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SEISMIC INVESTIGATIONS OF CRUSTAL STRUCTURE IN SOUTHEASTERN AUSTRALIA NOVEMBER 1976 - MARCH 1977 (MADAR SURVEY): OPERATIONAL REPORT

by

D.M. FINLAYSON

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CONTENTS

TABLES

FIGURES

SUMMARY

During November and December 1976 and February and March 1977, BMR made seismic recordings, at 49 sites between South Marulan in NSW and Dartmouth in northern Victoria, of quarrying shots fired at 7 locations. The objective of the survey was to determine crustal structure under the eastern part of the Lachlan Fold Belt in the region of the highest mountain ranges in Australia. Forty of the recording sites were on the line between Marulan and Dartmouth, and 9 sites were on a cross traverse near Canberra. Routine quarrying shots used in the survey were from Singleton (3 sites), Marulan South, Queanbeyan (2 sites), and Dartmouth. Interpretation of the data will be reported elsewhere.

INTRODUCTION

In March, April, and May 1976, BMR made seismic recordings of quarry blasts in central NSW, along a line of sites between Bass Point (near Wollongong) and Ardlethan (Collins, 1976). These recordings were made as the initial part of an investigation of crustal structure under the Lachlan Fold Belt. The survey reported in this Record is the second part of the seismic investigation, and concerns work conducted in the period November 1976 to February 1977.

Quarry and mining blasts being fired routinely in central and southern NSW, and in northern Victoria, are used as seismic sources. The principal sources for the survey reported in this Record were at the Marulan South limestone quarry and at the Dartmouth dam site on the Mitta Mitta River in Victoria (MARDAR Survey). The distance between these sources is about 300 km, sufficient to record seismic waves traversing the upper mantle from both sources. Additional sources were near Queanbeyan and near Singleton. The locations of shots and stations used in the survey conducted in early 1976 (SAMBA Survey) and in the present survey (MARDAR Survey) are shown in Figure 1.

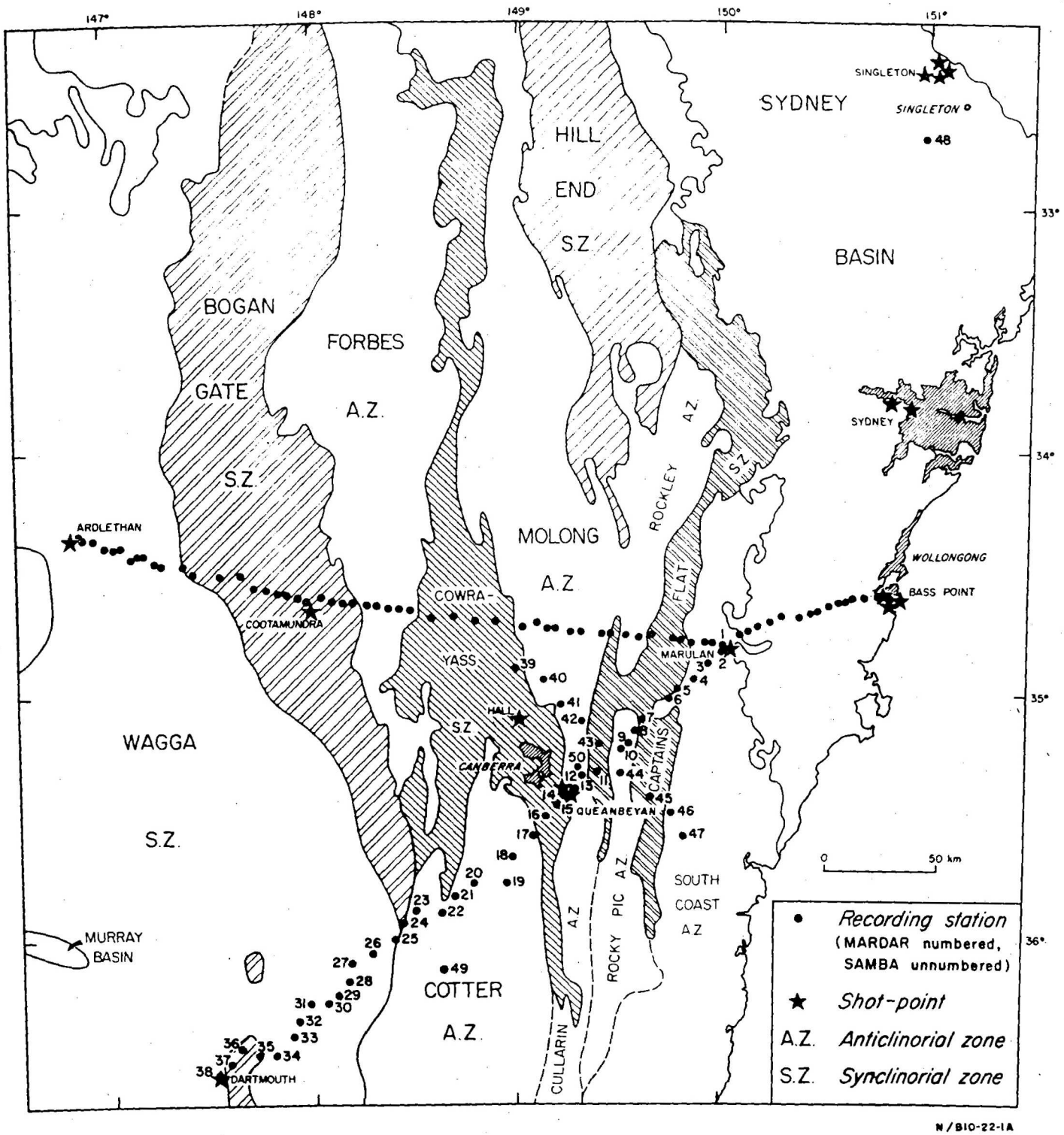
There were 39 recording sites along the main MARDAR survey line, 9 on a cross-traverse running at right angles to the main line just north-east of Canberra, and one site at Eaglehawk quarry near Lake Eucumbene dam in the Snowy Mts. This latter quarry, now disused, was the location of several large blasts in 1956 and 1957 which were recorded at seismic stations towards Sydney (Doyle et al. 1959).

This Record sets out the basic information on the MARDAR Survey; the data from the survey will be combined with data from the SAMBA and other previous surveys to enable a composite interpretation to be made and reported elsewhere.

Collins (1976) has made a brief outline of the geology and geophysics of the Lachlan Geosyncline which will not be repeated here. Scheibner (1973) and Markham & Basden (1974) have described the Lachlan Fold Belt in terms of a Palaeozoic plate tectonic accretion model and this is used as the basis for geological provinces shown in Figure 1.

..2/..

Fig.1



SHOT AND RECORDING STATION LOCATIONS RELATIVE TO GEOLOGICAL PROVINCES OF THE LACHLAN FOLD BELT

Record No. 1977/62

The MARDAR recording line commences at Marulan South on the edge of the Sydney Basin and traverses the Molong-South Coast Anticlinal Zone, the Captains Flat and Cowra-Yass Troughs, and part of the Wagga Trough. Many of the recording stations lie on the granitoid batholiths which make up about one quarter of the exposed Palaeozoic rocks of the Lachlan Fold Belt (Chappell and White, 1976).

FIELD WORK

Altogether, 50 recording sites were used during the survey, 49 between South Marulan and Dartmouth and one at Bulga near Singleton to determine the shot times at the Hunter Valley coal mines.

Nineteen sets of seismic tape recording equipment were used on the survey, in a manner similar to that reported by Collins (1976) for the SAMBA Survey. Recording sites were occupied for about 7 days during which they recorded at least one shot from each of the 4 shot locations, near Singleton, South Marulan, Queanbeyan, and Dartmouth. Many sets of squipment thus occupied three sites during the survey period from 22 November to 14 December 1976. Lead acid accumulators of 80 ampere-hours capacity were used to power the seismic tape recording systems, two being required to enable recording for about 10 days if necessary. One tape recorder was set up near each of the shot sites at Dartmouth, South Marulan, and Singleton to provide precise shot timing. The shots near Queanbeyan were timed for part of the survey by the BMR seismic observatory at Kowen Forest.

Unfortunately during the period 5-13 December 1976 no shots were fired near Queanbeyan, so a short survey was undertaken in the period 21 February to 3 March 1977 to re-occupy those sites at the southern end of the line which missed a shot from this source.

Survey personnel used long-wheelbase Land Rover vehicles in rugged country and a panel van for sites with easy access. Communication between field parties and BMR was achieved using Codan 25-watt SSB transceivers.

..3/..

SHOTS

Shot locations and type

As on previous surveys of this type all mine/quarry managements were asked to maintain a log of shot details. There is normally either a shooting engineer or a shooting foreman at each site who is responsible for maintaining details of the shots for company purposes, and therefore the BMR logs merely contain extracts from the company records. These logs contain information on the date and approximate time of shot, brief details of the shot-hole pattern, the total mass of explosive used, details of delays in the shooting pattern, and the location of the shot on a mine grid map.

The latitude and longitude of the shot were determined by converting from the mine grid map to fixed reference points on the Australian 1:100 000 or 1:250 000 scale maps. In the Singleton area, airphotos had to be used to transfer to the 1:250 000 scale maps because the mines are not shown on these maps.

Shots in the Singleton area were located at three open-cut coal mine sites: Ravensworth Mine operated by Costain Australia Pty Ltd, Howick Mine operated by Clutha Development Pty Ltd, and Swamp Creek Mine operated by the Hebden Mining Co. In most cases explosives consisted of ANFO and Quarigel supplied by ICI subcontractors. Up to 235 drillholes were used per shot and these were ranged in patterns of up to 25 rows. The shot duration was typically about 250 ms but ranged from instantaneous to 400 ms between the firing of the first and last rows.

Shots at Marulan South were fired in the limestone quarry operated by Blue Circle Southern Portland Cement Pty Ltd. The explosive used was mostly ANFO but occasionally NITROPRIL. Shots were usually in a single row of up to 16 holes, and most were fired instantaneously.

Shots near Queanbeyan were fired at the Googong Dam construction site by Thiess Bros Pty Ltd under the supervision of the Department of Construction, and at the blue metal quarry operated by the Readymix Group (ACT). Explosive was usually ANFO or AN60 in up to 360 holes; a typical shot had less than 100 holes. Most shots were instantaneous but some had a duration of up to 1.7 s.

..4/..

Shots at the Dartmouth dam site in northern Victoria were fired under the supervision of the State Electricity and Water Supply Commission by Thiess Bros Pty Ltd. Shots were sometimes fired simultaneously at more than one location within the spillway area. They were fired in patterns of up to 69 holes but were typically less than 20 holes. Most shots were instantaneous but some had a duration of up to 400 ms.

A summary of shot details is contained in Table 1. The MARDAR Survey used 46 shots from all sites: 8 from Ravensworth, 3 from Howick, 2 from Swamp Creek, 8 from Marulan South, 10 from Googong, 2 from Queanbeyan quarry, and 13 from Dartmouth. It is estimated that shot positions have an uncertainty of no more than $\pm$ 0.1 minutes of arc in latitude and longitude.

Shot timing

The system of shot timing was the same as that used on previous surveys of this type. A seismic tape recording system was installed near all shot sites: one at Bulga near Singleton (site No. 48), one at Marulan South (site No. 1), one at Kowen Forrest near Queanbeyan (site No. 50), and one near Dartmouth (site No. 38). These were operated for the duration of the survey; at Kowen the seismic observatory visual recording system was used on a number of occasions when the tape recorder was required for mobile field use. Arrangements were made with the persons responsible for shot firing to make an on-site recording of one shot on each site (Collins, 1976). These recordings were timed using VNG radio time signals, and the seismic travel-time between the quarry and the tape recording system was determined. This enabled the tape recording system to be used for accurate shot timing throughout the survey; corrections were made for the variation of shot locations within the quarry and mine sites. All shot times are listed in Table 1. Shot time uncertainties are less than $\pm$ 0.1 s.

RECORDING STATIONS

Two types of BMR seismic tape recording equipment were used on the survey: a $\frac{1}{4}$ inch tape recording system and a $\frac{1}{4}$ inch tape recording system. These are commonly referred to as the PI (Precision Instruments) and Akai systems respectively. 15 Akai systems were used on the survey a 4 PI systems. The capabilities of the two types of systems are described by Collins (1976) for the SAMBA survey.

TABLE 1

Shot Information

Shot Number	Date	Site Name	Latitude(S) deg.	min.	Longitude(E) deg.	min.	Elevation m.	Eastern Summer Time h.	min.	s.	Size t.	Total delays ms.
1	22.11.76	Ravensworth	32	26.6	151	02.1	90	14	12	02.34	46.8	275
2	"	Googong	35	25.1	149	15.7	640	17	24	51.85	-	-
3	23.11.76	Dartmouth	36	33.8	147	31.3	520	02	49	01.19	16.0	0
4	24.11.76	Marulan	34	47.2	150	01.7	550	12	03	50.19	3.5	0
5	"	Ravensworth	32	26.7	151	02.2	90	13	58	46.00	16.3	75
6	"	Dartmouth	36	33.6	147	30.9	420	16	24	03.96	5.0	200
7	25.11.76	Dartmouth	36	33.8	147	30.9	520	03	15	05.26	4.4	0
8	"	Marulan	34	47.2	150	01.6	550	15	33	13.17	3.5	0
9	"	Dartmouth	36	33.6	147	30.9	420	16	12	37.29	4.6	175
10	"	Googong	35	25.1	149	15.7	640	17	29	00.27	1.5	-
11	26.11.76	Ravensowrth	32	25.5	151	02.6	90	13	28	55.79	28.5	100
12	"	Howick	32	26.4	150	57.6	130	13	59	49.05	34.0	255
13	"	Swamp Ck.	32	25.0	151	04.7	90	17	28	55.30	33.0	-
14	28.11.76	Dartmouth	36	33.6	147	31.0	420	03	31	53.56	7.3	0
15	29.11.76	Dartmouth	36	33.7	147	30.9	420	16	26	13.02	4.0	0
16	"	Marulan	34	47.2	150	01.7	550	15	45	19.23	2.0	100
17	"	Googong	35	25.1	149	15.7	640	17	15	12.05	3.3	-
18	30.11.76	Ravensworth	32	25.4	151	02.5	90	13	40	20.77	25.6	150
19	"	Ravensworth	32	26.7	151	02.2	90	15	33	03.95	17.8	75
20	"	Marulan	34	47.2	150	01.6	550	15	41	02.42	2.3	0
21	"	Googong	35	25.1	149	15.7	640	17	14	10.05	2.3	-
22	1.12.76	Dartmouth	36	33.8	147	30.9	520	02	55	55.16	6.2	325
23	"	Ravensworth	32	26.8	151	02.2	90	14	38	43.73	22.5	75
24	"	Googong	35	25.1	149	15.7	640	17	17	16.25	2.7	-
25	2.12.76	Marulan	34	47.2	150	01.6	550	15	31	53.24	2.1	0
26	"	Googong	35	25.1	149	15.7	640	17	13	23.93	1.3	-
27	3.12.76	Dartmouth	36	33.8	147	31.1	520	03	23	38.83	11.2	300
28	"	Howick	32	26.4	150	57.6	150	13	44	42.57	35.0	289
29	4.12.76	Googong	35	25.1	149	15.7	640	15	20	40.55	4.2	-
30	"	Dartmouth	36	33.5	147	31.0	380	16	24	45.45	7.6	0
31	6.12.76	Marulan	34	47.2	150	[illegible]	550	15	40	11.13	3.0	0
32	"	Dartmouth	36	33.[illegible]			20	16	23	28.09	7.1	200
33	7.12.76	Swamp Ck.	32	25.0	151	04.7	90	10	16	03.83	15.0	-
34	"	Marulan	34	47.2	150	01.7	550	10	51	16.47	2.4	0
35	"	Ravensworth	32	25.7	151	02.7	90	11	46	26.98	14.5	75
36	8.12.76	Dartmouth	36	33.6	147	30.9	420	03	40	59.91	6.9	400
37	9.12.76	Howick	32	26.4	150	57.6	130	13	44	41.25	30.0	255
38	10.12.76	Marulan	34	47.2	150	01.7	550	15	40	55.35	2.6	0
39	11.12.76	Dartmouth	36	33.8	147	31.3	520	16	30	48.05	4.3	400
40	13.12.76	Ravensworth	32	26.9	151	02.2	90	14	38	27.66	51.0	150
41	"	Dartmouth	36	33.8	147	31.0	520	16	13	01.97	2.7	0
42	14.12.76	Googong	35	25.1	149	15.7	640	16	41	09.25	-	-
43	"	Googong	35	25.1	149	15.7	640	17	12	45.55	4.6	-
44	22. 2.77	Googong	35	25.1	149	15.7	640	14	17	28.93	2.6	-
45	24. 2.77	Queanbeyan	35	24.0	149	13.3	740	15	27	01.80	-	-
46	25. 2.77	Queanbeyan	35	24.0	149	13.3	740	11	59	19.22	-	-

Their mode of operation was similar to that used during the SAMBA Survey. All systems on the MARDAR Survey used a single short-period vertical seismometer (Willmore Mk 2 or 3A).

Fifty recording sites were used during the survey; the details of positions, etc. are contained in Table 2. The locations of the recording stations in relation to geological provinces in the Lachlan Fold Belt are shown in Figure 1. Sites were occupied for about 7 days at a time. A reconnaissance to select recording sites was conducted along the recording line in late 1975; this proved very valuable by saving time in setting up stations during the survey.

Wherever possible, seismometers were placed on solid unweathered rock outcrop. If none was available, the seismometer was usually buried and packed in soil. In siting the equipment, consideration was given to local microseismic noise and animal disturbance. If possible, heavily timbered areas were avoided, but in this part of southeast Australia it was difficult to avoid such areas altogether. On some days of the survey high winds created so much microseismic noise that all useful shot signals were swamped.

Rock samples were collected from most recording and shot sites to enable near-surface velocities to be estimated from laboratory ultrasonic measurements. Rock densities were also determined for use in gravity interpretation (Table 3).

All recording site positions were scaled from 1:100 000 maps except the Bulga site, which was scaled from a variety of more detailed maps. In all cases the uncertainty of position is estimated to be less than $\pm$ 0.1 minutes of arc in latitude and longitude. Elevations of the stations were also scaled off the appropriate maps.

COMMENTS

Playback of the seismic tapes in analogue form was done in BMR on completion of the survey. On some Akai recordings instrument noise due to motor-drive jitter was evident. This was eliminated by subtracting the low gain from the high gain signal. The incorporation of versatile variable filters into the playback system enabled some of the microseismic noise to be eliminated from the shot signals. Usually a bandpass filter of between 2 and 9 Hz was used.

TABLE 2

Recording Station Information

Station Number	Station Name	Mnemonic	Latitude (S) deg.	Latitude (S) min.	Longitude(E) deg.	Longitude(E) min.	Elevation m
1	Marulan	MU	34	47.4	150	00.8	560
2	Meadow	MW	34	48.8	150	00.2	550
3	Bungonia	BU	34	51.9	149	56.4	590
4	Kooringaroo	KO	34	55.6	149	52.1	660
5	Fassifern	FN	34	58.0	149	47.2	680
6	Bungong	BG	35	00.2	149	44.6	720
7	Pylara	PA	35	05.4	149	36.8	710
8	Glendale	GE	35	08.2	149	34.8	800
9	Herberton	HN	35	11.2	149	32.9	820
10	Werriwa	WA	35	12.7	149	30.6	720
11	Bald Hill	BH	35	18.4	149	23.6	870
12	Mt Atkinson	MA	35	19.3	149	19.1	730
13	Wanna	WN	35	22.5	149	17.0	760
14	Knoll	KL	35	24.1	149	13.4	740
15	Mt Campbell	MC	35	26.9	149	11.5	740
16	Rob Roy	RR	35	29.9	149	08.2	840
17	Ingledene	IE	35	34.6	149	04.5	700
18	Orroral	OL	35	39.9	148	58.8	980
19	Gudgenby	GY	35	46.0	148	57.0	1020
20	Mt Morgan	MM	35	46.1	148	47.1	1300
21	Circuits Hut	CH	35	49.3	148	41.2	1250
22	Gang Gang	GA	35	53.4	148	37.4	1410
23	Kiandra	KA	35	52.9	148	29.6	1400
24	Kings Cross	KC	35	56.0	148	25.7	1650
25	Happy Jack	HJ	36	00.0	148	23.7	1600
26	Tooma	TA	36	03.1	148	16.8	1210
27	Dargals	DS	36	05.4	148	10.8	840
28	Bradneys Gap	BP	36	10.1	148	09.9	600
29	Khancoban	KN	36	13.4	148	06.3	360
30	Indi	II	36	15.6	148	03.1	400
31	McCormacks Gap	MP	36	15.5	147	58.4	710
32	Thowgla Upper	TU	36	20.0	147	55.0	410
33	Nariel	NL	36	23.7	147	53.0	900
34	Gibbs Sawmill	GS	36	28.6	147	48.0	1000
35	Raymond Ck	RC	36	28.1	147	42.9	1140
36	Benambra Spur	BS	36	26.6	147	37.5	1120
37	Mt. Benambra	MB	36	30.5	147	34.3	1470
38	Dartmouth	DH	36	32.9	147	30.3	400
39	Glen Roy	GR	34	53.1	148	59.9	530
40	Sandy Vale	SV	34	55.9	149	07.7	560
41	Gundaroo	GO	35	02.0	149	12.8	640
42	Mt Murray	MY	35	06.0	149	18.9	660
43	Lake George	LG	35	11.7	149	23.9	700
44	Glasgow	GW	35	18.9	149	30.5	880
45	Bombay Ck.	BC	35	24.7	149	39.3	690
46	Jillamatong	JG	35	28.3	149	45.8	700
47	Reidsdale Ck.	RC	35	34.5	149	49.7	720
48	Bulga	BA	32	42.0	150	58.6	107
49	Eaglehawk	EK	36	8.2	148	37.7	1110
50	Kowen	KN	35	17.3	149	17.9	792

Only a selection of the best shots out of the total of 46 were played back. This was done to try to eliminate possible variation in source effects from the recorded seismic wave train. Record sections, such as those shown in Figure 2, were compiled manually from the various playback records; these will be used to interpret the data, which will be reported elsewhere.

ACKNOWLEDGEMENTS

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Costain Australia Pty Ltd.
Clutha Development Pty Ltd.
Hebden Mining Co.

Many property owners co-operated in allowing access to recording sites; their help is also gratefully acknowledged.

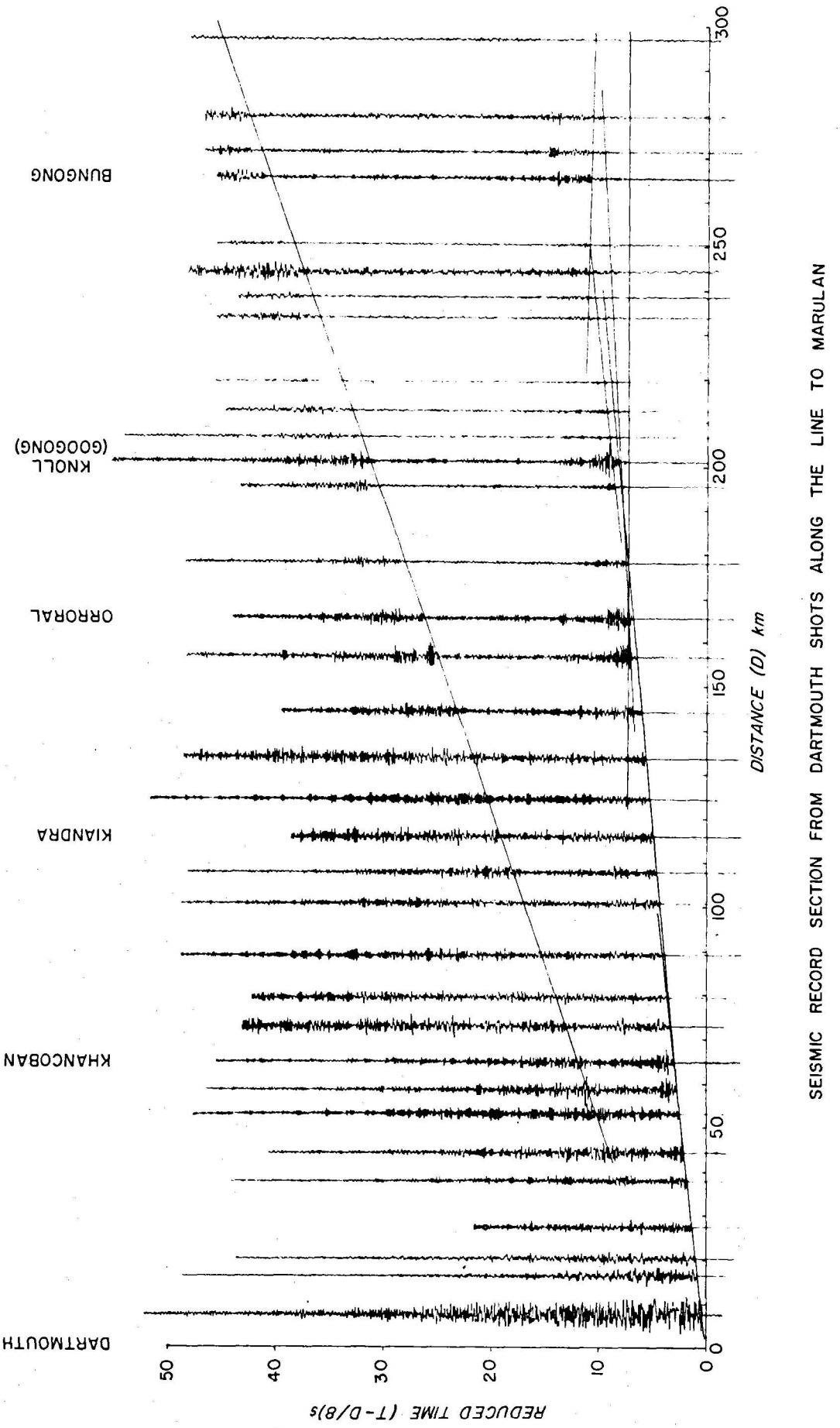
..7/..

TABLE 3

Seismic velocities and densities of rock samples taken from shot and recording sites

Site Number	Site Name	Sample geological description	Density (kg/m^3)	P Velocity (km/s)		
				Isotopic Samples	Anisotopic Samples	
1	Marulan	Marble	2.70	6.3	-	- -
5	Fassifern	Rhyolite ?	2.62	4.5	-	- -
8	Glendale	Aplite	2.55	-	4.2	2.8
10	Werriwa	Sheared silty sandstone	2.58	4.3	-	- -
10	Werriwa	-	2.59	-	4.64	4.58 3.06
13	Wanna	Siltstone	2.47	-	2.8	1.6 -
14	Knoll	-	2.86	-	5.24	5.00 5.43
15	Mt Campbell	-	2.59	-	3.33	4.30 5.08
16	Rob Roy	-	2.64	-	5.48	5.46 5.48
18	Orroral	Biotite granite	2.62	4.4	-	- -
20	Mt Morgan	Microcline granite	2.61	4.0	-	- -
21	Pedens/Circuits Hut	Epidotised mudstone	2.61	5.2	-	- -
22	Gang Gang	Rhyolite	2.64	5.3	-	- -
23	Kiandra	-	2.94	-	6.43	6.36 6.11
24	Kings Cross	Granodiorite	2.75	5.4	-	- -
24	Kings Cross	-	2.57	-	3.74	5.60 5.62
25	Happy Jack	Siltstone	2.38	4.1	-	- -
25	Happy Jack	-	2.50	-	3.67	3.67 2.84
26	Tooma	Granite	2.75	5.7	-	- -
27	Dargals	Leucogranite	2.54	3.9	-	- -
29	Khancoban	Micaceous mudstone	2.54	-	2.9	1.5 -
32	Thowgla Upper	Mudstone	2.72	-	5.8	4.5 -
33	Nariel	Rhyolite	2.57	4.3	-	- -
37	Mt Benambra	Porphyritic rhyodacite	2.61	5.3	-	- -
37	Mt Benambra	-	2.63	-	5.61	5.70 5.71
37	Mt Benambra	-	2.60	-	4.94	4.83 5.02
38	Dartmouth	Granodiorite (foliated)	2.80	-	5.1	4.9 -
38	Dartmouth	Andesite (foliated)	2.75	-	5.4	4.0 -
39	Glenroy	-	2.68	-	5.69	5.22 5.36
40	Sandy Vale	-	2.64	-	5.27	5.33 4.65
42	Mt Murray	-	2.73	-	5.55	5.64 5.52
44	Glasgow	-	2.64	-	4.35	4.00 4.23
45	Bombay Ck.	-	2.64	-	5.85	5.66 6.20
46	Jillamatong	-	2.71	-	5.44	5.22 5.13
49	Eaglehawk	Metamorphosed shale	2.68	-	4.80	6.10 5.70

Fig.2



SEISMIC RECORD SECTION FROM DARTMOUTH SHOTS ALONG THE LINE TO MARULAN

Record No. 1977/46 and 1977/62

N/BIO-17AR

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