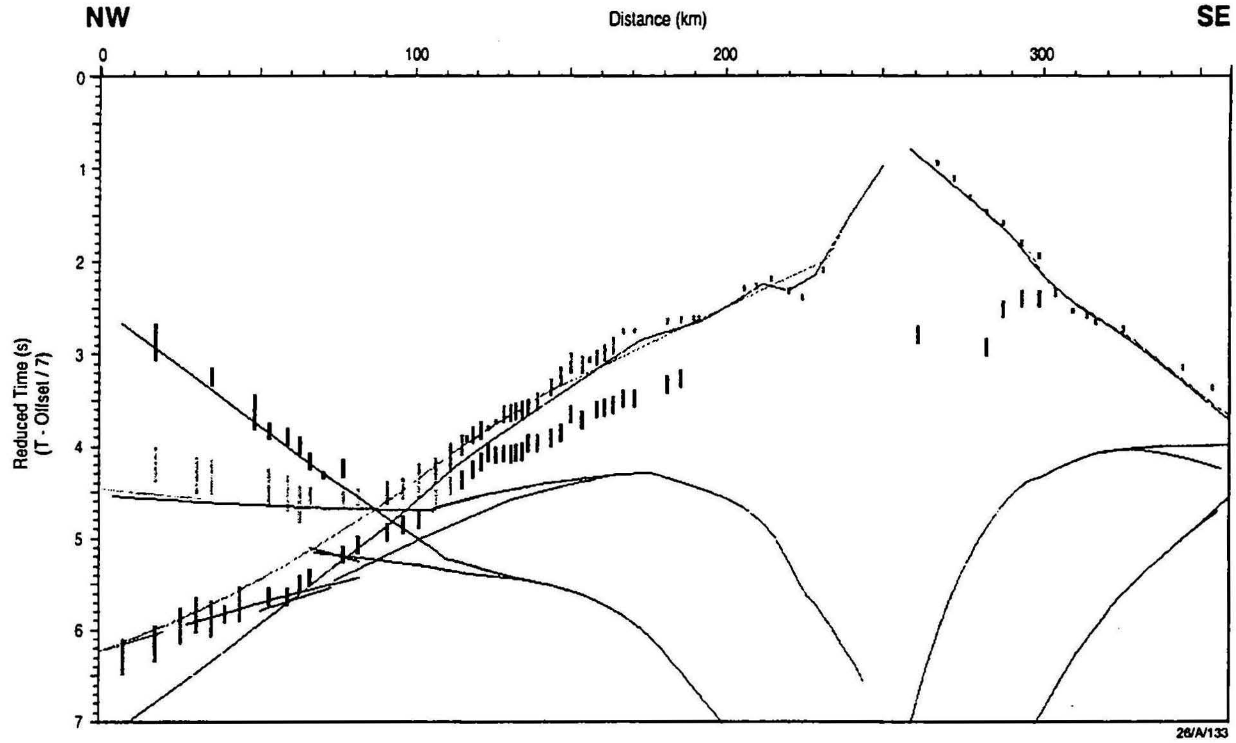
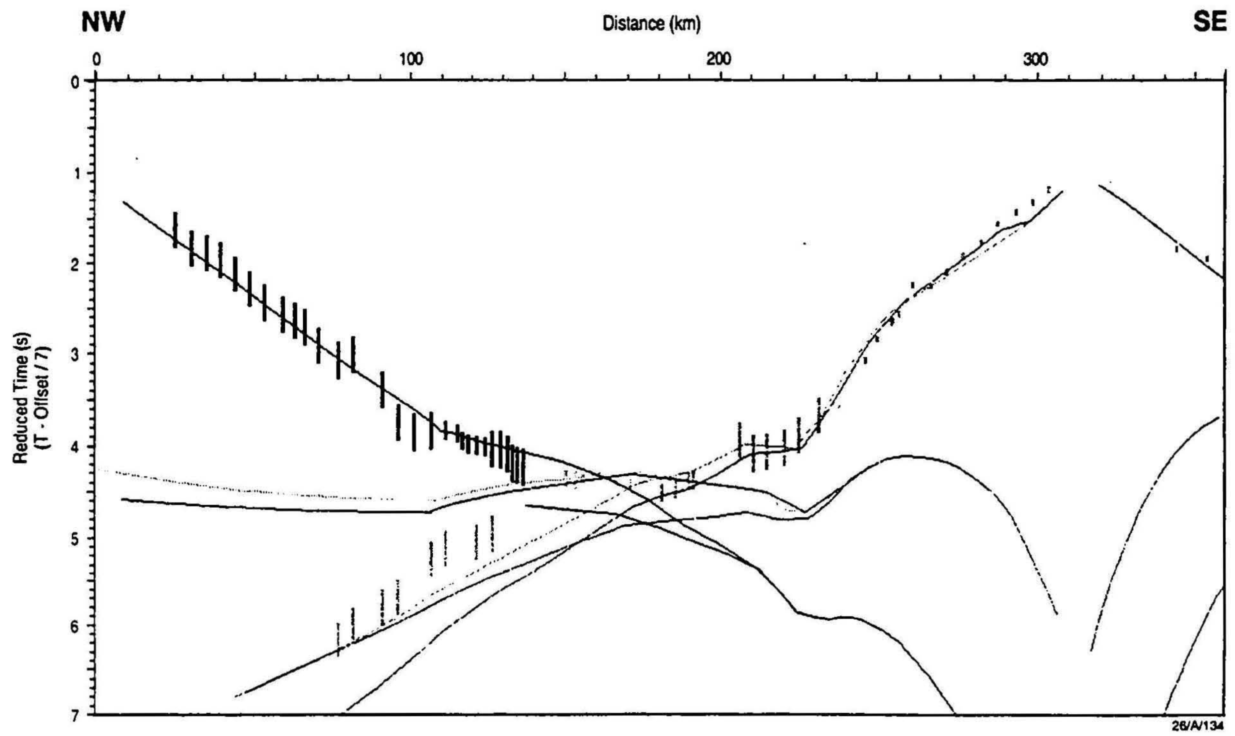


Figure 10. Reduced travel time plot of arrivals from Shot 4 along the Broken Hill Profile.



SHOT 5

Figure 11. Reduced travel time plot of arrivals from Shot 5 along the Broken Hill Profile.



SHOT 6

Figure 12. Reduced travel time plot of arrivals from Shot 6 along the Broken Hill Profile.

SHOT 1(NORTH), GUNDAROO: TRAVEL-TIME PLOT AND VELOCITY-DEPTH PROFILE

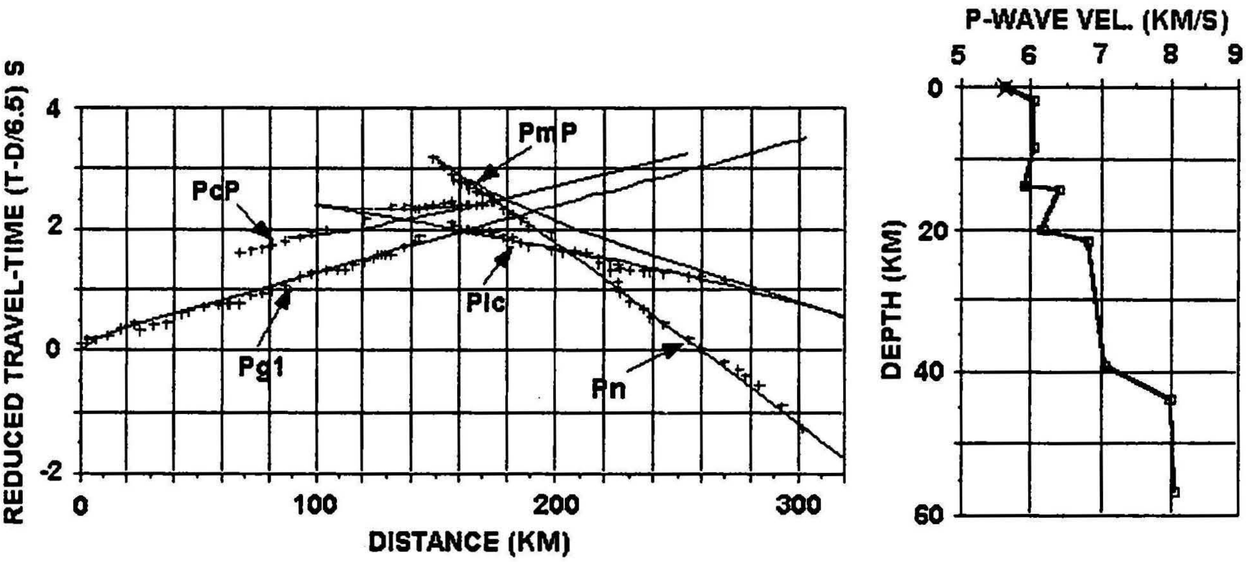


Figure 13. Reduced travel time plot of arrivals from Shot 1 to the north along the East Lachlan Profile, and a one-dimensional wavespeed model for these arrival times.

SHOT 2(NORTH), RUGBY: TRAVEL-TIME PLOT AND VELOCITY-DEPTH PROFILE

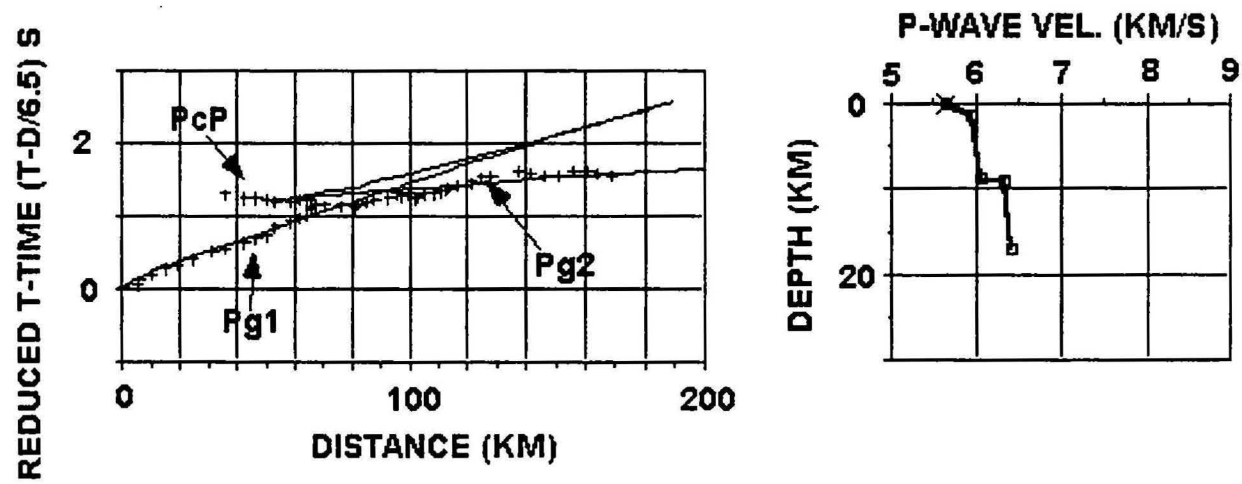


Figure 14. Reduced travel time plot of arrivals from Shot 2 to the north along the East Lachlan Profile, and a one-dimensional wavespeed model for these arrival times.

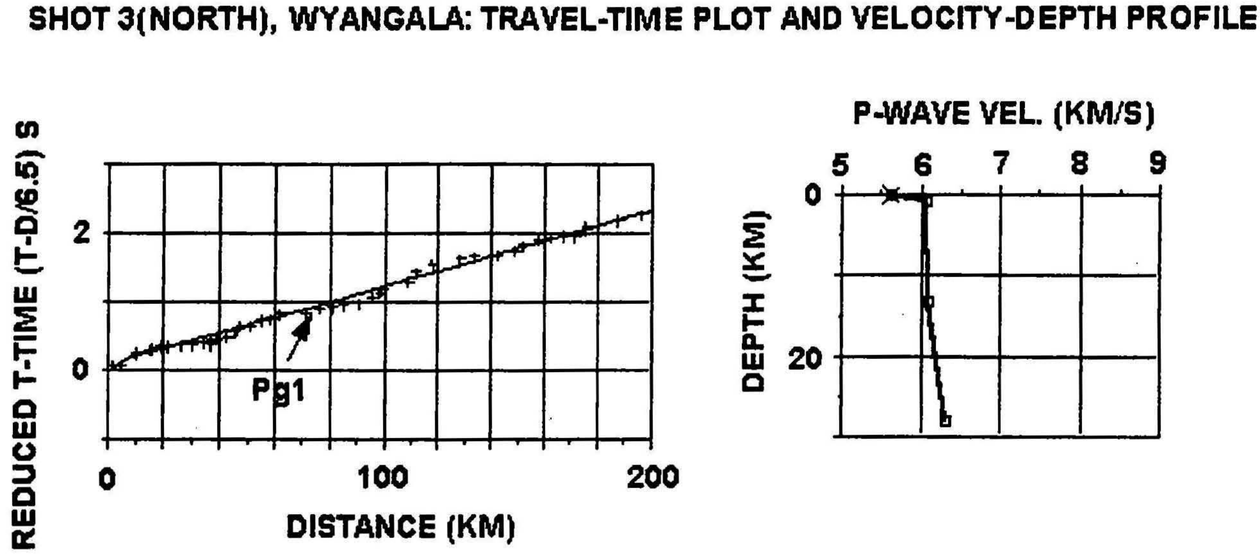


Figure 15. Reduced travel time plot of arrivals from Shot 3 to the north along the East Lachlan Profile, and a one-dimensional wavespeed model for these arrival times.

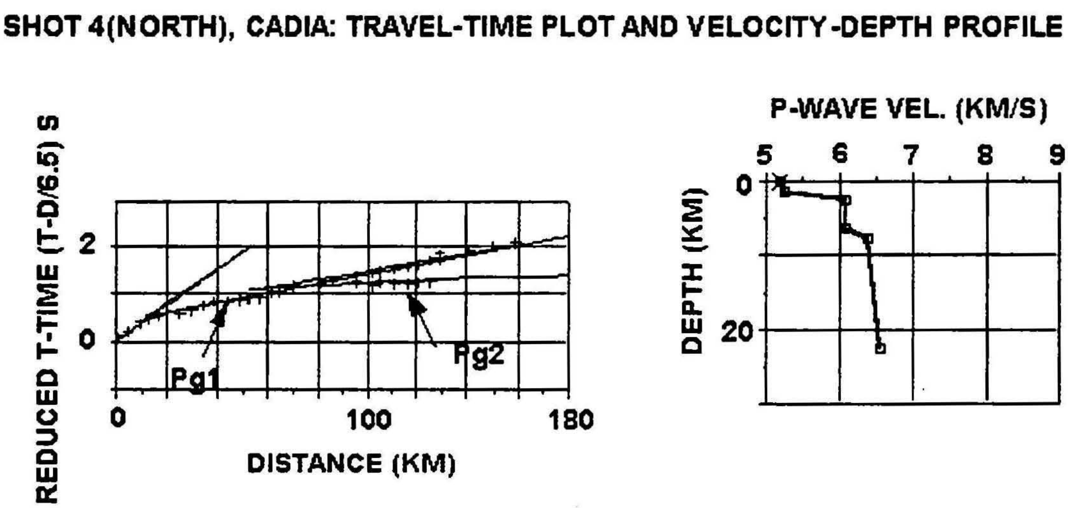


Figure 16. Reduced travel time plot of arrivals from Shot 4 to the north along the East Lachlan Profile, and a one-dimensional wavespeed model for these arrival times.

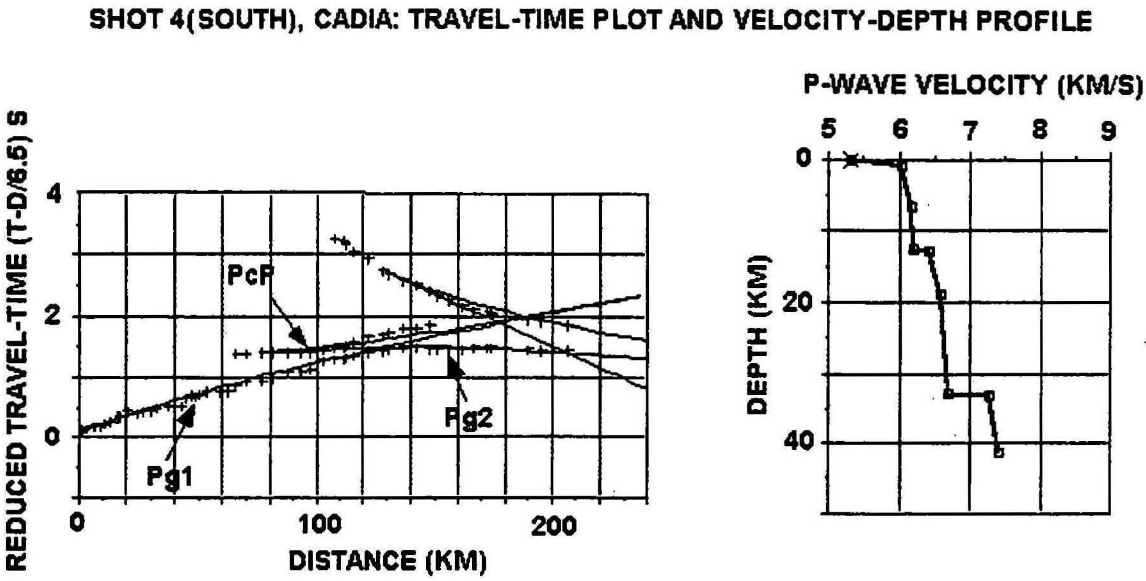


Figure 17. Reduced travel time plot of arrivals from Shot 4 to the south along the East Lachlan Profile, and a one-dimensional wavespeed model for these arrival times.

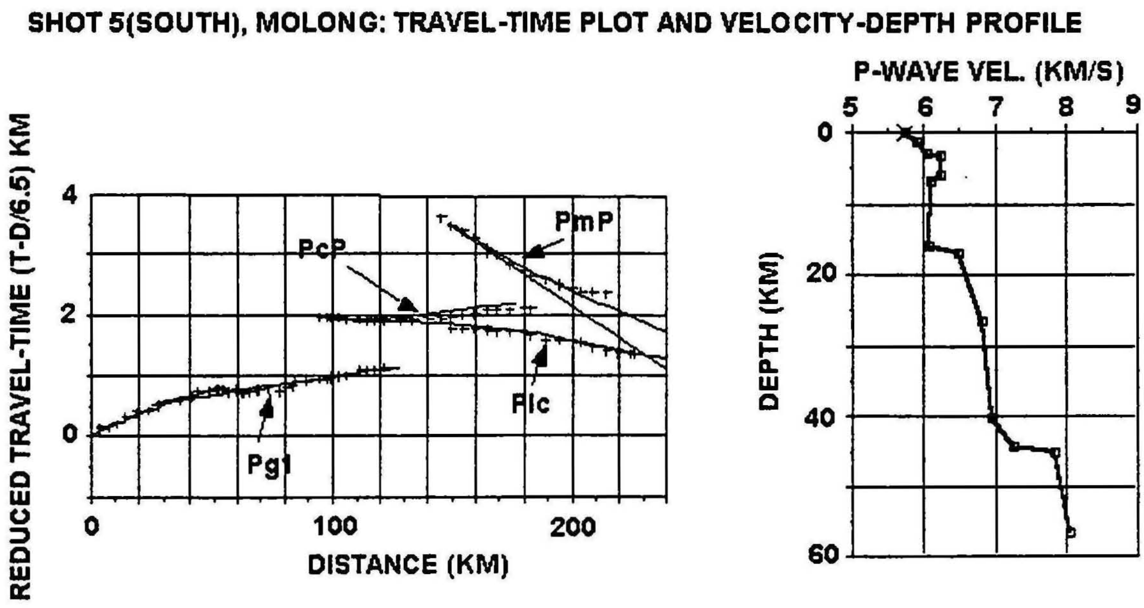


Figure 18. Reduced travel time plot of arrivals from Shot 5 to the south along the East Lachlan Profile, and a one-dimensional wavespeed model for these arrival times.

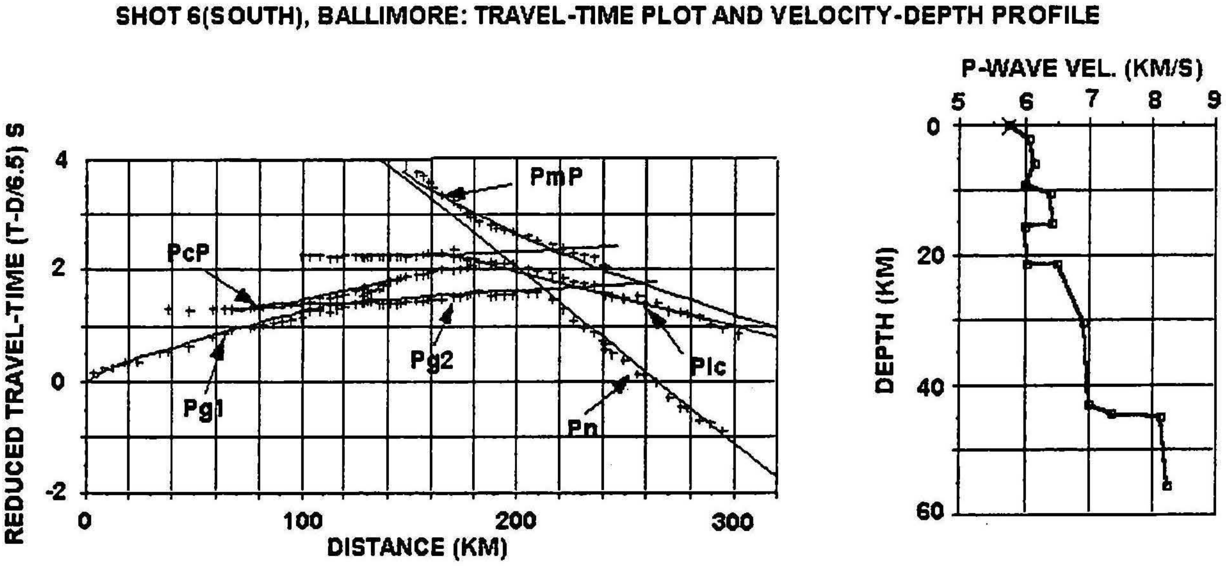


Figure 19. Reduced travel time plot of arrivals from Shot 6 to the south along the East Lachlan Profile, and a one-dimensional wavespeed model for these arrival times.

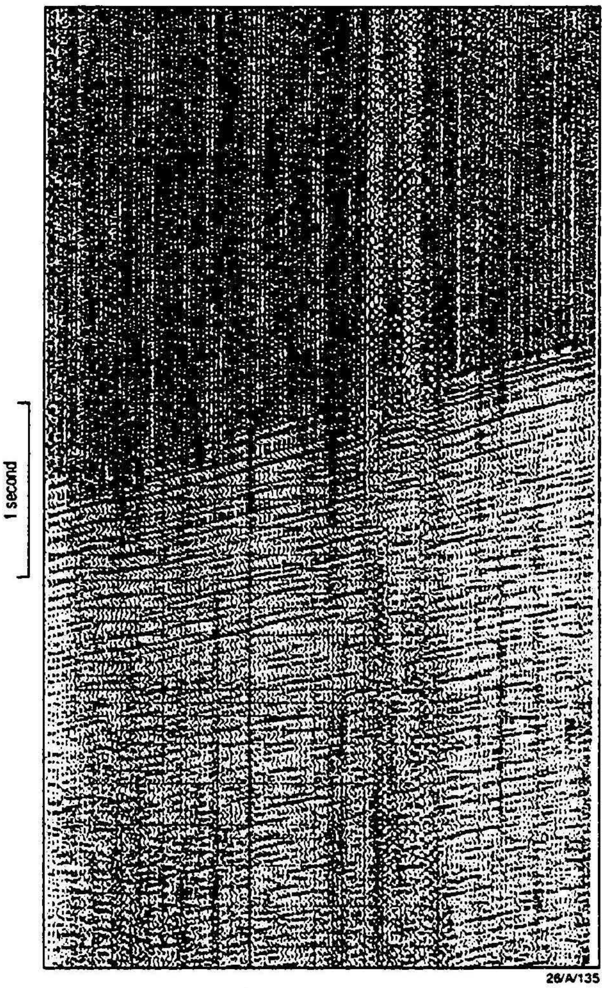


Figure 20. Recording of Shot 1 from the Broken Hill survey using the Sercel seismic acquisition system, and a station spacing of 60 m.

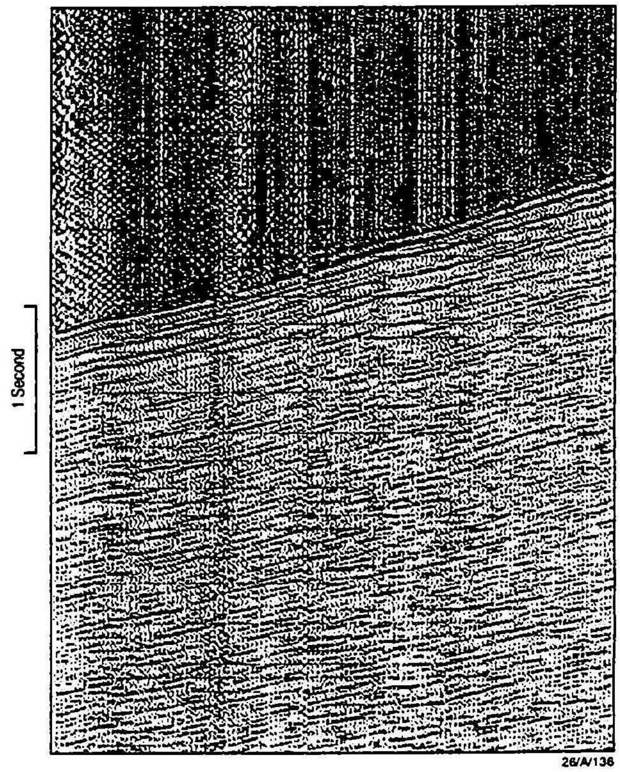


Figure 21. Recording of Shot 3 from Broken Hill using the Sercel seismic acquisition system, and a station spacing of 60 m.

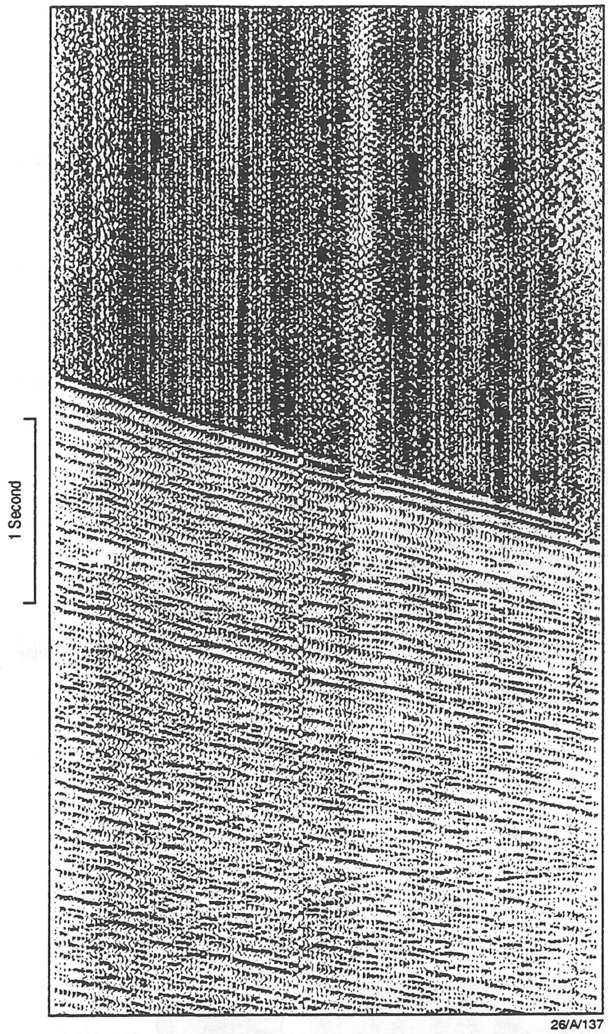


Figure 22. Recording of Shot 5 from the Broken Hill survey using the Sercel seismic acquisition system, and a station spacing of 60 m.

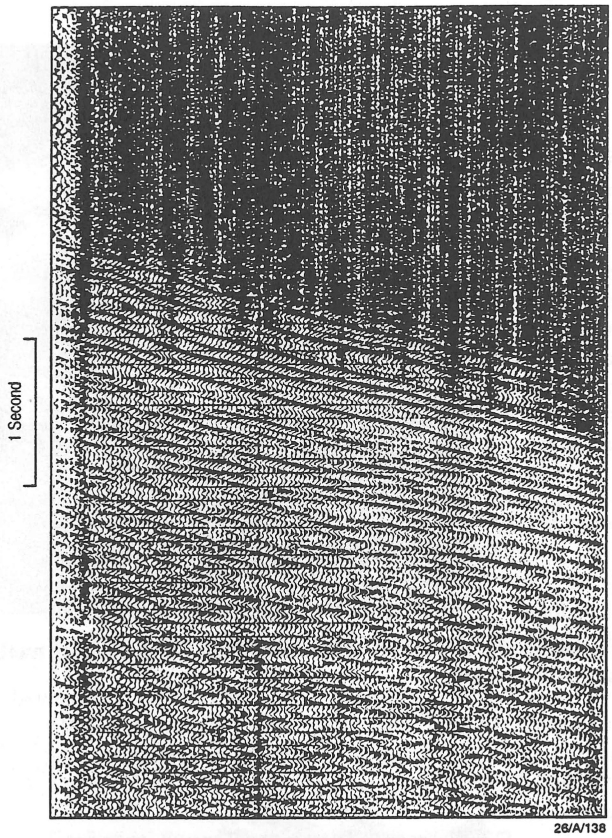


Figure 23. Recording of Shot 6 from the Broken Hill survey using the Sercel seismic acquisition system, and a station spacing of 60 m.

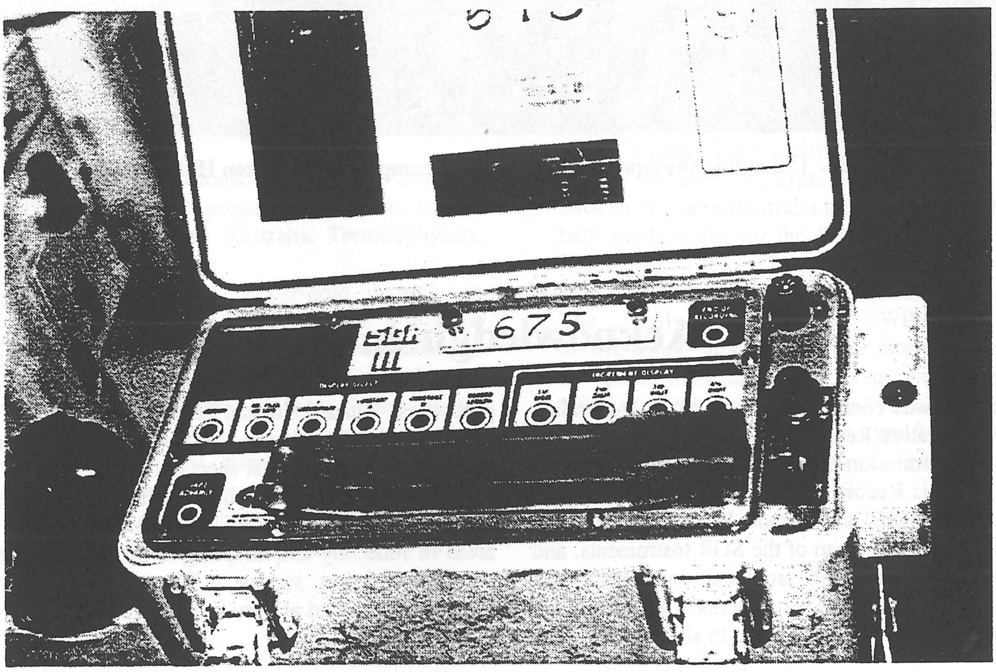


Figure 24. Detail of the SGR instrument, showing the control panel and tape.

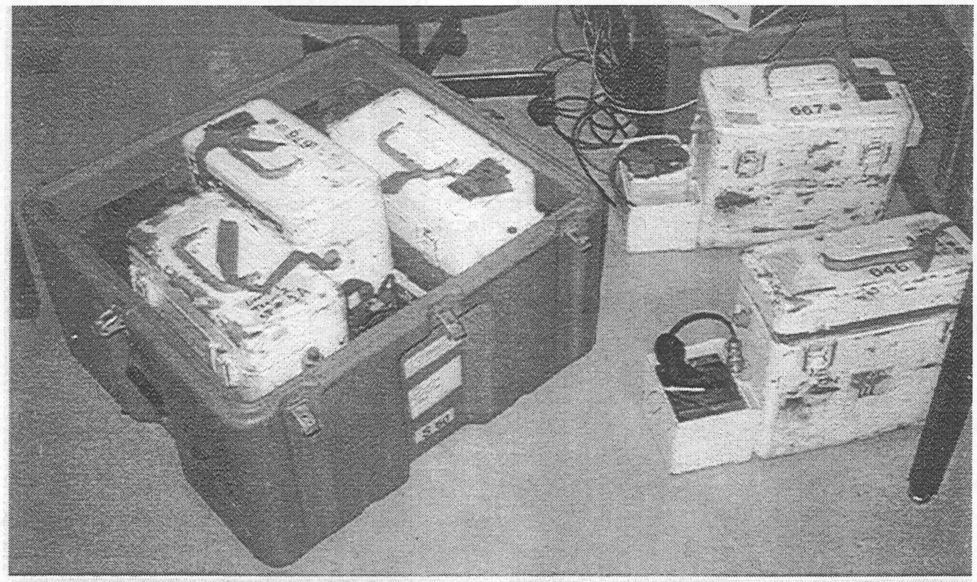


Figure 25. Several SGR instruments and the packaging method, with three SGRs and their batteries arranged in a strong plastic container

Figure 26. Unloading the equipment at the field camp for the Broken Hill survey.

Acknowledgments

Work reported here was conducted as part of the Australian Geodynamics Cooperative Research Centre, and this record is published with the permission of the Director, AGCRC.

The authors of this Record wish to thank Walter Mooney and Tom Burdette (USGS) and Simon Klemperer (Stanford University and IRIS) for the loan of the SGR instruments, and Brian Laird who provided the technical and operational expertise in the use of the SGR instruments. We also thank the property owners who willingly agreed to shot sites on their properties. Russell Korsch, Lesley Wyborn, Dick Glen, Chris Mawer, and John Walshe are thanked for defining geological targets for this program at short notice.

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Appendix 1. Schedule of operations

Broken Hill Block

Shot hole drilling commences	8 June
Brian Laird arrived in Canberra	11 June
Unpack; test SGRs in cold: surface & bury SGR	16 June
Program SGRs	17 June
Deployment SGRs	18 & 19 June
Shots recorded	20 June
Recovery SGRs	21 & 22 June
Drilling crew mobilise to Lachlan	23 June
Pack SGRs	23 June
Recording crew mobilise to Parkes area	24 to 26 June

Eastern Lachlan Orogen

Shot hole drilling commences	25 June
Charge SGR batteries	1 & 2 July
Deployment SGRs	3 & 4 July
Shots recorded	7 July
Recovery SGRs	8 & 9 July
Pack SGRs	10 July
SGRs to Circle for shipment to Canada	11 July
Brian Laird departed Canberra	12 July
Data tapes shipped to USGS	14 July

Figures 24 to 26 show photographs of the SGR equipment.

Appendix 2. Table of Shot Location & Times

Broken Hill Shots (Friday 20 June 1997)

Shots		Latitude		Longitude		Elev (m)	Time	Shot Size
	Location	Deg. S	Min.	Deg. E	Min.		EST	(tonnes)
Shot 1	Benagerie	31	24.362	140	24.527	60	14:22	3
Shot 2	Mundi Mundi	31	44.485	141	4.851	150	11:22	1
Shot 3	Nine Mile	31	52.756	141	30.017	250	9:22	1.06
Shot 4	Kaars	32	10.543	142	1.077	110	8:22	0.92
Shot 5	Largoona	32	27.677	142	35.945	75	10:22	1.07
Shot 6	Gum Lake	32	41.069	143	10.068	80	13:22	2.79

Eastern Lachlan Shots (Monday 7 July 1997)

Shots		Latitude		Long		Elev	Time	Shot Size
	Location	Lat Deg. S	min.	Long. Deg E	min.	(m)	EST	(tonnes)
Shot 1	Booth Xing	34	58.750	149	14.118	590	16:42	3.155
Shot 2	Rugby	34	26.461	149	0.633	570	13:42	1.000
Shot 3	Roseberg	33	50.867	149	0.624	700	11:42	0.700
Shot 4	4 Mile	33	25.809	148	57.153	800	13:22	1.000
Shot 5	Three Rivers	32	57.493	148	55.703	570	11:22	0.900
Shot 5a	Three Rivers	32	57.493	148	55.703	570	11:52	0.110
Shot 6	Glenroy	32	16.158	148	59.489	400	9:22	3.000

Absolute times of the Lachlan shots Monday 7 July 1997 (EST)

Estimate error (± 50 ms).

	EST	UT
Shot 1	16:42 5.00 s	06:42 5.00 s
Shot 2	13:42 4.19 s	03:42 4.19 s
Shot 3	11:42 5.15 s	01:42 5.15 s
Shot 4	13:22 3.40 s	03:22 3.40 s
Shot 5	11:22 3.35 s	01:22 3.35 s
Shot 6	09:22 3.57 s	23:22 3.57 s

Appendix 3. Table of SGR Locations

SGR Recorder Informattion - Broken Hill Profile							
Station	SGR	Lat	min	Long	min	GPS Elev (m)	Map Est. Elev (m)
1	506	31	20.058	140	15.365	85	60
2	544	31	21.212	140	19.253	75	60
3	545	31	22.307	140	22.205		60
4	548	31	24.206	140	23.745		60
5	555	31	24.665	140	26.528	121	70
6	564	31	26.543	140	28.877	3	77
7	573	31	27.563	140	31.93	60	77
8	599	31	28.712	140	34.527	70	80
9	614	31	29.43	140	37.134	37	80
10	615	31	29.458	140	40.536	97	80
11	616	31	32.017	140	42.284	52	85
12	617	31	33.144	140	44.95	128	90
13	618	31	35.232	140	47.846	87	90
14	619	31	37.924	140	48.922	100	100
15	620	31	39.916	140	50.019	136	112
16	621	31	42.02	140	51.76	85	115
17	622	31	43.711	140	55.085	96	120
18	623	31	44.13	140	58.364	122	125
19	624	31	44.367	141	1.644	134	137
20	625	31	44.244	141	4.91	141	150
21	628	31	45.26	141	8.105	191	165
22	629	31	46.123	141	11.167	156	190
23	630	31	47.691	141	14.017	287	320
24	631	31	47.591	141	17.65	291	360
25	633	31	47.866	141	20.264	281	360
26	634	31	47.74	141	21.609	355	350
27	635	31	47.428	141	23.305	320	340
28	636	31	47.99	141	24.92	189	300
29	637	31	48.978	141	26.157	317	290
30	638	31	49.764	141	27.326	237	270
31	639	31	50.473	141	28.845	267	260
32	640	31	52.033	141	29.479	249	250
33	641	31	53.745	141	30.707	253	250
34	644	31	55.359	141	31.043	304	260
35	645	31	56.958	141	32.284	286	260
36	646	31	58.762	141	32.194	289	No power
37	647	31	59.897	141	33.412	338	300
38	649	32	1.157	141	35	326	300
39	651	32	2.77	141	36.27	262	240
40	653	32	3.678	141	38.039	181	200
41	654	32	3.923	141	39.592	196	195
42	655	32	4.649	141	41.008	160	185
43	656	32	5.187	141	42.33	180	180
44	657	32	5.739	141	43.88	204	195
45	659	32	6.449	141	45.638	161	165
46	660	32	7.034	141	48.306	172	150
47	661	32	7.947	141	51.467	135	130
48	662	32	9.154	141	54.534	117	125
49	663	32	9.296	141	57.483	93	115
50	664	32	10.216	142	0.117	94	110
51	No SGR						
52	668	32	11.765	142	7.21	142	110

53	669	32	12.403	142	10.557	38	100	
54	666	32	12.784	142	13.396	67	90	
55	671	32	14.218	142	15.818	26	75	
56	672	32	15.879	142	18.631	87	70	
57	673	32	16.552	142	21.467	84	70	
58	674	32	19.38	142	24.253	39	75	
59	675	32	20.775	142	26.952	50	70	
60	No SGR							
61	677	32	25.887	142	30.98	69	70	
62	678	32	27.31	142	32.898	191	70	
63	681	32	28.563	142	37.034	133	70	
64	682	32	29.486	142	39.541	12	70	
65	683	32	30.666	142	42.876	143	70	
66	684	32	31.685	142	45.885	198	70	
67	685	32	32.683	142	48.915	129	70	
68	686	32	33.766	142	52.015	114	70	
69	687	32	34.843	142	55.009	125	70	
70	689	32	36.052	142	58.433	130	70	
71	690	32	37.105	143	1.712	189	70	
72	691	32	38.14	143	4.754	54	70	
73	692	32	39.538	143	7.929	72	70	
74	693	32	41.491	143	11.797	85	75	
75	696	32	43.539	143	16.625	117	75	
76	697	32	46.063	143	22.23	91	75	
77	698	32	47.624	143	27.929	128	85	
78	699	32	50.534	143	33.423	114	95	
Shot Monitor SGR		Lat		Long		GPS Elev	Map Elev	
S1	549	31	24.286	140	24.544		60	
S1A	550	31	24.277	140	24.663		60	
S2	626	31	44.416	141	4.883	119	150	
S2A	627	31	44.387	141	4.997	185	150	
S3	642	31	52.704	141	30.093		250	
S4	665	32	10.468	142	1.119	79	110	
S5	679	32	27.513	142	35.928	155	75	
S5A	680	32	27.552	142	36.073	89	75	
S6	694	32	40.991	143	10.09	96	80	
S6A	695	32	41.036	143	10.221	112	80	
Shots		**Friday 20 June**				**Elev (m)**	**Time**	**Shot Size**
	Location	**Lat**		**Long**		**(estimate)**	**EST**	**(tonnes)**
Shot 1	Benagerie	31	24.362	140	24.527	60	14:22	3
Shot 2	Mundi Mun	31	44.485	141	4.851	150	11:22	1
Shot 3	Nine Mile	31	52.756	141	30.017	250	9:22	1.06
Shot 4	Kaars	32	10.543	142	1.077	110	8:22	0.92
Shot 5	Largoona	32	27.677	142	35.945	75	10:22	1.07
Shot 6	Gum Lake	32	41.069	143	10.068	80	13:22	2.79

Lachlan Refraction Program - AGCRC								
Station	**SGR**	**Lat**	**min**	**Long**	**min**	**GPS Elev**	**Map Est.**	
						Elev (m)	**Elev (m)**	
1	506	35	16.598	149	15.573	755	620	
2	544	35	10.309	149	15.283	546	640	
3	545	35	7.400	149	14.722	553	600	
4	548	35	0.815	149	15.862	588	580	
5	564	34	57.908	149	15.734	603	600	
6	573	34	54.956	149	14.506	614	640	
7	599	34	52.144	149	14.770	696	680	
8	614	34	49.425	149	14.585	631	640	
9	615	34	46.565	149	14.477	634	640	
10	616	34	45.103	149	12.079	619	570	
11	617	34	42.195	149	10.405	495	520	
12	618	34	39.295	149	10.173	494	520	
13	619	34	35.983	149	9.538	521	520	
14	620	34	34.560	149	7.248	515	520	
15	621	34	31.227	149	5.958	452	500	
16	622	34	28.140	149	3.920	557	560	
17	623	34	25.906	149	3.805	425	510	
18	624	34	23.510	149	2.138	628	600	
19	627	34	20.936	149	1.736	675	560	
20	628	34	18.314	149	1.804	557	480	
21	629	34	16.144	149	1.641	648	460	
22	630	34	13.018	149	2.313	534	420	
23	631	34	9.551	149	1.291	440	400	
24	633	34	7.073	149	0.197	524	400	
25	634	34	3.429	148	59.577	390	440	
26	635	34	1.105	148	58.922	394	600	
27	636	33	59.236	148	59.133	491	400	
28	637	33	57.616	148	59.269	551	500	
29	638	33	54.583	149	0.619	392	400	
30	639	33	52.890	148	59.774	539	500	
31	640	33	51.664	149	0.544	681	660	
32	643	33	49.931	149	0.929	775	760	
33	644	33	48.526	149	1.498	671	740	
34	no SGR							
35	645	33	45.461	149	1.296	676	720	
36	no SGR							
37	646	33	42.850	149	1.399	686	680	
38	647	33	41.997	149	1.042	782	680	
39	649	33	40.490	149	0.940	299	700	
40	651	33	38.989	149	0.769	585	700	
41	653	33	36.459	149	0.051	732	620	
42	654	33	34.705	149	1.055	635	660	
43	655	33	34.041	149	1.800	680	660	
44	656	33	32.442	149	1.207	691	660	
45	657	33	30.895	149	0.775	700	700	
46	659	33	30.703	148	58.858	709	700	
47	660	33	29.619	148	57.590	574	720	
48	661	33	27.871	148	57.007	746	760	
49	662	33	26.616	148	56.828	781	800	
50	664	33	25.285	148	57.515	812	810	
51	665	33	23.492	148	57.712	1010	1010	
52	666	33	20.903	148	58.921	1336	1330	

53	no SGR							
54	667	33	19.176	148	58.811	983	980	
55	688	33	17.132	148	59.354	860	920	
56	669	33	14.691	148	58.342	793	800	
57	670	33	12.342	148	57.030	721	740	
58	671	33	10.046	148	55.268	694	640	
59	672	33	7.407	148	54.513	548	600	
60	673	33	5.033	148	53.818	606	570	
61	674	33	2.491	148	52.228	531	520	
62	675	32	0.000	148	0.000	528	530	
63	678	32	57.958	148	53.405	528	540	
64	679	32	55.385	148	53.453	504	480	
65	680	32	52.483	148	54.070	543	520	
66	681	32	50.687	148	54.435	460	500	
67	682	32	47.550	148	54.995	447	450	
68	683	32	44.447	148	56.068	370	370	
69	684	32	41.762	148	56.852	367	430	
70	685	32	39.140	148	56.448	280	330	
71	686	32	36.470	148	55.933	248	300	
72	687	32	34.093	148	55.510	319	300	
73	689	32	30.393	148	56.087	270	300	
74	690	32	28.838	148	56.598	411	330	
75	691	32	25.990	148	57.150	330	390	
76	692	32	23.010	148	57.937	340	400	
77	693	32	20.465	148	58.025	450	400	
78	694	32	18.152	148	59.040	414	380	
79	695	32	16.153	148	59.472	404	420	
80	697	32	9.710	148	58.070	338	340	
81	698	32	4.658	148	56.687	400	340	
82	699	32	0.042	148	56.565	303	420	
Shot monitor SGRs								
1010	555	34	58.732	149	14.079	576	590	
1011	549	34	58.745	149	14.158	552	590	
1020	625	34	26.488	149	0.634	597	570	
1021	626	34	26.435	149	0.633	595	570	
1030	641	33	50.906	149	0.616	735	700	
1031	642	33	50.889	149	0.583	575	700	
1040	663	33	25.810	148	57.155	893	800	
1050	677	32	57.528	148	55.733	587	570	
1060	696	32	16.153	148	59.472	404	400	
Shots		**Monday 7 July**				**Estimated**	**Time**	**Shot Size**
	Location	**Lat deg.**	**minutes**	**Long. deg**	**minutes**	**Elev (m)**	**EST**	**(tonnes)**
Shot 1	Booth Xing	34	58.750	149	14.118	590	16:42	3.00
Shot 2	Rugby	34	26.461	149	0.633	570	13:42	1.00
Shot 3	Roseberg	33	50.867	149	0.624	700	11:42	0.70
Shot 4	4 Mile	33	25.809	148	57.153	800	13:22	1.00
Shot 5	Three Rive	32	57.493	148	55.703	570	11:22	0.89
Shot 5a	Three Rive	32	57.493	148	55.703	570	11:52	0.11
Shot 6	Glenroy	32	16.158	148	59.489	400	9:22	3.00

Appendix 4. SGR Instrument Performance

Broken Hill SGR recording status

SGR Station		Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6
1	Total failure	x	x	x	x	x	x
2		1	1	1	1	1	1
3		1	1	1	1	1	1
4	Total failure	x	x	x	x	x	x
5		1	1	1	1	1	1
6		1	1	1	1	1	1
7		1	1	1	1	1	1
8		1	1	1	1	1	1
9	Partial failure	x	1	1	1	1	1
10		1	1	1	1	1	1
11		1	1	1	1	1	1
12		1	1	1	1	1	1
13		1	1	1	1	1	1
14		1	1	1	1	1	1
15		1	1	1	1	1	1
16		1	1	1	1	1	1
17		1	1	1	1	1	1
18		1	1	1	1	1	1
19	Partial failure	1	1	x	x	x	x
20		1	1	1	1	1	1
21		1	1	1	1	1	1
22		1	1	1	1	1	1
23		1	1	1	1	1	1
24		1	1	1	1	1	1
25		1	1	1	1	1	1
26		1	1	1	1	1	1
27		1	1	1	1	1	1
28		1	1	1	1	1	1
29		1	1	1	1	1	1
30		1	1	1	1	1	1
31		1	1	1	1	1	1
32		1	1	1	1	1	1
33		1	1	1	1	1	1
34		1	1	1	1	1	1
35		1	1	1	1	1	1
36	Total failure	x	x	x	x	x	x
37		1	1	1	1	1	1
38		1	1	1	1	1	1
39		1	1	1	1	1	1
40		1	1	1	1	1	1
41		1	1	1	1	1	1
42		1	1	1	1	1	1
43		1	1	1	1	1	1
44		1	1	1	1	1	1
45		1	1	1	1	1	1
46		1	1	1	1	1	1
47	Total failure	x	x	x	x	x	x
48		1	1	1	1	1	1
49		1	1	1	1	1	1
50		1	1	1	1	1	1
51	No SGR	0	0	0	0	0	0

Broken Hill SGR recording status

SGR Station		Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6
52	Total failure	x	x	x	x	x	x
53		1	1	1	1	1	1
54		1	1	1	1	1	1
55		1	1	1	1	1	1
56		1	1	1	1	1	1
57		1	1	1	1	1	1
58		1	1	1	1	1	1
59	Total failure	x	x	x	x	x	x
60	No SGR	0	0	0	0	0	0
61		1	1	1	1	1	1
62		1	1	1	1	1	1
63		1	1	1	1	1	1
64		1	1	1	1	1	1
65		1	1	1	1	1	1
66		1	1	1	1	1	1
67		1	1	1	1	1	x
68		1	1	1	1	1	1
69		1	1	1	1	1	1
70		1	1	1	1	1	1
71		1	1	1	1	1	1
72		1	1	1	1	1	1
73		1	1	1	1	1	1
74		1	1	1	1	1	1
75	Partial failure	1	1	1	1	x	1
76	Total failure	x	x	x	x	x	x
77		1	1	1	1	1	1
78		1	1	1	1	1	1
1010	Shot 1 monitor	1	1	1	1	1	1
1020	Shot 2 monitor	1	1	1	1	1	1
1021	Shot 2 monitor	1	1	1	1	1	1
1030	Shot 3 monitor	1	1	1	1	1	1
1040	Shot 4 monitor	1	1	1	1	1	1
1050	Shot 5 monitor	1	1	1	1	1	1
1051	Shot 5 monitor	1	1	1	1	1	1
1060	Shot 6 monitor	1	1	1	1	1	1

Lachlan SGR recording status

SGR Station		Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 5a	Shot 6
1		1	1	1	1	1	1	1
2		1	1	1	1	1	1	1
3		1	1	1	1	1	1	1
4	Total failure	x	x	x	x	x	x	x
5	Partial failure	x	1	1	1	1	1	1
6		1	1	1	1	1	1	1
7		1	1	1	1	1	1	1
8		1	1	1	1	1	1	1
9		1	1	1	1	1	1	1
10		1	1	1	1	1	1	1
11		1	1	1	1	1	1	1
12		1	1	1	1	1	1	1
13		1	1	1	1	1	1	1
14		1	1	1	1	1	1	1
15		1	1	1	1	1	1	1
16		1	1	1	1	1	1	1
17		1	1	1	1	1	1	1
18		1	1	1	1	1	1	1
19		1	1	1	1	1	1	1
20		1	1	1	1	1	1	1
21		1	1	1	1	1	1	1
22		1	1	1	1	1	1	1
23		1	1	1	1	1	1	1
24		1	1	1	1	1	1	1
25		1	1	1	1	1	1	1
26		1	1	1	1	1	1	1
27		1	1	1	1	1	1	1
28		1	1	1	1	1	1	1
29		1	1	1	1	1	1	1
30		1	1	1	1	1	1	1
31		1	1	1	1	1	1	1
32		1	1	1	1	1	1	1
33		1	1	1	1	1	1	1
34	No SGR	0	0	0	0	0	0	0
35		1	1	1	1	1	1	1
36	No SGR	0	0	0	0	0	0	0
37		1	1	1	1	1	1	1
38		1	1	1	1	1	1	1
39		1	1	1	1	1	1	1
40		1	1	1	1	1	1	1
41		1	1	1	1	1	1	1
42		1	1	1	1	1	1	1
43		1	1	1	1	1	1	1
44		1	1	1	1	1	1	1
45		1	1	1	1	1	1	1
46		1	1	1	1	1	1	1
47		1	1	1	1	1	1	1
48		1	1	1	1	1	1	1
49		1	1	1	1	1	1	1
50		1	1	1	1	1	1	1
51		1	1	1	1	1	1	1

Lachlan SGR recording status

SGR Station		Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 5a	Shot 6
52		1	1	1	1	1	1	1
53	No SGR	0	0	0	0	0	0	0
54		1	1	1	1	1	1	1
55		1	1	1	1	1	1	1
56	Partial failure	1	x	x	x	x	x	x
57		1	1	1	1	1	1	1
58		1	1	1	1	1	1	1
59		1	1	1	1	1	1	1
60		1	1	1	1	1	1	1
61		1	1	1	1	1	1	1
62		1	1	1	1	1	1	1
63		1	1	1	1	1	1	1
64	Partial failure	x	x	x	1	x	1	1
65		1	1	1	1	1	1	1
66		1	1	1	1	1	1	1
67		1	1	1	1	1	1	1
68	Total failure	x	x	x	x	x	x	x
69		1	1	1	1	1	1	1
70	Partial failure	x	1	1	1	1	1	1
71	Partial failure	1	x	x	x	x	x	x
72		1	1	1	1	1	1	1
73	Partial failure	x	1	1	1	1	1	1
74		1	1	1	1	1	1	1
75		1	1	1	1	1	1	1
76		1	1	1	1	1	1	1
77		1	1	1	1	1	1	1
78		1	1	1	1	1	1	1
1001	Shot 1 monitor	1	1	1	1	1	1	1
1002	Shot 2 monitor	1	1	1	1	1	1	1
1004	Shot 4 monitor	1	1	1	1	1	1	1
1005	Shot 5 monitor	1	1	1	1	1	1	1
1006	Shot 6 monitor	1	1	1	1	1	1	1
1011	Shot 1 monitor	1	1	1	1	1	1	1
1021	Shot 2 monitor	1	1	1	1	1	1	1
1030	Shot 3 monitor	x	1	1	1	1	1	1
1031	Shot 4 monitor	x	1	1	1	1	1	1

Appendix 5. Wide-Angle Survey Data Archival

Seismic data transcription SGR Tape cartridges to SEGY format nine track tapes done in the US by Brian Laird
Data provided at 2 ms and 6 ms sampling rates.

Original USGS 6 ms 9-track tapes
87 traces per ensemble
1 aux trace
2 ms original sample rate - 6ms actual sample rate
16001 samples - which gives 96.006 seconds
data is floating point SEGY and each trace is 64244 bytes
Within the trace headers - Energy source, ffid and cdp are defined

The long block tapes have the original 2 ms sample rate, and therefore 48003 samples per trace - which exceeds the SEGY capacity of a signed 2-byte integer to define the number of samples per trace.

AGCRC Seismic Refraction Data Broken Hill - SEGY Long Block Tape # 97/9001
(2 ms sampling interval)

AGCRC Seismic Refraction Data Lachlan - SEGY Long Block Tape # 97/9002
(2 ms sampling interval)

AGCRC Seismic Refraction Data Broken Hill - SEGY Decimated x3 Tape # 97/9003
(6 ms sampling interval)

AGCRC Seismic Refraction Data Lachlan - SEGY Decimated x3 Tape # 97/9004
(6 ms sampling interval)

Archival of reduced travel-time data on 3480 and exabyte tapes
Data lodged with the Australian Archives at Mitchell, Canberra, and stored with the AGSO land seismic tape holdings.
Archive tapes in Disco format:
- 3480
- Exabyte

Appendix 6. Recording Equipment

Ninety Seismic Group Recorders (SGR) borrowed from PASSCAL were used to record the seismic data for these two surveys. These recorders are GUS SGR-II units modified to allow an internal clock to control the recording windows. Each system used a L22 2 Hz seismometer buried about 1 m away from the SGR recorder. Seismic signals to each recorder are amplified and recorded onto digital tape cartridge. These tape cartridges were not read in Australia, but were shipped to the USGS, Menlo Park, US, for data transcription and clock correction. Further information about the PASSCAL program and the SGR recorders can be obtained from:

http://www.iris.washington.edu

http://www.iris.edu/passcal/passcal.htm

SGR Specifications

- Single channel recorder
- Digital recording 12 bit gain ranging, 6 dB steps, 0-90 dB @ 2 ms sampling
- Internal clock pre-programmed prior to deployment
- Max. number of pre-programmed windows 99
- Max. recording time for each window 99 s
- Total tape recording time 24 min. - quarter inch re-useable tape cartridges
- Sensor 2 Hz L22 Mark Products vertical seismometer
- Weight SGR with battery ~15 kg

Recorder timing

Relative timing is of paramount importance for refraction seismic recording. The system developed by the PASSCAL organisation uses a master clock and two synchronised slave-master clocks, all with thermostatically controlled oscillators. The internal SGR clocks were synchronised to one of the master clocks before deployment, and the drift of the SGR clocks recorded onto tape after instrument recovery at the conclusion of the recording period. The master clock is assumed not to have drifted. The drift of the slave-master clocks was recorded as less than 2 ms over both surveys. The drift of the SGR clocks is assumed to be linear over the recording period, and this assumption provides the greatest uncertainity and error. Normal USGS practice is to deploy the instruments during the day, detonate the shots that night and recover the instruments the following day. Due to logistic constraints, this two day operation was not possible, and during the Lachlan survey there was a 6 day interval between deployment and recovery of the SGR instruments.

Appendix 7. SERCEL Recording

Four shots (Shots 1, 3, 5, 6) from the Broken Hill Profile were successfully recorded on the Sercel SN368, with the array of 120 channels and a group interval of 60 m. The recording of Shot 4 started late, and therefore there are no first breaks, and Shot 2 was not recorded because of line problems. There is no timing information - this can only be obtained by calibrating with adjacent SGR records.

The location of the stations of this Sercel spread is detailed in the Table below.

Figures 19 to 22 show the seismic data recorded from these refraction shots by the Sercel array. Note that the timing is not relative to the shot time for these records.

There is no evidence of S-wave arrivals on records from shots 3 & 5. (The S-wave arrivals should be about 7 s after P-arrivals at 60 km offset)

The detailed recording of the seismic waveform achieved by the 60 m station interval provides information and insight into the seismic propagation not revealed by the more coarsely sampled (2.5 km) recording of the SGR Array. For example, the back-dipping event about 3 s behind the first arrivals on the record from Shot 5 (Fig. 21) at 13 s is not evident on the SGR record section of this shot.

Sercel Array Position

Broken Hill Refraction Shots

Channel	Latitude S			Longitude E				
Number	degrees	minutes	seconds	degrees	minutes	seconds	East	North
1	32	09	52.06	141	58	55.52	592600	6440900
18	32	10	06.37	141	59	33.86	593600	6440450
30	32	10	14.28	142	00	00.67	594300	6440200
84	32	10	45.86	142	01	51.75	597200	6439200
120	32	11	04.69	142	03	12.16	599300	6438600