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PILBARA CRUSTAL SURVEY, 1977:

OPERATIONAL REPORT

by

B.J. Drummond

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ABSTRACT

The Pilbara Block is an Archaean craton with rock ages of 2600 m.y. and older. It is separated from the Yilgarn Block in the south by the Proterozoic Hamersley, Bangemall, and Nabberu Basins. The structural relation between the cratons is masked by the sediments of the basins.

From July to September 1977, BMR used routine blasts at 7 iron ore mines as energy sources to make seismic recordings at 137 sites along traverses which both crossed and paralleled the regional geological strike. Gravity measurements were made at over 2000 stations along roads in the area.

The aims of the investigation were to delineate crustal structure within the Pilbara Block and below the sedimentary basins between the Pilbara and Yilgarn Blocks.

This Record describes the fieldwork and tabulates the shot and station information. Two record sections are presented as examples of record quality. No interpretation is reported here; this will be published elsewhere. The purpose of this Record is to compile into one document the basic survey information, for reference and later use.

1. INTRODUCTION

From June to September 1977, BMR undertook the Pilbara Crustal Survey (PCS), a detailed deep seismic refraction and gravity investigation of the crust in the Pilbara region of Western Australia. It was the first such survey to be undertaken in the northwest of Australia.

The Pilbara region was chosen for a crustal investigation for several reasons, the most significant being:

1. The area is richly mineralised. More than 25 minerals are present in economic amounts (The Pilbara Study Group, 1974). The most commercial mineral is iron ore, and yet theories on the source of the mineralisation are still speculative.
2. The Pilbara region appears to be the oldest part of the Australian continent. The crustal model derived from the PCS will be valuable for studying crustal evolution.
3. Little is known about structural relations between Precambrian cratons in Australia. This is the first Australian crustal investigation to study in detail the mobile belt between two Precambrian cratons.
4. Unlike the rest of the Western Australian shield, the Pilbara region has several conveniently located iron ore mines which fire large blasts. These produce energy suitable for seismic refraction surveys capable of delineating lower crustal and upper mantle structures.

For the PCS, blasts at seven iron ore mines were used as seismic sources. Portable field seismographs were moved between the mines, along traverses both parallel to and across the gross geological features of the region. Gravity and magnetic readings were made at bench-marks along roads and tracks in the area. The positions of the iron ore mines, seismic stations, and road gravity traverses are shown in Figure 1.

Geological summary

The geology of the region is shown in Figure 1, which is based on the geological map of Australia (BMR, 1976a). Most of the following discussion is drawn from Memoir 2 of the Geological Survey of Western Australia (GSWA, 1975).

The oldest rocks in the region are the greenstone belts of the Archaean Pilbara and Yilgarn Blocks. They are intruded by several phases of granites which have ages of 2600 to 2800 m.y. in the Yilgarn Block and 2600 to 3400 m.y. in the Pilbara Block. Archaean sedimentary successions overlie both the greenstone belts and the granites.

Lower to Middle Proterozoic sediments and volcanics of the Hamersley Basin unconformably overlie the Pilbara Block. The Fortescue, Hamersley, and Wyloo Groups, collectively named the Mount Bruce Supergroup, comprise the stratigraphic succession of the Hamersley Basin. The structural complexity increases southwards across the basin. In the north, the sediments dip at a few degrees to the south. Farther south the dips increase. South of the axis of the basin, the sediments and volcanics dip to the north. Along the southern margin of the basin, the folding is intense with dips close to the vertical, and in some places the rocks are overturned to the north. The metamorphic grade ranges from lower greenschist facies in the north to amphibolite facies in the south (Horwitz & Smith, 1978).

The sediments of the Nabberu Basin (Hall & Goode, 1978) unconformably overlie the Yilgarn Block in the south of the survey area. They dip to the north, and the metamorphic grade and intensity of folding increase northwards across the basin.

The Bresnahan and Mount Minnie Groups were deposited in two small, structurally controlled basins, and unconformably overlie the Mount Bruce Supergroup. They are in turn overlain by the Bangemall Group, which also overlies the Nabberu Basin sediments in the south.

The Gascoyne Province, in the west, is a structurally complex region with migmatised Archaean rocks, Wyloo Group sediments, and relict synclinal remnants of Bangemall Group rocks.

The Patterson Province, in the east, has not been studied in detail but is considered (Blockley & de la Hunty, 1975) to be an eastern extension of the Pilbara Block.

The area has been a positive landmass since the Middle Proterozoic. Rejuvenated erosional surfaces testify to regional uplift on several occasions since the Tertiary (Hickman & Lipple, 1975). Phanerozoic sedimentary basins flank the area in the east and west and out to sea in the north. The entire region has superficial Tertiary and Quaternary sand and soil cover.

Aims of the investigation

The survey was designed after consultation with geologists in BMR, the Geological Survey of Western Australia, and CSIRO Division of Mineralogy. The road gravity traversing was designed to supplement the regional data already available (BMR, 1976b) and to aid the seismic interpretation.

The aims of the survey were:

1. To investigate the major structures within the Pilbara Block.
2. To investigate the major structures between the Pilbara and Yilgarn Blocks and, if possible, determine the mechanism of formation of the belt - for example, crustal extension, downwarping, rifting or some other mechanism.
3. To investigate, where possible, the crustal structure of the northern Yilgarn Block.

2. SEISMIC SURVEY PLANNING AND DESIGN

Initial planning

A study was made of the seismograms from the Marble Bar (MBL) and Meekatharra (MEK) seismological observatories to determine if the mining blasts were suitable seismic sources. Most were, and the blasting was frequent enough to allow a comprehensive survey to be planned.

D.M. Finlayson of BMR and V. Ingham of the Australian Survey Office visited the survey area in September and October 1976 to:

1. Visit all the iron ore mines in the area and: (a) explain the survey proposals, (b) request co-operation from the mining companies, (c) arrange for the mining companies to provide lists of shots fired each month, (d) obtain from the companies sufficient information for the Survey Office to be able to convert mine co-ordinates of shots to latitudes and longitudes and (e) arrange access to the mine sites for BMR staff to time explosions.
2. Determine the logistics of surveying the positions of the seismic and gravity stations.
3. Determine the availability of survey support facilities, especially for equipment and vehicle maintenance, and the availability of accommodation.

All mining companies agreed to co-operate fully in the project and to forward to the Mundaring Geophysical Observatory monthly summaries of their shooting logs.

Seismic observation objectives

Most seismic interpretation methods require the shots and stations to be positioned along straight lines, and therefore three lines of recording stations were occupied between the mines. The positions of the stations are shown in Figure 1:

1. Line ABC had its northern end in the north of the Pilbara Block. Southwards, it crossed the granites and greenstone belts of the block, the sediments of the Hamersley, Bangemall and Naberu Basins, and had its southern end at Meekatharra, in the Yilgarn Block. It crossed the geological strike. Shay Gap, Sunrise Hill, and Goldsworthy (at A and G) provided shots at the northern end of the line. Newman (B) was in the centre, and a specially prepared blast was fired at Meekatharra (C) at the southern end (see section 4).
   Recorder spacing on this line was about 20 kilometres, and less near the blasting centres. The sections AB and BC were between 300 and 400 km long, and the total length of line ABC was about 700 km. Because it was expected that the first arrivals at distances beyond about 150 km would be from beneath the Moho, line ABC was expected to give information on both crustal and upper mantle structures. Further information was expected from earthquake sources in the Banda Sea (a large earthquake occurred at about 14.09 Western Australian Time on 19 August when the recorders were deployed between B and C).
2. Lines GHDE and AHDE were across strike. For most of their length they crossed the Pilbara Block, both where it is exposed in the north and where Hamersley Basin sediments overlap it in the south. Tom Price and Paraburdoo, at D, provided blasts in the centre of the lines, which extended south of Paraburdoo into the region of Wyloo and Bangemall Group sedimentation and the Gascoyne Province. Unfortunately there was no shot at the southern end of these lines. Station spacing was about 20 km, and the lines were designed to give crustal information within the Pilbara Block and across the southern margin of the Hamersley Basin.
3. Line FDB was along the axis of the Hamersley Basin from Pannawonica in the west (at F) through Tom Price (D) to Newman in the east (B). Station spacing was about 20 km between F and D, and 8 to 10 km between D and B. This line was to provide upper crustal information between

the two major north/south traverses, and lower crustal and sub-Moho information along the axis of the Hamersley Basin.

It had been hoped to extend line GDE farther south to the Yilgarn Block, and several small traverses had been planned for fan shooting from Newman and Panawonica. However, insufficient time was available to complete this work.

The Australian National University (ANU) deployed 28 tape recorders in the region. Six were used as mine monitors and twenty-two were installed in a line between Meekatharra and Pannawonica. Several records from their mine monitors were used to time mine blasts.

3. SEISMIC RECORDING OPERATIONS

Survey logistics

The survey area was large and had poor communication facilities. An office was established in Wittenoom, which is in the centre of the survey area. Communications between survey personnel in the field was by two-way radio, and a base-station transmitter was set up at the office, which also had telephone communications with the mines. Equipment was serviced and repaired, and the batteries for the field seismographs were recharged, at the office.

Recording equipment

Four types of seismic equipment were used:

1. Mine Monitors

Six Precision Instrument (PI) slow-speed, frequency-modulated tape recorders were set up for the duration of the survey to provide accurate times for the shots. They have been described by Finlayson (1976). Their positions, and those of the 6 ANU mine monitors, are listed in Table 2. One was placed near Goldsworthy to monitor the blasting at the three northern mines. One was placed near Newman, one at Pannawonica, and one between Tom Price and Paraburdoo. A fifth was set up at Wittenoom, and a sixth was set up near the road from Wittenoom to Port Hedland. The last two systems were backups if any of the four near the mines failed. For the last five weeks of the survey the recorder from Wittenoom was used as a mobile field seismograph.

2. Shot timing equipment

Some mine monitors, especially the back-up monitors, were many kilometres from the shots they were timing. To measure the travel-times from the mines to the monitors, a shot at each of the mines was recorded on equipment placed very close to the blasts.

The equipment used was a 2Hz SIE geophone, a (BMR designed) TAM 5 seismic amplifier and a Hellige Helcoscripter HE 16 chart recorder. A Labtronics time signal receiver provided time signals.

3. The Wittenoom drum seismograph

To determine whether shots had been fired, a Sprengnether MEQ 800 drum seismograph was set up near the Wittenoom mine monitor. Its records were changed every two days and checked for blasts. The origin of the blasting was determined from S-P times, and from the time of day the blast was fired, a characteristic which proved quite reliable (see section 5).

4. Portable field seismographs

One hundred and thirty-seven sites were occupied by portable field seismographs using four-channel, slow-speed frequency modulated tape recorders (Finlayson, 1976). The seismographs were programmed to record from 0900 to 1800 hours every day. Battery and tape duration was about 10 days, but the recorders were usually shifted to new sites after about five days.

Surveying of recording stations

Up-to-date topographic maps at 1:100 000 scale were available for most of the survey area. At the time of the survey they were either published maps, pre-publication dyeline prints or orthophoto maps. Aerial photographs were available for every site.

When the recorders were installed at each site, the position was marked on an aerial photograph. It was then transferred to the topographic map and the latitude and longitude were scaled directly in degrees and minutes from the published maps and pre-publication prints, or in Australian Metric Grid co-ordinates from the orthophoto maps. The co-ordinates had an estimated accuracy of better than 100 m.

The positions of four stations could not be transferred with certainty from the aerial photographs to the maps because the maps were poor quality pre-publication prints. The Australian Survey Office provided the co-ordinates by relating the station position to the flight path diagrams of the photographs.

On six occasions in the field, the station positions could not be marked on either the aerial photographs or topographic maps. They were placed near bench-marks, the co-ordinates of which were provided by the Survey Office. All seismic station co-ordinates are listed in Table 1 together with recorder serial numbers and amplifier gains.

4. THE MEEKATHARRA BLAST

A charge of 11 tonnes of explosive was fired in a disused mines shaft near Meekatharra on the southern end of line ABC. The charge was constructed by a contractor under the guidance of a shooter from BMR and a mining inspector from the Western Australian Department of Mines. The dimensions of the mine and charge are shown in Figure 2. The details of the blast are given in the report of the shooter (Appendix A), and also in the report of the mining inspector (Appendix B), who also discussed the procedure for choosing a suitable mine shaft and the safety precautions observed for the blast.

The explosive used was Nitramon WW-EL, part of a gift to BMR by West Australia Petroleum (WAPET). The explosives were trucked from Perth to Meekatharra on 9 and 10 August, and were loaded into the mine on 11 August. The loading took about 6 hours.

The blast was timed by comparing the time-break from the shooter's shot-box with time signals from a Labtronics receiver. A geophone placed near the blast gave a similar time. The shot time was 10 h 10 m 00.36s (WAT) on 15 August, 1977.

The blast was recorded at seismological observatories over 700 km away in the south of the Yilgarn Craton (Gregson, 1978). Its estimated magnitude was $M_L = 3.0$ (Gregson, 1978) and it generated ground accelerations of 0.55 and 0.30 ms^{-2} at 500 m and 1000 m from the blast respectively.

5. IRON ORE MINE BLASTS

Shot details

As mentioned previously, the mining companies provided BMR with shot logs listing shot sizes, co-ordinates, and approximate times. The Marble Bar (MBL) and Meekatharra (MEK) seismograms and the Wittenoom drum seismograph records were searched for the shots to provide more accurate times at which to scan the mine monitor recorders.

For most shots, the nearest mine monitor was used for timing purposes. However, every monitor missed at least one shot because their batteries were flat, tape had run out, or they had broken down. On some occasions, the ANU mine monitors were used, but for some shots, more distant BMR mine monitors had to be used.

When using distant monitors to time blasts, care was taken to ensure that the same phase was used for all shots. Most distant monitors were several hundred kilometres away, so the first arrival was generally P_n, which was quite small and hard to pick accurately. However P_g, which followed shortly after, was usually a comparatively large phase and was used for timing the shots. A characteristic part of the waveform was used, rather than the actual onset of the phase. The mine monitors used to time the blasts are listed in Table 2.

Although this method of shot timing worked reasonably well in the PCS, it is recommended that in future surveys the monitor recorders be placed as near as possible to the mines as in some cases the seismic signals at the monitors were very emergent, making accurate picking of the arrivals difficult.

A list of blasts fired during the recording period of the PCS is given in Table 2. One hundred and fifty-four shots are listed. One hundred and fifteen shot times have been determined. Eighteen of the shots listed were not reported but were found on the Marble Bar and Goldsworthy recorders. Ten shots reported by the mining companies could not be found at or near the times reported. Several of those listed as unreported may be reported blasts that cannot be found on the monitor records. The discrepancy between the actual shot times and those reported was often considerable and it is conceivable that errors have been made in reporting the times.

The three mines in the north, Goldsworthy, Sunrise Hill, and Shay Gap, all fired their blasts at about the same time of day. Consequently on many occasions several shots were reported at the same time. S-P times to the Goldsworthy monitor were used to sort the shots into order. This method was also used to work out the origin of the unreported blasts, all of which originated at the three mines in the north.

The positions of the unreported shots are not known accurately so the corrections to the mine monitor times cannot be calculated.

Shot statistics

The three northern mines, Goldsworthy, Sunrise Hill, and Shay Gap, fired more often than the other mines. Goldsworthy fired several shots per week, with sizes ranging up to about 80 tonnes of explosive. The other two mines fired almost every weekday during the survey period, but their shots were much smaller. Shots at these three mines were generally fired between 11.00 and 12.00 with some at about 15.30.

Newman fired at least once per week, generally about 09.30. Some shots were fired at 11.00. The Mount Newman Mining Company did not provide details of the quantities of explosives used, but the number of holes in the shots indicates that the charges were probably in excess of one hundred tonnes. However, the delays within the charge, and the large area of the shots, reduced the effective seismic energy; nevertheless, the energy from the blasts is remarkably coherent between some shots, as can be seen in Figure 4b, which is a record section of traces from shots 088 and 089.

The Tom Price and Paraburdoo mines both fired at least one large blast per week. Most shots at these mines were over 100 tonnes; one Tom Price charge was almost 600 tonnes. The shots were all fired between 12.00 and 12.30.

Pannawonica fired several shots over 100 tonnes, but the delays in the blasts were very large and the seismic energy was noisy and low in amplitude. The Pannawonica shooting had no set time pattern, as in the other mines, but was at any time of day. They tended to fire several shots within a few days and then wait several weeks before the next shots.

6. GRAVITY SURVEY

(H. McCracken)

Gravity survey objectives

Before the PCS only regional gravity coverage of the area was available. It had been done by helicopter on a one-tenth of a degree grid, so that gravity stations were about 11 km apart. Some road traversing had been done along the major roads but was considered insufficient to support an interpretation from the seismic survey. A program of road gravity traversing was therefore planned, to be done concurrently with the seismic recording.

Gravity measurements were done in two ways:

1. Road gravity traversing, where gravity was measured at bench-marks beside roads and tracks throughout the area.
2. Helicopter traversing in more remote areas.

The aims of the gravity traversing were:

1. To provide closely spaced gravity values along the seismic lines for checking the seismic models.
2. To provide closely spaced gravity values across areas of high gradient to better define points of inflection on the gravity profiles. The Gravity Map of Australia (BMR, 1976b) was used to define such areas.
3. To provide accurate ties between isogal stations in the region.
4. To determine whether structures within the Hamersley Basin sediments reflected basement structures. The helicopter was used on five traverses for this work.
   (a) Traverses 1 and 2 crossed the Wyloo Anticline, a small outcrop of supposed Archaean basement around which Hamersley Basin sediments are draped. The Wyloo Anticline lies outside the gravity anomaly generally supposed to represent the southern margin of the Pilbara Block.
   (b) Traverses 3 and 4 crossed the east/west trend of the Hamersley Basin folding.
   (c) Traverse 5 was parallel to the general east/west Hamersley Basin fold texture. Only the central portion of the traverse required the helicopter, as portions at each end were accessible by road.

5. To make a traverse across the Fortescue River valley at the request of Hamersley Exploration in return for the provision of detailed gravity data in the Hamersley Basin. The traverse was on one of their prospecting areas. They provided all levelling information necessary.

The Australian Survey Office undertook the levelling for the road traverses. They provided bench-mark descriptions for all existing highway bench-marks. Where the bench-marks were more than 4 km apart, they placed intermediate pegs to reduce the spacing. Along roads which had not been levelled, they installed and levelled new bench-marks at 4 km intervals and intermediate pegs every 2 km. Table 3 lists the number of gravity stations at bench-marks and intermediate pegs. The helicopter stations are also included in the table.

All of the gravity traverses are shown in Figure 1.

All of the planned gravity work was accomplished and several extra traverses were also undertaken. 2203 new gravity stations were established, and 87 old stations were reoccupied.

Equipment

Two LaCoste & Romberg gravity meters (G20 and G101) were used, the second being used to check the drift of the first. Where site elevations were not available - for example, when extra stations were read in areas of high gradient, and at helciopter stations - two Mechanism microbarometers were used for levelling.

Road traverse procedure

The drift of LaCoste gravity meters consists of small tares and only a small long-term drift (Wellman & others, 1974). The long term drift of the meters used on this survey was only 0.1 $\mu m\ s^{-2}$ per day for G20, and 0.2 $\mu m\ s^{-2}$ per day for G101. It was therefore decided not to use conventional drift control (e.g., ladder sequence (ABC ... CBA) or full drift control (ABABCB ...)). Instead one-way traversing around closed loops was used. Tares or misreadings were detected on long loops by reading a second gravity meter at every second or third station. If, for logistic reasons, travelling along a road a second time was necessary, repeat readings were taken at selected stations to provide tighter control. The network of loops was interlocked, providing a means of locating and distributing errors. This survey method had the advantage of saving time and reducing petrol costs.

Ties were made to Isogal stations at Port Hedland, Roebourne, Mount Vernon, Mundiwindi and Meekatharra. In addition several stations of the BMR regional helicopter survey were reoccupied on each 1:250 000 map sheet.

Helicopter traverse procedure

A Bell Jet Ranger helicopter of Rotor Services, Darwin, was used for the helicopter traversing. Only one meter was used for each traverse, with repeat readings at a base station to check for meter drift. Navigation was by aerial photographs where available. Where photographs were not available 1:100 000 topographic and orthophoto maps were used. Levelling was by means of Mechanism microbarometers and contoured topographic maps.

Computations in the field

Because not all final height data were available to the field crew, final reduction of the data in the field was not possible. However, approximate Bouguer anomaly values were calculated in order to check the readings in areas of high gradient, and to compare the performance of the two meters.

Reduction of gravity data

Gravity intervals between tie points were calculated for each meter after corrections had been made for earth tides. The meter calibration factors used were those determined in 1975 by measurements along the Australian Calibration Line, namely 1.000395 for G20 and 1.002665 for G101. These scale factors gave consistent results for the two meters.

The unweighted root-mean-square value of the loop misclosures is 0.6 μms^{-2}. For the network adjustment the loop misclosures were weighted taking into account the length of traverses, the number of meters used, times when meters went off heat or were bumped, and long delays between readings. The adjustment was carried out twice, once tying to all Isogal stations (a fixed adjustment), and once keeping only the value of Port Hedland fixed (a free adjustment). The values calculated for the remaining Isogal stations during the free adjustments are given in Table 4 and compared with the May 1965 Isogal values. Since the interval between Mt Vernon and Mundiwindi was well controlled by a direct tie for the May, 1965 adjustment, there appears to be an error of 1.4 μms^{-2} in the interval measured by the road survey.

A comparison of gravity values at reoccupied stations showed that half agreed to better than 0.1 $\mu\ ms^{-2}$ and only one-quarter differed by more than 0.3 μms^{-2}. Figure 3 is a gravity map of the region. All data now available were used in its compilation.

Terrain corrections

Terrain corrections were not calculated for the gravity stations. In general the stations were in flat terrain. However, several traverses followed deep gorges that transect the ranges in the Wittenoom area. It was estimated, using two dimensional modelling, that a station at the bottom of a typical gorge would have a terrain correction of about 50 μms^{-2}.

7. MAGNETIC SURVEY

A proton magnetometer (G816) was carried by the gravity party and a reading of total magnetic intensity made at every gravity station. In a number of places a consistent reading could not be obtained, probably because of high magnetic gradients.

No attempt was made to remove the diurnal variation of the magnetic field. The data will be added to the third-order magnetic survey data bank compiled by the BMR Observatory Group, Canberra.

8. HEAT-FLOW MEASUREMENTS

During August, D. Denham of BMR made a supervisory visit to the field survey. During his visit he logged 13 holes for heat flow; eight were logged to depths of less than fifty metres because the holes were blocked. Core from all holes that were logged was obtained from the relevant authorities and sent to Canberra for laboratory measurement of thermal conductivity.

The results of the logging were published by Cull & Denham (1979). The details of the wells logged are shown in Table 5. The wells are marked on Figure 1.

9. VELOCITY AND SPECIFIC GRAVITY MEASUREMENTS OF ROCK SAMPLES

Rock samples were collected at all recording stations where fresh rock crops out, and in cuttings along railway lines and roads in the regions. The specific gravities and compressional wave velocities of the samples were measured in the laboratory at atmospheric pressure.

The results are listed in Table 6. Some samples were distinctly layered; in Table 6, they are indicated by two velocity measurements, the upper one being perpendicular to the bedding and the lower one parallel to the bedding.

10. SEISMIC DATA PROCESSING AND RESULTS

Although it is not within the scope of this Record to present an interpretation of the data recorded during the PCS, we present a brief outline of the data processing before interpretation, and some of the data as an example of their quality.

The tapes were returned to Canberra after the survey, the shot times calculated and the field tapes replayed.

As each shot was found on tape, an analog chart record was made, and the seismic trace, either high or low gain, was then digitised. For digitising, the Regional Structural Surveys playback system was linked through an analog-to-digital converter to a Hewlett Packard 21MX computer. The analog signal was anti-alias filtered with a low pass filter of 20 Hz. The sampling interval was 16 ms. About three minutes of each seismic trace were digitised. The digital data were stored on disc for processing, and then archived onto magnetic tape.

Record sections were then drawn on a Calcomp drum plotter. Figure 4a is a record section of the Meekatharra blast data northwards along line CBA. Figure 4b is a composite record section of Newman blasts recorded south to Meekatharra. The traces in both figures have been digitally filtered in the bandpass 0.5 to 8.0Hz. Record sections such as these will form the basis of the seismic interpretation.

11. ACKNOWLEDGEMENTS

BMR would like to thank the iron-mining companies of the Pilbara for their enthusiastic support for the survey, access to their mines and the shot information they freely provided. On several occasions the mining company personnel gave their own time in order to help with information required for smooth survey operations. In particular, BMR would like to thank John Alderson of Goldsworthy Mining Limited; Chris Robinson and Ron Siwinski of Cliffs Robe River Iron Associates; John Roberts and Bob Brooks of Hamersley Iron Pty Ltd; and Bill Willis, Sam Kale, and Mal Kneeshaw of Mount Newman Mining Company Pty Ltd.

Several people and organisations in Wittenoom gave freely of their time, notably John Evans of Hamersley Exploration and Dick Zeelenberg of Western Mining. Hamersley Exploration lent BMR most of the aerial photographs used for the helicopter gravity traversing.

BMR would also like to thank Esso, Texas Gulf, Hamersley Exploration, and the Geological Survey of Western Australia for access to drillhole information and core for heat flow measurements.

Discussions with geologists and geophysicists from the CSIRO Minerals Research Laboratories, the Geological Survey of Western Australia, and the Australian National University helped in the planning of the survey.

Professor A.L. Hales of the Research School of Earth Sciences, Australian National University, made available the records from the ANU mine monitors operating in the Pilbara at the time of the survey.

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APPENDIX A

REPORT BY M. PRESTON-STANLEY, SHOT FIRER

On 11 August 1977 a charge of 11 330 kg of Nitramon WW-EL explosive was loaded into a mine shaft about 7 km north of Meekatharra. The mine shaft was about 13 m deep with a drive running off it in an easterly direction for about 14 m. Midway along the drive was a stope heading back towards the shaft at about 75° (see Figure 2).

The explosive was in the form of 374 cannisters, each 20.5 cm in diameter and weighing 30.3 kg. The cannisters were laid side by side across the drive, then stacked in layers to the roof of the drive. Each such stack was primed with three AN 60 primers connected by branch lines to three trunk lines of ICI premium Cordtex attached to the roof. The trunk lines were attached to the roof of the drive for protection against chaffing. In the shaft they were carried inside 2.5-cm tubular steel conduits.

When the drive was completely loaded, props were placed under the conduits to avoid damage during backfilling. The shaft was backfilled with loose dirt, ensuring that the drive was filled as far as possible.

Initiation of the charge was to be by three no. 8 electric detonators attached to each trunk line. The detonators were in turn linked up in series to an Electrotech BC8A Blaster via about 500 m of Twin-flex.

At 10.10 a.m. on the 15 August 1977, after the necessary safety precautions has been observed, the shot was fired. After close scrutiny by Mr E. Shenton (of the WA Mines Department) and myself, it was agreed that the shot had been a complete success.

Physical results of the blast and dimensions of the ensuing crater can be found in the report made by Shenton.

APPENDIX B

REPORT BY E. SHENTON, INSPECTOR OF MINES, DEPARTMENT OF MINES, WESTERN AUSTRALIA*

Introduction

BMR approached the Department of Mines (WA) in December 1976, stating that it would like to detonate about 10 tonnes of explosives in a disused mine near the town of Meekatharra between July and September 1977.

Our assistance was requested in selecting a suitable site and recommending experienced miners, preferably from the local district, to assist with the preparation of the site and charging the explosive.

Site selection

The quantity of explosives to be used in the blast was to be about 10 tonnes.

Specifications for the required site were as follows:

(a) Not more than 30 km from Meekatharra.
(b) A heading off a shaft more than 10 m below the surface.
(c) Away from current mining activity.
(d) Reasonably accessible.
(e) Dry.
(f) Preferably more than 5 km from the town of Meekatharra (safe distance for noise and vibration effects).

As the only operating mine in the district was on the northern outskirts of the town it could be regarded as part of the town area. Originally two sites were proposed:

The first was the Phar Lap mine, which is about 2 km southeast of the town. This was considered too close as the noise could be distressing to some town residents.

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The second was the Golden Bracelet at Bourke Find. This mine had collapsed, and, as it had not been worked for many years, tracks to the mine were non-existent.

A third site, that of the 'Whitworth Group', 8.5 km north of Meekatharra, was then suggested as a possible site. This site proved to be suitable. From a shaft 13.5 m deep, cross-cuts east and west went 14.5 m and 9.2 m respectively. A small drive off the east cross-cut 6 m long had been stoped to 5.5 m above the level. Ground in the shaft and drives was safe and solid.

The proposed site was within 1 km of the Great Northern Highway and a station access road to the north. These roads would have to be closed for the blast, but a least access to the site was no problem.

The Whitworth Group of leases are currently held by Mines Administration Ltd. Agreement in writing by this company would be required before the blast could be proceeded with.

Mr L. Rinaldi assisted in the selection of sites and was engaged by BMR to prepare the mine for the blast and assist with the loading and stemming. A compressor, compressed air hoist, and tripod were supplied by this department and were used in the cleaning-out operations and the lowering of the explosives.

Loading, priming, and stemming

Loading started at the face of the east cross-cut. The cylindrical cans of explosives were stacked on their sides to fill the area of the heading. Each row of stacked cans was primed with three plugs of 25 mm x 100 mm, AN 60 Gelignite. One plug on top and one each side. Each plug was on a Cordtex branch line and each branch line was tied to one of three Cordtex branch lines. The east cross-cut was charged in this fashion, row by row, and the small stope was filled as far as possible. When all the explosive had been placed, a space 2.7 m from the shaft was left to be filled with rubble to act as stemming.

To protect the Cordtex lines, pipes had been installed in the shaft and bent under the brow. The Cordtex was threaded through these pipes. The shaft and cross-cut were filled with rubble from a nearby dump using a front-end-loader.

Immediately before firing, one no. 8 instantaneous electric detonator was connected to the top end of each Cordtex trunk line. The three detonators were then electrically connected in series to a firing cable 1000 m long. The electric firing device used was of the battery-operated electronic capacitor charging type which recorded a pulse in the seismic recording instruments for time reference purposes.

Safety precautions

To ensure safety of the public, property, and stock, the following safety precautions were taken:

(1) From the time that explosives first arrived on the site until immediately before detonation a member of the BMR staff was always on site day or night to prevent unauthorised entry.

(2) Managers of pastoral stations in the immediate area were informed of the time and location of the blast so they could remove any stock from the vicinity.

(3) For thirty minutes before the blast the Great Northern Highway would be closed by RTA and Police Officers 1 km north and south of the nearest point of the blast site. The roads to Yarlaweelor and Yoolthapina were also closed for the same period.

(4) Telecom Australia was advised of the blast time and position in case there was any damage to overland telegraphic lines.

(5) The Department of Transport at Meekatharra Airport was informed of the time and position of the blast so that aircraft which may be flying in the vicinity could be warned off.

(6) All preliminary radio communications for setting up the recording equipment was to be completed 15 minutes before blast time, then all outward transmissions would cease, and timing of the blast would be synchronised to a received signal from VNG (time and calibration station).

In these 15 minutes the shot firer would attach the electronic detonators to the Cordtex detonating fuse and connect them to the shot-firing line. He would then return to the firing position and connect the shot-firing cable to the exploder.

(Notices were to be placed around the perimeter of the resulting crater after the blast, warning people not to approach it).

Results

As the roads were not blocked off until 9.45 the blast was not set off until 10.10 a.m., not 10.00 a.m. as arranged. This did not affect the BMR recording arrangements, but our own Sprengnether seismograph was set to run at 10.00 a.m.; by the time the shot was fired there was no recording film left. (The distance between the shot firer's site and our seismograph site near the town water reservoir tanks was too great for the effective use of our walkie-talkie transceivers).

The blast was not heard or felt in Meekatharra. One kilometre from the blast centre the noise of the blast was said to sound like a loud, deep rumble. A dark brownish-purple cloud which rose 150 m above the ground dispersed slowly to the southwest under the influence of a northeast breeze. The maximum throw of fly rock was about 100 m.

The BMR officers were quite pleased with the results of the blast. The amplitude of the vibrations was higher than they had expected considering the size of the charge. The observatory at Mundaring recorded a magnitude of three on the Richter scale. Good readings were taken by instruments in the Pilbara and at Kalgoorlie and Narrogin.

The crater left by the explosion was 50 m long (north and south) by 20 m wide east and west at the surface. It was about 5 m long by 2 m wide at the bottom 13 m below the surface.

Physical details of blast:

Mass of explosive	= 11.33 tonnes
Estimate of tons of broken rock (assuming density of rock 2.7 tm^{-3})	= 17 443 tonnes
Explosives used/tonnes broken	= 0.650 kg/tonne

Conclusion

The blast successfully generated strong vibrations which could be used to record the data required. It would appear that this blast was more efficient from the seismic point of view than the Kunanulling one which apparently only recorded the same vibration level with a much higher mass of explosive.

Success of the whole project was only made possible by the co-operation between Mr L. Rinaldi and officers of the Bureau of Mineral Resources, and to a lesser extent officers of this department.

TABLE 1. SEISMIC RECORDING STATIONS

The following formats have been used: Latitudes are given in degrees and minutes south.
Longitudes are given in degrees and minutes east.
Recording periods are given in days, hours and minutes.

Station Number	Recorder Number	Latitude		Longitude		Elevation	Recording Period on d	h	m	off d	h	m	Amplifier gain in Decibels	Comments
001	013	20	31.4	120	08.4	120	24	11	45	30	11	04	96	
002	007	20	34.1	120	04.4	100	24	09	01	30	11	51	90	
003	012	20	38.4	120	02.7	80	24	15	03	29	17	07	90	
004	006	20	44.2	120	05.2	110	24	16	14	30	12	53	unknown	days incorrect some of the time
005	009	20	48.6	120	04.4	130	24	09	50	29	17	50	84	
006	008	20	53.5	120	04.2	190	24	11	15	29	17	15	84	
007	003	20	59.8	120	03.6	190	24	12	48	29	16	31	78	
008	002	21	04.1	119	58.0	180	24	14	00	29	15	55	84	
009	005	21	10.0	119	55.7	220	24	08	41	29	16	34	96	
010	011	21	16.3	119	58.8	260	24	10	04	29	17	08	96	
011	004	21	24.7	120	04.0	305	24	10	52	29	17	40	96	
012	010	21	33.1	120	05.6	420	24	12	11	29	18	18	96	
013	014	21	41.6	120	03.9	440	24	10	45	29	17	15	96	
014	001	21	52.7	120	06.5	400	24	08	35	29	18	47	96	
015	015	22	02.2	120	02.8	500	23	16	37	30	09	07	96	
016	012	22	09.6	119	56.7	470	38	17	22	43	18	11	96* 90+	*until 39 09 47 +from 39 09 47
017	013	22	22.2	119	58.5	550	38	15	27	43	17	19	96	
018	007 233	22	31.4	119	58.6	435	38 44	13 13	23 46	43 45	16 13	30 47	102 unknown	probable field error - add 1 day to clock times.
019	006	22	42.6	119	56.9	420	38	11	36	43	15	37	90	
020	010	22	49.4	119	59.5	430	38	13	19	43	15	30	96* 90+	*until 42 10 00 +from 42 10 00
021	232	22	54.9	119	59.8	460	45	16	37	53	12	00	96	
022	005	23	03.8	119	58.0	460	38	14	40	43	16	00	96	days: clock reads 2 less
023	004	23	09.8	119	56.0	480	38	15	17	43	16	33	96	
024	011	23	13.5	119	54.8	490	38	15	58	43	17	05	96	
025	255	23	18.7	119	50.8	540	03 07 53	16 14 14	50 23 30	07 53 79	14 14 16	23 10 48	96	Newman Mine Monitor
026	015	23	25.7	119	48.3	540	37	15	54	44	08	00	90	
027	006	23	34.0	119	45.6	565	44	16	52	51	11	20	96	
028	014	23	39.1	119	44.7	600	37	14	50	44	09	36	96	
029	001	23	46.0	119	43.1	650	37	13	30	43	16	10	96	
030	007	23	55.7	119	47.8	605	44	09	43	50	16	35	96	log book comment: "artificial time" - probably have to add 1 day.

Station Number	Recorder Number	Latitude	Longitude	Elevation	Recording Period on d	h	m	off d	h	m	Amplifier gain in Decibels	Comments
031	002	24 02.6	119 43.1	580	38	10	53	43	15	53	96	
032	012	24 16.1	119 42.8	630	45	11	00	50	17	47	96	
033	003	24 32.3	119 38.0	625	38	12	41	43	17	03	96	
034	013	24 40.6	119 37.2	615	45	13	00	51	08	10	102	
035	008	24 47.2	119 35.6	595	38	14	45	44	08	00	96	
036	004	24 55.1	119 26.3	550	45	08	51	50	15	29	90	
037	011	25 06.1	119 22.1	540	45	10	15	50	16	16	90	
038	005	25 14.6	119 19.7	540	45	11	26	50	17	56	90	
039	010	25 26.9	119 18.1	540	45	12	45	50	17	36	90	
040	015	25 36.6	119 11.3	555	44	13	26	50	17	28	90	
041	001	25 46.5	119 00.3	544	44	15	19	50	16	43	96	clock display showed 51 days when set collected but should be OK.
042	014	25 55.1	118 51.8	525	44	16	30	50	15	35	unknown	
043	008	26 01.4	118 41.5	490	44	11	41	50	17	25	96	
044	009	26 11.2	118 40.9	480	45	10	06	50	16	45	96	
045	003	26 19.7	118 38.2	500	44	17	05	50	16	05	96	
046	002	26 25.3	118 34.9	515	44	15	47	50	15	30	96	
047	009	26 31.5	118 31.7	510	39	09	00	44	11	45	96	
059	005	24 27.2	116 55.6	510	77	09	06	78	16	28	90	running continuously
060	001	24 15.5	117 00.0	370	77	10	49	78	15	15	96	running continuously
061	015	24 04.5	117 05.6	456	77	12	30	78	14	00	96	running continuously
062	014	23 58.2	117 03.7	481	77	14	13	78	13	01	96	running continuously
063	012	23 45.6	117 17.5	330	67	13	45	77	13	28	90	
064	006	23 46.2	117 23.1	330	67 74	10 16	08 09	74 76	15 16	56 40	90	clock-days are 1 low
065	007	23 39.8	117 28.0	280	66 74	17 14	04 40	74 78	14 08	30 30	96	tape 1 is tape 2 from site 147
066	013	23 30.2	117 35.0	310	66 74	15 13	38 30	74 77	13 11	16 05	90	
067	004	23 22.2	117 34.7	315	14	14	35	22	13	46	96	
068	010	23 14.0	117 33.7	345	14	15	50	22	13	15	96	
069	005	23 10.8	117 42.4	445	14	17	37	22	15	03	96	
070	011	23 07.5	117 50.6	480	15	11	38	22	15	35	96	tape 2 from site 089. Clock 1 minute slow until 15 14 36.
071	001	23 02.8	117 53.1	550	14	15	41	22	13	23	96	
072	014	22 58.4	117 51.9	600	14	16	42	22	13	50	96	tape 2 from site 084.

Station Number	Recorder Number	Latitude	Longitude	Elevation	Recording Period on d h m	off d h m	Amplifier gain in Decibels	Comments
073	256	22 53.1	117 49.3	700	01 12 42 09 12 49 55 17 15	09 12 28 55 17 15 77 10 30	96	Tom Price Mine monitor.
074	015	22 48.1	117 45.4	700	14 13 04	22 14 34	90	
075	012	22 44.2	117 48.4	780	15 15 55	22 14 38	90	
076	003	22 44.8	117 53.9	675	15 13 13	22 13 22	84	tape 2 from site 099.
077	013	22 34.4	117 54.3	710	15 11 03	22 16 46	90	tape 2 from site 098.
078	009	22 34.0	118 05.0	720	15 14 15	22 15 30	84	seismometer knocked over during recording period.
079	008	22 29.6	118 09.2	940	15 12 08	22 14 45	84	
080	002	22 24.2	118 16.0	680	15 10 38	22 14 00	84	
081	232	22 14.9	118 20.5	480	02 10 25 13 15 17	13 15 05 45 07 45	90	Wittenoom mine monitor.
082	006	22 08.4	118 21.6	400	16 13 16	22 15 48	84	tape 2 from site 097. Clock a day out for some of the time.
083	007	22 06.5	118 28.0	410	16 11 27	22 16 25	90	
084	014	22 08.1	118 46.3	460	03 11 00 12 14 49	12 14 49 13 17 36	96	tape 2 used at site 072.
085	233 232	21 58.0	118 50.6	350	02 11 30 10 13 29 54 13 06	10 13 29 49 16 00 77 14 42	96 90	Chichester Range mine monitor. Set inoperative 16 10 00 to 18 16 25 and 43 16 13 to 45 16 17.
086	001	21 46.7	118 49.6	270	02 14 17 12 15 41	12 15 41 13 16 33	96	
087	015	21 35.0	118 54.8	280	02 15 35 12 16 17	12 16 17 13 16 00	96	tape 2 used at site 074.
088	010	21 24.4	118 55.4	240	03 14 30 12 17 19	12 17 19 13 15 19	96	
089	011	21 18.4	118 59.2	240	03 16 01 13 08 59	13 08 59 13 14 12	96	tape 2 used at site 070.
090	005	21 11.4	119 02.3	260	04 11 05 13 09 40	13 09 39 13 15 15	96	
091	004	21 07.8	119 08.2	180	04 15 36 13 10 45	13 10 45 13 14 11	96	
092	007	20 59.8	119 11.2	140	03 14 12	13 15 40	90	set failed after day 8
093	012	20 53.4	119 08.1	120	03 11 07	13 14 39	90	
094	008	20 48.0	119 12.5	95	03 12 15	13 14 16	84	
095	002	20 42.2	119 15.3	75	02 16 38	13 15 01	78	
096	009	20 35.3	119 17.6	55	03 09 55	13 16 00	84	

Station Number	Recorder Number	Latitude	Longitude	Elevation	Recording Period on d	on h	on m	off d	off h	off m	Amplifier gain in Decibels	Comments
097	006	20 31.2	119 24.5	45	02	15	25	13	10	20	84	Days set 1 low. Set largely a failure. Tape 2 used at site 082.
					13	10	25	14	09	07		
098	013	20 27.9	119 24.9	40	02	13	05	13	09	32	96	
					13	09	38	14	08	25		Tape 2 used at site 077.
099	003	20 22.2	119 27.5	60	02	12	15	13	08	40	84	
					13	09	00	14	08	00		Tape 2 used at site 076.
100	257	20 19.9	119 40.2	80	01	16	55	10	09	12	84	Goldsworthy mine monitor.
					10	09	45	49	08	30		
	233				50	07	41	56	20	00		
					56	20	00	77	13	25		
101	015	20 29.5	119 31.3	40	67	16	05	74	12	22	90	
102	001	20 37.5	119 35.0	60	67	15	12	74	13	00	96	gain uncertain.
103	004	20 59.6	119 51.3	200	67	16	13	77	16	55	90	
104	010	21 11.8	119 44.6	200	67	14	40	77	18	29	90	
105	011	21 19.7	119 37.8	200	67	13	08	77	20	15	90	
106	002	21 27.0	119 31.8	280	67	19	11	77	15	41	96	
107	009	21 35.7	119 22.0	260	67	17	59	77	16	55	96	
108	003	21 45.2	119 15.1	300	67	13	19	77	17	48	96	
109	008	21 53.2	119 14.7	310	67	15	47	77	13	09	96	
110	257	21 59.6	119 01.4	400	67	11	15	77	-	-	90	Recorder failed - nothing on tape
112	014	20 45.7	119 42.0	85	67	13	56	74	13	29	unknown	
113	005	20 52.6	119 45.2	130	67	17	40	74	13	57	90	
118	015	23 09.8	119 36.7	660	64	15	30	66	11	03	96	tape 2 from site 162.
119	014	23 11.2	119 42.0	600	64	17	00	66	10	30	96	
121	001	23 18.9	119 40.9	560	31	13	00	37	10	51	78	72 db for first day.
122	014	23 19.5	119 36.2	600	31	11	42	37	10	00	96	
	001				65	07	46	66	08	52		
123	015	23 18.1	119 31.0	640	31	10	45	37	09	24	96	
124	005	23 17.5	119 27.3	665	64	15	51	66	09	25	90	
125	010	23 17.2	119 21.7	680	31	11	05	37	10	04	96	
126	010	23 16.3	119 17.5	705	64	17	07	66	10	09	90	
127	011	23 12.5	119 12.3	700	31	12	55	37	11	15	96	
128	004	23 08.8	119 12.0	720	65	07	45	66	11	03	96	
133	005	23 07.4	119 05.5	675	31	14	41	37	12	00	96	
134	011	23 05.2	119 01.6	700	64	10	02	66	11	54	96	
135	004	23 03.9	118 57.4	760	31	16	06	37	13	05	96	

Station Number	Recorder Number	Latitude	Longitude	Elevation	Recording Period on d	on h	on m	off d	off h	off m	Amplifier gain in Decibels	Comments
136	003	23 00.3	118 52.3	740	63	17	59	66	15	45	96	tape 2 from site 153.
137	003	22 58.4	118 47.6	720	31	08	59	36	19	20	96	
138	008	22 55.6	118 43.7	740	64	08	02	66	14	55	96	tape 2 from site 151.
139	002	22 54.3	118 41.2	740	31	10	20	36	18	49	96	
140	257	22 52.2	118 35.2	750	56	12	05	66	13	48	84	
141	008	22 54.0	118 27.8	800	31	12	05	36	17	33	96	
142	002	22 55.4	118 22.6	680	63	16	45	66	12	33	90	
143	009	22 55.3	118 17.1	620	31	13	45	36	16	37	96	
144	009	22 53.7	118 12.9	580	63	15	00	66	11	30	96	
145	013	22 53.0	118 08.4	560	32	09	30	36	11	00	96	
	012				64	10	30	66	09	37	unknown	tape 2 is from site 158.
146	012	22 51.3	118 04.8	600	31	16	04	36	17	29	90	
	006				64	09	10	66	08	50	84	tape 2 is from site 157.
147	007	22 48.1	118 01.8	630	31	14	30	36	16	31	90	
					64	12	32	66	10	28	84	tape 2 used at site 065.
148	006	22 45.7	117 58.3	655	31	12	28	36	15	27	90	days out by 1 some
	013				64	13	39	66	11	04	84	of the time.
149	009	22 38.6	117 41.7	680	52	14	32	61	14	30	96	
					61	14	30	63	12	16		
151	008	22 35.2	117 36.7	620	52	13	15	61	14	55	96	
					61	14	57	63	11	41		tape 2 used at site 138.
152	002	22 31.5	117 32.1	600	52	12	00	61	15	22	96	
					61	15	22	63	11	02		
153	003	22 29.0	117 27.2	620	52	10	15	61	16	09	96	
					61	16	09	63	10	44		tape 2 used at site 136.
154	011	22 24.5	117 22.6	610	52	09	00	61	16	41	90	
					61	16	41		-			
155	007	22 18.1	117 17.6	560	53	11	20	63	10	37	90	
					63	11	50		-			
156	013	22 14.4	117 10.9	530	53	09	17	63	11	27	84	
157	006	22 02.9	117 09.4	540	52	15	10	62	10	09	84	
					62	10	15	63	15	48		tape 2 used at site 146.
158	012	22 01.6	117 01.2	480	53	13	20	63	09	11	96	
					63	09	20	63	14	15	90	tape 2 used at site 145.
159	001	22 00.4	116 51.3	360	52	15	00	61	15	57	96	
					61	15	57	63	17	11		

Station Number	Recorder Number	Latitude		Longitude		Elevation	Recording Period on d	h	m	off d	h	m	Amplifier gain in Decibels	Comments
160	234	21	40.2	116	42.6	320	01	16	08	09	16	02	96	Pannawonica mine monitor. No tape spooled in first recording period.
							09	16	34	56	13	56		
							56	14	18	76	15	00		
161	014	21	58.2	116	48.0	440	52	16	45	61	14	35	96	
							61	14	54	63	18	00		
162	015	21	52.4	116	44.8	300	52	10	55	61	13	25	96	
							61	13	25	63	15	07		tape 2 used at site 118.
163	010	21	49.5	116	41.7	300	52	11	03	62	14	48	90	temporarily off during tape 1.
							62	15	31	63	14	30		
164	005	21	46.1	116	39.1	260	52	13	09	62	13	49	90	temporarily off during tape 1.
							62	13	54	63	15	05		
165	004	21	45.4	116	34.3	240	52	15	17	62	13	06	90	temporarily off during tape 1.
							62	13	12	63	13	53		

TABLE 2. MINE BLAST DETAILS

In this table, mine monitor numbers used are:

			Latitude	Longitude
025	BMR	Newman mine monitor	23 18.7	119 50.8
073	BMR	Tom Price mine monitor	22 53.1	117 49.3
081	BMR	Wittenoom mine monitor	22 14.9	118 20.5
085	BMR	Chichester mine monitor	21 58.0	118 50.6
100	BMR	Goldsworthy mine monitor	20 19.9	119 40.2
160	BMR	Pannawonica mine monitor	21 40.2	116 42.6
204	ANU	Goldsworthy mine monitor	20 20.4	119 31.8
205	ANU	Shay Gap mine monitor	20 28.9	120 06.6
206	ANU	Newman mine monitor	23 21.8	119 41.9
202	ANU	Tom Price mine monitor	22 43.8	117 45.7
201	ANU	Paraburdoo mine monitor	23 13.4	117 35.6
203	ANU	Pannawonica mine monitor	21 40.5	116 18.6

Latitudes are given in degrees and minutes south, and longitudes are given in degrees and minutes east. Days are numbered sequentially from 1 July 1977 (day 01) to 16 September 1977 (day 78). Reported times have the format: dd hh mm, and shot times have the format: dd hh mm ss.ss.

Note:- *estimated

When 'Total Delay in seconds' is marked by an asterisk, the delay is that calculated from the information on numbers of rows, holes, and delays between rows provided by the mining companies, and is a maximum likely value. In all other cases the delays are values provided for the entire blast by the companies.

Shot Number	Mine	Latitude	Longitude	Elevation (metres)	Shot Time (reported) d h m	Actual Shot Time d h m s	Mine Monitor	Shot Size (tonnes)	Total Delay in seconds (*estimated)	Comments
001	Pannawonica	21 41.5	116 27.0	260	01 14 55	01 14 50 12.00	073	32.0	unknown	
002	Newman	23 22.2	119 40.2	640	02 09 30	02 09 31 25.65	073	unknown	*0.210	
003	Sunrise Hill	20 27.0	120 03.0	200	02 11 30	02 11 24 10.79	100	3.1	0.144	
004	Tom Price	22 46.5	117 47.1	950	02 12 03	02 12 03 09.64	073	238.8	3.000	
005	Sunrise Hill	20 27.9	120 03.5	200	04 11 30	04 11 26 56.61	100	28.6	0.345	
006	Shay Gap	20 29.7	120 06.0	200	04 11 30	not found	-	12.5	0.342	
007	Shay Gap	unknown	unknown	unknown	not reported	no position	-	unknown	unknown	recorded at 05 11 17 38.40 on the Goldsworthy mine monitor (station 100)
008	Goldsworthy	20 21.3	119 32.0	100	05 11 58	05 11 59 44.56	100	23.1	.075	
009	Pannawonica	21 42.2	116 28.1	260	05 17 09	05 17 07 52.66	073	149.1	unknown	
010	Shay Gap	20 29.5	120 05.9	200	07 11 30	07 11 43 16.36	100	31.7	0.110	
011	Paraburdoo	23 13.9	117 35.9	400	07 12 05	07 12 06 46.76	073	146.3	0.595	
012	Paraburdoo	23 14.0	117 36.1	400	07 12 06	overrides 011	-	47.1	unknown	
013	Paraburdoo	23 14.2	117 36.1	400	07 12 07	overrides 012	-	10.3	0.315	
014	Shay Gap	20 30.2	120 06.9	200	08 12 00	08 12 16 04.90	100	10.5	0.180	
015	Shay Gap	unknown	unknown	unknown	not reported	no position	-	unknown	unknown	overrides shot 014
016	Sunrise Hill	20 27.9	120 03.5	200	08 15 00	08 15 12 26.09	100	6.0	0.120	
017	Sunrise Hill	20 27.6	120 03.5	200	08 15 00	08 15 15 32.58	100	7.5	0.270	
018	Goldsworthy	20 21.3	119 32.3	100	11 15 25	11 15 24 59.23	100	77.1	.085	
019	Newman	23 21.8	119 40.9	730	12 09 30	12 09 40 37.58	025	unknown	*0.640	
020	Sunrise Hill	unknown	unknown	unknown	not reported	no position	-	unknown	unknown	recorded at 12 11 22 22.27 on the Goldsworthy mine monitor (station 100)
021	Sunrise Hill	unknown	unknown	unknown	not reported	no position	-	unknown	unknown	recorded at 12 15 01 39.43 on the Goldsworthy mine monitor (station 100)
022	Newman	23 22.3	119 40.4	670	13 09 30	13 09 35 07.22	025	unknown	*0.190	
023	Paraburdoo	23 14.0	117 36.3	400	13 12 16	13 12 17 29.22	073	73.2	0.420	

Shot Number	Mine	Latitude	Longitude	Elevation (metres)	Shot Time (reported) d h m	Actual Shot Time d h m s	Mine Monitor	Shot Size (tonnes)	Total Delay in seconds (*estimated)	Comments
024	Sunrise Hill	20 27.9	120 03.4	200	14 11 45	14 11 45 25.90	100	8.6	0.186	shots 024 and 025 were reported as two charges fired as one shot but are clearly two separate shots
025	Sunrise Hill	20 27.6	120 03.5	200	14 11 45	14 11 47 32.41	100	6.8	0.198	
026	Paraburdoo	23 14.1	117 36.0	400	14 12 20	14 12 20 23.22	073	68.7	0.455	
027	Paraburdoo	23 14.1	117 35.6	400	14 12 20	overrides 026	-	159.2	1.470	
028	Newman	23 21.4	119 42.1	640	15 09 20	15 09 26 53.08	025	unknown	*0.110	
029	Shay Gap	20 30.1	120 06.7	200	15 11 30	not found	-	50.0	1.189	
030	Goldsworthy	20 21.3	119 32.1	100	15 11 40	15 11 39 15.51	100	68.8	.315	
031	Shay Gap	20 30.2	120 06.8	200	15 11 50	not found	-	16.4	0.199	
032	Paraburdoo	23 13.8	117 35.9	400	15 12 16	15 12 15 43.39	073	20.2	0.420	
033	Sunrise Hill	20 27.9	120 03.5	200	15 15 00	15 15 09 58.51	100	10.7	0.141	
034	Sunrise Hill	20 27.6	120 03.5	200	18 11 30	18 10 54 53.50	100	4.6	0.124	
035	Tom Price	22 46.4	117 47.0	950	18 12 00	18 12 30 17.48	073	505.3	6.750	
036	Newman	23 22.2	119 39.9	625	19 09 30	19 09 34 14.22	025	unknown	*0.180	
037	Sunrise Hill	20 27.9	120 03.4	200	19 11 30	19 11 19 11.54	100	11.7	0.370	
038	Shay Gap	20 29.8	120 06.0	200	19 11 30	not found	-	14.1	0.850	
039	Pannawonica	21 42.0	116 31.7	260	19 12 15	19 12 13 52.08	160	168.3	0.350	
040	Shay Gap	unknown	unknown	unknown	not reported	no position	-	unknown	unknown	recorded at 19 15 13 26.24 on the Goldsworthy mine monitor (station 100)
041	Pannawonica	21 41.6	116 27.0	260	19 15 29	19 15 28 13.01	160	94.8	unknown	
042	Tom Price	22 45.7	117 45.5	950	20 12 53	20 12 53 16.64	073	128.3	2.250	
043	Sunrise Hill	20 27.9	120 03.5	200	21 15 00	21 15 07 56.34	100	22.1	0.810	
044	Sunrise Hill	20 27.6	120 03.5	200	21 15 00	21 15 11 17.56	100	2.3	0.165	
045	Newman	23 21.5	119 41.1	680	22 10 30	not found	-	unknown	*0.210	
046	Shay Gap	20 29.7	120 06.1	200	22 11 30	22 11 28 07.96	100	6.3	0.096	
047	Shay Gap	20 30.3	120 06.9	200	22 11 30	overrides 046	-	15.1	0.450	
048	Pannawonica	21 41.9	116 28.0	260	22 11 40	22 11 40 12.64	160	248.2	unknown	

Shot Number	Mine	Latitude	Longitude	Elevation (metres)	Shot Time (reported) d h m	Actual Shot Time d h m s	Mine Monitor	Shot Size (tonnes)	Total Delay in seconds (*estimated)	Comments
049	Sunrise Hill	20 27.6	120 03.6	200	22 12 00	22 11 52 08.16	100	2.2	0.125	
050	Goldsworthy	20 21.3	119 32.0	100	22 12 02	22 12 05 17.33	100	53.3	0.630	
051	Shay Gap	20 30.0	120 06.6	200	22 15 00	22 15 06 02.95	100	7.8	0.215	
052	Shay Gap	unknown	unknown	unknown	not reported	no position	-	unknown	unknown	recorded at 25 15 10 47.70 on the Goldsworthy mine monitor (station 100)
053	Shay Gap	unknown	unknown	unknown	not reported	no position	-	unknown	unknown	recorded at 26 11 20 00.63 on the Goldsworthy mine monitor (station 100)
054	Goldsworthy	20 21.3	119 32.0	100	26 12 00	26 11 59 13.33	100	4.9	0.045	
055	Sunrise Hill	20 27.9	120 03.4	200	26 15 00	26 14 58 50.63	100	9.4	0.475	
056	shot number deleted	-	-	-	-	-	-	-	-	
057	Newman	23 22.0	119 40.8	780	28 09 30	28 09 34 55.01	025	unknown	*0.500	
058	Paraburdoo	23 13.8	117 35.8	400	28 12 20	28 12 20 00.09	073	57.5	0.490	
059	Paraburdoo	23 14.1	117 35.8	400	28 12 22	28 12 21 56.00	073	92.5	0.420	
060	Pannawonica	21 42.2	116 27.9	260	28 13 00	28 12 59 33.27	160	144.5	unknown	
061	Shay Gap	20 29.6	120 06.0	200	28 16 00	28 15 14 08.63	100	1.6	0.170	
062	Sunrise Hill	20 27.9	120 03.4	200	29 11 30	29 11 35 10.66	100	10.8	0.455	
063	Goldsworthy	20 21.3	119 32.1	100	29 11 58	29 11 57 46.12	100	68.0	0.410	
064	Tom Price	22 46.2	117 46.6	950	29 12 10	29 12 18 20.52	073	154.8	2.500	
065	Shay Gap	20 29.8	120 06.0	200	29 15 00	29 15 07 27.78	100	11.3	0.660	
066	Shay Gap	20 29.6	120 06.0	200	30 16 00	30 15 44 19.43	100	4.8	0.470	
067	Newman	23 21.6	119 41.3	610	33 09 30	33 09 24 50.26	025	unknown	*0.420	
068	Sunrise Hill	20 27.9	120 03.4	200	33 15 00	33 15 17 40.29	100	13.6	0.530	
069	Sunrise Hill	unknown	unknown	unknown	not reported	overrides 068	-	unknown	unknown	
070	Tom Price	22 45.9	117 46.0	950	34 13 00	34 13 01 21.36	073	110.0	0.125	
071	Tom Price	22 45.8	117 45.5	950	34 13 00	overrides 070	073	65.0	0.125	
072	Shay Gap	20 30.3	120 06.9	200	34 15 45	34 15 40 36.73	100	22.0	0.610	

Shot Number	Mine	Latitude	Longitude	Elevation (metres)	Shot Time (reported) d h m	Actual Shot Time d h m s	Mine Monitor	Shot Size (tonnes)	Total Delay in seconds (*estimated)	Comments
073	Goldsworthy	20 21.3	119 32.0	100	35 12 12	35 12 12 14.25	100	30.7	0.630	
074	Goldsworthy	20 21.3	119 32.0	100	35 12 12	overrides 073	-	unknown	-	
075	Parabardoo	23 14.0	117 36.3	400	35 12 18	35 12 18 04.97	073	84.1	0.525	
076	Newman	23 22.2	119 40.3	670	36 09 30	36 09 34 45.47	025	unknown	*0.490	
077	Shay Gap	20 29.8	120 06.0	200	36 11 30	not seen	-	9.9	0.415	
078	Sunrise Hill	20 27.9	120 03.4	200	36 11 45	36 11 40 03.10	100	20.2	0.415	
079	Shay Gap	unknown	unknown	unknown	not reported	no position	-	unknown	unknown	recorded at 36 17 12 30.88 at the Goldsworthy mine monitor (station 100)
080	Paraburdoo	23 14.1	117 35.6	400	37 12 15	37 12 13 58.20	073	44.4	0.315	
081	Shay Gap	20 29.6	120 06.1	200	37 15 00	37 15 33 45.14	100	11.5	0.500	
082	Goldsworthy	20 21.3	119 32.0	100	40 11 40	40 11 37 42.04	085	22.5	0.045	
083	Newman	23 22.2	119 39.7	680	41 09 30	41 09 29 54.27	025	unknown	*0.420	
084	Goldsworthy	20 21.2	119 32.2	100	41 11 49	41 11 50 50.90	085	18.9	0.090	
085	Goldsworthy	20 21.3	119 32.3	100	41 11 50	overrides 084	-	27.0	0.090	
086	Tom Price	22 46.1	117 45.9	950	41 12 14	41 12 14 26.36	073	94.0	0.150	
087	Shay Gap	20 30.2	120 06.9	200	41 16 30	41 16 50 08.49	085	7.2	0.495	
088	Newman	23 21.4	119 41.9	640	42 09 30	42 09 29 26.72	025	unknown	*0.940	
089	Newman	23 21.9	119 40.7	780	43 09 30	43 09 32 35.59	025	unknown	*0.530	
090	Shay Gap	20 30.0	120 06.6	200	43 16 30	43 16 36 53.54	205	10.9	0.700	
091	Meekatharra	26 31.8	118 32.3	500	46 10 10	46 10 10 00.36	-	11.3	0.000	Meekatharra Blast
092	Sunrise Hill	20 27.9	120 03.4	200	46 15 00	not seen	-	21.5	0.880	
093	unknown	unknown	unknown	unknown	not reported	no position	-	unknown	unknown	recorded at MBL at 47 11 36 40.5. Goldsworthy mine monitor not operating
094	Shay Gap	20 30.2	120 06.8	200	49 11 30	49 11 34 02.63	205	20.9	0.350	
095	Shay Gap	20 30.3	120 07.0	200	49 11 30	overrides 094	-	12.8	0.380	
096	Sunrise Hill	20 27.9	120 03.5	200	49 11 45	not seen	100	11.20	0.535	
097	Pannawonica	21 41.6	116 29.9	260	50 09 38	not seen	-	48.4	0.315	

Shot Number	Mine	Latitude	Longitude	Elevation (metres)	Shot Time (reported) d h m	Actual Shot Time d h m s	Mine Monitor	Shot Size (tonnes)	Total Delay in seconds (*estimated)	Comments
098	Newman	23 21.4	119 41.8	610	50 11 00	50 11 08 33.51	025	unknown	*0.940	
099	Shay Gap	20 30.3	120 07.0	200	50 11 30	50 11 35 53.79	100	7.2	0.290	
100	Goldsworthy	20 21.2	119 32.4	100	50 11 48	50 11 43 27.10	100	17.0	0.745	
101	Tom Price	22 46.4	117 47.1	950	50 12 10	50 12 09 50.26	073	587.0	0.275	
102	Paraburdoo	23 14.1	117 36.1	400	51 12 15	51 12 14 15.78	073	37.0	0.385	
103	Tom Price	22 45.6	117 45.3	950	51 12 57	51 12 57 03.84	073	188.0	0.175	
104	Tom Price	22 45.7	117 45.6	950	51 12 57	overrides 103	073	100.0	0.125	
105	Shay Gap	20 30.0	120 06.6	200	54 11 30	54 11 35 56.85	100	16.1	0.545	
106	Paraburdoo	23 13.8	117 35.8	400	54 12 16	not found	073	93.1	0.805	
107	Paraburdoo	23 13.8	117 36.0	400	54 12 21	54 12 21 11.89	073	162.1	1.435	
108	Paraburdoo	23 14.0	117 35.8	400	54 12 22	overrides 107	073	301.5	1.715	
109	Tom Price	22 45.7	117 45.6	950	54 12 50	54 12 50 36.73	073	371.0	0.275	
110	Shay Gap	20 29.4	120 05.7	200	54 15 00	54 15 03 32.64	100	84.2	0.930	
111	Sunrise Hill	20 27.9	120 03.5	200	55 11 30	no suitable mine monitor	100	37.9	1.329	Goldsworthy mine monitor malfunction
112	Goldsworthy	20 21.3	119 32.4	100	55 11 30	no suitable mine monitor	100	38.3	0.460	Goldsworthy mine monitor malfunction
113	Shay Gap	20 30.2	120 06.8	200	55 15 30	55 15 54 00.44	100	15.4	0.250	
114	Sunrise Hill	20 27.9	120 03.3	200	56 15 00	56 15 09 26.16	100	7.8	0.255	
115	Shay Gap	20 29.5	120 05.9	200	56 15 00	56 15 37 33.95	100	10.5	0.750	
116	Sunrise Hill	20 27.9	120 03.3	200	57 11 30	57 11 42 24.98	100	6.1	0.500	
117	Paraburdoo	23 13.9	117 36.0	400	57 12 17	57 12 14 36.10	073	88.5	0.525	
118	Newman	23 22.2	119 40.2	640	60 09 30	60 09 30 56.51	025	unknown	*0.490	
119	Paraburdoo	23 14.2	117 36.2	400	60 12 15	60 12 14 50.27	073	61.8	0.455	
120	Goldsworthy	20 21.3	119 32.0	100	60 15 37	60 15 37 34.71	100	21.2	0.090	
121	Paraburdoo	23 14.2	117 35.9	400	61 12 19	61 12 19 36.38	073	41.1	0.280	
122	Sunrise Hill	20 27.9	120 03.4	200	not reported	61 15 11 57.59	100	unknown	unknown	only shot position reported.

Shot Number	Mine	Latitude	Longitude	Elevation (metres)	Shot Time (reported) d h m	Actual Shot Time d h m s	Mine Monitor	Shot Size (tonnes)	Total Delay in seconds (*estimated)	Comments
123	Pannawonica	21 41.9	116 31.7	260	63 09 15	63 09 15 35.99	160	112.0	0.315	
124	Shay Gap	20 30.0	120 06.7	200	63 11 30	63 11 36 43.36	100	16.4	0.386	
125	Tom Price	22 46.0	117 45.8	950	63 13 30	63 13 28 53.19	073	180.0	0.075	
126	Shay Gap	20 30.1	120 06.8	200	64 11 45	64 11 54 25.69	100	27.5	1.005	
127	Sunrise Hill	20 27.9	120 03.4	200	65 11 30	65 11 25 15.96	100	17.7	0.546	
128	Newman	23 21.4	119 42.1	640	65 11 00	65 11 25 18.55	025	unknown	*0.210	
129	Tom Price	22 45.9	117 46.0	950	65 12 15	65 12 13 43.76	073	95.0	0.100	
130	Pannawonica	21 42.2	116 27.9	260	65 12 20	65 12 19 27.53	160	483.5	2.170	
131	Shay Gap	20 30.0	120 06.6	200	67 11 30	67 11 39 40.05	085	11.5	0.336	
132	Shay Gap	20 29.5	120 06.0	200	67 15 00	67 15 08 10.37	085	32.2	1.326	
133	Goldsworthy	20 21.3	119 32.3	100	68 11 55	68 11 55 33.30	100	25.2	0.380	
134	Newman	23 22.1	119 40.3	670	69 09 30	69 09 37 58.55	025	unknown	*0.810	
135	Goldsworthy	20 21.2	119 32.1	100	69 11 45	69 11 38 33.03	100	7.7	0.095	
136	Shay Gap	20 30.1	120 06.7	200	69 14 00	69 13 46 51.86	100	47.0	1.943	
137	Newman	23 21.6	119 41.1	680	71 11 00	71 11 02 24.17	025	unknown	*0.910	
138	Goldsworthy	20 21.3	119 32.0	100	71 11 52	71 11 51 35.10	100	41.6	.140	
139	Tom Price	22 46.4	117 46.9	950	71 12 05	71 12 05 26.70	202	125.0	.100	
140	Shay Gap	20 29.8	120 06.1	200	time not reported	earthquake on mine monitor	-	unknown	unknown	recorded at 72 11 30 06 at MBL. Earthquake on Goldsworthy mine monitor.
141	Sunrise Hill	20 27.9	120 03.4	200	72 11 30	72 11 49 51.51	100	33.5	1.335	
142	Shay Gap	20 30.0	120 06.6	200	74 11 30	not found	100	15.8	0.270	
143	Shay Gap	20 29.7	120 06.1	200	74 11 45	74 11 51 56.34	100	9.4	0.090	
144	Shay Gap	unknown	unknown	unknown	not reported	no position	-	unknown	unknown	recorded at 75 11 37 29.39 on the Goldsworthy mine monitor (recorder 100).
145	Newman	23 21.4	119 41.6	610	76 11 00	76 11 08 46.19	025	unknown	*0.600	
146	Shay Gap	20 30.1	120 06.7	200	76 11 30	76 11 32 58.71	100	4.8	0.135	

Shot Number	Mine	Latitude	Longitude	Elevation (metres)	Shot Time (reported) d h m	Actual Shot Time d h m s	Mine Monitor	Shot Size (tonnes)	Total Delay in seconds (*estimated)	Comments
147	Shay Gap	unknown	unknown	unknown	not reported	no position	-	unknown	unknown	recorded at 76 11 43 19.21 on the Goldsworthy mine monitor (recorder 100)
148	Sunrise Hill	20 27.9	120 03.4	200	76 11 30	76 12 04 13.07	100	35.2	0.090	
149	Paraburdoo	23 14.1	117 36.3	400	76 12 42	76 12 40 38.12	073	156.1	1.015	
150	Sunrise Hill	20 27.9	120 03.5	200	77 11 45	not found	100	10.6	0.390	
151	Pannawonica	21 41.6	116 29.9	260	77 11 42	77 14 26 04.62	085	95.2	0.350	
152	Newman	23 21.4	119 42.1	640	78 10 30	78 10 30 10.69	025	unknown	*0.390	
153	Paraburdoo	23 13.9	117 35.8	400	78 12 15	78 12 12 46.83	202	101.8	1.015	
154	Tom Price	22 45.8	117 45.8	950	78 12 44	78 12 40 54.64	202	157.0	0.175	

TABLE 3. GRAVITY STATION STATISTICS

		Number of readings
(a)	Existing bench marks where no intermediate pegs were required	1071
(b)	Existing bench marks where intermediate pegs were required	
	- bench marks	177
	- intermediate pegs	288
(c)	New bench marks and intermediate pegs	
	- bench marks	254
	- intermediate pegs	334
(d)	Readings in the Fortescue Valley at stations levelled by Hamersley Exploration	57
(e)	Helicopter stations	109
	Total	2290

TABLE 4. ISOGAL VALUES

Station	May 1965 Isogal Value (μms^{-2})	Calculated Value with Port Hedland fixed (μms^{-2})	Difference (μms^{-2})
Port Hedland Airstrip 6792.0326	9 786 313.9	-	
Roeburne Airstrip 6792.1220	6 646.2	6 646.2	0.0
Mundiwindi 6792.0323	7 250.9	7 252.1	1.2
Meekatharra Airstrip 6491.9090	9 039.6	9 040.6	1.0
Mount Vernon Airstrip 6792.9210	7 767.8	7 770.4	2.6

TABLE 5. HEAT-FLOW WELLS

Well Name	Latitude	Longitude	Depth penetrated (m)	Comments
Coppin Gap	20° 53'	120° 07'	25	Esso hole 10 (not logged)
			12	Esso hole 11 (not logged)
Talgar	20° 55'	119° 55'		hole not found
Chinnamon Creek	21° 05'	118° 53.5'	40	Esso hole R4-4-hole is 40° to vertical
Wittenoom	22° 20'	118° 14'	300	hole 47A - logged every 10 m from 40 m to 300 m
Weeli Wolli No. 1	20° 37.5'	118° 24'	40	GSWA stratigraphic test well
Millstream	21° 39'	117° 01'	230	Millstream No. 9
			40	unnamed hole
Nammuldi Prospect	22° 23'	117° 18'	100	NAMF, DH107; water table 70 m
			50	NAMD, DH1081
			50	NAM, DDH 94
Brockman 4 Deposit	22° 35'	117° 15'	90	DH 35 - blocked above the water table
Tom Price	22° 45'	117° 46'	190	Tom Price Mine G623 - dry hole
Rhodes Ridge	23° 04'	119° 15'	40	Rhodes Ridge RA 55 - hole blocked

TABLE 6. VELOCITY AND SPECIFIC GRAVITY MEASUREMENTS ON ROCK SAMPLES

Rock samples with a distinct layering were measured both perpendicular and parallel to the layering. In such cases the upper value of the velocity is the measurement perpendicular to the layering. All samples were from the surface; measurements were made at atmospheric pressure and room temperature.

Laboratory Number	Station Number or Approximate location	Latitude(S) °	'	Longitude(E) °	'	Geological Description	Specific Gravity	Velocity ($m\ s^{-1}$)
78/184	001	20	31.4	120	08.4	hematite ferricrete	2.79	5200
78/185	002	20	34.1	120	04.4	massive milky quartz	2.64	4200
78/117	009	21	10.0	119	55.5	basic extrusive volcanic	2.85	6225
78/118	011	21	24.7	120	04.0	metamorphosed acid igneous	2.84	6148
78/186	011	21	24.7	120	04.0	metamorphic	2.92	5700
78/119	012	21	33.1	120	05.6	quartzite	2.62	4888
78/187	012	21	33.1	120	05.6		1.93	2400
78/120	014	21	52.7	120	06.5		2.41	3671
78/121	014	21	52.7	120	06.5	quartzite	2.63	5161
78/188	015	22	02.2	120	02.8	basic extrusive volcanic	2.86	5700
78/189	016	22	09.6	119	56.7		2.87	5200
78/122	017	22	22.2	119	58.5	quartzite	2.61	5052 5652
78/123	033	24	32.3	119	38.0	slate	2.59	5478
78/190	033	24	32.3	119	38.0	pebbly sandstone	2.55	3000
78/124	035	24	47.2	119	38.6		2.39	4590
78/125	035	24	47.2	119	38.6	quartzite	2.57	5087
78/126	037	25	06.1	119	22.1	quartzite	2.54	5040
78/127	040	25	36.6	119	11.3	basic extrusive volcanic	2.95	6640
78/128	041	25	46.5	119	00.3		2.65	5277
78/129	044	26	11.2	118	40.9	quartzite	2.61	5481
78/130	047	26	31.5	118	31.7	claystone	1.88	2608
78/191	067	23	22.2	117	34.7		2.48	4600
78/131	069	23	10.8	117	42.4	quartzite	2.63	5421
78/132	069	23	10.8	117	42.4		2.57	5507
78/133	070	23	07.5	117	50.6		2.73	5671
78/134	071	23	02.8	117	53.1	metamorphic	2.92	5673
78/192	072	22	58.3	117	51.9	basic extrusive volcanic	2.86	6200
78/135	073	22	53.1	117	49.3		2.83	6126
78/193	073	22	53.1	117	49.3	basic extrusive volcanic	2.80	5800

Laboratory Number	Station Number or Approximate location	Latitude(S) °	'	Longitude(E) °	'	Geological Description	Specific Gravity	Velocity (m s^{-1})
78/136	074	22	48.1	117	45.4	quartzite	2.59	4871
78/194	074	22	48.1	117	45.4	quartzite	2.61	3700
78/195	074	22	48.1	117	45.4	ferricrete	2.54	5800
78/137	075	22	44.2	117	48.4	sandstone	2.38	5050 5652
78/138	077	22	34.4	117	54.3	basic extrusive volcanic	2.85	6159
78/139	079	22	29.6	118	09.2	ironstone	2.75	5092
78/140	080	22	24.2	118	16.0	ironstone	2.82	-
78/196	080	22	24.2	118	16.0		2.41	3200
78/141	081	22	14.9	118	20.5	quartzite	2.75	5507 6068
78/142	081	22	14.9	118	20.5	siltstone	2.71	4367 5378
78/143	between 078 and 081	22	34.0	118	05.0	ironstone	2.99	5714
78/144	between 078 and 081	22	34.0	118	05.0	breccia	2.53	5161
78/145	between 078 and 081	22	34.0	118	05.0	breccia	2.57	2600 4779
78/146	between 078 and 081	22	34.0	118	05.0	ironstone	2.82	4214
78/147	between 078 and 081	22	34.0	118	05.0	ironstone	3.36	5416 5597
78/148	092	20	59.8	119	11.2	gneiss	2.71	3930 4384
78/149	099	20	22.2	119	27.5	quartzite	2.65	5392
78/150	107	21	35.7	119	22.0	recrystallised sediment	2.60	5563
78/151	110	21	59.6	119	01.4	quartzite	2.54	2313
78/197	112	20	45.7	119	42.0	conglomerate	2.54	4700
78/198	118	23	09.8	119	36.7	hematite	3.78	5800
78/152	120	23	18.7	119	50.8	banded ironstone	3.40	5341 5802
78/153	120	23	18.7	119	50.8	breccia	2.82	-
78/154	122	23	19.5	119	36.2		3.02	5078
78/155	123	23	18.1	119	31.0		2.99	5806
78/156	134	23	05.2	119	01.6	basic extrusive volcanic	2.99	6423
78/157	137	22	58.4	118	47.6	ironstone	3.33	5851
78/158	139	22	54.3	118	41.2		2.54	4488
78/159	141	22	54.0	118	27.8	acid volcanic	3.04	6101

Laboratory Number	Station Number or Approximate location	Latitude(S) °	'	Longitude(E) °	'	Geological Description	Specific Gravity	Velocity (m s^{-1})
78/160	143	22	55.3	118	17.1	basic extrusive volcanic	2.88	6415
78/161	145	22	53.0	118	08.4	sandstone	2.47	-
78/162	147	22	48.1	118	01.8		2.67	5511
78/163	149	22	38.6	117	41.7	ironstone	3.36	5419
78/199	152	22	31.5	117	32.1	basic extrusive volcanic	2.92	6400
78/200	154	22	29.0	117	27.2	ferricrete	3.51	4700
78/165	Mt. Bruce 1:250 000 sheet	22	52.0	118	08.0	gneiss	2.63	4702
78/166	Mt. Bruce 1:250 000 sheet	22	53	118	08.4	acid volcanic	2.62	5735
78/168	Hamersley station	-		-		ironstone	2.54	5126
78/169	Hamersley station	-		-		ironstone	3.65	6030
78/170	Tom Price railway	McRae 1:100 000 sheet		-		mudstone	2.63	4390 5555
78/171	"	"		-		siltstone	2.67	5108
78/172	"	"		-		siltstone	2.65	5511
78/173	"	"		-		ironstone	2.98	3450 4650
78/178	Tom Price mine	-		-		hematite	4.65	6038
78/201	Newman Railway	22	22	119	00	quartzite	2.17	5500
78/202	Newman Railway	22	22	119	00		2.56	3900
78/203	Newman Railway	22	21	119	01		2.59	3900
78/204	Newman Railway	22	20	119	01	quartzite	2.63	5200
78/205	Newman Railway	22	14	119	01	ferricrete	2.81	4900
78/206	Newman Railway	22	14	119	01	ferricrete	2.78	5400
78/207	Newman Railway	22	13	119	01	siltstone	2.25	3500 5500
78/208	Newman Railway	22	11	119	01	siltstone	2.61	3200 5400
78/209	Newman Railway	22	09	119	01		2.81	5100
78/210	Newman Railway	22	07.5	119	00	feldspar trachyte porphyry	2.71	3000
78/211	Newman Railway	22	07	119	00	siltstone	2.71	5000
78/212	Newman Railway	22	05	119	00	siltstone	2.75	4300
78/213	Newman Railway	22	04	119	00		2.58	2900
78/214	Newman Railway	21	44.31	118	51.99		2.92	6900
78/215	Newman Railway	21	44.31	118	51.99	granite	2.64	3100

Laboratory Number	Station Number or Approximate location	Latitude(S) °	'	Longitude(E) °	'	Geological Description	Specific Gravity	Velocity (m s^{-1})
78/216	Newman Railway	21	53.73	118	57.45		2.63	5100
78/217	Newman Railway	21	50.94	119	00.51		2.61	5300
78/218	Yalga station	-		-		granite	2.68	5500
78/219	Yampire Gorge (near Wittenoom)					asbestos in ferricrete	3.31	5400
78/175	Wittenoom Gorge	Wittenoom 1:100 000 sheet		-		siltstone	3.19	4338 5000
78/176	Wittenoom Gorge	Wittenoom 1:100 000 sheet		-		ironstone	3.20	5196 5250
78/177	Wittenoom Gorge	Wittenoom 1:100 000 sheet		-		asbestos	3.20	4367 5378
78/164	Coolgardie					massive quartz	2.67	4620
78/167	Nullabor Plain					pebbly mudstone	2.32	4418

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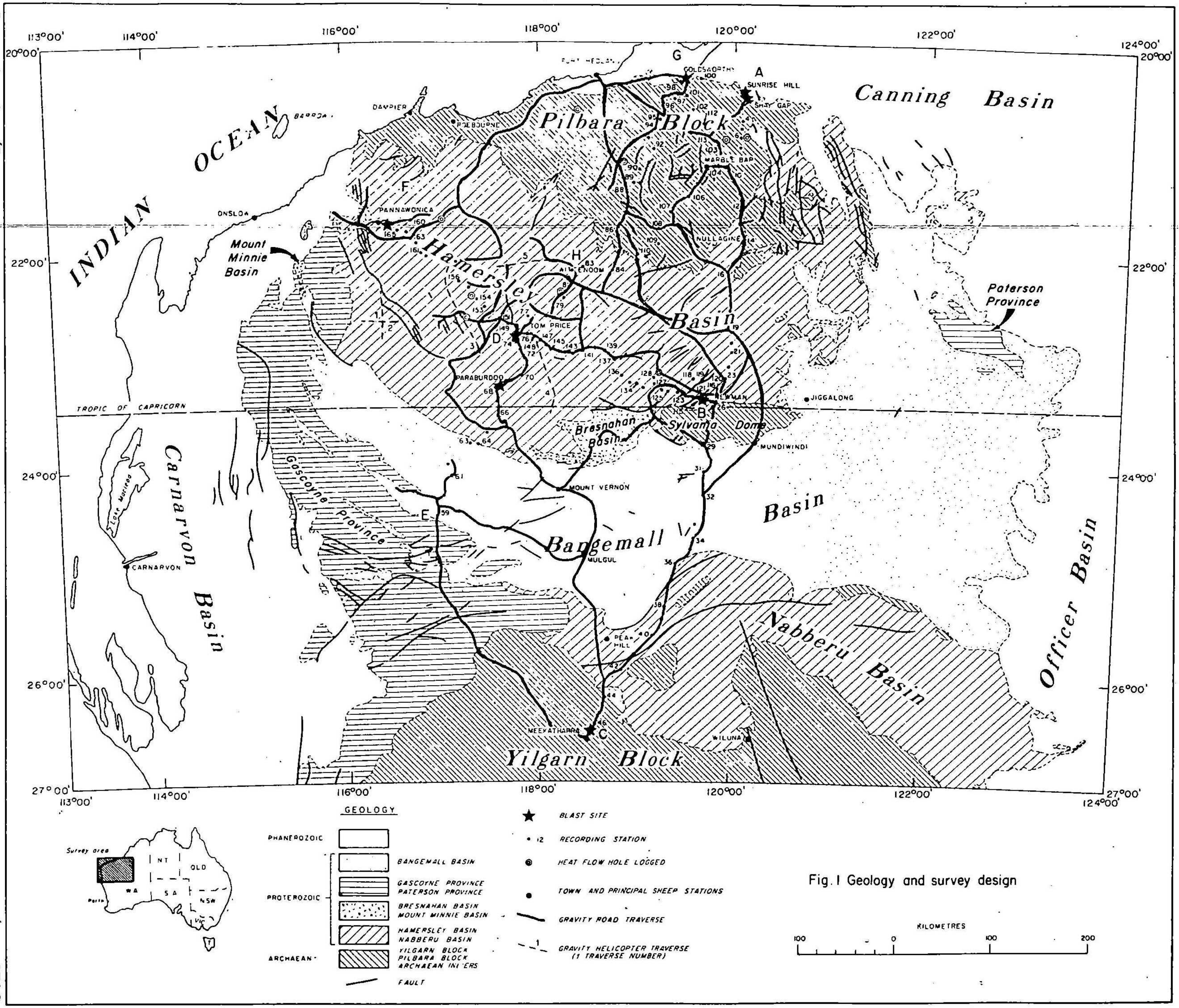

Fig. 1 Geology and survey design

WA/B10-67AR

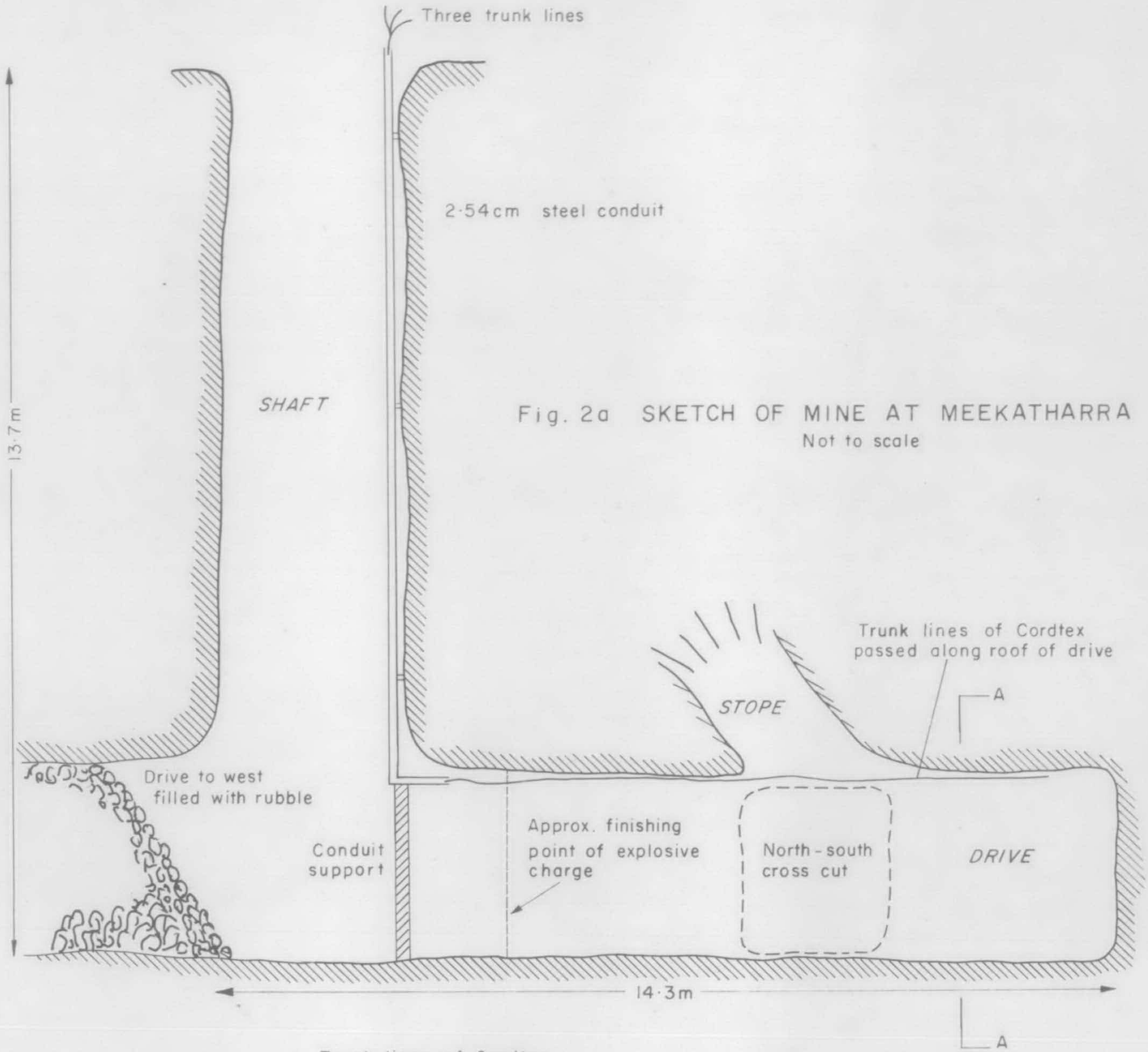

Fig. 2a SKETCH OF MINE AT MEEKATHARRA
Not to scale

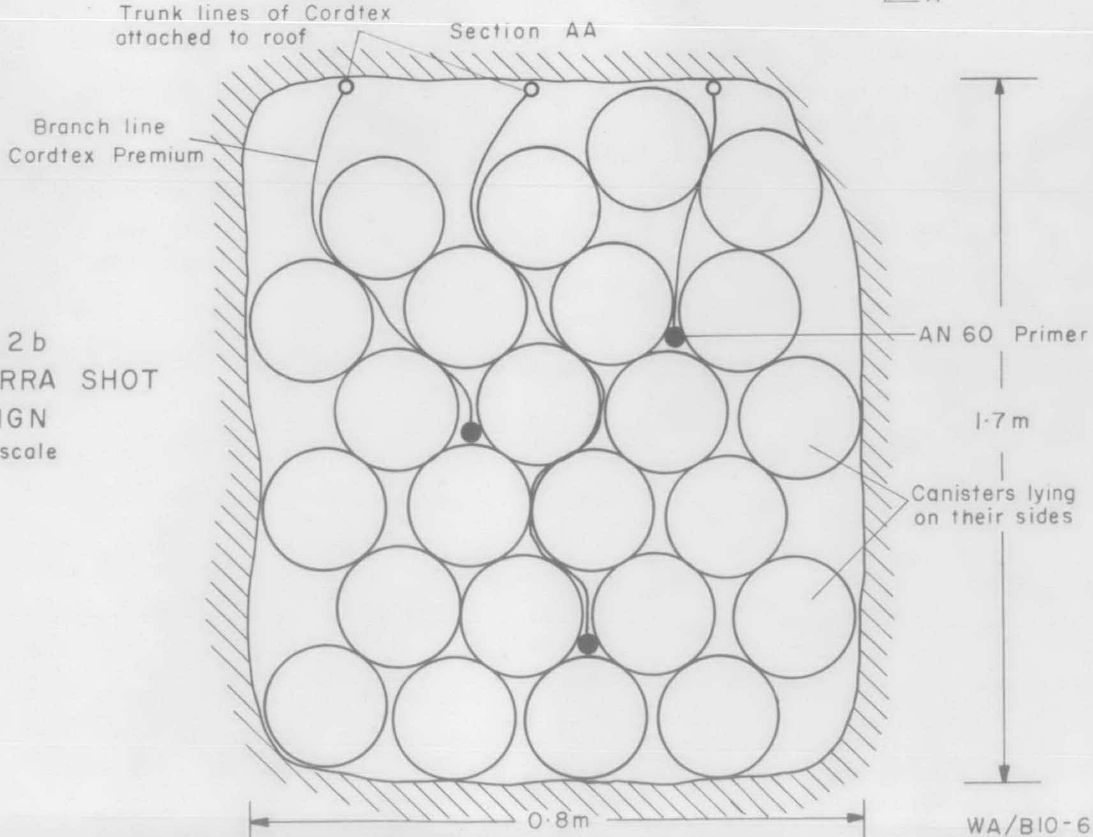

Fig. 2b
MEEKATHARRA SHOT DESIGN
Not to scale

WA/B10-68A

Record No 1979/54

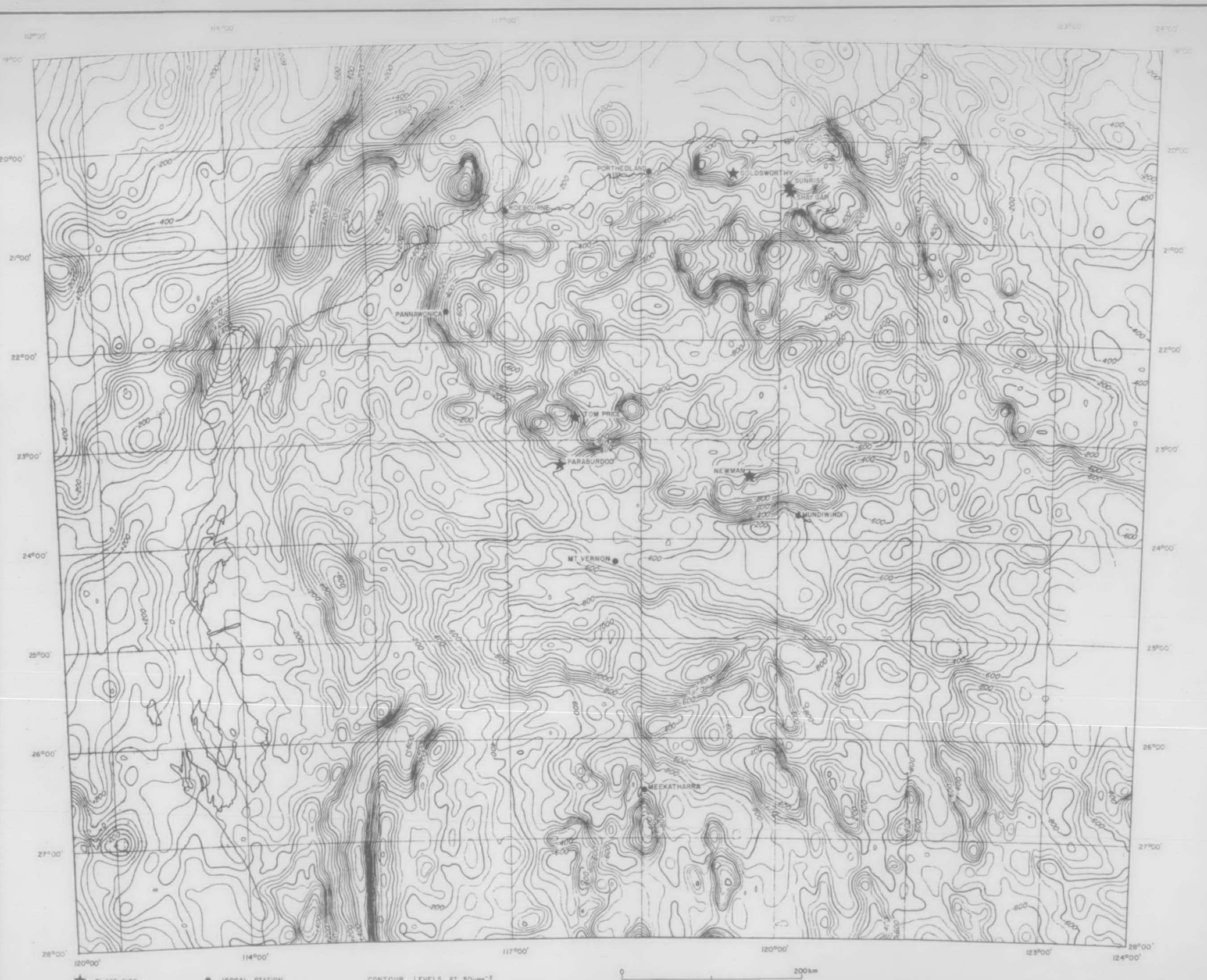

Fig.3 Gravity map of the Pilbara Region (simple Bouguer Anomalies onshore and Free Air Anomalies offshore are shown).

WA/BIO-70AR

Record No 1979/54

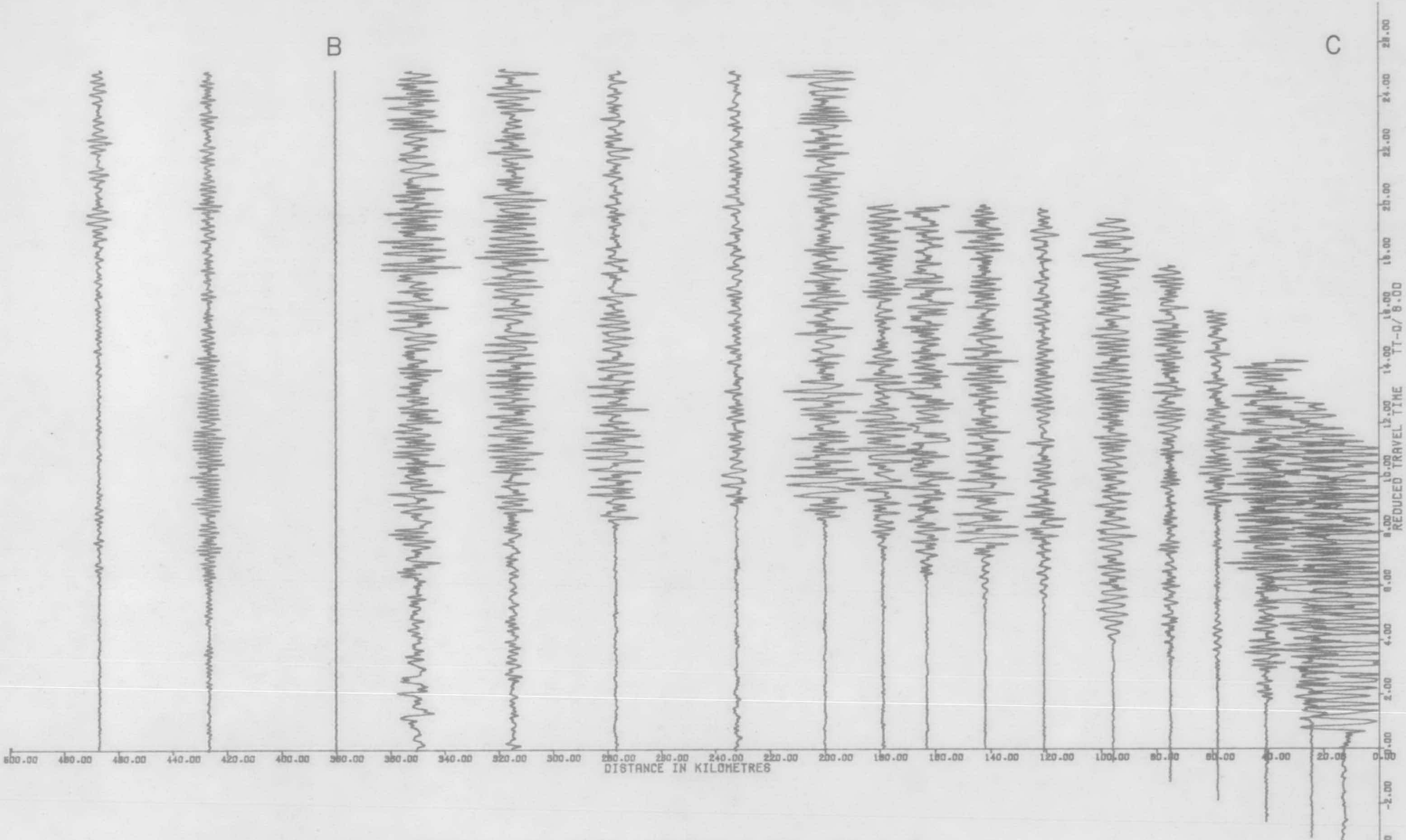

Fig. 4a MEEKATHARRA SHOT RECORDED ALONG LINE C-B

WA/B10-71A

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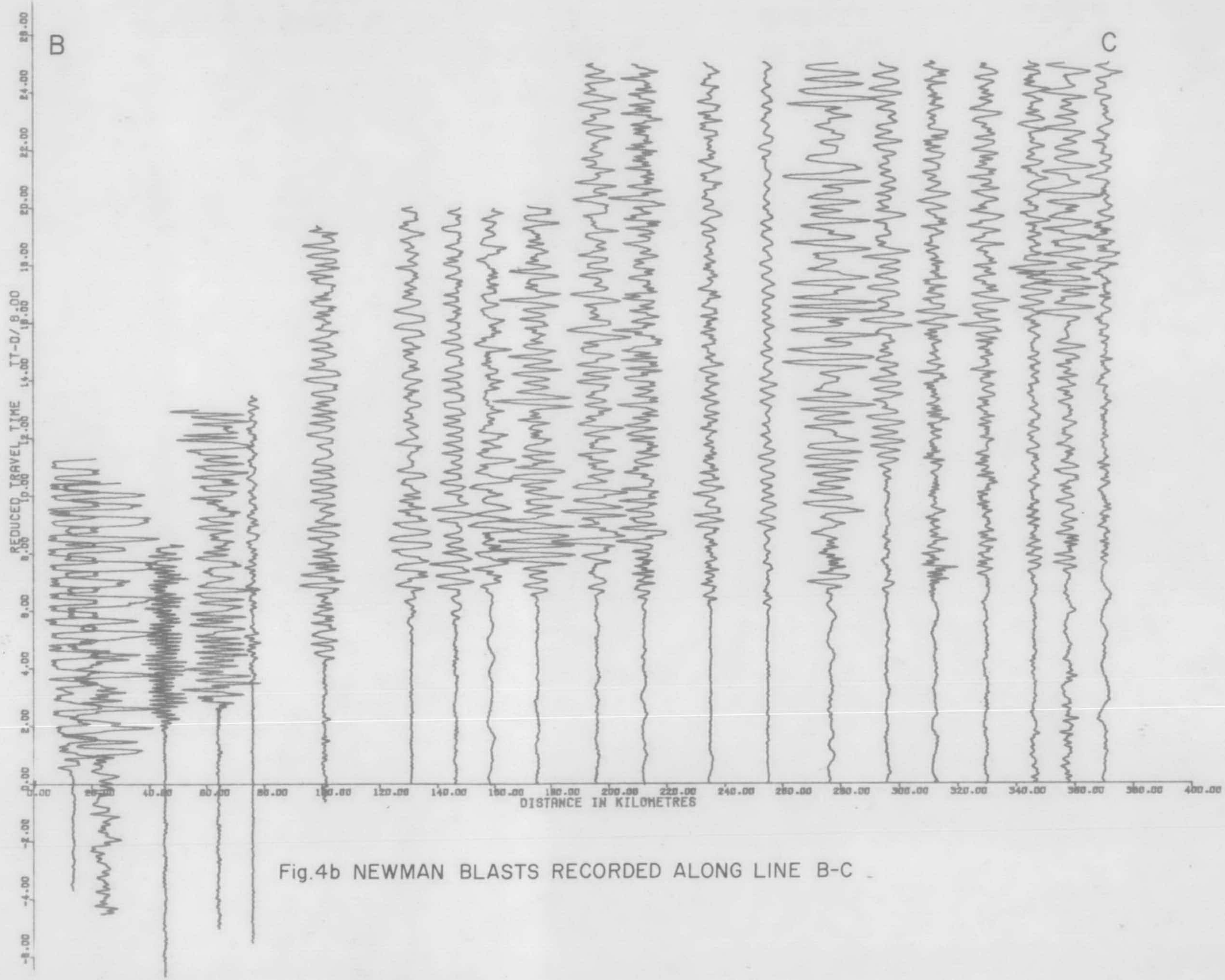

Fig.4b NEWMAN BLASTS RECORDED ALONG LINE B-C

WA/B10-72A