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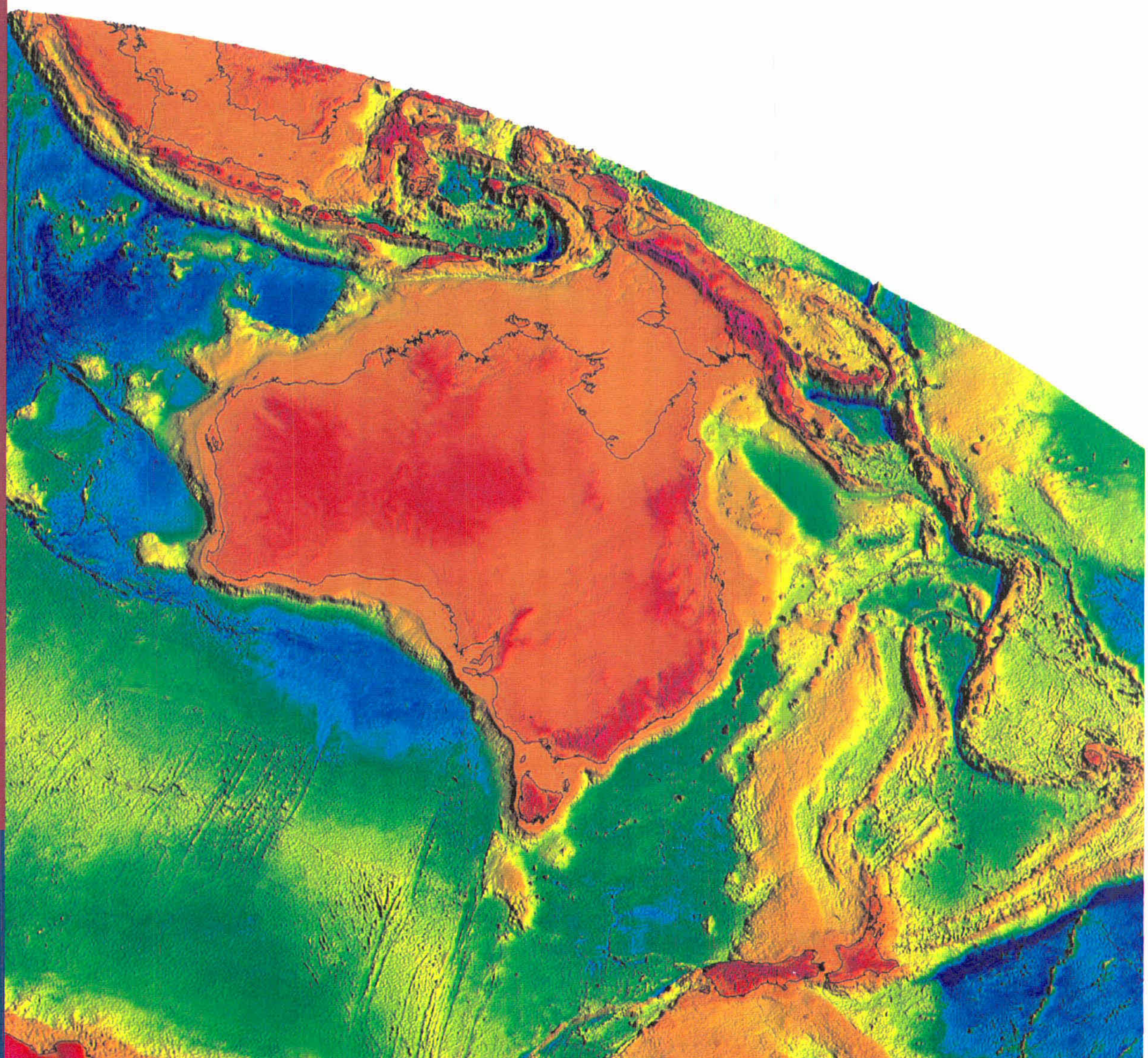
Hamersley Province Seismic Survey 1997: Operational Report

B.R. Goleby, T.J. Barton and E.H. Cherry



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Hamersley Province Seismic Survey 1997: Operational Report.

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by

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ABSTRACT

In 1997, the Australian Geological Survey Organisation (AGSO), now called Geoscience Australia (GA) and the Tectonics Special Research Centre (TSRC) at the University of Western Australian (UWA) and Curtin University conducted a joint research project to image the crustal setting of the Hamersley Province of northern Western Australia. For the rest of this report the original name AGSO will be used in reference to that organisation.

This joint research was aimed at investigating the shallow structure of the Hamersley Province, the regions deeper basement structure and in so doing, developing an understanding of the region's tectonics and possible fluid migration pathways.

The project's objectives were to obtain a better understanding of sub-surface geology of the Hamersley Province at a regional scale and a mine scale and relate this to the area's iron-ore mineral system. In particular, the project's objectives were to provide more information on:

- regional crustal thickness and major features,
- stratigraphic architecture of the regions mineral system,
- structural architecture of the mineral system,
- timing and locations of fluid migration pathways.

The seismic survey obtained 136 km of nominally moderate fold CMP (common midpoint) deep reflection seismic data along two transects over approximately 5 weeks of acquisition.

1. INTRODUCTION

Most of the concepts reported in this section came from documents prepared by Professor Chris McA. Powell, Director Tectonics Special Research Centre (TSRC), University of Western Australia (UWA), as part of the project proposal documentation. Chris's significant contribution to this section is hereby acknowledged.

1.1 Background

The Hamersley Province is one of the best-exposed late Archaean to Early Proterozoic successions in the world and is also host to several world-class iron ore deposits.

In 1996, the Australian Geological Survey Organisation (AGSO), now Geoscience Australia (GA), and the Tectonics Special Research Centre (TSRC), within the University of Western Australia and Curtin University started discussions regarding the use and potential of seismic acquisition in the Hamersley Province, Western Australia. The two principal iron-ore mining companies operating in the area, BHP Iron Ore and Robe River Mining Co. Pty. Ltd., were asked to become involved in discussions regarding the proposed regional deep seismic traverse across the Hamersley Province. MERIWA (Minerals and Energy Research Institute of Western Australia), a Western Australia state government funding agency was also asked to participate in the project. The project was accepted by MERIWA in early 1997 and given the MERIWA project number MERIWA 282. The members of the project planning team are listed in Appendix 1.

1.2 The Proposal

The MERIWA proposal centred around the acquisition of deep seismic reflection data to investigate the subsurface structure of the Hamersley Province, Pilbara Region, Western Australia. This would provide an aid to the iron-ore exploration companies in providing a regional framework to reconstruct the geometry of the subsurface and to determine the presence and possible influence of any subsurface structures and the impact of these structures on the form of the fold and thrust belt.

The proposal involved collecting one or more deep seismic reflection transects across the Ophthalmia fold-and-thrust belt within the western Hamersley Province. The seismic reflection data was to image deeper structures that would include:

- Detachment or décollement zones,
- Blind thrust faults,
- Step-up zones, or
- Deep basement structures.

The deep seismic sections, together with geological results from surface mapping as well as gravity and magnetic data, collected in conjunction with the seismic data, is used to construct geological cross-sections through the Hamersley Province. These, in turn, are to be used to provide constraints on the palinspastic reconstruction of the evolution of the Hamersley Province and existing ore genesis models.

In order to reconstruct the geometry of the Hamersley Province, it was recognised by all partners that an integrated stratigraphic, structural and geophysical approach would be needed. Fortunately, much of the necessary stratigraphic and structural work had been in progress between 1991 and 1997 through work undertaken by geologists (staff and students) from UWA, Curtin, BHP Iron Ore and Robe River. The results from the proposed deep seismic reflection traverses were to be used to extend this existing stratigraphic and structural knowledge to depth and to develop and investigate the three-dimensional concepts being proposed.

The earlier stratigraphic and structural studies resulted in the development of a late Archaean-Palaeoproterozoic model for the evolution of the Hamersley Province shown in Figure 1. This shows the increasing complexity of folding and thrusting

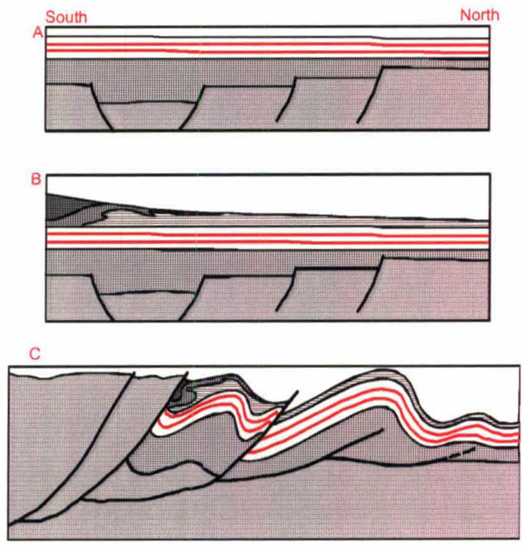

Figure 1: Schematic evolution showing the late Archaean - Palaeoproterozoic development of the Hamersley Province. It shows the increasing complexity of folding southwards and the possible structures that might be imaged by the seismic method. Figure from Powell, 1996.

with time. It also indicates a general southwards increase in deformation. This figure also shows the possible structures that might be imaged by the seismic reflection technique.

The deep-seismic reflection transects were collected during the middle of 1997 by AGSO's seismic acquisition crew. Processing of the data would be undertaken by AGSO. The first year of the project was expected to yield substantial amounts of new information, both geological and geophysical, that built on the extensive existing knowledge of the province gained by the participating companies, BHP Iron Ore and Robe River Iron Associates.

1.3 Traverse Objectives

From the initial proposal, two main transects were chosen, one through the Hamersley Province's Ophthalmia fold-and-thrust belt and the other through the Sylvania Dome. The Hamersley Province Transect was subdivided into three separate traverses.

A pre-seismic geological excursion involving all parties, with the exception of MERIWA staff, was undertaken in early 1997. During this excursion and at subsequent meetings, start and end points for each of the transects were determined and objectives for each of the seismic traverses were established. The seismic traverses chosen are shown in Figure 2 and included a Sylvania Dome Transect (SD1) and the Hamersley Province Transect; the later subdivided into three sections (HB1, HB2 and HB3).

The set of key project objectives, defined at the commencement of the proposal, was used as an aid to positioning the seismic traverses. Once the traverses were defined, the key objectives were refined to define a set of traverse specific objectives. Figure 3 shows the location of the traverses in relation to main regional geological structures.

The objectives for each traverse were:

Sylvania Dome Traverse (97AGS-SD1)

- Depth to older Archaean basement beneath the Hamersley Province;
- Offset across the Poonda Fault (Figure 3), a suspected Meso- to Neo-Proterozoic down-to-the-north normal fault;
- Subsurface extent of the Wheelarra Fault – a suspected low-angle normal fault (Figure 3);
- Subsurface extension of at least two south-dipping basement shears in the Sylvania Dome;
- Location of the major detachment zones in the Mount Bruce Supergroup (Table 1);
- Relationship between basement shear zones in the Sylvania Dome and the Hamersley Province;
- Nature of the deeper crustal architecture and depth to the Moho.

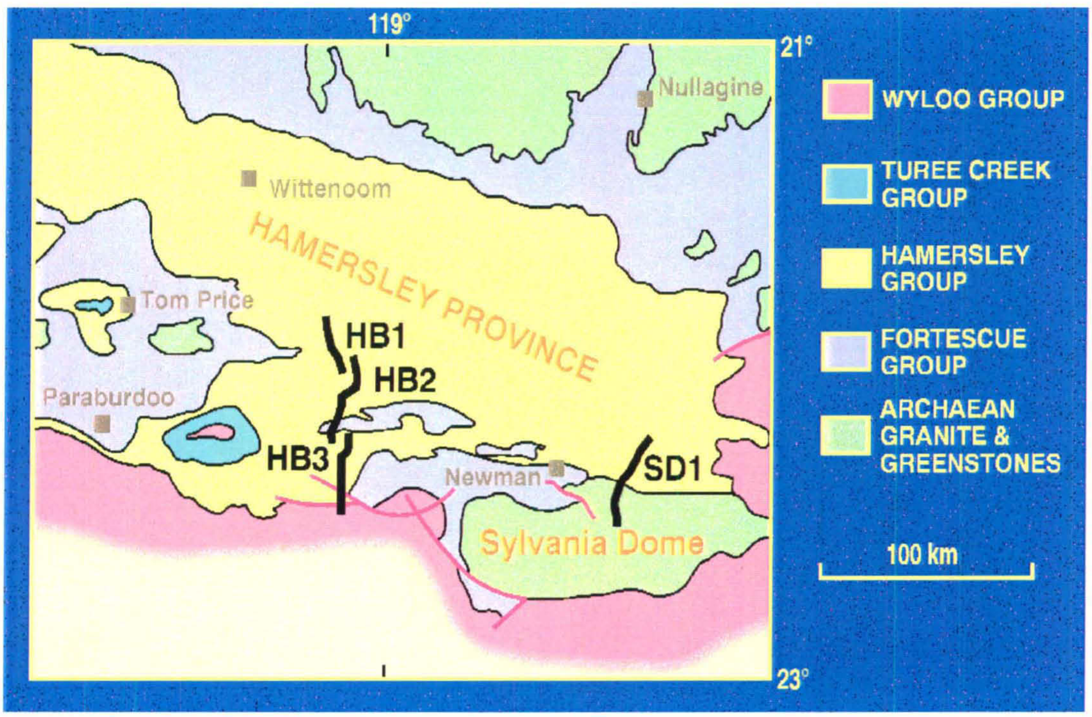

Figure 2: Simplified map of the Hamersley Province, showing location of the Hamersley Deep Seismic Lines

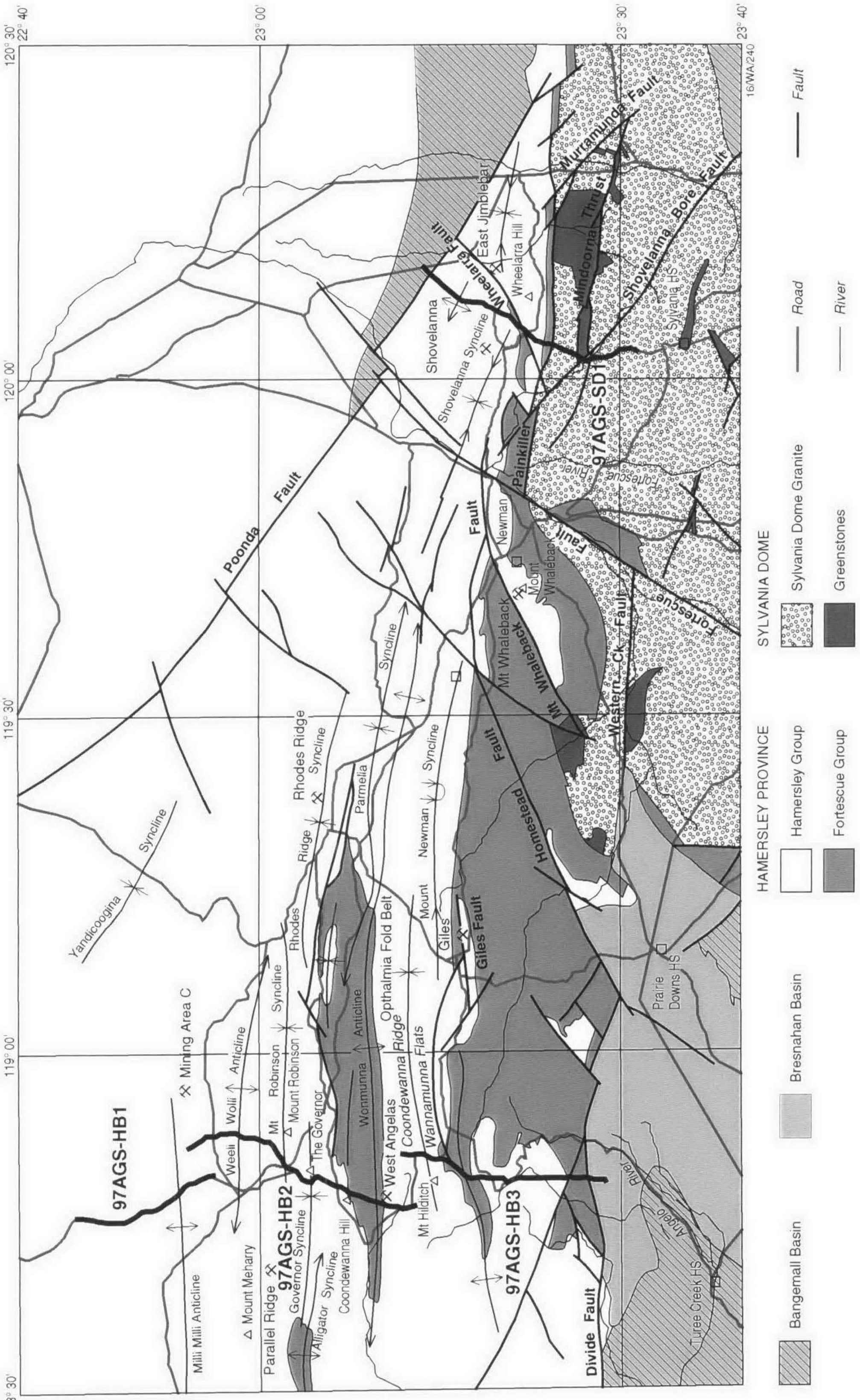

Figure 3: Location map of the eastern Hamersley Province, showing key geological structures, and main topographical features. The location of the 1997 Hamersley Deep Seismic Lines are shown.

Hamersley Traverse 1 (97AGS-HB1)

- Depth to older Archaean basement beneath Hamersley Province;
- Northern extent of the main F_2 deformation front;
- Nature of the Milli Milli Anticline – a basement-cored structure centred ~50 km to the west of the traverse (Figure 3);
- Nature of the deeper crustal architecture and depth to the Moho.

Hamersley Traverse 2 (97AGS-HB2)

- Depth to older Archaean basement beneath Hamersley Province;
- Nature of the Weeli Wolli Anticline – a suspected F_3 structure with a zone of intense F_2 folds on its northern limb (Figure 3);
- Structure below BHP Iron Ore's deposits in Area "C" (Figure 3);
- Nature of the deformation zone on the south side of "The Governor";
- Depth to possible detachment zones Hamersley Province detachments (Table 1);
- Structure across Robe River Mining Associates' Deposits "A" and "B" in their West Angelas region (Figure 3);
- Nature of the deeper crustal architecture and depth to the Moho.

Hamersley Traverse 3 (97AGS-HB3)

- Depth to older Archaean basement beneath Hamersley Province;
- Depth to possible Hamersley Province detachments (Table 1);.
- Subsurface structure of the Coondawanna Ridge – a 4 to 5 km wide intensely deformed F_2 synclinal zone immediately south of Robe River Mining Associates' Deposits "A" and "B" (Figure 3);
- Nature of the F_2 deformation zones towards the Angelo River end of the section (Figure 3);
- Nature of the possible normal fault extending west from the Homestead Fault in the Divide Fault region (Figure 3);
- Nature of the normal fault near the Angelo River separating the younger (late Palaeoproterozoic) Bresnahan Basin deposits from the Hamersley Province succession;
- Nature of the deeper crustal architecture and depth to the Moho.

1.4 Location

The 1997 Hamersley seismic survey was conducted in the Hamersley Province region of WA. The location of all lines; 97AGS-SD1 and 97AGS-HB1 through 97AGS-HB3 are shown on Figure 2 and Figure 3.

Sylvania Dome - 97AGS-SD1

Length of line: 38.84 km.
Start: AMG Grid Co-ordinates
103/285 Murramunda 1:100,000 sheet (#2951)
(intersection of track with old Great Northern Highway)
Finish: AMG Grid Co-ordinates
976/930 Murramunda 1:100,000 sheet (#2951)

Hamersley Basin - 97AGS-HB1

Length of line: 23.2 km.
Start: AMG Grid Co-ordinates
800/840 Munjina 1:100,000 sheet (#2652)
(alongside the Great Northern Highway)
Finish: AMG Grid Co-ordinates
867/630 Munjina 1:100,000 sheet (#2652)

Hamersley Basin - 97AGS-HB2

Length of line: 41.16 km.
(This traverse crossed both BHP's Area "C" and Robe River's West Angelas exploration regions.)
Start: AMG Grid Co-ordinates
912/660 Munjina 1:100,000 sheet (#2652)
Finish: AMG Grid Co-ordinates
812/323 Governor 1:100,000 sheet (#2651)

Hamersley Basin - 97AGS-HB3

Length of line: 32.8 km
Start: AMG Grid Co-ordinates
893/335 Governor 1:100,000 sheet (#2651)
Finish: AMG Grid Co-ordinates
847/000 Governor 1:100,000 sheet (#2651)
(bottom of sheet)

2. GEOLOGY

The Hamersley Province is a late Archaean to Early Proterozoic succession of shallow water sediments, carbonates, banded iron-formations (BIF's) and volcanics. The stratigraphy of the region can be simplified into 3 major units (Table 1), an Archaean granite-greenstone basement, the Mount Bruce Supergroup and younger Cover Rocks. The Mount Bruce Supergroup consists of three significantly different groups, the Fortescue Group, the Hamersley Group and the Turee Creek Group (Powell et al., 1996). More detailed descriptions on the geology of the Hamersley Province can be found in Tyler (1990, 1991), Li et al. (1993) and Powell et al. (1994).

Recent work on the region covered by the seismic traverses can be found in Cunneen (1998), Hackney et al. (1998), Hollingsworth et al. (1998) and Powell et al. (1998).

Two major phases of deformation have shaped this fold-and-thrust belt. The first deformation is a major folding event, (F_2), and is characterised by east-west (~90°-~270°) trending folds that are generally north verging and tight, and upright to recumbent and overturned. The second phase of deformation is also a folding event, (F_3), and is characterised by east-west (~100°-~280°) trending folds; however these are upright and usually open folds (Powell et al., 1996; Powell et al., 1998).

Although the region contains the Ophthalmian fold-and-thrust belt, there are very few thrusts exposed and there is little significant faulting. The only exposed major thrusts are at the southern margin of the province. It is therefore inferred that many of the thrusts are blind thrusts (Powell et al., 1996; Powell et al., 1998).

Being a fold-and-thrust belt, the presence of one or more detachment zones is very likely, given that the Hamersley Group is a succession of well-layered anisotropic rocks, and that the northern part of the province is at nost mildly deformed, if at all. However there is uncertainty as to what level the detachment surface would occur in different parts of the province.

Likely detachment horizons include the Mt McRae Shale and Mt Sylvia Formation, shaly parts of the Wittenoom Formation, and shaly parts of the Fortescue Group. Thrusts within the Sylvania Inlier indicate that the basement has also been detached during deformation (Powell et al., 1996).

The detachment surface is unlikely to be a smooth surface gradually climbing to the north. Rather it is likely to be a series of ramp-flats, with the ramps in the shaly horizons and the flats in the stronger BIF units as the detachment jumps from one weak zone to the next. The locations of the ramps are therefore important in determining the geometry of folded iron bearing units (Powell et al., 1996).

The region is host to several world-class iron ore deposits. These iron ore deposits are found within the Brockman Formation and Marra Mamba Iron Formation of the Hamersley Group (Powell et al., 1996). The iron deposits are contained within, or derived from, the above banded iron formations. These units have been subjected to at least two major folding events and several lesser folding events.

The seismic transects; one east of Newman to investigate the relationship of the Hamersley Province to the Sylvania Inlier, and the other transect in an series of overlapping north–south traverses across the main Hamersley deformed zone, were ideally suited to investigate the stratigraphy and deformation just discussed. The later seismic transect commenced in the undeformed flat-lying Hamersley Province strata lying unconformable on older Archaean basement

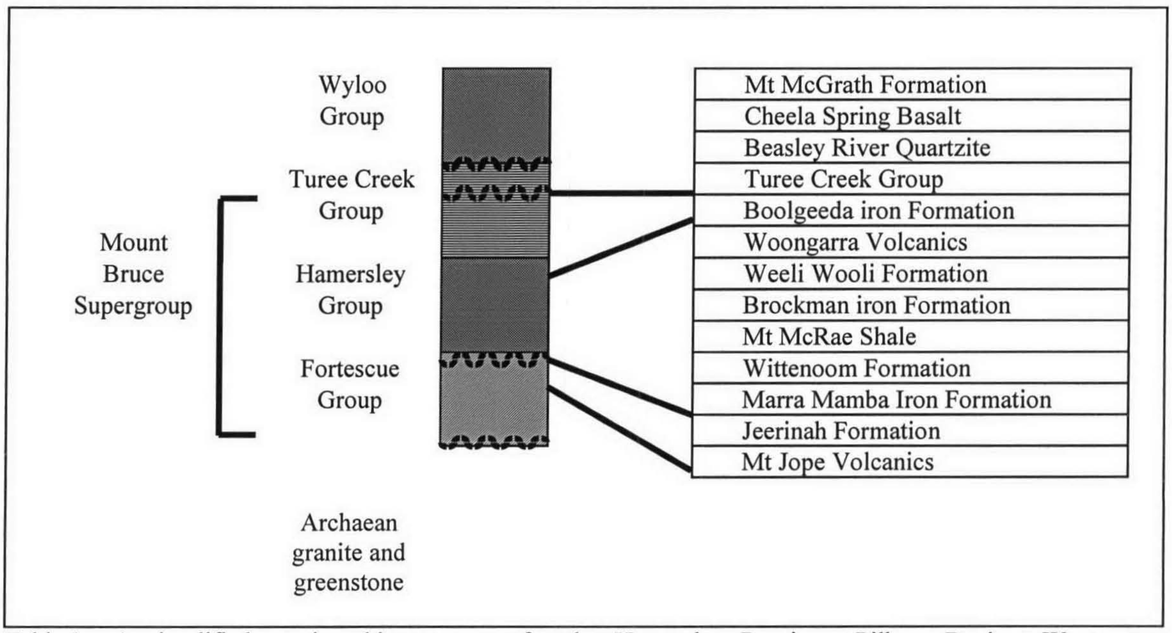

Table 1: A simplified stratigraphic sequence for the Hamersley Province, Pilbara Region, Western Australia. After Li et al, 1993 and Powell et al., 1996.

of the north Pilbara, crossed the Ophthalmian fold-and-thrust belt and ended in the younger Bresnahan Basin.

As already discussed, detachment or décollement zones, are very likely and would be restricted to the shaly units, the contact between the Hamersley and Fortescue groups and the underlying basement (Powell et al., 1996; Powell et al.,1998). One objective of the seismic is to identify the northern extent of any detachment surface.

Blind thrust faults usually form in the cores of large folds and, given the occurrence of broad concentric folding in the northern half of the province, several blind thrusts are inferred at depth (Powell et al., 1996).

Step-up zones in the detachment zone occur as one moves along the direction of tectonic transport (Powell et al., 1996).

A further objective of the seismic is to identify possible locations of step-up zones within the Hamersley province to enable reconstruction of the fold belt.

Deep basement structures have the potential to offer the most significant advancement to our knowledge. These structures generally develop over pre-existing weak zones within the basement and therefore may limit or influence deformation (Powell et al., 1996). They are also good sources of potential fluid pathways, if deep fluids drive the ore-forming process.

Late-stage faults are of interest as they are often associated with iron ore deposits and their relationship with the older faults needs to be defined (Powell et al., 1996).

3. THE SEISMIC PROPOSAL

The seismic project consisted of the collection of deep seismic data along two north-south orientated transects totalling 136 km (Figures 2 and 3).

The main Hamersley transect was located approximately 100 km west of Newman. Because of topography constraints, it was subdivided into three traverses (97AGS-HB1, 97AGS-HB2 and 97AGS-HB3).

The transect began within the central, relatively undeformed Hamersley Province foreland and ran southwards through two iron-ore prospects (BHP's Area "C" Prospect and Robe's West Angelas Prospect; Figure 3). These two ore deposits are located within the more highly deformed parts of the fold-and-thrust belt. The transect then crossed the southern margin of the Hamersley Province, ending in the Bresnahan Basin (Figure 3).

The second transect, 97AGS-SD1, was located 40 km to the east of Newman. It commenced in the Fortescue Group, crossed the southern margin of the Hamersley Province and continued into the exposed Pilbara Basement of the Sylvania Dome (Figure 3).

4. FIELD OPERATIONS

4.1 General

Of the four deep seismic reflection traverses, two were recorded at 10 fold CMP coverage and two were recorded at between 6 and 8 fold CMP coverage. Total line length was 136 km. The seismic traverses were pegged, cleared, surveyed, drilled and recorded beginning with line 97AGS-SD1 and finishing with line 97AGS-HB3. Operational statistics and survey timetables are given in Appendix 2. Spread and recording parameters for all lines are given in Appendix 3. Line recording parameters are given in Appendix 4.

Shot hole drilling for all lines was by done by AGSO, using five Mayhew 1000 drilling rigs. AGSO staff also undertook explosive pre-loading and shot firing.

Seismic data acquisition was undertaken using AGSO's SERCEL SN368 120 channel seismic acquisition system. Both the drilling and recording crews were based in various field camps located within the area of operations and adjacent to the seismic traverses.

4.2 Reconnaissance

An initial reconnaissance of the survey area was made on April 27th through May 6th, 1997 by Bruce Goleby of AGSO and Ron Hackney of TSRC. This trip focused on determining suitable access along the two proposed seismic traverses. Local property owners were also visited and the proposed seismic operations and their potential impacts on their properties were discussed with them. A list of stations, owners and related contacts is given in Appendix 5.

A follow up reconnaissance trip commenced on the July 7th 1997, just prior to the seismic operations commencing. This trip was timed to coincide with a geological reconnaissance excursion organised by Professor Chris Powell for the members of the Hamersley Province Seismic Project. These included Ron Hackney, Chris Powell, Jane Cunneen (TSRC, UWA), Peter Cawood, Dave Hollingsworth (TSRC, Curtin University), Mike Power, David McLean (BHP Newman), Doug Kepert (BHP Perth), Dave Mason (Robe River) and Bruce Goleby (AGSO, now GA). The team was able to comment on the location of the seismic traverses and to determine appropriate start and end locations for each traverse. The excursion team also investigated several sections of the traverse, not previously investigated. The BHP and Robe members provided valuable local knowledge and guidance. It was also an opportunity to finalise arrangements with several of the relevant authorities, mining contractors and pastoralists.

4.3 Environmental Management Plan

The WA Department of Conservation and Land Management (CALM) and the WA Environmental Protection Agency (EPA) had previously been visited and briefed on the seismic operations. Contact details for these organisations are given in Appendix 5. The seismic project was discussed and no significant impediments to undertaking the seismic survey were identified. CALM officers raised two environmental concerns. They recommended that we do all we can to avoid damaging several known sites of Declared Rare Fauna (DRF) and that we avoid disturbing or damaging any large patches of mulga in the region.

The locations of known Declared Rare Fauna (DRF) and Protected Fauna (PF) were provided by CALM staff to allow positioning of the traverses to avoid these DRF localities. This location information is given in Appendix 6.

Only one site (The Governor Site) was very close to the proposed route of the seismic traverse. On agreement with Department of Conservation and Land Management staff, this site could be avoided by keeping on the track or to the south of the track in the vicinity of this site.

The other environmental issue was the impact of the seismic operations on patches of mulga scrub within the Weeli Wolli anticline, north of Mt Robinson. At the suggestion of CALM staff, the section of 97AGS-HB2 between the Weeli Wolli anticline and Mount Robinson was relocated further up the slope away from the main mulga belt. This suggestion was adopted. Verbal information received from CALM staff indicated that positions of the traverses, as modified, were OK and there were no other environmental issues to be dealt with.

The Department of Conservation and Land Management were asked to report on the Environmental Impact of the seismic work during the survey and/or at the conclusion of the survey. They agreed to undertake an Environmental Impact study of the seismic work.

4.4 Trespass Issues

BHP Iron Ore Exploration and Robe River Mining Co. Pty. Ltd., as partners in the project, gave formal permission to work across their leases.

The seismic traverses crossed three other mining / exploration leases. These leases were owned by Hamersley Iron, Hampton Hill and Paladin Resources.

Letters were sent to Hamersley Iron, Hampton Hill and Paladin Resources seeking permission to conduct seismic across their leases. Hamersley Iron, Hampton Hill and Paladin Resources all gave written permission confirming that it was OK to conduct seismic across their lease. These companies were offered the opportunity to be involved with all aspects of any research undertaken across their leases.

4.5 Pastoralists

All station owners and managers were approached during the reconnaissance in April-May. The properties crossed are listed in Appendix 5.

No objections were received, with all station owners being positive toward the project. Several owners expressed interest in the drilling operations and wanted to be provided with any groundwater information that we gathered during the course of the survey. This was agreed to and the information sent to the station owners at the end of the drilling across their property.

Each station was contacted a few days prior to the commencement of each major phase of the seismic operations informing them of the start of that phase of operations.

4.6 Anthropological and Archaeological Surveys

Archaeological and Anthropological surveys commenced on July 8th, 1999. McDonald Hales and Associates were the Aboriginal Heritage Consultants selected for the survey.

The Archaeological survey identified four sites, one site on 97AGS-SD1 and three sites on 97AGS-HB3. The main area creating a problem for the seismic survey was at the very southern end of 97AGS-HB3 and as a result this line was shortened to avoid this large area involving numerous sites.

Sylvania Traverse 97AGS-SD1:

One Archaeological site was identified. Archaeologists have marked the site and identified a suitable route around the site.

Hamersley Basin 97AGS-HB1:

No archaeological sites were found. All of the line is clear.

Hamersley Basin 97AGS-HB2:

No Archaeological sites were found in sections inspected. Approximately 5–6 km within the centre of the Weeli Wolli Anticline could not be inspected in detail, however the consultants undertook spot reconnaissance inspections and the aboriginal elders were happy that there were no archaeological sites.

Hamersley Basin 97AGS-HB3:

Numerous Archaeological sites were found within the Angelo River corridor (Figure 3). This section is beyond the southern end of the traverse and was surveyed as an extension of the traverse to the Angelo River.

The Anthropological/Ethnographical survey found one site on 97AGS-HB2. This site, a native 'honey bee' site, was along a ridge south of Area 'C'. The elders did not want any vibrations in the region of the site there was no line clearing or drilling within a 1 km zone across the ridge. The elders agreed that we were allowed to drive a couple of vehicles through the area to carry cables and geophones.

The Anthropological and Archaeological Survey was completed on July 16th. An initial desktop review was prepared and provided to AGSO (McDonald, Hales and Associates, 1997a). A final Archaeological and Anthropological report as prepared, presented and lodged with AGSO (McDonald, Hales and Associates, 1997b).

4.7 Line Clearing

Line clearing was required for this survey. The line clearing operations were discussed with all the stakeholders. Permission was obtained where the seismic line crossed their land.

Tenders were called for line clearing for the Hamersley Province traverses. Young's Earthmoving of Newman was the successful tenderer for the provision of grading and bulldozing. The Capricorn Roadhouse also provided grading services.

Line clearing commenced on July 14th, using a mixture of grading and bulldozing. As most of the seismic was along existing tracks and grid lines a large portion of the line clearing could be done with minimal grading. The bulldozer was needed in the areas where there was new ground to be cleared or where old grid lines in rocky country had to be re-cleared.

4.8 Surveying

Tenders were called for surveying for the Hamersley Province traverses. Dynamic Satellite Surveys were selected.

Actual surveying commenced on July 23rd, using a differential GPS method for the surveying. A total of 137.8 km of line was surveyed.

Survey work was performed using NovAtel 3151R/RT20 c/w VHF telemetry and NovAtel 2151R c/w VHF telemetry GPS receivers to give real-time AMG84 altitude positions to better than 1.5 metres, and usually to sub metre accuracy. A DSS rapid Elevation meter was also used.

Survey coordinates were supplied as latitude/longitude and AMG positions in the WGS84 datum and spheroid together with height information in the AGD84 datum and ANS spheroid. Dynamic Satellite Surveys provided both survey data on PC floppy discs and a final report (DSS Report, 1997) which lists all relevant information.

The lines were connected to several control points in the region, one in the Shovelanna Syncline area (Standard Survey mark NWM13) and one in the Hamersley Province region (Standard Survey mark NWM16). The accuracy of the benchmarks was in the order of better than third order standards.

Surveying was completed on August 9th, with 3449 geophone stations pegged over a total of 18 days.

4.9 Drilling and Explosives

AGSO's five Mayhew 1000 drill rigs and drill water tankers were used for this survey. A total of 508 shot holes were drilled at an average depth of 23 meters. This gave a total of over 11,776 meters drilled. Further details are given in Appendix 2.

Two days of possible drilling were lost due to bad weather. It should be noted that approximately one and a half days was required to re-drill some shot holes because of problems caused by the caving in of holes prior to loading with explosives within areas where the regolith consisted of gravel sized material.

Safety of the crew and local traffic was of concern. The tracks used for the seismic line were mostly very narrow, hilly and winding. All care was taken to alert possible traffic of the drilling works ahead. Safety signs were posted, cones deployed around the work site, fluorescent jackets worn by staff and flashing orange beacons were displayed when necessary. It is a credit to the crew that no incidents were reported. The drilling crew is listed in Appendix 1. Drilling and recording vehicles used during the survey are provided in Appendix 7.

Water for the drilling operations was obtained from local bore fields or local mining operations.

ICI 'Powergel 3000' explosives were used as the seismic energy source, mainly as 2 kg plugs. A 10 kg charge was selected as the optimum size to use, considering the acquisition target. The charge size was reduced where shot holes were shallow.

In areas of thicker regolith, larger charge sizes (up to 18 kg) and deeper holes (up to 60 m) were tried in an attempt to improve signal. However neither of these changes did much to improve the signal.

Shot holes were, in the most, pre-loaded several days before detonation and, where possible as soon as drilling completed.

Two AGSO staff undertook shot firing. This ensured extra safety precautions at the site. The shot firing staff are listed in Appendix 1.

4.10 Seismic Operations

The crew arrived on site on July 24th 1997. Drilling commenced on July 25th, with seismic acquisition testing work commencing on the same day. Production recording commenced on July 29th.

Survey parameters determined and used for the survey were:

Group Interval	40 m
Shot Interval	240 m nominal
Record Length	20 sec
Sample Rate	2 msec
Spread	Split Spread 2400m - 0 - 2400m
Depth of Hole	variable 12 - 58 m
Charge Size	10 kg nominal

The seismic survey ran for approximately 5 weeks. Drilling finished on September 1st and recording finished on September 2nd. The crew departed site on September 3rd for their next survey.

Two days were lost to rain. Three days were lost to camp moves (Appendix 2).

The recording crew performed very well under some difficult circumstances. The majority of the acquisition was along roads. The crew had to contend with traffic control not only on lines that followed roads but also at intersection of the line with the numerous tracks. Safety was of paramount concern. All steps were taken to ensure that work was carried out in a safe and proper manner.

At most times there were eight field hands deploying and picking up equipment. Four 'jug buggies' were used for this work. Another two vehicles were available mainly for traffic control. The recording crew was a total of eleven staff, eight field hands, two shot firers, and one Observer. The recording crew is listed in Appendix 1. Recording and drilling vehicles used during the survey are given in Appendix 7.

4.11 Seismic Equipment

The Sercel SN368 telemetry seismic acquisition system operated in a 120-channel configuration for the survey. Four auxiliary channels were also recorded, channel 1 was the uphole geophone and channels 2 to 4 were unused. The SEG-D recordings were on 0.5 inch "Blackwatch" brand 9-track magnetic tapes. The tapes were 1200 feet long holding up to 24 shots at 2 ms sampling rate and 20 seconds data length. This first record on each tape was a 20-second internal sine wave test to test the system and check tape quality. A 'cap' test was also performed each day prior to production to test the system. The 'cap' test was recorded on tape. A second end of file (EOF) mark was always placed at the end of each tape.

A new tape was used at the beginning of each acquisition line. Field SEG-D tapes numbered

97/023 through to 97/052 inclusive were used for this survey. These details are given in Appendix 8.

The AGSO-designed SN368 eavesdropping system was also used for this survey.

This system captured the SEG-D data written to tape onto a 486 computer. The 486 computer, configured with the LINUX operating system, was used to demultiplex the SEG-D field shots and write them out in SEG-Y format to disk. This data was then copied to 8 mm Exabyte magnetic tape as a further backup.

4.12 Communications

Communications between the seismic party and head office during operations of the survey presented no problems.

Mobile phone service was not available at the campsites associated with 97AGS-HB1, 97AGS-HB2 and 97AGS-HB3, though it was available from the 97AGS-SD1 campsite via a station at Newman. In camp, an Optus satellite service was available for telephone and fax lines.

A post office box service for mail was organised in Newman.

While operating on the line VHF and UHF radio service was available to all working groups, with reception at base camp useable within a certain range.

5. ENVIRONMENTAL CONSIDERATIONS

Each of the station owners or their managers was contacted and any problems arising from the seismic survey were investigated and dealt with to the satisfaction of all parties.

All seismic survey pegs were removed from the ground. All flagging tape was collected and disposed of. An inspection was made of all shot sites and any holes that had collapsed were filled in with gravel. Any shot holes that had blown out during seismic operations were also inspected. In a couple of areas, the buried explosive charge did not detonate. Star droppers were placed at these shot holes and an identifying tag was bolted to the dropper. Details of the charge, depth and date were punched on the tag.

The three campsites were left in good condition. A few of the drain holes from the kitchen area had collapsed a few centimetres. These holes were re-filled.

An audit of the seismic traverse was undertaken by staff from the Department of Conservation and Land Management (CALM). They were asked to report on the environmental impact of the seismic work. In addition, the respective mining companies through whose leases we crossed were contacted and asked to advise if any section should be restored.

As the majority of the seismic traverses were along existing roads, tracks or grid lines, the Department of Conservation and Land Management staff deemed that only those sections that were cleared across natural scrub were required to be looked at and reported on.

Their report was positive. They were very pleased at the overall minimal damage to the topsoil and the amount of vegetation rootstock still alive in the ground. There was little windrow or ground disturbance. Their only major concern was preventing people from continuing to drive along the tracks.

The restoration work therefore focused on three aspects - removing windrows, fixing the seismic traverse and blocking access to the track.

Windrows and the mounds of vegetation left along the traverse were pulled back onto the seismic traverse and the seismic traverse was then scarified along the required sections. Those sections where vehicles could leave the track or road and follow the seismic traverse were blocked off.

On 97AGS-SD1, the middle section (~4 km) was the only section that had been cleared. It had its windrows pulled back in and the middle of the seismic track scarified. 97AGS-HB1 required no restoration. 97AGS-HB2 required restoration from the north of Mount Robinson to the northwest of 'The Governor' (Figure 3). This section was restored by having its windrows pulled back in and the middle of the track scarified. The ends were also blocked off, although the original style of the line clearing made these start and end points hard to see anyway. 97AGS-HB2 was also restored for the 1.5 km over the ridge near Coonawanna Hill (Figure 3). 97AGS-HB3 was restored for a short section south of the Wonmunna Flats and then for the section of seismic south of Angelo River (Figure 3).

6. DATA PROCESSING

6.1 Field Processing and Quality Control Procedures

The Sercel SN368 recorded raw data on 9 track tapes as 6250 bpi SEG-D multiplexed data. Additionally 5 Gb Exabyte tapes in SEG-Y format were recorded using the PC-based 'Eavesdropper' System.

The 'Vista' field-based seismic processing system was used on the seismic survey for quality control (QC). QC comprised reading in the SEG-Y eavesdropper tapes, concatenating the separate SEG-Y shot files and then writing them out to exabyte tape in 32bit IBM floating point format. Any corrupted shots or missing files could be re-demultiplexed from the original SEG-D field tape on 'Vista' and incorporated with the existing field backup data. The raw SEG-D tapes and the SEG-Y exabyte's used are listed in Appendix 8.

Uphole signals, recorded on auxiliary channel 1, were demultiplexed separately by the eavesdropper and written onto 3.5 floppy disk. These were also concatenated and analysed on the 'Vista' and uphole time arrivals picked in the field.

Field QC also involved the checking of shot geometry from the monitor records and observers report. Driller's Logs, Shot hole Loader's Logs and Observer's Logs were also crosschecked for consistency in the field.

6.2 First Pass Processing

In this section we discuss only the initial processing undertaken as part of the evaluation of the seismic survey results. A full description of the processing methodology used to final stack and migration is given in Jones and Goleby, 2001.

AGSO was responsible for processing the data, working on the advanced processing and preparing the various sections (deep sections (20s) and shallow sections (4 s), migrated and unmigrated as well as near surface regolith sections) and archival data tapes.

Processed sections of all seismic lines were produced in-house at AGSO, at both 20 and 4 seconds two-way-time (TWT). The software used in the processing stream was Paradigm's DISCO/Focus seismic processing package. It can be used in both batch mode (DISCO) and interactive mode (FOCUS). These programs were run on an IBM RISC 6000 machine ('Moho') using the 'Unix' operating system.

All lines were processed with 'crooked line processing' methods, where the CMP locations for binning were calculated from shot / receiver and midpoint distribution plots. As a rule, the deep 20 second (TWT) sections, have a large binning window while the shallow 4 second (TWT) sections were binned at about 250 metres.

The initial processing involved the data being processed to 'brute' stack and displayed to show both 4 sec (~12 km) and 20 sec (~60 km) sections. The brute stack processing was a first pass processing stage to get an indication of the data quality and variability along the sections, the

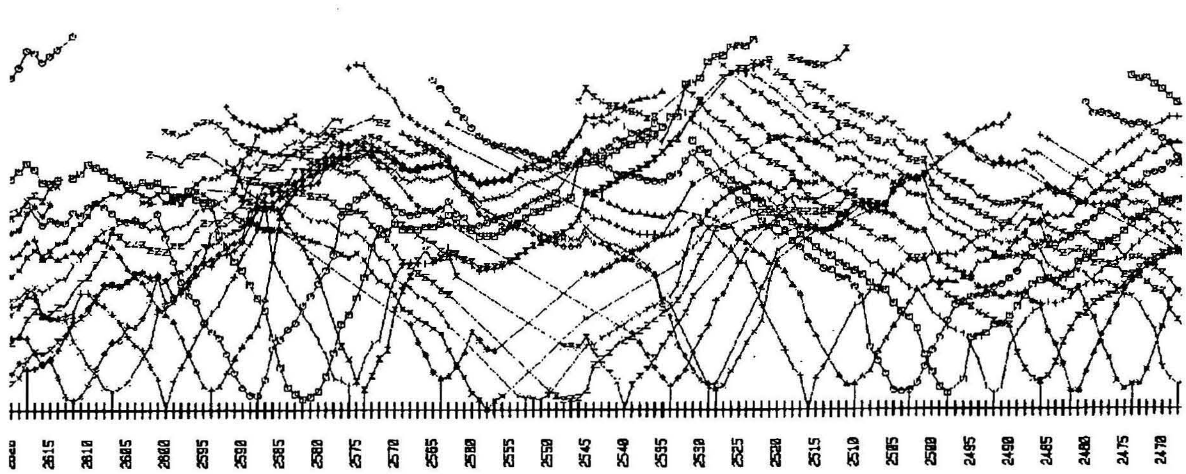

Figure 4: Computer plot of first arrivals from HB2 showing large variation in first break arrivals reflecting major changes in regolith thickness and velocity.

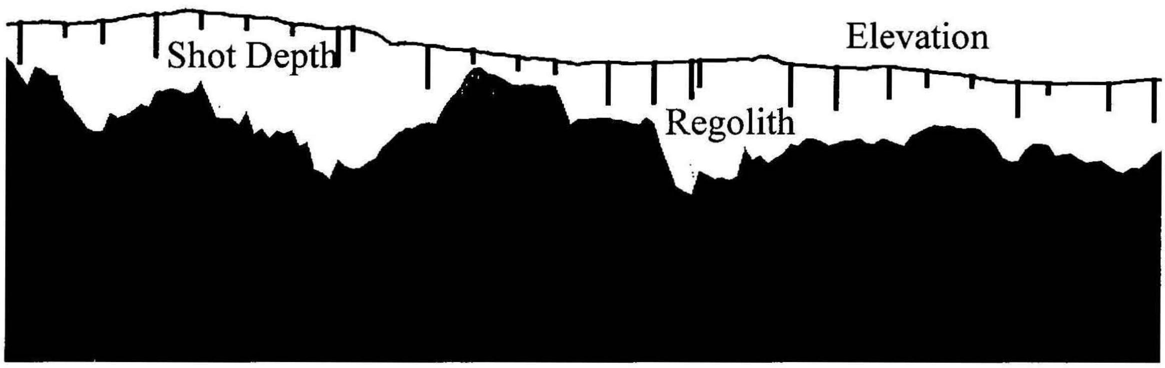

Figure 5: Initial solution obtained from the first break analysis, showing elevation, shot hole depths and surface on the top of the bedrock topography.

reflection characteristics along the sections and the main areas where additional special processing might be needed. The initial conclusions from the brute stack processing are divided into three main areas - Statics, Frequency Content and the Limited Coherency of the returned signal. Velocity variations were also a problem.

Statics (corrections for elevation and regolith variations) are a problem within the Hamersley Province. The 'first arrival' information indicates there are significant near-surface variations along the traverses, as shown in Figure 4. Special attention to these near-surface variations was required to resolve and calculate these static differences. More importantly, this information was then used to obtain a better image of the top 10 m to 100 m of the near-surface geology along the traverse; information particularly useful in any mining operations. An example of the initial weathering - sub-weathering solutions is shown in Figure 5.

The frequency content of the signal is dominated by low frequencies. However, there are considerable variations in the frequency content of the returned signal along the sections, with areas of good frequency range and areas where the main frequency content is dominated by low frequencies. This variation is a function of the near-surface geology and this variation can directly be correlated with mapped geological units.

Constant velocity analysis was undertaken on CMP stacked data, concentrating on the top three seconds.

Considerable work was required to get the best out of the four field processed sections. Already there are parts of the seismic sections where an interpretation of the structure of this part of the Hamersley Province has been started, however there are other sections where further processing will be required to improve reflection character and clarify possible interpretations.

6.3 General Processing Methodology

Traverse 97AGS-HB2 (Area 'C' to West Angelas) was selected as a test traverse for processing. The following processing steps were undertaken on this traverse:

- first breaks were picked and a statics solution computed, displayed and applied;
- shot edits and shot mutes were picked;
- some initial spectral analysis was undertaken on selected shots to get an indication of the frequency content and variation between the good and the bad shots; this spectral information was then used to run signal enhancement processing tests;
- several different filter methods were tested; including simple bandpass and FK filters;
- some limited gain recovery processing was tested.

The following processing strategies were to be investigated as part of the routine processing steps:

- Velocity analysis;
- Special transform processing;
- Deconvolution;
- Migration, before or after stack.

Figure 6 shows part of raw shot from line 97AGS-HB2. This shot contains predominantly low frequencies and with very few reflections. This shot record contains both high and low frequencies with the reflections characteristically having a much higher dominant frequency.

Figure 7 shows this shot after refraction statics and spectral equalisation (with one set of parameters). This processing methodology has enhanced the high frequency content of the shot

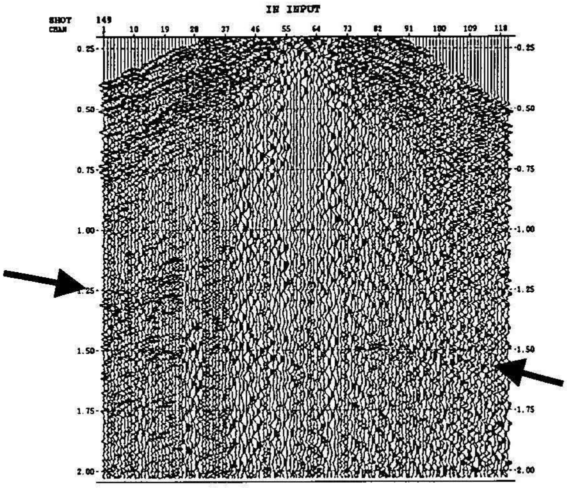

Figure 6: Raw shot number 149, 97AGS-HB2 (0.25-2.0 sec) showing characteristics of signal strength and continuity.

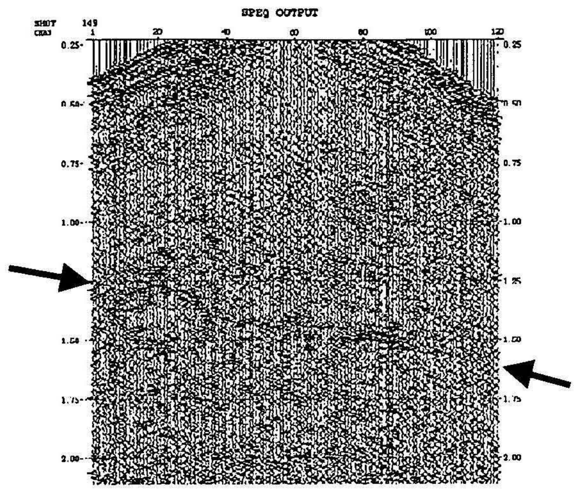

Figure 7: Partially processed shot number 149, 97AGS-HB2 (0.25-2.0 sec) showing effects of application of refraction statics and spectral equalisation.

over the previously dominant low frequencies. There is now an indication of several sets of sub-horizontal reflections appearing across the shot.

A typical processing stream used for the 20 second displays is:

- Crooked line geometry definition;
- Field SEG-Y to 'Disco' format;
- Resample to 4 milliseconds;
- Quality control display and edits;
- Crooked line binning;
- Spherical divergence and gain correction;
- Statics computation (first breaks or uphole method, differing datums);
- CMP sort;
- 50 Hz notch filter (where required);
- Constant Velocity analysis (CVS);
- Normal Moveout correction (NMO);
- Pre-stack NMO mute (stretch mute);
- Common depth-point stack;
- Bandpass filter;
- Time varying equalisation;
- Signal enhancement (digistack);
- Post stack balance;
- Migration.

Further details on the processing of the Hamersley Province data is given in Jones and Goleby, 2001.

7. ACKNOWLEDGEMENTS

The authors acknowledge the contributions and efforts made by all members of the 1997 Hamersley Seismic Survey team. The cooperation and assistance from local government authorities, landowners and exploration companies was appreciated. In particular the following organisations and people should be recognised.

Survey Design
C McA Powell, Ron Hackney (TSRC, UWA), Peter Cawood (Curtin University), Bruce Goleby (AGSO now GA), Mal Kneeshaw, Doug Keepert (BHP Iron Ore), Dave Mason, Tim James (Robe River).

Survey Crew (AGSO)
B. Goleby, T. Barton (scientific officers), A. Crawford (mechanical), M. Schade (technical officer), T. Cherry (drill supervisor), D. Eaton, A. Hinds, A. Porter, B. West, G. Gowans, (drillers), D. Keast, B. Devenish, C Bruce, S Richardson, R. Hobday, B. Howell (driller's offsiders) R Cherry, A Takken, S. Pardalis (shot firers) G Filmer, C Hindle, D Mc Appion, T Mikulic, J Moore, M Tully, M Cuzner, (field hands) R Asmus (camp attendant) Brett Emmerton (cook), Wendy Coombes (cooks offsider).

Environmental Issues, Access and General Support
J Sanders (Conversation and Land Management, WA), Bridgid Todd (Environmental Protection Agency, WA).

Field Processing/QC and
Final Data Processing (AGSO)
B. Goleby, Tim Barton, Leonie Jones.

Both BHP and Robe River are thanked for making their mining camp available to the crew during the initial reconnaissance and then during the seismic operations. Both companies were also very helpful in providing a good supply of camp and drilling water as well as handling other logistical issues. They also provided an emergency means of communications. Robe and BHP were also very helpful in post survey restoration work, with both companies providing valuable assistance during this work. Robe River is also thanked for providing a field assistant during the final two days of line clearing to assist with this work.

Ron Hackney and Dave Hollingsworth (PhD Students with UWA and Curtin respectively) are acknowledged for their assistance during the seismic survey.

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Li, Z. X., Powell, C. McA. and Bowman, R., 1993: Timing and genesis of Hamersley iron-ore deposits. *Exploration Geophysics*, **24**, 631-636.

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Powell, C. McA. and Horwitz, R. C., 1994: Late Archaean and Early Proterozoic Tectonics and Basin formation of the Hamersley Ranges. *Geological Society of Australia (WA Divison), 12th Australian Geological Convention, Excursion Guidebook*, **4**, 53 pp.

Powell, C. McA, Li, Z. X. and Martin, D. McB., 1998: Tectonic Evolution of the Paleoproterozoic Ophthalmia Fold belt on the Southern Margin of the Pilbara Craton, Western Australia. ARC Tectonics Special Research Centre, Inaugural Symposium, Department of Geology and Geophysics, The University of Western Australia, 76-77.

Tyler, I.M., 1990: Geology of the Newman 1:100,000 sheet, Geological Survey of Western Australia, Map and Explanatory Notes.

Tyler, I.M., 1991: The geology of the Sylvania Inlier and southeast Hamersley Basin. *Geological Survey of Western Australia, Bulletin*, **139**.

APPENDIX 1 - Survey Personnel

Project Planning Team

Peter Cawood	(Curtin University)
Bruce Goleby	(AGSO, now GA)
Ron Hackney	(UWA, PhD student)
David Hollingsworth	(Curtin University, PhD student)
Tim James	(Robe River Mining Co. Pty. Ltd.)
Douglas Kepert	(BHP Iron Ore Exploration)
Mal Kneeshaw	(BHP Iron Ore Exploration)
David Mason	(Robe River Mining Co. Pty. Ltd.)
Chris Powell	(University of Western Australia)

Acquisition Team

Australian Geological Survey Organisation:

Project Leader / Geophysicist	Bruce Goleby
Crew Chief / Clerk / Geophysicist	Tim Barton
Technical Officer (Electronics):	Mick Schade
Technical Officer (Engineering):	Allan Crawford
Drill Supervisor:	Edward (Ted) Cherry
Drillers:	Des Eaton
	Andrew Hinds
	Allan Porter
	Barry West
	Garry Gowans
AGSO Assistant Driller:	Darren Keast
	Ben Devenish
	Ron Hobday (start of survey to 29/8/97)
	Brad Howell (1/9/97 to end of survey)
	Colin Bruce
	Scott Richardson
Shot Firers / Preloaders:	Ron Cherry
	Stan Pardalis
	Alex Takken
Field Hands:	Morgan Tully
	Mark Cuzner
	Geoff Filmer
	Craig Hindle
	Darren McAppion
	Tony Mikulic
	John Moore
Camp Attendant:	Ray Asmus
Cook:	Brett Emmerton
Cook Offsider:	Wendy Coombes (29/7/97 to end of survey)

APPENDIX 2 - Operational Statistics and Timetable

Reconnaissance Conducted	27/4/1997 - 6/5/1997 8/7/1997 - 10/7/1997
Anthropological Survey Commenced	8/7/1997
Anthropological Survey Completed	16/7/1997
Line Clearing Commenced	14/7/1997
Line Clearing Completed	25/7/1997
Line Pegging / Surveying Commenced	23/7/1997
Line Pegging /Surveying Completed	10/8/1997
AGSO Drilling Crew Commenced drilling for Experimental Tests	25/7/1997
AGSO Drilling Crew Commenced production drilling	25/7/1997
AGSO Drilling Crew Completed Survey	1/9/1997
Recording Crew Commenced Experimental Tests	28/7/1997
Recording Crew Commenced Acquisition	29/7/1997
Recording Crew Completed Survey	2/9/1997
Crew Arrived Field	24/7/1997
Crew Departed Field	3/9/1997

Recording:

Total number of recording days worked	23 days
Recording days lost:	
Due to camp moves and weekends	13 days
Due to adverse weather	2 days
Due to instrument breakdown	0 days
CMP fold	10 (nominal)
Total number of production shots	508 shots
Average number of production shots recorded per day	22 shots
Explosives used	5072 kg
Detonators used	549
Average charge/production shot	10 kg

Drilling:

Total number of drilling days worked	25 days
Number of drilling rigs	5
Total number of rig days worked (including maintenance)	125 days
Rig days lost:	
Due to camp moves and weekends	13 days
Due to adverse weather	2 days
Due to rig breakdown	0 days
Shot holes:	
Total number of holes drilled	508
Total metres drilled	11,776 m
Average depth of each shot hole	23 m
Shot spacing	240m (nominal)

APPENDIX 3 - Spread and Recording Parameters

Spread Length	4760 m
Spread Type	Split Spread
Number of Channels (max)	120
Number of Station Units available	153
Geophone Station Interval	40 m
CDP Fold (nominal)	10
Number Geophones / Trace	16
Geophone Pattern	in-line
Geophone Spacing	2.67 m
Geophone Type	Geospace 10 Hz GSC-20D
Seismic System	Sercel SN368
Blaster	OYO Model 1340
Camera	OYO DFM-480
Station Unit Test and Repair System	Prosol TRS-2
Field Processing System	Vista PC based system
Sercel SN368 instrument settings:	
Recording mode	Digital
Recording format	SEG-D Multiplexed / PC SEG-Y
Number of input channels:	
Data	120
Auxiliary	4
Tape	9 track, 6250 bpi, GCR, 0.5 inch, 8.5 inch reel 1200 ft / Exabyte 5 gig uncompressed
Record Length	20 seconds
Sample Rate	2 ms
Input Filters:	
Low-cut	8 Hz / 18db / Oct
Hi-cut	178 Hz
Pre-Amp Gain	7**2
Playback Parameters:	
Low-cut	12 Hz
Hi-cut	90 Hz
Slope	18 ms
Seis Monitor Gain	42 db
Output Adjust	4 db
Gain Curve	1
Release Time	10 ms
Compression Delay	8 ms
Early Gain	36 db
AGC	1
Recovery Delay	32 ms

APPENDIX 4 - Line Recording Parameters

A summary of the line lengths and station numbers are given below.

Line	Station Range from	Station Range to	Line Length (kms)	Number of Stations	Shot Range from	Shot Range to	Number of Shots
97AGS-SD1	1000	1971	38.84	972	1000	1971	163
97AGS-HB1	1000	1580	23.20	581	1000	1580	78
97AGS-HB2	2000	3029	41.16	1030	2000	3029	170
97AGS-HB3	3000	3820	32.80	821	3000	3820	97
Total			**136.00**				**508**

AGSO Survey Name: Hamersley Province 1997.
AGSO Survey Number: L144

Line 97AGS-SD1

Orientation	N-S
(High SP numbers North, Trace 1 to the South)	
Recorded	N to S
Length	38.84 km
First Geophone station	1000
Last Geophone station	1971
First Shot Point	1000
Last shot Point	1971
Geophone Station Interval	40 m
Shot Point Interval	240 m
Fold	10 (nominal)

Line 97AGS-HB1

Orientation	N-S
(High SP numbers North, Trace 1 to the South)	
Recorded	N to S
Length	23.2 km
First Geophone station	1000
Last Geophone station	1580
First Shot Point	1000
Last shot Point	1580
Geophone Station Interval	40 m
Shot Point Interval	320 m
Fold	7.5 (nominal)

Line 97AGS-HB2

Orientation	N-S
(High SP numbers North, Trace 1 to the South)	
Recorded	N to S
Length	41.16 km
First Geophone station	2000
Last Geophone station	3029
First Shot Point	2000
Last shot Point	3029
Geophone Station Interval	40 m
Shot Point Interval	240 m
Fold	10 (nominal)

Line 97AGS-HB3

Orientation	N-S
(High SP numbers North, Trace 1 to the South)	
Recorded	N to S
Length	32.8 km
First Geophone station	3000
Last Geophone station	3820
First Shot Point	3000
Last shot Point	3820
Geophone Station Interval	40 m
Shot Point Interval	~320 m
Fold	7.5 (nominal)

APPENDIX 5 - General Survey Information

Maps covering area

1:250,000 Topographical / Geological

Robertson	SF51-13
Newman	SF50-16
Turee Creek	SF50-15
Mount Bruce	SF50-11
Roy Hill	SF50-12

Stations

Ethel Creek (3114/992)
Owned - BHP Iron Ore and BHP Minerals
Managed - Barry Gratte
Phone 08 9175 7008
Fax 08 9175 7066

Juna Downs (3114/1191)
Owned - Hamersley Iron
Managed - Shane and Mandy Day
Phone - 08 9189 8156

Sylvania (3114/1234)
Owned - BHP Iron Ore and BHP Minerals
Managed - Ben Newland
Phone 08 9175 7007
Fax 08 9175 7089

Turee Creek (3114/937)
Owned - Bruce and Suzanne McGuire
Phone 08 9175 7015

Nearby stations include -

Marillana (3114/984)
Roy Hill (3114/983)
Walagunya (3114/992)

Environmental Contacts

Conservation and Land Management (CALM)
Pilbara Regional Office
SGIO Building, Welcome Rd or PO Box 835
Karratha WA 6714
Ph 08 9186 8288, fax 08 9144 1118

Department of Environmental Protection
Pilbara Regional Office
SGIO Building, Welcome Rd or PO Box 276
Karratha WA 6714
Phone 08 9143 1499, Fax 08 9144 1326

Department of Minerals and Energy
Land Access Unit
100 Plain Street, East Perth, W.A., 6004.
Phone 08 9222 3151, Fax 08 9222 3808

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Fax 08 9351 3153
email - p.cawood@info.curtin.edu.au

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Perth, Western Australia, 6000

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  Phone 08 9320 4067, Fax 08 9320 4180
- Doug Kepert - Project Geologist, Projects and Engineering Department
  Phone 08 9320 4113, Fax 08 9320 4180

BHP's Packsaddle Camp
Herb and Sue Roe - Camp Managers
Phone - 08 9189 8160

BHP's Saterlite Mine - Jimblebar
John Jacobson - Mine Manager
Phone 08 9175 3203

ROBE RIVER MINING CO. PTY. LTD.
9th Floor, 12-14 St George's Terrace,
GPO Box P1224
Perth, Western Australia, 6000.

- Tim James - Senior Project Geologist, Exploration and Development
  Phone 08 9421 4765, Fax 08 9421 4777
- Dave Mason - Senior Project Geologist, Exploration and Development
  Phone 08 9421 4812, Fax 08 9421 4777

ROBE's - West Angelas Camp
Newman Address - P.O. Box 590,
Newman, WA, 6753
Fernando Barragin - Camp Manager
Phone 007 194 201, Fax 007 194 202

Mining Leases crossed

Palladin Resources
- Pending Tenements
  - E51/1170
- Live Tenements
  - Nil

Robe River Mining
- Pending Tenements
  - Nil
- Live Tenements
  - E52/434
  - E47/754
  - E47/801
  - E47/802
  - ML248SA Sec 68,
  - ML248SA Sec 69,
  - ML248SA Sec 70,
  - ML248SA Sec 71,
  - ML248SA Sec 72,
  - ML248SA Sec 73,
  - ML248SA Sec 89,
  - ML248SA Sec 90,

BHP
- Pending Tenements
  - Nil
- Live Tenements
  - E47/13
  - E47/629
  - E52/745 (Jimblebar)
  - TR3156H
  - ML244SA Sec 22
  - ML266 SA (Jimblebar)
  - ML244 SA Sec 23 (Jimblebar)
  - ML244 SA Sec 16 (Jimblebar)

Hamersley Iron
- Pending Tenements
  - Nil
- Live Tenements
  - E47/620

Hampton Hill
- Pending Tenements
  - E51/1176 (Jimblebar)
- Live Tenements
  - Nil

APPENDIX 6 - Declared Rare Flora Sites

Environmental information provided by either the WA Department of Conservation and Land Management (CALM) or the WA Environmental Protection Agency (EPA) as background information in siting the proposed seismic traverses.

Declared Rare Flora

Lepidium catapycnon

Locality: Latitude 23° 04'27", Longitude 118° 48'56". On Governor Ridge, 1.3 km SW of summit of 'The Governor', 5.8 km NE of Coondewanna Hill, 2.9 km SW of Mt Robinson. On east side of a N-S orientated 4WD track on the west side of 'The Governor'.

Priority 2 Flora

Acacia effusa

Locality: Latitude 23° 20'50", Longitude 118° 44'44". Track from West Angelas to Paraburdoo, 15.1 km SSW of Mt Hilditch, 15.6 km NW of Marralana Pool, 22km S of West Angelas Camp.

Indigofera 'gilesii subsp gilesii'

Locality: Latitude 23° 07'25", Longitude 118° 48'33". 2.3 km W of Padtherung Hill, 3.2 km ESE of Coondewanna Hill, also
750 m SW of Coondewanna Hill, Hamersley Range, also
400m S of Coondewanna Hill, also
2 km NE of Karijini National park Headquarters.

Triumfetta maconochieana ms.

Locality: Centered around Latitude 23° 20', Longitude 120° 00'. On road from Newman to Shovelanna Hill and eastward. Various sites, mostly concentrated around Shovelanna Hill Telstra Tower region.

Ptilotus aphyllus

Locality: Centered around Latitude 23° 17', Longitude 120° 22'. Area of ground approximately 18 km x 12 km, between Caramulla Creek in west and Thirteen Creek in east and Nunga Soak Bore (on Caramulla Creek) in north and Ethel Creek Road in south.

APPENDIX 7 - Survey Vehicles

Camp:

ZKD-780	Toyota	Land Cruiser 4x4	Station Wagon : Recon
ZRM-053	Toyota	Land Cruiser 4x4	Tray Top with Bionic Arm
ZAH-069	Toyota	Land Cruiser 4x4	Station Wagon
ZRM-015	Toyota	Land Cruiser 4x4	Tray Top Ute with Tailgate Lifter
ZJD-115	Toyota	Land Cruiser 4x4	GXL Station Wagon
ZBE-687	Mercedes	LA911b	Transport with Tailgate
ZBE-689	Mercedes	LA911b	Electronics
ZBE-775	Mercedes	LA911b	Mechanics Workshop
ZBE-781	Mercedes	LA911b	Fuel Tanker
ZBE-782	Mercedes	LA911b	Water Tanker
ZRM-348	International	Acco 2350e	Transport / Tray Top

Recording:

ZBE-748	Mercedes	LA911b	Recording Truck
ZKF-245	Toyota	Land Cruiser 4x4	Blue Jug-Buggy
ZKF-246	Toyota	Land Cruiser 4x4	White Jug-Buggy
ZKD-900	Toyota	Land Cruiser 4x4	Green Jug-Buggy
ZRM-019	Toyota	Land Cruiser 4x4	Shooting Truck

Drilling:

ZKA-067	Toyota	Land Cruiser 4x4	Station Wagon
ZBE-606	Mack	R685rs 8x6	Drilling Rig
ZSU-471	Mack	R685rs 8x6	Drilling Rig
ZSU-472	Mack	R685rs 8x6	Drilling Rig
ZSU-473	Mack	R685rs 8x6	Drilling Rig
ZSU-529	Mack	R685rs 8x6	Drilling Rig
ZSU-863	Mack	RM6866rs 6x6	Water Tanker
ZSU-864	Mack	RM6866rs 6x6	Water Tanker
ZSU-865	Mack	RM6866rs 6x6	Water Tanker
ZSU-866	Mack	RM6866rs 6x6	Water Tanker
ZSU-911	Mack	RM6866rs 6x6	Water Tanker

Pre-loading:

ZKA-505	Mitsubishi	Canter	Pre-Loading
ZRM-349	International	Acco 2350e	Explosives

Trailers:

ZXD-196	Jakab Caravan 2 axle/4-wheel	Ablutions Van
ZXD-197	Jakab Caravan 2 axle/4-wheel	Ablutions Van
ZTL-511	Freighter Caravan 2 axle4-wheel	6 ton Drill Parts Trailer
ZTL-514	Freighter Caravan 2 axle4-wheel	6 ton Drill parts/ Tyres
ZTL-915	Duravan Caravan 2 axle4-wheel	Kitchen Van
ZTL-917	Duravan Caravan 2 axle4-wheel	Kitchen Van
ZTL-845	Duravan Caravan 2 axle4-wheel	Kitchen-Freezers van
ZTL-994	Rogers Caravan 2 axle4-wheel	Office Van
ZTV-022	Rogers Caravan 2 axle4-wheel	4 ton Cargo - Mechanics
ZKD-329	2 axle4 wheel	MacFarlane Generator
ZKD-330	2 axle4 wheel	MacFarlane Generator
ZTL-501	2 wheel	Welding Trailer
ZTV-016	Treg Caravan 2-wheel	Furphy
ZTV-018	Treg Caravan 2-wheel	Furphy
ZXD-114	2 axle4 wheel	Cool Room

APPENDIX 8 - Field Tape Index

SEISMIC FIELD TAPE INDEX SEG-D (Record Mode - 9 Track, 6250bpi GCR)

Tape No	Line	FFID Range	Shot Point Range	Recording Dates
97/023	97AGSSD1EXP	408-416	1-3	28/7/97
97/024	97AGSSD1	417-437	1000-1096	29/7/97-30/7/97
97/025	97AGSSD1	438-454	1102-1192	30/7/97
97/026	97AGSSD1	455-475	1200-1300	30/7/97-31/7/97
97/027	97AGSSD1	476-499	1306-1427	31/7/97-1/8/97
97/028	97AGSSD1	500-521	1432-1541	1/8/97-4/8/97
97/029	97AGSSD1	522-540	1546-1648	4/8/97
97/030	97AGSSD1	541-563	1655-1762	4/8/97-5/8/97
97/031	97AGSSD1	564-579	1768-1840	5/8/97-6/8/97
97/032	97AGSSD1	580-602	1846-1965	6/8/97
97/033	97AGSSD1	603-604	1971	6/8/97
97/034	97AGSHB1	605-614	1000-1048	11/8/97
97/035	97AGSHB1	615-638	1056-1217	11/8/97-12/8/97
97/036	97AGSHB1	639-662	1224-1384	12/8/97-13/8/97
97/037	97AGSHB1	663-686	1392-1528	13/8/97-14/8/97
97/038	97AGSHB1	687-696	1534-1580	14/8/97
97/039	97AGSHB2	697-719	2000-2111	15/8/97
97/040	97AGSHB2	720-743	2136-2246	15/8/97-18/8/97
97/041	97AGSHB2	744-767	2251-2371	18/8/97-19/8/97
97/042	97AGSHB2	768-791	2378-2492	19/8/97-20/8/97
97/043	97AGSHB2	792-814	2498-2612	20/8/97-21/8/97
97/044	97AGSHB2	815-838	2618-2743	21/8/97-25/8/97
97/045	97AGSHB2	839-862	2743-2869	25/8/97-26/8/97
97/046	97AGSHB2	863-885	2869-3008	26/8/97
97/047	97AGSHB2	886-889	3016-3029	26/8/97
97/048	97AGSHB3	890-912	3000-3151	278/97-28/8/97
97/049	97AGSHB3	913-935	3151-3320	28/8/97
97/050	97AGSHB3	936-956	3327-3477	28/8/97-29/8/97
97/051	97AGSHB3	957-980	3483-3639	29/8/97-1/9/97
97/052	97AGSHB3	981-1002	3639-3820	1/9/97-2/9/97

SEISMIC FIELD TAPE INDEX SEG-Y EXABYTE (Record Mode - UNIX 'TAR' (Exabyte))

Tape No	Line	FFID Range	Shot Point Range
EX9723	97AGSSD1EXP	410-416	1-3
EX9724	97AGSSD1	417-437	1000-1096
EX9725	97AGSSD1	438-454	1102-1192
EX9726	97AGSSD1	455-475	1200-1300
EX9727	97AGSSD1	476-499	1306-1427
EX9728	97AGSSD1	500-521	1432-1541
EX9729	97AGSSD1	522-540	1546-1648
EX9730	97AGSSD1	541-563	1655-1762
EX9731	97AGSSD1	564-579	1768-1840
EX9732	97AGSSD1	580-602	1846-1965
EX9733	97AGSSD1	603-604	1971
EXHB1A	97AGSHB1	606-650	1000-1304
EXHB1B	97AGSHB1	651-696	1312-1580
EXHB2A	97AGSHB2	699-772	2000-2390
EXHB2B	97AGSHB2	774-848	2396-2793
EXHB2C	97AGSHB2	849-889	2798-3029
EXHB3A	97AGSHB3	891-960	3000-3495
EXHB3B	97AGSHB3	962-1002	3504-3820