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OTWAY BASIN EXPERIMENTAL SEISMIC SURVEY FOR COMPARISON WITH THE "VIBROSEIS" SURVEY, VICTORIA 1965 - VOLCANICS PROJECT

by

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CONTENTS

SUMMARY

An experimental seismic investigation was carried out along a north-south traverse, 13 miles south of Hamilton in the Otway Basin, Victoria. The investigation formed part of a survey designed to obtain a comparison of the shothole and "Vibroseis" seismic techniques, with regard to quality of data and operational costs. In particular, this area was chosen as being representative of areas of volcanic cover.

The anticipated problems associated with the presence of shallow volcanics proved to be minor and the major obstacle to obtaining good seismic records was shown to be surface noise.

A fairly heavy technique was found by which fair quality records could be obtained.

The principal reflection, which was of fair to good quality, had a pronounced overall north dip and occurred at reflection times between 0.6 and 0.95 seconds. This reflection was interfered by reflected refractions and by diffraction patterns, the latter suggesting the possibility of faulting.

1. INTRODUCTION

During the period mid-April to mid-June 1965, the No. 2 Seismic Party of the Bureau of Mineral Resources (B.M.R.) carried out an experimental seismic programme along the Mt. Napier road, 13 miles south of Hamilton, Victoria (Traverse V.2. Plate 1). A short traverse, V.3, 6 miles north of Heywood was also surveyed.

The work done on these traverses forms part of an experimental programme designed to provide a comparison between the shothole and Vibroseis seismic methods in certain difficult seismic areas. In particular, traverse V.2 and V.3 were selected as being representative of areas of Tertiary Volcanic cover, where previous seismic investigations had not produced good results. The experimental programme was carried out on traverse V.2 and traverse V.3 was surveyed to test the technique evolved, in a different area.

The traverses were laid along sealed roads, but access to the road reserves was hampered by heavy rain throughout the latter part of the survey. Operations were postponed in mid-June, due to the weather conditions and associated equipment troubles, and, although a second attempt was made in July, surface conditions were still too wet to permit the completion of the programme.

The work done on traverse V.3 is not satisfactory, and, as the party will be returning to the area in February 1966 to reshoot this traverse and the remaining six shotpoints on traverse V.2, this report will omit the results from traverse V.3.

No comparison with the results of the Vibroseis survey will be drawn in this present report, which covers only the 1965 shothole survey.

Staff and equipment on the field party and operational details are listed in appendices 1 and 2 respectively.

2. GEOLOGY

The Otway Basin, which extends over an area of 13,000 square miles on land, consists of Tertiary and Mesozoic sediments along, and off-shore from, the South-West coast of Victoria and the South-East coast of South Australia.

The land area is divided into several Tertiary Sub-basins; from west to east these are:

(1) The Gambier Sunklands - separated from the Murray Basin to the north, by the Padthaway Horst and its south-east extension, the Kanawinka Fault,

(2) the Portland Sunklands - separated from the Gambier Sunklands by the sub-surface Dartmoor Ridge.

(3) the Torquay Embayment - separated from the Portland Sunklands by a shallow sub-surface ridge between the Otway Range and the Barrabool Hills.

Most of the surface formations consist of Quarternary to Recent sands, dunes, marshes and colcanics, Tertiary Volcanics and Tertiary marine limestones. These formations confine knowledge of the deeper stratigraphy and structure to evidence from stratigraphic bores and geophysical surveys.

The stratigraphy of the basin is summarised below:-

		Max. Thickness
Pleistocene	basalts, tuff, scoria and sand dunes	?
Pliocene	alluvium	
Oligocene	Heytesbury Gp., Glenelg Gp., Gambier Limestone, limestone and marls	2900'
Eocene-Palaeocene	Wangerrip Gp., Knight Gp., Quartz sandstone, conglomeratic sandstone with much clay and siltstone	5000'
	______	disconformity
Upper Cretaceous	Paarrette Fm.	1000'
	Glauconitic sands and carbonaceous shales. Probably more abundant in Gambier Sunklands	
Upper Cretaceous	Belfast Mudstone	2000'
Lower Cretaceous	Mudstone, clayey, glauconitic	
	______	unconformity
Lower Cretaceous	Flaxman Beds Sandstone, limonitic, chloritic and sideritic greywacke)	400'
	Waarre Fm. Subgreywackes, minor sandstones, siltstones)	450'
Lower Cretaceous	Otway-Merino Gp.	7000'
Upper Jurassic	Basal sand (lower Cretaceous) Arkosic sands, Greywacke and Mudstone	

3. PREVIOUS SEISMIC INFORMATION

General. The Bureau of Mineral Resources carried out the first seismic tests mainly on basalt areas in the Otway Basin near Heywood, Vict., in 1956 (Lodwick and Vale, 1958). Since 1956 the South Australia Mines Department seismic crews, and contractors employed by the lease-holders have shot approximately 2700 miles of traverses using conventional seismic equipment and shot-hole methods. This work has been carried out in the coastal areas of the Portland Sunklands, in the Gambier Sunklands and offshore from the coast of S.W. Victoria.

The offshore work has been generally successful. It indicates the existence of a deep structural trend roughly parallel to the coast in a W.N.W. direction and a series of very gentle E.N.E. trending folds parallel to the Otway Ranges in the shallow section.

On land, seismic work has yielded good results in many areas, however no simple technique has yielded good results throughout the Otway Basin, and there are large areas where only poor or no reflection data has been obtained to date. In addition large areas, with volcanic cover, sand dune cover and Gambier Limestone cover, have been generally avoided due to difficulties experienced in the limited amount of seismic work which has been done on these formations.

Portland Sunklands - Shothole Seismic Surveys. The greatest amount of traversing in the Otway Basin has been carried out in the Portland Sunklands in areas with no basalt cover. In this sub-basin fair quality seismic results have been obtained with a relatively light technique consisting of 3 holes in line, 75 ft. apart and 12 geophones per trace, with up to 27½ ft. between geophones. The charge which varied from 5 to 15 lbs per hole was loaded to a miximum depth of 150'.

In areas, mainly bordering the basalt area, where reflection quality deteriorated, considerable testing has been carried out in attempts to improve reflection quality. This testing mainly consisted of increasing the number of holes per shot point, experimenting with hole depths and charge sizes and with increasing the number of geophones per trace. This type of testing has shown that increasing the effort factor generally improves the reflection quality. When shooting on weathered basalt east of the Glenely River during the Dartmoor-Nelson survey, Frome-Broken Hill Co. Pty. Ltd., used 10 hole patterns 30 ft. deep with a total charge of 250 lb. and recorded with 24 geophones per trace, 12.5 feet apart. Results were improved only slightly by this large increase in effort.

In addition to the above testing, noise spreads have been shot in the course of the various surveys, on surfaces with volcanics present, varying from tuff and weathered basalt to hard basalt. These noise spreads were not continuously recorded out from the shot-point and because of this the results are difficult to analyse. The main conclusion from the noise shooting is that the type of noise present varies over a small area.

The coastal non-basalt areas of the Portland Sunklands are now fairly extensively covered by seismic work, and the exploration of this sub-basin is extending northwards on to areas covered by the volcanics. Frome-Broken Hill Co. Pty. Ltd., recently conducted the reconnaissance Branxholme-Koroit survey on volcanics north of Pretty Hill No. 1 well, to investigate the extension of the basin northwords. The common depth point (C.D.P.) method was used on this survey, generally with 6 fold coverage. Initial results using this method in the basalt area are encouraging despite the difficulties experienced in obtaining good static and dynamic corrections to enable efficient compositing to be carried out. Multiples probably reflecting between the Upper Wangerrip Formation and the surface, and multiples of undetermined origin similar in appearance to the reverberation type multiples of marine work, are additional problems in this area. However, on the final C.D.P. sections multiple interference appears to be greatly reduced as compared with the normal sections.

Portland Sunklands - Vibroseis Survey 1964. Experimental "Vibroseis" surveys were carried out south of the volcanics shield near Pretty Hills No. 1 bore (Volcanics 1) and on areas of volcanics cover near Mount Napier (Volcanics 2) and north of Heywood (Volcanics 3) during a 6 weeks period in May and June 1964.

Recordings were made along the Volcanics 1 traverse, 2 miles long, using transposed and 10 fold C.D.P. methods. Results from this initial work ranged from fair to poor and were comparable to those obtained from previous shot hole work.

Noise spreads were recorded on the main experimental, Volcanics 2, traverse and detailed experimentation was carried out with different types of vibrator and geophone patterns, number of vibrator sweeps, different geophone to vibrator offsets and sweep frequencies. Testing indicated that the surface noise with velocities in the range 4,800 ft/sec - 9,000 ft/sec, should be attenuated satisfactorily by the vibrator and geophone patterns. The best "Vibroseis" transposed technique found used 400 ft long source patterns and 400 ft long by 200 ft wide detector patterns. These arrangements, equivalent to 400 ft long by 200 ft wide shothole petterns and 400 ft long in-line geophone patterns, gave effective cancellation of the noise events. A vibrator sweep frequency range of 20 to 57 c.p.s. (mean 38 c.p.s.) was found to be most effective for this traverse. The effective sampling using the transposed "Vibroseis" method was within the range 8000 - 12000 separate ray paths. Part of the 6 mile long traverse was repeated using a 10 fold C.D.P. method with source and detector patterns 264 ft long. The C.D.P. compositing gave cancellation of noise events and an improvement in continuity of reflectors despite the reduction in pattern length. Weathering corrections were applied to the results assuming a constant weathering depth of 25 ft along the traverse.

The C.D.P. compositing produced an improvement in record quality, thus it can be assumed that, when long source and detector patterns are used, on the Volcanics 2 traverse, weathering depth variations are not critical.

On the Volcanics 2 traverse reflection quality varied from poor to fair. A strong but intermittent reflection was recorded between 0.5 sec. and 1.0 sec reflection time. Continuity of this event was poor in the northern part of the traverse but fair towards the south. Continuity is best about vibrating point 180. The origin of this event is indeterminate, but from its character and the lack of reliable deeper events it has been tentatively correlated with basement. In the southern part of the traverse, interference occurs between this event and events with steep dip. It was suggested that the steeply dipping events could be multiples however there was no definite evidence to support this.

The same transposed and C.D.P. recording methods were used on the Volcanics 3 traverse as on Volcanics 2, to test the applicability of the methods to another area with the Volcanic cover. On this traverse fair quality reflections were recorded at approx. 0.5, 0.9 and 1.3 seconds. Continuity on these events was again intermittent probably due to the presence of a high ambient noise level on recording caused by heavy traffic, rain and wind in trees along the traverse. The synthetic seismogram from Eumeralla No. 1 bore, which lies 20 miles to the south-east of the traverse indicates that first order surface multiples could occur on the Volcanics 3 section at 1.3 sec, if correlation can be effected over this distance.

In general the "Vibroseis" work has indicated that a surface method, using long source and detector patterns and a high degree of compositing can be used effectively on the Volcanic cover. However the results obtained do pose problems in interpretation due to the probable presence of multiple reflections or variations in the velocity distribution in the section.

Velocity Information. The most reliable velocity information in the basin is that obtained from continuous velocity (sonic) logs and well-geophone survey information. Sonic logs are available for Pretty Hills No. 1 well, Eumeralla No. 1 and other recent wells in the Portland Sunklands. The "Vibroseis" results in the Volcanics area were dynamically corrected using the Pretty Hills velocity function. The appearance of the reflections of the corrected record sections generally indicates that the application of this function to the results instead of a function derived from the Vibroseis results for each area does not introduce significant errors in smoothing the reflections.

4. OBJECTIVES

The main objective of this survey was to obtain a comparison of the shothole and Vibroseis techniques in the difficult seismic reflection areas of the Otway Basin, with regard to both quality of data and operational costs.

The results of the experimental Vibroseis survey were of at least comparable quality to those of previous shothole seismic surveys. However, these previous surveys involved very little experimentation, and the maximum effort used, consisted of 24 geophones per trace and ten hole shot patterns.

An objective of this survey therefore was to obtain improved seismic reflection information using the shot-hole technique, by increasing the effort factor through a logical and detailed experimental procedure, until reliable results of equal or better quality to the "Vibroseis" results were obtained, or the effort required became economically prohibitive.

Production shooting was to be carried out in each problem area in the Otway Basin, and the comparisons of costs and quality of results obtained by the shothole and Vibroseis methods were to be based on this shooting. Production shooting was to be carried out in the exact locations used on the Vibroseis survey.

To obtain good quality results in the areas to be surveyed, solutions to certain problems occurring in these areas had to be found. These problems are discussed below.

(1) Volcanics - Portland Sunkland: S.W. Victoria

Several problems inherent to the presence of volcanics, exist in this area. These, and other problems in the area covered by volcanics, are as follows:-

1. Surface problems
   - (a) Energy transmission
   - (b) Variations in the weathered layer
   - (c) Hard drilling
2. Subsurface problems
   - (a) Lateral velocity variations
   - (b) Multiple reflections

1. Surface problems

(a) Energy transmission. Basalt, tuff and other volcanic matter which covers the northern part of the Portland Sunklands forms a screen which makes it difficult to transmit energy to the geologic section below the basalt, and to receive energy back from beneath it. These difficulties are commonly encountered in areas where formations with high velocities are on or near the surface.

On the volcanics, seismic results are best where the volcanics are thin and the charges were placed below them. Where the volcanics are thick or very hard and the charges were consequently placed them at shallow depth the results were poor to fair. Results were poorest when shooting was carried out in tuff or eroded basalt.

(b) Variations in the weathered layer. The thickness and velocities of the weathered layer formations were thought to be extremely variable. These are difficult to determine on the volcanics. It is thus difficult to calculate good static (weathering and elevation) corrections to apply to the seismic reflection data in the area. However, the results of the Vibroseis survey, and of the associated shot hole weathering survey on traverse Volcanics 2, show that this problem is not as critical as was originally thought.

(c) Hard drilling. Drilling is difficult and expensive in hard basalt. The drilling rate, using a Mayhew 1000 combination drill can be as low as one inch per hour. Thus on the volcanics any seismic method requiring drilling can be very costly.

2. Subsurface problems

(a) Lateral velocity variations. There is a dynamic (spread) correction problem due to lateral changes in vertical velocities in the section. These changes are due to the varying extent of basalt in the section, the presence of Gambier Limestone under the basalt in some areas, as well as variations in the thickness of deeper formations. The results of the Vibroseis survey, particularly from the C.D.P. technique, have shown that this constitutes less of a problem than was previously thought.

(b) Multiple reflections. Multiples are evident on most recordings made on or near the basalt areas. They are very strong in the area north of Pretty Hills No. 1 well. The synthetic seismogram from this well confirms that multiples are likely to be a problem in this area.

This synthetic seismogram indicates good reflecting conditions at the top of the Upper Wangerrip Group at 1100 ft, in the Otway-Merino Group at 2890 ft., and at basement at 7880 ft. Weaker reflecting conditions are indicated for the Pretty Hills sands. The synthetic seismogram shows the filtered primary reflections plus filtered first order surface multiples; the strongest of these appear to be multiples with reflection paths between the surface and the top of the Upper Wangerrip.

Another type of multiple is found when shooting is carried out on the basalt. As noted previously, these are similar to the reverberation type multiples (ringing) which are found in marine work. They are of indefinite origin but possibly may be reflections with multiple paths within limestone underlying the basalt.

5. PROGRAMME

A shotpoint interval of 880 feet was chosen (a) to conform with the vibroseis survey, and (b) because a shallow section had been indicated by the results of previous surveys.

Recording commenced at S.P.182 with tests to determine best pre-filter settings.

Using these settings a series of shots was fired at S.P.180 to determine the charge and charge depth giving the best reflection quality and energy return, for use in the noise recording. These shots were recorded over a spread laid between S.P.180 and S.P.182 to examine the relative reflection moveout over 880 feet and 1760 feet. An in-line geophone pattern of 16 geophones, 20 feet apart, was used to conform with the group length of 300 feet arrived at on previous shothole surveys.

20 lb. charges were fired,

(i) at the base of a hard basalt layer
(ii) in the hard basalt layer
(iii) at the top of the hard basalt layer
(iv) in the clay and weathered basalt.

Shooting in the hard basalt layer proved to give best results and charges of 25 lbs., and 30 lbs., were then fired at this depth, with little variation in resultant record quality.

20 lb charges at the same depth were therefore used for the noise recording. Five spreads were laid between 300 feet and 3870 feet northwards from S.P.180. A trace interval of 30 feet was used with 8 geophones, bunched, per trace, and the recordings were made using a linear gain to permit the measurement of relative amphitudes. The pre-filters were used in order that the noise recorded would be only that which had to be filtered spatially.

A transverse noise spread was laid through S.P. 181 a distance of 880 feet from the shot at S.P. 180. One geophone per trace was used with a 25 feet trace interval.

While the noise records were being analysed, an uphole survey was carried out at S.P. 181 using a normal 24 trace split-spread. Twelve shots were fired at depths varying from 250 feet to the surface, and were recorded using 8 geophones, bunched, per trace to permit the construction of a wave-front diagram (Meissner, 1961). It was decided, on the bases of energy level and reflection quality obtained during the uphole recording, that the charge depth should be increased from the previously determined value of 50 feet to between 80 and 90 feet, where a thick band of hard basalt existed.

Using this depth, two inline shothole patterns of 3 holes, 50 feet apart with 30 lbs per hole and 5 holes, 50 feet apart with 20 lbs per hole, were compared at S.P. 179. The geophone pattern of 32 geophones per trace, in two rows of 16 geophones, 20 feet apart, was chosen after studying the noise characteristics.

The 5 hole pattern gave the better result, and was used in a test at S.P. 180 to determine the best charge size. Charges of 5 x 5, 5 x 10, 5 x 15 and 5 x 20 lbs were fired into a split-spread using the same geophone group as at S.P. 179. Best results were obtained from the 5 x 20 lbs. (Plate 8).

A further comparison between 5 x 20 lbs and 5 x 2½ lbs was made at S.P. 181 to examine the effect of a large decrease in charge on the level of the low frequency energy occurring immediately after the main event at 0.8 seconds. The low frequency energy was decreased, but the reflection quality was also lowered. Two shots were then fired at S.P. 178, one with and one without prefilters, to confirm that the instruments were functioning satisfactorily.

In order to increase the rate of subsurface coverage it was decided that the spreadlengths would be increased from 880 feet to 1200 feet, giving a station interval of 100 feet and reducing the groundmixing from 4/1 to 3/1. Using this longer spreadlength, 5 hole shot patterns with 20 lbs unit charges and 32 geophones per trace as above, a short section was shot between shotpoints 178 and 173B.

Although shallow reflections were recorded on this section, it was apparent that the noise level was still high and it was decided that the quality of the shallow events could probably be improved by an increased effort factor. An attempt was made to obtain a further 6 db attenuation of the noise by enlarging the shothole pattern to 7 holes in line, 50 feet apart, and lengthening the geophone pattern to 24 per trace, 15 feet apart. These larger patterns coupled with the increase in spread length brought the main signal at 0.7 seconds within the range of significant attenuation (more than

3 db.), by the shothole and geophone groups. However the increase in noise attenuation was such that an overall improvement in the signal: noise ratio was obtained.

This heavier technique was used at S.P. 172 and the geophone pattern was subsequently increased to tow lines of 24 geophones per trace with the same geophone interval to obtain additional attenuation of random and transverse noise. The two lines were spaced 30 feet apart.

This technique gave good results at shotpoints 171 and 170 and it was used to complete the section from shotpoint 183B to shotpoint 195B.

Most of this part of the section and all the subsequent work on traverse V.3 was spoiled by faulty equipment operation caused by dampness. The party returned to Hamilton later in the year to reshoot this defective work before access became impossible due to waterlogged surface conditions.

A noise analysis was reshot at shotpoint 180 to determine whether any change had occurred in the characteristics of the surface noise due to the saturation of the ground.

Comparison between the effects of one and two lines of 24 geophones per trace, and between 7 and 5 holes, 50 feet apart, and 4 holes, 100 feet apart were made at shotpoints 180B and 181B.

Finally a section was shot from shotpoint 180B to 189B using the 7 hole pattern and 48 geophones per trace.

The remaining six shotpoints on this traverse will be shot when the party returns to the area in 1966.

6. RESULTS

6.1 Experimental Results

6.1.1 Near surface conditions

The drilling was not hard as had been anticipated, and penetration rates in places were as high as 100 feet per hour; however the average rates over the whole survey were between 70 and 90 feet per hour.

The near surface strata encountered in the shotholes consisted of intercalations of clay, weathered basalt and basalt.

Within these three basic formations, considerable variations in thickness, hardness and continuity were noted. Significant variations occurred within the individual shothole patterns, making the placement of the charge possible only after the logs of each constituent hole in the pattern had been studied.

At shotpoint 180 the best overall reflection quality was obtained when the charge was placed within the layer of hard basalt at 40 to 50 feet. However it was found after the deep uphole survey at shotpoint 181 that a thicker basalt layer, occurring below 70 feet provided a better shooting medium.

This deeper layer proved to be a more consistent formation than the shallow basalt and was used where present, throughout the remainder of the survey. The depth to the formation varied between 70 and 100 feet and consequently the normal shot depth lay between 75 and 105 feet. No basalt was present in the holes at the southernmost end of the traverse and here the shots were fired in clay.

The depth to the base of the low velocity layer (seismic weathering) was mostly within the range 20 to 30 feet, and the base appeared to coincide fairly closely with the top of the first layer of weathered basalt. No sharp variations in the thickness of the weathering were encountered.

The weathering and sub-weathering velocities measured from the uphole survey were 1800 feet/sec and 10,000 feet/sec respectively (Plate 3). This sharp velocity increase at the base of the weathering is shown in the wave-front diagram plotted from the uphole survey. The diagram also shows good correlation with the appropriate drill logs (Plate 4). A horizontal velocity of 12,000 ft/sec in the sub-weathering was determined from first breaks.

6.1.2 <u>Noise</u>

During the noise recording, the prefilter unit was used with a setting of 18 c.p.s. and a slope of 12 db/Octave.

The background noise level was found to lie between 10 and 30 micro volts, but during particularly windy periods, it could rise to 100 micro volts.

Two variable area sections of the noise recordings are shown on Plate 5, one with and the other without A.G.C. The time distance graph based on this section is shown on Plate 6. The frequency response and wavenumber response diagrams which appear on Plate 7 were computed from the velocity, apparent mean frequency and the highest significant amplitude of each train. The amplitude of noise event number 1 was selected as the standard to which the other amplitudes were referred. This value, 0 db, corresponds to an input voltage of 65.6 millivolts.

The events numbered 2 and 10 on the time-distance graph have low and therefore troublesome wave numbers. These events are thought to be refractions on the bases of their velocities and their apparent lack of curved moveout. Because of their offset distances, they should not affect the records. In particular, event number 10 appears to be a refraction closely associated with the main reflection band, which occurs between 0.75 and 0.85 seconds, and it has a velocity of 18,000 ft/sec.

From the frequency and wave number spectra it may be seen that events 7 and 15 have very low wave numbers. They are apparent only after the higher amplitude and shorter duration waves have died out; but could still pose a residual problem after attenuation of the stronger waves.

The highest amplitude events are numbers 1, 3, 4, and 6, but these have wave numbers of approximately 6 cycles/1000 feet and should be attenuated significantly by the shothole and geophone patterns used. The minor events 5, 8, 11, 12, 13 and 14 should be strongly attenuated.

Event number 9 has been interpreted as a reflection because of its curvature. Two wave numbers were computed for this event by choosing apparent velocities from 0 to 880 feet and from 880 to 1760 feet. These wave numbers gave an indication of the increase in signal attenuation likely to result from an increase in spreadlength.

The reflection has a fairly high amplitude and indicates a good signal to noise ratio in that particular time zone.

Interference between the longitudinal noise and transverse events could be seen on the record from the transverse noise spread. No parameters were computed for the transverse trains however, as they were ill defined and of low amplitude.

A reverse noise train may be seen on the variable area section on the farthest spread at a time of approximately 1.2 seconds. This event however has low velocity and amplitude, and no parameters were computed.

6.1.3 Input Energy

The comparison at S.P. 180 of the effect on record quality of various charge sizes showed that up to a total charge of 5 x 20 lbs there was a slight increase in signal to noise ratio with increase in charge size. This improvement in quality could only be seen in the shallow events. (Plate 8).

Below the main reflection band at approximately 0.8 seconds, a series of low frequency events were recorded. A reduction of the charge to 5 x 2½ lbs was successful in reducing the level of this low frequency energy, but only at the expense of the quality of the shallow events. The best unit charge therefore was taken to be 20 lbs.

The general energy return for a total charge of 100 lbs as depicted by the log level indicator consisted of an initial peak of 3 to 10 millivolts followed by a gradual decay to between 1 and 3 millivolts until the main reflection band was reached, when it again rose beyond 3 millivolts. Thereafter it decayed at a rate of approximately 15 dbs per second and the background noise level of 10 - 30 microvolts was usually reached between 2.5 and 3.0 seconds.

An initial gain setting of - 60 dbs was used, and the final gain setting varied between maximum and - 20 dbs according to the background noise level.

A medium A.G.C. speed of approximately 80 db/second was used.

6.1.4 Filtering

Mean signal frequencies were found to be between 25 and 35 cycles per second, with frequencies of 30 to 33 cps predominating. This placed a limit on the low cut electrical filtering. It was found that low cut filters above 21 cps destroyed the signal character, and accordingly the recordings were taken with an 18 cps cut-off on the pre filters and a slope of 12 db/octave. A high cut filter of K.92 was used on record and the best playback filters were found to be K21 - K75.

The wave number spectrum determined from the noise analysis indicated that cut-off wavenumber $k = 1/n.e = 3$ to 4 (n = number of units: e = distance between units), should be used for the spatial filter. This would give sifnificant attenuation of the main noise events 1, 3, 4 and 6 and would also attenuate the low wave number events numbers 7 and 15.

The shothole and geophone arrays chosen after the noise test were as follows:

shotholes: 5 holes in line, 50 feet apart

geophones: two lines of 16 per trace, in line.

Line spacing 25 feet

Geophone spacing 20 feet.

A smaller shothole pattern of 3 holes, 50 feet apart was tried initially, but gave poor results. Subsequent comparisons between 7 holes, 50 feet apart, 5 holes, 50 feet apart and 4 holes, 100 feet apart revealed that a slight improvement occurred in the quality of the early part of the section with the 7 hole pattern. The 4 hole pattern gave a poorer quality record, probably because of the large value of e. (Plate 8).

Further slight improvements in record quality were obtained by increasing the geophone pattern to 24 per trace in line, 15 feet apart, and then to 2 lines of 24 per trace.

It is probable that the slight improvements in quality obtained by lengthening the patterns was due to the increased attenuation of the noise events numbered 7 and 15.

The increase in spreadlength from 880 feet to 1200 feet, decreased the groundmixing from 4/1 to 3/1, but also increased the signal attenuation at the greater offsets. The main reflection band at 0.75 seconds was strong enough to overcome the extra attenuation resulting from the increased pattern lengths and spreadlengths but the shallower events were strongly attenuated on the outer traces, however the greater increase in noise attenuation was sufficient to provide a slight increase in signal:noise ratio. Therefore, although the continuity of these events was not good, a general improvement in their definition resulted from the increased pattern lengths.

The combined theoretical response curve for the final shothole and geophone patterns is shown superimposed on the response: wave number graph (Plate 7). Although the high amplitude noise should be attenuated at the main frequency by some 30 dbs, the signal is also appreciably attenuated and this attenuation may be as high as 15 to 20 dbs, for the outer traces of the shallow event.

6.2 Production Results

The final technique adopted for the production shooting on traverse V.2 and used in the northern part of the traverse was as follows:

Shothole:	7 in line, 50 feet apart Charge 7 x 20 lbs at 80/90 feet
Geophones:	48 per trace in two lines of 24 Line spacing 30 feet Geophone spacing 15 feet
Amplifier filters:	original, 0 - K92 playback, K21 - K75
Prefilters:	18 cps, 12 db/octave
Gain:	initial, - 60 final, usually - 20
A.G.C.:	medium speed

The section produced on traverse V.2 was of fair quality (Plate 10).

The principal event occurs at times ranging from 0.6 seconds to 0.95 seconds, slightly shallower events were recorded between shotpoints 189B and 194B, and again between shotpoints 181B and 184B. Continuity of the shallow events is poor.

Several abnormal events occurr on the section, particularly those with vertices at times of 0.7 seconds at S.P. 175B, 0.5 seconds at S.P. 183B, 1.0 seconds at S.P. 187B, and possibly at S.P. 194B. These events are associated with interference and loss of continuity of the main reflection event.

Low frequency events may be seen immediately following the main reflection event over most of the section.

A t/Delta t analysis was made from the production records and shows an initial decrease in average velocity due to the high velocity effect of the near surface basalt. A velocity function of Vi = 7170 + 0.65Z was found to reasonably fit the section.

7. DISCUSSION OF RESULTS

Several problems associated with the presence of volcanics were expected to occur. These were as follows:-

1. Surface problems

   (a) Energy transmission
   (b) Variations in the weathered layer
   (c) Hard drilling

2. Subsurface problems

   (a) Lateral velocity variations
   (b) multiple reflections

1. Surface Problems

(a) Energy transmission. The results of the experimental programme showed that the best transmission was obtained when the charge was placed within a hard basalt layer and that charges of 100 to 140 lbs gave a significant input down to approximately 2.5 seconds.

(b) Variations in the weathered layer. Although the near-surface formations encountered in the shotholes varied in thickness and extent, no large variations in weathering times were detected.

(c) Hard drilling. Drilling conditions were variable, but average penetration rates of between 50 and 90 feet her hour were achieved. These rates are not considered unenconomical.

2. Subsurface Problems

(a) Lateral velocity variations. The velocity function $V_i = 7170 + 0.65Z$ was found to satisfy the conditions along this traverse. Although the points on the t/Delta t graph were well scattered, no consistent lateral variation could be observed.

(b) Multiple reflections. No multiple reflections were identified within the section above the main reflection although it is possible that the low frequency energy which succeeds the main reflection, represents reverberation type multiples.

In this area the sedimentary section is most likely thin (Ray Geophysical Co., 1963a), although no holes have been drilled to confirm this, and the main interest lies in reflections within the first second. The geophone and shothole arrays used in the final technique have been shown to produce a significant attenuation of the longitudinal noise, but also attenuate the reflections, particularly at shallow depths. It is therefore difficult to obtain good quality records without shortening the spreadlength. This would greatly increase the cost of seismic work.

Although little transverse noise was recorded during the noise test, the irregular nature of the near surface basalt is such that transverse noise is likely to occur. The event with vertix at shotpoint 183B is considered to be a reflected refraction with a path in the near-surface basalt. Using the horizontal velocity for the basalt, of 12,000 feet/sec determined from the first breaks, a curve was computed for a reflected refraction and was found to agree well with the event. A diffraction curve was also computed but was found to have a different curvature. Several weaker events of similar curvature to the reflected refraction can be seen interfering with the shallow reflections.

The events with vertices at shotpoints 175B and 187B are considered to be diffraction patterns. Curves were computed using the velocity function for the area and assuming an origin in the vicinity of the principal reflection. The curves again agreed closely. It is possible that these events represent reflected refractions from a deeper layer of basalt, but their close associations with discontinuities in the main reflection event would suggest that they are diffraction patterns emanating from fault planes.

The main reflection exhibits a pronounced overall dip to the north with a fairly sharp reversal at S.P. 191B. The depth to this horizon varies between approximately 2600 and 4300 feet and no deeper horizons were noted. If the discontinuities at shotpoints 175B and 187B are associated with faults, the faults would be of small throw, probably to the south.

8. CONCLUSIONS

1. A fairly heavy technique, capable of producing reliable results on traverse V.2 was evolved from the experimental programme. The preliminary results on traverse V.3 suggest that this technique will also give reliable results on other volcanic areas in the Otway Basin.

2. None of the expected problems proved to be a significant barrier to obtaining good quality seismic results. The noise recorded at S.P. 180 did not appear to be severe, but the high degree of interference in the shallow part of the section suggests that surface noise may present the major problem in the area.

3. The shallow events are also interfered by reflected refractions with paths in the near-surface basalt, and could also be affected by faulting which appears to occur in the main reflecting horizon.

4. An increase in shallow record quality might be obtained by shortening the spreadlength and possibly by using larger areal patterns designed to attenuate transverse events. However, this would increase the cost of seismic exploration proportionately.

5. The main reflecting horizon is tentatively correlated with igneous basement for the following reasons.

(i) Previous surveys have found that the basement reflection is represented by two or three phases, with a tendency to split, followed by a band of lower frequency energy.

(ii) The depth of section in this area predicted by extrapolation from the previous surveys was of the order of 3,000 to 4,000 feet.

(iii) The high velocity of the refracted event recorded during the noise test and which appeared to be associated with the main reflection.

The depth of section under the traverse would vary therefore from approximately 2,600 feet at the southern end to approximately 4,300 feet at shotpoint 191B.

6. The low frequency energy occurring immediately below the main reflecting horizon remains unaffected by the changes in pattern size. It can therefore be assumed that it originates within the section.

It is particularly strong in the vicinity of the diffraction patterns where there is an overall build up of energy.

It is thought possible that this low frequency energy represents reverberation type multiples.

9. REFERENCES

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" " "	1961c	Velocity survey of Flaxman's No. 1, Victoria, Australia by Robert H. Ray Service Company, Inc. (Unpublished report of Commonwealth subsidised survey).
" " "	1962a	Reflection Seismic Survey. Dartmoor-Nelson Area (Area 4) August 1961 to March 1962 by K.A. Richards and C.L. Samz. Frome Broken Hill Co., Pty. Ltd. Report No. 7200-P.40. (Unpublished report of Commonwealth subsidised survey).
" " "	1962b	Seismic Survey of Area 4, Southwest Victoria, Australia by Ray Geophysics (Australia) Pty. Ltd. (Unpublished report of Commonwealth subsidised survey).
" " "	1962c	Well Completion Report Pretty Hills No. 1, Southwest Victoria by J.S. Bain. Frome Broken Hill Co., Pty. Ltd., Report No. 7200-G.94. (Unpublished report of Commonwealth subsidised survey).
" " "	1963a	Final Report (Reflection Seismograph) Branxholme-Koroit Area, Victoria by Ray Geophysics (Aust) Pty., Ltd., (Unpublished report of Commonwealth subsidised survey).
" " "	1963b	Final Report (Reflection Seismograph) Correimungle Area, Victoria by Ray Geophysics (Aust) Pty. Ltd. (Unpublished report of Commonwealth subsidised survey).
" " "	1963c	Final Report, Permit 22, Southwest Victoria Area, Australia, Marine Seismic Survey by Western Geophysical Co. of America. (Unpublished report of Commonwealth subsidised survey).
" " "	1963d	Final Report (Reflection Seismograph) Princetown Area by Ray Geophysics (Aust) Pty. Ltd., (Unpublished report on Commonwealth subsidised survey).

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1963f Well Completion Report, Eumeralla No. 1, Southwest Victoria by J.S. Bain, Frome Broken Hill Co. Pty. Ltd. Report No. 7200-W.21 (Unpublished report of Commonwealth subsidised survey).

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APPENDIX I.

Staff and Equipment

1. Staff

Party Leader	J.S. Raitt
Geophysicist	B.F. Jones
Observer	G.S. Jennings
Clerk	J.G. Terpstra
Shooter	R.D. Cherry
Driller Grade 2	K. Suehle
Driller Grade 1	J. Keunen
	W. Whitburn
Drill Assistant	L.A. Keast
	A. Murphy
Mechanic	E. McIntosh
Surveyor	P. Pullinen (Dept. of Interior)

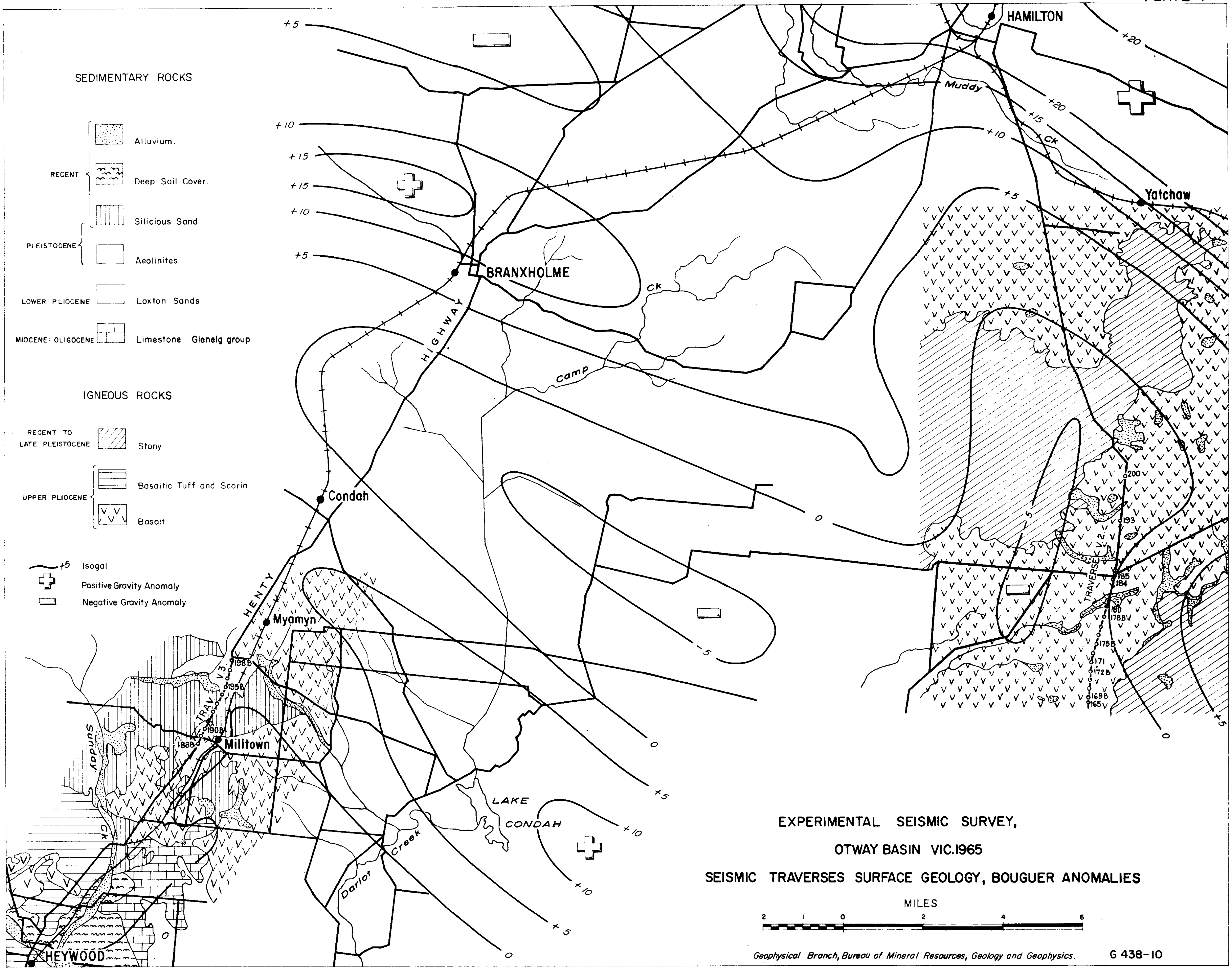
2. Equipment

Amplifiers	Texas Instruments 7000B
Oscillograph	S.I.E. V.T.6
Magnetic Recorders	S.I.E. F.M. PMR.20
	Electro Tech. DS7/700
Programme Gain Control Unit	S.I.E. G.C.U./3 E.C.
Pre Filters	C.G.G.
Geophones	Hall-Sears HS-J (1312 in groups of 8)
Cables	Vector 1800 feet and 1320 feet
Drills	1 Mayhew 1000
	2 Careys
	1 Failing (under contract)

APPENDIX 2.

Operational Data.

Sedimentary Basin	Otway	
Area	Hamilton, Victoria	
Headquarters established	21.4.65	
Surveying commenced	2.4.65	
Drilling commenced	22.4.65	
Shooting commenced	22.4.65	
	V.2	V.3
Datum level for corrections	600'	400'
Weathering Velocity	1,800 ft/sec	3,000 ft/sec
Sub-weathering velocity	10,000 ft/sec	10,000 ft/sec
Static correction method	Uphole times + interpolation	
Velocity function	Vi = 7170 + 0.65Z	
Derivation of velocity function	t/Delta t Analysis	
Total footage drilled	31,260 ft	8,755 ft
Total number of holes drilled	303	91
Total number of field hours	883 hrs.	221 hrs.
Total number of drilling hours	606 hrs.	120.5 hrs.
Average penetration rate (in ft/hour)		
1. Careys	28.5 ft/hr	55.4 ft/hr
2. Mayhew	51.4 ft/hr	69.7 ft/hr
3. Failing	78.4 ft/hr	89.2 ft/hr
Total number of field hours	345 hrs	73½ hrs
Total number of recording hours		
1. Experimental	158¾ hrs	44½ hrs
2. Production	84½ hrs	8½ hrs
Total number of profiles		
1. Experimental	160 hrs	51 hrs
2. Production	70 hrs	4 hrs
Total explosives uses - 3 inch	4260 lbs	620 lbs
2¼ inch	5935 lbs	913 lbs
Total detonators used - 100 feet	527	155
30 feet	73	19
Total miles traversed	5.5	2.3



EXPERIMENTAL SEISMIC SURVEY,

OTWAY BASIN VIC. 1965

SEISMIC TRAVERSES SURFACE GEOLOGY, BOUGUER ANOMALIES

MILES

2 1 0 2 4 6

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. G 438-10

PLATE 2

Traverse V.2

SHOT POINT	RED. LEVEL
165	600.5
166	599.8
167	610.1
168	608.8
169	607.1
170	603.4
171	610.0
172	617.4
173	610.3
174	598.5
175	620.3
176	613.5
177	617.2
178	632.5
179	634.1
180	621.2
181	626.5
182	615.2
183	639.0
184	645.0
185	649.3
186	648.0
187	625.8
188	638.9
189	655.8
190	648.7
191	641.9
192	660.6
193	662.9
194	664.9
195	643.2
196	643.3
197	661.3
198	671.4
199	683.6
200	689.3

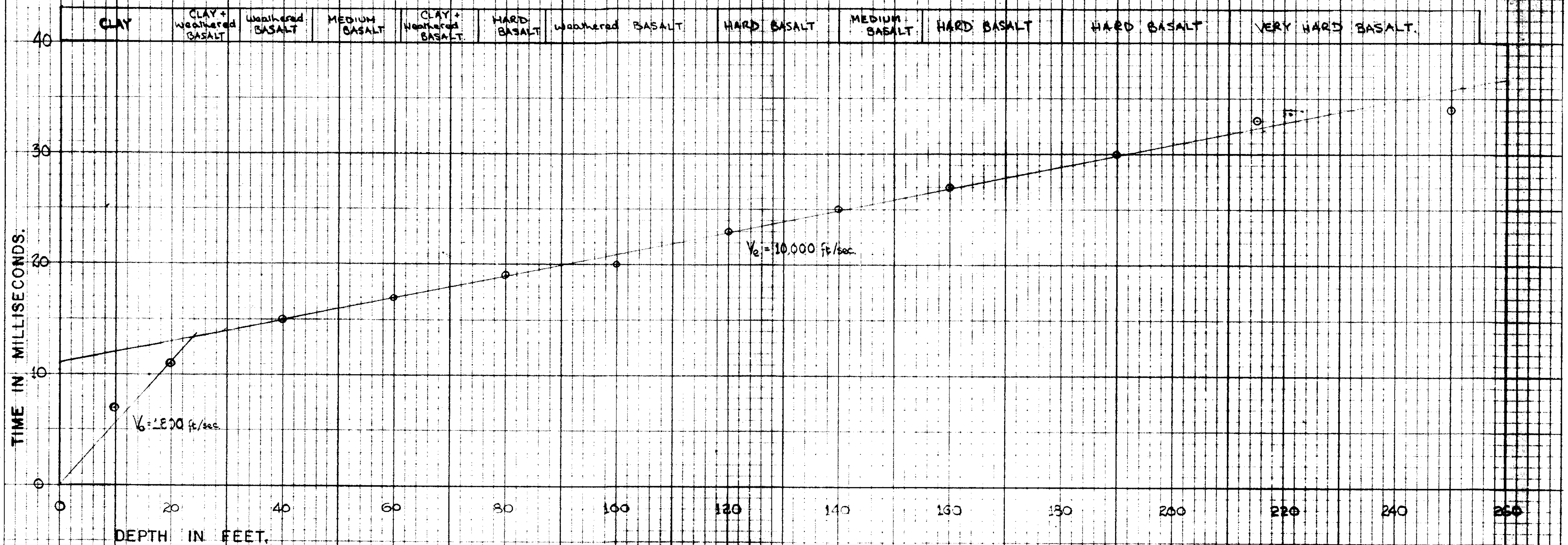
Traverse V.3

SHOT POINT	RED LEVEL
188 B	430.0
189 B	427.8
190 B	436.7
BM 158-E	436.8
191 B	440.1
192 B	436.1
193 B	426.8
194 B	399.3
BM 158-F	394.3
195 B	415.1
196 B	417.7
197 B	405.5
198 B	404.1
P.S.M	400.9

B.M.R. 104

Prepared by the Survey Branch Dept of the Interior Canberra, 1965

PLATE 8



EXPERIMENTAL SEISMIC SURVEY TO COMPARE WITH VIBROSEIS SURVEY

OTWAY BASIN 1965

TRAVERSE V2

UPHOLE SURVEY

S.P. 181.

J54/B3-19

CLAY.

CLAY & W. BASALT.

W. BASALT.

BASALT.

EXPERIMENTAL SEISMIC SURVEY TO COMPARE WITH VIBROSEIS SURVEY

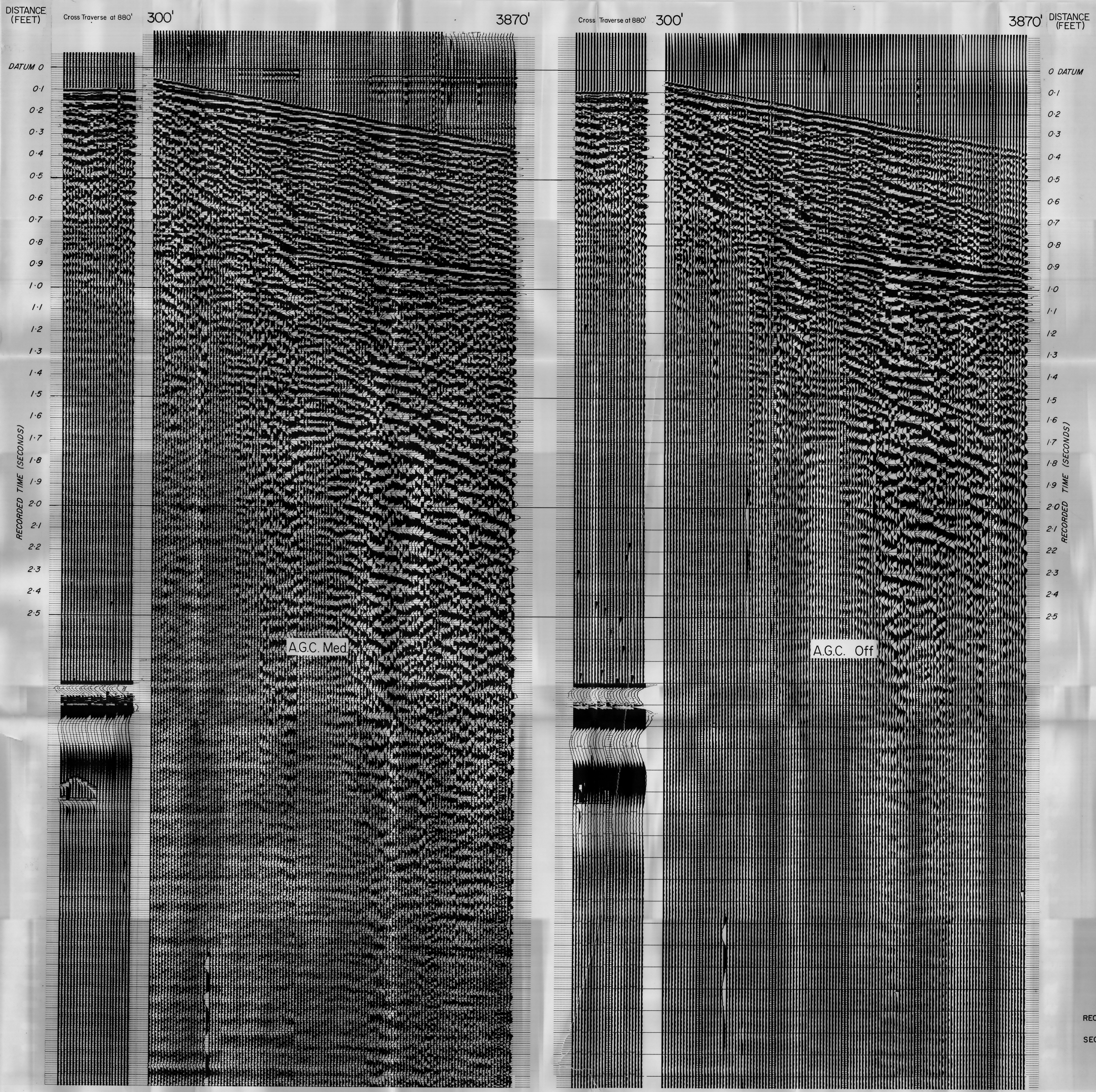
OTWAY BASIN 1965

TRAVERSE V2

WAVE FRONT DIAGRAM UPHOLE SURVEY S.P.181.

50 0 5
SCALE

J54/B3-20



RECORD SECTION

RECORDING INFORMATION

Magnetic Recorder : PMR 20

Amplifiers : 7000B

Filters : KO-K120 PREFILTERS 18c/s, 12db/o

A.G.C. : OFF

Gain Initial : } VARIOUS

Final :

Geophones : HSJ-14c/s

Geophone pattern : 8/ trace, bunched

Shot-hole pattern : —

PLAYBACK INFORMATION

Filters : 1/16-1/135

A.G.C. : Med. and Off

	With A.G.C.	W/out A.G.C.
Gain Initial :	-40	-40
Final :	-20	-30

Trip delay : 0

Compositing : Nil

VELOCITY INFORMATION

—

HORIZONTAL SCALE

Longitudinal bases – 30' between traces

Transverse bases – 25' between traces

EXPERIMENTAL SEISMIC SURVEY
FOR COMPARISON WITH
VIBROSEIS SURVEY, 1965
OTWAY BASIN

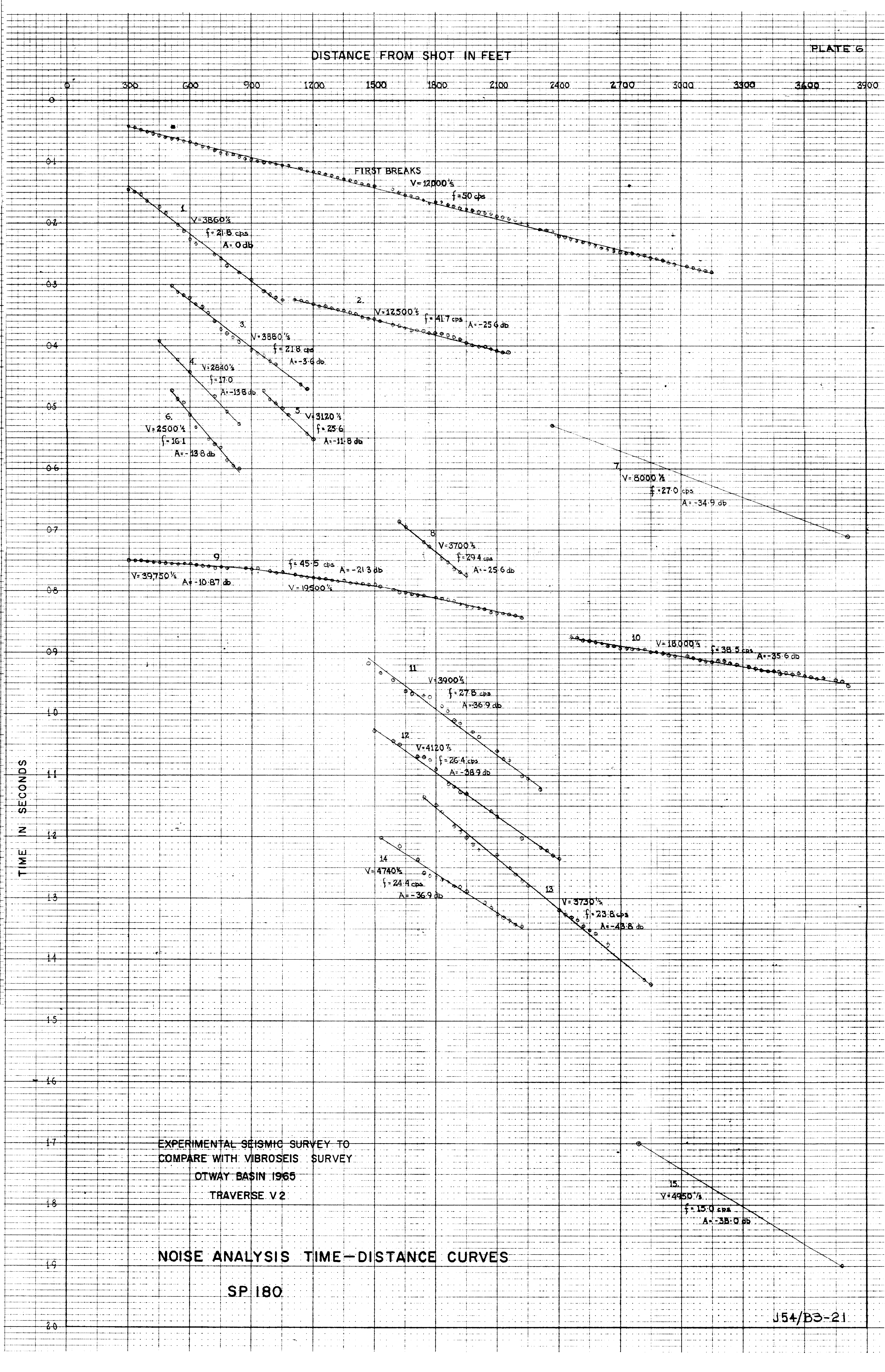
TRAVERSE V2

NOISE ANALYSIS S.P. 180

RECORDED BY : *Seismic Party No. 2*

SECTION BY : *Bureau of Mineral Resources Playback Centre SIE MS 42*

J54/B3-4-1



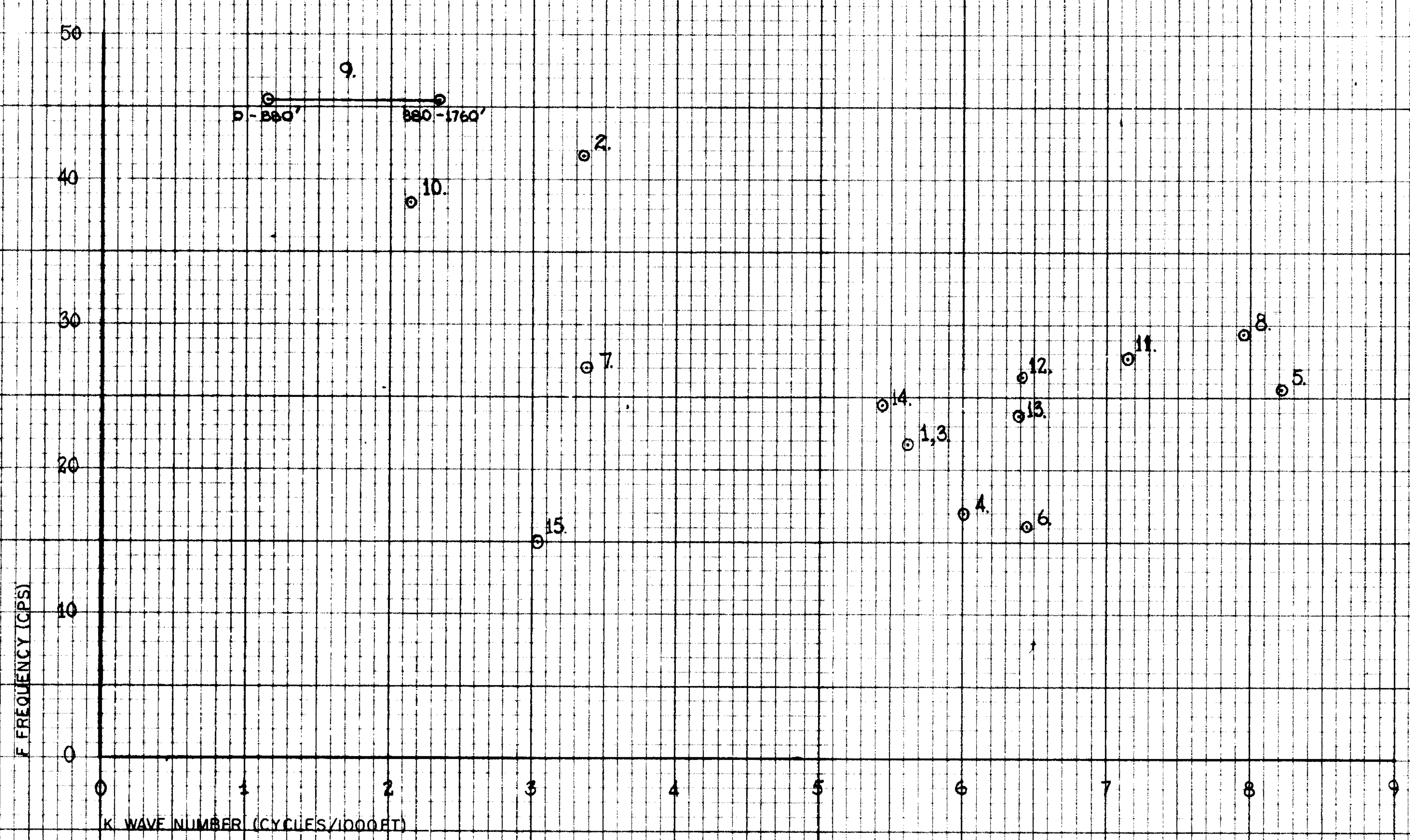
EXPERIMENTAL SEISMIC SURVEY TO
COMPARE WITH VIBROSEIS SURVEY
OTWAY BASIN 1965
TRAVERSE V2

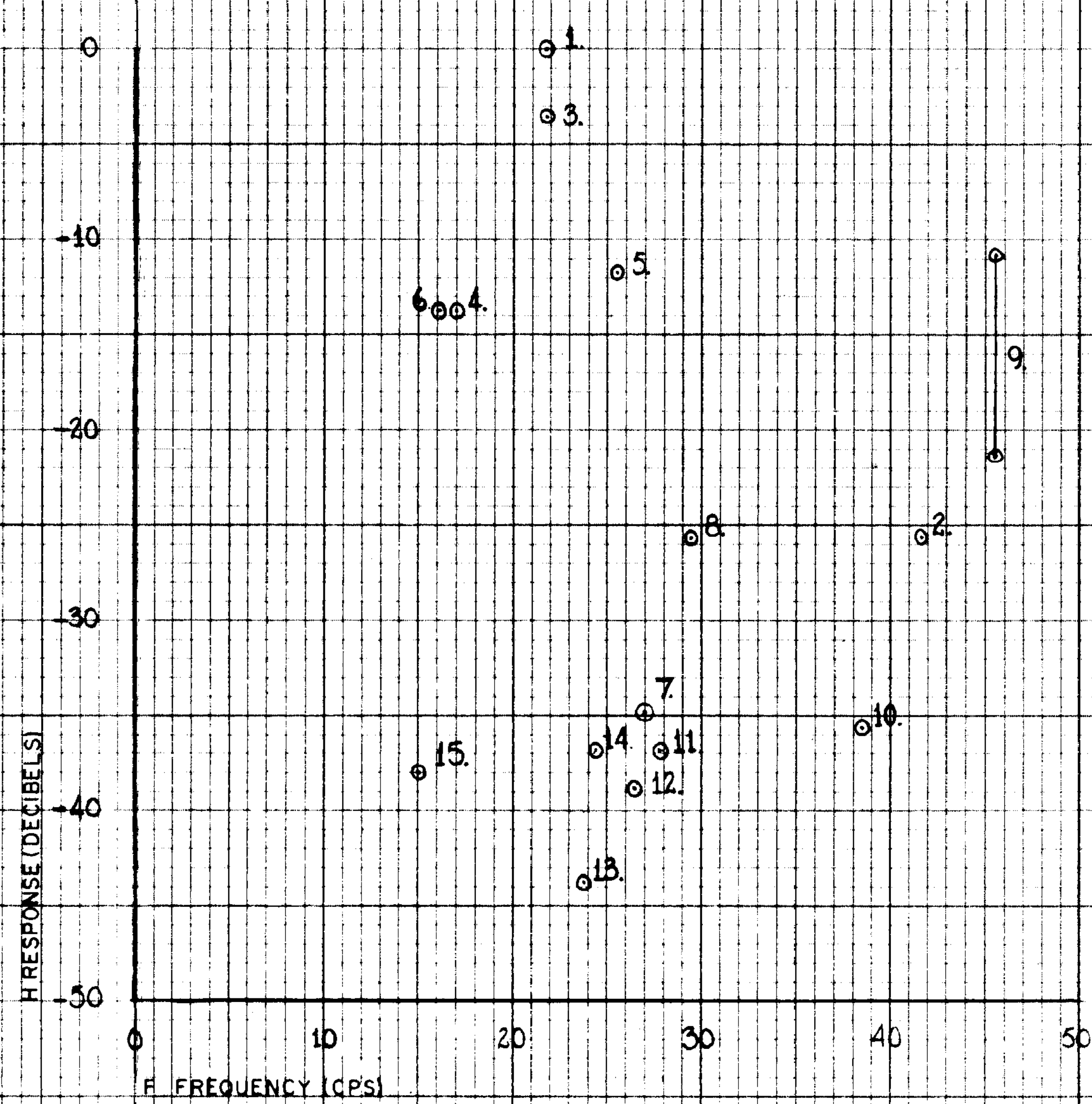
NOISE ANALYSIS TIME—DISTANCE CURVES

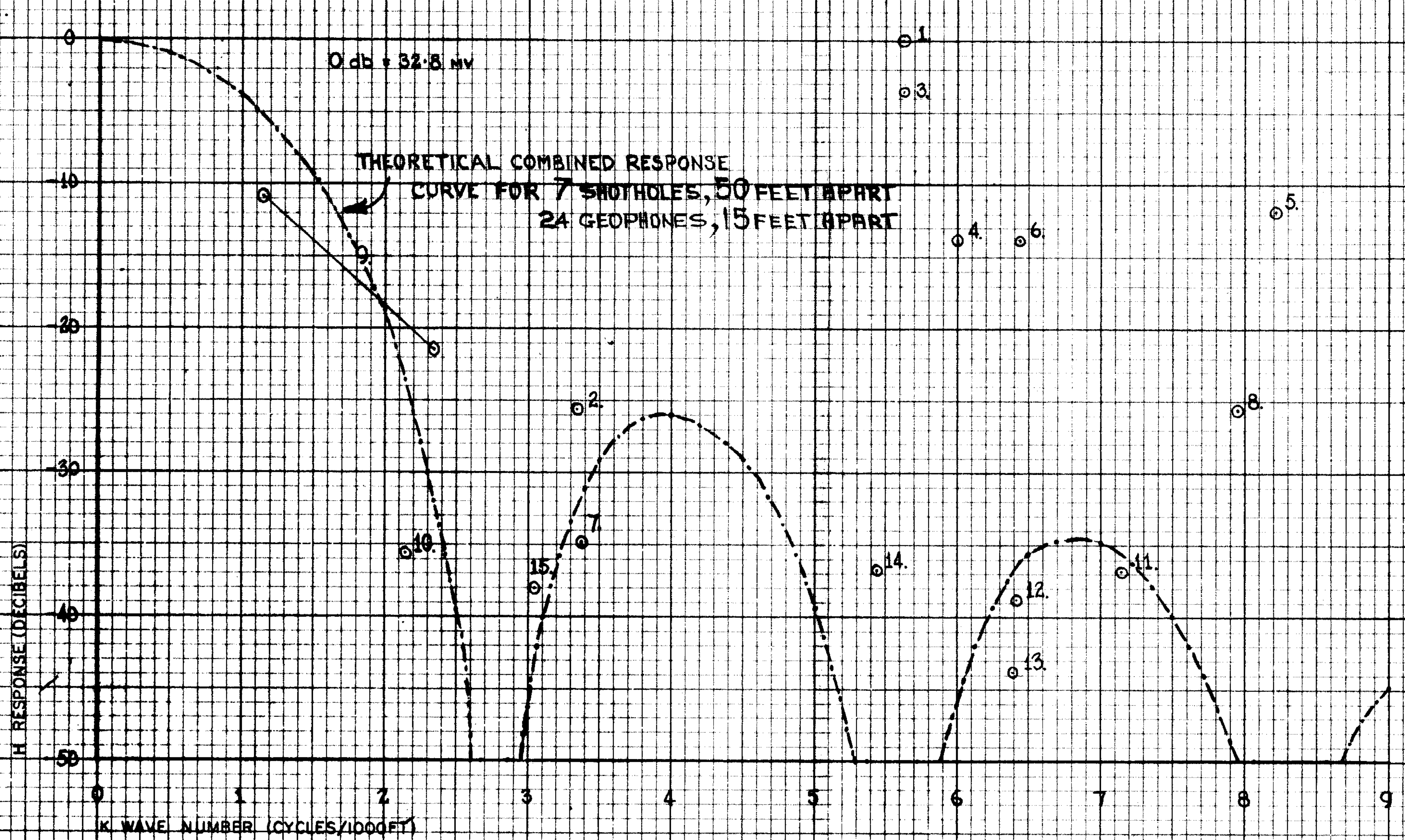
SP 180

J54/B3-21

PLATE 7







EXPERIMENTAL SEISMIC SURVEY TO COMPARE WITH VIBROSEIS SURVEY

OTWAY BASIN 1965.

TRAVERSE V2

NOISE ANALYSIS

SP 180

J54/B3-22

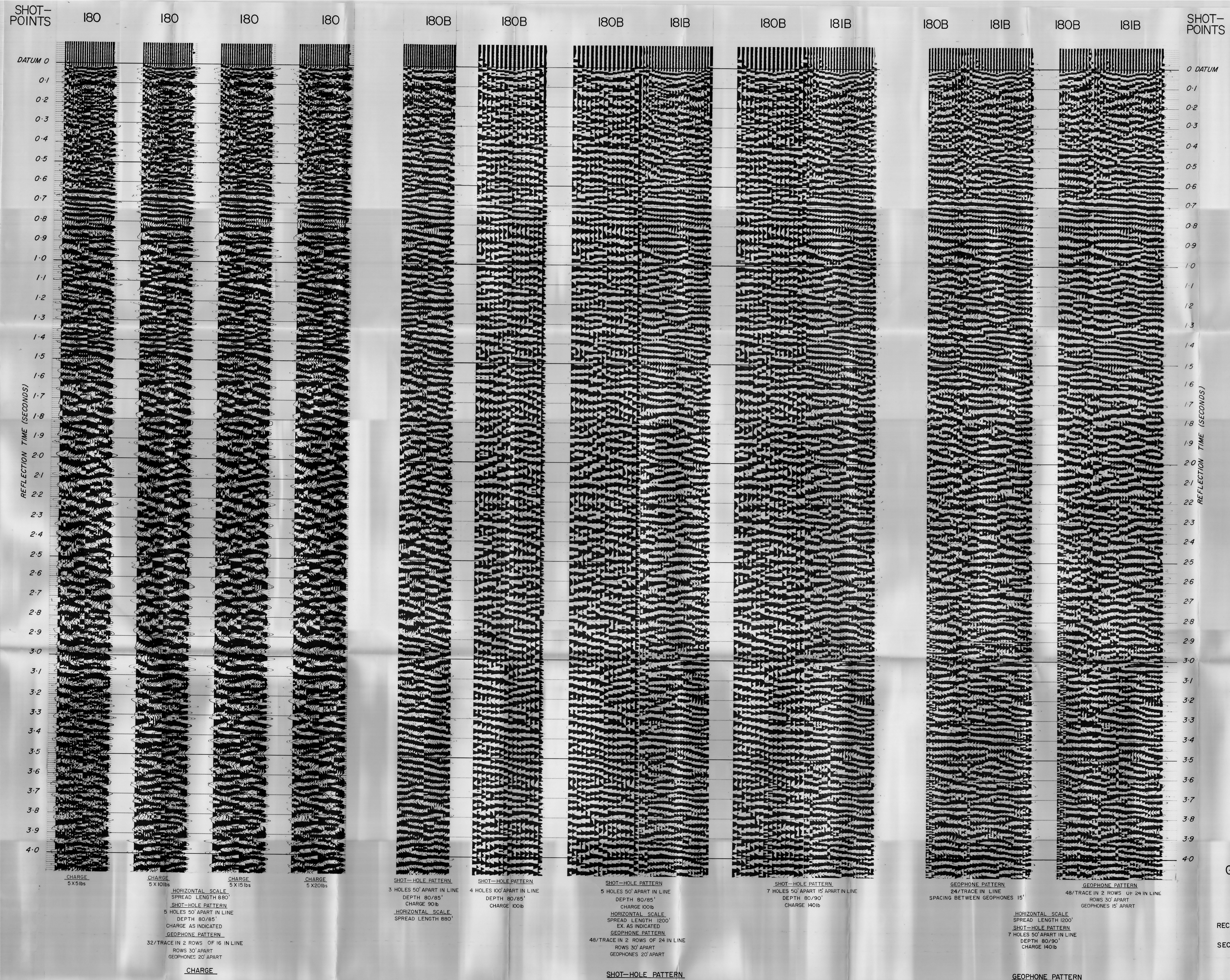


PLATE 8

CORRECTED RECORD SECTION

RECORDING INFORMATION

Magnetic Recorder : PMR 20

Amplifiers : 7000 B

Filters : KO–K92
PREFILTERS 18 c/s, 12 db/o

A.G.C. : Med.

Gain Initial : –60

Final : –20

Geophones : HSJ–14 c/s

Geophone pattern :
As Indicated

Shot-hole pattern :
As Indicated

PLAYBACK INFORMATION

Filters : 1/20–1/78

A.G.C. : Med.

Gain Initial : –40

Final : –20

Trip delay : 0

Compositing : Nil

VELOCITY INFORMATION

t∆t analysis

HORIZONTAL SCALE
As Indicated

EXPERIMENTAL SEISMIC SURVEY
FOR COMPARISON WITH
VIBROSEIS SURVEY, 1965
OTWAY BASIN

TRAVERSE V2

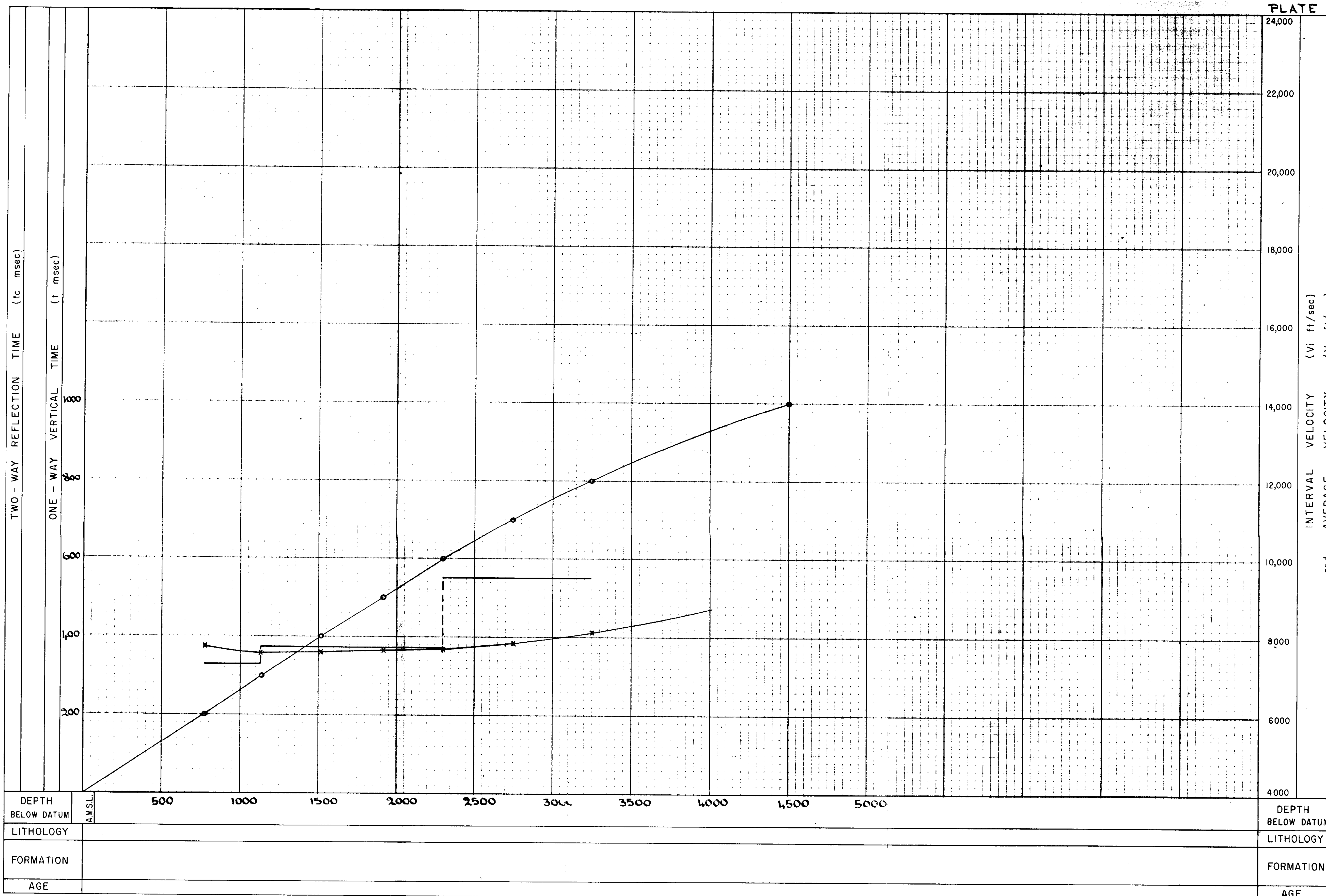
GEOPHONE PATTERN, SHOT-HOLE PATTERN
AND CHARGE COMPARISION

RECORDED BY : *Seismic Party No. 2*

SECTION BY : *Bureau of Mineral Resources*
Playback Centre SIE MS 42

J54/B3-3-1

PLATE 9



(Based on G 85/3-18)

LITHOLOGY

Time / depth curve (t-d)
Interval velocity (Vi)
Average velocity (Va)

Sandstone
Siltstone
Shale
Limestone

VELOCITY AND TIME VERSUS DEPTH

AREA **OTWAY BASIN, VIC.-V2.**

Basis **TΔT ANALYSIS.**

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

J54/B3-23

CORRECTED RECORD SECTION

RECORDING INFORMATION

Magnetic Recorder : PMR 20

Amplifiers : 7000B

Filters : KO-K92
PREFILTERS 18c/s, 12db/o

A.G.C. : Med.

Gain Initial : −60

Final : −20

Geophones : HSJ-14c/s

Geophone pattern :

SP170B, 171B, 172B, and 180B-195B	SP173B-179
48/trace in 2 rows of 24 in line	32/trace in 2 rows of 16 in line
Rows 30' apart	Rows 30' apart
Geophones 15' apart	Geophones 20' apart

Shot-hole pattern :

SP170B, 171B, 172B, and 180B-195B	SP173B-179
7 holes, 50' apart in line	5 holes 50' apart in line
Depth 80/90'	Depth 80/90'
Charge 7x20lb	Charge 5x20lb

PLAYBACK INFORMATION

Filters : 1/20-1/78

A.G.C. : Med.

Gain Initial : −40

Final : −20

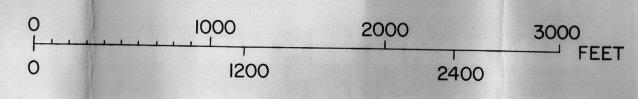
Trip delay : 0

Compositing : Nil

VELOCITY INFORMATION

tΔt

HORIZONTAL SCALE



EXPERIMENTAL SEISMIC SURVEY
FOR COMPARISON WITH
VIBROSEIS SURVEY, 1965
OTWAY BASIN

TRAVERSE V2

RECORDED BY : *Seismic Party No. 2*

SECTION BY : *Bureau of Mineral Resources*
Playback Centre SIE MS 42

J54/B3-5-1