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OTWAY BASIN SEISMIC TEST SURVEY 1991: OPERATIONAL REPORT

by K D Wake-Dyster, D W Johnstone and A J Owen

Record 1994/18

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by

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A CONTRIBUTION TO THE
NATIONAL GEOSCIENCE MAPPING ACCORD PROJECT:
EARLY DEVELOPMENT OF THE OTWAY BASIN

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SEISMIC TEST SURVEY 1991:
OPERATIONAL REPORT

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EXECUTIVE SUMMARY

The Australian Geological Survey Organisation (AGSO) (formerly the Bureau of Mineral Resources, Geology and Geophysics (BMR)) conducted a deep seismic reflection test survey in the onshore portion of the Otway Basin in the southeastern part of South Australia and southwestern part of Victoria, from late October to early November 1991. The seismic test survey was undertaken to test the feasibility of recording deep seismic reflection data prior to commencing a major deep seismic reflection survey in the Otway Basin. A planned major deep seismic reflection survey by AGSO formed part of a National Geoscience Mapping Accord (NGMA) project to study the early development of the Otway Basin.

The seismic reflection test survey operated for a period of three weeks, including mobilisation and demobilisation to the survey area, with five test sites occupied during the test survey. The seismic test sites were positioned to examine the feasibility of recording deep seismic reflections in areas with different outcropping rock types along the proposed main seismic lines. CMP seismic profiles were recorded along all five test lines, with uphole shoots, shot depth and charge size comparison tests performed at several of the sites.

Good quality deep seismic reflection events were recorded at several of the seismic test sites. The seismic test survey was important in highlighting areas with difficult shothole drilling conditions, especially the palaeo-sand dunes along the SA-Victoria border, and the Tertiary shelly sands with shallow water table near Lake Bonney. A major seismic survey would require all shothole drilling rigs to be equipped with portable mudpits to enable shotholes to be drilled in the palaeo-sand dunes and shelly sands.

INTRODUCTION

1.1 Background

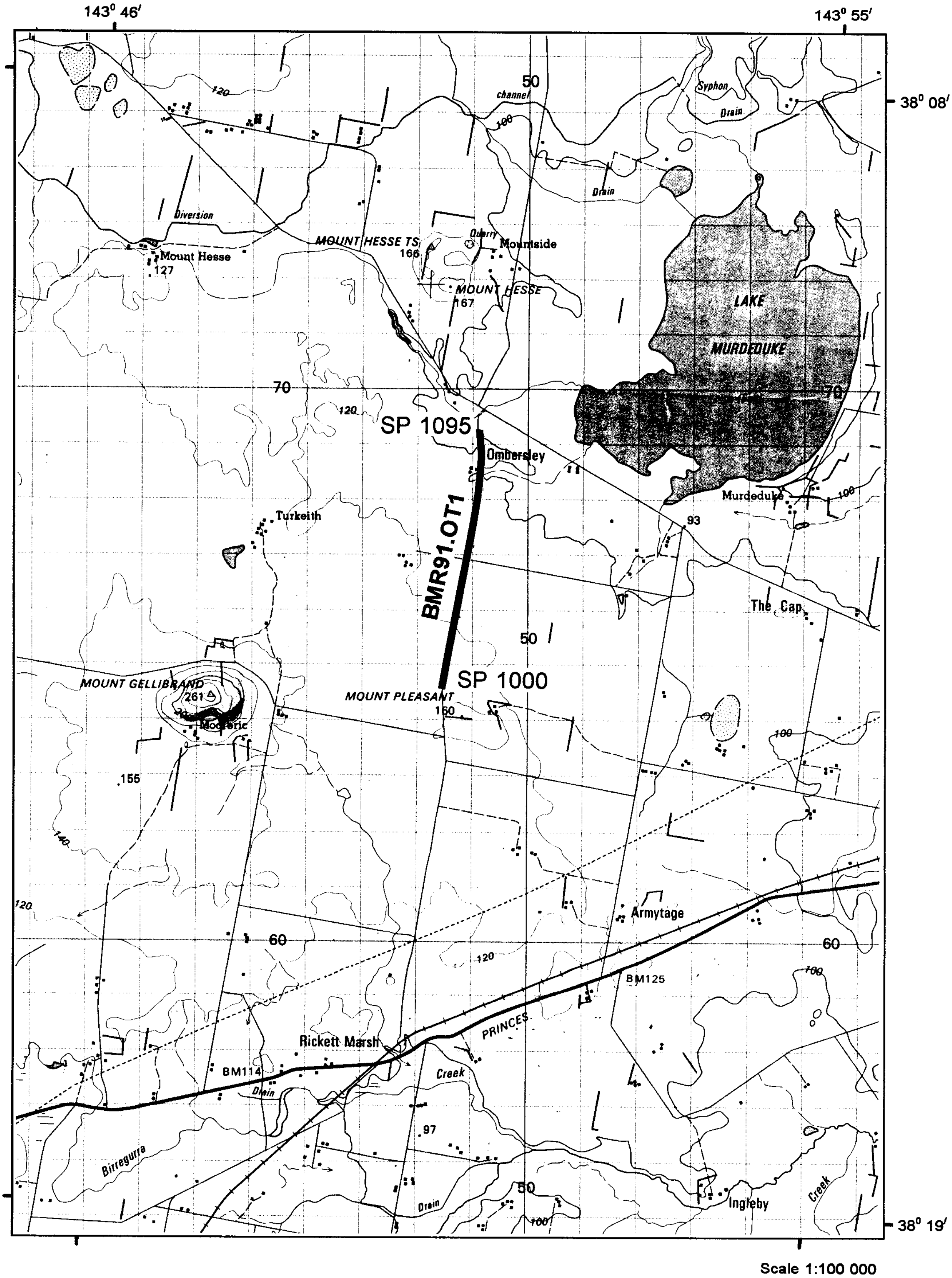
The Australian Geological Survey Organisation (AGSO) (formerly known as the Bureau of Mineral Resources, Geology & Geophysics (BMR)), as part of the Australian National Geoscience Accord (NGMA), proposed to conduct a deep seismic reflection profiling survey in the Otway Basin region of SW Victoria and SE South Australia during 1992. The NGMA project partners included AGSO, South Australian Department of Mines and Energy, Geological Survey of Victoria and various universities. The objectives for conducting a seismic survey were aimed at achieving a better understanding of the sub-surface geology of the onshore Otway Basin region, thought to have considerable resource potential, including hydrocarbons, industrial gases and geothermal energy. Previous AGSO deep seismic reflection profiling surveys (using explosives as the seismic energy source) in other areas of Australia to investigate basin sequences and basin formation have provided new perspectives on basin development not always apparent in industry seismic data.

Recent industry high CMP fold and higher spatial resolution seismic data using seismic vibrators as the seismic energy source, have produced excellent seismic data in the onshore region of the Otway Basin down to 3 seconds two-way travel time (ie. to 5 km depth). The lack of resolution of seismic reflection events at greater depths is possibly attributable to the restricted capacity of the commercial seismic vibrators to provide enough seismic energy to resolve deeper seismic reflection events at greater than 3 seconds two-way travel time. A proposal was therefore prepared to use explosives as the seismic energy source, with charge sizes in the vicinity of 10 kg of ICI Powergel in an attempt to input greater seismic energy into the earth to resolve seismic reflections from sediments greater than 5 km depth. The AGSO seismic reflection acquisition system is specifically designed for seismic acquisition using an explosive seismic source in conjunction with AGSO seismic shot hole drilling rigs.

To test the feasibility of recording deeper reflection events using large explosive charges as the seismic source, AGSO planned a seismic test survey using a reduced seismic crew over a short period of three weeks. The test sites were located in several areas of the Otway Basin with different technical problems for seismic acquistion, including areas with outcropping Tertiary volcanic rocks, near surface limestones and palaeo-sand dunes.

1.2 Previous Geophysical Investigations

Numerous seismic reflection surveys have been conducted in the onshore part of the Otway Basin since the early 1960's. The earlier seismic surveys used explosives as the seismic energy source, with areas of surface volcanics, limestones and palaeo-sand dunes being avoided due to recording and shothole drilling problems. With the development of the 'Vibroseis' technique in the mid-1960's, experimental seismic surveys by the BMR comparing 'Vibroseis' and explosive seismic energy sources (Jones, 1966; Raitt, 1966; Schwing & Moss, 1974) were conducted to develop seismic acquisition parameters and methods to record good quality seismic data in the difficult surface condition areas. Results of the experimental surveys showed similar data quality being obtained, for the same amount of effort for both 'Vibroseis' and explosive energy sources. However using explosives as the seismic energy source required 'a high-effort technique', ie. large explosive charges of between 45 to 140 kg and larger areal patterns of geophones and shotholes. Nowadays due to environmental



Scale 1:100 000

Figure 1. Location map, seismic test Line 1, Colac area.

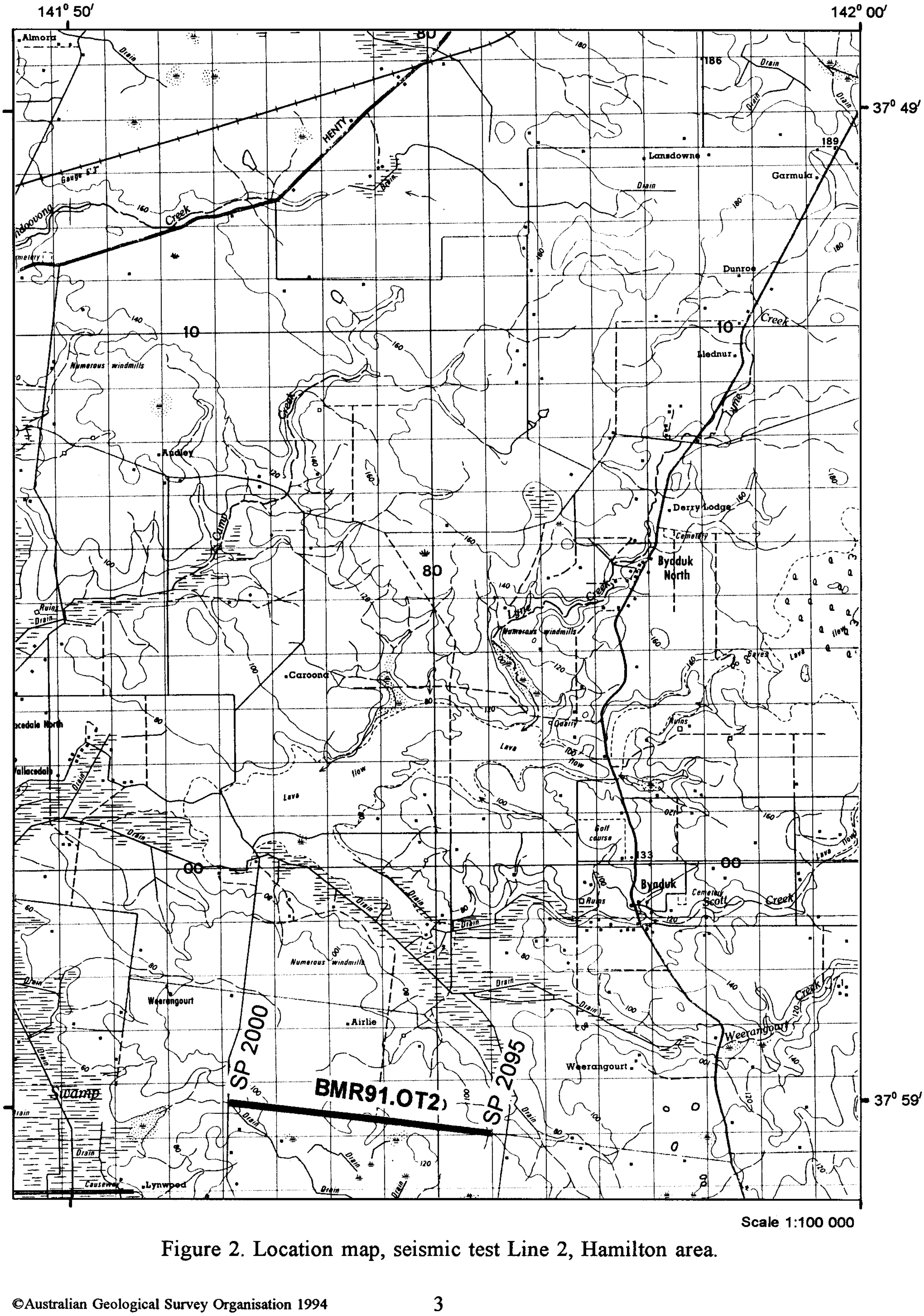


Figure 2. Location map, seismic test Line 2, Hamilton area.

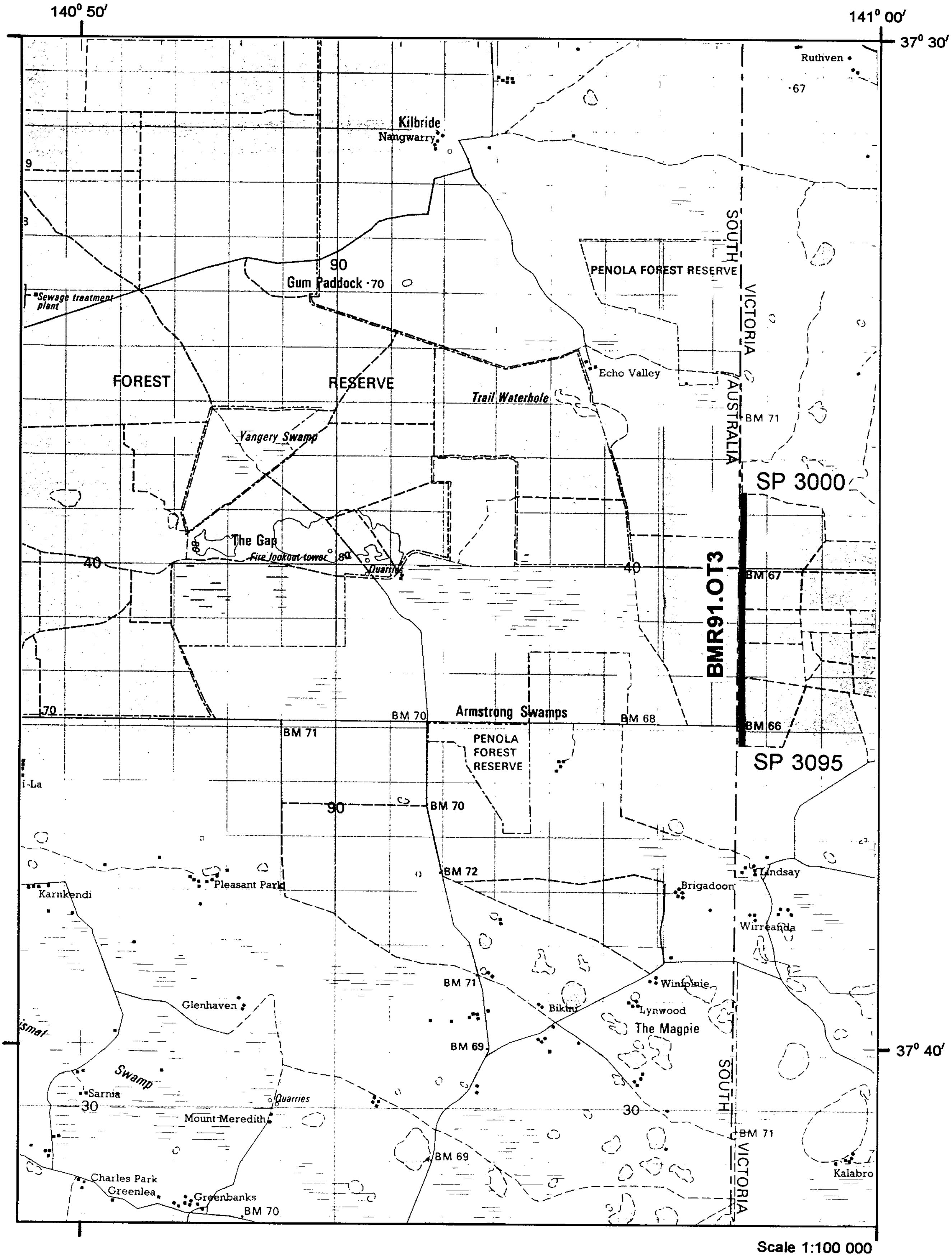


Figure 3. Location map, seismic test Line 3, Penola area.

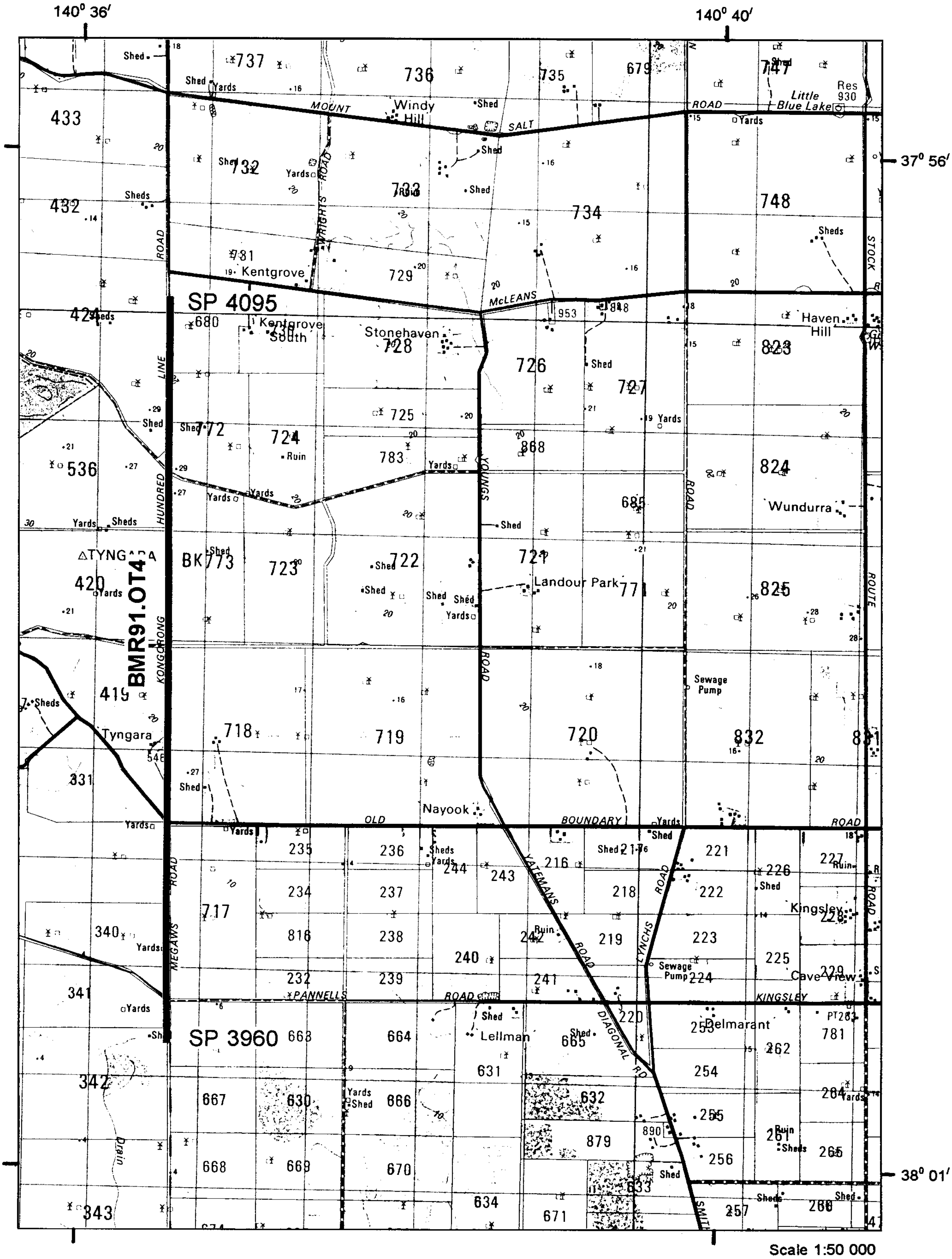


Figure 4. Location map, seismic test Line 4, Allendale East area.

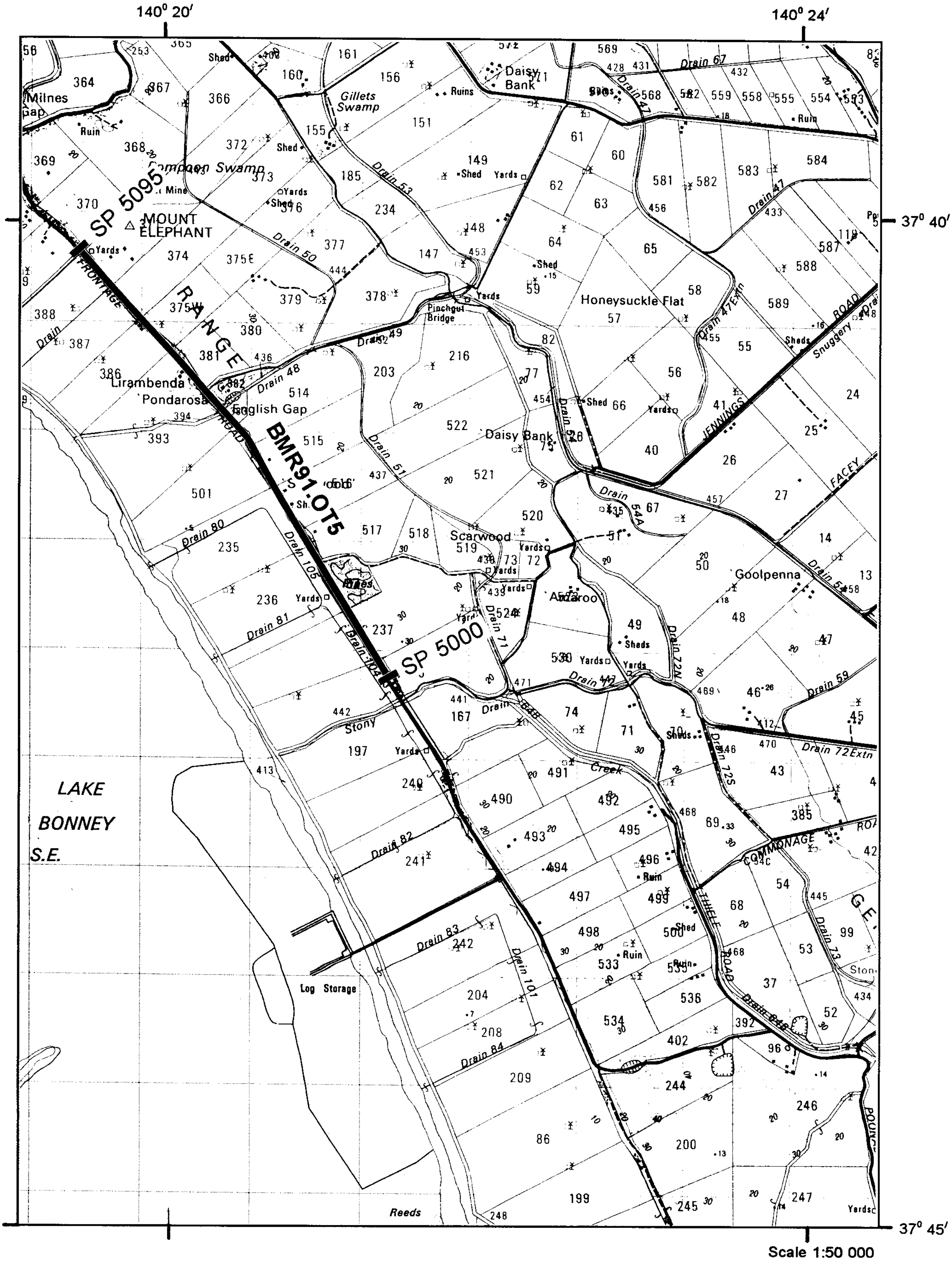


Figure 5. Location map, seismic test Line 5, Lake Bonney area.

constraints, urbanisation and the high cost of explosives, the 'high-effort technique' would be extremely difficult to implement. Modern seismic surveys in the Otway Basin by industry seismic crews have predominantly used 'Vibroseis' seismic methods, with less impact on the environment and agricultural land, with excellent data being recorded to 3 seconds TWT.

The development of digital seismic data acquisition systems with a large dynamic range, compared to AM and FM analogue seismic recording systems, plus the full implementation of CMP recording techniques, has allowed good quality seismic data to be obtained to depths of 5 km, using smaller size seismic sources (eg. reduced shot charge sizes and medium size seismic vibrators). The use of 'Vibroseis' compared to explosives in shotholes, avoids hard drilling conditions in volcanics, lost circulation in cavernous limestones and collapsing shotholes in palaeo-sand dunes, with good quality data still recorded. The disadvantage of 'Vibroseis' has been the limited size of the seismic vibrators available to produce sufficient seismic energy to resolve reflection events below 3 seconds TWT.

1.3 Location

The 1991 Otway Basin seismic test survey was conducted in SW Victoria and SE South Australia. The seismic lines were confined to the following 1:250000 map sheets; COLAC, HAMILTON and PENOLA. Topographic and cadastral maps were used to position the seismic test lines. Figures 1, 2, 3, 4 and 5 show the location of the 5 seismic test lines.

1.4 Seismic Lines

Five seismic test lines were recorded during the seismic test survey. The seismic test lines were numbered Line BMR91.OT1 through to Line BMR91.OT5. Line BMR92.OT1 was recorded first followed by Line BMR91.OT2 and Line BMR91.OT3. Line BMR91.OT5 was recorded next with Line BMR91.OT4 recorded last. To minimise disturbance to landowners, the seismic test lines were positioned along existing roads and tracks in consultation with local authorities.

1.5 Operations: Commencement, Personnel and Vehicles

The seismic test survey commenced on the 28/10/91 with the departure from Canberra of all seismic test survey vehicles to the survey area. Line pegging, drilling and recording commenced on the 30/10/91. Seismic recording was completed on 12/11/91, with all vehicles and personnel returning to Canberra on 15/11/91. A timetable of operations is shown in Appendix 5. Commercial accommodation (hotels/motels) was used by the seismic crew during the survey. Towns used for accommodation included Colac, Hamilton and Mt Gambier. The seismic crew worked a 6 day week with a rest day on Sundays.

A list of personnel involved in the test survey is shown in Appendix 2, with vehicles used for drilling and recording shown in Appendix 3. Based on the experience gained from previous seismic test surveys (Wake-Dyster and Johnstone, 1993), a seismic crew of 14 persons using 14 vehicles was used for the seismic test survey (ie. two more field hands and two more vehicles) to reduce the weight load on each of the 'jug buggies', allow increased personnel support for the recording operations and provide an additional personnel carrier for the drilling crew in case of emergencies.

1.6 Objectives and Program

The seismic test survey was designed to test the feasibility of recording deep seismic reflection data using explosives as the seismic source in the onshore area of the Otway Basin, especially in areas with surface volcanics, palaeo-sand dunes and Gambier limestone. The seismic test lines at various locations would involve recording CMP seismic data along lines of 4.75 km length at each location, and conducting uphole shoots, charge size and charge depth comparison tests if required.

The following seismic test line locations were chosen in consultation with NGMA partners to best target the survey objectives.

Line 1 (BMR91.OT1):

Located in an area of outcropping volcanics NE of Colac. Recent seismic data using seismic vibrators as the seismic source has been recorded in the area allowing a comparison to be made with explosive seismic source data.

Line 2 (BMR91.OT2):

Located in an area of outcropping volcanics south of Hamilton, over the central part of the Ardonachie Trough. The location would allow the feasibilty of recording deep seismic reflection data to be tested in one of the deeper sedimentary troughs within the onshore Otway Basin.

Line 3 (BMR91.OT3):

Located in an area with palaeo-sand dunes covering the landscape, SE of Penola, over a central part of the Penola Trough. The location would allow the feasibilty of recording deep seismic reflection data to be tested in another of the deeper sedimentary troughs within the onshore Otway Basin.

Line 4 (BMR91.OT4):

Located in area south of Mt Gambier with outcropping Gambier Limestone. The location would allow the feasibilty of recording deep seismic reflection data to be tested in an area with outcropping Gambier Limestone.

Line 5 (BMR91.OT5):

Located in area SE of Millicent with more recent palaeo-sand dunes near Lake Bonney. The location would allow the feasibilty of recording deep seismic reflection data to be tested in another locality with palaeo-sand dunes, and also allow a comparison with recently recorded seismic data using seismic vibrators.

FIELD OPERATIONS

2.1 General

During the seismic test survey the planned five testing sites were occupied with CMP seismic lines being recorded at each site and additional uphole shoots, charge size and charge depth comparison tests being made at several of the sites.

The CMP seismic reflection lines consisted of recording shots into a recording spread of 96 channels with geophone group interval of 50 m, with shotpoints located at 300 m intervals along the recording spread. Provided all shotpoints were drilled, normally 17 shots would be fired into the fixed recording spread giving a mix of off-end and split-spread recording arrangements, and allow a CMP stack seismic section to be processed with 17 fold CMP data in the centre of the spread and decreasing to single fold CMP data at the ends of the recording spread. Uphole shoots were recorded using 96 channels with bunched geophones at a geophone group interval of 5 m into a split-spread arrangement (ie 48 channels either side of the uphole shoot). Uphole shot charges were individually loaded at 5 m intervals up the shothole, fired and recorded by the 96 channel recording spread. Charge size and charge depth comparison tests were done by drilling a cluster of shotholes and using separate shotholes for each shot, with recording into a normal 96 channel spread with geophone group intervals of 50 m.

The seismic test site near Colac (BMR91.OT1) was recorded first, followed by BMR91.OT2, BMR91.OT3, BMR91.OT5 and BMR91.OT4. With additional time and available explosives, the Line BMR91.OT4 was extended by 2 km using normal CMP recording techniques.

2.2 Occupational Health & Safety Issues

The Otway Basin seismic test survey lines followed existing roads and tracks. A major problem existed in maintaining a safe working environment along the roads without risking injury to members of the seismic crew, or damage to vehicles. For the survey, safety signs were purchased to warn other road users of the nature of the work along the roads. To increase the visibility of vehicles, rotating flashing yellow/orange warning beacons were mounted on vehicles. Local shires/district councils and police were notified of our activities to allow work along the roads with the minimum of inconvenience to other road users.

2.3 Communications

To improve communications between the seismic test survey party and head office in Canberra, two transportable mobile telephones (3 watt output) were purchased. One mobile phone was a slimline NEC C3, purchased so that on return to Canberra the unit could be also used for conference purposes, etc, while not being used on seismic surveys. The other unit purchased was a Motorola 3000T with an Intercel 900 Cellular Interface to enable a facsimile machine to be connected to the mobile telephone. The Motorola unit is more bulky and heavier than the NEC C3, but cheaper in price and of more robust construction. Most of the Otway Basin area is covered by Telecom Mobilenet cells, making the survey area ideal for using relatively inexpensive new age technology for communication. External 3 db gain antennae with magnetic bases were also purchased to allow roof mounting of antennae with quick placement and removal, to allow use in a vehicle or accommodation housing.

One mobile telephone was used by Doug Finlayson while doing reconnaissance for the main Otway Basin seismic survey. The other mobile telephone was used by the Party Leader, with the telephone vehicle-based during the day and accommodation-based during the evening. The mobile phones proved valuable for solving urgent problems that arose during the survey, with direct communications with Canberra while doing survey operations. The mobile telephones provided the following advantages:

- direct communication link between the seismic survey and head office
- direct communication link between the party leader and project leader
- direct communication link between the party leader, landowners and local authorities
- time saving in not having to locate public telephones

2.4 Reconnaissance

A brief reconnaissance of the seismic test line sites was made in early October 1991 by Kevin Wake-Dyster and David Johnstone to select sites for the proposed seismic test survey. Paul MacDonald of GSV provided assistance in site selection in the Colac area and Rob Langley from SADME provided assistance in site selection near Lake Bonney and south of Mt Gambier.

The proposed seismic test Line 1 near Colac was planned to coincide with a company seismic line LM91-03 with a well-tie to stratigraphic borehole Warracburunah #2. The coincident seismic lines would provide a comparison between using explosives and seismic vibrators as seismic sources. However access to the test line location was hindered by boggy wet ground conditions making access difficult. The seismic test line position was relocated along a gravel road (Prices Lane) one kilometre east and parallel to the originally proposed seismic test line location. Seismic test Line 2, south of Hamilton was positioned to avoid both high tension power lines and to minimise vehicular traffic flow affecting seismic recording. Seismic test Line 4, north-west of Allendale East was positioned to avoid vehicular traffic flow, underground sewage pipelines (with pumps) and power lines.

During the seismic test survey, Doug Finlayson carried out a major reconnaissance of the proposed major seismic lines to highlight acquisition and environmental problems and make contact with local authorities and landowners. During the major reconnaissance the proposed line positions were finalised, highlighting problem areas for data acquisition.

2.5 Environmental Management Plan

The seismic test lines were all conducted along roads using the road verges between the formed road and property fence boundaries. All local authorities including district councils and shires were notified of the proposed seismic test lines with all public concerns being addressed. Following the reconnaissance of the proposed major seismic lines, Doug Finlayson formulated an Environmental Management Plan for the main Otway Basin seismic survey.

2.6 Line Clearing

No grass slashing, grading or bulldozing was required for seismic line clearing on the seismic test survey. Several of the shotholes on Line BMR91.OT3 in pine plantation areas which had very shallow shothole depths collapsed after shotfiring and left large holes on the surface. These were backfilled with sand and compacted.

2.7 Surveying

Quotes were obtained from surveying contractors to provide chaining, pegging, levelling and coordinate data for geophone stations and shotpoints on the five proposed seismic test lines. The quotes were excessive in cost and no surveying contractor was hired. All chaining and pegging of geophone stations was performed by various members of the seismic test survey crew. Elevations for geophone stations and shotpoints were extrapolated from available topographic maps with coordinate control obtained by using a combination of topographic maps and readings obtained using a hand held GPS receiver (Pronav).

2.8 Drilling and Explosives

Two BMR Mayhew 1000 drilling rigs and two Mack water tankers were used on the seismic test survey for shothole drilling. The BMR explosives truck and preloading vehicle were used for transport and storage of the ICI 'Powergel' explosives and electrical detonators.

Shotpoint locations for the survey were, where possible, located midway between geophone station positions to give a better distribution of receiver offsets for velocity analysis. Drilling water was obtained from local councils and shires (using overhead standpipes). Shotholes were solid tamped with drill cuttings prior to shotfiring, except for the uphole shoot which used water tamping.

2.81 Drilling

Line BMR91.OT1:

Shothole drilling was reasonably good using air and water injection, intersecting clays and sandy clays to about 15 m, with weathered and hard basalt to at least 20 m. Water was found at depths between 12 m to 15 m. The water table level coincides with the uphole shoot depth of weathering at 14.5 m.

Line BMR91.OT2:

Shothole drilling was good using air and water injection, intersecting mainly clays, sandy clays and weathered basalt. Shotholes were drilled on average to about 22 m with water intersected at between 15 m to 20 m.

Line BMR91.OT3:

The palaeo-sand dunes proved to be difficult to drill, with sloughing of the holes with sand using water injection. By using mud drilling, drilling was slow but shotholes could be drilled to reasonable shothole depths of 13.5 m. Water was intersected at about 4 m on most holes. The drilling in the palaeo-sand dunes highlighted a need for the construction of portable mudpits for the drilling rigs, and the requirement to purchase large quantities of drilling mud, rapid-gel, bran and cotton seed for any reasonable shothole drilling progress for a major seismic survey.

The shothole drilling crew were warned in advance by SADME drilling inspectors, not to drill into a black sticky clay formation that could be encountered in drilling on Line BMR91.OT3. The black sticky clay formation provides a seal to a perched water table in that area, especially east of Penola. The black clay formation was not encountered during shothole drilling on Line BMR91.OT3 due to the shotholes only reaching shallow depths.

Line BMR91.OT4:

The shothole drilling was good using air and water injection, intersecting limestone and hard chert layers. The chert nodules would occassionally cave into the shotholes blocking the hole when loading the shot charge, which required re-reaming of the shotholes on several occassions. On the northern end of the test line water was encountered at depths of 20 m compared to 2 m depth to water table at the southern end of the line. Gravel from a local quarry was used to tamp the shotholes on the southern end of the line due to the lack of cuttings available from drilling the holes.

Line BMR91.OT5:

Shothole drilling used air and water injection, intersecting sands and shelly layers in the palaeo-sand dune margins. Water was encountered at depths of 8 m, where sloughing of the sands and shells made drilling to deeper depths virtually impossible. Mud drilling was not attempted as all mud supplies were exhausted drilling shotholes on Line BMR91.OT3. To hold the shot charge, two shotholes were drilled at many shotpoints with the 10 kg charge split between the two holes.

2.82 Explosives

ICI 'Powergel' explosives were used as the seismic energy source, available as 2 kg plugs in plastic cylindrical containers. ICI detonators with 45 m leads were used on the survey. Explosive statistics are given in Appendix 1. A total of 936 kg of 'Powergel' and 115 detonators were used on the seismic test survey.

Explosive stocks were obtained from the ICI magazine in Tocumwal, NSW. At the end of the survey the excess stocks of 'Powergel' were returned to the magazine at Tocumwal for storage. During the test survey the mobile magazine was temporarily stored at the council depots at Winchelsea and Hamilton. The quarry at Mt Schank south of Mt Gambier was used for storage while in that area.

The 'Powergel' explosives performed well with no misfires. Depths to the top of the charge were measured for each shothole by using a 'Hip-Chain' with cotton thread tied to the top of the charge and the digital counter set to zero before lowering the shot charge assembly down the shothole. The 'Hip-Chain' measuring device proved to be easy to use with reliable depths to the top of the charge being obtained.

2.9 Seismic Recording

The BMR Sercel SN368 telemetry seismic acquisition system operated in a 96 channel configuration for the test survey. An additional 20 station units were taken in case of station unit failures and also in case some unscheduled CMP roll-a-long recording was undertaken.

Summary of seismic tests

Line BMR91.OT1:

<u>Uphole Shoot (SP 1048)</u>:

Geophone Spread: 96 channel, bunched geophones, 5 m geophone group interval, split-spread

Depth to Top of Charge (m)	Charge Size (kg)	Charge Length (m)
38.3	2	0.53
35.0	2	0.53
30.0	2	0.53
25.0	1	0.26
20.0	1	0.26
15.0	1	0.26
10.0	1	0.26
04.9	1	0.26

Uphole shoot shothole drilled to 41 m depth, intersecting basalts, weathered basalts and clays. Sands intersected at 40 m, probably the base of the basalts or top of Tertiary sediments.

One 10 kg shot at 20 m depth was also fired into the uphole shoot geophone spread configuration.

<u>Charge Depth Comparison (SP 1048)</u>:

Depth to Top of Charge (m)	Charge Size (kg)	Charge Length (m)
08.3	10	2.6
18.3	10	2.6
27.9	10	2.6

Charge Size Comparison (SP 1048):

Depth to Top of Charge (m)	Charge Size (kg)	Charge Length (m)
14.3	7	2.8
12.9	10	2.6
12.2	16	4.2
11.1	20	5.2

CMP Production Shots:

16 shots, 10 kg charge size, average shothole depth 18 m.

Line BMR91.OT2:

CMP Production Shots:

15 shots, average charge size 10 kg, average shothole depth 22 m.

Line BMR91.OT3:

CMP Production Shots:

11 shots, average charge size 10 kg, average shothole depth 10 m.

Line BMR91.OT4:

Charge Depth Comparison (SP 4048):

Depth to Top of Charge (m)	Charge Size (kg)	Charge Length (m)
08.0	10	2.6
18.4	10	2.6
24.6	10	2.6
32.4	10	2.6

Charge Size Comparison:

Shotpoint	Depth to Top of Charge (m)	Charge Size (kg)	Charge Length (m)
4030	37.1	10	2.6
4035	35.2	16	4.7
4018	35.4	20	5.2

CMP Production Shots:

19 shots, average charge size 10 kg, average shothole depth 37 m.
(Charge size comparison shots and one charge depth comparison shot used in CMP stack.)

Line BMR91.OT5:

CMP Production Shots:

13 shots, average charge size 10 kg, average shothole depth 8 m.

(Many of the shots were shot using two holes drilled close together with the shot charge split between the two shotholes, due to the shallow shothole depths.)

Small Charge Size Production Test:

6 shots, average charge size 2 kg, average shothole depth 7 m.

DATA PROCESSING

The 'Vista' PC computer based field seismic processing system was used on the seismic test survey for quality control analysis and to produce 'Brute Stacks'. Field tapes were demultiplexed in the field, however, due to tape header information not being transferred to the demultiplexed tapes, the demultiplexed tapes were only used by the 'Vista' system to process the seismic data. The field tapes were demultiplexed again on the Vax based DISCO system in Canberra on the return to head office. Some shot records which proved difficult to demultiplex on the Vax based system, were later recovered from the 'Vista' demultiplexed tapes. Field processing of the seismic data allowed preliminary 'Brute Stack' seismic sections to be produced to highlight any shot/spread geometry errors and provide a close approximation of velocity functions required for Normal Moveout corrections. Accommodation for the field processing system was arranged jointly with the accommodation of the field geophysicist, allowing security for the system and data, and ease of access for the field geophysicist.

On return to Canberra, the seismic data were fully processed using the Vax based DISCO processing system. Copies of the final seismic sections are available for purchase through the AGSO Sales Centre, GPO Box 378, Canberra, ACT, 2601.

TABLE 1

Processing sequence for the seismic sections using the BMR/AGSO Disco processing system.

1. Demultiplex field tapes (SEGD to SEGY Disco internal format).
2. Crooked geometry definition.
3. Quality control displays and trace editing.
4. Spherical divergence correction.
5. Statics computation by the uphole method.
6. CDP sort and brute stack.
7. Velocity analysis with statics applied.
8. Normal Moveout correction.
9. Pre-Stack NMO mute (35% stretch).
10. Time varying equalisation (gate length 500ms).
11. Common Depth Point Stack.
12. Bandpass Filtering.
13. Time varying equalisation (gate length 1000ms).
14. Signal enhancement (Digistack)
15. Display

RESULTS

Seismic reflection data collected from the seismic test survey do show some reflections at Moho and mid-crustal depths. The deeper sedimentary sequences of the Otway Basin were imaged on some of the seismic lines but not clearly on others. The seismic test survey showed that seismic lines recorded on a major seismic survey using explosives as the seismic energy source would record deeper reflection data in some areas and poorer to no deeper data in others.

The seismic test survey was extremely useful in highlighting shothole drilling problems in the palaeo-sand dune areas. To overcome the palaeo-sand dune drilling problems, portable mud pits would need to be designed and built for the main seismic survey, with large supplies of drilling fluid consumables required to be ordered for any extensive shothole drilling program using drilling mud to prevent collapse of the shotholes during drilling.

Line BMR91.OT1:

The uphole shoot at SP 1048 showed that the depth of weathering was 14.5 m which corresponds closely with the depth to the water table recorded by the shothole drilling. The uphole shoot results are graphically represented as a shot depth versus uphole time plot and also as a Meissner plot in Figures 6 and 7 respectively. Several of the raw shot monitors for the uphole shoot are also shown in Figures 8 to 12 to highlight the effect of shothole depth on data quality, especially considering the layered nature of the near surface basalts in the area. The shallow shot at 5 m (Figure 8) shows severe seismic signal ringing of 15 hz frequency which saturates the majority of the shot record, with seismic reflections being difficult to pick. The uphole shots at deeper depths (Figures 11 and 12) show a marked attenuation of the seismic noise due to ringing within the basalt layers with seismic reflection events clearly evident. By comparing Figures 10 and 13, a large increase in shot charge size (from 1 kg to 10 kg) at a shot depth of 20 m also results in a significant improvement in seismic reflection signal levels compared to the 15 hz seismic noise. The good quality results shown in Figure 13 suggest that if high spatial resolution data is required for seismic sequence stratigraphy intepretation, a seismic survey designed with low CMP fold coverage (even single fold) and short geophone station intervals (5 m) could be a viable option, both in terms of cost and data quality required.

The charge depth and charge size comparison tests recorded into the normal 50 m geophone group interval spreads showed shot depths should be greater than depth of weathering (approximately 15 m) and charge sizes should be 10 kg, as larger charge sizes showed little improvement in signal to noise on the shot records.

CMP stack seismic sections to 4 seconds TWT and 20 seconds TWT are shown in Figures 14 and 15. Strong reflection events are evident between 400 ms and 600 ms from sedimentary layers within the Tertiary sediments. A steeply dipping reflection event to the south between 600 ms and 1400 ms can be interpreted to be basement of a half graben. Reflection events from sediment layers within the half graben are of poor quality. Deep crustal reflection events can be seen at 9 seconds TWT.

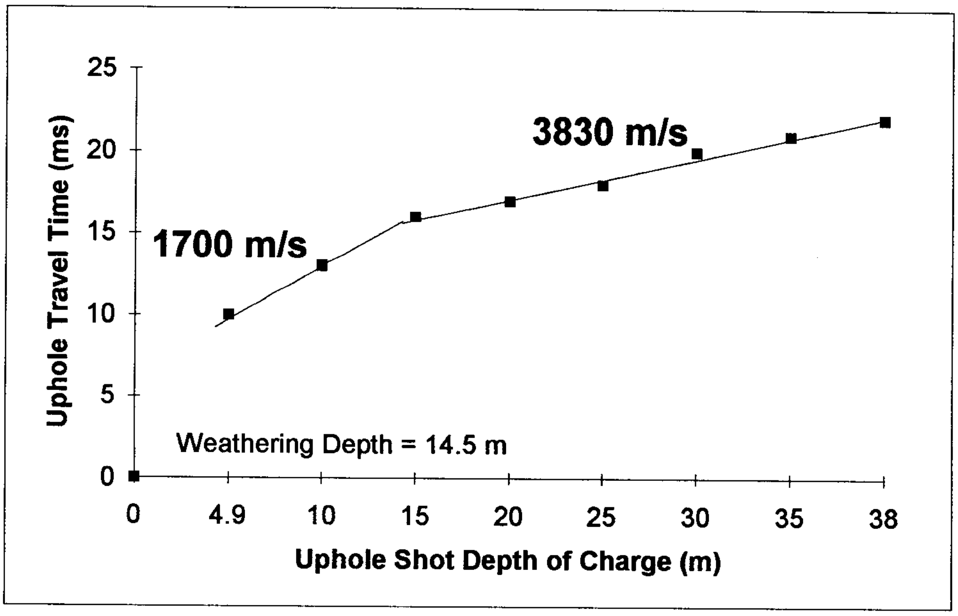


Figure 6. Uphole shoot, test Line BMR91.OT1, SP 1048.

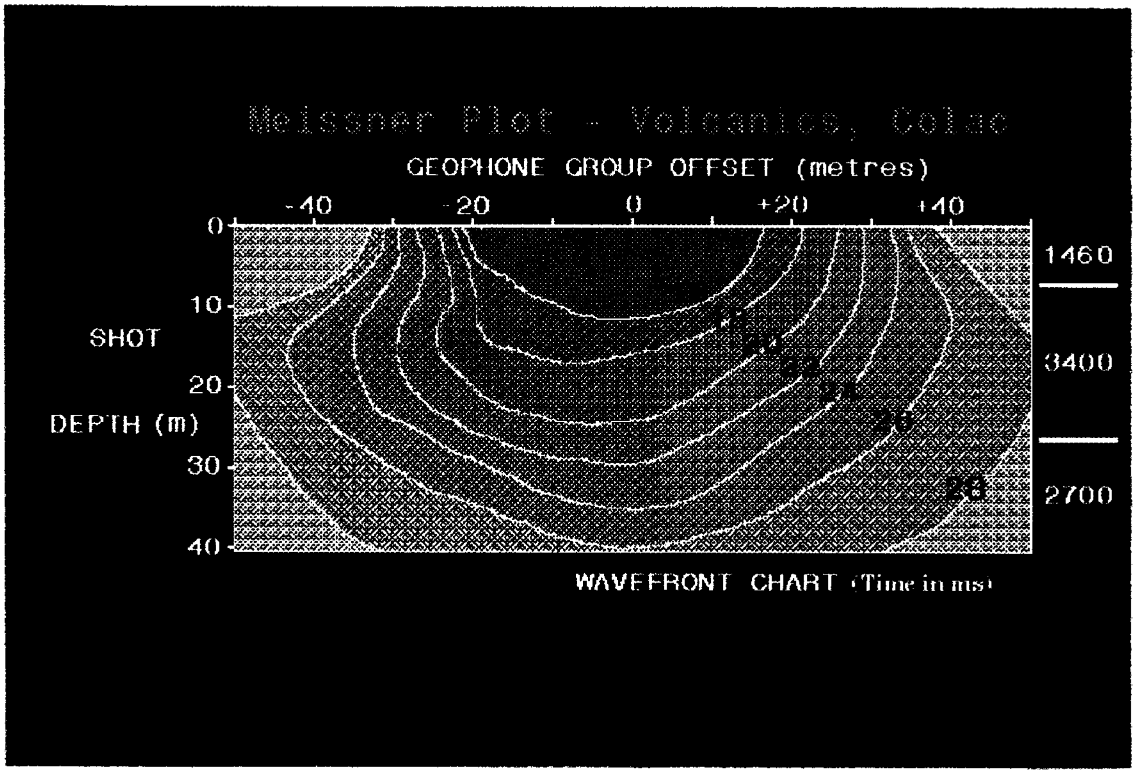
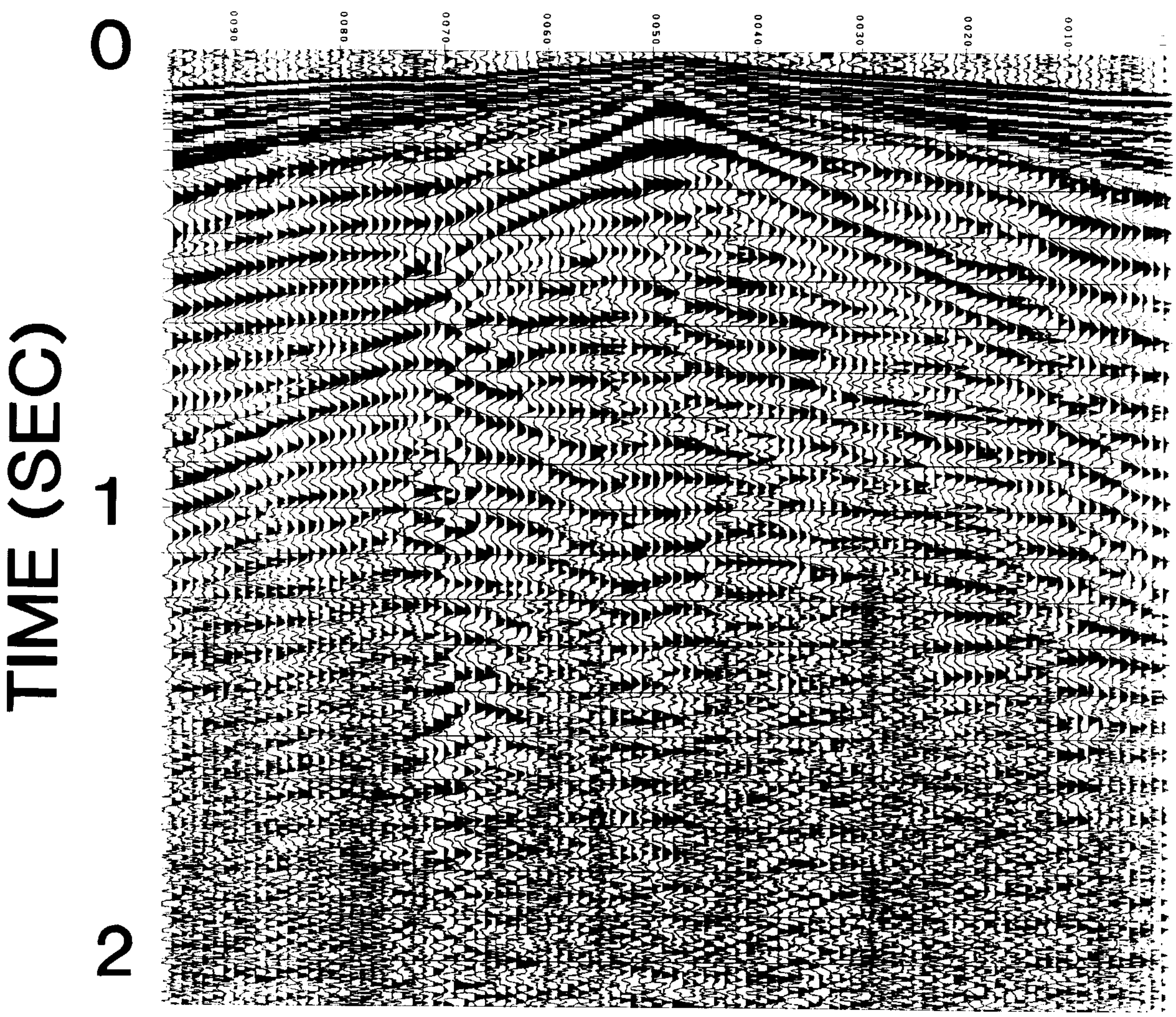


Figure 7. Uphole shoot, Meissner Plot, Test Line BMR91.OT1, SP 1048

UPHOLE SHOOT - VOLCANICS

1 kg @ 5 m

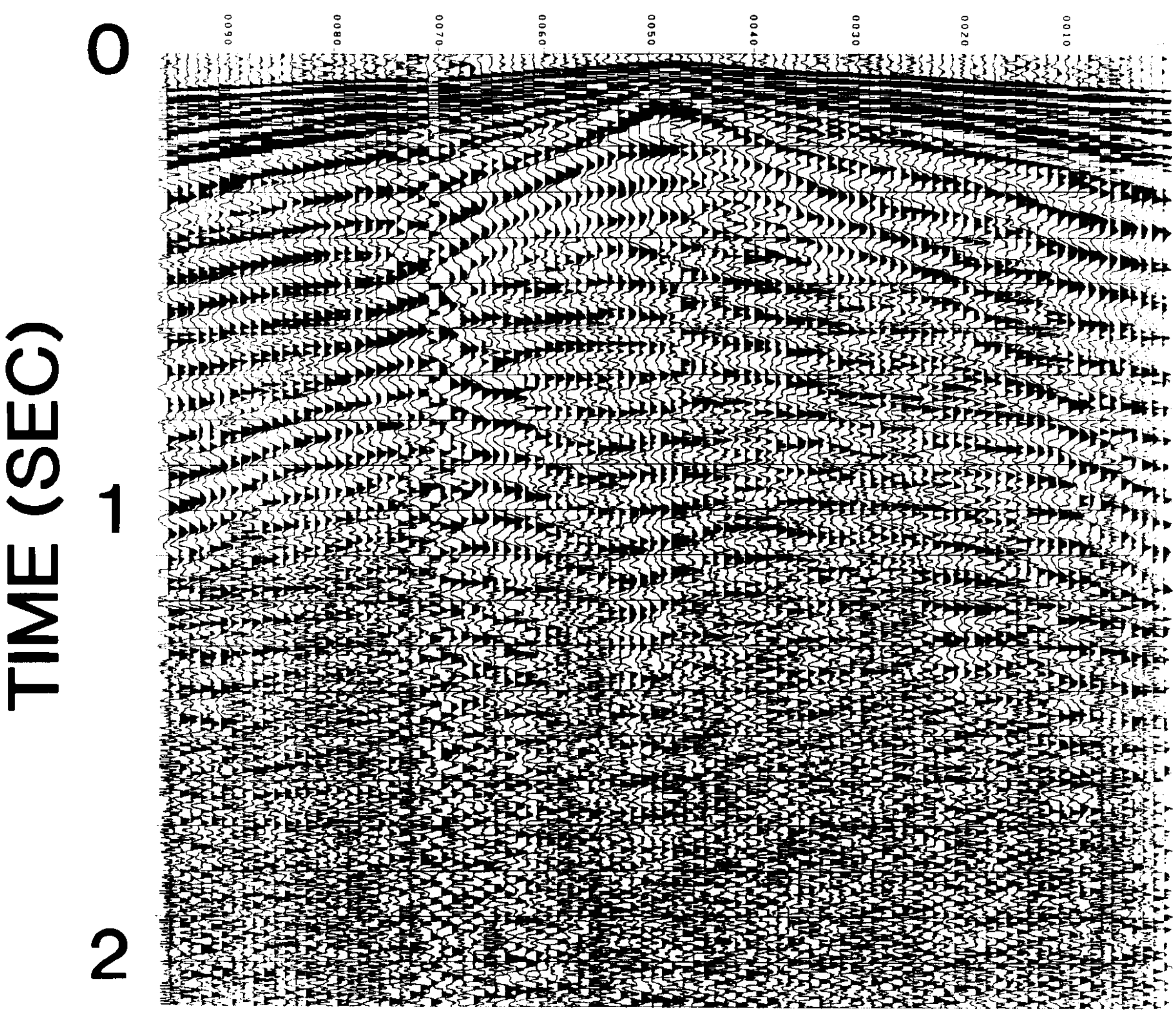


5 m GI Bunched Geophones

Figure 8. Uphole shoot, test Line BMR91.OT1, SP 1048, shot record from 1 kg charge at 5 m depth.

UPHOLE SHOOT - VOLCANICS

1 kg @ 10 m

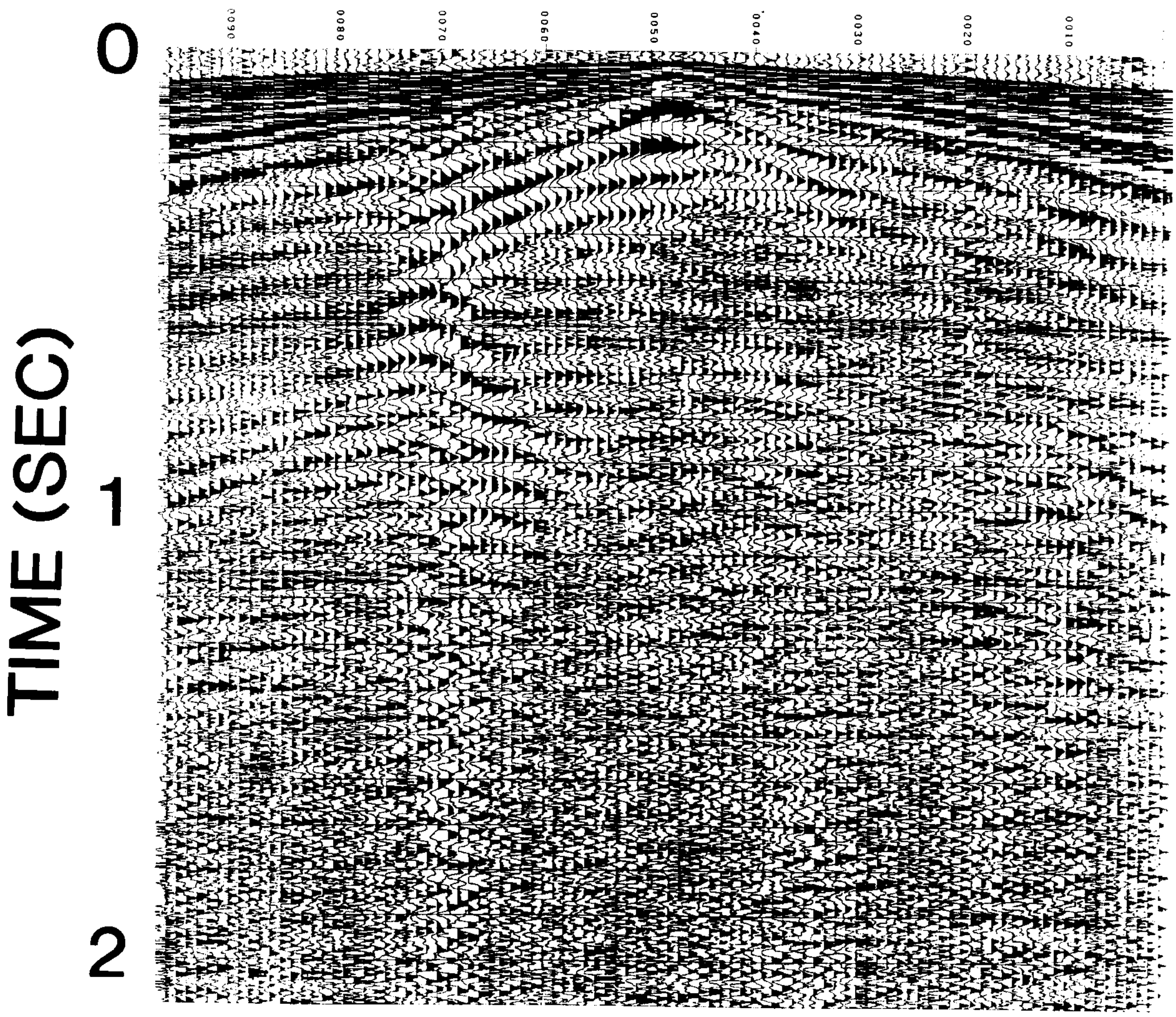


5 m GI Bunched Geophones

Figure 9. Uphole shoot, test Line BMR91.OT1, SP 1048, shot record from 1 kg charge at 10 m depth.

UPHOLE SHOOT – VOLCANICS

1 kg @ 20 m



5 m GI Bunched Geophones

Figure 10. Uphole shoot, test Line BMR91.OT1, SP 1048, shot record from 1 kg charge at 20 m depth.

UPHOLE SHOOT - VOLCANICS

2 kg @ 30 m

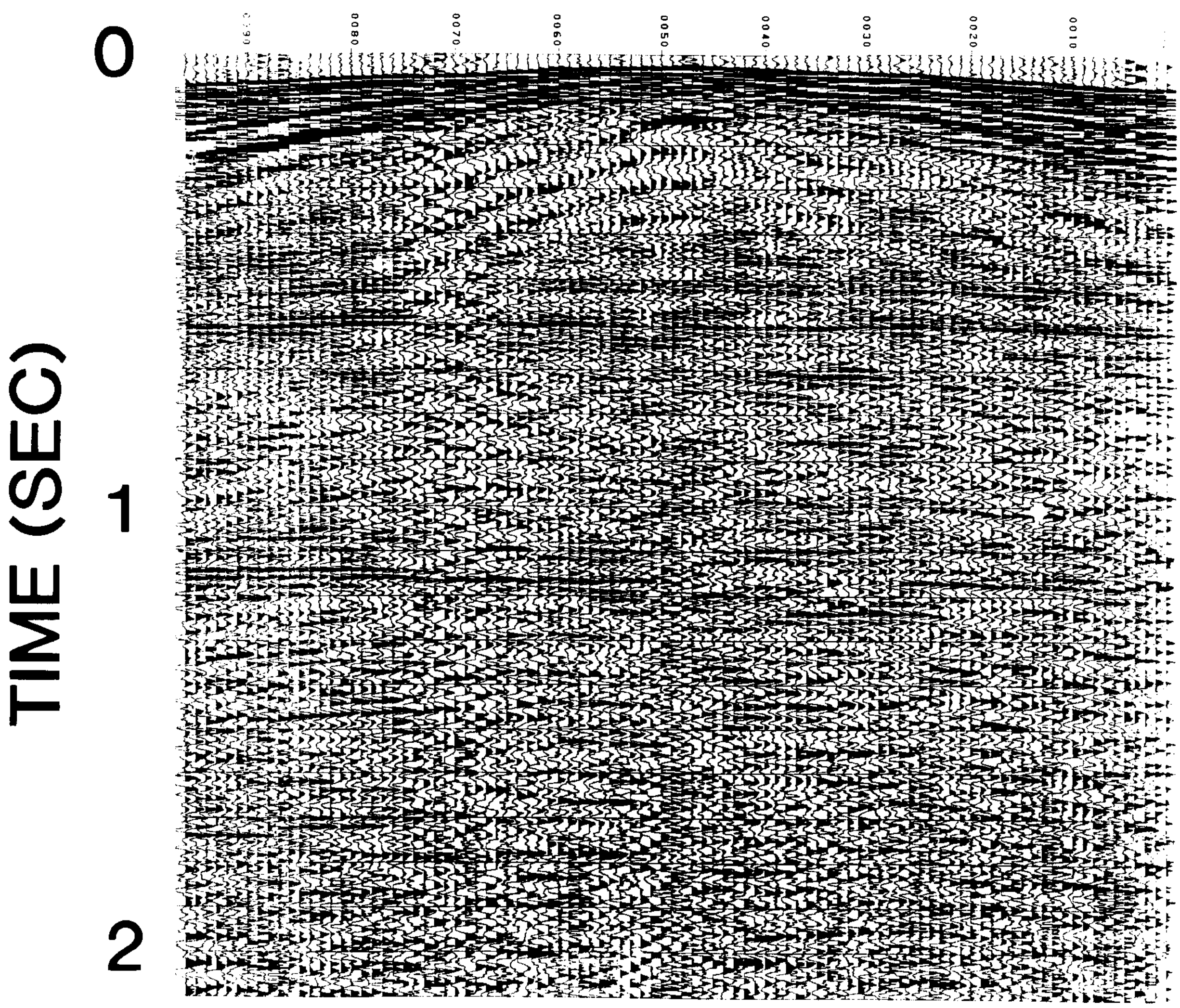


Figure 11. Uphole shoot, test Line BMR91.OT1, SP 1048, shot record from 2 kg charge at 30 m depth.

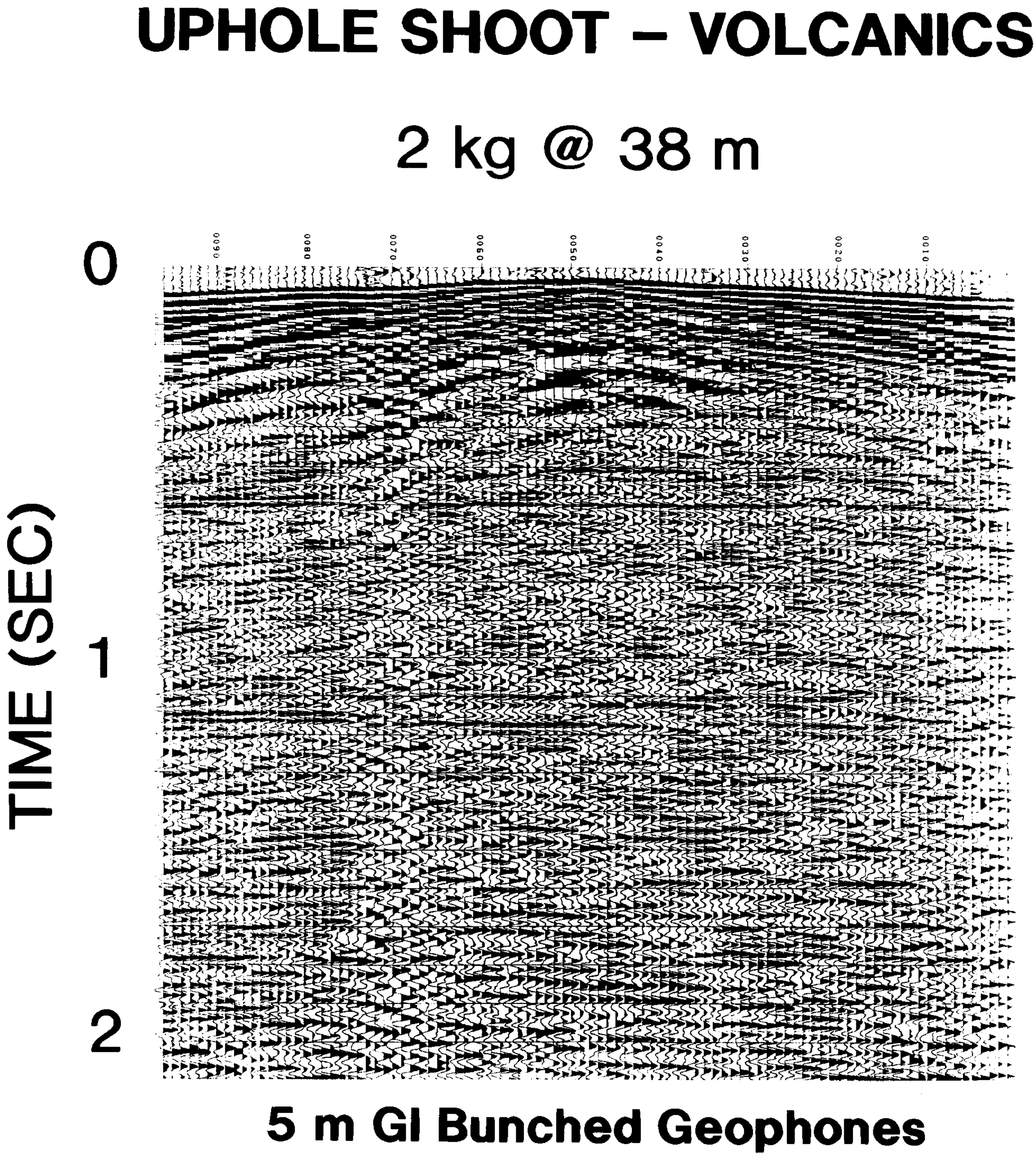
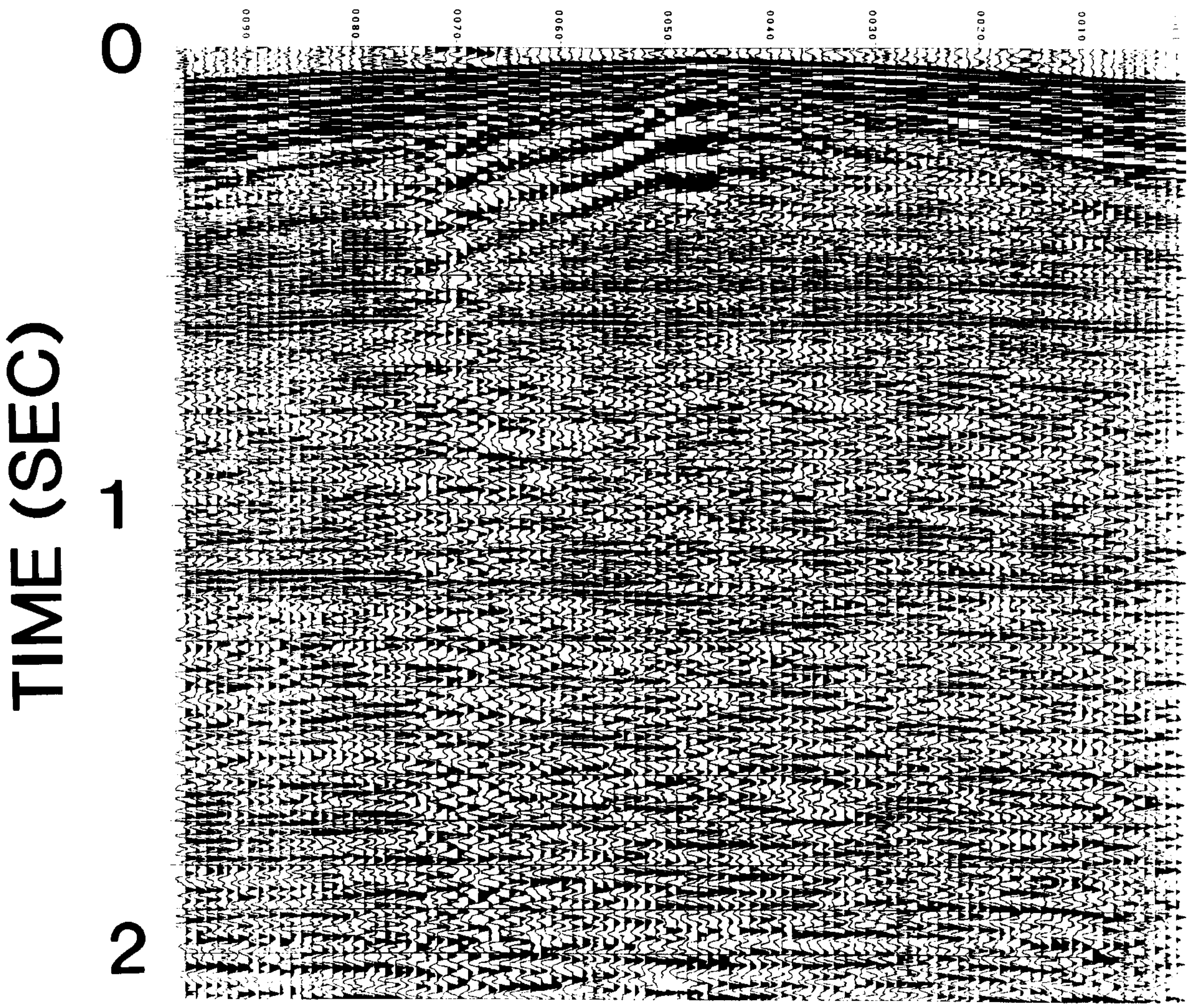


Figure 12. Uphole shoot, test Line BMR91.OT1, SP 1048, shot record from 2 kg charge at 38 m depth.

VOLCANICS, COLAC

10 kg @ 20 m



5 m GI Bunched Geophones

Figure 13. Test Line BMR91,OT1, SP 1048 shot record from 10 kg charge at 20 m depth.

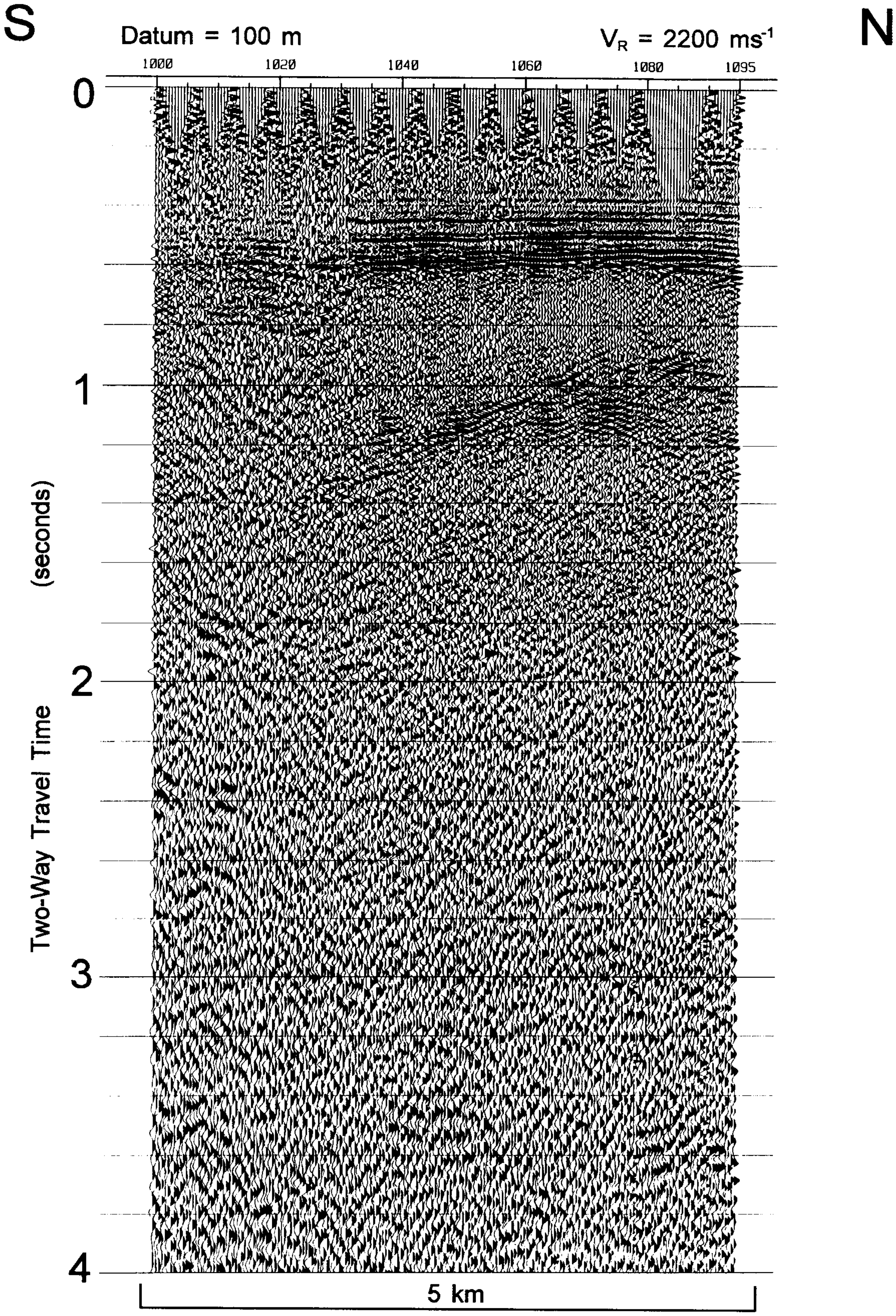


Figure 14. CMP final stack, Line BMR91.OT1, 4 sec TWT.

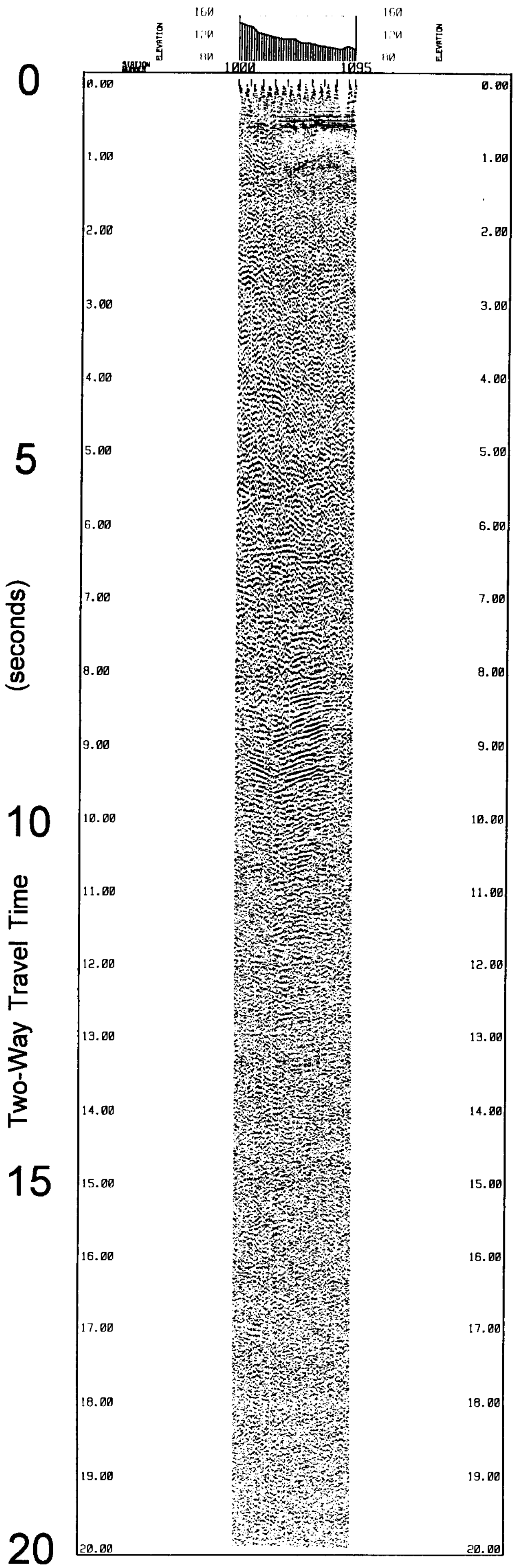


Figure 15. CMP final stack, Line BMR91.OT1, 20 sec TWT.

Line BMR91.OT2

An uphole shoot was not performed on Line BMR91.OT2 because earlier work by BMR (Raitt, 1965) at a location 20 km east (BMR Traverse V2) recorded an uphole shoot indicating a weathered layer 7 m in depth with a velocity of 550 ms^{-1} and a subweathering velocity of 3050 ms^{-1}. The near surface layers on Line BMR91.OT2 also contained Tertiary basalts similar to Line BMR91.OT1, and so charge depth and charge size comparison tests were not made because the results would be similar. The work by Raitt (1965) along BMR Traverse V2 also discusses reverberation type multiples (ringing) when recording seismic over basalt covered areas, which is similar to the seismic noise recorded in the uphole shooting on Line BMR91.OT1.

The CMP stack seismic sections for Line BMR91.OT2 are shown in Figures 16 and 17 with a 4 second TWT display and a deep reflection seismic display to 20 seconds TWT. Strong sub-horizontal reflection events were recorded between 200 ms and 600 ms from Tertiary sediments. A westerly dipping event was also recorded between 1800 ms and 2400 ms from probable basement. As with Line BMR91.OT1 the seismic reflection events between the Tertiary sediments and basement are of a poor quality. The deep seismic section (Figure 17) shows deep crustal events at 9 seconds and 14 seconds TWT, with the later probably from near the crust-mantle boundary (Moho).

Line BMR91.OT3

Due to the poor drilling conditions in the palaeo-sand dunes along Line BMR91.OT3, no attempt was made to perform an uphole shoot (difficulty in drilling a deep hole) or perform charge size and charge depth comparison tests. An experimental shot using a shothole pattern of 3 shots with shothole depths around 4 m (kelly depth) and 12 kg shot charge size distributed between the 3 shotholes produced a shot record with a high degree of low frequency seismic signal with difficulty in resolving higher frequency reflection events. The best shot records were obtained from shots with a shothole depth of 9 m. Shallower single hole shots resulted in some reflection data being recorded with an increase in low frequency ground roll noise.

The CMP stack sections shown in Figures 18 and 19 for Line BMR91.OT3 show good reflection events in the first 800 ms of the displays, with poorer quality reflections deeper down. Deep reflection events are not apparent and incoherent. Due to the poor drilling conditions only 8 of the planned 17 CMP production shotholes were drilled resulting in a reduced CMP fold coverage and data infill in the top part of the seismic section.

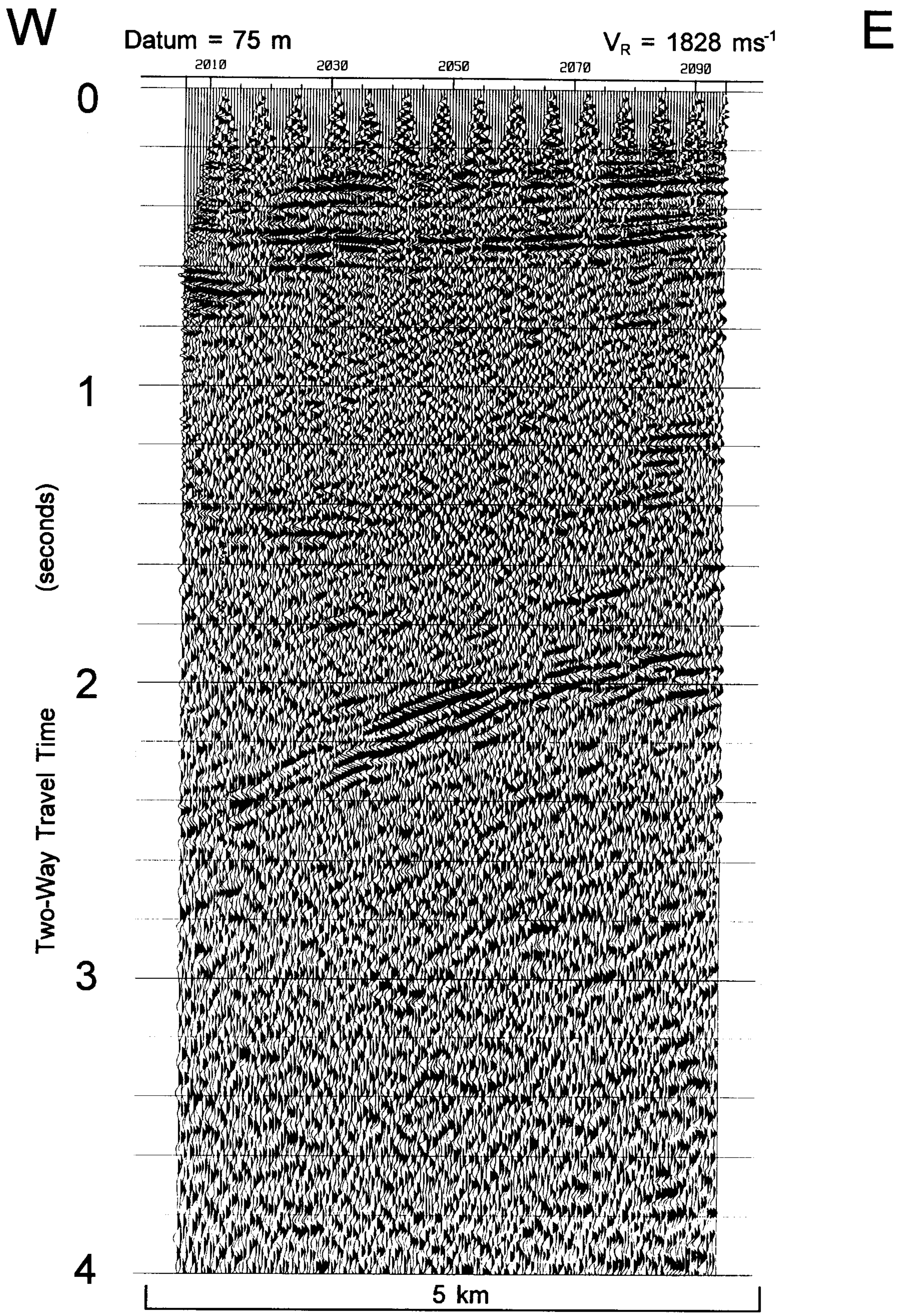


Figure 16. CMP final stack, Line BMR91.OT2, 4 sec TWT.

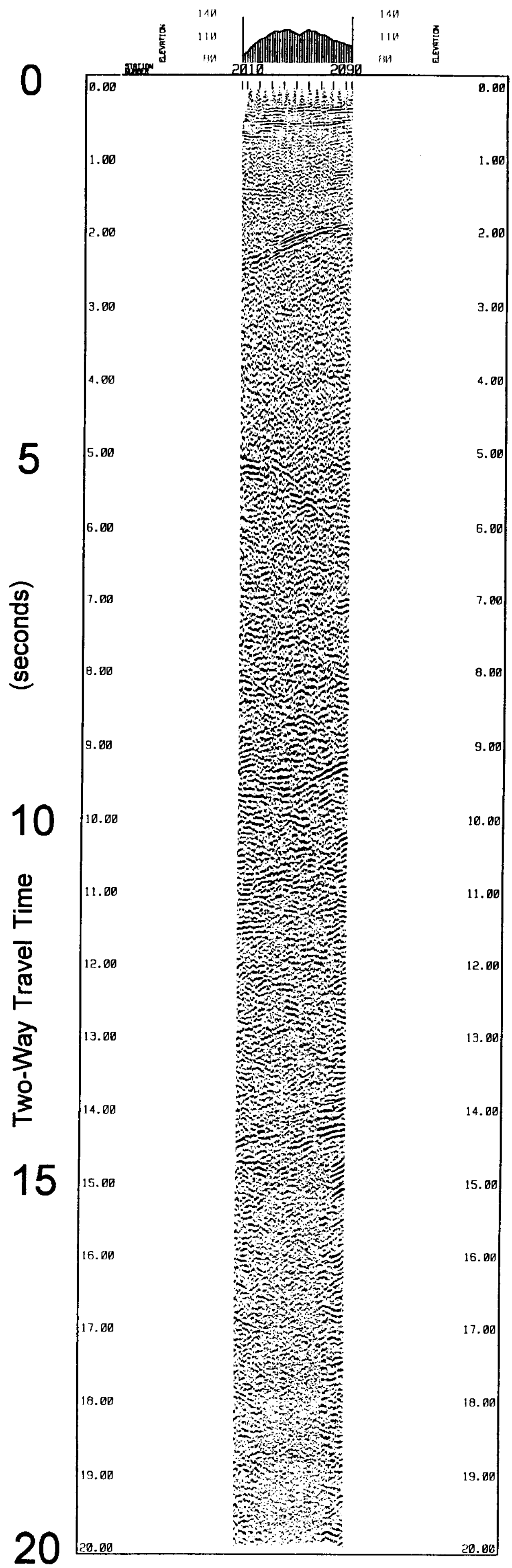


Figure 17. CMP final stack, Line BMR91.OT2, 20 sec TWT.

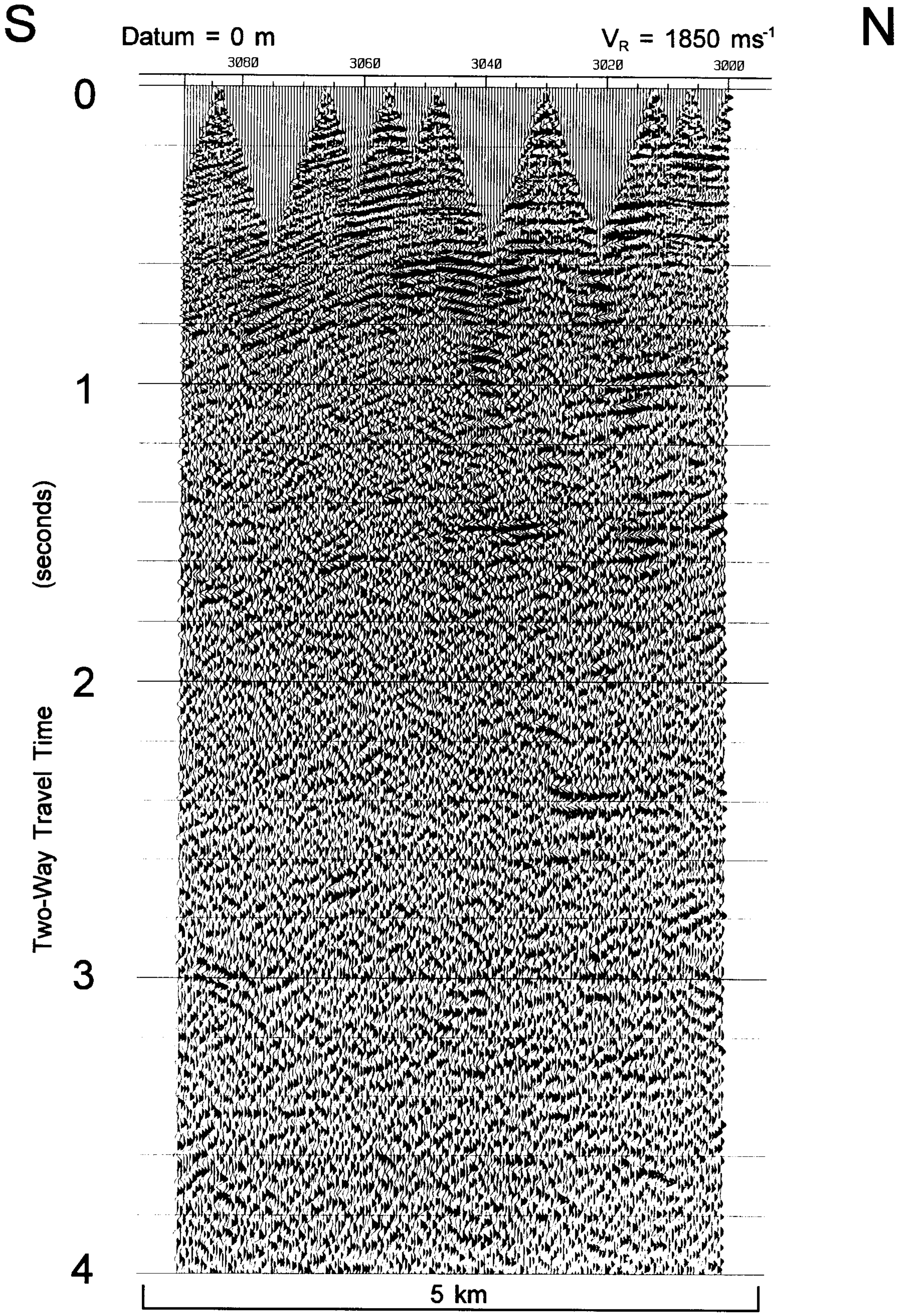


Figure 18. CMP final stack, Line BMR91.OT3, 4 sec TWT.

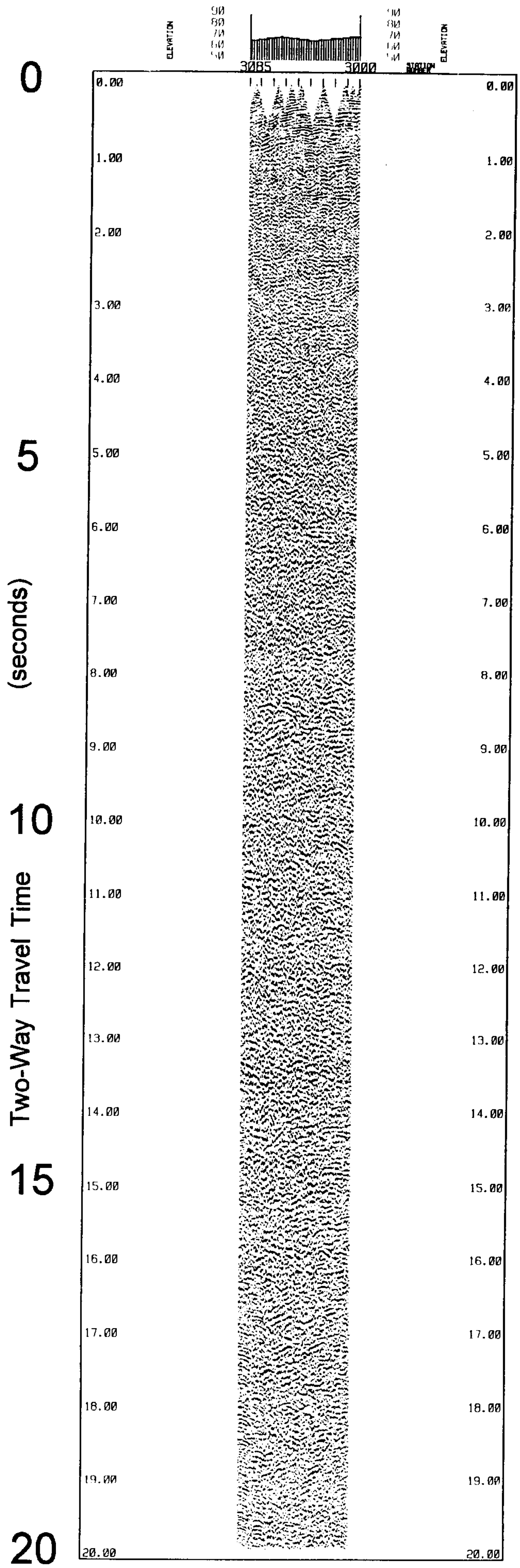


Figure 19. CMP final stack, Line BMR91.OT3, 20 sec TWT.

Line BMR91.OT4

No uphole shoot was performed on Line BMR91.OT4 as an earlier seismic survey by BMR (Jones, 1966) recorded an uphole survey on BMR Traverse GL2, several kilometres east of BMR91.OT4. The earlier uphole survey showed that the weathering depth was 6 m with a weathered layer velocity of 610 ms^{-1} and a sub-weathering velocity of 2195 ms^{-1}. The results also showed that the best charge depth was about 18 m. A shot depth comparison test on Line BMR91.OT4 also showed that the shot depth needed to be at least 18 m deep, or more specifically the shot depth should be deeper than the depth to the water table. One shot fired above the water table (shot depth 8 m) produced a shot record containing very little high frequency signal with loss of definition of many reflection events compared to those shots with shot depths greater than the water table depth. On the Line BMR91.OT4 the depth to the water table varied between 2 m to 25 m, depending on the surface elevation at the shot points and the level of the potentiometric water surface (i.e. water table). A charge size comparison test was made by loading three of the CMP production shots with varying charge sizes. An increase in charge size reduced ground roll marginally (i.e. increased signal to noise ratio) with little improvement in the overall shot record signal quality.

CMP stack seismic sections for Line BMR91.OT4 are shown in Figures 20 and 21. In Figure 20 discontinuous reflection events occur down to 2 seconds TWT. The quality of reflection events below 2 seconds is poor, with no coherent deep crustal reflections in the deep seismic reflection section in Figure 21.

Line BMR91.OT5

Due to the poor drilling conditions in the palaeo-sand dunes shotholes could only be drilled to shothole depths of between 8 m and 13 m, with a water table depth of 8 m. Difficulty was found in loading the shot charges to any significant depth below the water table due to sloughing of sand and collapse of the bottom of the shot hole. Because of the drilling difficulties no uphole shoot, charge size and charge depth comparison tests were made. On a small section of the test line some experiments were made using 2 kg charges in shotholes spaces at 100 m intervals. Results from the CMP data using the smaller charge sizes were very poor with very few reflections recorded.

CMP stack sections for Line BMR91.OT5 are shown in Figures 22 and 23. Reflection events can be interpreted from the top of the section down to 1400 ms (Figure 22), with no prominent reflection events at deeper depths. No deep crustal events can be interpreted either on Figure 23.

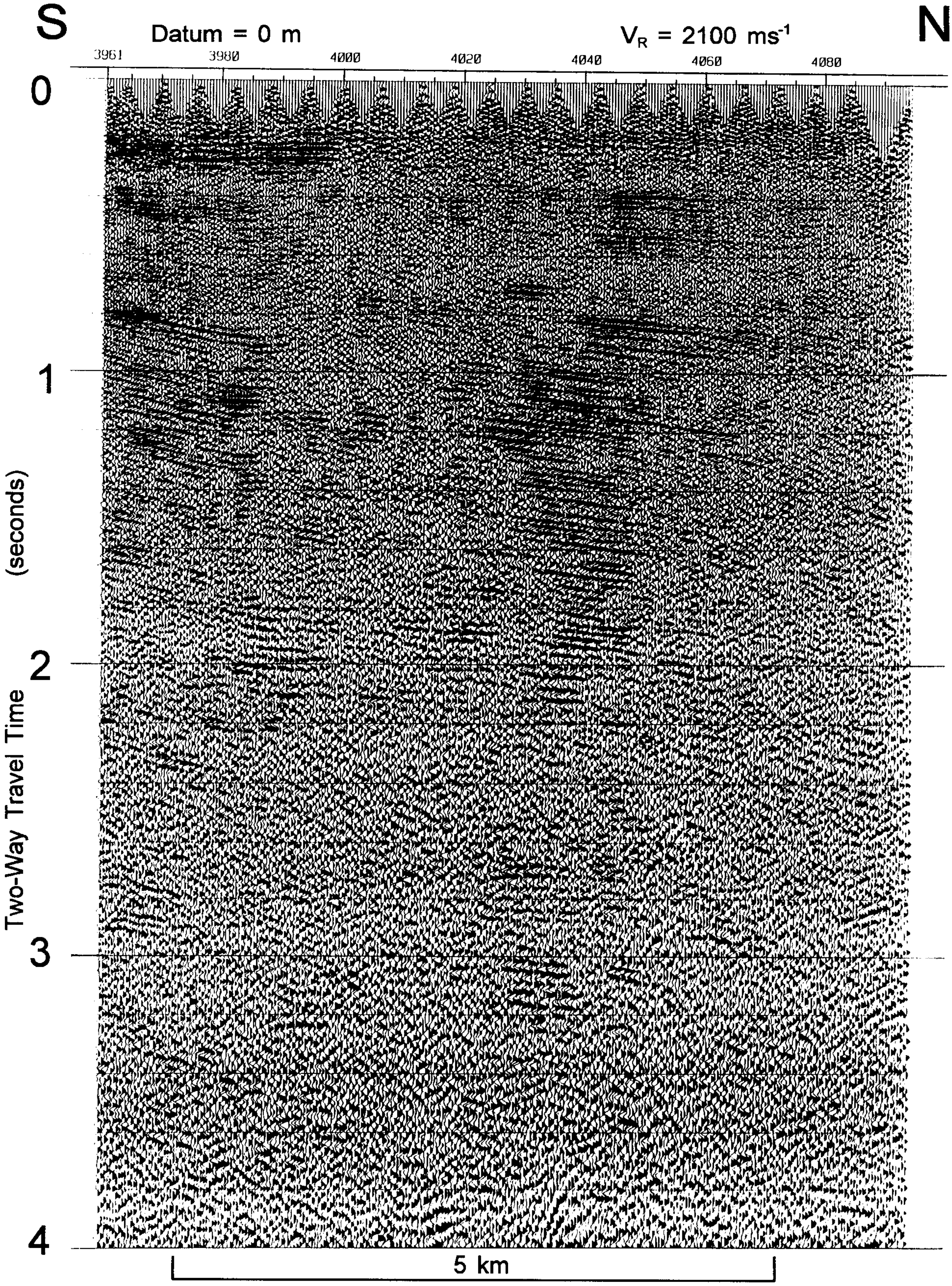


Figure 20. CMP final stack, Line BMR91.OT4, 4 sec TWT.

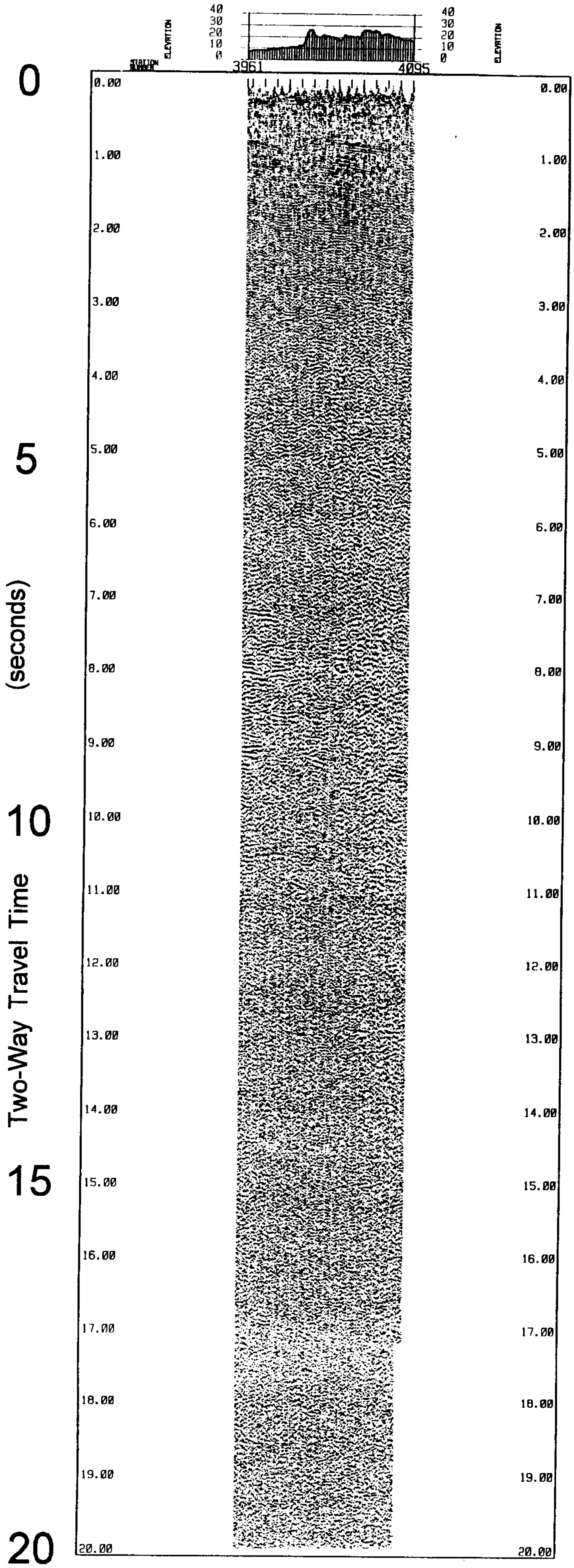


Figure 21. CMP final stack, Line BMR91.OT4, 20 sec TWT.

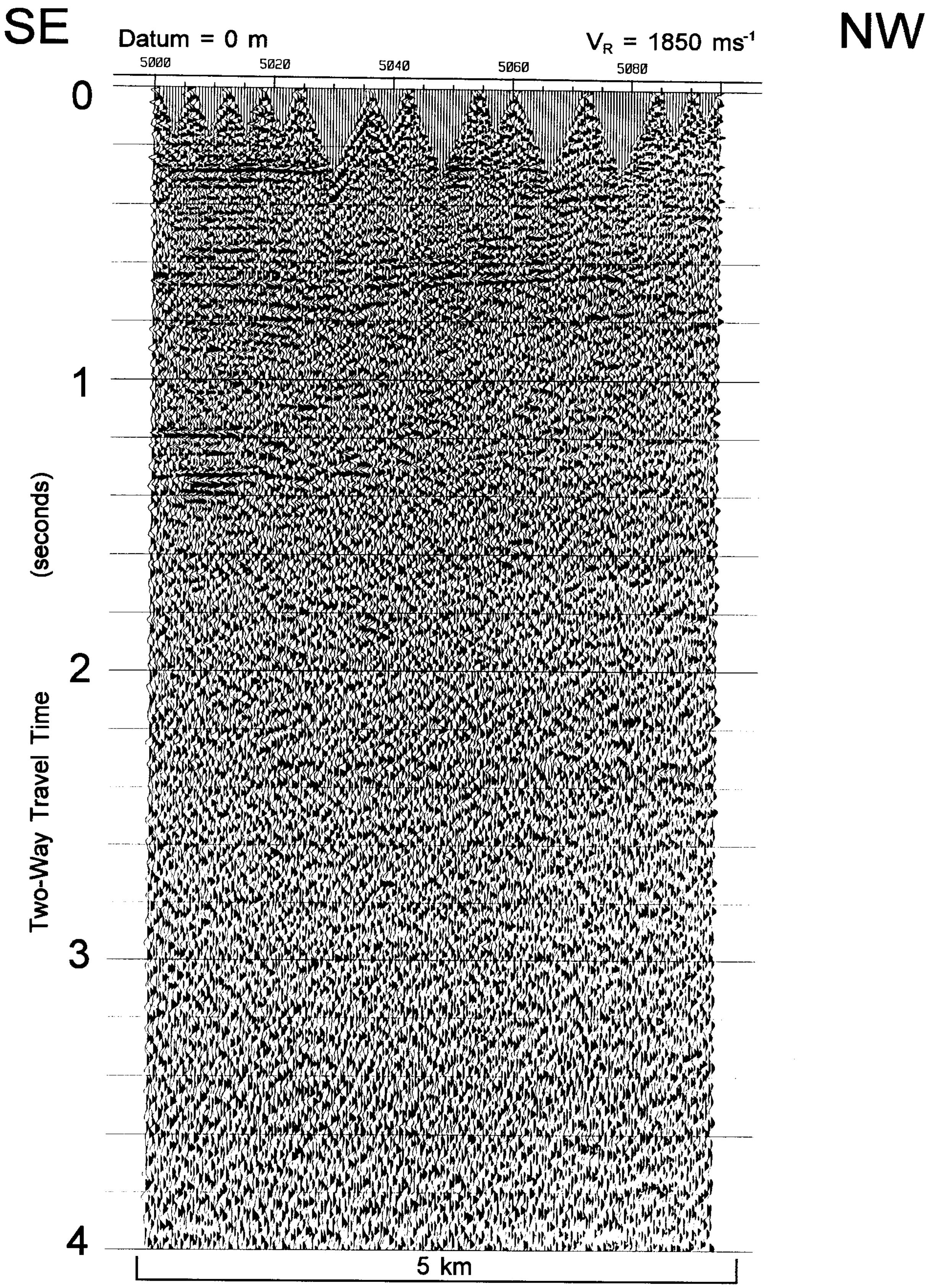


Figure 22. CMP final stack, Line BMR91.OT5, 4 sec TWT.

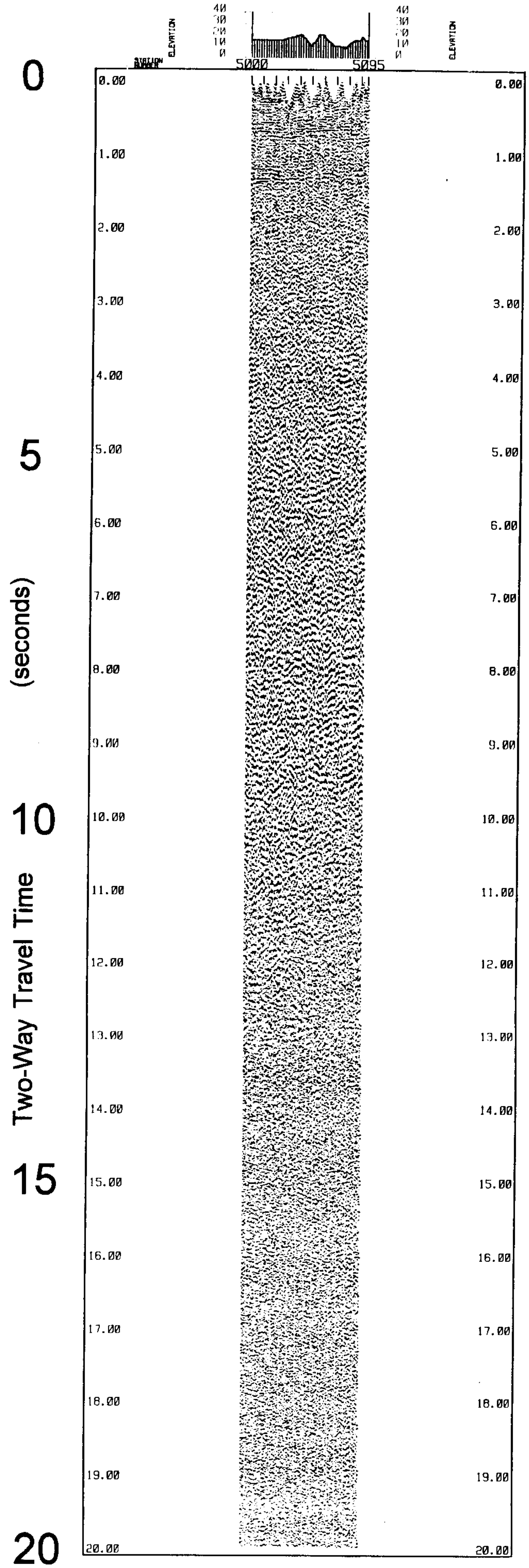


Figure 23. CMP final stack, Line BMR91.OT5, 20 sec TWT.

ACKNOWLEDGEMENTS

The authors acknowledge the contributions and efforts made by all members of the seismic test survey party. The cooperation and assistance from local government authorities, petroleum exploration companies (Gas & Fuel Corporation of Victoria, SAGASCO and AGL) and State Government geological, environmental and forestry authorities, in all areas of the survey was gratefully appreciated.

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APPENDIX 1

Operational Statistics

Drilling crew departed Canberra	28-10-1991
Recording crew departed Canberra	28-10-1991
Drilling commenced	30-10-1991
Recording commenced	30-10-1991
Drilling completed	12-11-1991
Recording completed	12-11-1991
Drilling crew returned to Canberra	15-11-1991
Recording crew returned to Canberra	15-11-1991

Total CMP line kilometres	25.75 km
Number of seismic test sites	5

Recording:

Total number of recording days worked	11
Recording days lost:	
Due to travel to and from Canberra	5
Due to townshifts	2 x 0.5
Due to adverse wet weather	1
Due to instrument breakdown	0
Due to Public Holidays	0
Due to windy weather and heat (Total Fireban)	0

Reflection:

CMP fold	1 - 17
Total number of shots	103
Average number of production shots/recording day	10
Average surface coverage/recording day	2.34 km
Explosives used	936 kg
Detonators used	115
Average charge/production shot	9 kg

Drilling:

Number of drilling rigs	2
Total number of rig days worked	22
Rig days lost:	
Due to townshifts	2 X 0.5
Due to adverse wet weather	1
Due to equipment breakdowns & maintenance	0
Reflection shotholes;	
Total number of shotholes	
Total metres drilled	2046 m
Ave depth/shothole	20 m
Average number of holes/rig/day	4.7

OTWAY BASIN SEISMIC TEST SURVEY 1991- OPERATIONAL STATISTICS						
Line	Seismic Test	Explosives			Drilling	
		Total (kg)	Dets (45m)		Shotholes	Metreage (m)
1	Uphole Shoot	11	8		1	41
	Charge Size	40	4		4	96
	Charge Depth	53	6		4	67
	CMP Production	160	16		16	289
2	CMP Production	152	15		15	322
3	CMP Production	96	12		11	108
4	Charge Depth	40	4		4	94
	Charge Size	46	5		3	120
	CMP Production	194	19		19	706
5	CMP Production	132	20		20	159
	CMP Small Charge	12	6		6	44
Total		936	115		103	2046

APPENDIX 2

Seismic Survey Personnel

Australian Geological Survey Organisation:

Project Leader (major survey reconnaissance)	D.M. Finlayson
Seismic Field Party Leader:	K.D. Wake-Dyster
Geophysicists:	D.W. Johnstone
	A. Owen
Technical Officers (Engineering):	J. Whatman
	M. Timms
Drillers:	D. Eaton
	A. Porter
Assistant Drillers:	A. Hinds
	K. Popple
Field Assistants: (Explosives)	R.D.E. Cherry
	S. Pardalis (Contract)
	A.C. Takken
Temporary Personnel:	
Field Hands (GSO3)	Ross Deacon
	Allan Whichelo

APPENDIX 3

Seismic Survey Vehicles

Recording:

Recording truck	Mercedes 911 4tonne 4X4	ZBE-748
Computer truck	International 1830C 8tonne	ZBE-964
Geophone carrier	Toyota Landcruiser 4X4 T/Top	ZJE-052
Geophone carrier	Toyota Landcruiser 4X4 T/Top	ZJE-053
Geophone carrier	Toyota Landcruiser 4X4 T/Top	ZJE-057
Geophone carrier	Toyota Landcruiser 4X4 T/Top	ZJE-058
Personnel carrier	Toyota troop carrier, 4X4	ZJE-025

Drilling:

Drilling rig	Mayhew 1000/Mack R600, 8X6	ZBE-606
Drilling rig	Mayhew 1000/Mack R600, 8X6	ZSU-473
Drill water tanker	Mack R875, 6X6, 8645 litres	ZSU-863
Drill water tanker	Mack R875, 6X6, 8645 litres	ZSU-864
Explosives truck	International 1830C 8tonne	ZBE-966
Preloading truck	Toyota Landcruiser, 4X4, T/Top	ZJE-055
Personnel carrier	Toyota troop carrier, 4X4	ZJE-011

APPENDIX 4

Timetable of Operations

28-10-91	Depart Canberra for field. Overnight at Shepparton (Overlander Hotel/Motel).
29-10-91	Travel from Shepparton to Colac (Commercial Hotel/Motel). At Colac to 31-10-91.
30-10-91	Peg Site 1, commence drilling and recording Site 1.
31-10-91	Drilling and recording Site 1.
01-11-91	Peg and commence drilling Site 2. Completed recording Site 1, shift to Hamilton (George Hotel/Motel).
02-11-91	Completed drilling and recording Site 2.
03-11-91	No work (Sunday).
04-11-91	Peg and commence drilling and recording Site 3. Shift to Mt Gambier (Federal Hotel/Motel).
05-11-91	Complete drilling Site 3, recording Site 3.
06-11-91	No work due to wet weather.
07-11-91	Completed recording Site 3. Peg and commence drilling and recording of Site 5.
08-11-91	Completed drilling and recording Site 5.
09-11-91	Peg and commence drilling and recording Site 4.
10-11-91	No work (Sunday).
11-11-91	Drilling and recording Site 4.
12-11-91	Completed drilling and recording Site 4.
13-11-91	Return to Canberra. Mt Gambier to Bendigo.
14-11-91	Bendigo to Holbrook.
15-11-91	Holbrook to Canberra.

APPENDIX 5

Spread and Recording Parameters

Spread length	4750 m
Spread Type	Split Spread
Number of channels (max)	96
Number of station units available	116
Geophone station interval	50 m
CDP fold	1-17
Number geophones/trace	16
Geophone pattern (GSC-20D)	in-line
Geophone spacing	3 m
Seismic System	Sercel SN368
Blaster	OYO Model 1340
Camera	OYO DFM-480
Station Unit Test & Repair System	Prosol TRS-2
Field Processing System	Vista PC based system
Sercel SN368 instrument settings:	
Recording mode	digital
Tape format	SEG-D Multipexed
Number of input channels:	
Data	96
Auxiliary	4
Tape: 9 track, 6250bpi GCR, 0.5inch, 8.5inch reel, 1200ft	
Record length	20 second
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	0 db
AGC	1
Recovery Delay	32 ms

APPENDIX 6

Line recording spread parameters

Line BMR91.OT1

Orientation (High SP numbers North, Trace 1 to the South)	N-S
Length	4.75 km
First Geophone station	1000
Last Geophone station	1095
First Shotpoint	1000
Last shotpoint	1095
Geophone station interval	50 m
Shotpoint interval	300 m

Line BMR91.OT2

Orientation (High SP numbers East, Trace 1 to the West)	E-W
Length	4.75 km
First Geophone station	2000
Last Geophone station	2095
First Shotpoint	2012
Last Shotpoint	2095
Geophone Station interval	50 m
Shotpoint interval	300 m

Line BMR91.OT3

Orientation	N-S
(High SP numbers South, Trace 1 to the North)	
Length	4.75 km
First Geophone station	3000
Last Geophone station	3095
First Shotpoint	3000
Last Shotpoint	3095
Geophone Station interval	50 m
Shotpoint interval (nominal)	300 m

Line BMR91.OT4

Orientation	N-S
(High SP numbers North, Trace 1 to the South)	
Length	6.75 km
First Geophone station	3960
Last Geophone station	4095
First Shotpoint	4000
Last Shotpoint	3961
Geophone Station interval	50 m
Shotpoint interval (nominal)	300 m

Line BMR91.OT5

Orientation (High SP numbers Northwest, Trace 1 to the Southeast)	NW-SE
Length	4.75 km
First Geophone station	5000
Last Geophone station	5095
First Shotpoint	5000
Last Shotpoint	5095
Geophone Station interval	50 m
Shotpoint interval (nominal)	300 m

APPENDIX 7

Seismic Field Tape Index

Tape No.	Line	Shotpoints	Recording Dates	Record Mode	Survey
91/105	BMR91.OT1	Uphole1048	30/10/91-30/10/91	6250 bpi	GCR OTWAY TEST
91/106	BMR91.OT1	1000 - 1095	31/10/91-01/11/91	6250 bpi	GCR OTWAY TEST
91/107	BMR91.OT2	2012 - 2095	02/11/91-02/11/91	6250 bpi	GCR OTWAY TEST
91/108	BMR91.OT3	3000 - 3084	04/11/91-05/11/91	6250 bpi	GCR OTWAY TEST
91/109	BMR91.OT5	5000 - 5095	08/11/91-08/11/91	6250 bpi	GCR OTWAY TEST
91/110	BMR91.OT4	3961 - 4095	11/11/91-12/11/91	6250 bpi	GCR OTWAY TEST