DEPARTMENT OF
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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1973/212

BOWEN BASIN SEISMIC REFRACTION SURVEY, MAY-JUNE 1973: OPERATIONAL REPORT

by

J.B. Connelly and C.D.N. Collins

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CONTENTS

TABLES

PLATES

SUMMARY

During the period May-June 1973 a deep crustal seismic refraction survey was undertaken jointly by the Bureau of Mineral Resources, Geology & Geophysics (BMR) and the University of Queensland in the Bowen Basin, central Queensland. Dr. J.P. Webb of the university's Department of Geology and Mineralogy organised and supervised the survey.

The survey was undertaken partly to clarify the structure of the basin and partly to provide field tests for the remote seismic recording systems constructed by the Bureau before their use in Papua New Guinea. The Bowen Basin was chosen because there are a number of open-cut coal mines in which 50 to 300-ton explosions are used to break up overburden. These explosions provide excellent energy sources for a seismic refraction survey.

Explosions at the Blackwater, Goonyella, Moura, and Peak Downs mines were used, and a seismic refraction traverse about 370 km long was surveyed between the Goonyella mine in the north and the Moura mine in the south. Recording stations were placed at about 10 km intervals along the traverse, and most stations recorded seismic events from all four mines.

This Record provides information on the logistics of the survey; the interpretation will appear in later reports. Preliminary results indicate that the recorders operated satisfactorily, and 90 percent of possible arrivals were recorded.

1. INTRODUCTION

The Bowen Basin in central Queensland (Plate 1) geographically forms an inverted V, with the apex south of Townsville and the base bounding on the sediments of the Great Artesian Basin south of Springsure. The basin is filled with a sequence of Permian to Triassic rocks (Dickins & Malone, 1971), whose geological characteristics vary greatly from one part of the basin to another. Plate 2 shows the major structural and depositional units in the area.

Extensive coal measures have been known since last century (Jack, 1879). Coal has been mined in a small way for many years, but since the early 1960s mining has expanded dramatically using open-cut methods. Before 1965 the main coal production came from the open-cut mine at Moura, operated by Thiess Peabody Mitsui Coal Pty Ltd. After 1965 Utah Development Co. opened large open-cut mines at Blackwater, Goonyella and Peak Downs, Thiess Bros. at South Blackwater, and the production of the existing Callide mine was greatly increased.

The open-cut mines frequently detonate large explosions to break up the overburden so that it can be removed by dragline and thus exposing the coal. These explosions are usually in the range 50-300 tons, but the entire charge is not detonated instantaneously. Usually the explosive is placed in six rows of holes and detonated with a delay of 17 milliseconds between each row (Table 2). It was anticipated that the delays would reduce the effective size of the explosion, perhaps even to the weight of explosive detonated at each delay. However, recordings made at the Charters Towers Seismic Observatory indicated that the amplitudes of the seismic arrivals depend on the total weight of explosive used, and therefore all rows must contribute to the effective seismic energy.

The idea of a seismic refraction experiment in the Basin was first suggested by Dr. J.P. Webb of the University of Queensland. However, the University had insufficient equipment to mount the survey and it was suggested that a joint project with the BMR be undertaken, with the dual purpose of determining the crustal structure of the Bowen Basin and testing the BMR remote seismic recording equipment in preparation for the 1973 east Papua crustal survey.

2. AIM OF THE SURVEY

The aim of the survey was to obtain a crustal section of the Bowen Basin with the additional possibility of some information being obtained on layers immediately below the Mohorovicic discontinuity. A reversed seismic refraction profile line about 375 km long was surveyed between the

Goonyella and Peak Downs mines in the north and the Moura and Kianga mines in the south. Shots from the Blackwater mine, which is about 150 km northwest of the Moura mine, were also included although this mine is a little off the main refraction traverse.

It was intended to obtain recordings from both ends of the traverse at intervals of 10 km. This plan had to be modified according to circumstances, but the coverage along the traverse was still good, with no more than 20 km between any two stations except for the southern 50 km of the traverse, which was not covered owing to lack of time.

3. GEOLOGICAL AND GEOPHYSICAL BACKGROUND

Geological Background

The present geological structure of the Bowen Basin and adjoining areas reflects a complex tectonic history, and only a broad outline of the geological structure of the region is given. The geology was discussed in the Resources Series of the Fitzroy Region, Queensland, published by the Department of National Development (1966), and by Dickins & Malone (1971). The following geological summary of the region is taken from these two publications.

The Bowen Basin is a Permian to Triassic sedimentary basin in central Queensland extending from Collinsville in the north to Springsure in the south, where it is overlapped by Mesozoic rocks of the Great Artesian Basin. It probably continues southward under this younger cover and may be continuous with the Sydney Basin.

It is bounded to the northwest by the Anakie High and Drummond Basin, (Plate 2), to the east by the Connors Arch and Auburn Arch, and to the west by the Birkhead axis, which separates it from the Galilee Basin.

Sedimentation commenced in the early part of the Lower Permian, and thick terrestrial sediments, including numerous coal beds, were deposited; contemporaneous vulcanism was a feature along the eastern margin. The main centres of deposition were the Denison Trough in the south and a northern trough, which was located on the present site of the Connors Arch and Nebo Synclinorium. Later in the Lower Permian, the sea transgressed westwards and replaced the terrestrial environment with a marine one. Marine and fluviatile sedimentation, accompanied by deepening and expansion of the northern trough, continued into the early Upper Permian.

Towards the end of the Permian, thick freshwater sediments and extensive coal measures were laid down in the northern trough (now the Nebo Synclinorium) and also in the central and western areas of the Basin. In the Lower Triassic, the main locus of sedimentation shifted from the part of the northern trough that is not the Nebo Synclinorium to the region now occupied by the Mimosa Syncline in the south (Plate 2). Rapid subsidence recommenced in the Middle to Upper Triassic, and in the Mimosa Syncline a total of 5500 m of sediments accumulated. Uplift and igneous intrusion in the east proceeded at the same time as the downwarping.

Deposition ceased in the Upper Triassic, and the sediments were uplifted and eroded. Tertiary terrestrial sediments are widespread and locally thick, and extensive basalt flows, which have been largely removed by erosion, were also laid down.

Geophysical Background

Previous geophysical work done in the region was mainly concerned with the search for economic minerals, particularly petroleum and coal.

Extensive seismic work was carried out mainly in the south and southwest area between Clermont, Springsure, and Theodore. Early work was carried out by Smith (1951) and Shell (Qld) Development (1952). Of particular interest to this survey is a BMR reconnaissance reflection and refraction seismic survey (Robertson, 1961, 1965), which outlined the structure of the basin on an east-west line between Emerald and Duaringa, and in the course of which deep reflecting horizons were recorded in the Comet area (Moss, in prep.).

Gravity surveys were conducted by BMR and private companies (Lonsdale, 1965; Darby, 1966) and 1:250 000 gravity maps were compiled for the region. Positive anomalies exist over the Anakie High in the west, the Connors Arch and Auburn Arch in the east, and the Comet Ridge in the central Bowen Basin, while negative anomalies are found over the Denison Trough, Mimosa Syncline, and Nebo Synclinorium. Between the coastal areas and the Bowen Basin there is a zone of low gravity gradients, with the gravity increasing towards the coast; this was interpreted (Darby, 1966) as evidence for a hinge zone between the centre of uplift of the Tasman Geosyncline and the Bowen Basin.

An aeromagnetic survey was undertaken by BMR from 1961 to 1963 (Wells & Milsom, 1966) and the estimates of the depths to magnetic basement were in reasonable agreement with those expected from a study of the structural units.

A deep crustal seismic refraction survey was carried out across Cape York Peninsula and as far south as Charters Towers (Finlayson, 1968). This was later extended into the Galilee Basin (Cull & Riesz, 1972) on a line commencing at Charters Towers and extending to about 80 km west of Clermont (Plate 1).

General conclusions of surveys. The depth to the mantle is greatest (about 45 km), in the interior of Cape York Peninsula, and decreases to about 25 km on either side of the peninsula. The depth to the intermediate crustal layer in the interior of the Peninsula is about 25 km and decreases to 10 km towards the continental margins. Farther south, at Charters Towers, the depths to the mantle and intermediate layer are about 45 km and 20 km respectively, and in the Galilee Basin these depths ranged between 35 and 40 km, and 20 and 25 km respectively.

Seismic velocities of about 6 km/sec for the upper crust, 6.75 km/sec for the intermediate layer, and 8 km/sec for the mantle were obtained in both surveys.

4. MINE PARTICIPATION

The operators of five coal mines were contacted and asked to participate in the experiment; they were the Blackwater, Goonyella, and Peak Downs mines (operated by Utah Development Company), and the Moura and Kianga mines (operated by Thiess Peabody Mitsui Ltd).

Their participation involved (a) firing their large overburden charges in the first 15 minutes of any hour so that the remote recorders (which are switched on only during this period) would record the shots; (b) allowing BMR and University of Queensland personnel onto mine property and close to the shots to record shot instants; (c) providing information about the position and distribution of shot holes, weight and type of explosive used, shot delay times, depth of shot holes, thickness of overburden, and overburden removed; and (d) providing information on the position of shot-instant recording sites where these were not close to the shots.

The mine managements willingly agreed to co-operate, and during the whole survey only one large shot was fired outside the 15-minute recording time slot. In addition, the chief engineer at the Peak Downs mine volunteered to provide information on the positions of recording stations along the northern part of the line, if they were sited on survey pegs or other landmarks that could be located on the large scale maps which the company had made of this area.

The frequency of mine shots is shown in Table 1.

5. LOGISTICS AND RECORDINGS

5.1 General Background

Duration

15th May - 13th June 1973

Personnel - BMR

J.B. Connelly - Party Leader

B.J. Drummond - Geophysicist Class 1

D.L. Woolfenden - Field Hand Grade 1

D.M. Finlayson - Geophysicist Class 3 (22/5/73 - 27/5/73)

Personnel - University of Queensland

Dr. J.P. Webb (20/5/73 - 2/6/73)

G.W. Tweedale (20/5/73 - 27/5/73)

C.D.N. Collins - BMR Cadet studying for a masters degree at the University.

Vehicles and Movements

Three long wheel-base Landrovers were used for the transport of all BMR personnel and equipment to and from the survey area. One Holden utility was used for the transport of University of Queensland personnel and equipment to and from the survey area. The BMR party left Canberra on 15/5/73, arrived in the survey area on 20/5/73, left the survey area on 10/6/73, and arrived back in Canberra on 13/6/73.

The University of Queensland party left Brisbane on 20/5/73, and arrived in the survey area on 21/5/73. Two members of the party (J.P. Webb and G.W. Tweedale) left the survey by air on 3/6/73 and 27/5/73, and the party was visited by D.M. Finlayson (Geophysicist Class 3) from 22/5/73 to 27/5/73.

It was found that three complete sets of recording equipment, plus 9 lead-acid batteries, plus all the necessary auxilary material such as tools and camping equipment could be transported in a LWB Landrover. However, with three sets, it was not possible to carry a passenger in the front seat for any distance.

The party had to fulfil two functions:

1. Record the shot instants at the Blackwater, Goonyella, Moura, Kianga, and Peak Downs mines

2. Install the recording stations.

One vehicle was maintained at each end of the traverse for use by the shot-timing personnel (usually two persons). The remaining vehicles and personnel were employed in the installation and moving of the recording stations. The shot-timing parties assisted with the installation of recording stations and the reconnoitring of recording sites as time allowed. At the end of the survey, after J.P. Webb and G.W. Tweedale had left, the northern shot-timing personnel was limited to one man, and the remaining three people were responsible for installing stations along the southern half of the line and for timing the shots at the Blackwater, Moura, and Kianga mines.

5.2 Shot-Instant Recording

Two sets of shot-instant recording equipment were used during the survey. One was used at the northern end of the line to record shots at the Goonyella mine, and the other at the southern end of the line to record shots at the Moura, Kianga, and Blackwater mines. Owing to the high frequency of shots at the Peak Downs mine (Table 1) a remote recording station was set up to record the shot instants there.

At the Blackwater, Goonyella, Moura, and Kianga mines a geophone was set up as close as possible to the shot, and the recorder was set up near the shooter. The shooter signalled when he was ready to fire and from then the count-down was given by the man in charge of the recorder. In this way it was possible to arrange that the shot was fired just after a minute. This procedure was not always adhered to, and in these instances the shooter indicated when he was going to fire and the recorder was then switched on.

At Peak Downs the remote recording station was left unattended except for battery servicing. The position of the geophone relative to the shots was surveyed in by the surveyor at Peak Downs so that the necessary time corrections could be made to the shot instant. The corrected shot instants are listed in Table 2.

5.3 Recording Station Installation

Station installation was started at the northern end of the recording line near the Goonyella and Peak Downs mines and then continued in as straight a line as possible to the Moura and Kianga mines. Only nine sets of recording equipment were available for the survey, so that to cover the traverse at 10 km intervals it was necessary to move the stations to a new location once they had recorded an event from each of the mines. Towards the end of the survey when time became short, stations were moved after they had recorded an event from each end of the traverse.

Stations were located on hard rock wherever possible; alternatively the seismometer was buried and the earth well tamped down around it. Site locations were limited by the need to position the station on a landmark which could be identified on the 2 mile or 4 mile maps.

It was found that the most time-consuming part of the station installation was finding suitable landmarks and contacting property owners to ask permission to place the station on their land. To reduce the time taken to move stations, later sites were reconnoitred before the stations were moved. However site reconnoitring was often done by personnel other than those setting up the station, and then the time saved was not great.

Under the conditions of this survey two stations per day could be set up by a party. The following is a guide to the number of stations which can be set up in a day by one or two men.

Three stations per day

Desirable conditions to achieve 3 stations per day were:

(a) All sites reconnoitred by the personnel eventually setting up the station

(b) Short driving distances between stations, and between start and finish positions for the day

(c) No equipment breakdowns.

Two stations per day

This is the optimum number when planning this type of survey. It can be achieved without site reconnaissance and a station interval of up to 50 to 100 km. Breakdowns and extra jobs such as moving stations can be handled if the distance between stations is not excessive.

One station per day

Any extra jobs, major breakdowns of the equipment, or difficulty in selecting a site limits the output to one station per day. Two men working together speed up work but not to a great extent. Throughout the survey no more than two stations were ever put in on one day by one or two men.

6. POSITIONING

6.1 Shot Locations

The shot locations were accurately determined by the companies firing the shots. Utah Development Company provided maps of the Peak Downs and Goonyella mines at scales of 1:6000 (showing shot locations) and 1:25 000 (showing positions of recording geophones). These maps were based on the Australian grid and the company supplied a list with eastings and northings of the shots, which can be converted easily to latitudes and longitudes.

The Blackwater, Moura, and Kianga mines were surveyed on a local grid which was not related to the Australian grid. At these mines the latitudes and longitudes of the shots were obtained by relating the Australian grid and the local grid using landmarks which appeared both on the 2-mile sheets and on the Company's local maps. Shot locations are listed in Table 2, and the seismic wave travel times, distances and azimuths from the shots to the recording stations are listed in Table 3. The travel times were corrected for recorder parallax using Table 4, which lists the constants for all BMR recorders.

6.2 Positioning of Recording Stations

Positioning of stations by siting them on landmarks such as fence-road intersections which could be identified on the 2-mile or 4-mile maps made it easy to determine their co-ordinates. The stations at Broadmeadows and Winchester Downs were located at survey pegs along seismic refraction traverses which had been shot by Utah Development Company. The station at Saraji was located at a Queensland Railway bench-mark. The stations at Phillips Creek and Dysart were located at bench-marks put in by Ullman & Nolan, construction engineers and contractors for many of the new roads, pipelines, and towns in the area. The station at Kirkcaldy was located on a creek-bed crossing identifiable on Utah Development Company's map.

Unfortunately, personnel at the Ullman & Nolan head office in Brisbane did not know the coordinates of the bench-marks at Phillips Creek and Dysart. The company's local office at Mackay was also unable to locate them and thus only approximate positions are available from the 2-mile map series. It seems advisable not to use bench-marks put in by private companies as a station marker unless prior assurance can be given that their co-ordinates are known.

7. EQUIPMENT

The seismic equipment is listed below.

1. Nine sets of BMR automatic seismic tape recording equipment, of which six used Precision Instruments (PI) tape recorders and 3 used Akai tape recorders

2. Queensland University shot-timing equipment consisted of an SIE camera and amplifiers connected to a two-cycle geophone, Labtronics time-signal receiver, and clock.

3. Queensland University recording equipment consisted of Sercel 24-channel refraction amplifiers and SIE camera with ten 4½-cycle and 2-cycle geophones.

4. BMR shot-timing equipment consisted of a Visigraph recorder connected without amplification to a two-cycle geophone and a Labtronics time-signal receiver.

5. Communications equipment consisted of one 100-watt single side band (SSB) Codan base-station, three 25-watt SSB Racal mobile radio units, and two 25-watt SSB Racal mobile radio units.

Remote Seismic Recording Equipment Performance (BMR equipment)

Each set of seismic recording equipment consisted of a seismometer, a tape recorder, and a 1'9" x 1'5" x 1'4" Haliburton case containing amplifiers, power supplies, modulator, clock, and a radio. The signal from the seismometer is amplified and frequency modulated, and is then recorded on tape together with time signals from both the clock and the radio. There is provision for the clock to be set to within one millisecond of the radio pips using a comparator. Once set the clock has an error of only a few milliseconds a day, so that it can be used for timing during periods of bad radio reception. Plate 3 shows photographs of the equipment.

Six of the tape recorders used were low-speed frequency-modulated (FM) tape recorders mounted in air-tight cases. These were purchased complete from Precision Instruments Ltd, Palo Alto, USA. The remaining three were ordinary commercial Akai tape recorders which had been modified by the BMR to run at low speeds and had been remounted in the Haliburton cases. The remainder of the electronic equipment except for the radio was manufactured by BMR. Willmore mark II seismometers were used.

Haliburton Cases

Both the large cases and the Akai cases leaked when exposed to light rain. Capillary action round the lid is thought to be the most likely cause of water seeping into the cases. The PI cases did not leak in rain, but one which was standing in water did; it is thought that the water entered through the holes used to screw the feet to the case. About ¼" of water was present in the bottom of the cases. The water evaporated and condensed on all parts of the equipment within the case. However, the only pieces of equipment which appeared to be affected by water condensation were three tension rollers in the PI recorders. These tension the belts transmitting the drive from the motor to the capstan, and overnight, while the equipment was not operating, they rusted to the belts and prevented the tape recorder from operating. It is possible that parts of the Akai drive system would suffer from similar faults if exposed to condensation for long periods.

Clocks

Faults occurred on three out of the nine clocks used in the survey, but only one of the faulty clocks resulted in a loss of most of the records for that station. Of the two other faulty clocks, the display of the days and hours failed on one, but the rest of the clock functioned correctly and the time code was correct on the tape. This fault was not a serious problem, except that when setting up, the days and hours had to be set by counting the number of times the buttons were pushed. On the second clock the display was correct and the clock was keeping correct time as evidenced by the fact that the shots appeared at the correct position on the tape, but the time code was incorrect or missing, except for the hours.

Two separate faults were apparent with the clock that resulted in a loss of records. Firstly it switched off at 10 minutes past the hour instead of 15 minutes past the hour. Furthermore, although the clock appeared to be only two-and-a-half minutes out on the display when picked up, playback of the tape indicated that the clock had stopped incrementing for long periods and had consequently switched on and off at the wrong times. Apart from being two-and-a-half minutes out when picked up it was noticed that this clock sometimes failed to increment while the display was switched off. When reset the clock appeared to function correctly, and malfunctions were explained by water which had been in the bin. However, it failed again after a short period. Hence, it would appear advisable not to use a clock that has failed once even though it subsequently appears to be operating correctly.

TAM5 Low-Noise Amplifiers

One TAM5 out of the nine failed and was replaced. The failure was not complete, but the signal seemed one-sided when listened to on the PI phone. All other electronic components in the bins functioned correctly.

PI Tape Recorders

Two out of the 6 PI tape recorders failed owing to mechanical faults. Of these, one failure was due to water leaking into the case and causing the tension rollers on the drive to rust onto the belts (see above). The second fault was caused by a small allen screw on the underside of the drive-stop switch coming loose, presumably from vibration. This caused the pinch-rollers to cease pinching and consequently the tape ceased transporting past the heads.

Akai Tape Recorders and Other Equipment

No faults occurred in the three Akai tape recorders, and no significant faults occurred on any of the other equipment. The radios performed very well and good reception was obtained between two mobile units at distances of up to 400 km.

8. CONCLUSIONS

Table 5 is a table of the numbers of possible arrivals and arrivals received, and shows that 90 percent of possible arrivals were recorded. The main cause of record loss was the malfunctioning of one of the clocks which switched on and off at wrong times, thus failing to record the arrivals. The mechanical faults on the PI tape recorders did not cause any record loss, although they could have done so had they remained undiscovered.

The amount of information which the survey yielded could have been increased by placing some recording stations away from the main refraction traverse. Stations located off the traverse would have provided direction control for refractor contour lines on a map.

9. ACKNOWLEDGEMENTS

The unfailing cooperation of the management and staff of the Blackwater, Goonyella, Moura, Kianga, and Peak Downs mines is gratefully acknowledged. Special thanks are due to the following people:

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At the Kianga mine, Mr G. Jaques, for his co-operation in the timing of the shot.

At the Peak Downs mine, Mr R. Chadwick, the chief engineer, for approving the participation of the mine in the project; Mr C. Seymour, for supplying large-scale maps of the mine with the shots marked, and for providing information on the positions of four of the recording stations; and Mr T. West, for co-operating in the timing of one of the shots.

The co-operation of the station owners at Winchester Downs, Picardy, Warwick Downs, Foxleigh, Barwon Park, Wilpeena Park, Yarrabee, Pearl Creek, Coomooboolaroo, and Carinya for allowing us to place recording stations on their property is gratefully acknowledged.

The results of this survey will be used by one of the authors (CDNC) in a thesis for the degree of M.Sc. at the University of Queensland.

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TABLE 1 - SHOT FREQUENCY AT THE MINES PARTICIPATING IN THE SURVEY

21 May to 11 June 1973

DAY AND DATE		BLACKWATER	GOONYELLA	MOURA-KIANGA	PEAK DOWNS
Mon.	21				
Tues.	22		1		1
Wed.	23	Not Contacted	2	1	1
Thurs.	24				
Fri.	25			1	1
Sat.	26				
Sun.	27				
Mon.	28			1	
Tues.	29				1
Wed.	30	1			1
Thurs.	31				1
Fri.	1	1			
Sat.	2				
Sun.	3				
Mon.	4				1
Tues.	5				
Wed.	6	1	1		
Thurs.	7				1
Fri.	8				
Sat.	9			1	
Sun.	10				

TABLE 2 - SHOT STATISTICS

No.	Date	Location	Position Lat.	Position Long.	Time (Hrs,	mins,	secs)	No. of stations recording the shot	Size (lbs)	No. Rows	No. Holes	Delays between rows (msecs)	Total delay (msecs)	Average Depth (ft)
1	22-5	GOONYELLA			12	06	(1)	5	6,000					
2	22-5	PEAK DOWNS	(2)		17	12	50.60	6		6		17	85	
3	23-5	GOONYELLA	21°47.4'	147°58.8'	09	02	04.32	6	264,800	11	395	17	170	
4	23-5	MOURA	24°37.9'	150° 2.7'	13	03	05.18	4	261,000	25	148	10	240	68
5	23-5	GOONYELLA	21°46.0'	147°58.5'	13	08	25.87	6	177,830	7	91	17	102	
6	23-5	PEAK DOWNS	22°15.8'	148°11.0'	16	10	22.90	6	134,483	6		17	85	
7	25-5	PEAK DOWNS	22°15.9'	148°11.1'	14	10	37.82	8	85,981	6		17	85	
8	25-5	KIANGA	24°43.1'	150° 3.9'	17	03	06.93	8	203,915	9		25/17	84	
9	28-5	MOURA	24°37.4'	150° 3.1'	16	44	05.74	1	451,000		122			114
10	29-5	PEAK DOWNS	22°13.7'	148°10.3'	16	12	50.65	8	78,485	6		17	85	
11	30-5	BLACKWATER	23°48.2'	148°51.3'	15	03	03.26	8	123,280	6		17	85	
12	30-5	PEAK DOWNS	22°13.6'	148°10.3'	15	09	17.20	8	93,124	6		17	85	
13	31-5	PEAK DOWNS	22°15.9'	148°11.1'	16	09	55.96	4	103,794	6		17	85	
14	01-6	BLACKWATER	23°48.3'	148°51.4'	15	01	00.16	4	141,280	7	140	17	102	68
15	04-6	PEAK DOWNS	22°13.6'	148°10.3'	16	10	43.35	7	106,263	6		17	85	
16	06-6	BLACKWATER	23°42.5'	148°47.5'	15	05	05.66	7	153,920	5	180	17	68	60
17	06-6	GOONYELLA	21°47.6'	147°58.8'	16	02	15.81	7	164,960	10		17	153	
18	07-6	PEAK DOWNS	22°16.1'	148°11.2'	16	10	30.41	8	87,360	6	91	17	85	
19	09-6	MOURA	24°37.4'	150°03.1'	14	13	36.33	8	672,000					

(1) Shot instant recorder failed.

(2) Position not provided by the mine.

TABLE 3. SHOT TO STATION DISTANCES, AZIMUTHS AND SEISMIC WAVE TRAVEL TIMES

SHOT	RECORDER	LOCATION	ABREV	DISTANCE	AZIMUTH	TRAVEL TIME	REMARKS
3	2	BROADMEADOW	BW	15,9	177,5	3.31	GOOD
3	4	MORANBAH	MH	35,3	157,9	6.21 6.46 43.46	GOOD GOOD FAIR
3	5	WINCHESTER	WR	45,9	157,6	8.32	GOOD
3	6	PEAK DOWNS	PD	55,8	155,4	9.53	GOOD
3	7	SARAJI	SI	76,3	153,0	12.89 20.89 34.84	GOOD FAIR FAIR
5	1	GOONYELLA	GA	7,9	196,5	1.85	GOOD
5	2	BROADMEADOW	BW	18,5	181,6	3.74	GOOD
5	4	MORANBAH	MH	37,3	161,1	6.61 7.01 12.69 17.86	GOOD FAIR POOR POOR
5	5	WINCHESTER	WR	47,9	160,1	8.72	GOOD
5	6	PEAK DOWNS	PD	57,7	157,6	10.12	GOOD
5	7	SARAJI	SI	78,1	154,6	13.30 16.52	GOOD POOR
6	1	GOONYELLA	GA	53,4	333,1	9.53 16.38 18.65	GOOD FAIR FAIR
6	2	BROADMEADOW	BW	43,0	328,6	7.80	GOOD
6	4	MORANBAH	MH	22,2	333,8	4.43	GOOD
6	5	WINCHESTER	WR	11,5	331,5	2.16	GOOD
6	7	SARAJI	SI	19,3	142,7	3.44	GOOD
7	1	GOONYELLA	GA	53,4	333,1	9.51 16.22	GOOD FAIR
7	4	MORANBAH	MH	22,2	333,8	4.44 10.29 16.41	GOOD FAIR FAIR
7	9	DYSART	DT	38,7	144,8	6.89 7.60 11.79 20.55	GOOD FAIR FAIR FAIR
7	10	PICARDY	PY	48,9	145,9	8.48 16.58 17.34	GOOD POOR POOR
7	11	KIRKCALDY	KY	57,5	148,0	9.44 15.81 24.77	GOOD FAIR FAIR
7	12	WARWICK	WK	69,0	139,3	13.17 22.02 27.44	GOOD GOOD FAIR
8	1	GOONYELLA	GA	385,5	325,5	63.11 106.08	FAIR POOR
8	4	MORANBAH	MH	364,6	324,9	51.18	FAIR
8	9	DYSART	DT	294,0	324,4	44.05 50.20 81.46	POOR FAIR POOR
8	10	PICARDY	PY	283,8	324,6	41.85 44.90 78.79	FAIR FAIR POOR
8	11	KIRKCALDY	KY	275,2	323,8	44.02	FAIR

SHOT	RECORDER	LOCATION	ABREV	DISTANCE	AZIMUTH	TRAVEL TIME	REMARKS
8	12	WARWICK	WK	264.1	325.9	39.40	FAIR
						42.10	POOR
						50.27	FAIR
						74.62	FAIR
9	11	KIRKCALDY	KY	266.0	322.7	39.90	FAIR
						42.58	FAIR
						75.20	FAIR
						100.04	FAIR
						113.07	FAIR
10	1	GOONYELLA	GA	49.2	332.2	8.84	GOOD
						19.95	POOR
						15.07	POOR
10	4	MORANBAH	MH	18.0	331.5	3.73	GOOD
						26.15	FAIR
10	9	DYSART	DT	42.7	146.6	7.62	GOOD
						8.16	FAIR
						12.91	POOR
						22.54	FAIR
10	10	PICARDY	PY	52.9	147.3	9.33	GOOD
						15.67	POOR
						10.15	FAIR
						19.42	FAIR
10	11	KIRKCALDY	KY	61.6	149.0	10.19	GOOD
						11.01	FAIR
						17.34	GOOD
						24.05	FAIR
						29.09	FAIR
10	12	WARWICK	WK	72.9	140.6	13.91	GOOD
						15.51	POOR
						22.89	FAIR
10	18	CHARLEVUE CREEK	CC	192.4	143.0	30.84	FAIR
						32.41	FAIR
						33.98	FAIR
						35.06	FAIR
						54.53	POOR
11	1	GOONYELLA	GA	236.8	336.8	36.89	FAIR
						38.26	GOOD
						65.81	FAIR
						67.53	GOOD
11	4	MORANBAH	MH	205.8	337.5	32.13	FAIR
						33.90	GOOD
						45.84	POOR
						58.18	POOR
11	5	PEAK DOWNS	PD	185.3	338.2	29.61	FAIR
						30.57	FAIR
						54.33	POOR
						70.22	FAIR
11	9	DYSART	DT	146.3	341.5	24.53	GOOD
						41.23	POOR
						44.66	FAIR
11	10	PICARDY	PY	186.3	342.4	22.75	GOOD
						41.08	GOOD
11	11	KIRKCALDY	KY	187.4	342.5	21.81	GOOD
						27.99	FAIR
						37.84	FAIR
						41.09	GOOD
						69.67	FAIR
11	12	WARWICK	WK	120.4	348.7	20.40	GOOD
						36.67	FAIR
						74.84	FAIR
11	18	CHARLEVUE CREEK	CC	51.0	65.5	9.43	GOOD
						21.11	FAIR
						40.29	FAIR
12	1	GOONYELLA	GA	49.2	332.2	9.43	GOOD
						15.53	GOOD
						17.94	GOOD
12	4	MORANBAH	MH	18.0	331.5	4.31	GOOD

SHOT	RECORDER	LOCATION	ABREV	DISTANCE	AZIMUTH	TRAVEL TIME	REMARKS
12	9	DYSART	DT	42,7	146,6	7.73	GOOD
						8.78	FAIR
12	10	PICARDY	PY	52,9	147,3	9.39	GOOD
						10.35	FAIR
						19.04	POOR
						25.63	POOR
12	11	KIRKCALDY	KY	61,6	149,0	10.29	GOOD
						17.33	GOOD
						27.19	POOR
12	12	WARWICK	WK	72,9	140,6	13.09	GOOD
						15.88	GOOD
						22.73	GOOD
						31.99	GOOD
12	18	CHARLEVUE CREEK	CC	192,4	143,0	31.02	FAIR
						31.99	FAIR
						33.58	FAIR
						54.70	FAIR
						56.01	FAIR
13	11	KIRKCALDY	KY	57,3	148,0	9.52	GOOD
						15.84	GOOD
13	12	WARWICK	WK	68,8	139,3	13.21	GOOD
						21.97	GOOD
						27.35	FAIR
13	18	CHARLEVUE CREEK	CC	188,2	142,5	30.32	FAIR
						31.42	GOOD
						53.62	POOR
14	6	PEAK DOWNS	PD	185,5	338,2	26.79	FAIR
						69.81	GOOD
						29.53	FAIR
						30.41	FAIR
14	15	WILPEENA PARK	WP	78,2	5,3	13.68	GOOD
						23.63	POOR
14	17	MAYFIELD	MD	50,3	40,6	9.17	GOOD
14	18	CHARLEVUE CREEK	CC	51,0	65,2	9.44	GOOD
						12.47	FAIR
						31.66	POOR
15	13	FOXLEIGH	FH	93,3	139,2	16.01	GOOD
15	16	YARRABEE	YB	143,3	140,3	23.80	GOOD
						25.05	GOOD
						41.28	GOOD
						44.26	GOOD
15	17	MAYFIELD	MD	170,9	143,1	28.18	GOOD
						28.58	GOOD
						31.96	FAIR
						39.60	POOR
						49.33	POOR
15	18	CHARLEVUE CREEK	CC	192,5	142,9	31.11	FAIR
						54.66	FAIR
						55.73	FAIR
15	19	PEARL CREEK	PE	218,2	141,8	35.54	POOR
						62.78	POOR
15	21	CARINYA	CA	240,7	142,6	38.53	FAIR
						70.98	GOOD
						40.55	FAIR
16	6	PEAK DOWNS	PD	173,3	338,8	27.95	FAIR
						28.75	GOOD
						49.93	GOOD
16	13	FOXLEIGH	FH	93,4	358,1	16.14	GOOD
						16.76	FAIR
						27.88	POOR
16	16	YARRABEE	YB	60,5	27,1	10.91	GOOD
						11.91	POOR
						28.94	FAIR

SHOT	RECORDER	LOCATION	ABBREV	DISTANCE	AZIMUTH	TRAVEL TIME	REMARKS
16	17	MAYFIELD	MD	47,5	54,7	8.91	GOOD
						9.05	GOOD
16	18	CHARLEVUE CREEK	CC	53,5	78,5	9.97	GOOD
16	19	PEARL CREEK	PE	71,7	95,8	13.30	GOOD
						22.70	GOOD
16	21	CARINYA	CA	87,0	107,9	15.53	GOOD
						17.32	GOOD
						26.96	FAIR
17	6	PEAK DOWNS	PD	54,8	156,9	9.78	GOOD
						16.86	FAIR
17	13	FOXLEIGH	FH	143,7	145,8	23.63	GOOD
						24.80	FAIR
						25.74	FAIR
17	16	YARRABEE	YE	193,7	144,9	30.91	GOOD
						31.66	GOOD
						32.22	GOOD
						54.56	GOOD
17	17	MAYFIELD	MD	231,8	146,5	34.34	GOOD
17	18	CHARLEVUE CREEK	CC	243,4	146,1	36.87	FAIR
						39.13	GOOD
						67.86	FAIR
17	19	PEARL CREEK	PE	268,8	144,9	40.25	FAIR
						44.65	FAIR
						45.04	POOR
						75.85	FAIR
17	21	CARINYA	CA	291,4	145,3	42.97	FAIR
						47.95	POOR
18	14	BARWON PARK	BP	105,8	138,9	17.83	GOOD
						19.21	POOR
						35.15	FAIR
						37.03	FAIR
18	15	WILPEENA PARK	WP	119,6	140,6	19.93	GOOD
						20.42	FAIR
						21.13	FAIR
						37.89	POOR
18	16	YARRABEE	YE	139,0	139,6	23.05	GOOD
						24.45	GOOD
						40.20	FAIR
						43.12	GOOD
18	17	MAYFIELD	MD	166,6	142,6	27.39	GOOD
18	18	CHARLEVUE CREEK	CC	188,2	142,4	30.32	GOOD
						31.34	FAIR
						31.76	FAIR
						52.94	POOR
18	19	PEARL CREEK	PE	213,9	141,4	34.07	POOR
						61.46	POOR
						34.97	POOR
18	21	CARINYA	CA	236,4	142,2	36.31	GOOD
						37.83	FAIR
						38.69	FAIR
						66.96	FAIR
19	3	ISAAC RIVER	IR	346,3	325,0	51.06	FAIR
						54.35	FAIR
						57.94	FAIR
						75.85	POOR
19	14	BARWON PARK	BP	217,9	326,0	34.04	FAIR
						35.55	FAIR
						59.52	POOR
19	15	WILPEENA PARK	WP	203,8	325,5	32.13	FAIR
						33.48	GOOD
						56.79	GOOD
19	16	YARRABEE	YE	184,8	326,9	29.95	GOOD
						31.10	FAIR
						51.67	POOR

SHOT	RECORDER	LOCATION	ABREV	DISTANCE	AZIMUTH	TRAVEL TIME	REMARKS
19	17	MAYFIELD	MD	156,6	325.2	25.87	GOOD
						47.11	FAIR
19	18	CHARLEVUE CREEK	CO	135,1	325.9	22.71	FAIR
						23.46	FAIR
						23.81	POOR
						24.40	POOR
19	19	PEARL CREEK	PE	109,9	329.0	18.54	GOOD
						19.55	FAIR
						28.04	FAIR
						36.99	GOOD
						42.69	POOR
						66.90	GOOD
19	21	CARINYA	CA	87,2	329.0	15.07	GOOD
						18.33	FAIR
						32.21	POOR
						58.14	POOR
						34.70	FAIR

TABLE 4 - Tape recorder parallax corrections in seconds as at July 1973 referred to the radio channel

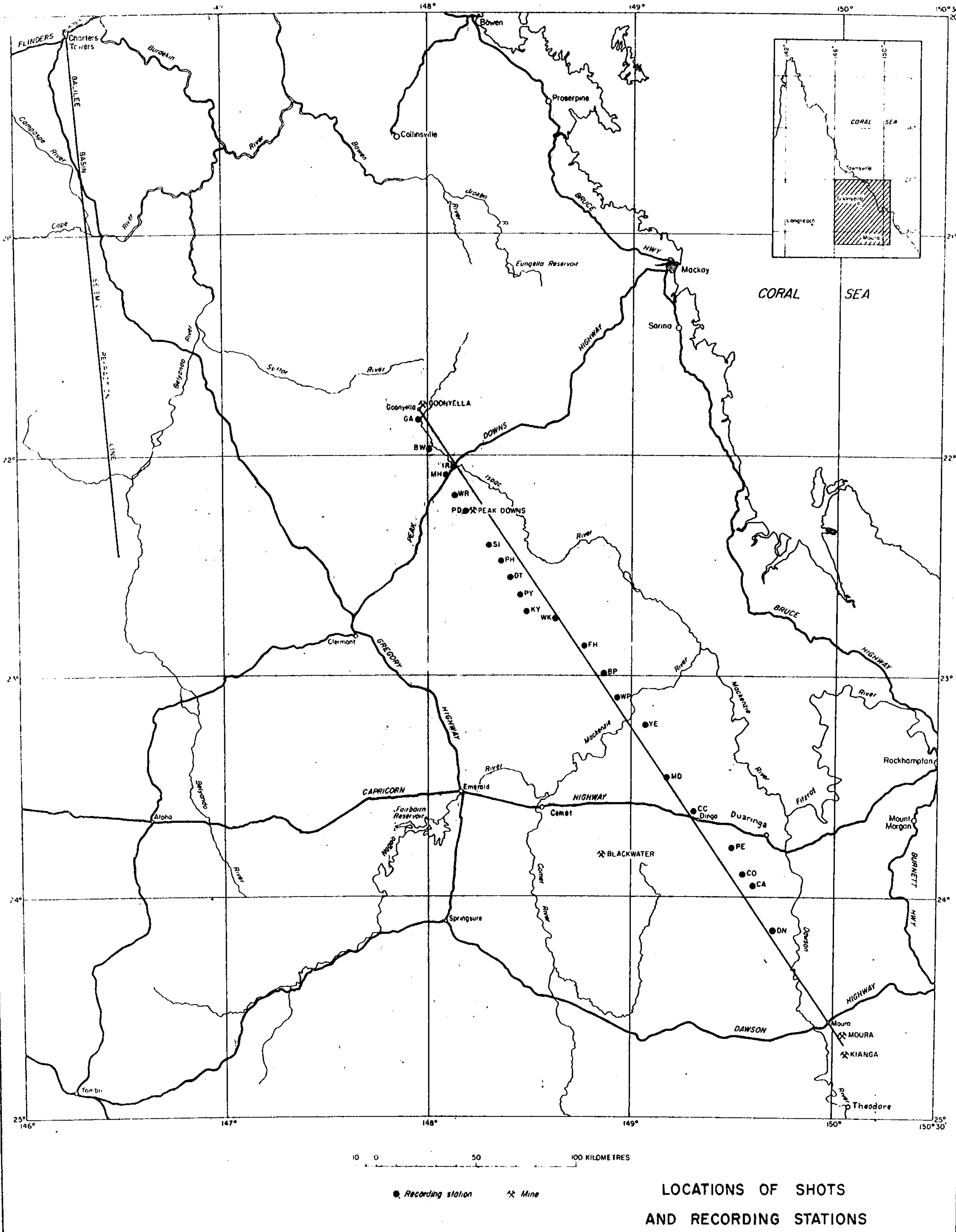
Recorder	Radio	Clock	Low gain	High gain
P.I. No. 1	Reference	-0.28	0.0	-0.30
" " 2	"	-0.04	+0.01	-0.06
" " 3	"	-0.03	0.0	-0.05
" " 4	"	-0.05	0.0	-0.07
" " 5	"	-0.04	0.0	-0.06
" " 6	"	-0.03	0.0	-0.05
Akai No. 7	"	0.0	+0.01	+0.01
" " 8	"	0.0	0.0	0.0
" " 9	"			
" " 10	"	0.0	0.0	0.0
" " 11	"	0.0	+0.01	+0.01
" " 12				
" " 13	"	+0.01	-0.02	-0.02
" " 14	"	0.0	+0.01	+0.01
" " 15	"	0.0	+0.01	+0.01
" " 16	"	+0.01	0.0	0.0
" " 17				
" " 18	"	0.0	0.0	+0.01
" " 19	"	0.0	+0.01	0.0
" " 20	"	+0.01	-0.01	0.0
" " 21	"	+0.01	+0.03	+0.02

Note: Only PI recording systems 1 to 6 and Akai reading systems 7, 8 and 9 were used on the Bowen Basin Survey.

TABLE 5 - Recorder Performance

1 = arrival received
* = arrival not received

Station Location	Shot No.																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Goonyella				*	1	1	1	1		1	1	1							
Broadmeadow	*	1	1	*	1	1													
Isaac River																			1
Moranbah	1	1	1	*	1	1	1	1		1	1	1							
Winchester	1	1	1	1	1	1	1	1											
Peak Downs	*	1	1	*	1	1	1	*		1	1	1	1	1	1	1	1	1	
Saraji	1	1	1	*	1	1													
Phillips Creek	1	*	*	*	*	*	*	*		*	*	*							
Dysart							1	1		1	1	1							
Picardy							1	1		1	1	1							
Kirkaldy							1	1	1	1	1	1	1						
Warwick							1	1		1	1	1	1						
Foxleigh													*	*	1	1	1		
Barwon Park																		1	1
Wilpeena Park														1	*	*	*	1	1
Yarrabee															1	1	1	1	1
Mayfield														1	1	1	1	1	1
Charlevue Creek										1	1	1	1	1	1	1	1	1	1
Pearl Creek															1	1	1	1	1
Coomooboolaroo															1	1	1		
Carinya															1	1	1	1	1
Dawson																		1	1

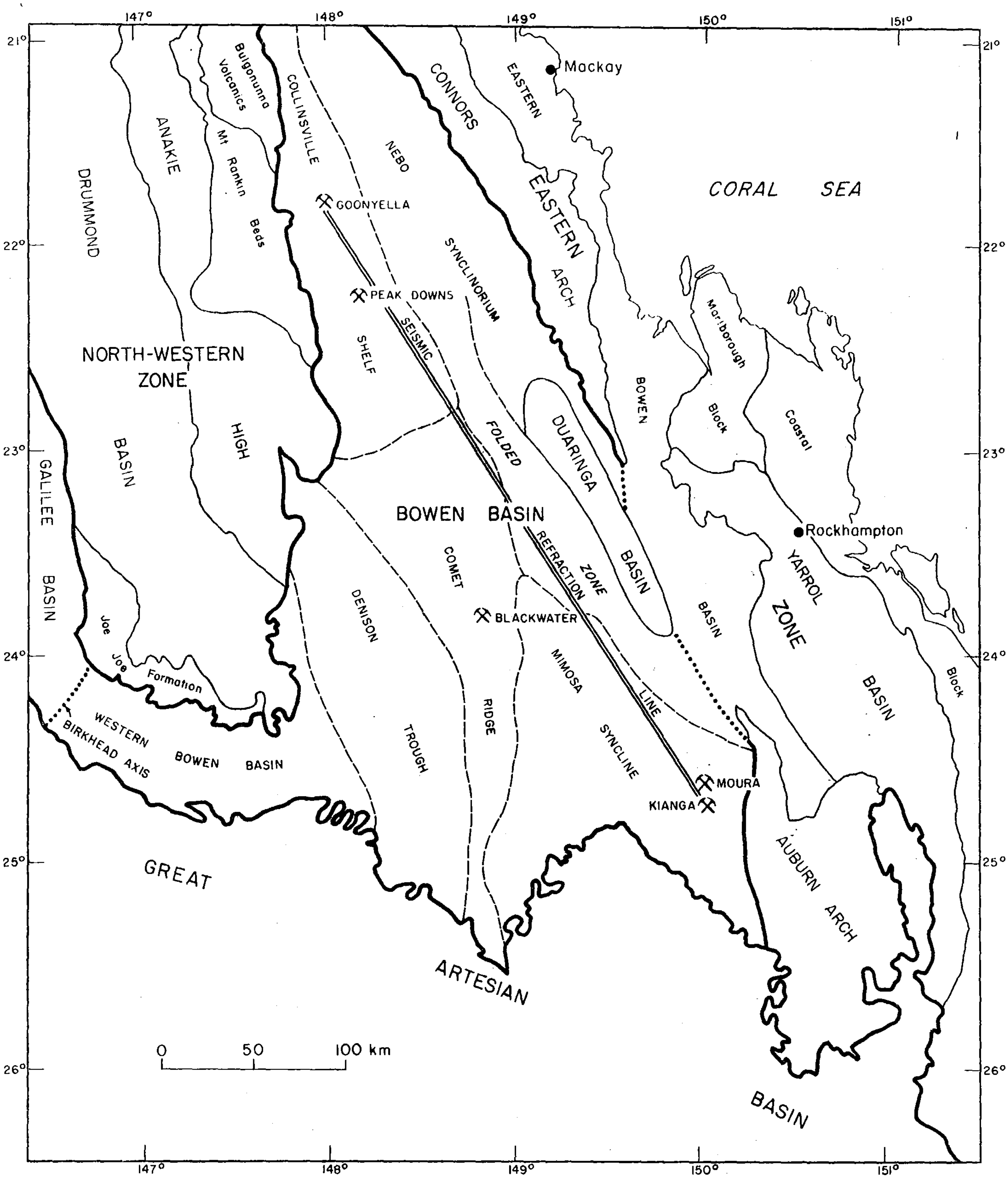


LOCATIONS OF SHOTS AND RECORDING STATIONS

TO ACCOMPANY RECORD NO. 1973/212

F55/B3-103AR

PLATE 2



Major boundary

Major boundary (inferred)

Minor boundary

Minor boundary (inferred)

Mine

Town

MAJOR STRUCTURAL AND DEPOSITIONAL UNITS

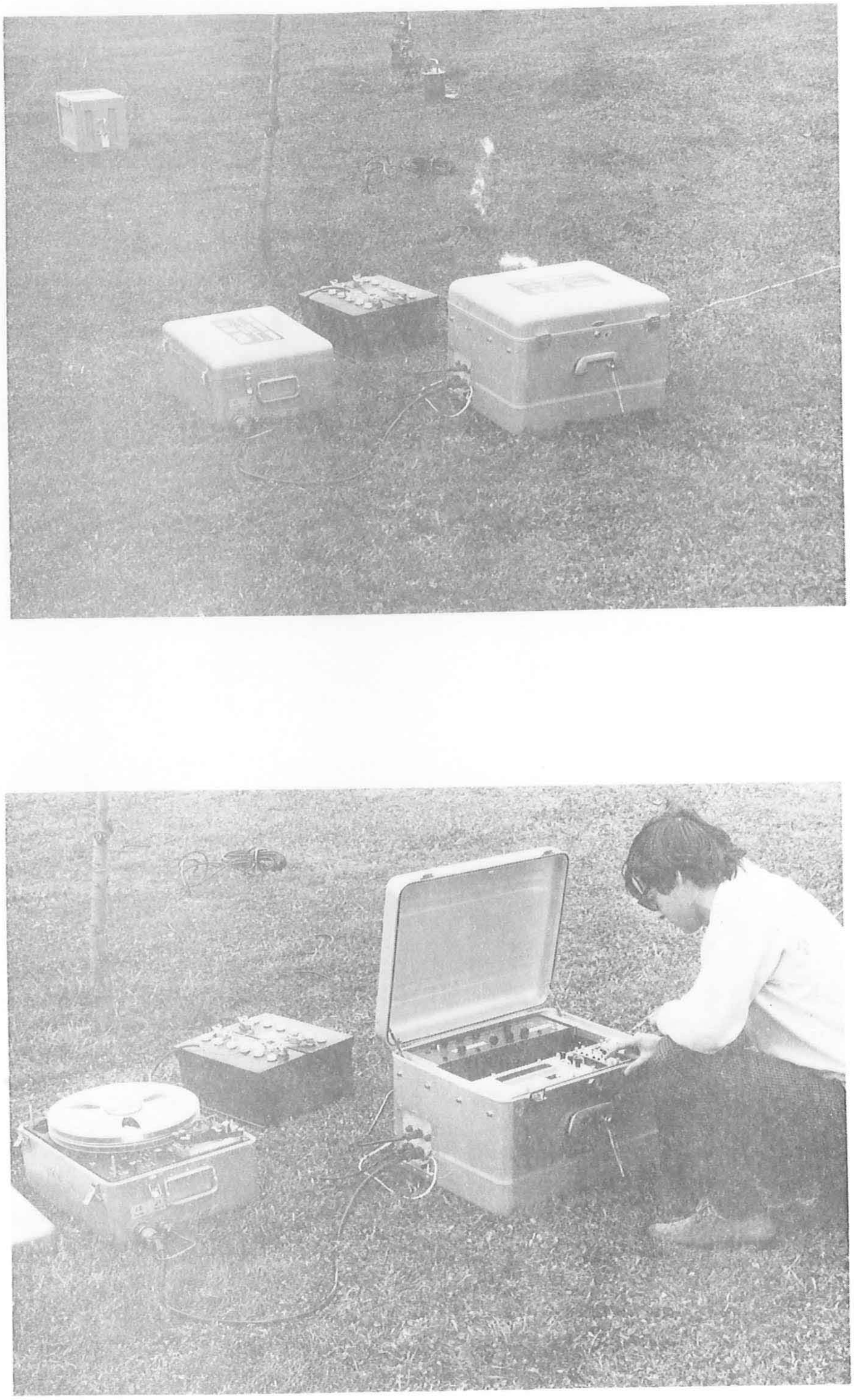


Plate 3 - BMR remote seismic recording equipment.