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OTWAY BASIN (GAMBIER LIMESTONE AND SAND DUNE PROJECTS) EXPERIMENTAL SEISMIC SURVEY FOR COMPARISON WITH A "VIBROSEIS" SURVEY,

SOUTH AUSTRALIA 1965

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SUMMARY

Experimental seismic surveys using conventional shot-hole techniques were made on three traverses in the Otway Basin, South Australia, over two types of surface formation. The investigation formed part of a project to obtain a comparison of the shot-hole and "Vibroseis" techniques on the basis of quality of results and operation costs, in areas where previous seismic work had obtained poor results. Two traverses were chosen as being representative of areas of Gambier Limestone cover and one traverse as representative of areas with Pleistocene sand dune cover.

On all traverses, "heavy" techniques were developed which yielded fair to good results, and which are considered to be an improvement on the results obtained by the "Vibroseis" survey in 1964.

1. INTRODUCTION

During the period mid-June to the end of August 1965, the Bureau of Mineral Resources Seismic Party No. 2 made an experimental seismic survey on three traverses in the Mount Gambier region of South Australia. The traverses were Traverse GL2, twelve miles south of Mount Gambier; Traverse GL3, near Glencoe; and Traverse SD2, north from Tarpeena (Plate 1).

The work forms part of an experimental programme designed to provide a comparison between the conventional shot-hole and the "Vibroseis" seismic methods in certain seismic 'problem areas'. The three traverses described in this Record were selected as being representative of areas of outcropping Tertiary limestone (Traverses GL2 and GL3) and of outcropping Pleistocene dune sand (Traverse SD2). On both of these formations, previous shot-hole seismic investigations had not produced good results.

The traverses were laid out alongside good roads and access was not, in general, a problem; however, a fourth traverse in the area, Traverse SD1, immediately south of Traverse SD2, which was to have been surveyed, was omitted from the programme as it lay under water for the duration of the period of the survey.

This Record covers the shot-hole seismic work done during 1965 and does not attempt a detailed comparison with the "Vibroseis" survey which was carried out in 1964 (Seismograph Service Limited, 1964). This comparison will be made in a later report (Moss, in preparation).

The staff employed and equipment used on the field party are listed in Appendix 1; operation details are listed in Appendix 2.

2. GEOLOGY

This section is based on a summary of the geology of the Otway Basin abstracted by F. J. Moss (pers. comm.) from numerous reports by private companies and the South Australian Mines Department.

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 regional geology of the basin is shown in Plate 2.

The land area is divided into several Tertiary sub-basins, which are, from west to east :

(1) the Gambier Sunklands - separated from the Murray Basin to the north by the Padthaway Horst and its south-easterly 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 Quaternary to Recent sands, dunes, marshes, and volcanics and Tertiary volcanics and marine limestones. Knowledge of the deeper stratigraphy and structure has been obtained from stratigraphic bores and geophysical surveys.

The main stratigraphy of the basin is summarised in Table 1.

TABLE 1

Stratigraphy of the Otway Basin

Age	Description	Maximum thickness(ft)
Pleistocene	Basalts, tuff, scoria, and sand dunes	?
Pliocene	Alluvium	
Oligocene	Heytesbury and Glenelg Groups (Gambier limestone, limestone, and marls)	2900
Eocene-Palaeocene	Wangerrip and Knight Groups (Quartz sandstone and conglomeratic sandstone with much clay and siltstone)	5000
	Disconformity	
Upper Cretaceous	Paarrette Formation (Glauconitic sands and carbonaceous shales. Probably more abundant in the Gambier Sunklands)	1000
Upper and Lower Cretaceous	Belfast Mudstone (Clayey and glauconitic mudstone)	2000
	Unconformity	
Lower Cretaceous	Flaxmans Beds (Sandstone, limonitic chloritic and sideritic greywacke)	400
	Waarre Formation (Subgreywackes, minor sandstones and siltstones)	450
Lower Cretaceous/ Upper Jurassic	Otway-Merino Group (Basal sand - Lower Cretaceous - arkosic sands, greywacke, and mudstone)	7000

The surface formation in the area of Traverses GL2 and GL3 is the Gambier Limestone; a soft, white, friable marine limestone with occasional hard flint beds in the sequence. It is present throughout the Gambier Sunklands and in parts of the Portland Sunklands mostly beneath more recent formations. The formation has a maximum thickness of about 530 feet near the coast and thins out inland. It crops out in the Gambier Sunklands over an area to the south and east of Mount Gambier, where the prospective sedimentary sequence thickens considerably. It is very cavernous in the south-eastern part of the Gambier Sunklands (in the area of Traverse GL2), but less cavernous in the Portland Sunklands.

Traverse SD2, near Tarpeena, is over aeolian consolidated beach sands of Pleistocene age, which overlie Gambier Limestone.

3. PREVIOUS SEISMIC WORK

General

The Bureau of Mineral Resources made the first seismic tests in the Otway Basin, mainly in areas of basalt cover near Heywood, Victoria, in 1956 (Lodwick & Vale, 1958). Since 1956, seismic crews of the Department of Mines, South Australia, and contractors employed by the leaseholders have shot approximately 2700 miles of traverses using conventional seismic equipment and shot-hole methods. This work has been done in the coastal areas of the Portland Sunklands, in the Gambier Sunklands, and off shore from the coast of south-west Victoria.

The off-shore work has been generally successful. It indicates the existence of a deep structural trend roughly parallel to the coast in a WNW direction and a series of very gentle ENE-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 have been obtained. Large areas with sand dune cover and Gambier Limestone cover have been generally avoided owing to various difficulties experienced in the limited amount of seimic work that has been done on these formations.

Shot-hole seismic surveys

Seismic traverses, made in the Gambier Sunklands by seismic parties of the Department of Mines, South Australia, and contractors employed by the leaseholders, have generally been of a reconnaissance nature. The techniques used have generally been simple ones and little experimental work has been conducted in no-reflection and poor-reflection areas other than normal testing for optimum hole depths and charge sizes.

Single holes, 30 to 60 ft deep, with a normal charge of 5 to 10 lbs have been shot into conventional split spreads, normally with four geophones per trace and 10 to 15 ft between geophones. Seismic results are fair in most areas that have been surveyed, but results are generally poor when shooting on Gambier Limestone or on sand dunes.

"Vibroseis" survey, 1964

Experimental "Vibroseis" surveys were made on :

(a) areas of outcropping Gambier Limestone (a six-week period in June and July);

(b) areas of sand cover (a two-week period in July and August); and

(c) an interdunal poor reflection area (a three-day period in August).

The main experimental Gambier Limestone traverse over Gambier Limestone (Traverse GL2) was located two miles west of Mount Schanck (Plate 1). Noise spreads recorded on this traverse indicated three discrete high-amplitude events with velocities of 2500, 3300, and 7200 ft/s. After considerable experimentation designed to attenuate these interference events in order to obtain effective penetration, four miles of traverse were recorded using a transposed method. Diamond-shaped detector patterns, 400 ft long by 400 ft wide, and 200 ft long source patterns were used with a sweep in the 14-57 c/s range (mean 35 c/s). The effective sampling was over 24,000 separate ray paths. The low velocity, high-amplitude interfering events were not effectively attenuated using this transposed "Vibroseis" method, thus the reflection events are of poor quality relative to this noise. Part of the traverse was repeated using a ten-fold common-depth-point (C.D.P.) method with source and detector in-line patterns 200 ft long. In this case the compositing considerably attenuated the interfering events.

Fair quality results were obtained on this traverse, with reflections recorded down to about 2.3 seconds. The continuity of a shallow band of reflections between 0.8 and 1 second was good, but the continuity of deeper reflections was poor especially at the ends of the traverse. The C.D.P. work slightly improved the quality of the shallower events at about 0.8 to 1 second, but no improvement was noted in the quality or continuity of the deeper events. Thus the possibility that some of the deeper events recorded are multiples cannot be discounted.

Recordings were also made on Gambier Limestone outcrops near Glencoe, about 15 miles north-east of Mount Gambier, on Traverse GL3, to test the applicability of the methods found to be best for recording on Traverse GL2. The coherent noise level was found to be considerably lower on this traverse. Fair quality reflections were recorded down to 1 second and poorer quality non-continuous events are evident to approximately 2.8 seconds. The results were comparable with those obtained by shot-hole methods.

Generally, fair quality reflection information was obtained on Gambier Limestone outcrops using "Vibroseis" methods, but the problem of overcoming the high-amplitude interference events was not resolved. This appears to limit penetration by this surface method.

"Vibroseis" recordings were made along Traverse SD1 along the highway south of Tarpeena on the Mount Gambier to Penola road (Plate 1), to the south of a sand sheet. Fair quality reflections showing slight south dip were obtained to a reflection time of 1 second over 1 mile of traverse, and poorer quality reflections to about 2 seconds using source patterns 400 ft long, detector patterns 400 ft long by 200 ft wide, and a sweep within the range 14-57 c/s (mean 35 c/s). The results were comparable with those obtained by shot-hole methods.

A noise test was recorded on the sand cover to the north of Tarpeena on Traverse SD2 (Plate 1). A transposed recording technique was developed similar to that used on the Traverse SD1 but using twice the number of sweeps to obtain effective penetration. Fair to poor quality reflections were recorded to about 1.8 seconds. These showed consistent southerly dip. It was concluded, from the limited amount of "Vibroseis" work carried out, that the reflection information could be obtained on this sand covered area using a high effort.

Velocity information

In the Gambier Sunklands, vertical velocity information has been found from t:Δt analyses computed from fair-reflection information. The velocity function V_a=5300 + 0.65d was found to apply in the northern part of the Sunklands and V_a=6300 + 0.3d in the Beachport area. The "Vibroseis" results in the Sunklands were generally dynamically corrected using the Beachport area function, but on Traverse GL2 the application of this function slightly overcorrected the curvature of reflection. Consequently a function derived from the Beach Petroleum Geltwood Beach No. 1 well (Bureau of Mineral Resources, 1965), viz. V_a=5934 + 0.25d, was adopted for correction purposes on results from Traverse GL2.

4. OBJECTIVES

The main objective of the survey was to obtain a comparison of the shot-hole and the "Vibroseis" techniques in difficult seismic reflection areas in 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 with those of previous shot-hole seismic surveys. However, these previous surveys involved very little experimentation and the techniques used on the Gambier Limestone and Sand Dunes areas had been fairly 'light'.

An objective of the survey was, therefore, to appraoch an increased effort factor, by means of a logical and detailed experimental procedure, arriving at a technique which, while limited by economic considerations, was to be capable of producing reliable results.

Maximum possible depth of penetration was to be sought, and if it was thought that multiples were present, attempts would be made to attenuate them.

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 shot-hole and "Vibroseis" methods will be based on this shooting. Production shooting was necessarily 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 must be found. These problems are discussed below.

Gambier Limestone

The problems thought to be associated with the limestone where it crops out, were as follows :

(a) Energy transmission. The transmission of seismic energy through the section was thought to be difficult mainly owing to the cavernous nature of the limestone. There may be other reasons for the poor transmission of seismic energy but nothing further was known. However, the "Vibroseis" survey had indicated that energy transmission was not so bad as had been thought.

(b) Noise problem. The "Vibroseis" results indicated that there was a definite noise problem. It was considered that if this could be overcome it might result in good reflections being recorded, since the "Vibroseis" results showed that energy transmission does not constitute a major problem.

(c) Difficult drilling. Previous drilling had been difficult and costly in this formation owing to loss of circulation and to a slow penetration rate through flint beds, which are often present in the limestone sequence.

Sand dunes

Recent coastal sand dunes and consolidated fossil dunes form low ranges parallel to the coast in the Gambier Sunklands. These dunes have been avoided wherever possible but where shooting has been carried out on them, seismic results have been poor.

Previous drilling on these dunes has been difficult and there have been problems of poor energy transmission.

5. PROGRAMME

Three problems were outlined in the Gambier Sunklands for the "Vibroseis" survey. Of these, the Gambier Limestone was exhaustively tested, but the two others, the sand dunes and the interdunal poor-reflection area were very superficially treated. Since the "Vibroseis" results were not good for these last two problems and since very little effort had been made towards their improvement, it was felt that no great effort should be made on the shot-hole survey to obtain results for comparison purposes. In particular it was decided to abandon the interdunal poor-reflection area, on which the "Vibroseis" party spent only three days. Traverse SD1, part of the sand dunes problem, was abandoned during the present survey, without any work being done on it, because the area lay under water for the duration of the survey.

Gambier Limestone

Approximately six weeks were spent on Traverse GL2 on experimentation and shooting a profile. The technique found was also used to record a profile on Traverse GL3, this work taking three days. Included in the six weeks of shooting on Traverse GL2 were two weeks of additional experimentation and profiling forming an investigation into the significance of traverse noise in the area; this portion of the work does not form part of the main programme, viz., the comparison of the shot-hole and "Vibroseis" methods, but was an additional programme proposed after the completion of the first four weeks work on Traverse GL2. It will be described in a later report and no further mention of it will be made here.

Uphole shoot

The experimental programme on Traverse GL2 commenced with an uphole shoot at SP 689 from a maximum depth of 202 ft. The shooting was also recorded with a conventional split-spread of total length 3520 ft, with 24 geophones per trace, 10 ft apart and in line. Several reflections were recorded and a best shooting depth of about 60 ft was indicated.

Noise test

After the uphole shoot, a noise test was shot from SP 689 into spreads extending 3870 ft to the west. The nearest geophone to the shot was at 300 ft, and the trace interval was 30 ft (a total of 120 traces in 5 spreads of 24 traces, numbered 1 to 5 from the shot-point). Eight geophones per trace were used in a bunch. The charges used were 20 lb per shot into spreads 1 to 5, 10 lb per shot into spreads 1 to 4, and 30 lb per shot into spreads 3 to 4. The charges were placed 60 ft deep. The reason for shooting several charges into some spreads was to attempt to measure the change in signal-to-noise ratio with charge size. The shots were recorded with linear gain, varied according to the distance from the shot; 18 c/s low-cut pre-filters and 120 c/s high-cut amplifier filters were used.

In addition, a transverse noise spread was recorded from the same shot-point with a 10-lb charge, the spread being at a distance of 1720 ft from the shot. The take-out interval was 25 ft (24 traces altogether). Eight geophones per trace were used, spaced 20 feet apart and parallel to the traverse. The same recording and shot parameters were used.

Three main groups of longitudinal organised noise were recorded in addition to some signal (Plate 3). The noise analysis (Plate 4) indicated that patterns of shots and geophones had to be more than 250 ft long; a geophone group of 24 geophones 10 ft apart was used in most of the subsequent testing.

Depth and charge comparisons. An additional comparison was made at SP 693 to check the best shot-depth that was indicated by the uphole shoot at SP 689. Depths between 40 and 100 ft were tried with one hole. A best depth in the region of 50 to 60 ft was confirmed.

Five-hole patterns with 50-ft intervals between holes and charges of 5 x $1\frac{1}{2}$ lb, 5 x $2\frac{1}{2}$ lb, and 5 x 5 lb were shot into a split spread to compare charges. Of these, the 5 x 5-lb charge gave the best results. Despite the improvement in quality with charge there was also an apparent increase in the amount of high frequency noise on the records.

Split spreads of total length 3520 ft were used for all these comparisons.

Further comparison tests. Poor continuity on the reflection events recorded with the charge and depth comparison shots suggested that a shorter spread length would improve the records. Using five-hole patterns, a comparison of split spreads having total lengths of 3520 ft and 2640 ft was made over a short section of traverse. The improvement with the shorter spread was questionable so that shooting was continued using 3520-ft spreads at this stage.

As 5 x 5 lb was the largest charge size tried at this stage it was decided to investigate the effect of further increasing the charge. At the same time, in an effort to suppress the high frequency noise, the unit charge size was kept as low as possible by increasing the number of holes, and the spatial filter was modified slightly by small changes in the shot-hole pattern length. The following shot-hole pattern comparisons were made :

SP 687 : 5 holes in 1 line 50 ft apart (5 x 5 lb at 53/55 ft)
SP 685 : 5 holes in 1 line 50 ft apart (5 x 5 lb at 53/55 ft)
SP 687 : 18 holes 40 ft apart (18 x $2\frac{1}{2}$ lb at 18 ft) in 3 lines 40 ft apart
SP 685 : 18 holes 40 ft apart (18 x $2\frac{1}{2}$ lb at 18 ft) in 3 lines 40 ft apart
SP 687 : 10 holes 50 ft apart (10 x 5 lb at 52/54 ft) in 2 lines 40 ft apart
SP 687 : 7 holes in 1 line 40 ft apart (7 x 15 lb at 47/50 ft)

The 18-hole, Kelly-depth patterns gave poor results, probably because the charge was positioned above the water table; however, it was considered that deeper holes would prove uneconimical with such a large pattern. The 10-hole pattern gave no significant improvement over the 5-hole pattern. The 7-hole pattern, however, improved continuity on the outside traces.

A more detailed comparison of 5-hole patterns with 50-ft spacing and 7-hole patterns with 40-ft spacing was then made at SP 687 using different charge sizes: 5 x 5 lb, 5 x 10 lb, 7 x $7\frac{1}{2}$ lb, 7 x 10 lb, and 7 x 15 lb. The 7-hole patterns gave better results and the largest charge tried (7 x 15 lb) gave the best results.

A comparison of 24 geophones per trace 10 ft apart in one line and 48 geophones per trace 10 ft apart in two lines 30 ft apart was made at SP 687. The larger pattern gave a definite improvement in the quality of events down to two seconds.

Production shooting, Traverse GL2. Production shooting was commenced at SP 699 using the following technique :

Spread length : 3520 feet, 24 take-outs 146.7 ft apart

Shot-holes : 7 holes 40 ft apart in line, 7 x 15 lb charge at 50/56 ft

Geophones : 48 geophones per trace in two rows of 24, 10 ft apart, the rows being 30 ft apart.

During, and at the completion of, production shooting, comparisons were made with a longer pattern length: 9 holes 40 ft apart and with the geophone interval increased from 10 to 15 ft. Although the larger patterns improved most events to some extent, the improvement was offset by the deterioration of the outside traces on the shallow events, and it was decided not to use them. Also, the charge was increased to 7 x 20 lbs, at SP 681, SP 683, and SP 689, where quality deteriorated with 7 x 15 lb.

Velocity shoot. The best section of the production profile was in the region of SP 691, so this section was chosen for the shooting of an extended spread velocity shoot.

Additional profiling. In view of the general improvement shown by using longer patterns in comparison tests made during the production shooting, it was decided to shoot a small section using these with a reduced spread length to prevent the outside traces on shallow events from being attenuated. The section from SP 675 to SP 681 was re-shot using the following technique :

Shot pattern : 7 holes in line 50 ft apart with 7 x 20 lb charge at 50/55 ft

Geophone pattern: 48 per trace in rows of 24, 15 ft apart, the rows being 30 ft apart

Spread : split spread of total length 2640 ft

This profile gave a significant improvement in record quality over the main production section. Lack of time prevented the re-shooting of the whole traverse with this technique.

Production shooting, Traverse GL3. The same technique as described above under "Additional profiling" was used to shoot the production profile on Traverse GL3.

Sand dunes

Twelve days were spent on Traverse SD2 on experimentation and on shooting a profile with the best technique found.

Uphole shoot. The experimental programme on Traverse SD2 commenced with an uphole shoot at SP 1101-1/3 from a maximum depth of 87/95 ft using 20-lb charges. The shooting was recorded with a split spread of total length 3520 ft, using 16 geophones per trace 15 ft apart in one line. Several reflection events were recorded and the best quality was from a shooting depth of about 40 ft. Another, deeper hole at SP 1105-1/3 collapsed to 80 ft after the first shot at 200 ft.

Noise shoot. A noise shoot was conducted from SP 1100, (Plate 5) using the same spread as described for Traverse GL2. A large number of events was recorded at times down to 1.0 second , several of which were classed as signal. From the noise analysis (Plate 6) it was decided to try patterns about 250 ft long for initial experimentation. The preponderance of shallow events, and the proposed pattern lengths of 250 ft indicated that the total spread length should be reduced from 3520 to 2640 ft.

Comparison shots. Comparisons were made at SP 1100 between 3 and 5 holes and at SP 1101 between 5 and 7 holes, the intervals being 50 ft in all cases. The geophone pattern used was 16 geophones in line 15 ft apart. The 7-hole pattern gave the best results. Using this shot-hole pattern at SP 1101, comparisons were made using the following geophone patterns :

16 in line, 20 feet apart.

3 rows of 16 as above, rows 30 ft apart.

24 in line, 15 feet apart.

2 rows of 24 as above, rows 30 ft apart.

The 3 rows of 16 geophones gave the best result.

Using this geophone pattern, shot-hole patterns of 5 holes in line 70 ft apart, and 7 holes in line 50 ft apart (all 40/45 ft deep) were compared at SP 1102, SP 1103, and SP 1104. The charges used were 5 x 20 lb and 7 x 15 lb. Very little difference could be seen at any of the shot-points so that the 5-hole pattern was chosen, being more economical.

Production shooting, Traverse SD2. Production shooting was carried out on Traverse SD2 using the following technique:

Spread : Split spread of total length 2640 ft

Shot-hole pattern: 5 holes in line 70 ft apart, with 5 x 20 lb of Geophex at 40/45 ft

Geophone pattern : 48 geophones per trace in 3 rows of 16 geophones 20 ft apart, the rows being 30 ft apart.

At SP 1112 and SP 1113 the record quality was poor owing to low energy, so these two shot-points were re-shot using 10 holes in line 35 ft apart and a charge of 10 x 30 lb. These records showed considerable improvement.

6. RESULTS AND DISCUSSION

Traverse GL2

Near-surface conditions. Despite reports of difficult drilling conditions on the Gambier Limestone, the conditions presented no problem on this traverse. Drilling logs show limestone with some hard flint bands up to 6 inches thick. The deepest hole drilled (210 ft at SP 689) did not penetrate further than this formation. No cavities large enough to cause circulation difficulties were encountered. The penetration rates for drilling on all traverses are shown in Appendix 2.

The uphole shoot at SP 689 showed only one vertical subweathering velocity, 7200 ft/s, down to at least 200 ft. The horizontal velocity as recorded by first breaks was also 7200 ft/s. There were no significant changes in these velocities along the traverse. The weathering depth was subject to only minor variations and was about 20 ft, the velocity of the weathered layer being about 2000 ft/s.

Noise shoot. The noise shoot sections using 10-lb charges and 20-lb charges are shown in Plate 3, played back both with A.G.C. and without A.G.C. The events on the sections with 10-lb charges and those with 20-lb charges are very similar and the noise analysis, shown in Plate 4 is a composite of events from both sections. The charge difference has been allowed for, in relative amplitude values given, with a value of 10 dB. In addition to some signal events (24 to 28) there are three main groups of longitudinal noise present, with apparent velocities of about 2400 ft/s, 3200 ft/s, and 5400 ft/s. Noise and signal appear to be well separated in terms of wave number. A wave number in the region of 0.004 cycles/ft was chosen to be used for separation of signal and noise with subsequent pattern shooting.

In accordance with an expected relationship, $A \propto Q^{0.3}$, between relative signal amplitude A and charge Q, values of A were plotted for several signal and noise events on spreads 3 and 4 against the logarithm of the charge values: 10, 20, and 30 lb. As only three points could be obtained for each event, the results were not good; however, a general increase in A with log Q was obtained, with a slope consistent with the theoretical value of 0.3 in the case of the signal. It was hoped that the point of nearest approach of the lines for signal and noise could be chosen, this giving the charge value for the best signal-to-noise ratio; however, the two sets of lines were still converging with the charge at 30 lb, indicating that this charge was insufficient.

Preliminary assessment of the traverse noise results from the field records indicated that although some noise was present, it would not be a serious problem. Further investigation of transverse noise, done on this traverse after the project was completed, has indicated, however, that transverse noise probably constitutes a significant problem (see Section 7).

Energy transmission. At SP 687 and SP 693, the comparisons of charges with 5-hole patterns (5 x $1\frac{1}{4}$ lb, 5 x $2\frac{1}{2}$ lb, 5 x 5 lb, and 5 x 10 lb) showed that although 5 x $1\frac{1}{4}$ lb was sufficient to give an energy return greater than background level for 3 seconds, and all the higher charges for at least 4.5 seconds, the signal-to-noise ratio increased appreciably with charge size to at least 5 x 10 lb. Subsequent production shooting showed that quality still increased up to the largest charge used, which was 7 x 20 lb.

The general energy return with a total charge of about 100 lb was sufficient to maintain an input level of 3 to 10 millivolts down to 1.2 seconds (the background noise level was 10 - 30 microvolts).

Production results. The production section for Traverse GL2 is shown in Plate 7. The quality of the section is fair and is considered to be slightly superior to that obtained by the "Vibroseis" tests in 1964. Reflection events are recorded down to about 2.3 seconds. The continuity of a shallow band of reflections, between 0.75 and 1.05 seconds, is good but that of the deeper events is poorer. The additional short section (SP 675 to SP 681), which was shot with the larger patterns and the shorter spread length, is shown in Plate 8. This section shows a significant increase in quality over the main production section. The main events on the section appear to have a slight overall dip to the east.

Velocity shoot. The velocity shoot was centred on SP 691. The time/depth curve obtained agreed closely with that obtained from the Geltwood Beach No. 1 well. From the time/depth curve, a linear velocity function for Traverse GL2 has been calculated :

$$V_i = 7000 + 0.55\ d$$

The events with centre times of 0.981 second and 1.776 seconds are considered to be possible multiples.

Traverse GL3

Near-surface conditions. Drilling logs from this traverse show rapid changes in the near-surface formations, with varying thicknesses of unconsolidated sand, sandstone, clay, and limestone present. The water table was at about 5 ft and several holes, especially at the southern end of the traverse, were blocked by small boulders and sand falling in as the drill pipes were withdrawn.

From uphole times and first breaks, a weathering velocity of 200 ft/s and a sub-weathering velocity of 6000 ft/s were estimated. The weathering depth varied from 10 to 15 ft.

Energy transmission. The total charge of 140 lb used for production shooting was sufficient to maintain an input level of 3 to 10 millivolts down to about 1.3 seconds (the background level was 3 to 10 microvolts).

Production results. The production section for Traverse GL3 is shown in Plate 9. The quality of the section is fair, several strong events being present. There is a possibility that some of the later events are multiples. There is a slight overall dip to the south. The quality of the section is considered to be superior to that of the "Vibroseis" section. The move-out corrections applied to the section were obtained from an analysis of the production records.

Traverse SD2

Near-surface conditions. Drilling on Traverse SD2 encountered alternations of sand, sandy clay, soft sandstone, and friable limestone. The limestone and sandstone content was low at the northern part of the traverse, there being large thicknesses of soft sand at this end. A deep hole drilled at SP 1105-1/3 passed into a succession of clays and coarse sands, which persisted to 200 ft. Hole collapses were very common and it was necessary to load immediately on withdrawal of the drill pipes. At the northern end, collapses during withdrawal of the pipes necessitated frequent cleaning out of holes.

The uphole shoot at SP 1101-1/3 revealed a vertical sub-weathering velocity of 6700 ft/s, slightly faster than the first break refraction velocity of 6100 ft/s. The 200-ft deep hole drilled at SP 1105-1/3 collapsed to 80 ft after the first shot and the additional uphole times from 80 ft upwards were widely scattered and gave no useable information. A study of uphole times and first breaks from production records gave a weathered layer velocity of 1500 ft/s and a weathered depth of 15 to 25 ft all along the traverse, with no sudden variations.

Noise. The noise shoot section for Traverse SD2 is shown in Plate 5 and the analysis in Plate 6. There are two main classes of noise: one with a velocity of 7000 to 10,000 ft/s and the other with a velocity of 2000 to 3000 ft/s. Events 8 and 15 may be either signal or noise. Events 2, 4, 5, 10, and 12 are considered to be signal. No transverse noise is evident on this traverse.

Energy transmission. The comparisons made of charges in pattern holes showed that, as for Traverse GL2, although a medium charge was sufficient to produce an energy return above background level for several seconds, large charges were required to give a high enough signal-to-noise ratio for good quality records, and the largest charges tried gave the best quality. With the background noise level at about 3 to 10 microvolts, a total charge of 100 lb was sufficient to maintain an input level of 3 to 10 millivolts down to about 1 second at the southern end of the traverse. The input level began to drop going north from SP 1109, and at SP 1113, it was down to about 300 microvolts for the first second. These last few shot-points correspond to the area of soft sands and clays encountered by the drills. SP 1112 and SP 1113 were re-shot with a total charge of 300 lb, and a record quality comparable with the rest of the section was obtained.

Production results. The production section for Traverse SD2 is shown in Plate 10. The quality of the section is, in general, good. Down to one second, there are several strong events with good continuity. Below one secondthere are no good events, but there are some line-ups, which may be multiples. The section shows dip to the south. The results obtained are superior to those obtained by the "Vibroseis" survey in all respects. In particular, they are better with regard to the continuity of the main events and the presence of events at times less than half a second.

A t : Δt analysis was made from the production records. The time/depth curve obtained from the analysis is closely parallel to the Geltwood Beach No. 1 well curve.

7. CONCLUSIONS

Gambier Limestone

A "heavy" technique capable of producing fair seismic results on the Gambier Limestone, as exemplified by Traverses GL2 and GL3, was developed by the experimental programme. The production results are considered to be a significant improvement on the results obtained by the "Vibroseis" survey in 1964.

The problems expected in the area were difficult drilling, the noise problem, and poor energy transmission. Drilling did not prove to be a problem, average penetration rates of between 50 and 140 ft/hour being obtained. Longitudinal organised noise was not investigated deeply on this project but further work done on transverse noise (Turpie, in preparation) has shown that it constitutes a considerable problem and patterns designed to reduce it showed improvement in results and economy. Although large charges were not required to obtain sufficient energy return, large charges (of the order of 100 lb) were required to give a high enough signal-to-noise ratio for good results.

The results of the main production section for Traverse GL2 could be improved upon by using larger in-line patterns combined with shorter spreads so that a signal on the outside traces would not be cancelled out. Part of the traverse shot with such a technique showed improvement. Traverse GL3 was also shot using such a technique.

Sand dunes

On Traverse SD2, a "heavy" technique was developed that produced fair results. The "Vibroseis" survey obtained better results on Traverse SD1 than on Traverse SD2, which indicates that the technique used on Traverse SD2 should give reasonable results elsewhere on the sand dunes. The results obtained were considerably better than those obtained by the "Vibroseis" survey.

Problems encountered by previous surveys on sand dune areas were difficult drilling and poor energy transmission. Drilling on this survey was not a problem and average penetration rates between 70 and 120 ft/hour were obtained. Heavy charges, from 100 lb at the souther end of the traverse to 300 lb at the northern end, were required to give a signal-to-noise ratio sufficiently high for good results.

8. REFERENCES

BUREAU OF MINERAL RESOURCES (ED.) 1965 Summary of data and results, Otway Basin, SA: Geltwood Beach No. 1 Well of Beach Petroleum N.L. Bur. Min. Resour. Aust. P.S.S.A. Publ. 65.

LODWICK, K.B. and VALE, K.R. 1958 An experimental seismigraph survey at Heywood, Western District Basin, south-western Victoria Bur. Min. Resour. Aust. Rec. 1958/28.

MOSS, F.J. -- Comparison between experimental "Vibroseis" and shot-hole seismic surveys in the Otway and Sydney Basins 1964-1965 Bur. Min. Resour. Aust. Rep. (in preparation).

SEISMOGRAPH SERVICE LTD 1964 Experimental "Vibroseis" survey, south-eastern South Australia, 1964. Bur. Min. Resour. Aust. Rec. (Restricted). 1964/183.

TURPIE, A. -- A report on the transverse noise investigation over the Gambier Limestone. Bur. Min. Resour. Aust. Rec. (in preparation).

APPENDIX 1

Staff and equipment

Staff

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

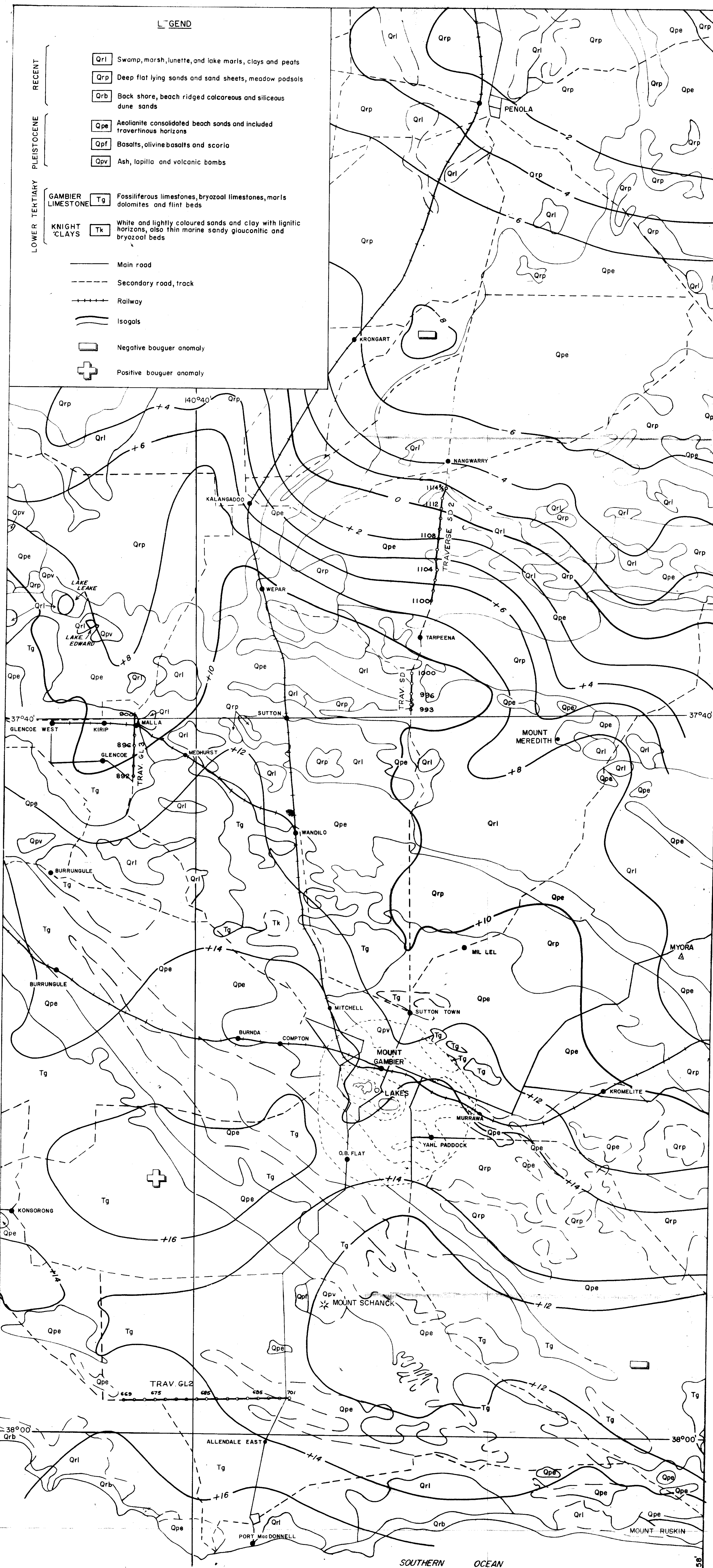
Equipment

Seismic amplifiers	Texas Instruments Model 7000B
Seismic oscillograph	S.I.E. Model VT6
Magnetic recorder	S.I.E. Model PMR-20 (frequency modulation)
Programme gain control unit	S.I.E. Model GC9/3EC
Prefilters	C.G.G.
Geophones	Hall-Sears HS-J 14-c/s (approx. 1300 in groups of 8)
	T.I.C. 20-c/s (32)
Cables	Vector 1800 ft
Drills	1 Mayhew 1000 2 Careys 1 Failing (under contract)

APPENDIX 2

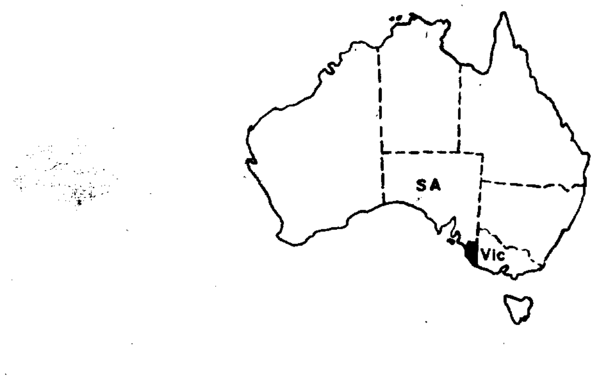
Operational data

Sedimentary basin	Otway		
Area	Mount Gambier, SA		
Headquarters established	21st June 1965		
Surveying commenced	18th June 1965		
Drilling commenced	21st June 1965		
Shooting commenced	23rd June 1965		
	GL2	GL3	SD2
Datum level for corrections (ft)	M.S.L.	200	200
Weathering velocity (ft/s)	2000	2000	1500
Sub-weathering velocity (ft/s)	7000	6000	6700
Static correction method	uphole times with interpolation		
Derivation of velocity function	Velocity shoot		
Total footage drilled	30109	3110	9865
Total number of field hours(drills)	$649\frac{3}{4}$	$91\frac{1}{4}$	$302\frac{1}{2}$
Total number of drilling hours	$288\frac{1}{2}$	$41\frac{1}{4}$	$101\frac{3}{4}$
Average penetration rate (in feet/hour) : 1. Careys	75.1	46.7	94.8
2. Mayhew	92.1	67.0	68.1
3. Failing	139.7	96.3	122.1
Total number of field hours(recorder)	264[illegible]	$23\frac{3}{4}$	131
Total number of recording hours :			
1. Experimental	126	-	$44\frac{1}{2}$
2. Production	103	$16\frac{1}{4}$	$36\frac{1}{2}$
Total number of profiles			
1. Experimental	151	-	53
2. Production	72	10	30
Total explosives used(lb):			
1. 3" 'Geophex'	$4032\frac{1}{2}$	200	1880
2. $2\frac{1}{4}$" 'Geophex'	$6096\frac{1}{4}$	680	$1786\frac{1}{4}$
Total detonators used :			
1. 100-ft	702	44	157
2. 30-ft	18	-	32
Total miles traversed	5	1	$3\frac{1}{2}$
Total number of holes drilled	500	51	185



SCALE IN MILES

2 1 0 2 4



EXPERIMENTAL SEISMIC SURVEY

OTWAY BASIN S A 1965

SEISMIC TRAVERSES, SURFACE GEOLOGY

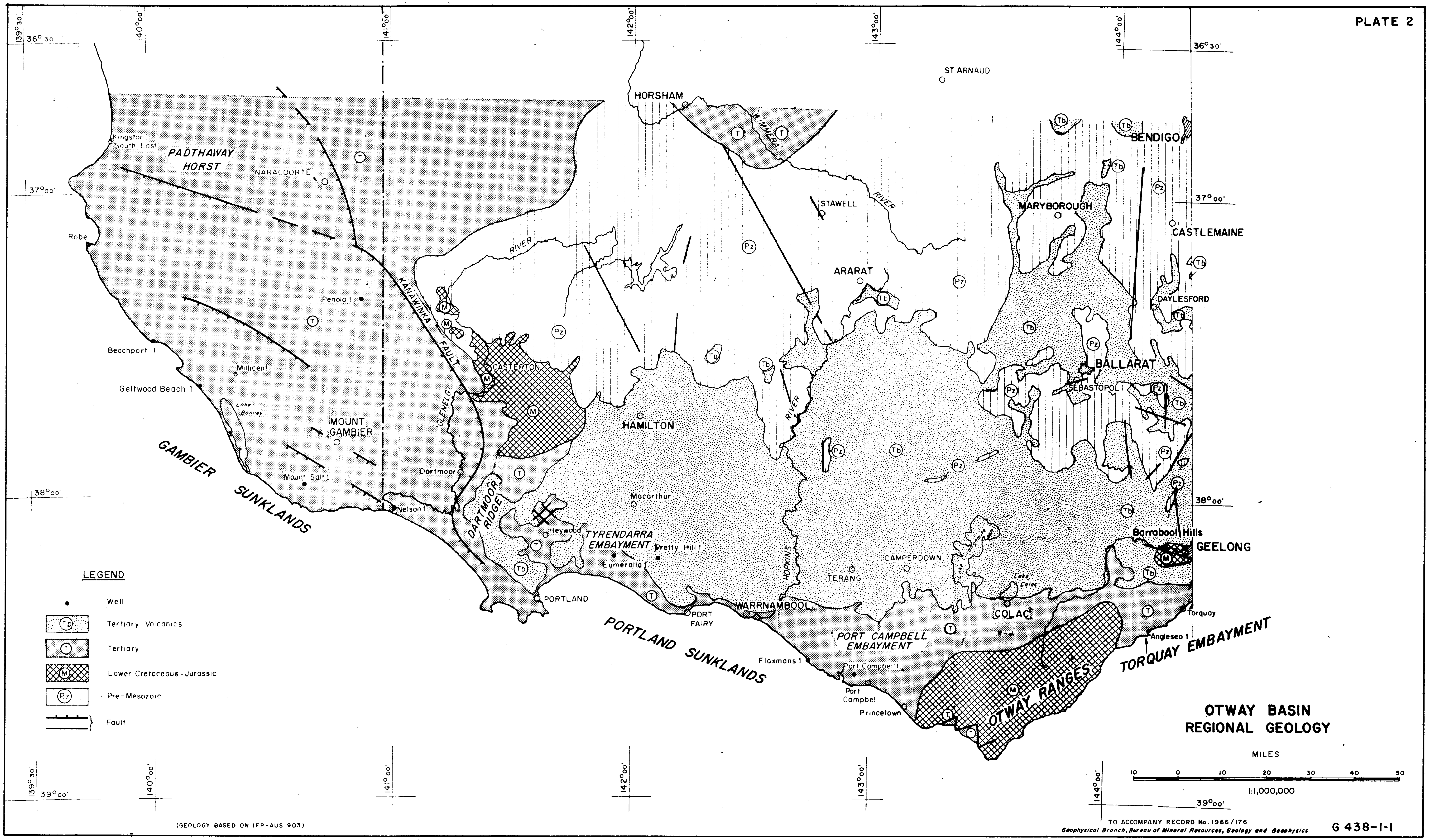
BOUGUER ANOMALIES

J54/B3-8

TO ACCOMPANY RECORD No 1966/176

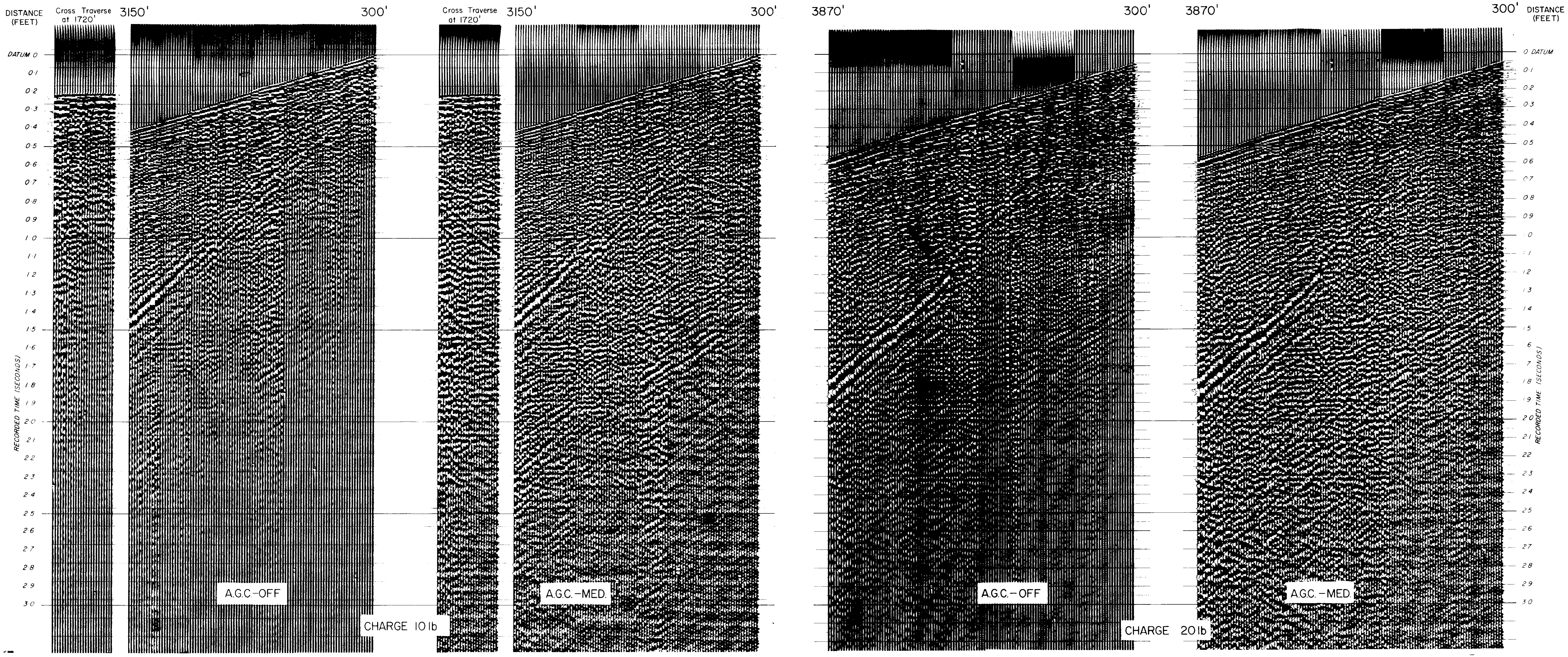
GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

PLATE I



TO ACCOMPANY RECORD No. 1966/176
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

G 438-1-1



RECORD SECTION

RECORDING INFORMATION

Magnetic Recorder: PMR-20

Amplifiers: 7000B

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

A.G.C.: Off

Gain Initial / *Final*: Various

Geophones: HSJ-14c/s

Geophone pattern: 8/trace, bunched

Shot-hole pattern:

Depth 60/64'

Charge as indicated

PLAYBACK INFORMATION

Filters:	0-1/135	
A.G.C.:	Med.	Off
Gain Initial:	-40	-40
Final:	-20	-40
Trip delay:	0-·2 sec	
Compositing:	Nil	

VELOCITY INFORMATION

—

HORIZONTAL SCALE

Longitudinal bases - 30' between traces

Transverse bases - 30' between traces

EXPERIMENTAL SURVEY FOR COMPARISON WITH VIBROSEIS SURVEY, 1965

OTWAY BASIN

TRAVERSE GL2

NOISE SHOOT SP689

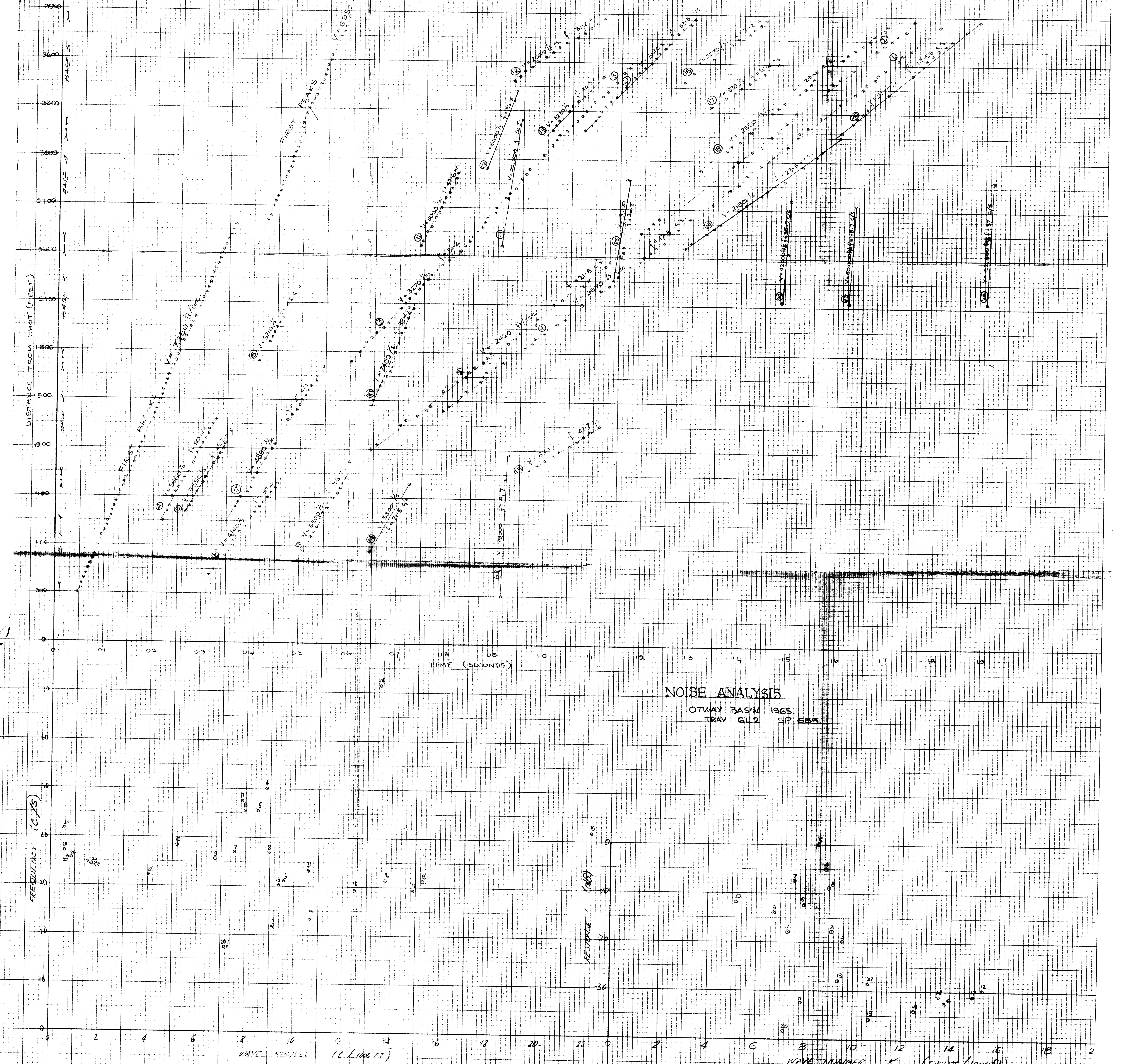
RECORDED BY: *Seismic Party No. 2*

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

TO ACCOMPANY RECORD No 1966/176

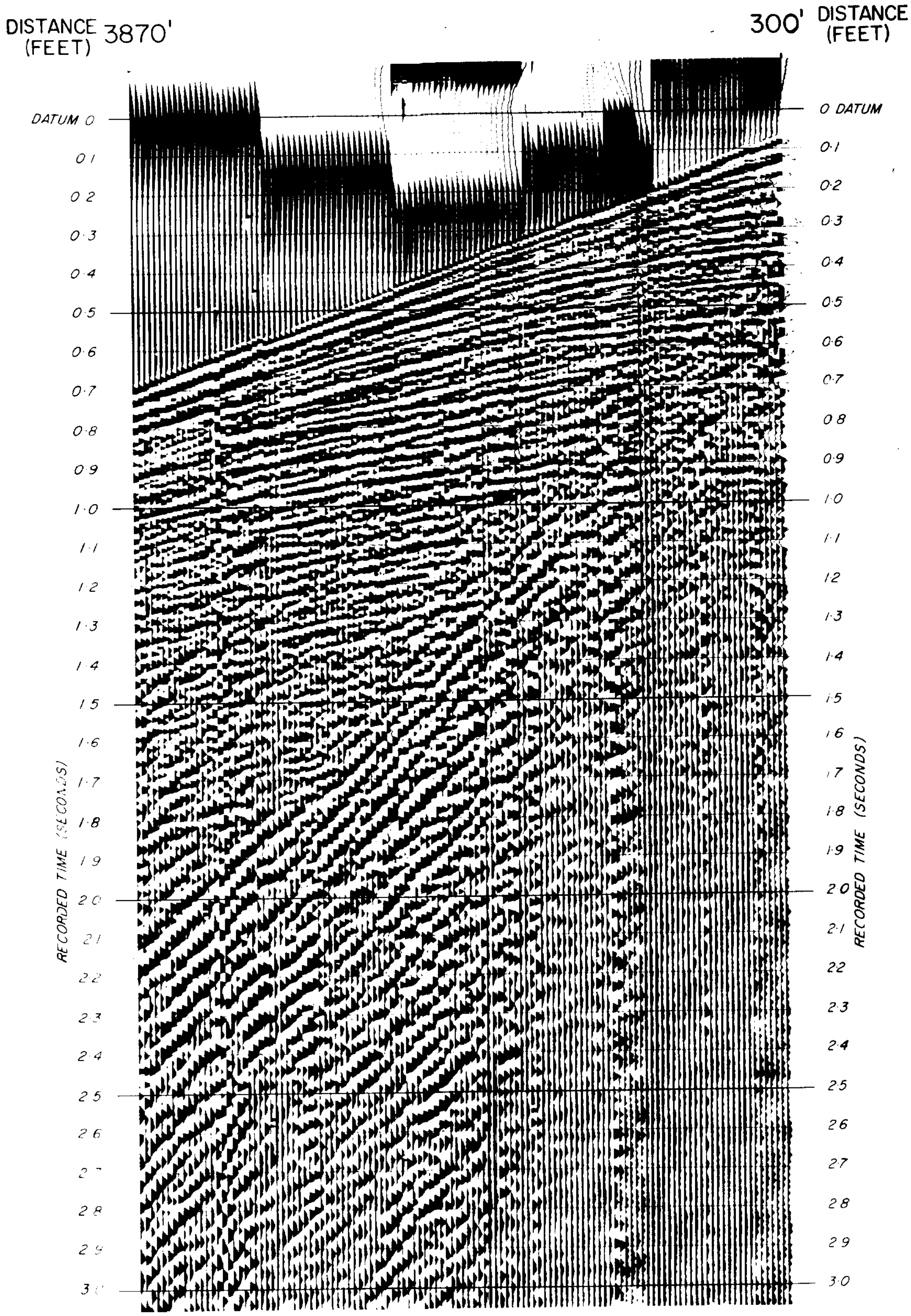
J54/B3-15

PLATE 4



J54/B3-10

TO ACCOMPANY RECORD No. 1966/176



RECORD SECTION

RECORDING INFORMATION

Magnetic Recorder : PMR-20

Amplifiers : 7000B

Filters : KO-K120

A.G.C. : Off

Gain Initial : } Various
Final : }

Geophones : HSJ-14c/s

Geophone pattern :
8/trace, bunched

Shot-hole pattern :
—

PLAYBACK INFORMATION

Filters : 0-1/135

A.G.C. : Off

Gain Initial : -40

Final : -40

Trip delay : 0

Compositing : Nil

VELOCITY INFORMATION

—

HORIZONTAL SCALE

Longitudinal bases -30' between traces

EXPERIMENTAL SURVEY FOR COMPARISON WITH VIBROSEIS SURVEY, 1965 OTWAY BASIN

TRAVERSE SD2

NOISE SHOOT SP1100

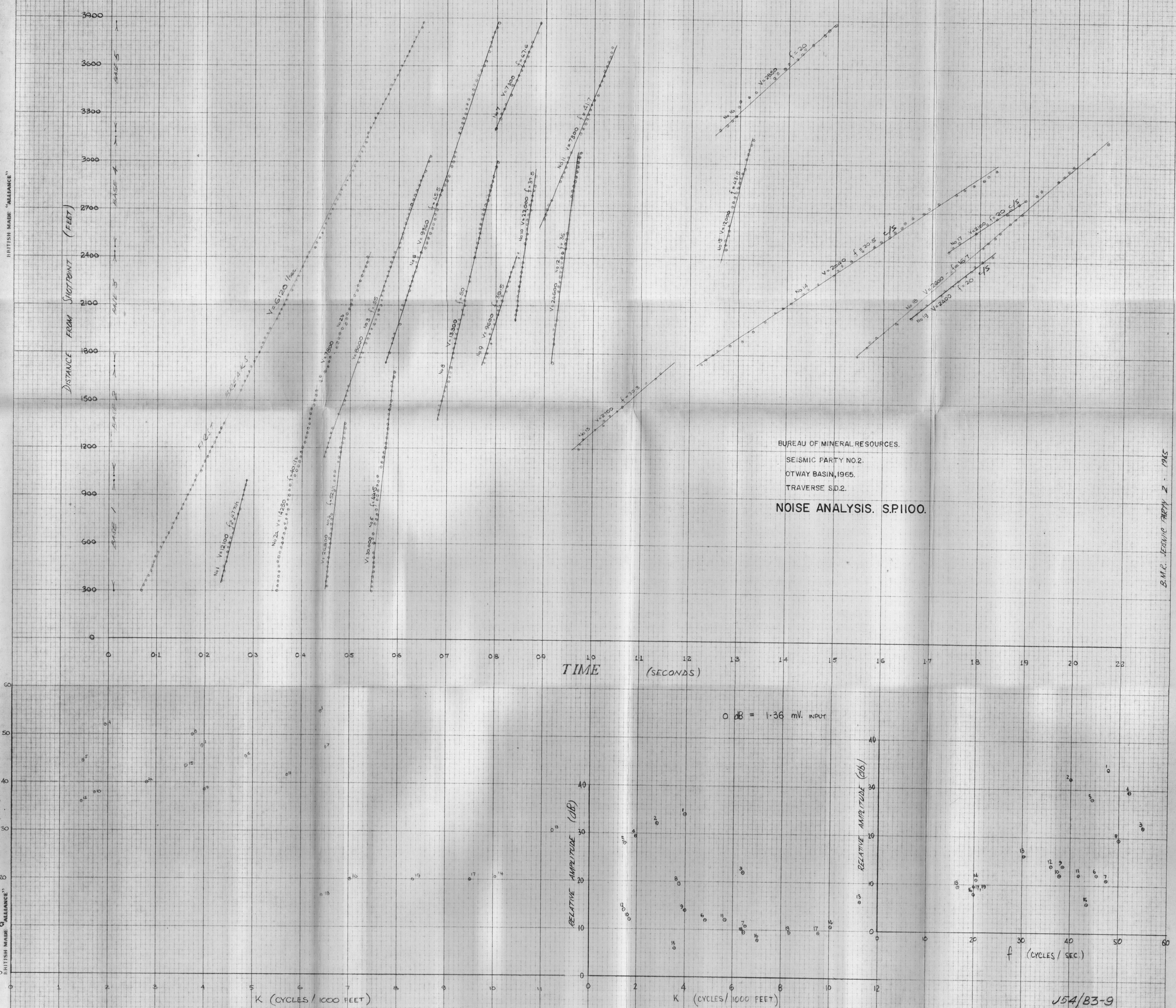
RECORDED BY : *Seismic Party No. 2*

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

TO ACCOMPANY RECORD No 1966/176

J54/B3-17

PLATE 6

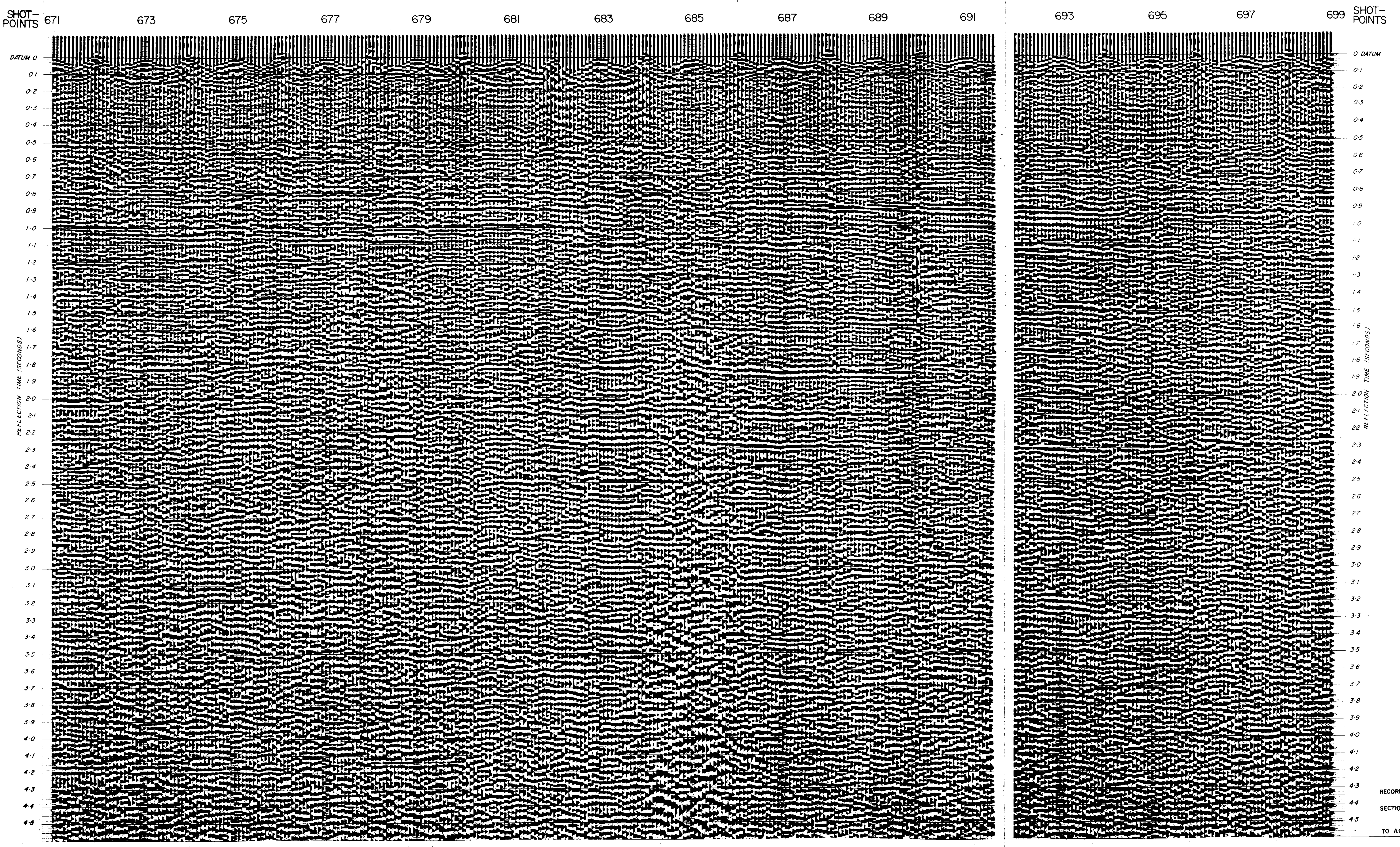


J54/B3-9

TO ACCOMPANY RECORD No. 1966/176

PLATE 7

CORRECTED RECORD SECTION



RECORDING INFORMATION

Magnetic Recorder: PMR 20

Amplifiers: 7000B

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

A.G.C.: Med.

Gain Initial: −60

Final: −20

Geophones: HSJ-14 c/s

Geophone pattern:

48/trace in 2 rows of 24 in line

Rows 30' apart

Geophones 10' apart

Station interval 146·7'

Shot-hole pattern:

	SP 693 and 691
7 holes 40' apart in line	9 holes 40' apart in line
Depth 50/54'	Depth 50/54'
Charge 7x15 lb	Charge 9x15 lb

Ex. SP681, 683, 689 - 7x20 lb

PLAYBACK INFORMATION

Filters: 1/20-2/60

A.G.C.: Med.

Gain Initial: −40

Final: −20

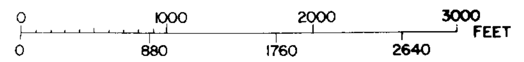
Trip delay: 0·5 sec

Compositing: Nil

VELOCITY INFORMATION

t:Δt analysis

HORIZONTAL SCALE



EXPERIMENTAL SURVEY FOR COMPARISON WITH VIBROSEIS SURVEY, 1965
OTWAY BASIN

TRAVERSE GL2

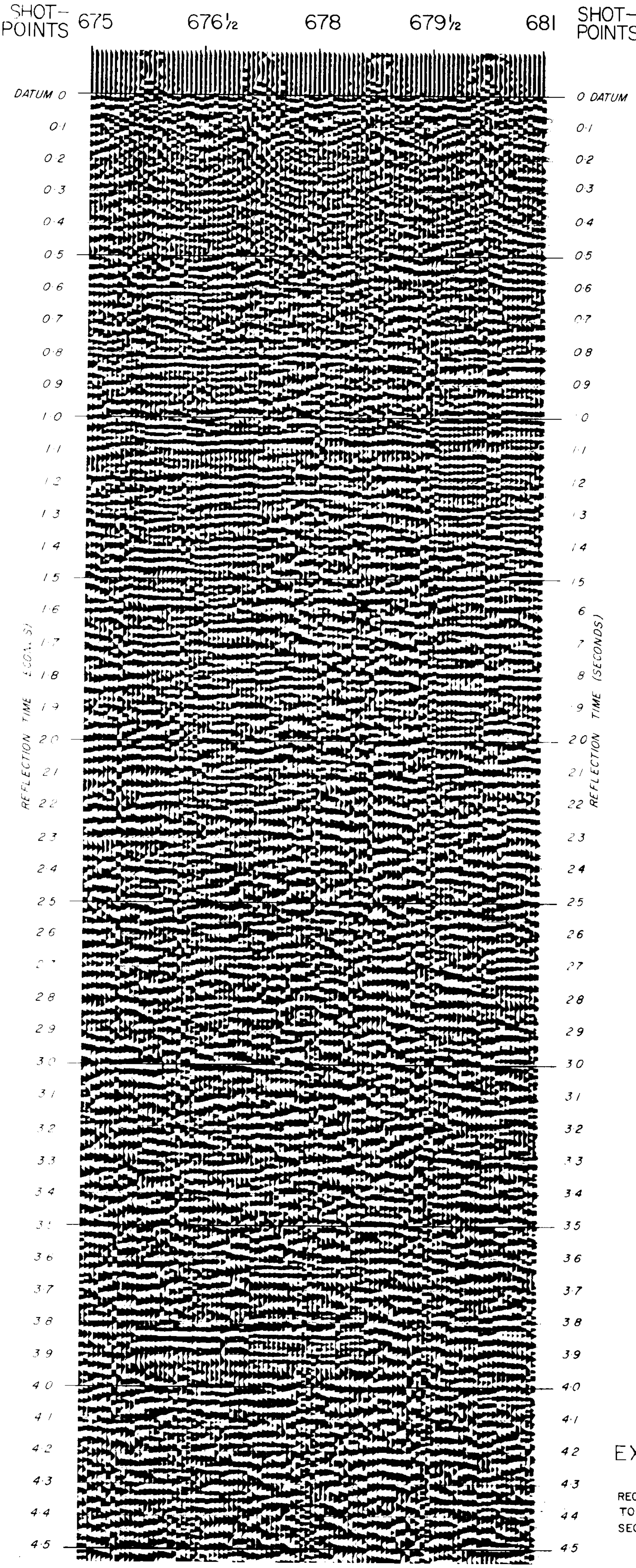
PRODUCTION SECTION

RECORDED BY: *Seismic Party No. 2*

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

J54/B3-14

TO ACCOMPANY RECORD No 1966/176



CORRECTED RECORD SECTION

PLATE 8

RECORDING INFORMATION

Magnetic Recorder : PMR-20

Amplifiers : 7000B

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

A.G.C. : Med.

Gain Initial : -60

Final : -20

Geophones : HSJ-14c/s

Geophone pattern :

48/trace, in 2 rows of 24 in line

Geophones 10' apart

Rows 30' apart

Station interval 110'

Shot-hole pattern :

7 holes, 50' apart in line

Depth 50/55'

Charge 7 x 20lb

PLAYBACK INFORMATION

Filters : 1/20-2/60

A.G.C. : Med.

Gain Initial : -40

Final : -20

Trip delay : 0·5 sec

Compositing : Nil

VELOCITY INFORMATION

Velocity Shoot at SP691

HORIZONTAL SCALE

FEET

0 500 1000 2000 3000

0 1320 2640

EXPERIMENTAL SURVEY FOR COMPARISON WITH VIBROSEIS SURVEY, 1965 OTWAY BASIN

TRAVERSE GL2

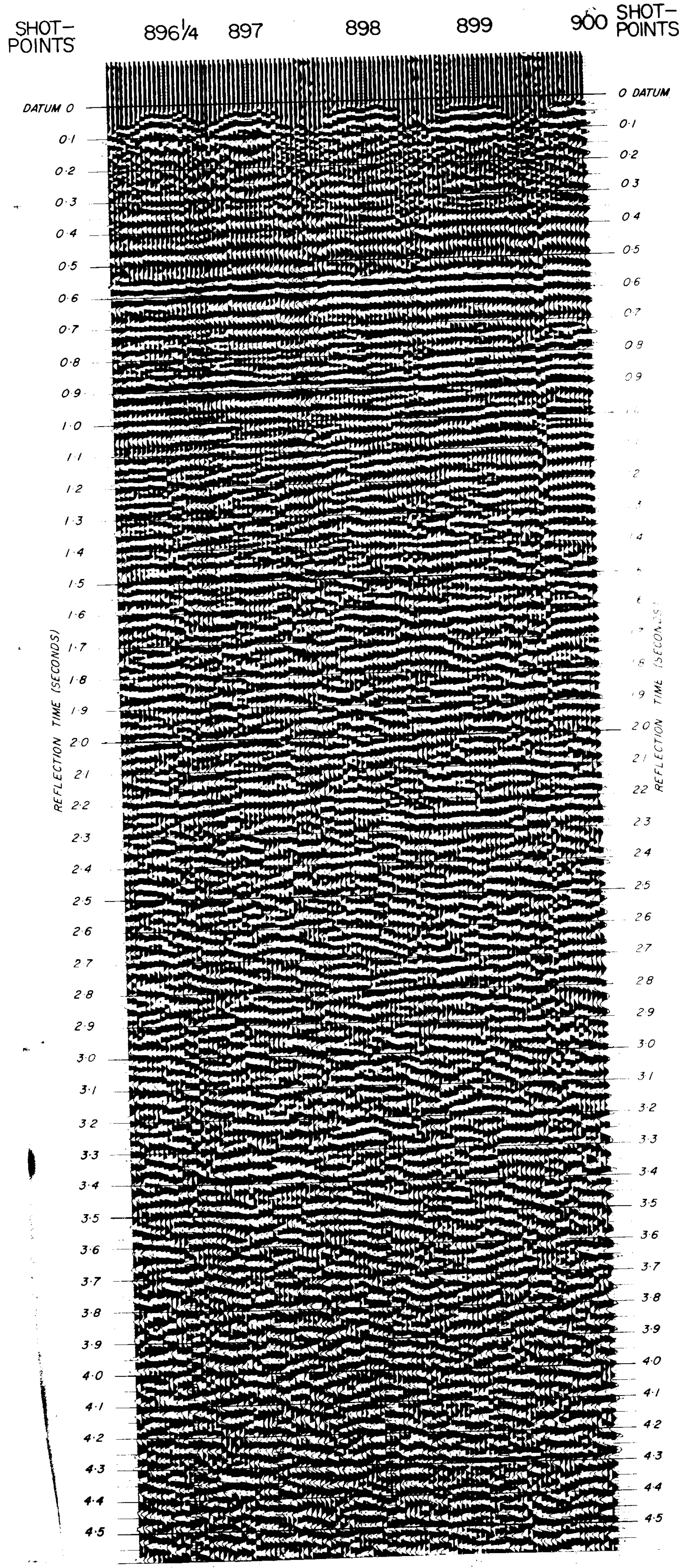
EXPERIMENTAL SECTION, SP675-SP681

RECORDED BY : *Seismic Party No. 2*
TO ACCOMPANY RECORD No 1966/176
SECTION BY : *Bureau of Mineral Resources Playback Centre SIE MS 42*

J54/B3-13

PLATE 9

CORRECTED RECORD SECTION



RECORDING INFORMATION

Magnetic Recorder: PMR20

Amplifiers: 7000B

Filters: PREFILTERS 18c/s, 12db/0 KO-K92

A.G.C.: Med.

Gain Initial: −60

Final: −20

Geophones: HSJ−14c/s

Geophone pattern:

48/traces in 2 rows of 24 in line

Rows 30' apart

Geophones 15' apart

Station interval 110'

Shot-hole pattern:

7 holes, 40 apart in line

Depth 52/60'

Charge 7 x 20 lb

PLAYBACK INFORMATION

Filters: 1/20 − 2/60

A.G.C.: Med.

Gain Initial: −40

Final: −20

Trip delay: 0·5 sec.

Compositing: Nil

VELOCITY INFORMATION

t:Δt analysis

HORIZONTAL SCALE

0 1000 2000 3000 FEET

0 1320 2640

EXPERIMENTAL SURVEY FOR COMPARISON WITH VIBROSEIS SURVEY, 1965 OTWAY BASIN

TRAVERSE GL3

PRODUCTION SECTION

RECORDED BY: *Seismic Party No. 2*

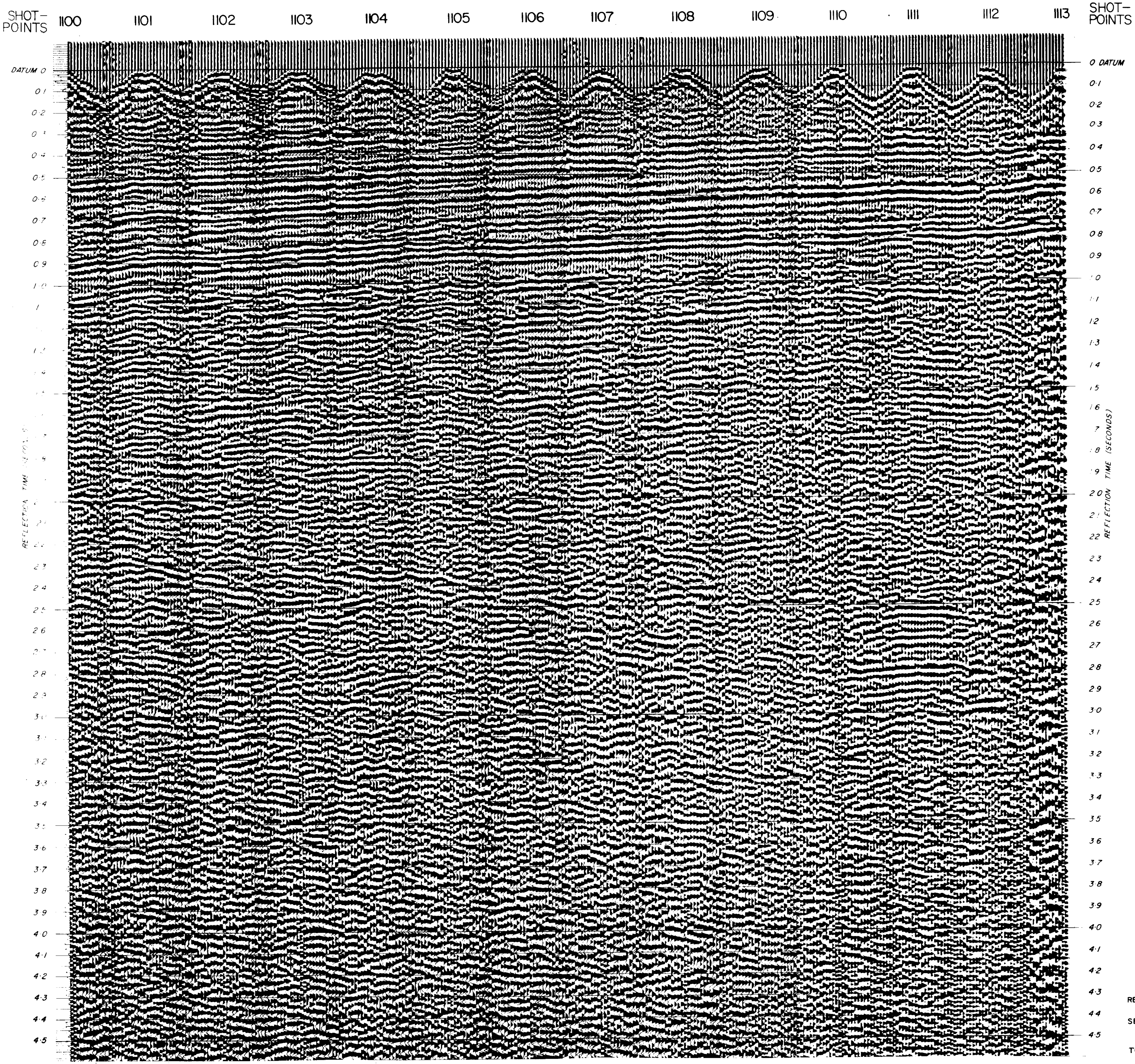
SECTION BY: *Bureau of Mineral Resources Playback Centre SIE MS 42*

J54/B3−18

TO ACCOMPANY RECORD No 1966/176

CORRECTED RECORD SECTION

PLATE 10



RECORDING INFORMATION

Magnetic Recorder: PMR20

Amplifiers: 7000B

Filters: PREFILTERS 18c/s, 12db/O K0–K92

A.G.C.: Med.

Gain Initial: −60

Final: −30

Geophones: HSJ–14c/s

Geophone pattern:

48/traces in 3 rows of 16 in line

Rows 30' apart

Geophones 20' apart

Station interval 110'

Shot-hole pattern:

5 holes, 70' apart in line

Depth 40/48'

Charge 5x20 lb

PLAYBACK INFORMATION

Filters: 1/20 – 2/60

A.G.C.: Med.

Gain Initial: −40

Final: −20

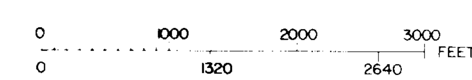
Trip delay: ·15 sec.

Compositing: Nil

VELOCITY INFORMATION

t:Δt analysis

HORIZONTAL SCALE



EXPERIMENTAL SURVEY FOR COMPARISON WITH VIBROSEIS SURVEY, 1965 OTWAY BASIN

TRAVERSE SD2

PRODUCTION SECTION

RECORDED BY: *Seismic Party No. 2*

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

J54/B3–16

TO ACCOMPANY RECORD No 1966/176