Bureau of Mineral Resources, Geology & Geophysics

R E C O R D

Record 1991/87

Seismic Field Trials on the Nullarbor Plain, South Australia, 1991

Operational Report

by

Jim Leven & Tim Barton

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The authors acknowledge the contribution of all members of the seismic party.

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SUMMARY

In preparation for a National Geoscience Mapping Accord project involving a seismic survey planned for 1993, seismic tests were conducted on the Nullarbor Plain south of Cook to investigate the feasibility of imaging the sedimentary sequences and basement beneath the platform carbonates of the Eucla Basin, and to anticipate scientific and logistic difficulties associated with seismic acquisition on the Nullarbor Plain. The major conclusions are:

1. The near-surface limestones of the Eucla Basin efficiently absorb seismic energy. Explosive charges should be detonated in shotholes which are around 15 m deep or as deep as drilling conditions permit. The cavity-prone limestones act as a high-cut filter on seismic energy.

2. Drilling of shotholes in the cavity-prone Nullarbor Limestone is difficult. The depth of the holes cannot be pre-determined as it is controlled by drilling conditions.

3. The near-offset seismic channels are noisy, due to shot-generated acoustic reverberation in the cavities of the Nullarbor Limestone.

4. It is possible to shoot seismic through the limestones of the Eucla Basin, but the high-cut frequency filtering of the seismic data, the near surface static variation caused by the karstic weathering, and the noisy near-offset data will result in a low-quality seismic image of the sub-surface.

5. The deepest event identified as a reflection which could be associated with the sedimentary section is at 600 ms at the southern test site and 400 ms at the northern test site. The seismic character below 600 ms is relatively non-reflective at both sites.

6. Prior to any major seismic acquisition on the Nullarbor, careful consideration must be given to the logistics of providing water and accommodation for the operations. The camping equipment traditionally used by the BMR seismic party is not suitable for work on the Nullarbor Plain.

7. As the sedimentary section appears to be relatively thin, and the underlying basement non-reflective, we believe the geological investigation of this region of the Eucla Basin might be best pursued by a drilling program.

INTRODUCTION

Aims

The purpose of these seismic tests is to investigate the feasibility of imaging the sedimentary sequences and basement beneath the platform carbonates of the Eucla Basin, and to anticipate scientific and logistic difficulties associated with operating on the Nullarbor. This is preliminary to a seismic program, planned in conjunction with the South Australian Department of Mines and Energy as part of the National Geoscience Mapping Accord Officer Basin Project (Lindsay, Leven & Krieg, 1991). Two sites were selected in the Mallabie Depression where aeromagnetic interpretation indicated a thickness of up to 1500 m of sediments beneath the Eucla Basin.

Geographical Area

The location of the seismic tests is shown in Figure 1. The two test sites were 28 and 60 km north of the turnoff to Cook from the Eyre Highway, and the seismic spread was deployed south-to-north along this road. The geographical coordinates of the centre of the southern site were 31°16'S 130°29'E, and those of the northern test site were 30°59'S 130°29'E. The sites lay in the far eastern portion of the area covered by the Coompana 1:250,000 map sheet.

GEOLOGY

A regional cross-section of the Eucla Basin region is illustrated in Figure 2. The platform carbonates of the Eucla Basin consist of three units: the basal Wilson's Bluff Limestone (Eocene), the Abrakurrie Limestone, and the Nullarbor Limestone (Miocene), (James & Bone, 1990; Lowry & Jennings, 1974). The thickness of the Nullarbor Limestone is around 50 m at the coast, and thins inland. It is a hard white to pink massive fine-grained limestone. The Abrakurrie Limestone wedges out rapidly north of the coast, and is probably not present beneath either test site. The Wilson's Bluff Limestone is about 100 m thick near the coast and thins to around 50 m near the trans-continental railway line, 100 km north. It is a white/yellow, soft, fine-to-medium grained biosparite with chert nodules. The Pidinga Formation (Eocene) lies unconformably beneath these carbonates. This unit has a thickness up to 45 m where it has been intersected by drilling, and consists of carbonaceous sandstone, siltstone and lignite.

An older sequence, correlated to the Cambrian Observatory Hill Beds of the Officer Basin, underlies the Pidinga Formation. The maximum known thickness (399 m) of this sequence was intersected in the YL3 well near the O'Malley siding. However, the base of this sequence has not been drilled in this area, so the actual thickness of the Palaeozoic section is unknown. Depth to magnetic basement interpretations from aeromagnetic data suggest that several thousand metres of Palaeozoic section may be present in the Mallabie Depression. Little is known of the geology of the Coompana Block in this area, which is believed to underlie the Officer Basin sequence in this area.

PREVIOUS GEOPHYSICAL SURVEYS

Gravity and aeromagnetic data were collected by the BMR over this portion of the Eucla

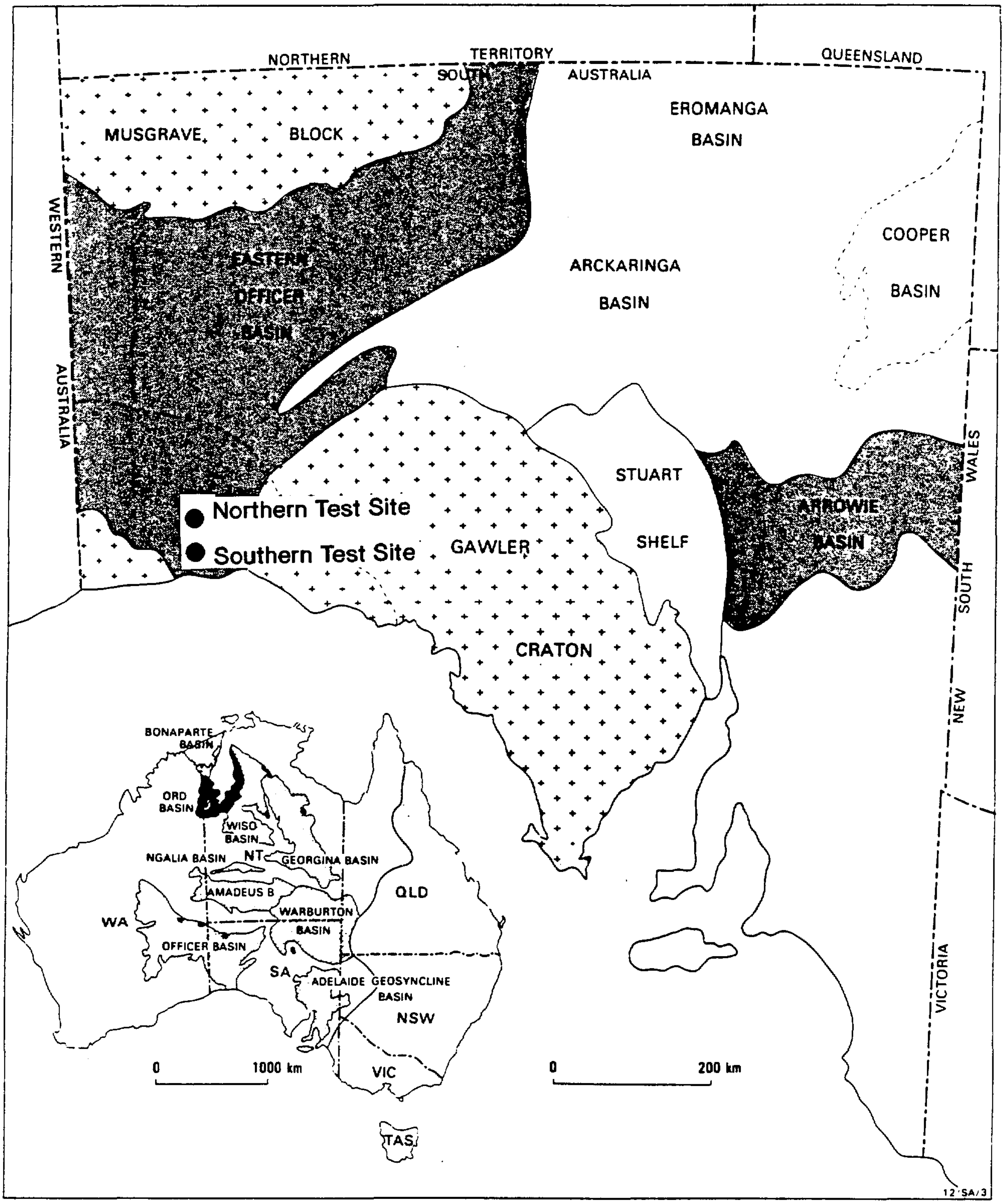

Fig. 1. Location of the two test sites

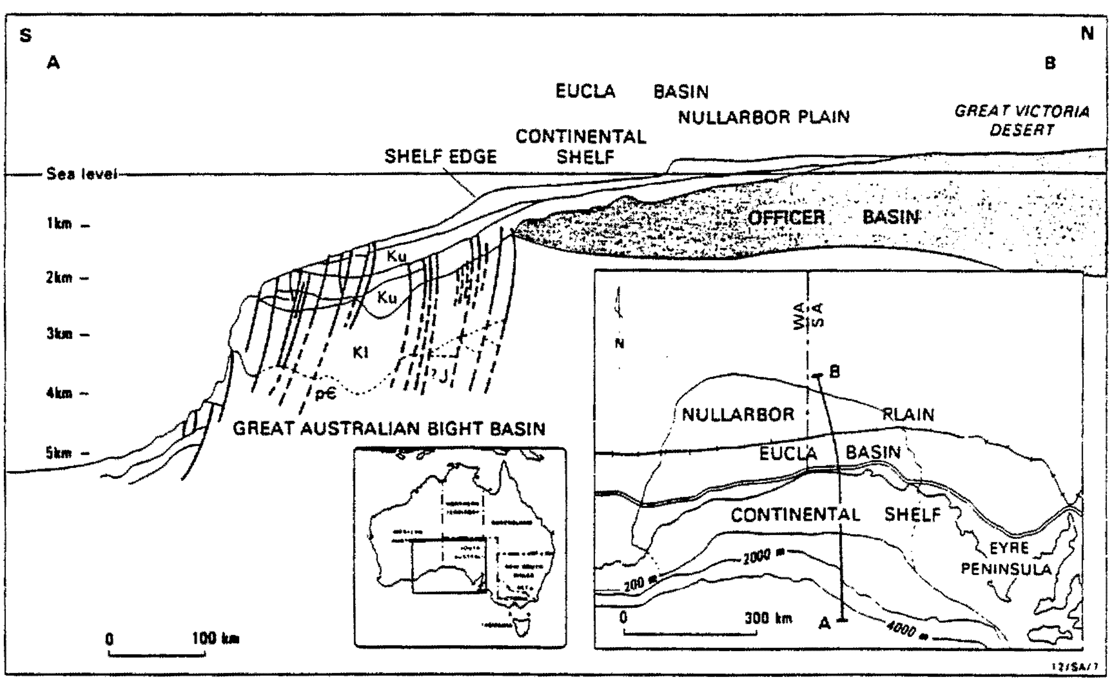

Fig. 2. Simplified geological cross-section of the Nullarbor Plain showing the relationship of the Eucla Basin and underlying Officer Basin (modified from James and Bone, 1991).

Basin as part of the national coverage. An interpreted depth to magnetic basement map (SADME, 1982) shows the Mallabie Depression extending to the west of the main trough into the region covered by the present survey, and indicates a depth to basement of around 1500 metres in the survey region.

The earliest seismic work carried out on the Nullarbor Plain was the reconnaissance refraction survey carried out by SADME in 1964 (Kendall, 1965). This survey was conducted along the old Eyre Highway and the road to Cook. The experiment used sub-surface explosive sources and large charges (450 kg of ANFO) to record to offsets of up to 50 km. Along the old Eyre Highway, a high speed refractor (5943 m s^{-1}) was interpreted as indicating basement dips eastward at a depth of around 1500 m. On the road north of the Eyre Highway, the interpretation indicated basement shallowed to around 1200 m depth at a point 15 km south of Cook.

In 1974 further seismic refraction and reflection experiments were carried out by SADME to the north of the railway line (Milton, 1974). These experiments used surface line sources (cordite). The quality of the reflection data was poor.

The Denman Seismic Survey carried out in 1987 by Geosystems Pty Ltd for LAPP Resource Consultants in PEL 33 (Lapp, 1987) recorded 40 km of 200 channel reflection profiling 20 km southwest of the Denman siding. Data quality was poor, but "a possible basement reflector is visible at 600 to 700 ms on most sections" (Poynton, 1988).

FIELD OPERATIONS

Reconnaissance

The reconnaissance for this test work was carried out during the southern Officer Basin reconnaissance in May 1991, and is described in Lindsay et al. (1991).

Schedule, personnel and vehicles

These seismic tests were undertaken on the opportunity basis, on the return of the seismic crew from Western Australia along the Eyre Highway. The schedule for these seismic tests on the Nullarbor Plain is outlined in Appendix I. Personnel and vehicles involved in this test work are listed in Appendix III.

Accommodation

The crew was accommodated in tents in an area sheltered by low trees near the intersection of the road to Cook and the Eyre Highway.

Weather

The weather on the Nullarbor is largely controlled by the Southern Ocean and fronts which regularly sweep across the Bight and the southern part of the continent. During the survey, temperatures were pleasant during the days but cool at night. We received scattered showers on several days, but these only stopped acquisition on one occasion - early on the afternoon of the 20 July. We also received over 2 mm of rain overnight on Sunday 21 July, which made the Cook road extremely slippery the following day. High wind speeds are common on the Nullarbor where there is nothing to impede the near-surface airflow. Fortunately, we experienced moderately high-speed winds only on one occasion: the night of the 21 July; otherwise wind speeds were low.

Surveying

Station coordinates for the survey were determined using a ProNav GPS instrument, which provides geographical locations to a sufficient accuracy for seismic work. Elevation control was poor (±10 m), but this was not considered a problem on the relatively flat low relief terrain on the Nullarbor Plain.

The location of the centres of the spreads at the two test sites, and the details of the spreads, are listed in Appendix 4. Star pickets, with identifying aluminium tags, were driven into the ground at the centre of each spread to enable reoccupation for future test work. All station markers were removed after completion of the test work.

Drilling and Loading explosives

Drilling the shot holes for the test work proved to be more difficult than expected. Because of the ubiquitous cavities in the Nullarbor Limestone, return of drill cuttings to the surface usually stopped after the first few metres of drilling. Thereafter, the cuttings collected in the sub-surface cavities, falling back into the drill hole whenever air circulation was stopped. These cuttings could easily jam the drillstring, as happened on several occasions during this work.

The cavernous nature of the limestone and the shortage of water meant that mud drilling was not feasible. Drilling for a shothole was therefore stopped when it was felt that further work might result in the rods becoming stuck. Shothole depths ranged from 9 to 38 m - short of the planned 50 m holes.

Two types of seismic explosive were used: 0.5 kg power gel seismic in hard plastic geoloc containers, and 2 kg power gel magnum in soft plastic "sausage" bags. The cavities in the limestone and the resulting irregular walls of the shothole also presented problems for loading the explosive charges. As individual containers of explosive could have easily become separated in a cavern, or caught at a level above the rest of the charge during loading, the explosives had to be loaded as one charge. The magnum bags were therefore wrapped together in plastic sheeting before loading, and this additional care needed in loading the charges could slow operations in a production mode. The geoloc containers were more suitable in this respect.

An interesting and unusual logistic problem of loading explosives on the Nullarbor is caused by atmospheric conditions: tamping the shotholes is not possible during significant decreases in atmospheric pressure. In this situation, the reservoir of sub-surface air in the cavernous limestone vents pressure to the atmosphere through the drillhole - creating an artificial blowhole. Drill cuttings shovelled into the hole to tamp the explosive charge are blown back out by the air current, and it is impossible to load shotholes in these barometric conditions.

Seismic Recording

The recording equipment and parameters used for this survey are detailed in Appendix II. The Sercel SN368 acquisition equipment recorded 106 shots (Appendices I and V). Four recording errors (mainly parity errors) occurred during recording in the southern test area.

The southern 10 m group interval (GI) spread was deployed from station 1001 to 1096, with bunched geophones at each station. The uphole and noise tests were then recorded into this spread. The spread was then redeployed with a 40 m GI from station 2001 to 2096 with geophones in the groups deployed at a 2.5 m interval. The three charge size comparisons shots, the twenty nine kelly depth shots, and the seven production shots were then recorded with this spread.

A similar procedure was followed at the northern test site. The 10 m group interval spread from station 3001 to 3096, with bunched geophones, was used to record the six noise shots. The spread was then redeployed with a 40 m GI from station 4001 to 4096. This spread was used to record the uphole shots, the three charge size comparison shots, the thirty kelly depth shots, and the six production shots.

Logistic Problems

These tests identified several significant logistic problems which would beset any future seismic acquisition work on the Nullarbor.

Water

Water on the Nullarbor is a scarce resource. For the survey we obtained water from the Cook Railway Station at a price of $1.20 per kilolitre. The station has its own desalination plant to service the residents and restock the trans-Nullarbor trains. Providing our requirements do not exceed the capacity of this facility (or the good will of the station supervisor) this is a convenient source. For seismic operations away from the railway sidings, water would have to carted from Cook or pumped from the water table (at a considerable depth) and desalinated.

Operations within the Regional Reserve

National Parks and Wildlife Service has responsibility for the conservation of the Nullarbor Regional Reserve. NPWS officers expressed concern about new vehicle tracks formed on the Nullarbor as access routes to our campsite. These tracks invite future use by other vehicles, which inhibits regeneration of the natural vegetation. Seismic operations away from the main roads may not present such a problem, but care should be taken to minimise the visibility of any traverses or access tracks.

Use of tents

The BMR has traditionally used tents to accommodate the crew during seismic surveys. However, the use of tents in the exposed conditions of the Nullarbor is not recommended. Strong winds are prevalent on this plain, and the problem is exacerbated by the total absence of shelter and the difficulty of driving a tent peg into the hard limestone surface in order to adequately secure tents. Future seismic operations on the Nullarbor Plain would require the use of caravans or mobile accommodation units. Although the initial financial outlay for this facility could be large, the cost could be recouped through increased operational efficiency of shorter daily travelling times and less non-productive time for camp shifts.

Fuel

Cook (or dumps at the other railway sidings) or the Nullarbor Roadhouse are the only available sources of fuel in the area.

General supplies
The station at Cook has a shop selling a range of groceries. This is possibly the only "general store" in southwest South Australia, west of Ceduna. North of Cook, no other source of supplies exists in the South Australian portion of the Nullarbor or the Great Victoria Desert. The store manager at Cook could, by arrangement, fill orders from the supply train.

Wood
It is customary to use wood in the seismic camp, both for camp fires and some water heating. There is no wood available on the Nullarbor Plain.

Drilling and charge loading
The specific difficulties associated with these operations on the Nullarbor are discussed above.

RESULTS FROM THE SOUTHERN TEST SITE

Uphole tests
The planned 70-metre hole for the uphole experiment was not possible, due to drilling conditions. The deepest available hole was used for the uphole test, and this was drilled to 38 m at station 1007.

The first breaks are characteristic of seismic wavespeed reversal with depth, or "low velocity zones" (LVZ), as discussed by Milton (1974). These are indicated by the refraction branches which diminish in amplitude until they are no longer distinguishable, whereafter another refraction branches at a greater arrival time becomes dominant (Fig. 3). In the intervening offset range, determining the first break arrival times becomes very subjective and a strong function of the ambient noise on the particular trace. Given this difficulty, the onset times of the first breaks at offsets greater than 250 m are not particularly useful for refraction statics analysis.

The first breaks from the uphole test shots have been digitised and are compiled in Appendix VI. In Figure 4, a Meissner analysis of the near surface velocity profile using these data (Meissner, 1962), indicates an increase in seismic wavespeed between the shots at depths of 6.1 and 17.8 m and depths of 22.8 and 28.4 m, with relatively constant wavespeeds in the depth ranges sandwiching these intervals.

Noise tests
Milton (1974) reported wavelengths of groundroll varied from 20 to 130 m and that the frequency bandwidth of the surface noise was similar to the frequency of the seismic reflection energy. Short-wavelength high-frequency surface waves pose problems in the processing of low fold seismic data, as this noise cannot be removed by either low-cut frequency filtering or FK filtering (due to aliasing).

Experimental work during the Denman Survey indicated the ground roll to have a dominant frequency of 14-15 Hz and a speed of around 1000 m s^{-1}, corresponding to a wavelength of

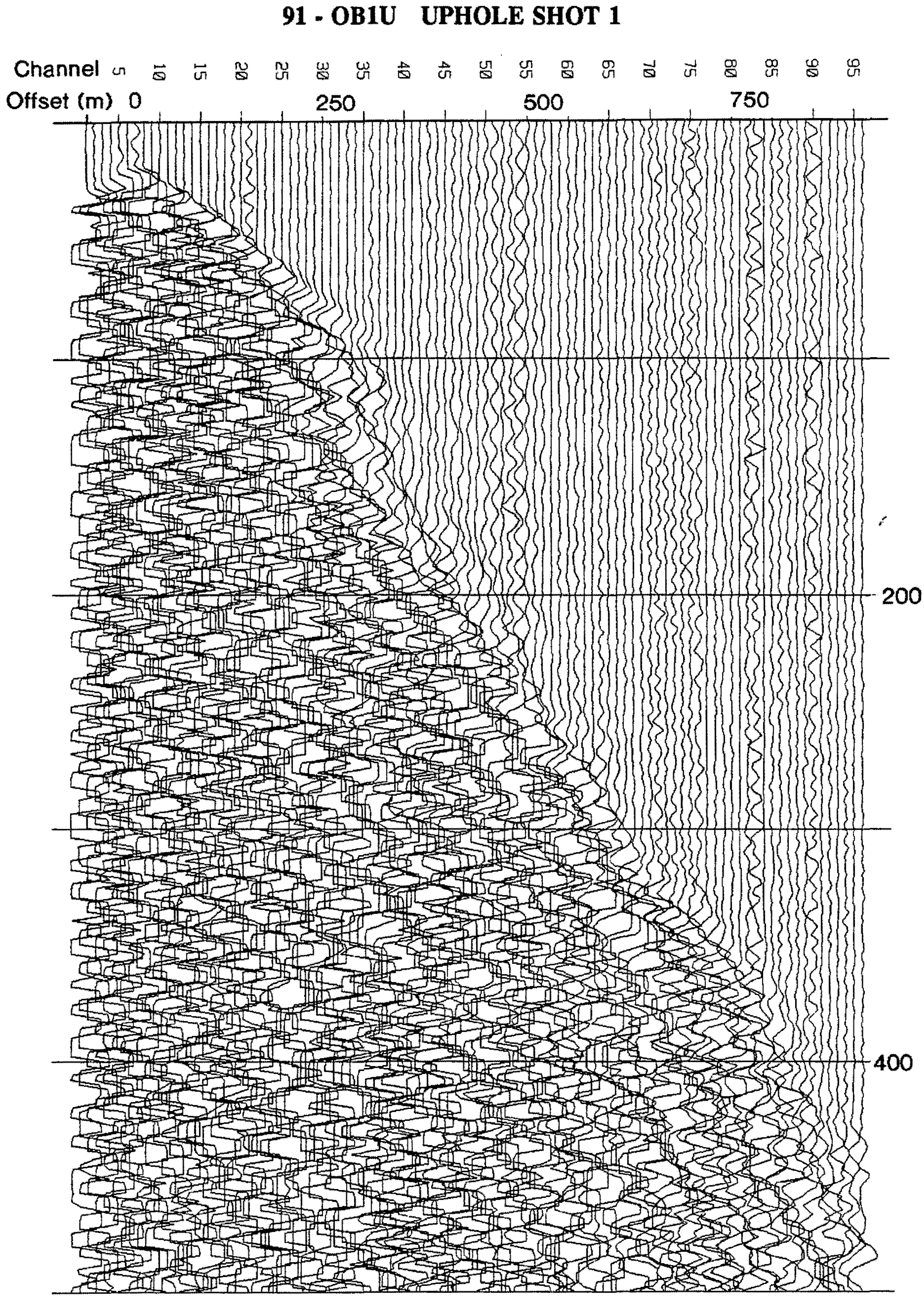

Fig. 3. An example of the first break pattern from Shot 1 of the uphole shots recorded with a 10 m group interval and bunched geophones at the southern test site. Note the first breaks that appear to have a negative intercept in the offset range 280 to 400 metres.

Channel	Offset metres	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6	Shot 7
Depth	metres	38	32.6	28.4	22.8	17.8	6.1	2.6
Charge	kg	4	4	2	2	2	0.5	0.5
		FB time ms	FB time ms	FB time ms	FB time ms	FB time ms	FB time ms	FB time ms
1	-65	28	28	24	21	20	14	13
2	-55	27	25	24	20	19	13	12
3	-45	26	24	23	19	18	12	11
4	-35	23	23	21	17	17	10	9
5	-25	22	22		17	16	8	8
6	-15	20	20	18	16	16	7	7
7	-5	19	17	18	14	15	6	3
8	5	20	18	17	13	15	6	5
9	15	21	20	20	14	17	10	9
10	25	24	22	22	19	20	10	10
11	35	26	25	23	20	20	11	11
12	45	27	26	25	21	21	13	12
13	55	30	30	28	26	26	16	15
14	65	32	30	30	26	27	18	17
15	75	35	34	32	29	29		19
16	85	36	35	32	30	30	22	21
17	95	40	39	37	35	33	25	25
18	105	42	40	39	36	35	27	26
19	115	44	42	43	39	39	30	29
20	125	47	44	44	40	41	32	32
21	135							
22	145	53	51	51	46	46	41	39
23	155	57	54	54	51	51	45	41
24	165	56	55	54	52	48	46	40
25	175	59	59	59	56	51	51	43
26	185	63	62	62	59	55	54	48
27	195	65	65		60	56	56	49
28	205	67	67		63	60	57	50
29	215	69	70		65	62		
30	225	71	71		66	65		
31	235	73	74		66	65		
32	245	75	76		70	70		
33	255	80	77					

Fig. 4 Analysis of the first break times of the refracted arrivals from the uphole shots. The morphology of the contours indicates increases in wavespeed in the depth range between shots at 6.1 and 17.8 m and also between 22.8 and 28.4 m. Note the depths are not to scale.

Fig. 5.

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65 to 70 m.

Figure 5 illustrates the results of the noise shots recorded into the 10 m GI spread. The dominant surface wave has a speed of 1130 m s^{-1}, a frequency 14 Hz, and a wavelength of approximately 80 m. Ground roll with an 80 metre wavelength would be adequately sampled in the spatial domain using a 40 m group interval, so that subsequent FK filtering could satisfactorily remove this noise train. Other tests indicate that surface wave trains are more pronounced with surface sources, but considerably reduced if charges can be detonated at depths greater than 10 m.

Charge size comparison
Detonations of three different charge sizes (4, 12 and 24 kg) between stations 2048 and 2049 (Fig. 6) were recorded to compare varying source energy on record quality. The lack of deep reflection events makes this comparison difficult. The basement refraction event at offsets greater than 1500 m is significantly stronger from the 24 kg shot. A more pronounced surface wave is generated from the larger 24 kg detonation (Shot 203) in comparison with the records of the smaller charges, but the depth to the top of this charge was 11.3 m; significantly shallower than the others charge comparison shots.

A graph of the energy level of the records versus time (Figure 7) shows that recorded energy has diminished to the level of the ambient noise after 3.5 s for the 4 kg shot, after 5.2 s for the 12 kg shot, and after 6.0 s for the 24 kg shot. Although such an analysis includes source generated noise as well as reflected energy, it does give an upper bound on the useful seismic penetration of the various charge sizes. The lack of deeper events prevents a more quantitative comparison.

Kelly depth shots
A novel acquisition technique suggested by M. Sexton (pers. comm, 1991) was investigated during these seismic tests. This involved reducing the drilling effort per hole by drilling shot-holes only to kelly depth and increasing the number of these shallow holes to boost the fold. To complement this low fold data from deep shot holeswould be recorded to provide deep data. The sacrifice in data quality by going from deeper to shallower shots could be compensated by the increased fold. From a logistic point of view, the greater number of shallower holes gives an overall decrease in total m drilled, which has to be balanced against a significant increase in the use of detonators, and a slight increase in the use of explosives. Estimates of the amount of drilling and consumables for kelly depth shots every 40 m (giving 48 fold data) and 3 fold data using larger charges in deeper shotholes is compared with more conventional 12 fold shooting in Table I.

During these tests on the Nullarbor, drillers found they expended considerable effort spudding the holes into the near surface limestone, due to the hard surface and the presence of limestone boulders in the soil. Their experience indicates that a disproportionate amount of time was spent on drilling to kelly depth in comparison with drilling deeper shothole. This acquisition technique is therefore not an attractive option on the Nullarbor, although it may be viable elsewhere.

The kelly depth shots have a pronounced surface wave train (ground roll), but this can be removed by FK filtering (Figure 8). Occasionally these shots, detonated at a shallower depth,

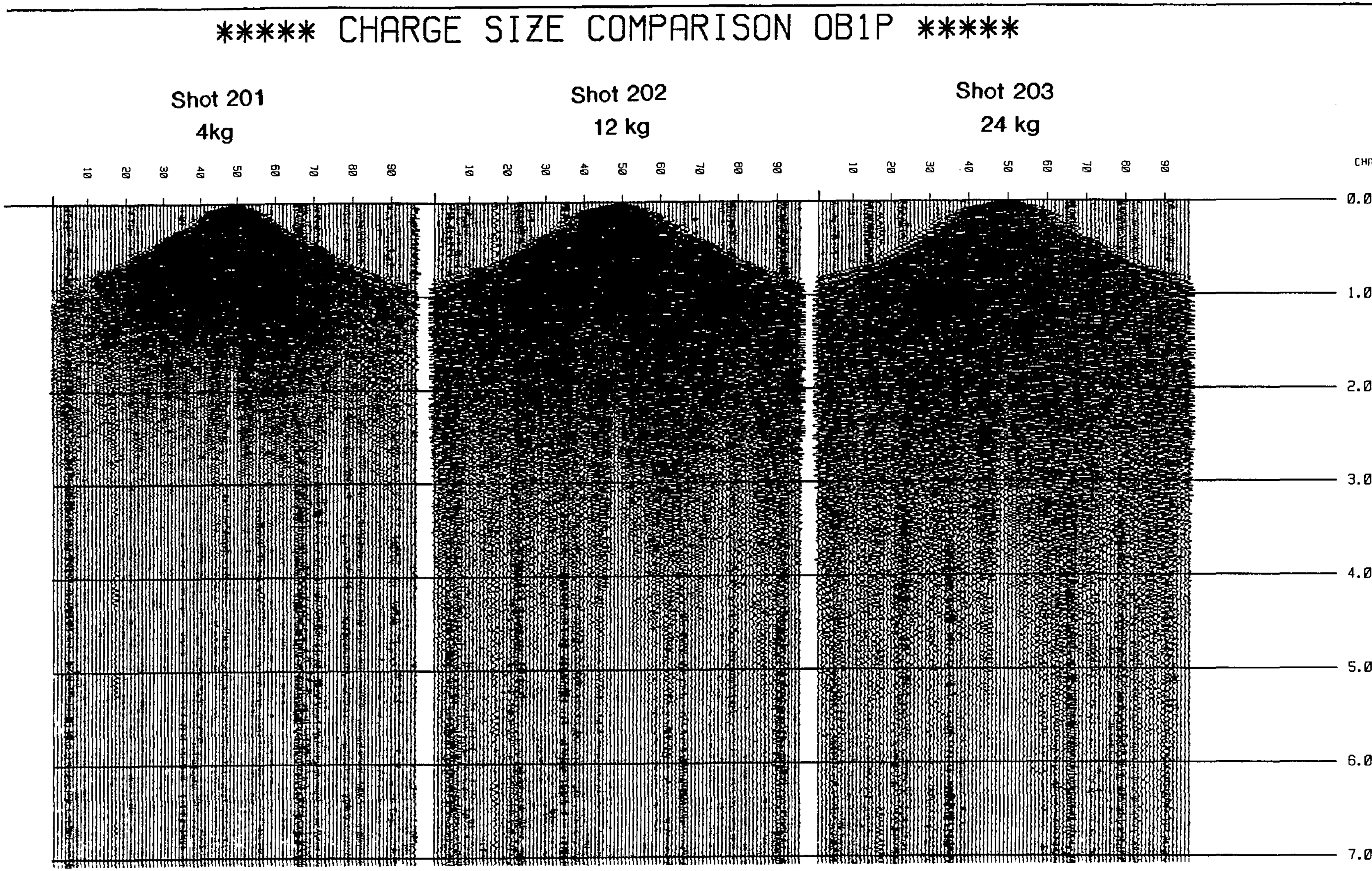


Fig. 6. Display of the three charge size comparison shots of OB1P, plotted at the same relative scale.

Charge Size Comparison

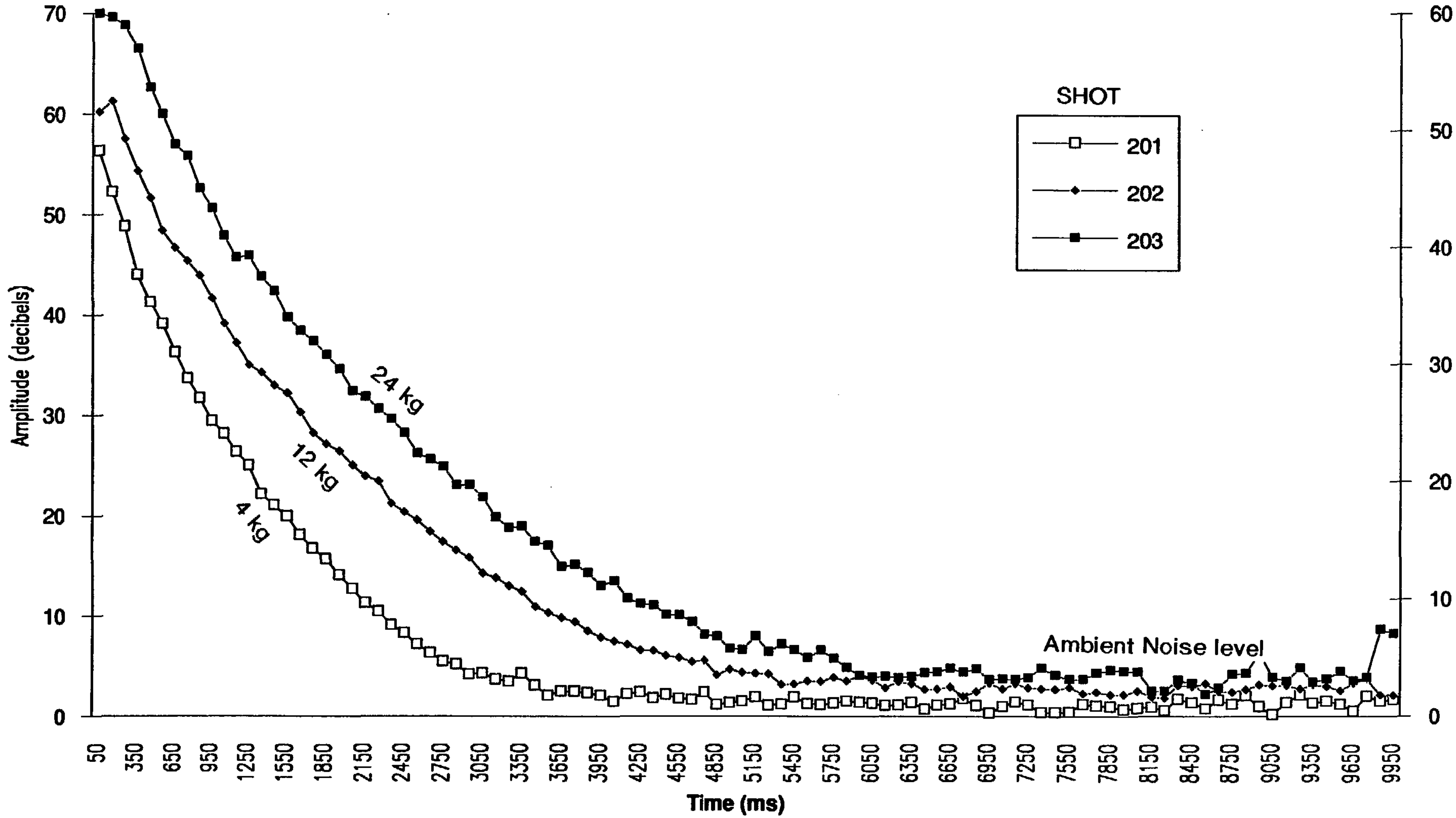


Fig. 7. Amplitude as a function of time for the charge size comparison shots.

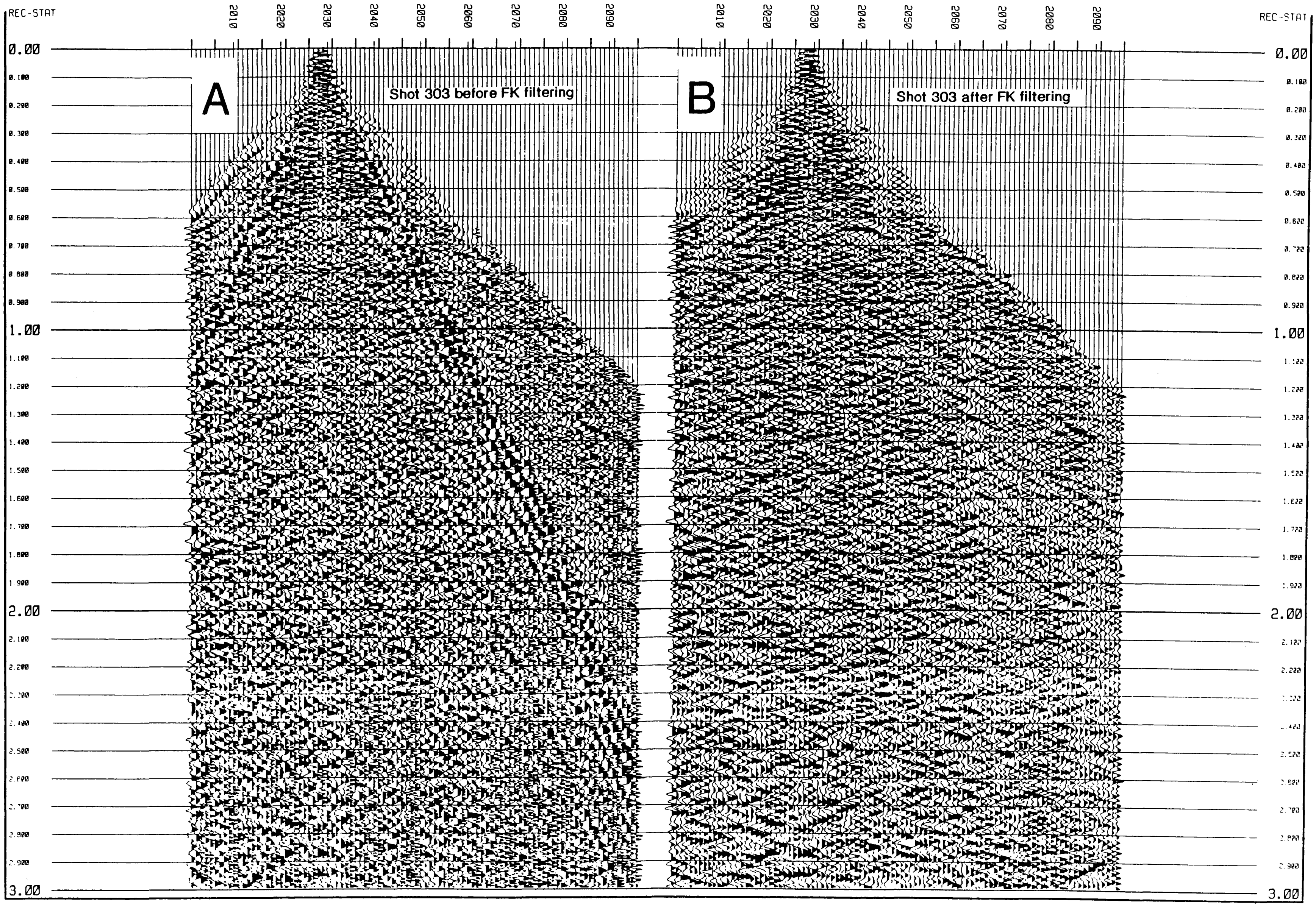


Fig. 8. Comparison of kelly depth Shot 303 (a) before, and (b) after FK filtering to remove the ground roll.

were not contained in the shothole by the tamping. The resulting blowout produced high frequency air wave trains with the characteristic wavespeed of 330 m s^{-1}. This air wave would be severely alaised if not removed by low-pass filtering before any FK filtering on these shot records. Blowouts from these shallow shots were an operational hazard, which would have to be addressed if this acquisition technique was adopted.

Table I

Comparison of Kelly vs Production shots	Conventional production shots	Kelly depth technique	
Fold	12	48	3
Explosive (kg/hole)	12	2	25
Shot interval (m)	160	40	640
Hole depth (m)	30	4	30
Explosive (kg/km)	75	90	
Detonators (#/km)	7	27	
Drilling (m/km)	188	147	

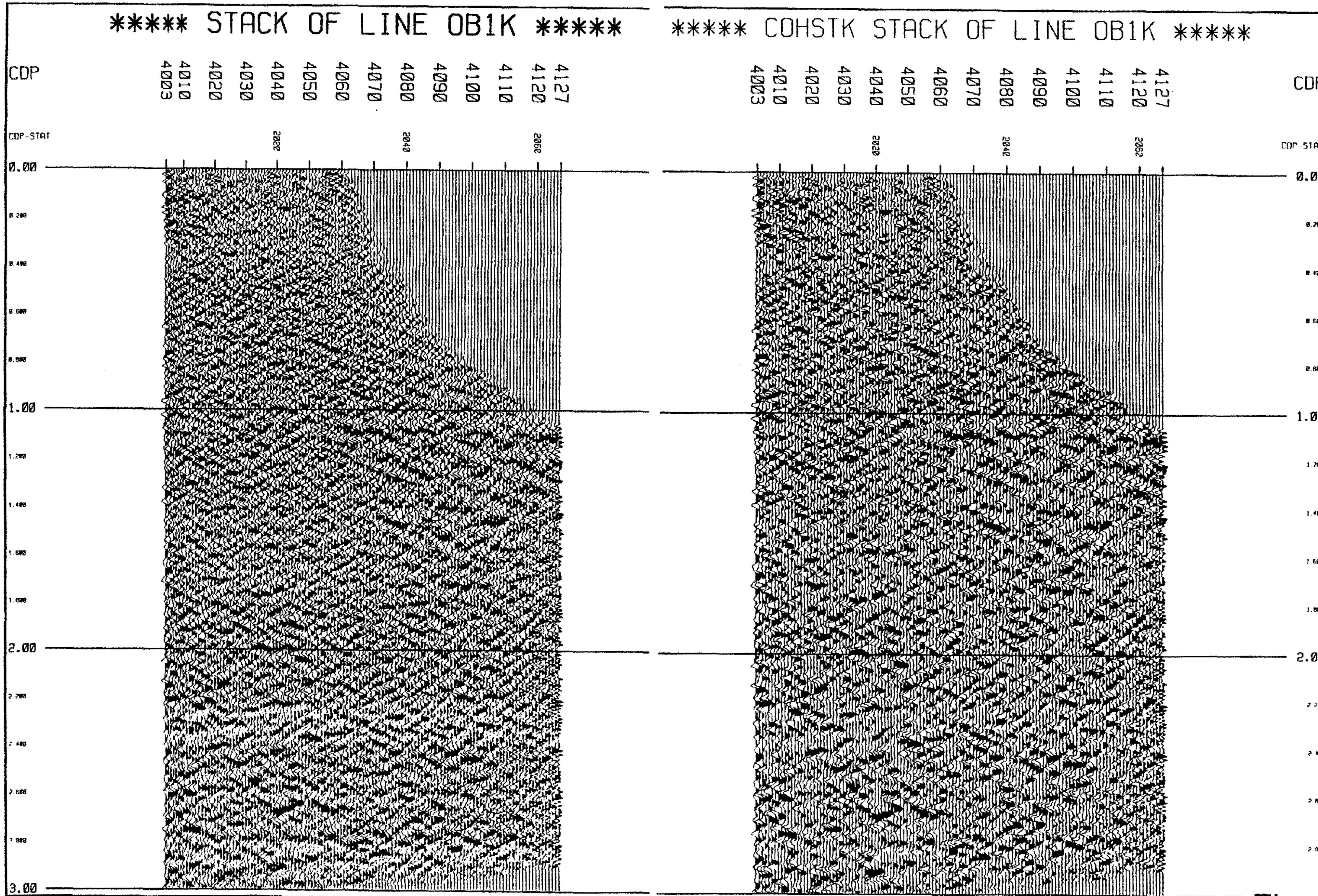
Figure 9 shows a stack of the kelly depth shots, after the application of FK filtering to remove ground roll.

Production depth shots

Data quality of these 12 kg shots detonated at depths ranging from 11.3 to 31.9 m is poor: there is little evidence of coherent reflection energy in the shot gathers. In Figure 10 the amplitude spectrum of two channels recorded from shot 204 are compared. The near offset trace recorded in channel 72 from 500 ms to 1500 ms after the shot has significant energy in the bandwidth from 8 to 80 Hz, and a high frequency spike around 170 Hz. The far offset trace recorded in channel 2 from 3 to 4 seconds after the shot has a narrower energy bandwidth which tapers off above 40 Hz. The near offset traces have very poor signal-to-noise ratios. This is thought to be due to the acoustic reverberation of shot generated noise in the interconnected caverns of the Nullarbor Limestone. The ratio of these two spectra indicates the absorption of higher frequency energy by the porous limestone.

Several shots were selected for detailed velocity analysis. After initial demultiplexing and gain recovery, a mute and NMO correction was applied using a estimated velocity function to approximately flatten possible reflectors. A semblance filter (Leven and Chowdhury, 1984) was then applied to enhance events which were coherent over more than five consecutive traces and which had a moveout in the range ±0.12 ms m^{-1}. The NMO correction was then removed ("backed out") and velocities determined using a constant velocity analysis (CVA). Figure 11 illustrates selected panels from such a CVA analysis.

A 50% stretch mute was applied before stack. Field static corrections calculated from the elevations and the uphole times were applied. No refraction statics have been calculated or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CDP
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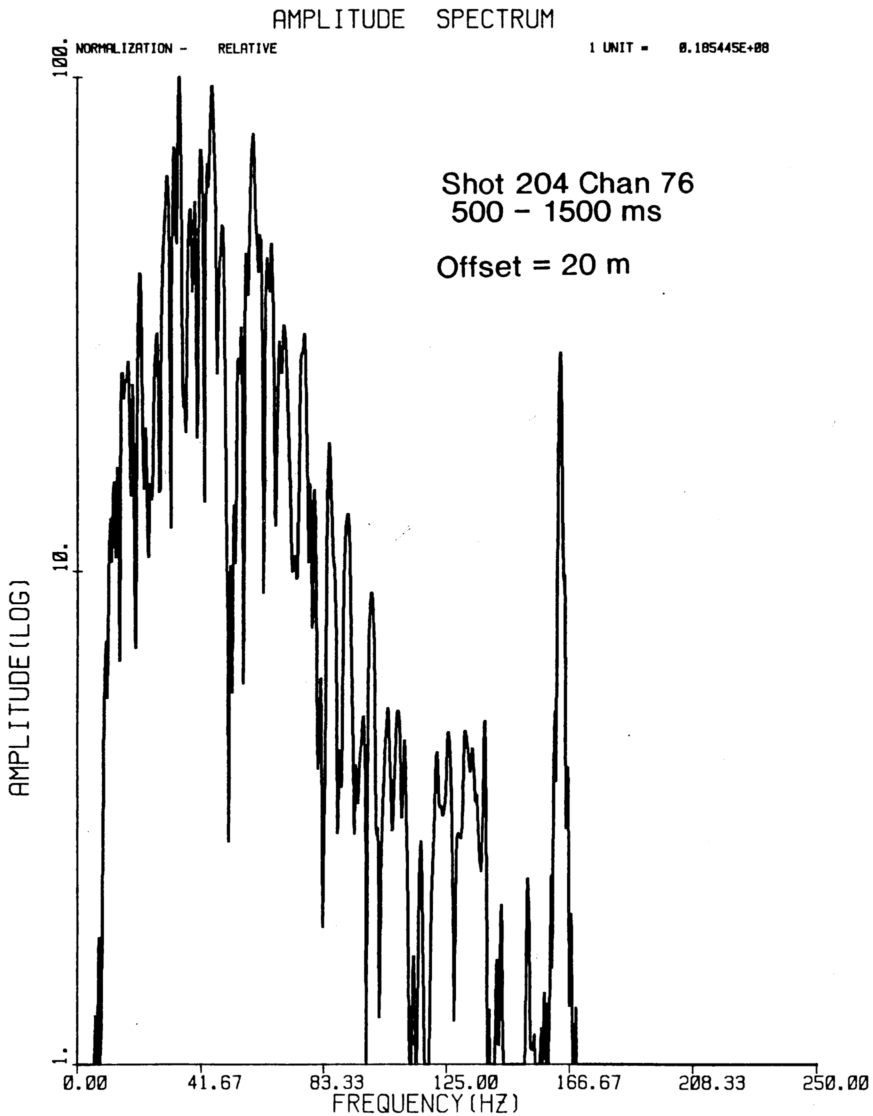
Fig. 9.



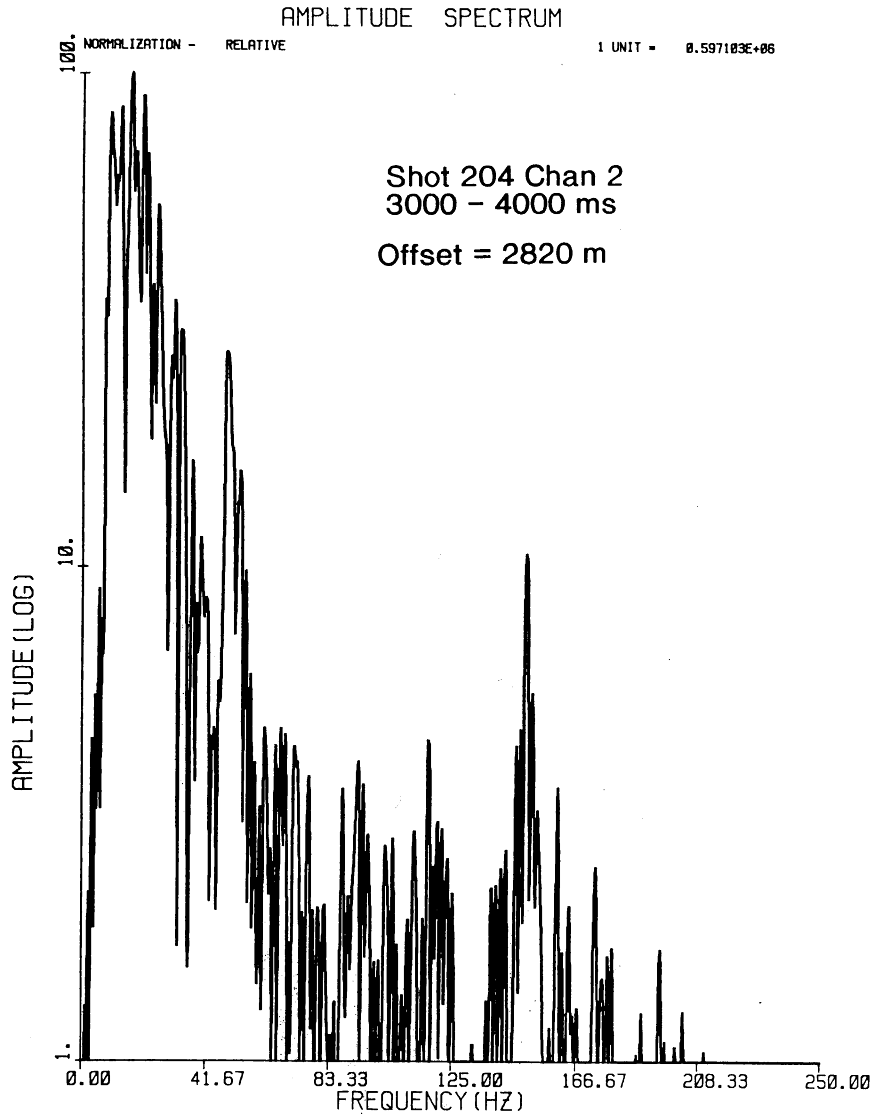


Fig. 10. Power spectrum of the near and far channels of Shot 204.

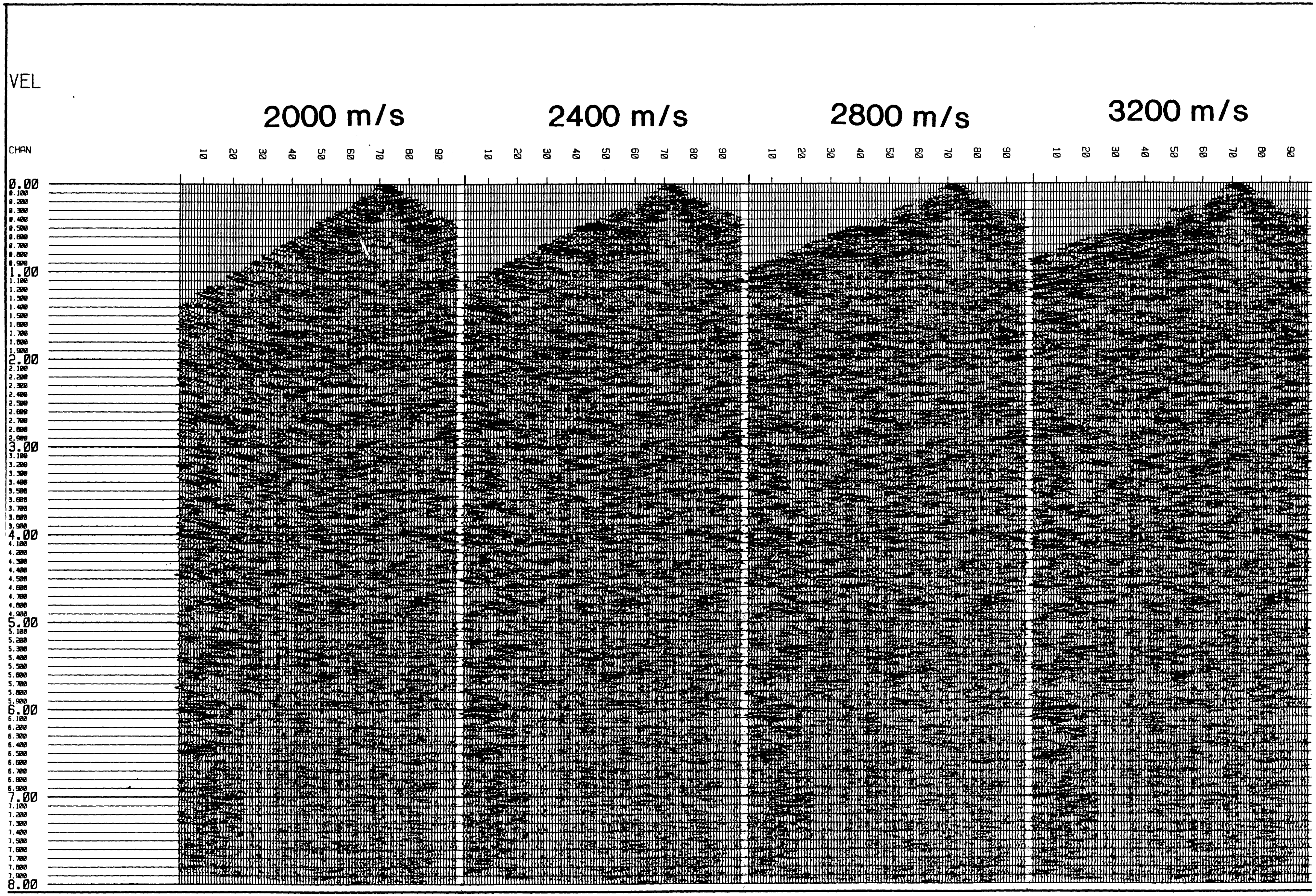


Fig. 11. Velocity analysis of Shot 204 after coherency filtering.

applied, due to the limited distance over which the first break times can be reliably measured. The velocity function used combined velocities from the refraction analysis, discussed below, with the velocities obtained from the CVA analysis from selected shots. Several stacking techniques were tested on the normal-moveout corrected common-midpoint gathers (Fig. 12).

RESULTS FROM THE NORTHERN TEST SITE

Uphole

As for the southern test site, the planned 70 m hole for uphole measurements was not possible, due to drilling conditions. The deepest available hole was used for the uphole test, and this was drilled to 38.2 m at station 4024. As this was off the end of the 10 metre GI spread, the uphole shots were recorded into the 40 m GI spread. This gave a better range of shot depths for the charge depth comparisons.

The recorded pattern of the first breaks (Figure 13) is consistent with those observed at the southern test site, and characteristic of seismic wavespeed reversal with depth. The first breaks from this uphole test have been digitised and are compiled in Appendix VI.

Noise tests

Figure 14 shows the results of the noise shots recorded into the 10 m GI spread at the northern test site. The dominant surface wave has a speed of 1070 m s^{-1}, a frequency 13 Hz, and a wavelength of approximately 80 m.

Charge size comparison

Detonations of three different charge sizes (4, 12 and 24 kg) between stations 4048 and 4049 (Fig. 15a) were recorded to investigate the effects of varying source energy on record quality. As at the southern test site, the basement refraction event at offsets greater than 1500 m is significantly stronger from the 24 kg shot. These charge size comparison shots were fired at depths of 10.0 ± 0.3 m, and so provide a better charge size comparison than the shots at the southern test site.

These results corroborate those from the southern test site. A graph of the energy level of the records versus time (Fig. 15b) shows that recorded energy has diminished to the level of the ambient noise after 4.5 s for the 4 kg shot, after 6.2 s for the 12 kg shot, and after 9.0 s for the 24 kg shot.

Charge depth comparison

The energy decay pattern of similar sized shots detonated at varying depths is compared in Figure 16. Figure 16a compares the energy decay with time for the uphole charges. This graph illustrates that there is little difference in the recorded energy in charges detonated between 38 and 25 m depth. Even the 2 kg charge at 20 m is only 6 dB down in energy in comparison with the 4 kg charge at 38.2 m. The comparison of the 12 kg charges shown in Fig. 16b suggests that a charge depth of 15 m is optimal.

A comparison of a 4 kg charge at 9.7 m with a 3.5 kg charge at 3.2 m (Figure 16c) illustrates the pronounced decrease in recorded energy associated with the shallower charge depth, with

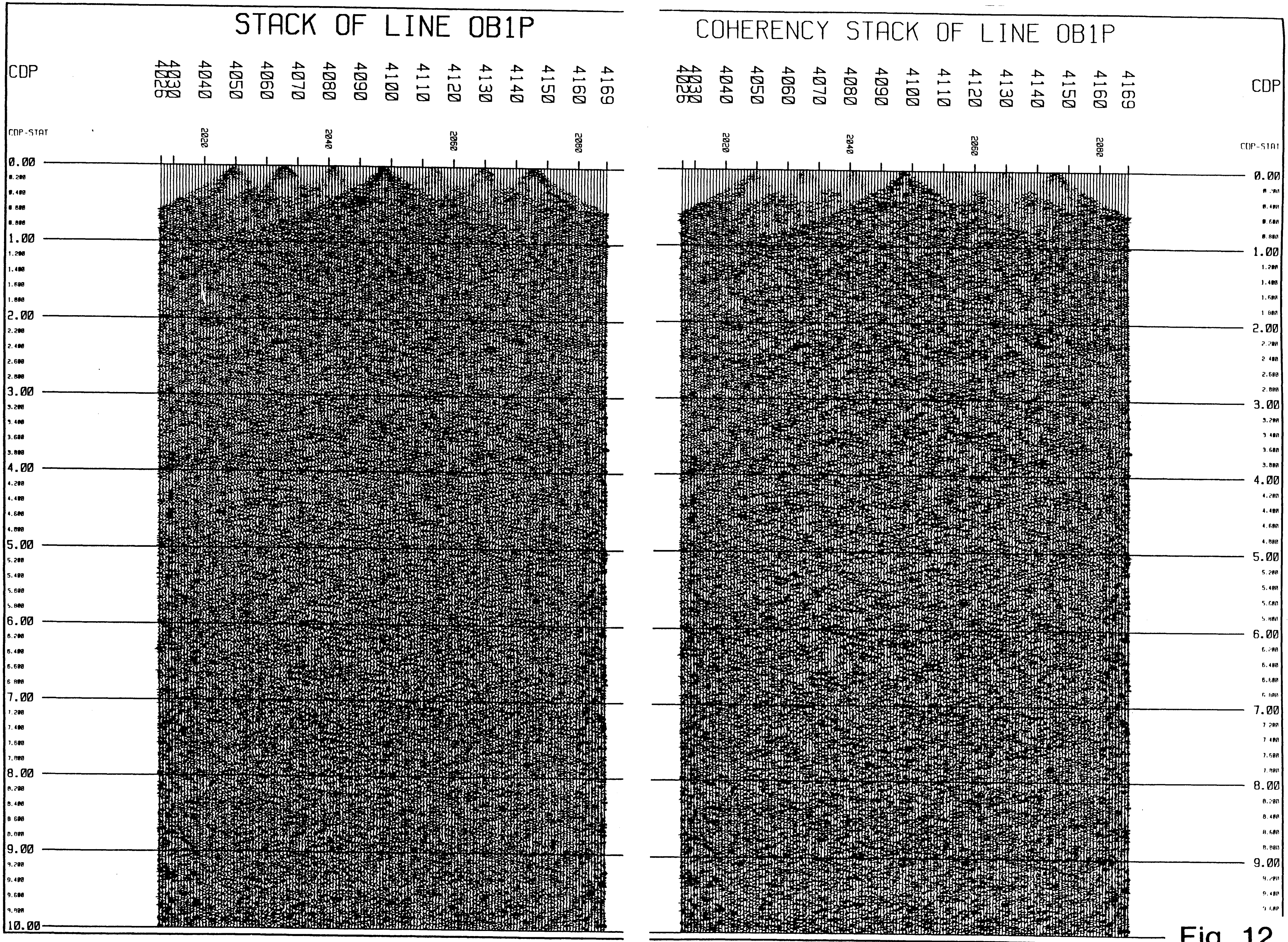


Fig. 12.

91 - OB2U UPHOLE SHOT 1

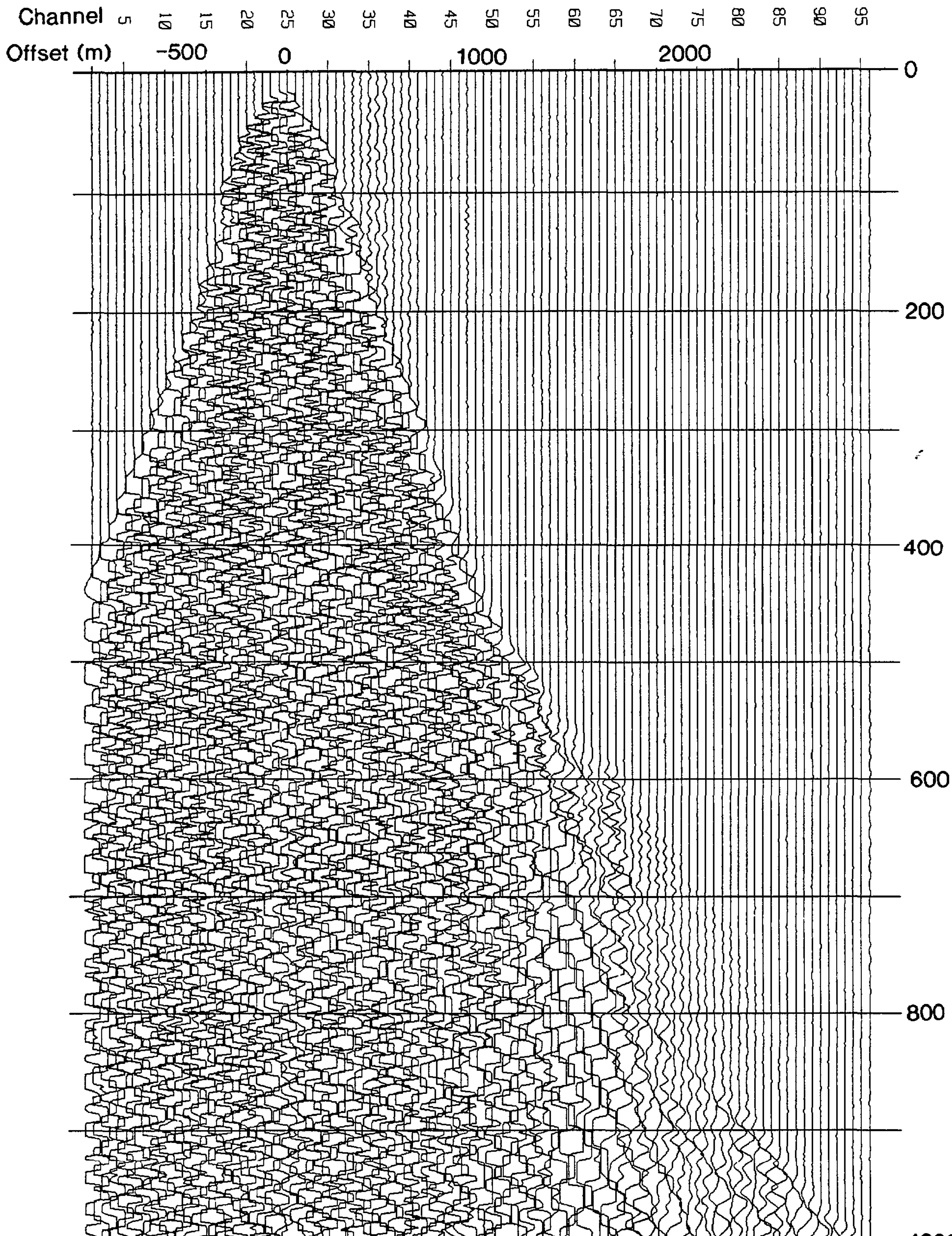


Fig. 13. An example of the first break pattern from Shot 1 of the uphole shots recorded with a 40 m group interval at the northern test site. Note the second LVZ evident at offsets in the range 1600 to 2300 metres.

Fig. 14.

R9108704

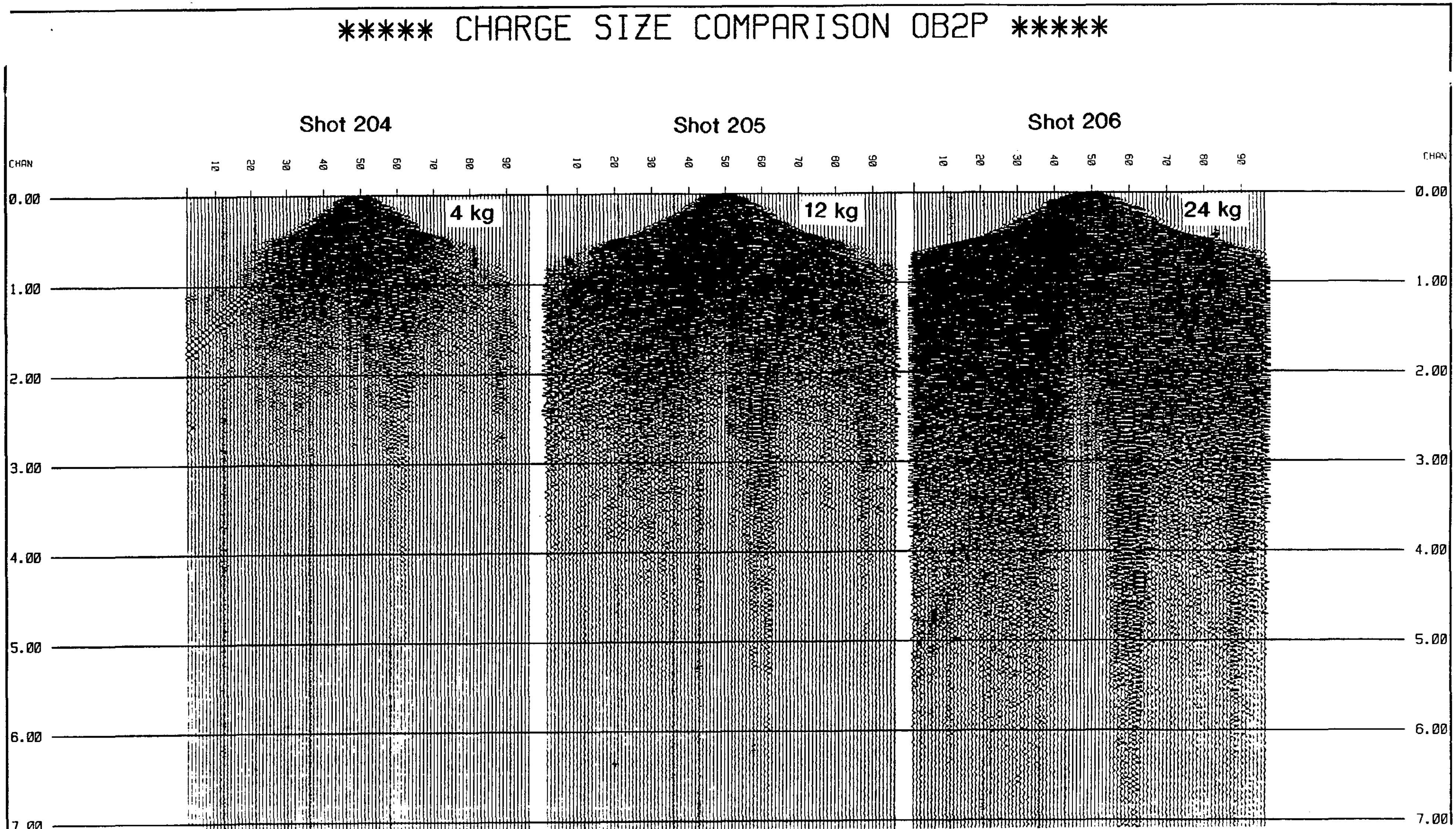


Figure 15a. Display of the three charge size comparison shots of OB2P, plotted at the same relative scale.

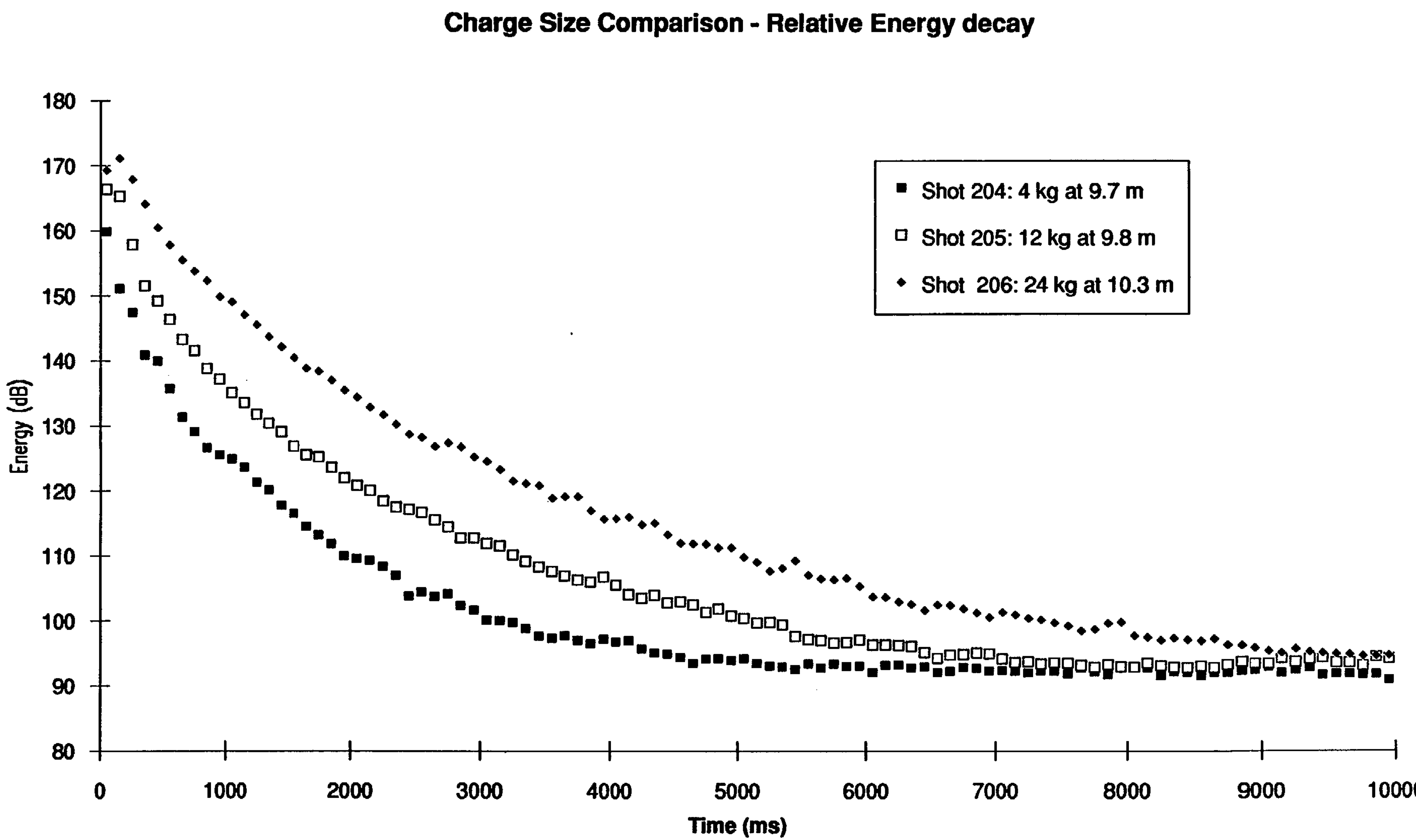


Figure 15b. Energy decay with time of the charge size comparison shots.

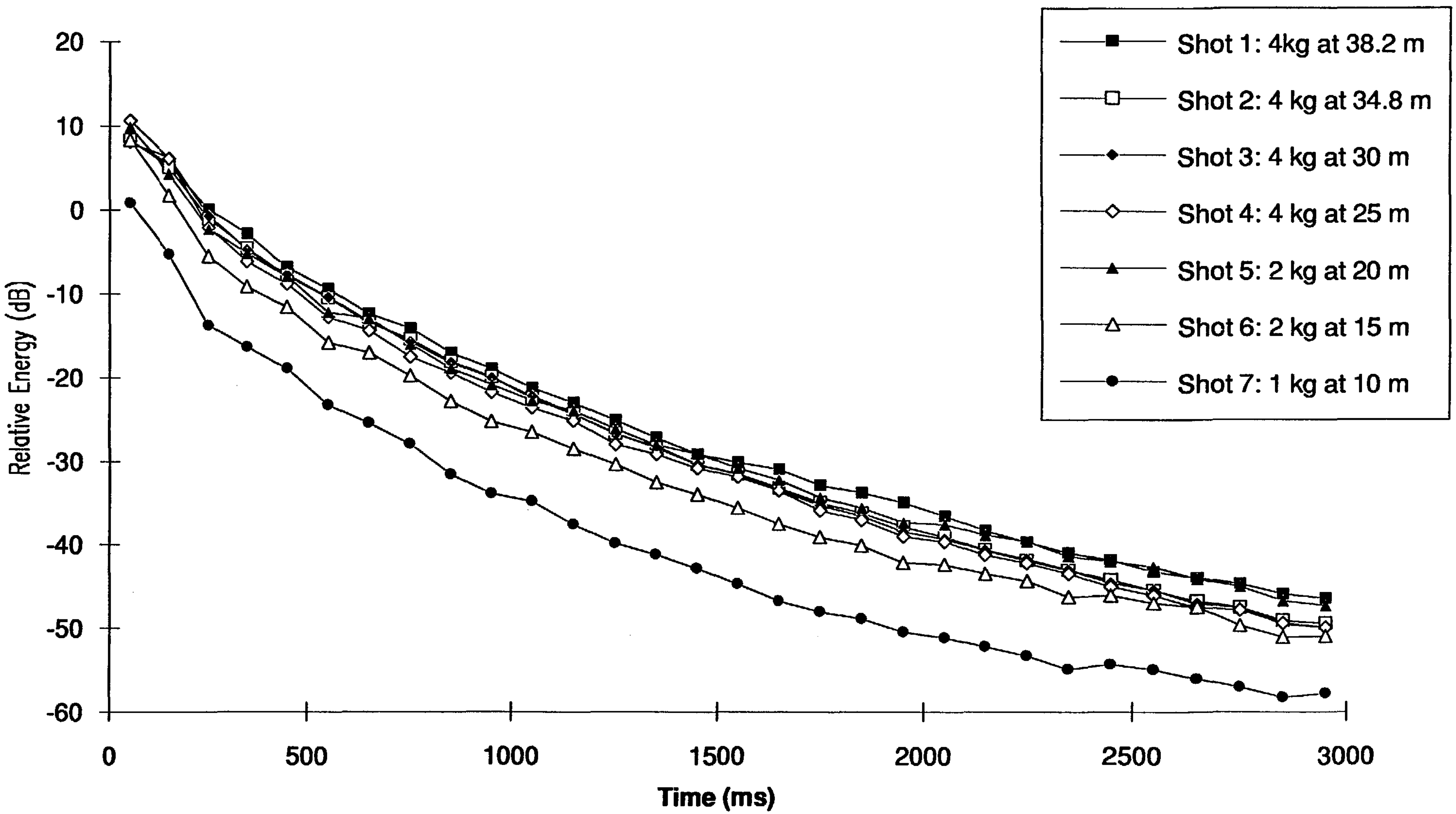


Figure 16a. The relative energy decay of the Uphole Shots from the Northern Test Site.

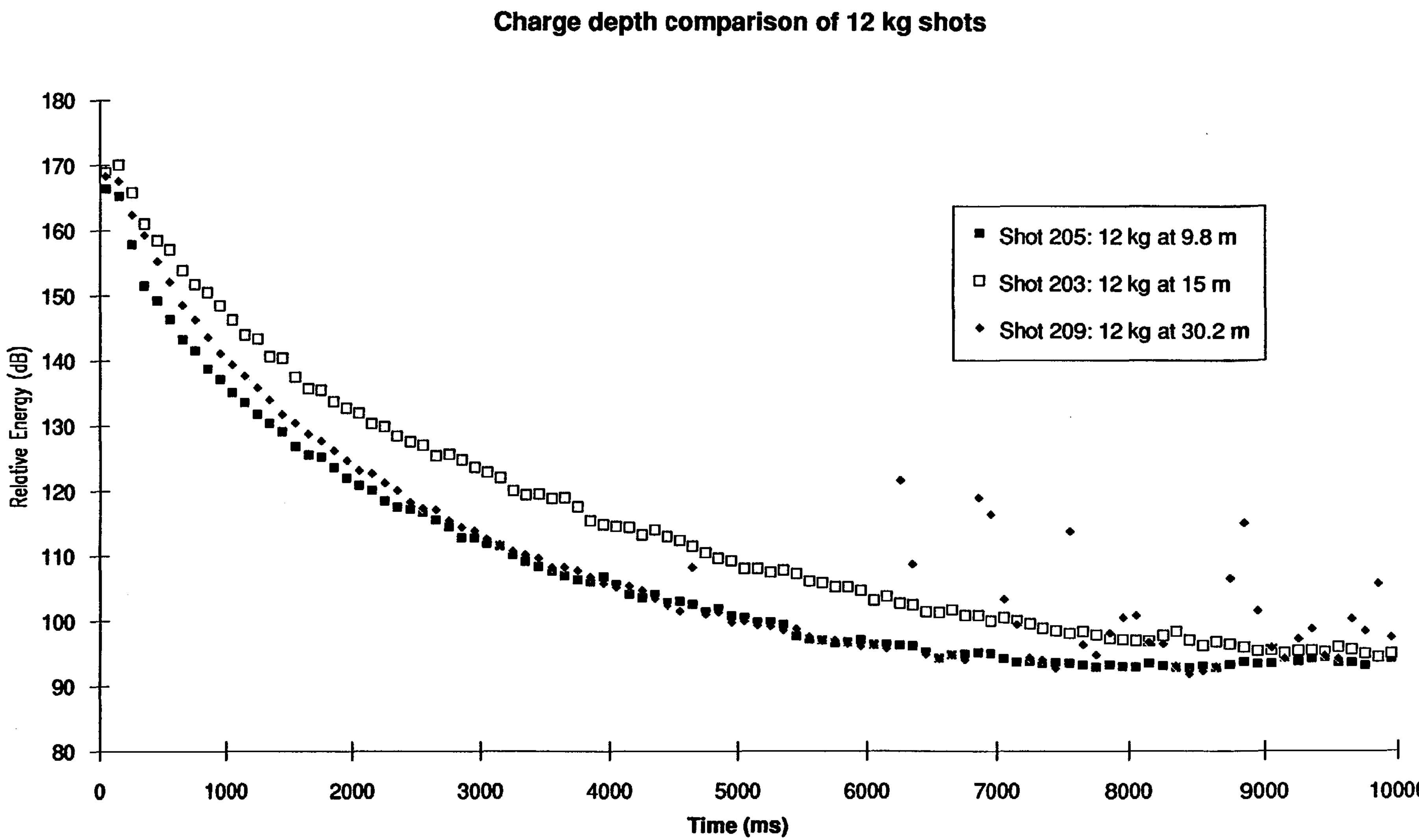
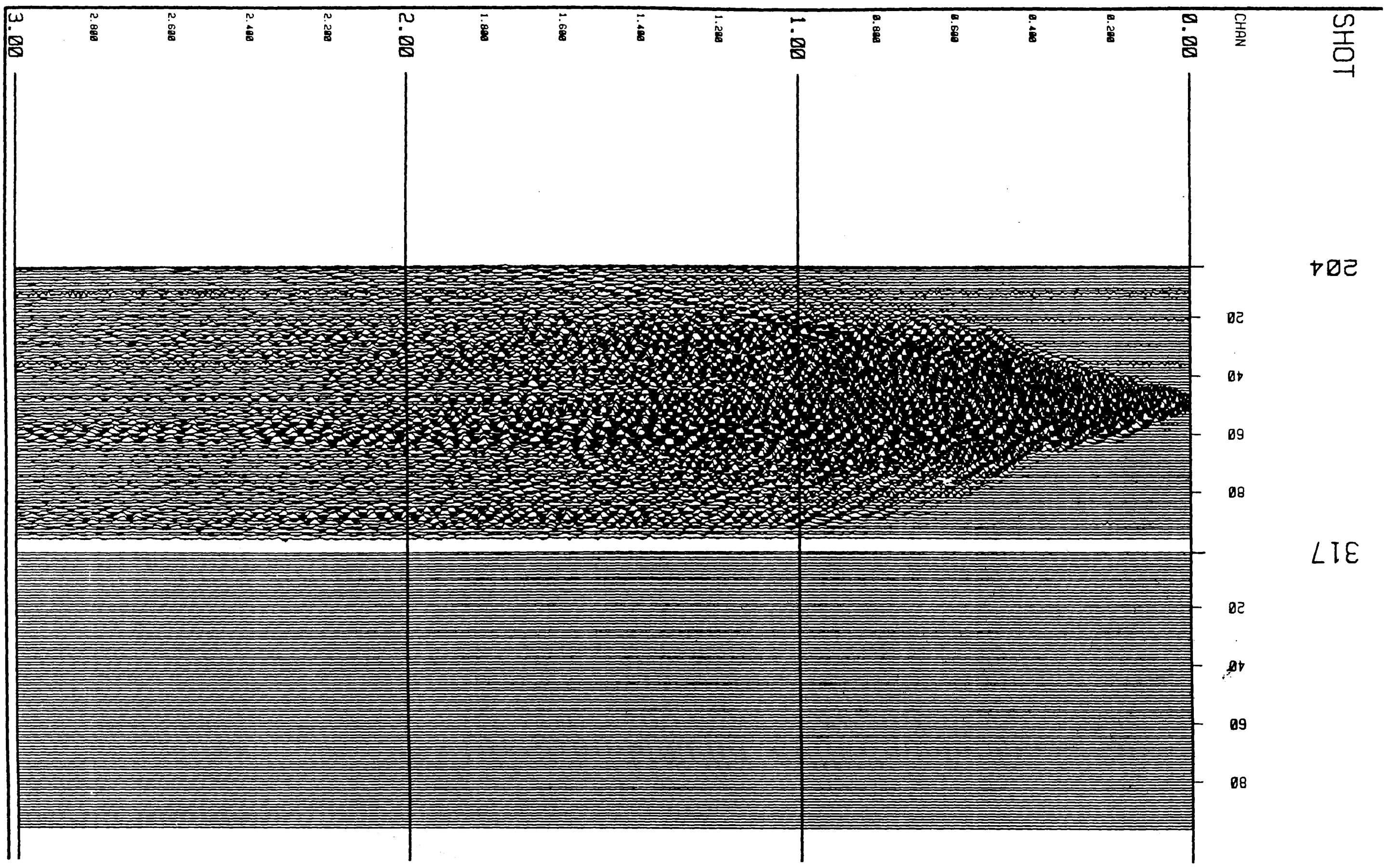


Figure 16b. Energy decay of 12 kg charge depth comparison shots



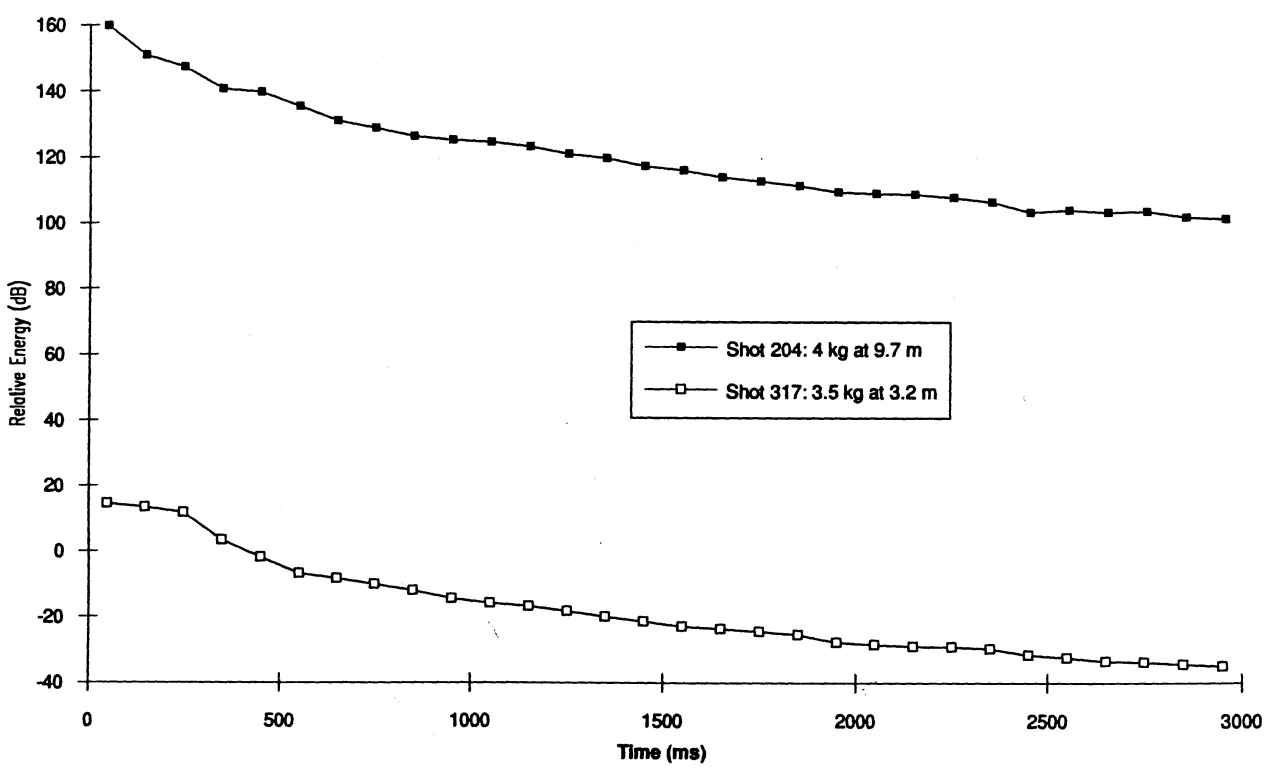


Fig. 16c. Comparison of two shots at 3.2 and 9.7 m depth.

the average recorded energy 140 dB down (Fig. 16c). As the receiver array was the same for all these records, the influence of receiver response and receiver coupling have been isolated in this comparison. The difference in recorded energy is therefore related only to the charge coupling and seismic absorption during propagation through the upper 30 m of the Nullarbor Limestone. Although this comparison compares charges detonated at different locations, the shothole drilling and charge loading techniques were the same for all holes, and this together with the uniformity of the surface geology suggests that the adsorption of the seismic energy during its downward propagation through the Nullarbor Limestone is responsible for the large differences in amplitude between these shot records. The shot detonated near surface is not visible when plotted at the same scale (Fig. 16c), indicating the profound affect of the near surface attenuation.

This comparison demonstrates that shots should be detonated at a depth of around 15 m to optimise the energy return.

Kelly depth shots

The kelly depth shots at the northern test site produced a greater number of blowouts than at the southern site, although the reason for this was not clear. The recorded data confirm the conclusions obtained from the southern test site. A 29-fold stack of these kelly depth shot records, after FK filtering to remove the ground roll, shows poor results (Fig.17).

Production depth shots

These shots were detonated at depths ranging from 7.5 to 30.2 m. As with the records from the southern test site, there is little evidence of coherent reflection energy in the shot gathers, and the near offset traces have very poor signal-to-noise ratios.

After initial demultiplexing and gain recovery, a constant velocity stacking technique was used to determine a velocity function. A 50% stretch mute was applied before stack. Field static corrections calculated using the elevations and the uphole times were applied but no refraction statics have been calculated or applied, due to the limited distance over which the first break times can be reliably measured. Several stacking techniques were tested on the normal-moveout corrected common-midpoint gathers. Figure 18 illustrates a normal and coherency stack of these data, and these stacks after coherency filtering.

REFRACTION ANALYSIS

The interpretation of first break refraction data from areas with low velocity zones is beset with difficulties. The speeds and intercept times of the weaker refracted arrivals beyond offsets of 250 m are quite subjective, and it is difficult, even with a 40 metre station interval, to correlate these weaker refraction branches at the opposite ends of the spreads. We have therefore used unreversed (flat layer) models for these shots. The speed and intercept times of the first breaks measured from production shot 210 (Fig. 19a) from the southern spread and Shots 201 and 209 fired at opposite ends of the northern spread (Fig. 19b) are listed in Tables II to IV.

The southern model indicates a depth of 700 m to a layer with a wavespeed of 5810 ± 200

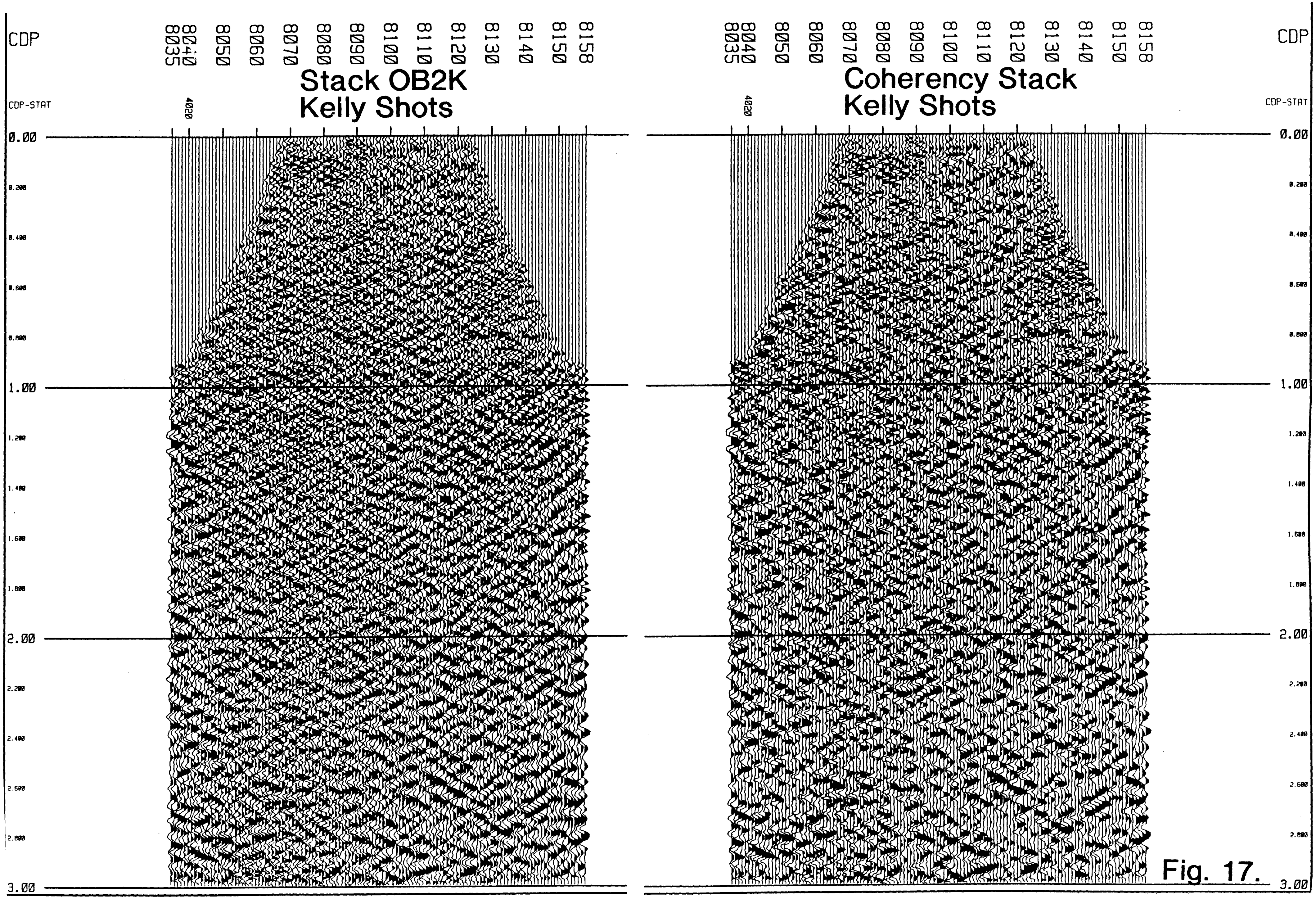

Stack OB2K
Kelly Shots
Coherency Stack
Kelly Shots
CDP
8035 8040 8050 8060 8070 8080 8090 8100 8110 8120 8130 8140 8150 8158
CDP-STAT
4020
0.00
1.00
2.00
3.00

Fig. 17.

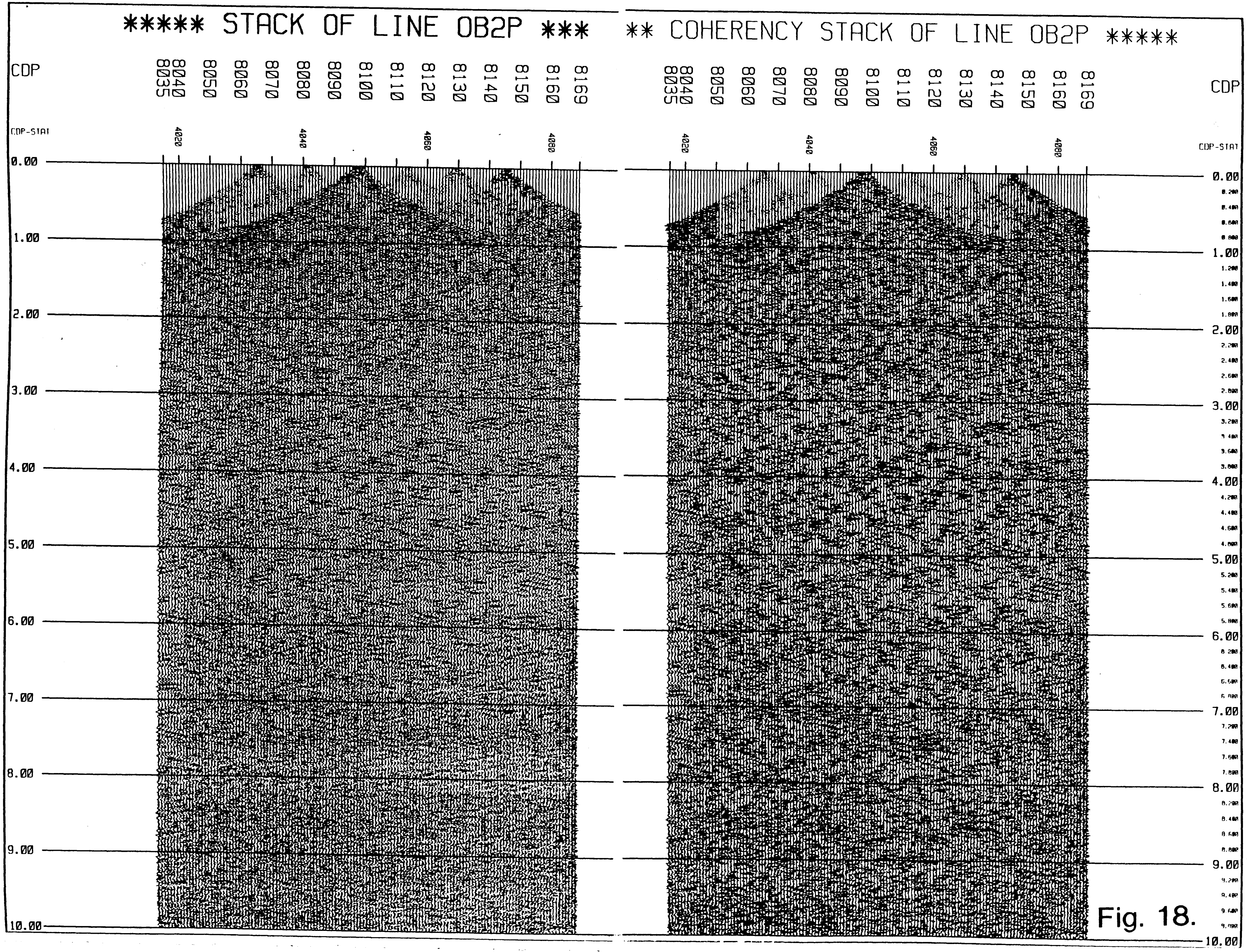

***** STACK OF LINE OB2P ***
** COHERENCY STACK OF LINE OB2P *****
CDP
8035 8040 8050 8060 8070 8080 8090 8100 8110 8120 8130 8140 8150 8160 8169
CDP-STAT
4020 4040 4060 4080
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00

Fig. 18.

m s^{-1}. This speed is comparable with the refraction event having a 5943 m s^{-1} wavespeed recorded by the 1963 SADME survey (Kendall, 1965). This was correlated with "basement granitic rock as noted in the Albala and Guinewarra bores". The CVA analysis corroborates a depth of 700 m, with a V_{rms} = 2600 m s^{-1} to events at 500 and 580 ms, giving approximate depths of 650 and 750 m. However, this interpreted depth conflicts with the interpretation of Kendall (1965) which suggests this refractor is deeper than 1200 m and attains a maximum depth of 1820 m near the Nullarbor Homestead.

Table II
Refraction Analysis of Shot 210 from Southern Test Site

T_0 (ms)	V (m s^{-1})	Depth to Top (m)
5	1790	0
75	2370	100
130	2500	290
199	2720	400
290	3170	500
358	3490	640
500	5810	700

The northern refraction models are simpler and suggest a depth of around 340 m to a refractor with a refraction speed of 5100 ± 250 m s^{-1} .

Interpreted depth to magnetic basement maps indicate that the YL3 well drilled near O'Malley siding is in a deeper portion of the Mallabie Depression. This well intersected what was interpreted as Observatory Hill Beds between the depths of 100 and 499 m. The refraction data recorded during the reflection survey suggests that the sedimentary thickness is significantly less than that indicated by the depth to magnetic basement interpretation in the area south of Cook.

Table III
Refraction Analysis of Shot 201 from Northern Test Site

T_0 (ms)	V (m s^{-1})	Depth to Top (m)
0	2070	0
325	5350	360
500	5670	

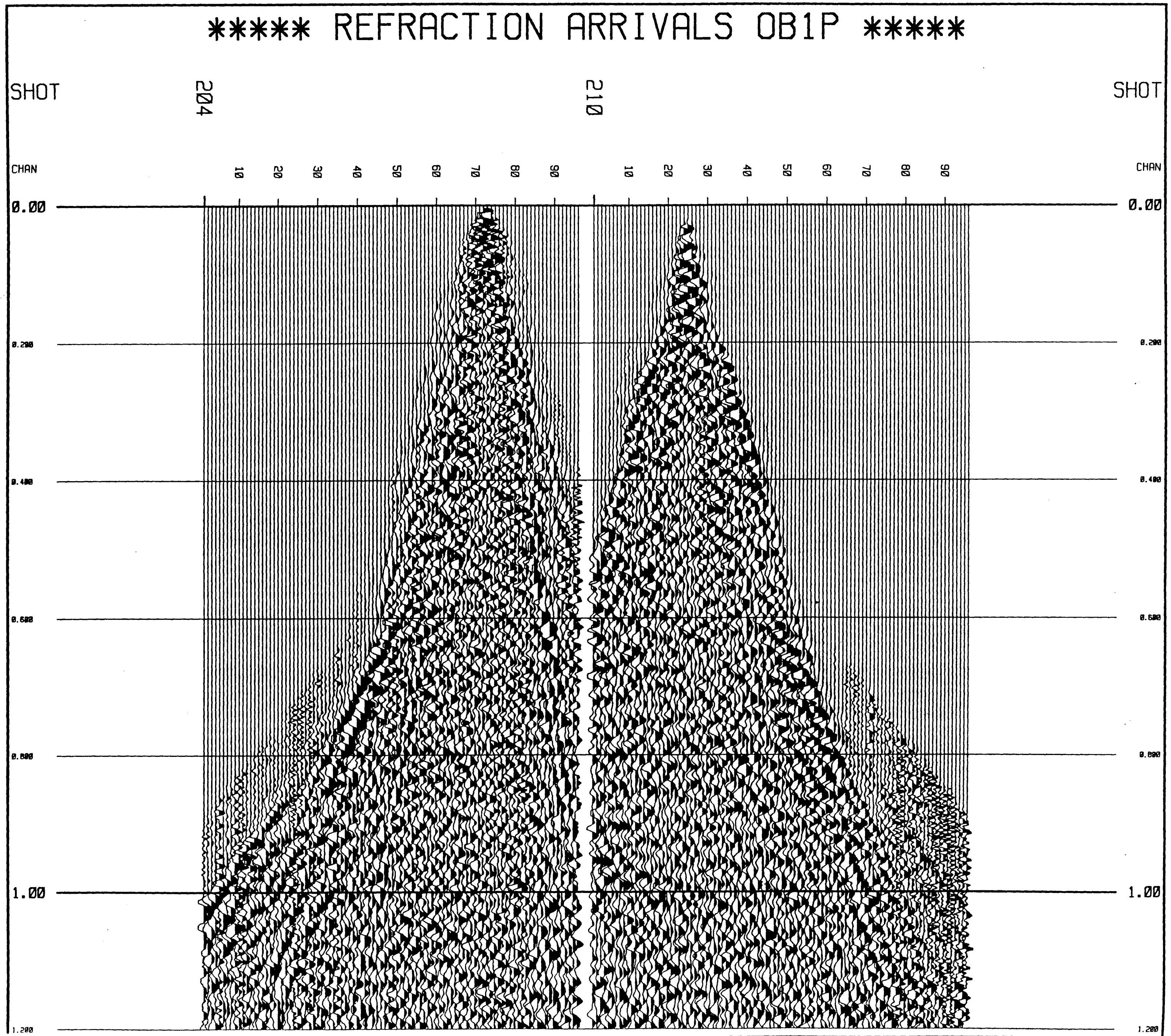

***** REFRACTION ARRIVALS OB1P *****
SHOT
204
210
SHOT
CHAN
10
20
30
40
50
60
70
80
90
CHAN
0.00
1.00
0.00
1.00

Figure 19a.

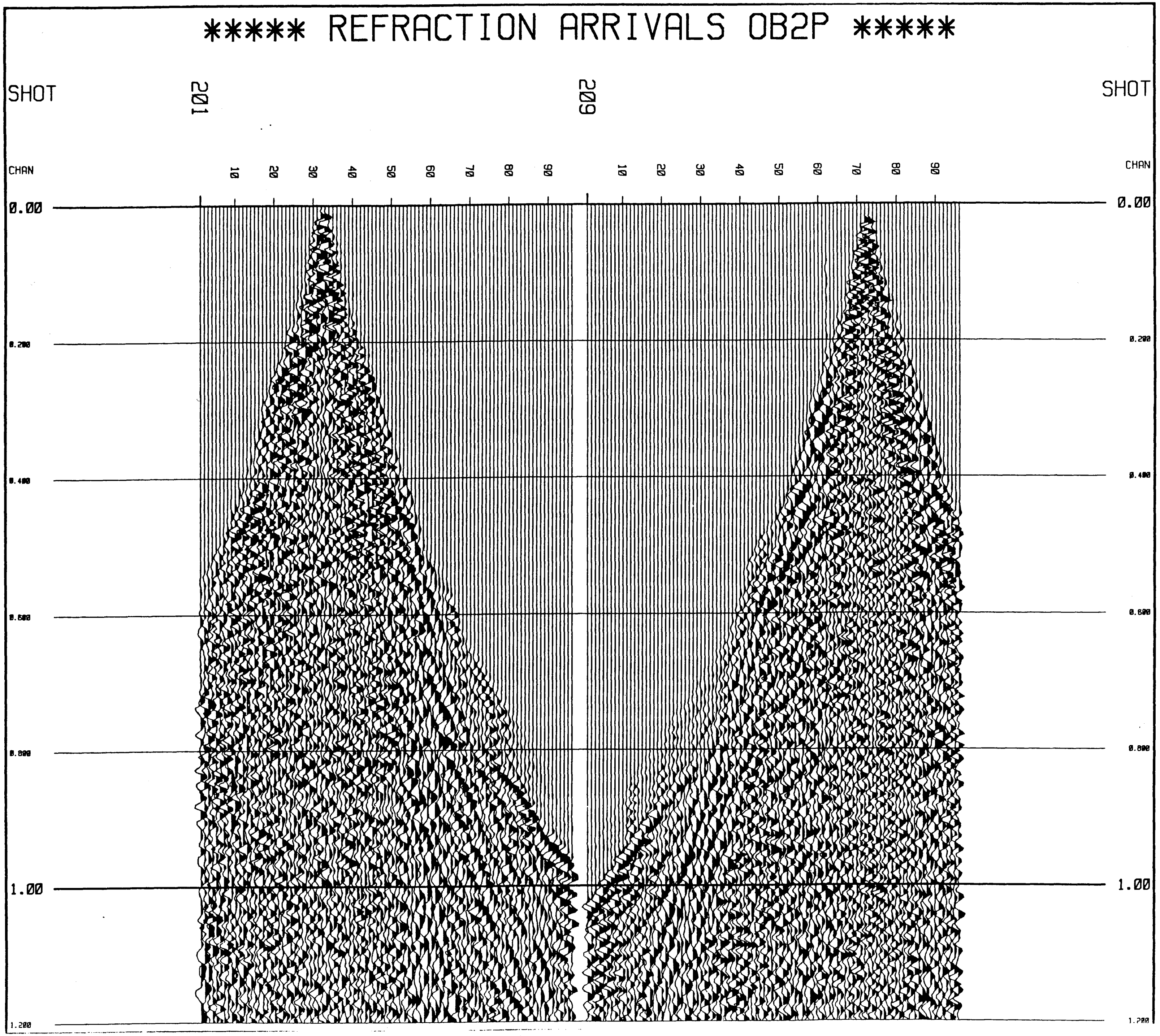

***** REFRACTION ARRIVALS OB2P *****
SHOT
201
209
SHOT
CHAN
10 20 30 40 50 60 70 80 90
10 20 30 40 50 60 70 80 90
CHAN
0.00
0.200
0.400
0.600
0.800
1.00
1.200
0.00
0.200
0.400
0.600
0.800
1.00
1.200

Figure 19b.

Table IV
Refraction Analysis of Shot 209 from Northern Test Site

T_0 (ms)	V ($m\ s^{-1}$)	Depth to Top (m)
0	1260	0
60	2490	40
260	4850	320
433	4910	

CONCLUSIONS

These tests on the Nullarbor Plain indicate a significant advantage of using subsurface sources at depths around 15 m, both for the reduction of ground roll and the increased energy retúrn. Experience also indicates that the maximum depth of drilling for shot holes (which need to be drilled quickly) is in the vicinity of 30 m. The ideal charge size for the subsurface shots will depend on the target depth of the survey. It appears that in this region, if the desired data is no greater than 3 s two-way time, then a charge size of around 12 kg is suitable.

The near-surface limestones act as a high-cut filter for the seismic energy, reducing the resolution of the data. The near-offset traces also have very poor signal-to-noise ratios, due to reverberation of shot-generated acoustic energy in the cavernous Nullarbor Limestone. At two-way times of less than 1 second, useful reflection data is therefore bracketed by the poor quality near offset traces and the refraction arrivals, so that the optimum offset range is narrow and varies with target depth. Careful muting of the refraction arrivals is necessary to preserve this data.

Results from the kelly-depth shots show pronounced ground roll, as well as air wave from those shots which blew out. The ground roll has a dominant frequency of around 16 Hz and a group velocity of around 1100 $m\ s^{-1}$. This noise can therefore be effectively filtered either by low-cut frequency filtering or by FK velocity filtering. However, considering the disproportionate amount of effort required to drill these kelly-depth holes, the increased surface and air wave noise, and the operational hazard of blowouts, it is felt that this acquisition technique is not appropriate for the Eucla Basin.

There is some evidence of an event near 600 ms at the southern site and 400 ms at the northern site which is thought to be the base of the sediments. The YL3 well drilled near O'Malley to a total depth of 499 m intersected 399 m of Observatory Hill Formation. Although there are hints of events in basement, these are not particularly consistent from shot to shot, and the seismic data, in general, show a non-reflective upper crust.

As the sedimentary section appears to be relatively thin, and the underlying basement non-reflective, the geological investigation of this region might be best pursued by a drilling program.

ACKNOWLEDGMENTS

The cooperation and assistance of several organisations is gratefully acknowledged: SADME for organising permission for the operations in the Regional Reserve; National Parks and Wildlife for providing this permission at short notice and assisting with camp site selection; and Australian National for granting permission for the survey to be conducted in the railway corridor and providing water.

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Appendix I

Operational Statistics

Drilling commenced	18 July
Drilling finished	22 July
Total metres drilled	1060 m
Number of shotholes drilled	97
Seismic recording commenced	20 July
Seismic recording finished	23 July
Number of recording days worked	3 days
Recording time lost due to weather	2 hours
Total number of shots	106
Explosives used	500 kg
Detonators used	139

Appendix II

Recording Parameters

Seismic Acquisition Equipment	Sercel SN368	
Geophones	GSC20D 8 Hz	
Spread length	3800 and 950 m	
Geophone station interval	40 and 10 m	
Number of channels recorded	96	
Geophones per trace	16 : grouped or inline @ 2.5 m	
Recording format	SEGD multiplexed	
Tape format	9 track GCR 6250 bpi	
Record length	20 s	
Sample rate	2 ms	
Filters	lowcut:	8 Hz @ 18 db/oct
	highcut:	178 Hz @ 18 db/oct
Notch filter	out	

Appendix III

Personnel Schedule and Vehicles

Personnel

Permanent Staff		
Jim Leven		Party leader
Tim Barton		Geophysicist
Jim Whatman		Technical officer
Ted Cherry		Drilling supervisor
Ron Cherry		Loader
Alex Takken		Shooter
John Keyte		Mechanic
Alan Crawford		Mechanic
Temporary Staff		
Rob Banks	GSO3	Juggie
Felex Ciechan	GSO6	Driller
Russell Fitzgerald	GSO3	Juggie
John Gebett	GSO6	Driller
Doug Haldane	GSO3	Cook's assistant
Jim Kalma	GSO3	Camp attendant
Steve Kay	GSO3	Juggie
Peter Kramer	GSO4	Juggie
Harry Latham	GSO6	Driller
Peter Lenehan	GSO3	Juggie
Brad Martin	GSO4	Offsider
Stan Pardalis	GSO5	Shot loader
Kevin Popple	GSO3	Offsider
Alan Porter	GSO6	Driller
Dick Proudfoot	ASO	Party clerk
Mark Ramsay	GSO3	Juggie
John Robinson	GSO4	Offsider
John Ryan	GSO3	Juggie
Alan Travers	GSO5	Cook

Schedule

Wednesday 17 July	Crew departed Eucla and sets up camp near the turnoff to Cook
Thursday 18 July	Drilling and line surveying commenced
Friday 19 July	Completed the surveying and laid out the southern 10 m GI spread
Saturday 20 July	Completed drilling at the southern test site. Recorded the uphole and noise shots with the 10 m GI spread, redeployed to 40 m GI spread and started recording the kelly and production shots before wind and rain stopped production.
Monday 22 July	Finished recording at the southern test site, and laid spread to northern 10 m GI spread. Finished drilling shot holes of the northern test site.
Tuesday 23 July	Finished recording at the northern test site. Cleaned and packed up gear
Wednesday 24 July	Camp packed up, crew drove to Ceduna.

VEHICLES

Recording truck	ZBE-748		
Workshop	ZBE-775	towing Workshop trailer	ZTV-022
Water tanker	ZBE-634	towing Ablutions	ZTI-344
Cable truck	ZBE-633	towing Stores trailer	ZTV-020
Stores truck	ZBE-687	towing Kitchen	ZTL-914
Computer truck	ZBE-964	towing Generator	ZTV-021
Jug buggy	ZJE-052	towing Furphy	ZTV-016
Jug buggy	ZJE-053	towing Furphy	ZTV-018
Jug buggy	ZJE-057		
Jug buggy	ZJE-058		
Shooting truck	ZJE-054		
Stores wagon	ZJE-028	towing Welding trailer	ZTV-501
Troop carrier	ZJE-025		
Tray-Top Ute	ZJE-056		
Drill rig	ZSU-473		
Drill rig	ZSU-529		
Drill rig	ZSU-471		
Drill rig	ZSU-472		
Drill tanker	ZSU-865	towing Office	ZTL-996
Drill tanker	ZSU-864	towing Drill Trailer	ZTL-511
Drill tanker	ZSU-911	towing Kitchen	ZTL-915
Drill tanker	ZSU-866	towing Stores trailer	ZTL-674
Stores truck	ZBE-645		
Water tanker	ZBE-782	towing Ablutions	ZTI-343
Workshop	ZBE-647	towing Workshop trailer	ZTV-023
Explosives truck	ZUE-136		
Pre-loader	ZJE-055		
Troop carrier	ZJE-013	towing Generator	ZTL-984

Appendix IV

Surveying

Centre of southern spread	31°16.86'S	130°29.17'E
Centre of northern spread	30°59.44'S	130°29.19'E

Southern site - 10 metre station interval
From the central star picket on the western side of the road, station markers were placed 5 m either side of this central picket. The northern one was marked station number 1049 and the southern one 1048. Pegs were then placed at a 10 metre station interval, with increasing station numbers to the north to station 1096, and decreasing station numbers to the south to station 1000.

Southern site - 40 metre station interval
From the central star picket on the eastern side of the road, station markers were placed 20 m either side of this central picket. The northern one was marked station number 2049 and the southern one 2048. Pegs were then placed at a 40 metre station interval, with increasing station numbers to the north to station 2108, and decreasing station numbers to the south to station 1988.

Northern site - 10 metre station interval
From the central star picket on the western side of the road, station markers were placed 5 m either side of this central picket. The northern one was marked station number 3049 and the southern one 3048. Pegs were then placed at a 10 metre station interval, with increasing station numbers to the north to station 3096, and decreasing station numbers to the south to station 3000.

Northern site - 40 metre station interval
From the central star picket on the eastern side of the road, station markers were placed 20 m either side of this central picket. The northern one was marked station number 4049 and the southern one 4048. Pegs were then placed at a 40 metre station interval, with increasing station numbers to the north to station 4108, and decreasing station numbers to the south to station 3988.

Station Number	Latitude	Longitude	Latitude	Longitude	Elevation m
1001	-31.2853	130.4860	31°17.12'S	130°29.16'E	76
1096	-31.2767	130.4860	31°16.60'S	130°29.16'E	82
1988	-31.3028	130.4860	31°18.17'S	130°29.16'E	79
1998	-31.2993	130.4860	31°17.96'S	130°29.16'E	79
2001	-31.2982	130.4858	31°17.89'S	130°29.15'E	67
2003	-31.2975	130.4858	31°17.85'S	130°29.15'E	67
2004	-31.2972	130.4858	31°17.83'S	130°29.15'E	67
2005	-31.2967	130.4858	31°17.80'S	130°29.15'E	67
2008	-31.2957	130.4858	31°17.74'S	130°29.15'E	64

2010	-31.2950	130.4858	31°17.70'S	130°29.15'E	64
2015	-31.2930	130.4860	31°17.58'S	130°29.16'E	64
2020	-31.2913	130.4860	31°17.48'S	130°29.16'E	67
2025	-31.2895	130.4860	31°17.37'S	130°29.16'E	73
2027	-31.2888	130.4860	31°17.33'S	130°29.16'E	76
2030	-31.2878	130.4860	31°17.27'S	130°29.16'E	79
2035	-31.2860	130.4860	31°17.16'S	130°29.16'E	76
2037	-31.2852	130.4860	31°17.11'S	130°29.16'E	76
2038	-31.2848	130.4860	31°17.09'S	130°29.16'E	76
2042	-31.2835	130.4860	31°17.01'S	130°29.16'E	79
2047	-31.2818	130.4860	31°16.91'S	130°29.16'E	79
2050	-31.2805	130.4860	31°16.83'S	130°29.16'E	76
2054	-31.2792	130.4860	31°16.75'S	130°29.16'E	76
2059	-31.2773	130.4860	31°16.64'S	130°29.16'E	79
2064	-31.2755	130.4860	31°16.53'S	130°29.16'E	76
2069	-31.2737	130.4860	31°16.42'S	130°29.16'E	79
2070	-31.2733	130.4860	31°16.40'S	130°29.16'E	82
2074	-31.2720	130.4860	31°16.32'S	130°29.16'E	82
2076	-31.2713	130.4860	31°16.28'S	130°29.16'E	85
2080	-31.2698	130.4860	31°16.19'S	130°29.16'E	88
2082	-31.2692	130.4860	31°16.15'S	130°29.16'E	88
2085	-31.2680	130.4860	31°16.08'S	130°29.16'E	88
2090	-31.2662	130.4860	31°15.97'S	130°29.16'E	88
2096	-31.2642	130.4860	31°15.85'S	130°29.16'E	88
2108	-31.2597	130.4860	31°15.58'S	130°29.16'E	85
2109	-31.2593	130.4862	31°15.56'S	130°29.17'E	85
3001	-30.9949	130.4865	30°59.696'S	130°29.19'E	104
3096	-30.9868	130.4865	30°59.208'S	130°29.19'E	101
4000	-31.0080	130.4865	31°0.48'S	130°29.19'E	104
4001	-31.0077	130.4865	31°0.46'S	130°29.19'E	104
4003	-31.0070	130.4865	31°0.42'S	130°29.19'E	104
4011	-31.0040	130.4865	31°0.24'S	130°29.19'E	104
4018	-31.0015	130.4865	31°0.09'S	130°29.19'E	104
4022	-31.0002	130.4865	31°0.01'S	130°29.19'E	104
4036	-30.9952	130.4865	30°59.71'S	130°29.19'E	104
4046	-30.9915	130.4865	30°59.49'S	130°29.19'E	104
4051	-30.9898	130.4865	30°59.39'S	130°29.19'E	101
4060	-30.9867	130.4865	30°59.20'S	130°29.19'E	101
4068	-30.9828	130.4865	30°58.97'S	130°29.19'E	101
4070	-30.9830	130.4865	30°58.98'S	130°29.19'E	101
4080	-30.9793	130.4865	30°58.76'S	130°29.19'E	104
4083	-30.9777	130.4865	30°58.66'S	130°29.19'E	104
4089	-30.9762	130.4865	30°58.57'S	130°29.19'E	101
4090	-30.9758	130.4865	30°58.55'S	130°29.19'E	101
4096	-30.9737	130.4865	30°58.42'S	130°29.19'E	101
4109	-30.9688	130.4863	30°58.13'S	130°29.18'E	101

Appendix V

BMR OFFICER BASIN TEST SEISMIC SURVEY 1991

LINE : 91-OB1U **STATION RANGE : 1001 - 1096**

Uphole shoot. (SP 1048 = 2048 on 91-OB1, 10 m station spacing)

SP RANGE	TAPES	FFID RANGE	SEQNO
1007	91/099	0001-0009	001-007

LINE : 91-OB1N **STATION RANGE : 1001 - 1096**

Noise shoot. (SP 1048 = 2048 on 91-OB1, 10 m station spacing)

SP RANGE	TAPES	FFID RANGE	SEQNO
0810-1286	91/099	0010-0017	101-107

LINE : 91-OB1K **STATION RANGE : 2001 - 2096**

Kelly depth shots. (2kg at 40 m shot spacing)

SP RANGE	TAPES	FFID RANGE	SEQNO
2001-2031	91/100-91/101	0029-0061	301-329

LINE : 91-OB1P **STATION RANGE : 2001 - 2096**

Production & charge size comparison shots. (40 m station spacing)

SP RANGE	TAPES	FFID RANGE	SEQNO
2024-2056	91/100	0018-0035	201-207

LINE : 91-OB2U **STATION RANGE : 4001 - 4096**

Uphole shoot. (40 m station spacing)

SP RANGE	TAPES	FFID RANGE	SEQNO
4024	91/102	0070-0077	001-008

LINE : 91-OB2N **STATION RANGE : 3001 - 3096**

Noise shoot. (SP 3048 = 4048 on 91-OB2, 10 m station spacing)

SP RANGE	TAPES	FFID RANGE	SEQNO
2808-3288	91/102	0063-0069	101-106

LINE : 91-OB2K **STATION RANGE : 4001 - 4096**

Kelly depth shots. (3kg at 40 m shot spacing)

SP RANGE	TAPES	FFID RANGE	SEQNO
4033-4062	91/102-91/104	0078-0118	301-330

LINE : 91-OB2P **STATION RANGE : 4001 - 4096**

Production & charge size comparison shots. (40 m station spacing)

SP RANGE	TAPES	FFID RANGE	SEQNO
4032-4072	91/102-91/104	0078-0118	201-209

Survey : OFFICER BASIN Tests S.A. 1991
Traverse : 91OB1U
Observer : Barton
SN368

No. Chans	96	Geop/Trace	16	Alias	178 Hz
Sample Rate	2 ms	Geop/Spac	2.5 m	Notch	out
RLU	1024 ms	Station Int.	10 m	LCF	8Hz
Rec. Length	20	Tape format 6250 bpi GCR			

Field tape No. : 91099

Seq	Shot	File	FCP	RUP	Chan	Len	Shot	DTC	Kg	ILO	PO	TUH[1]
0	0	1	0	1048	96	5	sine wave					
0	1007	2	1001	1048	96	5	det test					
1	1007	3	1001	1048	96	20	1007	38.0	4.0	-5	18	20
2	1007	4	1001	1048	96	20	1007	32.6	4.0	-5	18	18
3	1007	5	1001	1048	96	20	1007	28.4	2.0	-5	18	17
4	1007	6	1001	1048	96	20	1007	22.8	2.0	-5	18	14
5	1007	7	1001	1048	96	20	1007	17.8	2.0	-5	18	13
6	1007	8	1001	1048	96	20	1007	6.1	0.5	-5	18	4
7	1007	9	1001	1048	96	20	1007	2.6	0.5	-5	18	2

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Survey : OFFICER BASIN Tests S.A. 1991
Traverse : 91OB1N
Observer : Barton
SN368

No. Chans	96	Geop/Trace	16	Alias	178 Hz
Sample Rate	2 ms	Geop/Spac	2.5 m	Notch	out
RLU	1024 ms	Station Int.	40 m	LCF	8Hz
Rec. Length	20	Tape format 6250 bpi GCR			

****

* FFID 011 1 SYNC, F6 PARITY, 7A15 (4A00 1400)

****

Field tape No. : 91099

Seq	Shot	File	FCP	RUP	Chan	Len	Shot	DTC	Kg	ILO	PO	TUH
101	1286	10	1001	1048	96	20	1286	14.8	14.0	0	16	8
102	1202	11	1001	1048	96	20	1202	17.4	12.0	0	23	12
103	1095	13	1001	1048	96	20	1095	32.2	12.0	0	16	18
104	1062	14	1001	1048	96	20	1062	19.7	12.0	0	15	8
105	810	15	1001	1048	96	20	810	23.3	14.0	0	15	10
106	895	16	1001	1048	96	20	895	14.7	12.0	0	15	4
107	1004	17	1001	1048	96	20	1004	11.4	14.0	0	15	9

[1] FCP: first channel position; RUP: recording unit position, Chan: number of channels; Len: length of record (s); DTC: depth to top of charge (m); Kg: charge size (kg); ILO: in-line offset (m); PO perpendicular offset (m); TUH uphole time (ms).

Survey : OFFICER BASIN Tests S.A. 1991
Traverse : 91OB1K
Observer : Barton
SN368

No. Chans	96	Geop/Trace	16	Alias	178 Hz
Sample Rate	2 ms	Geop/Spac	2.5 m	Notch	out
RLU	1024 ms	Station Int.	40 m	LCF	8Hz
Rec. Length	20	Tape format 6250 bpi GCR			

****

* FFID 056 1 SYNC, F0 PARITY, 7A15 (4A00 1400)
* FFID 060 1 SYNC, F6 PARITY, 7A15 (4A00 1400)

****

Field tape No. : 91100

Seq	Shot	File	FCP	RUP	Chan	Len	Shot	DTC	Kg	ILO	PO	TUH
301	2031	29	2001	2048	96	20	2031	3.5	2.0	-14	0	4
302	2029	30	2001	2048	96	20	2029	3.5	2.0	20	0	4
303	2028	31	2001	2048	96	20	2028	3.5	2.0	20	0	2
304	2027	32	2001	2048	96	20	2027	3.5	2.0	20	0	2
305	2026	33	2001	2048	96	20	2026	3.5	2.0	20	0	4
306	2025	34	2001	2048	96	20	2025	3.5	2.0	20	0	4
307	2023	36	2001	2048	96	20	2023	3.5	2.0	20	0	4
308	2022	37	2001	2048	96	20	2022	3.5	2.0	20	0	4
309	2021	38	2001	2048	96	20	2021	3.5	2.0	20	0	4

End of tape 91100

Field tape No. : 91101

Seq	Shot	File	FCP	RUP	Chan	Len	Shot	DTC	Kg	ILO	PO	TUH
0	2020	40	2001	2048	96	5	det test					
310	2020	41	2001	2048	96	20	2020	3.5	2.0	20	0	2
311	2019	42	2001	2048	96	20	2019	3.5	2.0	20	0	4
312	2018	43	2001	2048	96	20	2018	3.5	2.0	20	0	4
313	2017	44	2001	2048	96	20	2017	3.5	2.0	20	0	4
314	2016	45	2001	2048	96	20	2016	3.5	2.0	20	0	4
315	2015	46	2001	2048	96	20	2015	3.5	2.0	20	0	4
316	2014	47	2001	2048	96	20	2014	3.5	2.0	20	7	4
317	2014	48	2001	2048	96	20	2014	3.5	2.0	15	5	5
318	2012	49	2001	2048	96	20	2012	3.5	2.0	20	0	4
319	2011	50	2001	2048	96	20	2011	3.5	2.0	20	0	4
320	2010	51	2001	2048	96	20	2010	3.5	2.0	15	18	6
321	2009	52	2001	2048	96	20	2009	3.5	2.0	20	0	4
322	2008	53	2001	2048	96	20	2008	3.5	2.0	20	0	4
323	2007	54	2001	2048	96	20	2007	3.5	2.0	20	0	4
324	2006	55	2001	2048	96	20	2006	3.5	2.0	20	5	8
325	2005	56	2001	2048	96	20	2005	3.5	2.0	20	4	6
326	2004	58	2001	2048	96	20	2004	3.5	2.0	20	0	4
327	2003	59	2001	2048	96	20	2003	3.5	2.0	20	0	4
328	2002	60	2001	2048	96	20	2002	3.5	2.0	20	0	6
329	2001	61	2001	2048	96	20	2001	3.5	2.0	20	0	2

Survey : OFFICER BASIN Tests S.A. 1991
Traverse : 91OB1P
Observer : Barton
SN368

No. Chans	96	Geop/Trace	16	Alias	178 Hz
Sample Rate	2 ms	Geop/Spac	2.5 m	Notch	out
RLU	1024 ms	Station Int.	40 m	LCF	8Hz
Rec. Length	20	Tape format 6250 bpi GCR			

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* FFID's 019 TO 021 CHARGE SIZE COMPARISON
* FFID 023 1 TRANS PARITY, 1 ENC, 1 WC, 7A17, 7C40 2074, 5C38 (4A00 0521)
* FFID's 025 TO 028 & 035 PRODUCTION SHOTS

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Field tape No. : 91100

Seq	Shot	File	FCP	RUP	Chan	Len	Shot	DTC	Kg	ILO	PO	TUH
0	0	18	0	2048	96	5	sine test					
201	2049	19	2001	2048	96	20	2049	26.9	4.0	10	0	14
202	2049	20	2001	2048	96	20	2049	31.9	12.0	0	0	16
203	2049	21	2001	2048	96	20	2049	11.3	24.0	5	0	5
204	2072	22	2001	2048	96	20	2072	12.6	12.0	20	5	6
205	2064	23	2001	2048	96	20	2064	14.9	12.0	20	5	8
0	0	24	0	2048	96	5	sine test					
206	2056	25	2001	2048	96	20	2056	15.4	12.0	20	8	10
207	2048	26	2001	2048	96	20	2048	15.3	12.0	20	0	8
208	2040	27	2001	2048	96	20	2040	24.1	12.0	20	5	12
209	2032	28	2001	2048	96	20	2032	30.2	12.0	20	2	18
210	2024	35	2001	2048	96	20	2024	15.2	12.0	20	0	10

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Survey : OFFICER BASIN Tests S.A. 1991
Traverse : 91OB2U
Observer : Barton
SN368

No. Chans	96	Geop/Trace	16	Alias	178 Hz
Sample Rate	2 ms	Geop/Spac	2.5 m	Notch	out
RLU	1024 ms	Station Int.	40 m	LCF	8Hz
Rec. Length	20	Tape format 6250 bpi GCR			

Field tape No. : 91102

Seq	Shot	File	FCP	RUP	Chan	Len	Shot	DTC	Kg	ILO	PO	TUH
1	4024	70	4001	4036	96	20	4024	38.2	4.0	20	7	15
2	4024	71	4001	4036	96	20	4024	34.8	4.0	20	7	13
3	4024	72	4001	4036	96	20	4024	30.0	4.0	20	7	12
4	4024	73	4001	4036	96	20	4024	25.0	4.0	20	7	11
5	4024	74	4001	4036	96	20	4024	20.0	2.0	20	7	10
6	4024	75	4001	4036	96	20	4024	15.0	2.0	20	7	8
7	4024	76	4001	4036	96	20	4024	10.0	1.0	20	7	4
8	4024	77	4001	4036	96	20	4024	5.0	1.0	20	7	2

Survey : OFFICER BASIN Tests S.A. 1991
Traverse : 91OB2N
Observer : Barton
SN368

No. Chans	96	Geop/Trace	16	Alias	178 Hz
Sample Rate	2 ms	Geop/Spac	2.5 m	Notch	out
RLU	1024 ms	Station Int.	40 m	LCF	8Hz
Rec. Length	20	Tape format 6250 bpi GCR			

Field tape No. : 91102

Seq	Shot	File	FCP	RUP	Chan	Len	Shot	DTC	Kg	ILO	PO	TUH
0	0	62	0	3000	96	5	sine test					
0	2808	63	3001	3000	96	5	det test					
101	2808	64	3001	3000	96	20	2808	13.0	12.0	0	10	8
102	2896	65	3001	3000	96	20	2896	15.7	10.0	0	10	8
103	3000	66	3001	3000	96	20	3000	20.5	10.0	0	13	10
104	3096	67	3001	3000	96	20	3096	15.2	10.0	5	15	12
105	3200	68	3001	3000	96	20	3200	15.7	10.0	0	13	10
106	3288	69	3001	3000	96	20	3288	9.8	12.0	0	20	6

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Survey : OFFICER BASIN Tests S.A. 1991
Traverse : 91OB2K
Observer : Barton
SN368

No. Chans	96	Geop/Trace	16	Alias	178 Hz
Sample Rate	2 ms	Geop/Spac	2.5 m	Notch	out
RLU	1024 ms	Station Int.	40 m	LCF	8Hz
Rec. Length	20	Tape format 6250 bpi GCR			

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* FFID 116 5 SECOND RECORD

****

Field tape No. : 91102

Seq	Shot	File	FCP	RUP	Chan	Len	Shot	DTC	Kg	ILO	PO	TUH
301	4033	79	4001	4036	96	20	4033	3.3	4.0	20	6	6
302	4034	80	4001	4036	96	20	4034	3.3	4.5	20	6	4
303	4035	81	4001	4036	96	20	4035	3.3	4.5	20	6	4
304	4036	82	4001	4036	96	20	4036	3.3	4.5	20	5	4
305	4037	83	4001	4036	96	20	4037	3.3	4.5	20	8	2
306	4038	84	4001	4036	96	20	4038	3.3	4.5	20	8	2
307	4039	85	4001	4036	96	20	4039	3.3	4.5	20	5	4
308	4040	87	4001	4036	96	20	4040	3.3	4.5	20	5	2

End of tape 91102

Field tape No. : 91103

Seq	Shot	File	FCP	RUP	Chan	Len	Shot	DTC	Kg		ILO	PO	TUH
0	0	88	0	4036	96	20							
309	4041	89	4001	4036	96	20	4041	3.3	4.5	20	0	2	
310	4042	90	4001	4036	96	20	4042	3.3	2.5	20	0	4	
311	4043	91	4001	4036	96	20	4043	3.2	3.5	20	0	2	
312	4044	92	4001	4036	96	20	4044	3.2	3.5	20	0	2	
313	4045	93	4001	4036	96	20	4045	3.2	3.5	20	0	2	
314	4046	94	4001	4036	96	20	4046	3.2	3.5	20	0	4	
315	4047	95	4001	4036	96	20	4047	3.2	3.5	20	5	4	
316	4048	96	4001	4036	96	20	4048	3.2	3.5	20	0	4	
317	4049	101	4001	4036	96	20	4049	3.2	3.5	20	5	8	
318	4050	102	4001	4036	96	20	4050	3.2	3.5	20	4	8	
319	4051	103	4001	4036	96	20	4051	3.2	3.5	20	3	8	
320	4052	104	4001	4036	96	20	4052	3.2	3.5	20	4	6	
321	4053	105	4001	4036	96	20	4053	3.2	3.5	20	4	8	
322	4054	106	4001	4036	96	20	4054	3.2	3.5	20	4	8	
323	4055	107	4001	4036	96	20	4055	3.2	3.5	20	0	6	
324	4056	108	4001	4036	96	20	4056	3.2	3.5	20	10	12	
325	4057	110	4001	4036	96	20	4057	3.2	3.5	20	0	10	
326	4058	111	4001	4036	96	20	4058	3.2	3.5	20	3	12	
327	4059	112	4001	4036	96	20	4059	3.4	3.5	20	3	10	
328	4060	113	4001	4036	96	20	4060	3.4	3.0	20	0	12	
329	4061	114	4001	4036	96	20	4061	3.4	3.0	20	5	12	

End of tape 91103

Field tape No. : 91104

Seq	Shot	File	FCP	RUP	Chan	Len	Shot	DTC	Kg	ILO	PO	TUH
0	0	115	0	4036	96	20	sine test					
330	4062	116	4001	4036	96	5	4062	3.4	3.0	20	5	12

End of tape 91104

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Survey : OFFICER BASIN Tests S.A. 1991
Traverse : 91OB2P
Observer : Barton
SN368

No. Chans	96	Geop/Trace	16	Alias	178 Hz
Sample Rate	2 ms	Geop/Spac	2.5 m	Notch	out
RLU	1024 ms	Station Int.	40 m	LCF	8Hz
Rec. Length	20	Tape format 6250 bpi GCR			

Field tape No. : 91102

Seq	Shot	File	FCP	RUP	Chan	Len	Shot	DTC	Kg	ILO	PO	TUH
201	4032	78	4001	4036	96	20	4032	10.7	10.0	20	5	6
202	4040	86	4001	4036	96	20	4040	8.1	10.0	20	0	4

Field tape No. : 91103

Seq	Shot	File	FCP	RUP	Chan	Len	Shot	DTC	Kg	ILO	PO	TUH
203	4048	97	4001	4036	96	20	4048	15.0	12.0	20	5	10
204	4049	98	4001	4036	96	20	4049	9.7	4.0	3	5	10
205	4049	99	4001	4036	96	20	4049	9.8	12.0	-7	0	6
206	4049	100	4001	4036	96	20	4049	10.3	24.0	-16	21	10
207	4056	109	4001	4036	96	20	4056	22.4	14.5	20	4	16

Field tape No. : 91104

Seq	Shot	File	FCP	RUP	Chan	Len	Shot	DTC	Kg	ILO	PO	TUH
208	4064	117	4001	4036	96	20	4064	7.5	10.0	20	0	8
209	4072	118	4001	4036	96	20	4072	30.2	12.0	20	4	14

End of tape 91104

Appendix VI

UPHOLE ANALYSIS 91OB1

		Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6	Shot 7
Depth	metres	38	32.6	28.4	22.8	17.8	6.1	2.6
Charge	kg	4	4	2	2	2	0.5	0.5
	Offset	FB time	FB time	FB time	FB time	FB time	FB time	FB time
Channel	metres	ms	ms	ms	ms	ms	ms	ms
1	-65	28	28	24	21	20	14	13
2	-55	27	25	24	20	19	13	12
3	-45	26	24	23	19	18	12	11
4	-35	23	23	21	17	17	10	9
5	-25	22	22		17	16	8	8
6	-15	20	20	18	16	16	7	7
7	-5	19	17	18	14	15	6	3
8	5	20	18	17	13	15	6	5
9	15	21	20	20	14	17	10	9
10	25	24	22	22	19	20	10	10
11	35	26	25	23	20	20	11	11
12	45	27	26	25	21	21	13	12
13	55	30	30	28	26	26	16	15
14	65	32	30	30	26	27	18	17
15	75	35	34	32	29	29		19
16	85	36	35	32	30	30	22	21
17	95	40	39	37	35	33	25	25
18	105	42	40	39	36	35	27	26
19	115	44	42	43	39	39	30	29
20	125	47	44	44	40	41	32	32
21	135							
22	145	53	51	51	46	46	41	39
23	155	57	54	54	51	51	45	41
24	165	56	55	54	52	48	46	40
25	175	59	59	59	56	51	51	43
26	185	63	62	62	59	55	54	48
27	195	65	65		60	56	56	49
28	205	67	67		63	60	57	50
29	215	69	70		65	62		
30	225	71	71		66	65		
31	235	73	74		66	65		
32	245	75	76		70	70		
33	255	80	77					
34	265	82						
35	275	83					170	
36	285	86		121			174	
37	295			126			181	
38	305			132			193	
39	315			137			196	
40	325			143			201	
41	335	155		150	191	196		
42	345	161	175		200	201	211	
43	355	167	180	193	202	205	219	
44	365	170	184	199		207	222	
45	375		189	202	209	210		

		Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6	Shot 7
Depth	metres	38	32.6	28.4	22.8	17.8	6.1	2.6
Charge	kg	4	4	2	2	2	0.5	0.5
	Offset	FB time	FB time	FB time	FB time	FB time	FB time	FB time
Channel	metres	ms	ms	ms	ms	ms	ms	ms
46	385	195	193	205	211	214		
47	395	200	199	207	218	221		
48	405	210	203	211	222	226		
49	415	214	209	216	228	232		
50	425	220	216	220	233	234		
51	435	222	223		238	238		
52	445	226	227	230	242	242		
53	455		233					
54	465		240					
55	475	240	245	242		255		
56	485	244	252					
57	495	247				265		
58	505	252		261		267		
59	515	256		264		270		309
60	525	260		267		273		313
61	535	263		272		277		316
62	545	266		276		283		325
63	555			281		288		346
64	565							352
65	575							357
66	585	293						361
67	595	299						364
68	605	305						369
69	615	307						374
70	625	314						378
71	635	318						383
72	645	320						
73	655	322						
74	665	327	332					
75	675	329	338					
76	685	336	343					
77	695		344					
78	705		346					
79	715		348					
80	725		352					
81	735		356					

Uphole Analysis of 91OB2

		Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6	Shot 7	Shot 8
Depth	metres	38.2	34.8	30	25	20	15	10	5
Charge	kg	4	4	4	4	2	2	1	1
	Offset	FB time	FB time	FB time	FB time	FB time	FB time	FB time	FB time
Channel	metres	ms	ms	ms	ms	ms	ms	ms	ms
1	-940	423	427	428	431	428	442	440	441
2	-900	409	413	414	415	413	417	418	423
3	-860	394	393	394	398	396	396	400	402
4	-820	373	375	376	379	378	377	382	381
5	-780	352	349	354	357	359	358	365	362
6	-740	316	332	334	332	338	341	345	345
7	-700	297	316	317	320	322	321	327	322
8	-660	281	298	295	298	294	301	312	302
9	-620	267	269	274	281	273	281	294	284
10	-580	250	252	258	267	258	265	276	258
11	-540	235	239	241	244	241	245	262	241
12	-500	220	224	231	230	226	223	241	247
13	-460	206	208	210	212	209	197	218	217
14	-420	180	182	123	192	153	150	204	207
15	-380	158	162	108	177	117	130	187	174
16	-340	141	145	141	157	101		170	146
17	-300	92	90	124	87	86	70	150	90
18	-260	68	68	79	77	62	62	70	60
19	-220	55	55	54	53	47	49	55	50
20	-180	47	47	45	41	39	36	40	40
21	-140	34	36	35	32	34	29	30	27
22	-100	28	27	26	24	25	26	23	21
23	-60	19	18	17	15	13	14	13	12
24	-20	15	13	12	12	9	7	7	5
25	20	15	14	13	12	9	8	8	6
26	60	26	24	24	21	19	18	19	14
27	100	38	35	34	32	29	28	29	26
28	140	43	43	44	40	38	37	36	33
29	180	55	54	54	50	48	46	56	42
30	220	65	63	64	61	59	61	64	55
31	260	77	72	74	84	80	80	94	64
32	300	88	110	95	98	85	102	110	94
33	340	99	121		107	108	126	167	140
34	380	108	128			140	144	191	146
35	420					191	171	205	163
36	460		193	202					
37	500		221	229		222	236	249	235
38	540	235	238	241	250	250	252	258	260
39	580	253	256	261	257	262	260	272	282
40	620	271	272	276	271	279	280	289	292
41	660	286	287	289	291	294	297	310	308
42	700	301	304	302	309	311	323	341	322
43	740	324	326	326	329	328	346	357	342
44	780	346	343	355	353	349	362	377	360
45	820	364	366	369	370	369	377	393	376

Uphole Analysis of 91OB2

		Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6	Shot 7	Shot 8
Depth	metres	38.2	34.8	30	25	20	15	10	5
Charge	kg	4	4	4	4	2	2	1	1
		FB time	FB time	FB time	FB time	FB time	FB time	FB time	FB time
Channel	Offset	ms	ms	ms	ms	ms	ms	ms	ms
46	860	382	383	385	389	390	399	413	
47	900	401	400	400	406	408	419	432	
48	940	418	419	420	424	426	439	448	
49	980	439	437	441	444	444	456	466	
50	1020	455	459	458	460	463	472		
51	1060	472	476	474	473	477	490		
52	1100	484	485	486	485	487	499		
53	1140	493	495	493	494	498	505		
54	1180	499	500	503	505	506	515		
55	1220	506	510	513	513	516			
56	1260	515	521	522	524	526			
57	1300	527	532	532					
58	1340	539	542	539					
59	1380	550	551	547					
60	1420	560	555						
61	1460	569	565						
62	1500	578	574						
63	1540	585	581						
64	1580	586	590						
65	1620	593	598						
66	1660	601	608						
67	1700	609							
68	1740	617							
69	1780	627							
70	1820	635							
71	1860	644							
72	1900	653							
73	1940								
74	1980								
75	2020								
76	2060					855			
77	2100					864			
78	2140	862				873			
79	2180	868			867	880			
80	2220	876	874		881	888			
81	2260	882	882	887	881	895			
82	2300	887	889	895	892	902			
83	2340	897	899	904	902	908			
84	2380	907	909	913	908	918			
85	2420	917	920	923	923	928			
86	2460	926	930	932	927	936			
87	2500	937	938	943	935	944			
88	2540	948	948	953	948	952			
89	2580	958	957	964	954	961			
90	2620	968	966	973	971	969			
91	2660	971	974	981		976			
92	2700	976	982	983		984			
93	2740	981	986	989		990			
94	2780	987	995	992		1000			
95	2820	999	1005	1001					