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RECORD No. 1966/203

BULLSBROOK SEISMIC SURVEY,

PERTH BASIN, WESTERN AUSTRALIAN 1964

by

D.J. WALKER and B.F. JONES

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ILLUSTRATIONS

Note: This Record supersedes Record No. 1964/155

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SUMMARY

Seismic reflection studies in the Perth Basin, between the coast and the Darling Range, 30 miles north of Perth, were conducted in an attempt to derive a suitable recording technique for obtaining reflections when shooting on the Coastal Limestone formation, to investigate geological structure in the basin, and to supplement hydrological studies being made by the Geological Survey of Western Australia.

Experimental work occupying half of the survey period failed to yield a technique for obtaining seismic reflections on the Coastal Limestone, but led to reflections being obtained across the major part of the basin.

Record quality with a fairly 'heavy' technique was poor to fair in the western half of the basin off the Coastal Limestone but improved considerably to the east. A complex geological section in the west gave way to a more concordant thick synclinal section in the east, terminated at its eastern end by the Darling Fault. Of interest is an apparent anticlinal reversal of dip in beds lying deeper than 7000 ft, with the reversal axis near the centre of the major gravity 'low' of the basin.

1. INTRODUCTION

During the period mid-March to mid-June 1964, the No. 2 Seismic Party of the Bureau of Mineral Resources carried out a seismic survey in the Wanneroo - Bullsbrook area, approximately 30 miles north of Perth, Western Australia. Two east-west reflection traverses were recorded using a continuous profiling method: Traverse A, over the Pleistocene Coastal Limestone formation; and Traverse B to the east of the Coastal Limestone outcrops, on a Pleistocene sand formation (see Plate 1).

In previous seismic surveys in the Perth Basin, difficulty has been experienced in obtaining reflections when shooting on the Coastal Limestone, a thin (about 200 ft thick) Pleistocene formation which crops out in a narrow belt along the coast. In this survey, experimental shooting was conducted in this formation in an attempt to develop a successful shooting technique.

Traverse B was shot across the basin from the edge of the Coastal Limestone area to the Darling Escarpment (the eastern margin of the Basin) to investigate the structures of the Basin, and in particular to ascertain whether faulting of the type found in the Rockingham/Mundijong seismic survey in 1956 (Moss, 1962) was present.

The Bullsbrook area was chosen as the location for the survey because:

1. there is a suitably large area of Coastal Limestone outcrop near the coast west of Bullsbrook,

2. the Geological Survey of Western Australia were drilling a series of bores across the Perth Basin at that latitude for hydrological studies and requested further geophysical work, and

3. the area filled in a gap between previous BMR seismic surveys.

In accordance with BMR practice, two attempts were made to record reflections from the region of the Mohorovicic discontinuity, the sites being chosen after discussion with I. B. Everingham of the BMR Observatory at Mundaring, WA. The recording method and results obtained are discussed in Appendix D.

2. GEOLOGY

General discussions of the known geology of the Perth Basin are given by McWhae et al (1958), Fairbridge (1949), and Playford and Johnstone (1959).

The Perth Basin is a long narrow basin, having an average width on land of about 40 miles and a length of about 600 miles; it is bounded on the east by the Darling Fault, a major structural feature which extends north-south for almost the whole length of the basin (see Plate 2). Gravity evidence suggests that the maximum throw of the Darling Fault is 30,000 ft or more down to the west. The fault has been well delineated by a gravity survey (Thyer and Everingham, 1956). The sediments of the basin have a regional dip to the east and abut the Precambrian shield along the Darling Fault. The results of an aeromagnetic survey by the BMR (Quilty, 1963) indicate that the western margin of the basin, which is the Dunsborough Fault in the southern part, extends north-west from Cape Naturaliste out to the edge of the continental shelf as shown by the depth contours in Plate 2. The northern boundary is represented by the Hardabut Fault and its projection to the north-east to the Carandibby Range (McWhae <u>et al</u>, 1958). The aeromagnetic results also indicated subsidiary basement ridges within the basin, often close to, and parallel with, the boundaries of the basin. More detailed gravity work by West Australian Petroleum Pty Ltd (WAPET) has shown residual gravity 'highs' generally corresponding to the magnetic anomalies interpreted as basement ridges (Felcman and Lane, 1963).

The surface geology and major tectonics are shown in Plate 2. The basin contains a very thick sequence of sediments ranging from probably older Palaeozoic or Proterozoic to Tertiary, the total thickness being more than 65,000 ft. The stratigraphic succession in the Perth Basin is summarised in Table 1. This information has been obtained from observation and measurements of outcrops and from stratigraphic drilling.

Several bores have been drilled in the northern part of the basin to test the hydrocarbon potential. These are all over 100 miles from the present survey, with the exception of Gingin No. 1 (Johnson, 1965), which is situated only 35 miles north of Traverse B and 8 miles west of the Darling Fault. It was drilled to 14,908 ft.

Outcrop geology in the area of the survey is restricted to Tertiary and Recent deposits; mainly sand with a strip of Coastal Limestone running down the coast. Precambrian granite and granitic gneisses crop out east of the Darling Fault zone, about 3 miles east of Bullsbrook.

The Coastal Limestone is mainly an aeolian deposit with marine limestone horizons, and is considered to be Pleistocene in age. It crops out in a belt 4 to 10 miles wide down the coast of Western Australia. This formation is of particular importance to this survey because of the difficulty experienced in the past in obtaining seismic reflections when shooting in it (see Section 3). The Coastal Limestone generally forms parallel ridges of old dunes up to 300 ft high. Lithologically the deposit is generally a calcareous, medium- to coarse-grained sandstone consolidated with a secondary calcitic cement, containing up to 50% of limestone. The surface layers have been leached leaving a white to yellow siliceous sand with a very hard travertine horizon at the top. This layer is cut through by solution pipes and other limestone weathering phenomena. At Yanchep, 9 miles north of the area of this survey, several large limestone caves occur in the formation. The thickness of the formation varies from 50 to 500 ft. In the Bullsbrook-Wanneroo area the outcrop extends from the coast to 4 miles inland and is probably of the order of 200 ft thick.

TABLE 1

Stratigraphic succession in the Perth Basin

Age	Maximum Thickness (feet)		Lithologic Character
Pleistocene	200	200	Coastal Limestone, sands, and clays
Eocene	1960	2160	Shale and siltstone
Upper Cretaceous	200		Greenstone and chalk
Lower Cretaceous	3340	5700	Sandstone, siltstone, conglomerate, and coal (continental)
Jurassic	11,260 +		Sandstone, siltstone, coal, and claystone (continental)
Triassic	6200	23160	Sandstone, siltstone, claystone, and conglomerate (marine and deltaic)
Upper Permian	4500		Coal, shale, sandstone, and minor limestone (marine and continental)
Lower Permian	1500	29160	Glacial tillite
? Silurian / ? Ordovician	6-10,000	35160	Red sandstone, siltstone, and conglomerate
Older Palaeozoic or Proterozoic	30,000	65160	Siltstone, minor sandstone, conglomerate, chert, and lava

Petroleum prospects

In the Gingin area, about 35 miles north of Bullsbrook, a BMR seismic survey (Vale, 1956) disclosed a deep-seated anticline, the Gingin Anticline. Detailed follow-up work by WAPET (Andrews, 1964) on this structure showed it to be a large north-south trending anticline with a possible closure of 4300 ft over an area of 90 square miles on a Middle Jurassic (?) phantom horizon. The structure does not appear to be cut by major faulting but there is some evidence of minor faulting associated with the anticlinal axis. It is on this structure that Gingin No. 1 (Johnson, 1965) was drilled. This well encountered 14 gas shows, some with minor fluorescence, between 12,425 ft and 14,908 ft (total depth) in the Lower Jurassic Cockleshell Gully Formation. Seven of these shows flowed at between 1.8 and 3.85 million cubic feet per day. Most of these were accompanied by condensate of 45° to 46° API.

Several of the wells in the northern part of the basin have encountered traces of hydrocarbons; Woolmulla No. 1 (Pudovskis, 1963b), Jurien No. 1 (Pudovskis, 1963a), and Eneabba No. 1 (Pudovskis, 1962) all encountered traces of gas and flourescence in sandstone beds in the lower Triassic Kockatea Shale, but in all cases the formation had very low porosity and permeability.

In Yardarino No. 1 (Pearson, 1964) in addition to considerable amounts of gas in the Kockatea Shale, a flow of 15 million cubic feet per day was encountered in the Upper Permian Wagina Sandstone. The upper part of this formation had moderate porosity and good permeability. The gas flow was accompanied by a light kerosene condensate and some heavy crude oil.

Thus the existence of reservoir beds in the Jurassic and Permo-Triassic sequences of the Perth Basin is well established.

3. PREVIOUS GEOPHYSICAL SURVEYS

As pre-Tertiary outcrop and deep well information is sparse over most of the Perth Basin, most of the present knowledge of the regional form of the basin has come from gravity and magnetic surveys. The BMR has conducted regional gravity surveys (Thyer and Everingham, 1956) and aeromagnetic surveys (Quilty, 1963) over the whole of the basin, and a more detailed gravity survey for the basin south of Moora has been conducted for WAPET (Felcman and Lane, 1963).

Plate 1 shows the Bouguer anomaly contours of the basin, which show the clear delineation of the Darling Fault, and which indicate that the area of the present survey is about 80 miles south of the deepest part of the basin.

Plate 2 shows the depth to magnetic basement calculated from aeromagnetic results. An idea of the location of the western margin of the basin can be gained from these depth contours.

The gravity survey conducted by WAPET consisted of reading stations approximately half a mile apart on a 4- by 6-mile grid. The survey disclosed a number of minor positive residual gravity features, in particular, in the area of the present survey, an elongated north-south trending ridge extending from north-west of Gingin to south of Fremantle along the coast. Felcman and Lane (1963) have interpreted this as a normal fault, with a downthrow to the east of 6000 to 10,000 ft. They have named this structure the Yanchep Fault; however, the real form of the structure giving rise to this anomaly must be considered uncertain.

Seismic reconnaissance surveys have been conducted by the BMR at Gingin in 1955 (Vale, 1956), Busselton in 1956 (Lodwick, 1962), Cookernup in 1955-56 (Vale and Moss, 1962), and Rockingham/Mundijong in 1956 (Moss, 1962). In the Rockingham/Mundijong area, the BMR conducted a single east-west traverse, which indicated two faults. One fault in the centre of the line, in a region of relatively steep dips, is thought to be of possible importance for oil accumulation.

Since 1955, several detailed seismic surveys have been done by WAPET in the Perth Basin over possible oil reservoir structures indicated by gravity and magnetic work. Most of these surveys were in the northern part of the basin but two, at Gingin (Andrews, 1964) and Lake Preston (Denton, 1964), are in the central part of the basin near the area of this survey.

Results in the Coastal Limestone area

The BMR surveys failed to record reliable reflections when shooting in the Coastal Limestone area. However, a single experiment conducted during the Cookernup survey yielded promising results. In this experiment a 36-hole diamond pattern of 5-lb charges at depths of 30 ft, with holes 50 ft apart, was shot into a spread using groups of four geophones per trace at 5-ft intervals (Vale and Moss, 1962).

In the course of their investigations crews working for WAPET have on several surveys conducted reflection traverses on outcrops of the Coastal Limestone. These surveys were in the areas of Witcherina - Mungara - Dongara - Depot Hill (Warwick, 1964), Dongara (Kendall, 1963), Eridon - Hill River - Woolmulla South (Sheriff et al, 1962) and Lake Preston (Denton, 1964). Reflection quality was poor on all these surveys when shooting on the limestone outcrop. Sheriff et al (1962) reported that a noise analysis on the limestone in the Eridon area gave a high intensity noise with a dominant wave-length of about 105 ft.

4. OBJECTIVES AND PROGRAMME

Objectives

The objectives of the seismic survey were:

1. To do experimental shooting in the Coastal Limestone area in an attempt to find a reliable shooting procedure for obtaining reflections from beneath this formation.

2. To carry out an east-west reflection traverse across the Perth Basin at the latitude of Bullsbrook to examine whether faulting is present in the sedimentary section similar to that suggested by the BMR seismic survey at Rockingham in 1956 (Moss, 1962), and to investigate the tectonics of the sedimentary section beneath the Coastal Limestone.

3. To assist the hydrological programme of the Geological Survey of Western Australia by providing structural information to assist in siting a proposed line of holes in the Bullsbrook area. Special attention was to be given to the obtaining of shallow information.

4. To investigate the tectonics beneath the western end of the Rockingham/Mundijong traverse where no reflections were obtained in 1956.

Proposed programme

The programme for this survey proposed four to six weeks of experimental shooting in the Coastal Limestone area (Traverse A) west of Bullsbrook, followed, if necessary, by a further two weeks of experimentation in the sand area between the Coastal Limestone outcrop and Bullsbrook. Then, six weeks was to be spent on continuous reflection profiling on an east-west line across the Perth Basin through Bullsbrook. This latter traverse was to extend from the Pre-cambrian granite outcrops, about 3 miles west of Bullsbrook, to the coast.

With regard to objective (3), it was intended to use short spread lengths in order to record events from shallow layers (less than 2000 ft deep).

Objective (4) was to be investigated only if the programme at Bullsbrook was completed in less than three months, and was to occupy the remainder of the three months. The work was to have consisted of continuous reflection profiling on the 'no reflection area' of Traverses A and B of the previous Rockingham/Mundijong survey (Moss, 1962) using the technique found optimum in the Bullsbrook area.

The experimental work on the Coastal Limestone was to consist of two phases as follows:

Weathering analysis. This consisted of a combined uphole and refraction shoot. Two holes 200 - 300 ft deep at the ends of a 4500-ft long line were to be shot from various depths into 1800-ft spreads, extending along the 4500-ft line from the holes, thus giving the vertical velocities in the weathered layers and giving a weathering profile along the 4500-ft line. From these results the suitability of the line for noise analysis was to be decided and the noise analysis programme carried out. Otherwise an alternative site was to be investigated.

Noise analysis. Noise recording using six 720-ft longitudinal bases on the 4500-ft line was then to be carried out. A transverse spread was to be laid across the line 1290 ft from the hole.

The spread layout is shown in Plate 7. The noise shooting was to be conducted using a charge and depth estimated from the uphole shooting, and then a more complete charge and depth test was to be made in the area of the noise spread showing minimal noise (10 shots for best depth and 5 for best charge).

After completion of the noise analysis, the best shot-hole and geophone group sizes and configurations for cancellation of noise were to be determined and tried out.

5. FIELD WORK

The programme as carried out consisted of seven weeks of experimental shooting and six weeks of continuous reflection profiling across the basin.

Experimental shooting, Traverse A

Weathering analysis and noise shoot AB. The area chosen for the shooting of the initial weathering analysis was between shot-points A and B on Traverse A (see Plate 1). Shot-point A is 900 ft along the traverse west of SP5 and Shot-point B is identical with SP2. The area was chosen because it lay within a large cleared area within easy access of the sealed road to Quinns Rocks, and because the Coastal Limestone outcrops, although covering an appreciable area, appeared to be no more numerous than elsewhere on the traverse.

After initial difficulties with drilling at Shot-points A and B, test drilling was carried out at every shot-point on Traverse A. This showed that the maximum obtainable hole depth was between 30 and 120 ft owing to loss of circulation in the cavernous limestone (see Appendix C). The deepest hole that could be drilled, 120 ft at SP6, was used for an uphole shoot.

A series of reflection split-spreads each of 3600 ft total length was shot from SP6 for initial information on weathering data and reflection quality. Because of poor first arrivals on the reflection records no useful weathering information was obtained. In the shooting of these reflection spreads, preliminary tests were made to determine a probable best charge size and depth to use, but owing to the poor quality of the records obtained it was not possible to deduce these parameters.

The layout for the noise shooting consisted of six longitudinal spreads and one transverse spread, using single 20-c/s geophones, as shown in Plate 7. The shot-point used was Shot-point A and the spread extended to Shot-point B.

It was found that at Shot-point A most holes could be drilled to 50 ft, so this depth was chosen as the most practical shot depth. Because the holes remained open for more than one shot, it was decided to shoot two series of noise tests, one shooting a 20-lb charge at 50 ft into each of the noise spreads, and the other shooting a 50-lb charge in the same holes into the same spread. It was thought that the deepest hole possible would be the best depth to yield optimum signal-to-noise ratio. The best charge size was unknown, but because the amount of energy imparted to the ground in this cavernous limestone medium was extremely variable, it was thought that possibly a large charge should be used. Recording was carried out with the filter pass-band as wide as possible, with no AGC, and with the gains varied according to shot-to-geophone distance, so as to produce records showing seismic energy at readable levels.

Noise shoot EF. After completion of noise shoot AB and a series of tests to determine optimum shot-hole arrays it was found that a very large shot array would be necessary to obtain readable records in the area. Because of the excessive time required for drilling large shot-point arrays in the cavernous limestone, and the difficulty in manoeuvering drilling rigs over the limestone outcrops, it was decided to test surface shooting methods. To determine whether these methods might be satisfactorily used in the area, a noise shoot using a surface charge of 5 lb was conducted in the time made available to the recording crew by delays in drilling.

Line EF, west of SP8 on Traverse A, was chosen as it offered easier access than the area of line AB and it was not expected to have very different subsurface conditions (see Plate 1). A 20-ft interval between geophones was used because it seemed that the resolution of noise events in the first 2000 ft from the shot-point was difficult in noise shoot AB, where a 30-ft geophone interval was used. Nine longitudinal spreads were laid out between 200 ft and 4500 ft from the shot-point, E, and a charge of 5 lb, which was laid on the ground at the shot-point, was shot into each of the nine spreads in turn. As before, no AGC or filtering was used and the amplifier gains were varied according to the shot-to-geophone distance.

Optimum recording tests. The results of the noise analyses (see Plates 11, 12, and 13) indicated that the best criteria for separating noise from events of high apparent velocity, which were considered as being possible signal, were to reject frequencies below 24 c/s and to reject wave numbers above 0.002 cycles per ft. These conditions were used as an initial guide in designing shot-hole and geophone arrays.

The initial experimental spreads were shot from Shot-point A. For the first spread a cut-off wave number of 0.0055 c/ft for the shot (a square pattern with 9 holes and 30-ft spacing) and 0.0038 c/ft for geophones (18 phones 7-1/3 ft apart) were tried. The record obtained was very poor, showing no line-ups and a lot of low frequency noise. The cut-off wave number values for both holes and geophone arrays were gradually reduced in subsequent tests down to about 0.001 c/ft (30 geophones 18 ft apart and 3 rows of 15 holes, 20 ft apart, rows 100 ft apart) giving an improvement in quality as regards reduction of noise and the appearance of some poor events. Of those tried, a cut-off wave number of about 0.001 c/ft appeared to give the best quality record.

Shot depths from 30 ft down to 60 ft (the deepest practicable drilling depth) were tried. The energy return increased with shot depth; however, with large patterns it was found that depths greater than 30 ft could not be obtained with sufficient reliability owing to losses in circulation of the drilling fluid.

As no definite reflections were recorded with the shooting at Shot-point A up to this stage, it was decided to try shooting with the spread perpendicular to the traverse at Shot-point A, and to try shooting from other shot-points, in case the poor results were a feature of the orientation and position of the spreads at Shot-point A. The spread shot perpendicular to the traverse yielded no improvement, and the improvement from the other shots, at Shot-points 2, 6, 6½, 7, 7½, and 8, was questionable.

The arrangement finally adopted as being the best consisted of:

<u>Shot-holes</u>: 45 holes in 3 rows parallel to the traverse, and 100 ft apart. Each row had 15 holes, 20 ft apart and 30 ft deep. A charge of 10 lb of "Geophex" per hole was used. Although the hole depth was only 30 ft, it took an average of a day per pattern to drill.

<u>Geophones</u>: 24 geophones per trace, in line, at 21-ft intervals.

The cut-off wave numbers for the shot-hole and geophone arrays for longitudinal waves are 0.0017 and 0.0010 c/ft respectively. In addition the shot-hole pattern has a cut-off wave number of 0.0017 c/ft for transverse waves.

Record quality was found to be best with the frequency pass-band at 27 to 72 c/s.

<u>Production shooting, Traverse A</u>

Using the best recording techniques determined by the experimental programme, continuous profile reflection shooting was commenced on Traverse A. The spread was a split spread of total length 3600 ft with take-outs at 150-ft intervals. Shot-points 4 to 8 were shot but as reflection quality was very poor it was decided to discontinue the profiling.

<u>Experimental shooting, Traverse B</u>

Before production shooting was commenced on Traverse B, a short experimental programme was carried out. This consisted of uphole shooting and noise shoot CD.

The area chosen for experimentation on Traverse B was an open, flat area, one mile long, in the region of SP114 to SP116. The area was originally chosen for its flatness and easy accessibility; uphole shooting and preliminary split-spread reflection shots at SP 114 confirmed that the character of the immediate subsurface was regular enough to make the area suitable for a noise shoot.

A series of uphole shots into normal split-spreads was shot from SP114 from depths down to 255 ft. The reflection shots showed that the minimum suitable shot depth that would ensure good record quality was 25 ft; the best charge size was 15 lb. Accordingly these were used for the noise shooting.

The noise spreads were laid out in the same way as for noise shoot AB on Traverse A, and were shot from Shot-point C, 720 ft east of SP114, without filtering or AGC and with gains varied according to the shot-to-geophone interval.

Some signals were recorded on noise shoot CD (see Plate 14). The noise analysis (see Plate 15) indicated that the signal was separated from noise events by a wave number value of 0.0025 to 0.003 c/ft and a frequency of about 32 c/s. These values were used as a guide in designing shot-hole and geophone arrays. Uphole shooting into geophone arrays with a cut-off wave number of 0.0038 c/ft (18 geophones 7-1/3 ft apart, 12 geophones 11 ft apart, and 6 geophones 22 ft apart) had previously been tried and had confirmed that this value was too high.

Experimental spreads for determining the best patterns were shot at Shot-points 114, 115, and 116. The first spreads shot consisted of 10 holes in line 20 ft apart (cut-off wave number 0.0025 c/ft) and 18 geophones in line 11 ft apart (cut-off wave number 0.0025 c/ft). The charge size and depth of holes were varied from $2\frac{1}{2}$ lb to 10 lb per hole and from 20 ft to 100 ft respectively. Many pickable events were recorded on all records, the quality improving with both charge and depth increases. The minimum suitable depth found was about 25 ft, but it appeared to be a function of the depth of the water table, which varied according to the amount of rain that fell at various times during the survey. In general, the requirement for a good record was to place the shot well into the second weathered layer (see Plate 5). A total charge of 100 lb or more seems necessary to produce a sufficient energy level. A further reduction in cut-off wave number was tried by using 18 geophones 18 ft apart (0.0015 c/ft) and this gave a definite improvement in the quality of the events. Further experiments in varying the cut-off wave number values for both holes and geophones around this figure resulted in a figure of 0.0016 c/ft being adopted for both shot-holes and geophones in the spread used for production work. Increasing the number of geophones per trace to 30 while maintaining the same wave number value did not improve quality to any noticeable degree.

The difference in the effect on the signal of recording on a narrow pass-band compared with recording with filters wide open was found to be very small. For this reason recording was done with the widest frequency band possible so as to allow a greater choice in the subsequent processing of the data.

<u>Production shooting, Traverse B</u>

Following the results and interpretation of the experimental work, the following production technique was adopted, using a split spread of total length 3600 ft. The shot pattern consisted of seven holes in line at 45-ft intervals, each hole being 100 ft deep and loaded with 20 lb of charge. The geophone pattern considted of 24 geophones per trace, in line, at intervals of 12 ft.

During the production programme, some different hole patterns were tried in an attempt to improve production efficiency while maintaining the same reflection quality. These patterns were designed using the same optimum recording conditions as for the standard spread; however, their use improved neither production efficiency nor reflection quality sufficiently to warrant their continued use. In particular a shot-hole pattern of 10 holes 70 ft deep and 30 ft apart, with 10-lb charges, which gave slightly improved results, was sometimes used when extra drilling time was available. However, the time required to drill this pattern was longer than for the seven deeper holes.

It had been intended to use short spread lengths in order to record very shallow reflections (from less than 200 ft) to assist the hydrological studies of the basin. However, in view of the multiple shot-hole patterns required, 1800-ft spreads had to be used in order to maintain a reasonable coverage rate.

6. RESULTS

Experimental shooting, Traverse A

Surface velocities. Owing to the drilling difficulties (see Appendix C), the deepest shot obtained on Traverse A was at 120 ft. An uphole shoot upwards from this depth at SP6 showed a vertical velocity of 7100 ft/s in the limestone.

The nature of the near-surface of the limestone varied to such an extent that no consistent velocity values could be obtained from first arrival times on reflection records. They did confirm, however, a near-surface velocity in the vicinity of 7000 ft/s, this value also agreeing with the first arrival times on the noise shoot recording.

Computing procedure for noise shooting. All interpretation measurements were made on wiggle-trace monitor records.

A time-distance plot was first constructed for the best line-ups of each event showing on the records, and apparent velocities were measured from this plot. Average periods and frequencies for each event were then measured from the records and a wave number ($k = f/v$) was calculated for each event.

Average maximum amplitudes of events were then measured and related to each other in terms of relative response in decibels. Maximum response was defined as a trace amplitude of 1 inch on a seismic record when amplifier gains were set at minus 37 decibels, and amplitudes of events recorded in the noise shoot were calculated in terms of decibels below this maximum level.

By plotting average frequencies and wave numbers of each recorded event against relative response, a convenient inspection of the characteristics of the events was made possible.

From each noise analysis, the wave number value that best separates the signal events (high apparent velocity) from the low velocity noise is usually chosen for the design of shot-hole and geophone arrays. Similarly, the frequency value that best separates the two types of events is usually chosen as the low-cut filter value for recording. Where no signal events were present, as on the

Traverse A noise shoots, the wave number and frequency values to be used are chosen so as just to exclude the noise events.

Noise shooting. The noise shoot record sections for noise shoot AB (20 and 50 lb charges) and noise shoot EF are shown in Plates 8, 9, and 10 respectively. These record sections are photographed reductions of sections produced in the BMR playback centre in Melbourne on the SIE Playback System MS42. No corrections were applied in the production of these sections.

The analysis of the results of the noise shoots were carried out on the original monitor records. The results of these analyses for the three noise shoots on Traverse A are shown in Plates 11, 12, and 13.

There is a very high level of coherent noise generated when shooting in the limestone. The average level of low velocity (3000 to 4000 ft/s) coherent noise is very much higher than the level of the first arrivals and there is no part of the 4500-ft section covered by the analysis which shows an appreciable reduction in noise level (i.e. no 'window').

No definite signal could be recognised on the records from noise shoots AB; some high velocity events present are probably due to transverse noise. This transverse noise is evident on the record from the transverse spread, but it appears relatively unimportant compared to the longitudinal noise.

There is also a high level of random noise when shooting in the Coastal Limestone.

As no signal could definitely be recognised on the noise shoot, the selection of a wave number that differentiates signal from noise could not be made, and the selection of a cut-off wave number became a question of adopting the highest value that did not exceed the wave number of any of the high-level coherent noise. The low wave number noise having a value of 0.003 c/ft indicated that the cut-off wave number was somewhat less than this.

Noise analysis EF showed that the same type of noise characteristics existed for surface shooting as for hole shooting. Very large shot-hole and geophone patterns would be needed if surface shooting methods were to be used, but the technique may still be more economical than the shot-hole method because of the considerable time, and large quantity of bentonite, required to drill large shot patterns. Unfortunately no time was available to experiment further with surface shooting techniques.

Production shooting, Traverse A

As stated in the Section 4, only Shot-points 4 to 8 were shot with the finally adopted production technique for Traverse A. The record section for this profile is shown in Plate 3; elevation corrections, but no weathering corrections, have been applied. Dynamic corrections as for Traverse B have been applied.

Experimental shooting, Traverse B

Surface velocities. The drilling log at SP114 showed unconsolidated sand to 180 ft, then green sandy clay to a depth of 255 ft, the maximum depth drilled. The water table was at 25 ft. Uphole shooting in this hole showed an average vertical velocity of 2000 ft/s above the water table, and 5400 ft/s in the sand below the water table.

First arrivals on the reflection records showed two refracting layers, one with a velocity of 5800 ft/s and the other with a velocity of 7000 ft/s.

Had this traverse been straight, and if more uphole times had been available to use in correction estimations, the static corrections applied to the records on this traverse may have been improved.

Noise shooting. The record section for noise shoot CD is shown in Plate 14 and the results of the noise analysis are shown in Plate 15. Disregarding the first arrivals, the coherent noise is of very low amplitude, and in places, non-existent. Some reflection events can be seen on the section; in particular, the event at about 1.5 seconds can be followed to some extent across the entire section. Most of the coherent noise present is of low apparent velocity (1000 to 2300 ft/s) and has wave numbers in excess of 0.009 c/ft. No significant transverse noise is apparent.

Results of the noise analysis and subsequent tests indicated that the use of all the geophones available on the party was necessary to obtain suitable record quality. As no transverse noise was evident on the noise analysis, the 18 geophones per trace on 24 traces were placed in line with the spread to give the maximum possible improvement in signal-to-noise ratio for noise energy travelling along the traverse.

Record quality improved with the number of holes per pattern but drilling difficulties limited the number of holes that it would be practical to drill. The minimum number of holes that could be used in line for suitable record quality was considered to be seven, and the maximum number of holes which could be drilled per shot-point for reasonable economy was considered to be ten.

Production shooting, Traverse B

The record section for Traverse B is shown in Plate 4. The section has had both static and dynamic corrections applied. Weathering corrections were calculated from first arrival times on the reflection records. The velocity relation used for the dynamic corrections was calculated from a $t:\Delta t$ analysis of the records from SP110 to SP147. The results of the $t:\Delta t$ analysis are shown in Plate 6. The analysis was made from good quality records, but the errors arising in estimating depths to reflecting horizons by this method must be recognised.

The dynamic corrections from this analysis for use in the record section seem to give a reasonable straightening of reflection events.

Of the section shot (SP97 to SP150), reflection quality is considered good to the east of SP121, but to west of this shot-point, the quality deteriorates slightly.

The reflection horizons shown in Plate 5 are from an interpretation of some of the better reflection events showing in Plate 4; they are not intended to represent geological formations, no geological correlation having been established, but are intended to show more clearly the structure indicated on the records comprising Plate 4.

7. INTERPRETATION

Traverse A

The record section of Traverse A (Plate 3) does not show any definite seismic reflection events although a few poor line-ups are visible.

Traverse B

Changes in traverse direction and probable complex geological structure help to make correlation of seismic events on the record section west of SP121 difficult. East of SP121, however, improved record quality shows what appears to be a thick synclinal section yielding clear seismic reflections from depths down to at least 10,000 ft, with the axis at about SP138.

In the region of Shot-points 110-112, the presence of a fault is indicated by the loss of reflection data and the presence of anomalously dipping line-ups, which are consistent in form with diffraction events. An area of special interest seems to be between Shot-points 110 and 121, where beds, which are possibly conformable, overlay an apparent earlier erosional surface at 2000 to 2500 ft.

Between SP112 and SP125, at a depth greater than 7000 ft, the bedding appears to undergo a reversal of dip. Another apparent slight reversal in dip occurs in beds deeper than 3000 ft east of SP 147. This may be mainly due to changes in traverse direction.

There is no direct evidence that the Darling Fault has been crossed by Traverse B; however, the number and quality of reflection events falls off rapidly in the region of SP152, and at SP153 there are no definite reflections recorded. There are no significant changes in the near-surface velocities. The record from Shot-point M indicates a sharp increase in the near-surface velocity about 0.8 mile south-east of SP153 (see Appendix D).

8. CONCLUSIONS

Although several weeks were spent shooting with 'heavy' techniques on Traverse A, no useable reflection results were obtained. It would seem that even heavier techniques will be necessary if satisfactory results are to be obtained on the Coastal Limestone formation with conventional techniques as there is no evidence to suggest that the area of Traverse A is atypical of the Coastal Limestone formation.

Record quality on Traverse B, off the limestone, is in general satisfactory; improvement could probably be obtained with a more detailed experimental programme.

With regard to the assistance that was to be given to hydrological programme, as no short spreads were used, no definite reflections were recorded from shallower than 1500 ft and only very sparse information is available from between 1500 ft and 2500 ft on Traverse B.

More detailed seismic reflection work seems desirable in the case of four features which may be of importance for oil or gas accumulation:

1. The deep reversal of dip between SP110 and SP125.

2. The probable anticline at about SP149.

3. The shallow unconformity at about 2000 to 2500 ft.

4. The probable fault in the region of SP110 to SP112.

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APPENDIX A

Staff and equipment

Staff

Party leader:	D. J. Walker
Geophysicists:	J. S. Raitt B. F. Jones
Surveyors:	J. Ritchie P. Pullinen
Observer:	R. Krege
Shooter:	C. Wood
Driller Gr. 2:	J. Chandler
Drillers Gr. 1:	K. Suehle J. Keunen
Drill assistants:	R. Vigar (left on April 17th) L. Watts (left on March 26th)
Mechanic:	E. MacIntosh

Equipment

Seismic amplifiers:	TI 8000 (Explorer)
Seismic oscillograph:	SIE TR06
Magnetic recorder:	Electro-Tech DS7/700
Geophones:	Electro-Tech EVS 8B 4.5 c/s (26 sets of 4) Electro-Tech EVS 2B 20 c/s (122 sets of 6) T.I.C. 20 c/s (28 singles)
Drills:	1 Mayhew 1000 2 Carey
Water tankers:	3 Bedford RLHC3, 4 x 4 with 600-gallon cylindrical tank 2 Bedford RLHC3, 4 x 4 with 1000-gallon flat tank
Shooting truck:	Bedford RLHC3, 4 x 4 with 600-gallon cylindrical tank
Recording truck:	International AB120, 4 x 4 with BMR Ansair cab
Geophone trucks:	2 Landrover L.W.B.

Other mobile equipment held on the party were:

Landrover (survey)

Landrover station wagon

Utility, 1-ton

Supply truck, 3-ton

Workshop truck

Chamberlain tractor

Office caravan

5 Trailers, 4-wheel articulated

APPENDIX B

Table of operations

Sedimentary basin:	Perth Basin, Western Australia
Area:	Wanneroo - Bullsbrook
Camp site:	Corner of Yanchep Road and Quinns Rocks Road
Established camp:	18th March 1964
Surveying commenced:	13th March 1964
Drilling commenced:	16th March 1964
Shooting commenced:	23rd March 1964
Miles surveyed:	23
Topographic survey control:	Lands and Survey Dept WA, 4-mile series Levels: main roads bench-marks
Total footage drilled:	87,798
Explosives used:	19,968 lb Geophex 1790 electric detonators
Datum level for corrections:	Sea level
Weathering velocities:	V_o = 2000 ft/s V_1 = 5400 ft/s V_2 = 6900 ft/s
Source of velocity distribution:	t:Δt analysis

Reflection shooting data

Shot-point interval:	1800 ft	
Geophone group:	Traverse A:	24 in line of traverse 21 ft apart
	Traverse B:	24 in line of traverse 12½ ft apart
Geophone group interval:	150 ft	
Common shooting depth:	Traverse A: Traverse B:	30 ft 70 ft or 100 ft
Usual recording filter:	Traverse A: Traverse B:	K27-K72 K22-K92
Usual playback filter:	Traverse A: Traverse B:	K27-K72 K27-K72
Common charge size:	Traverse A: Traverse B:	45 x 10 lb 7 x 20 lb 10 x 10 lb
Total number of shots:	214	
Miles traversed:	23	
Number of experimental profiles:	73	
Number of production profiles:	62	
Number of noise analyses:	4	

APPENDIX C

Field operating conditions

Access and topography

The survey area was situated about 20 miles north of Perth and access was provided by the Perth-Yanchep road. The party was camped 23 miles from Perth on this road.

The topography of the area is flat to undulating from the coast to the Darling Ranges, with many swamps at the western end and dunes bordering the coast.

Traverse A

This traverse was located on the Coastal Limestone formation close to the bitumen road to Quinns Rocks. The traverse was clear of vegetation for most of its length. Access to the shot-points was, however, very difficult owing to the rough limestone outcrops which made vehicle travel slow and often limited the size of shot-hole patterns. Considerable mechanical damage was caused to the vehicles in this area. No suitable alternative location for the traverse could be found in the vicinity, it being necessary to remain on the limestone outcrops.

Traverse B

Because the area between the Coastal Limestone belt and the Darling Ranges contains many small farm holdings and some dense scrub, it was impractical, in the time allocated for the survey, to lay a straight traverse. The traverse was then located along the side of the bitumen surfaced road from Bullsbrook to Wanneroo. East of SP147, where the traverse crossed the foothills of the Darling Ranges, there was no road, but as the slopes were gentle and well cleared of vegetation, no serious access problems were encountered.

Drilling conditions

Traverse A. Although the Coastal Limestone formation was not hard to drill, considerable difficulty was experienced owing to frequent complete loss of circulation between depths of 35 to 120 ft. The depth of loss of circulation, due to caverns in the limestone, was unpredictable and this depth varied considerably in a single pattern. In view of the desirability of having all holes of the same depth in pattern shooting, the hole depth was finally limited to 35 feet. Holes usually stayed open for at least two shots.

Fluid drilling using large quantities of bentonite was generally necessary but occasionally air with water injection was successful. At Shot-points 2 and 6, most holes could be drilled with air to 30 ft.

Traverse B. The drill logs on Traverse B showed sand and clay, with laterite and clay east of SP147. The water table was generally shallow (12 to 20 ft) and seldom exceeded 80 ft, and in the sand, hole collapses jamming the drill stem were frequent, necessitating the use of large quantities of bentonite. It was also necessary to load holes immediately on completion of drilling. This introduced problems during experimental work on Traverse B; in many cases holes had to be shot, the records assessed, and decisions made on pattern, charge, and depth before drilling could be completed for the next shot.

Because the sand became very fluid after a shot, it was very difficult and sometimes impossible to drill another hole within about 40 ft of a hole just shot. Immediate redrills of a hole just shot were impossible. For this reason, in some cases comparison shots had to be done several days apart. Simultaneous loading of several patterns at a shot-point was tried, in an effort to overcome this, but sympathetic detonation of the preloaded patterns made this unsatisfactory.

Drilling statistics

Two types of drill were used during this survey and data relevant to the performance of the drills are listed below:

	Mayhew	Carey C10672	Carey C10673
Traverse A			
Total footage drilled	14369	9321	3555
Deepest hole (ft)	120	104	101
Actual drilling time (hr)	135	109½	49¾
Average rate of penetration (ft/hr)	106	85	71
Time lost waiting for water (hr)	-	12	2
Time lost waiting for repairs to drill (hr)	3¾	9	1
Time lost waiting for repairs to drill engine (hr)	1	-	4
Bentonite used (80-lb bags)	37	56	7½
Traverse B			
Total footage drilled	24684	11169	14391
Deepest hole (ft)	255	124	124
Actual drilling time (hr)	170¼	72½	99¼
Average rate of penetration (ft/hr)	145	154	145
Time lost waiting for water (hr)	4½	3½	11½
Time lost waiting for repairs to drill (hr)	2¼	9	20½
Time lost waiting for repairs to drill engine (hr)	1	-	-
Bentonite used (80-lb bags)	188	70	117½
Both traverses			
Maintenance to drill (hr)	39	24	22¾
Time lost owing to rain (hr)	17	7	1

APPENDIX D

Mohorovicic discontinuity

In accordance with standard BMR procedure, and in association with the BMR Geophysical Observatory, Mundaring, an effort was made to record reflection events from within the Earth's crust, down to the region of the Mohorovicic discontinuity, at locations in the Perth Basin and on the Precambrian shield east of the Darling Fault. This was done at SP105, with a 24-trace spread between SP105 and SP109, and at Shot-point M (east of SP153), with 19-trace spread between Shot-point M1 and M19 (see Plate 1).

No experiments were conducted and only two shots were taken, one at each of the shot-points, and the shooting technique used was simply that which was expected to yield the best results with the recording equipment available.

The longest possible spreads were laid out with a single string of geophones at each outlet, placed in a bunch so as to obtain the maximum response and the minimum wavelength discrimination. Because the object at the shot-point was to place a very large charge as deep as possible, a pattern of holes was drilled, and the area of this pattern was kept small, so that a pulse of energy very rich in frequencies would be generated. The slowest possible AGC rate was used in recording and a magnetic tape was made of each shot by using two 12-second tapes fastened together with transparent mending tape.

Particulars relating to the techniques are listed below:

SP105, Perth Basin

Charge:	275 lb in a five-hole array with hole spacing 15 ft
Depth of charge:	120 ft to bottom of charge
Spread length:	7200 ft. 24 outlets with outlet 1 on SP109 and outlet 24 300 ft from SP105
Geophones:	4 geophones (4.5 c/s) per trace bunched Outlet interval 300 ft
Recording filter:	'out' - 40 c/s
AGC:	$\frac{1}{1}$ 50 dB per second

Shot-point M, Precambrian shield

Charge:	500 lb in a five-hole array with hole spacing 15 ft. Shot-point M is 3660 ft east of Shot-point M1 and offset from the line of the spread
Depth of charge:	60 to 100 ft
Spread length:	5400 ft (between outlet 1 and outlet 19). The spread was laid beside the longest straight section of road in the area so as to make it easily accessible. Only 19 outlets were laid.

Geophones:	6 geophones (20 c/s) per trace bunched on traces 1 to 12 4 geophones (4.5 c/s) per trace bunched on traces 13 to 19 Outlet interval 300 ft
Recording filters:	'out' - 72 c/s
AGC:	$\frac{1}{1}$ 50 dB per second

As no events were recorded on the shot in the Perth Basin it was decided to broaden the frequency pass-band used in recording, and to offset the shot from the spread when taking the shot on the Precambrian shield.

Shot-point M was located in a laterite formation to make the drilling easier, while the spread was laid along the longest portion of relatively straight road in the area. The spread was located east of the position of the Darling Fault as determined from gravity data, and was thought to lie over the granite of the Precambrian shield.

It became apparent from the first arrivals on the seismic record obtained from this shot, however, that the near-surface expression of the Darling Fault was beneath outlet 8 of the spread - that is, 0.8 miles south-east of Shot-point 153.

No definite reflections from the Mohorovicic discontinuity were obtained from the recording from Shot-point M, but some suggestion of seismic events did occur on the record at various times down to that which could correspond to the depth of the Mohorovicic discontinuity. [Uncorrected two-way times to these events are tabulated below, together with an indication of the relative reliabilities of the events. A possible interpretation, derived from information contained in a report by Everingham (1966) is also shown in the table. The depth values shown were computed using average velocities measured by Everingham.]

Shot-point M

Shot at 0600 hrs GMT on 15th June 1964

Uncorrected two-way-time (seconds)	Reliability	Depth (km)	Interpretation
1.45	Doubtful		
2.76	"		
4.06	"		
4.41	Fair	13.6	
4.81	"	14.9	Top of intermediate crustal layer
5.35	Doubtful		
6.23	"		
9.70	Poor	32.6	
11.23	"	38.1	
11.36	Fair	38.6	
11.62	Poor	39.5	Mohorovicic discontinuity
12.78	Doubtful		
12.99	"		
14.97	"		

Absolute time was recorded on the 'Moho' seismic records by connecting the output of a commercial radio into the uphole trace. In this way the hourly time pips given by a commercial radio station were recorded, and the 'Moho' shot was recorded on the same record immediately after the time pips. The taking of absolute time for each shot was necessary because the shots were simultaneously recorded in the Mundaring Seismic Observatory, and on the observatory's field seismographs, placed at other locations east of the Darling Fault.

Of interest is that the seismic instruments at Mundaring Observatory recorded events from most of the charges of over 100 lb detonated in the Perth Basin (except on the Coastal Limestone) during this survey. On two occasions, where time permitted, the absolute time of the shot was recorded on the seismic reflection records, as described above for the 'Moho' shots, for the information of the observatory.

Results of attempts to record reflections from the Mohorovicic discontinuity were inconclusive. No events were recorded in the Perth Basin and only events of dubious significance were recorded on the Precambrian shield. [The uncorrected two-way times to events obtained on the Precambrian shield tests are tabulated above. The possible interpretation of two events shown in this table is based on results of previous crustal studies conducted in the area by Everingham (1966).]

In the Perth Basin some records from the Traverse B shooting programme were run for over 10 seconds to find whether deep reflecting horizons could be defined. This was done at shot-points where the energy transmission characteristics were good and where heavy charges were used.

Events were recorded at unusually large times as can be seen from the following table:

Date	Shot-point	Two-way event time Band 1 (seconds)	Band 2 (seconds)
30.5.64	102	7.390	
2.6.64	106		9.165
4.6.64	107	7.010	
4.6.64	108	7.215	
		7.540	
		7.790	
4.6.64	109	7.115	9.145
18.5.64	110	7.848	
15.4.64	115	7.050	
		7.9	
16.4.64	115	7.032	
		7.957	
4.5.64	116½		9.250
30.4.64	117	7.450	
4.5.64	117½	7.355	

All of these events are of poor quality but their times appear to group into two bands, one approximately between 7 and 8 seconds and the other at approximately 9.2 seconds two-way time. It appears that if these two bands of events are reflections from deep layers, which seems reasonable, then events at times between 7 and 8 seconds could be from between 50,000 and 58,000 ft deep, near the base of the Perth Basin sediments, and the deeper event times could correlate with the top of an intermediate crustal layer. On the other hand, it is possible that the events near 9.2 seconds arise from reflections from the base of the Perth Basin sediments. Crustal studies by Everingham indicate a possible 66,000-ft depth to basement, agreeing well with the depth of 65,000 ft estimated from geological studies. Velocity values used to compare the depths given above were average velocities measured by Everingham.

ROADS Major Secondary

RAILWAY - Station

WATERCOURSE Perennial Non-perennial

SEISMIC SHOT POINT

-40 ISOGALS

? shot points not shown: they are on drawing H50-B3-1-1 (see BMR Rec. 1964/155).

TERTIARY TO RECENT

COASTAL LIMESTONE

BOG LIMESTONE

CLAYS AND LOAMS

LATERITE DEPOSITS

SILICEOUS SANDS

PRECAMBRIAN

METAMORPHOSED SEDIMENTS

GRANITE AND GRANITIC GNEISS

SCALE IN MILES

1 0 1 2 3 4

BULLSBROOK SEISMIC SURVEY, PERTH BASIN W.A. 1964

SEISMIC TRAVERSES, GEOLOGY, AND BOUGUER ANOMALIES

TO ACCOMPANY RECORD No. 1966/203

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

H50/B3-1

BULLSBROOK SEISMIC SURVEY 1964

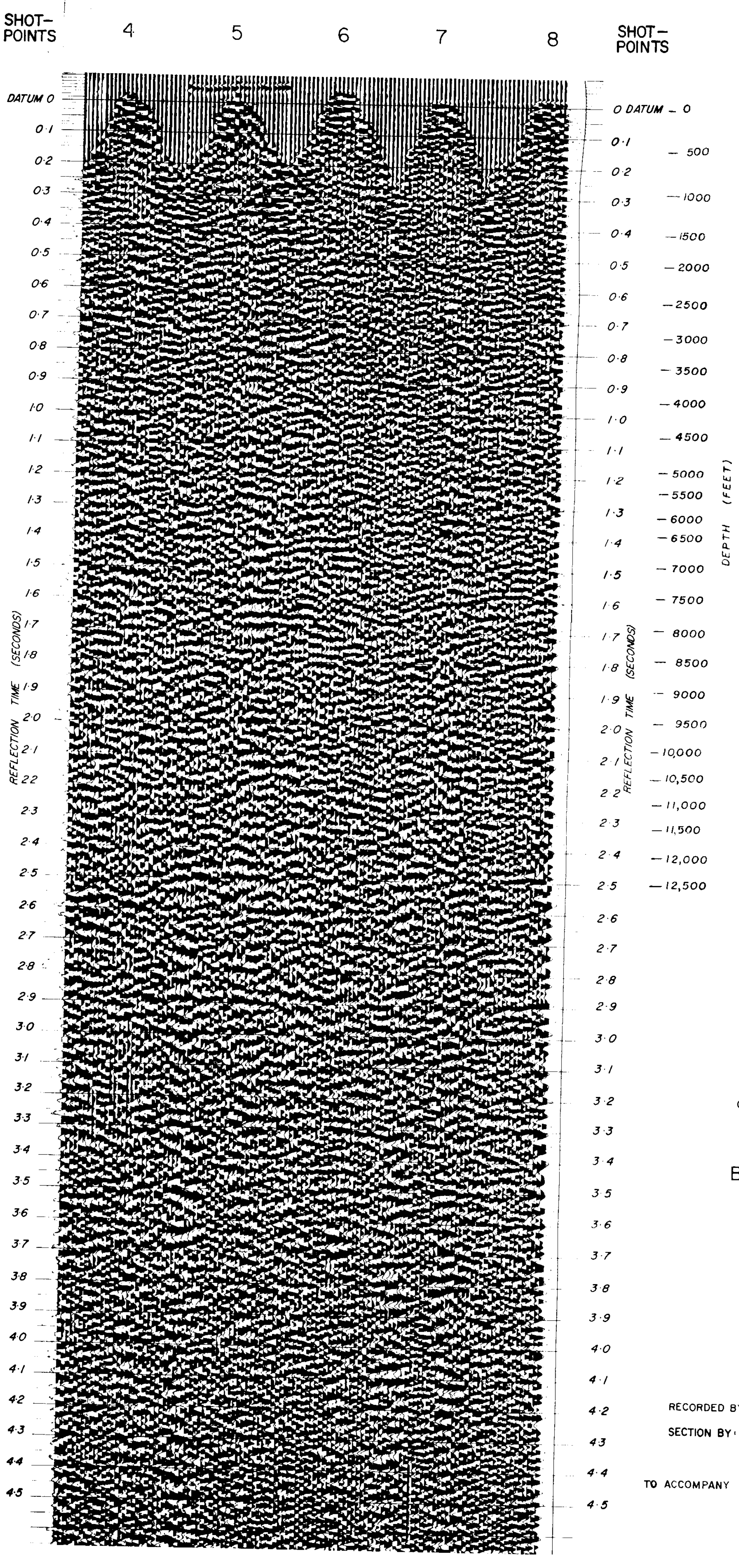
PERTH BASIN, WA
REGIONAL GEOLOGY AND
CONTOURS OF DEPTHS TO MAGNETIC BASEMENT ROCK
ESTIMATED FROM AEROMAGNETIC DATA

TO ACCOMPANY RECORD No. 1966/203

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. H50/B3-3

PLATE 3

CORRECTED RECORD SECTION



<u>RECORDING INFORMATION</u>

Magnetic Recorder ETL DS7/700

Amplifiers : 8000 Explorer

Filters : K22–72

A.G.C. : 1/1 125

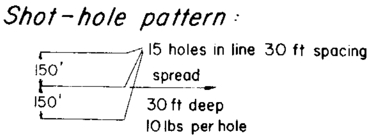
Gain Initial : –60

Final : 1–31

Geophones : EVS 2B 20 c/s

Geophone pattern :
24 x 21 ft in line

Shot-hole pattern :



<u>PLAYBACK INFORMATION</u>

Filters : 1/25 1/47

A.G.C. : Super slow

Gain Initial : –50

Final : –30

Trip delay : –2

Compositing : Nil

<u>VELOCITY INFORMATION</u>

Va = 6900 + 1420 t (from t : Δt)

HORIZONTAL SCALE

0 1000 2000 3000 4000 FEET
1800 3600

BULLSBROOK SEISMIC SURVEY
1964
PERTH BASIN WA

TRAVERSE A

RECORDED BY: *Seismic Party No. 2*

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

TO ACCOMPANY RECORD No. 1966/203

H50/B3-8

PLATE 4

CORRECTED RECORD SECTION

RECORDING INFORMATION

Magnetic Recorder ETL DS7/700

Amplifiers: 8000 Explorer

Filters: K22–92

A.G.C.: 1/1 125

Gain Initial: –70

Final: 1–31

Geophones: EVS 2B–20 c/s

Geophone pattern:

24 x 12½ ft in line

Shot-hole pattern:

7 holes in line 45' spacing

100 ft deep 20 lbs per hole

PLAYBACK INFORMATION

Filters: 1/25 – 1/47

A.G.C.: Super slow

Gain Initial: –50

Final: –20

Trip delay: –2

Compositing: Nil

VELOCITY INFORMATION

Va = 6900 + 1420 t (from t : Δt)

HORIZONTAL SCALE

FEET

0 1000 2000 3000 4000 5000

0 1800 3600

BULLSBROOK SEISMIC SURVEY 1964
PERTH BASIN WA

TRAVERSE B

RECORDED BY: *Seismic Party No. 2*

SECTION BY: *Bureau of Mineral Resources Playback Centre S/E MS 42*

TO ACCOMPANY RECORD No 1966/203

H50/B3–9

TRAVERSE B

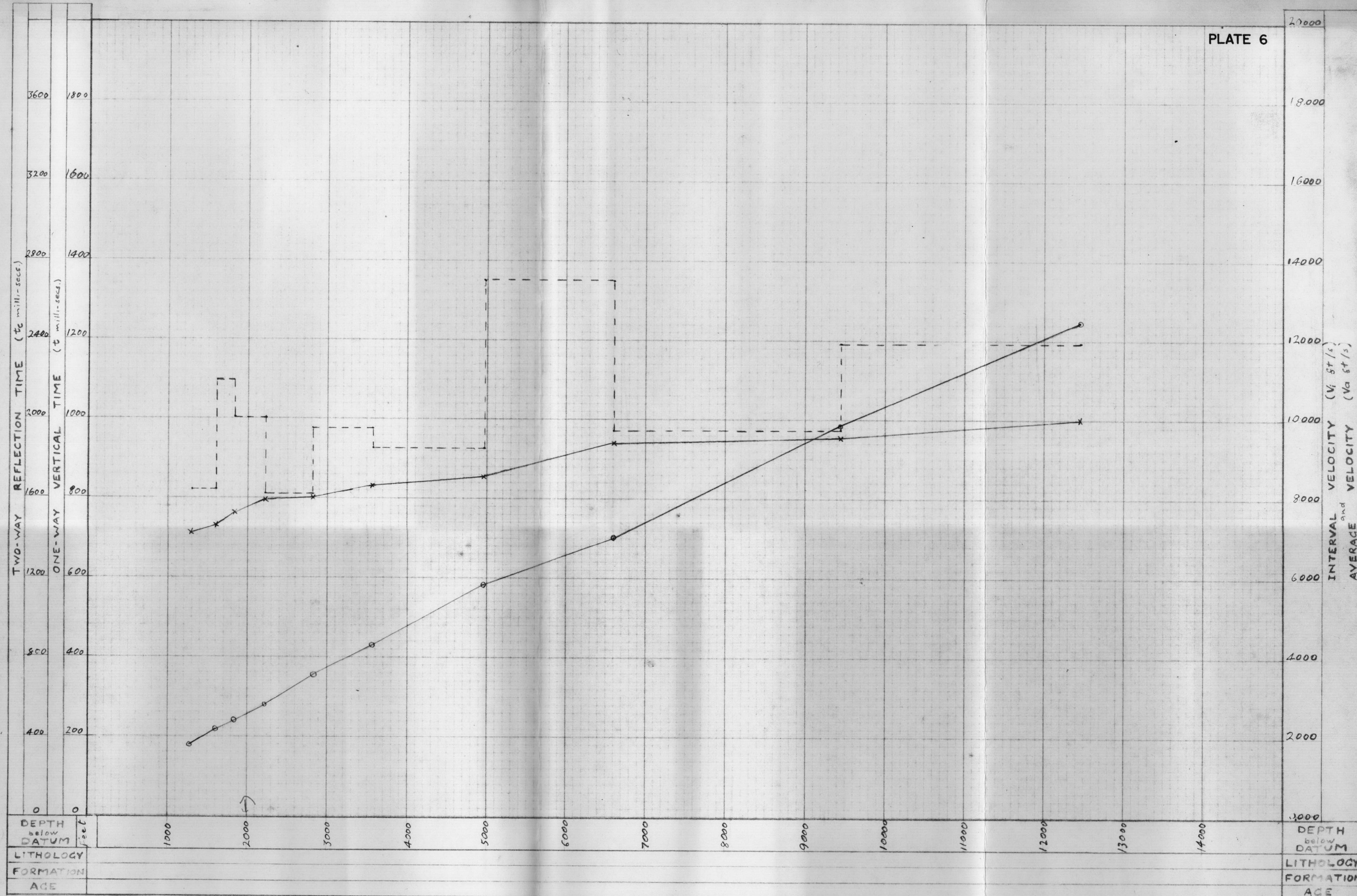
REFLECTION HORIZONS AND WEATHERING DATA.

BULLSBROOK SURVEY 1964.

PERTH BASIN W.A.

TO ACCOMPANY RECORD No 1966/203

H50/B3-10



TO ACCOMPANY RECORD No. 1966/203

H50/B3-14

$V_a \simeq 6900 + 1420t.$

LEGEND

Time - Depth Curve (t-d)

Interval Velocity (Vi)

Average Velocity (Va)

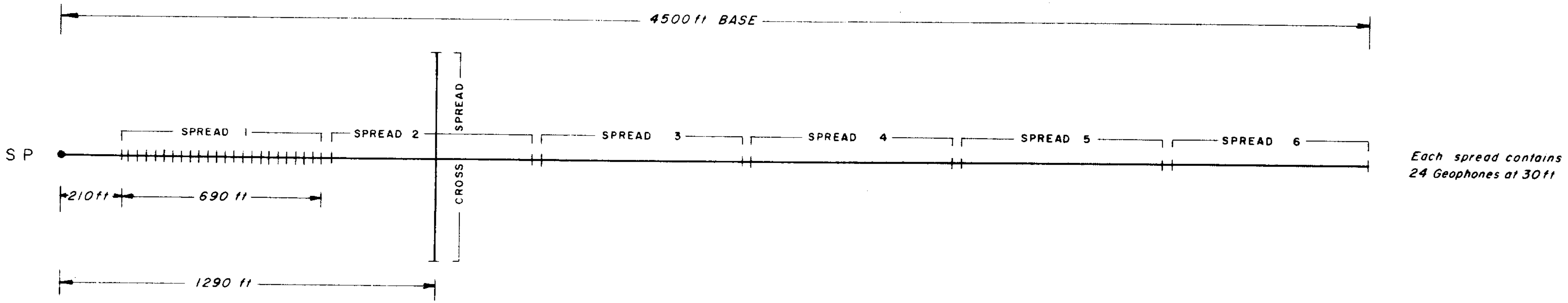
Lithology

Sandstone Shale Limestone

VELOCITY AND TIME VERSUS DEPTH

AREA Bullsbrook. Traverse B. (110-147) SHOT-POINTS

Basis t:Δt analysis

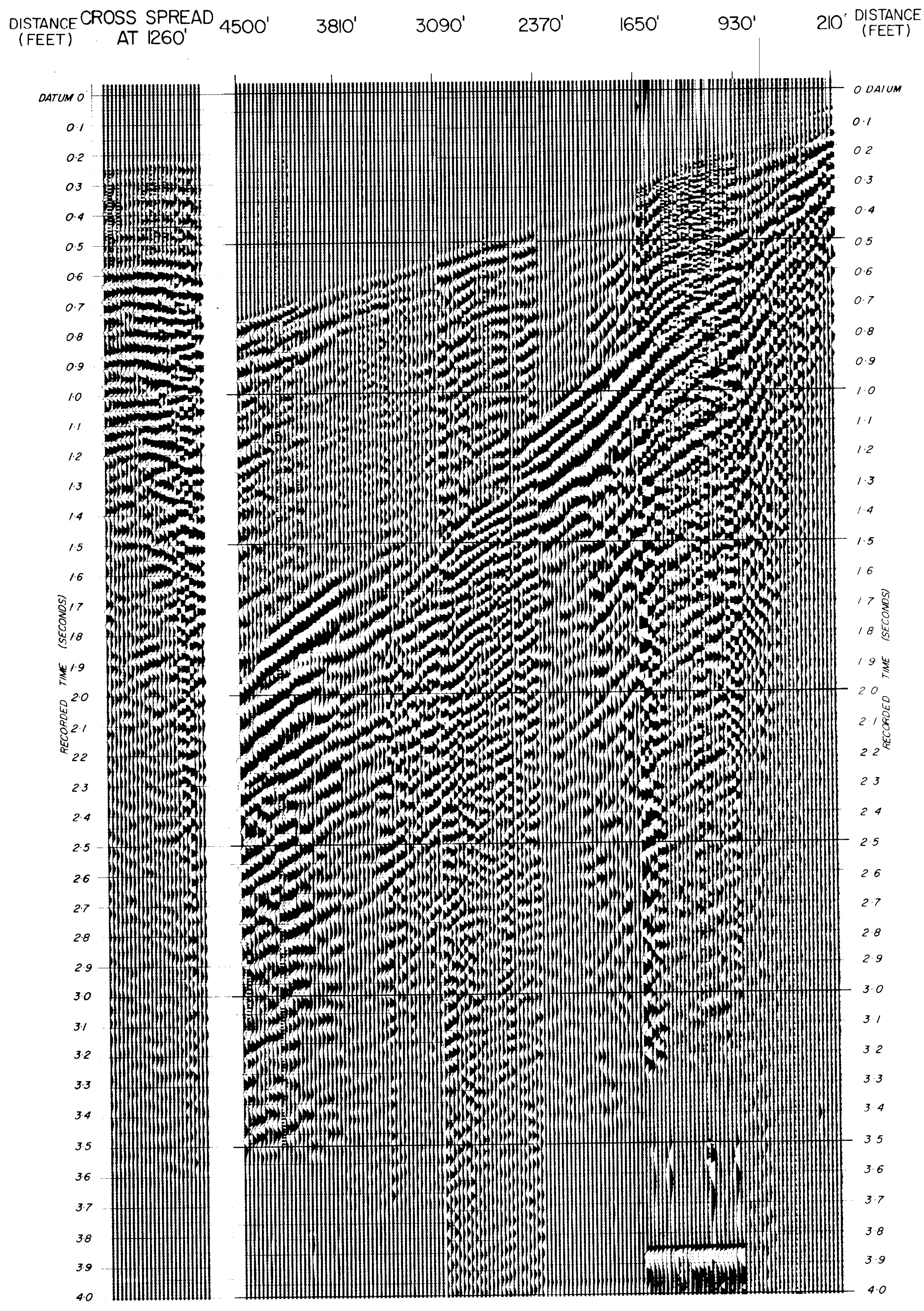


SPREAD ARRANGEMENT FOR NOISE SHOOTS

PLATE 7

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. H50/B3-28

TO ACCOMPANY RECORD No. 1966/203



CORRECTED RECORD SECTION

RECORDING INFORMATION

Magnetic Recorder ETL DS7/700
Amplifiers: 8000 Explorer
Filters: Out
A.G.C.: Off
Gain Initial: Varied
Final: 1-31
Geophones: T.I.C. - 20 c/s
Geophone pattern: Single

Shot-hole pattern: Single
Charge: 20 lb at 50'

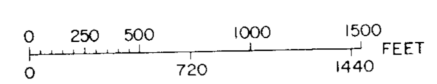
PLAYBACK INFORMATION

Filters: Out
A.G.C.: Off

	Spread 1-2	Spread 3-6
Gain Initial:	-40	-20
Final:	-10	-20
Trip delay:	0·8	0
Compositing:	Nil	

VELOCITY INFORMATION

HORIZONTAL SCALE



BULLSBROOK SEISMIC SURVEY 1964
PERTH BASIN WA

TRAVERSE A

NOISE SHOOT AB
20 - lb CHARGE

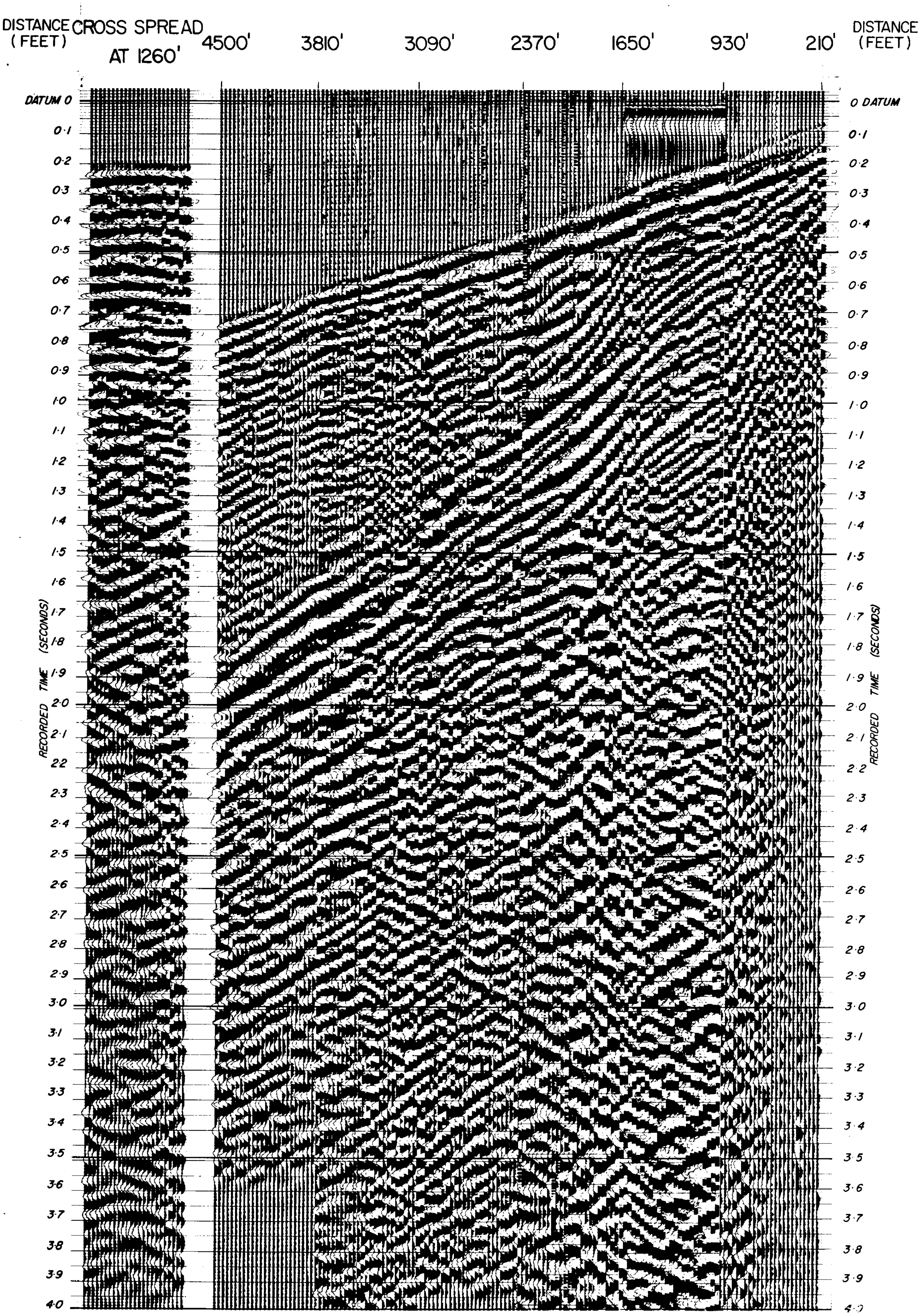
RECORDED BY: *Seismic Party No. 2*

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

TO ACCOMPANY RECORD No 1966/203

H50/B3-15

PLATE 9



CORRECTED RECORD SECTION

RECORDING INFORMATION

Magnetic Recorder ETL DS7/700

Amplifiers: 8000 Explorer

Filters: Out

A.G.C.: Off

Gain Initial: Varied

Final: 1-31

Geophones: T.I.C. - 20 c/s

Geophone pattern: Single

Shot-hole pattern:

Charge: 50 lb at 50'

PLAYBACK INFORMATION

Filters: Out

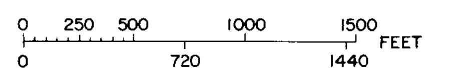
A.G.C.: Off

	Spread 1	Spread 2	Spread 3
Gain Initial:	-40	-40	-10
Final:	-10	-10	-10
Trip delay:	0·8	2·5	0

Compositing: Nil

VELOCITY INFORMATION

HORIZONTAL SCALE



BULLSBROOK SEISMIC SURVEY 1964
PERTH BASIN WA

TRAVERSE A

NOISE SHOOT AB
50-lb CHARGE

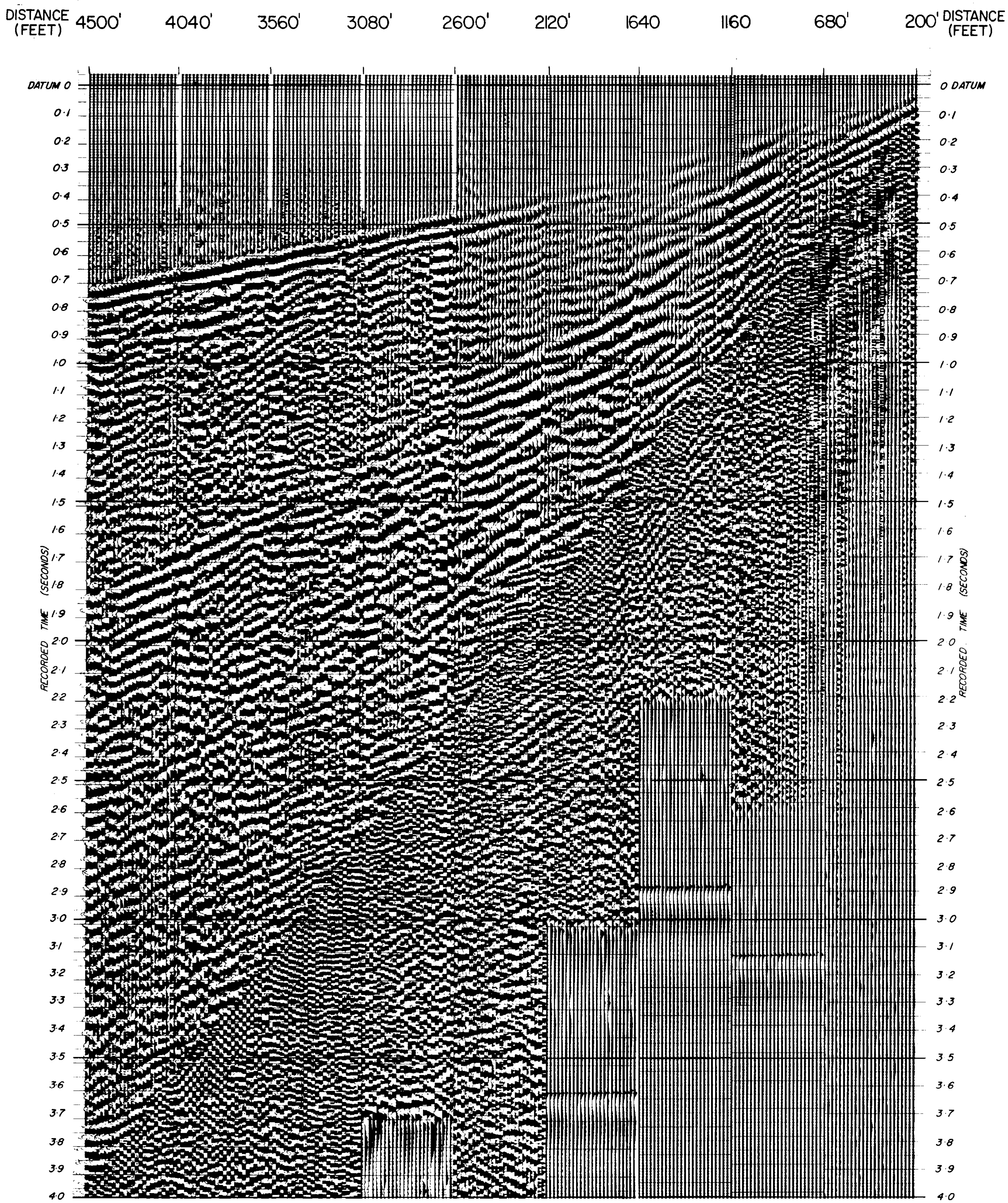
RECORDED BY: *Seismic Party No. 2*

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

TO ACCOMPANY RECORD No. 1966/203

H50/B3-17

PLATE 10



CORRECTED RECORD SECTION

RECORDING INFORMATION

Magnetic Recorder ETL DS7/700

Amplifiers: 8000 Explorer

Filters: Out

A.G.C.: Off

Gain Initial: Varied

Final: 1-31

Geophones: T.I.C.-20c/s

Geophone pattern:

Single

Shot-hole pattern:

Charge: 5 lb at surface

PLAYBACK INFORMATION

Filters: Out

A.G.C.: Off

Gain Initial: -20

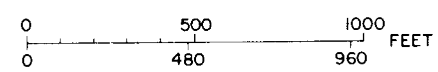
Final: -20

Trip delay: 0

Compositing: Nil

VELOCITY INFORMATION

HORIZONTAL SCALE



BULLSBROOK SEISMIC SURVEY 1964
PERTH BASIN WA

TRAVERSE A

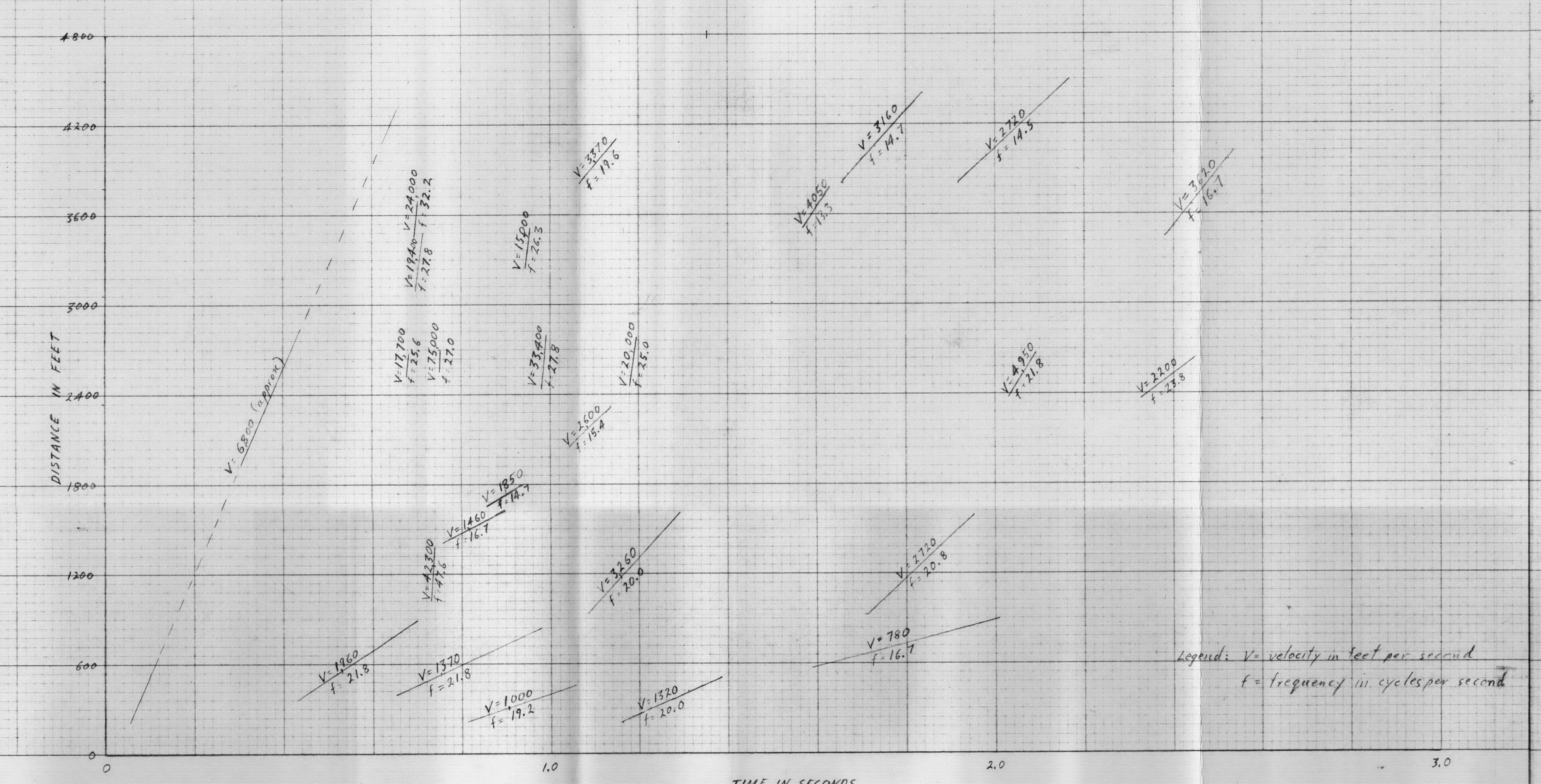
NOISE SHOOT EF

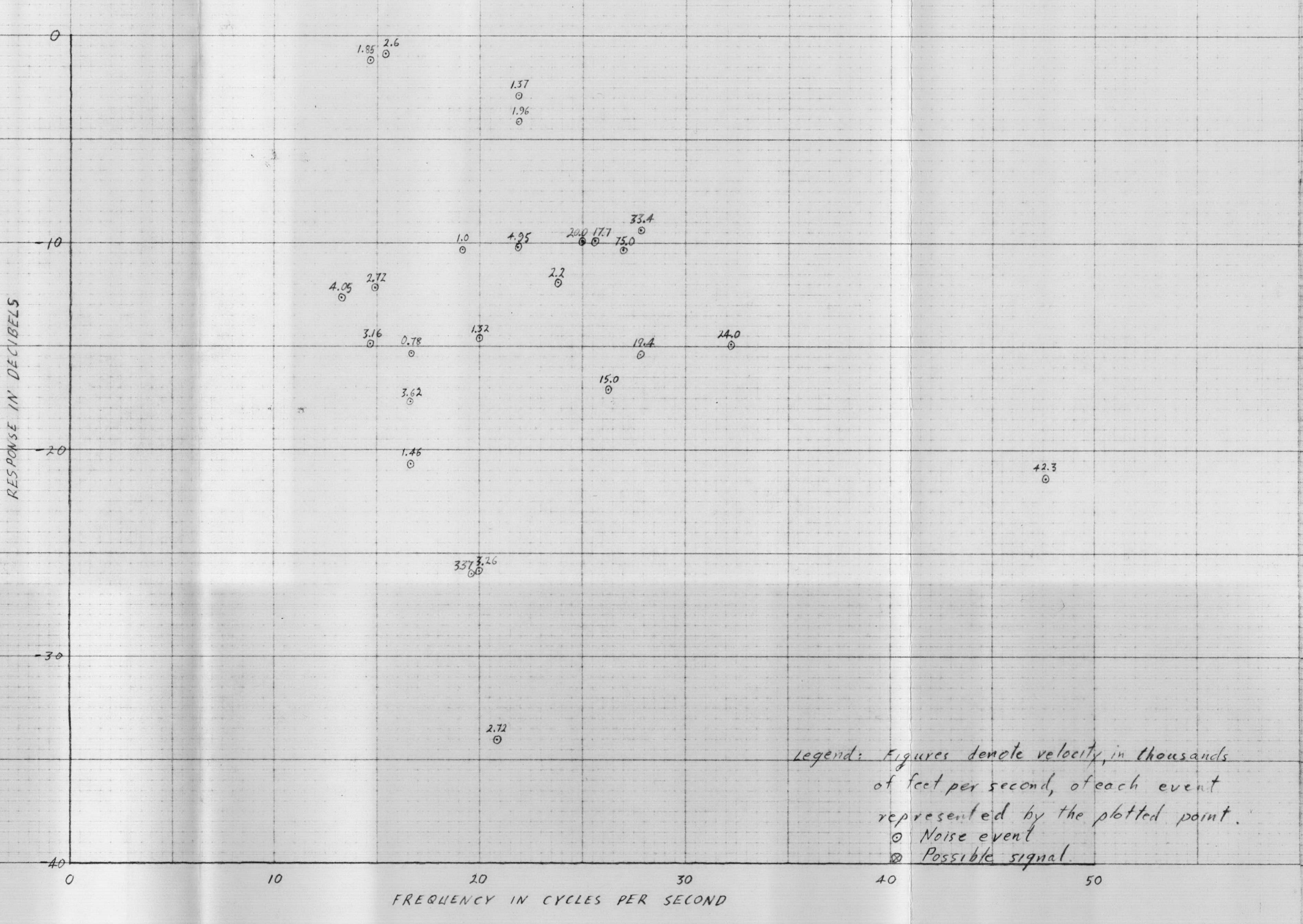
RECORDED BY: *Seismic Party No. 2*

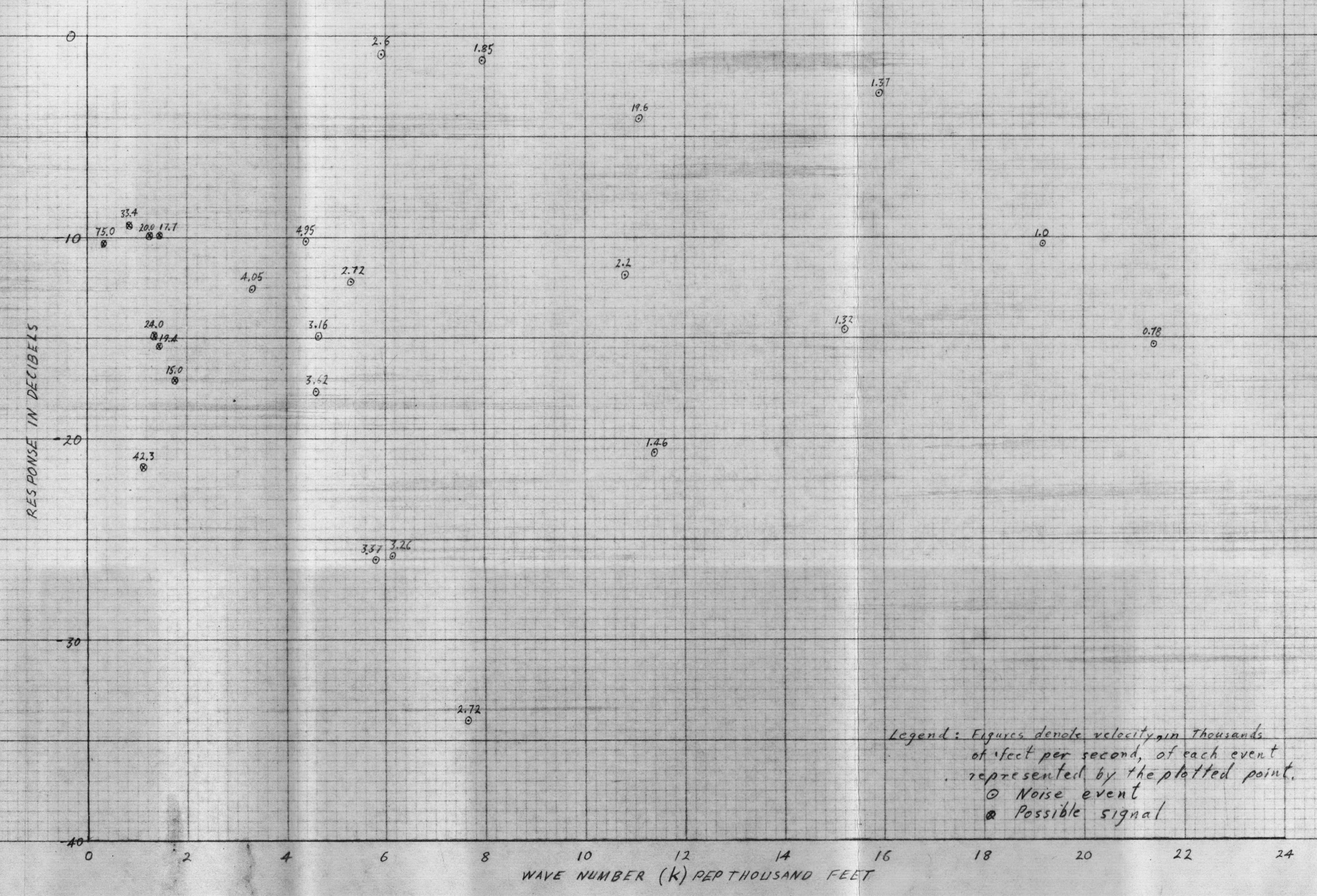
SECTION BY: *Bureau of Mineral Resources Playback Centre SIE MS 42*

TO ACCOMPANY RECORD No 1966/203

H50/B3-16







NOISE ANALYSIS AB.

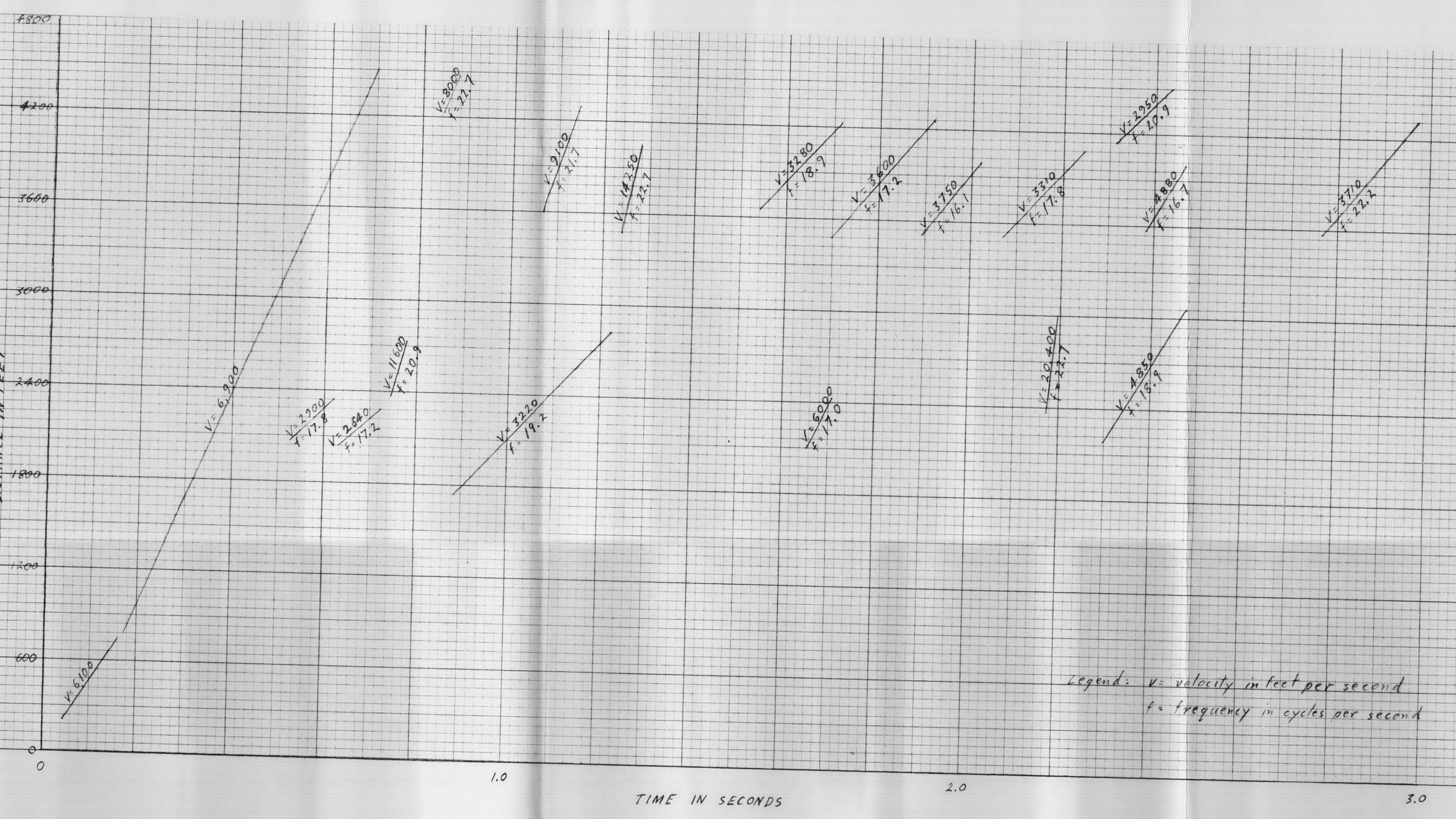
Bullsbrook. Traverse A.
Perth Basin. 1964.

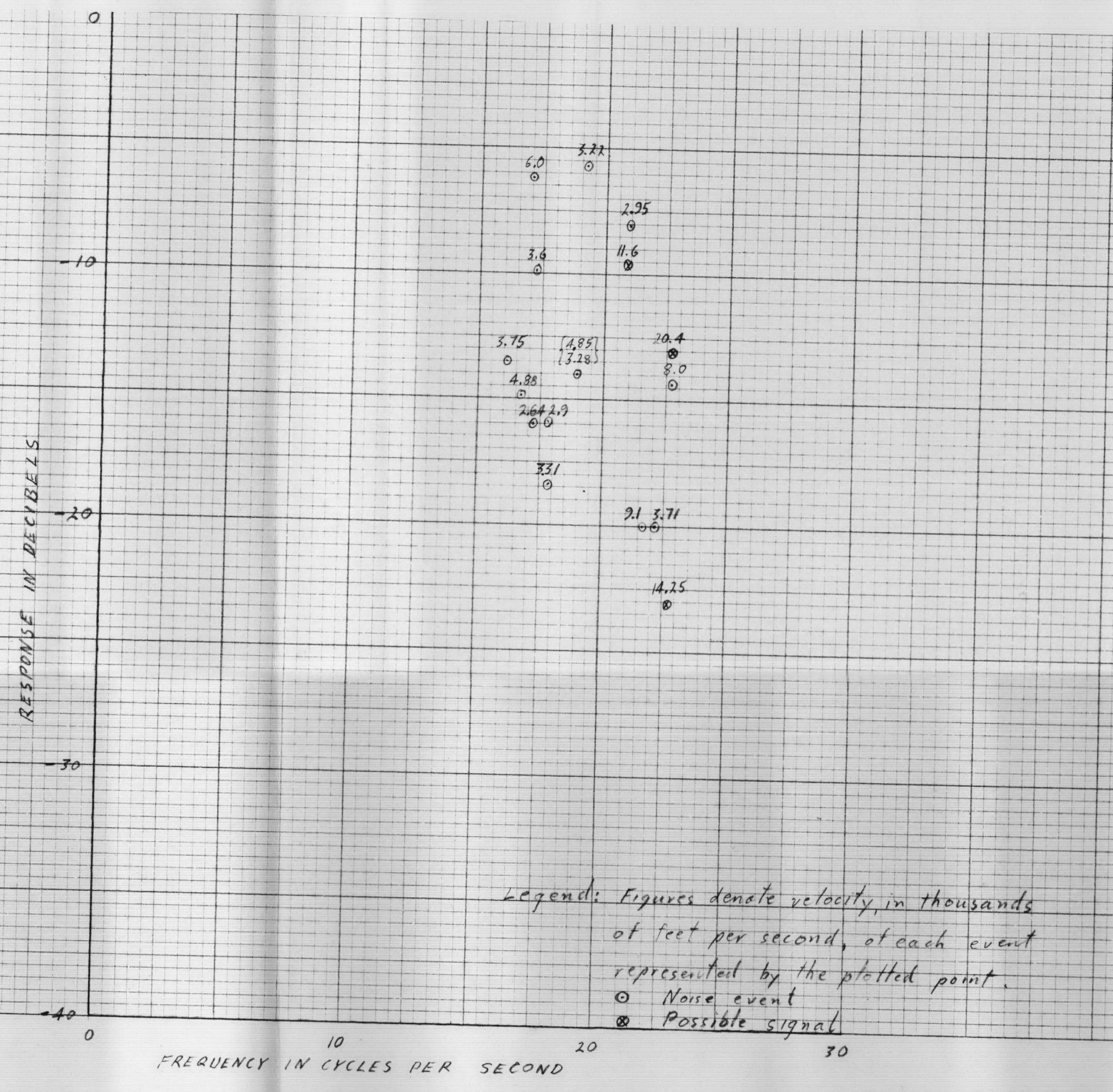
Charge : 20 lb
Shot depth : 50 feet.

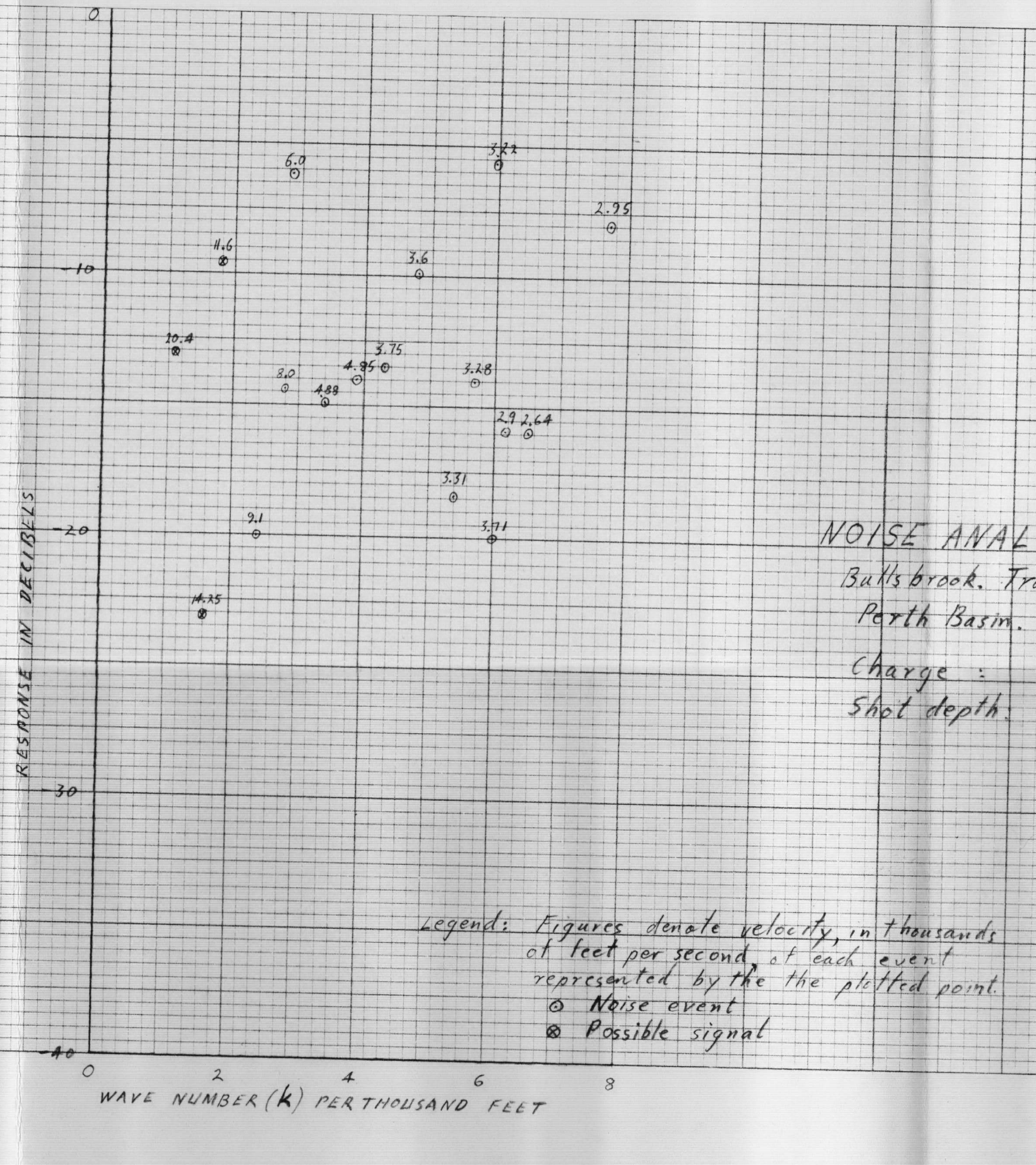
TO ACCOMPANY RECORD No. 1966/203

H 50/B3-17-1

PLATE 12





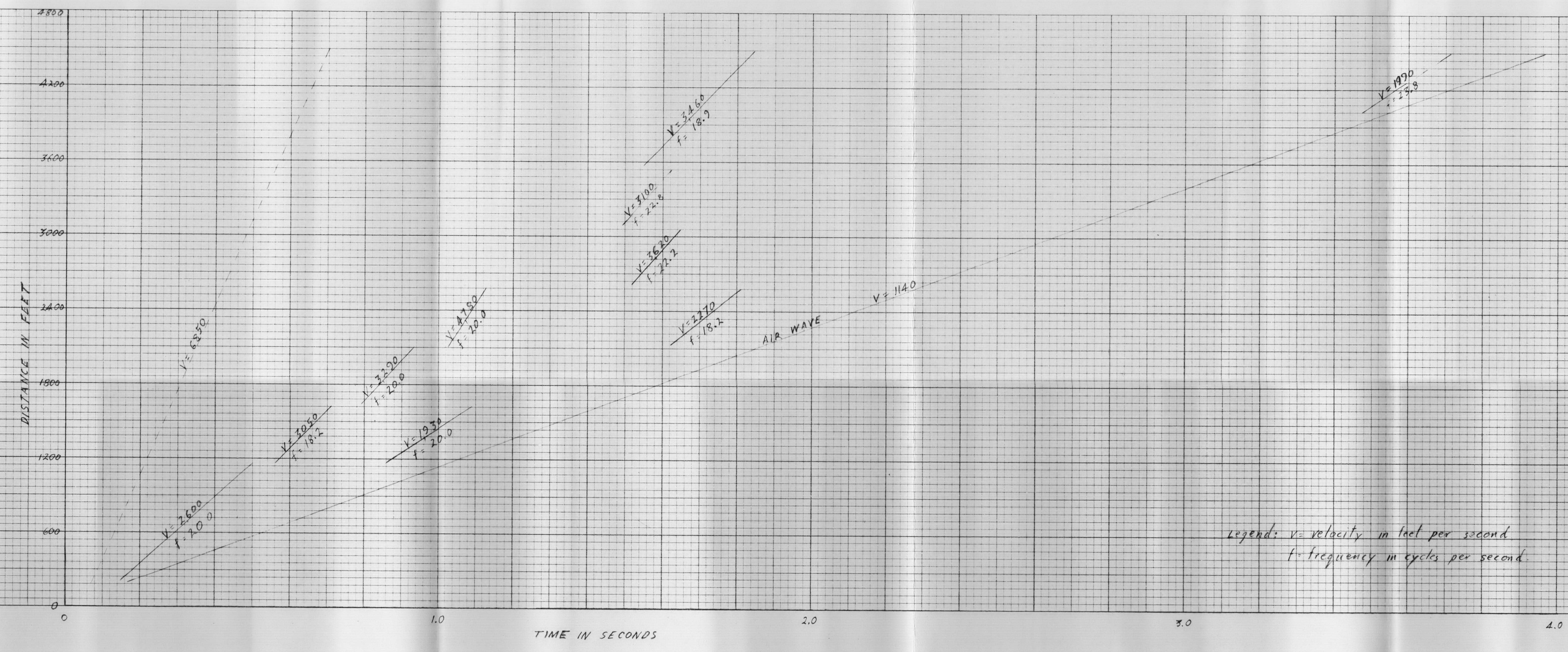


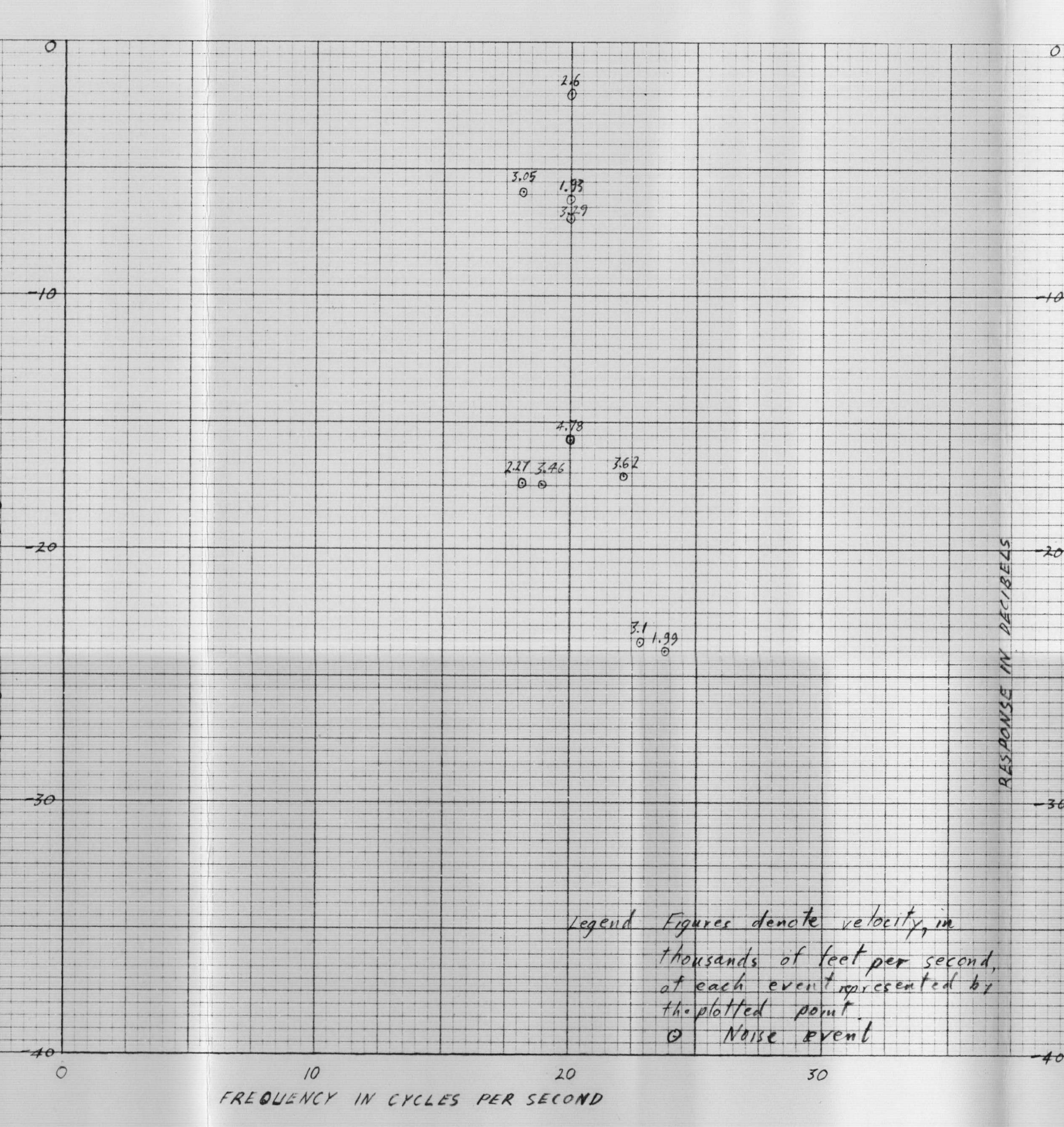
NOISE ANALYSIS AB.
Bullsbrook. Traverse A
Perth Basin. 1964
Charge: 50 lbs
Shot depth: 50 feet.

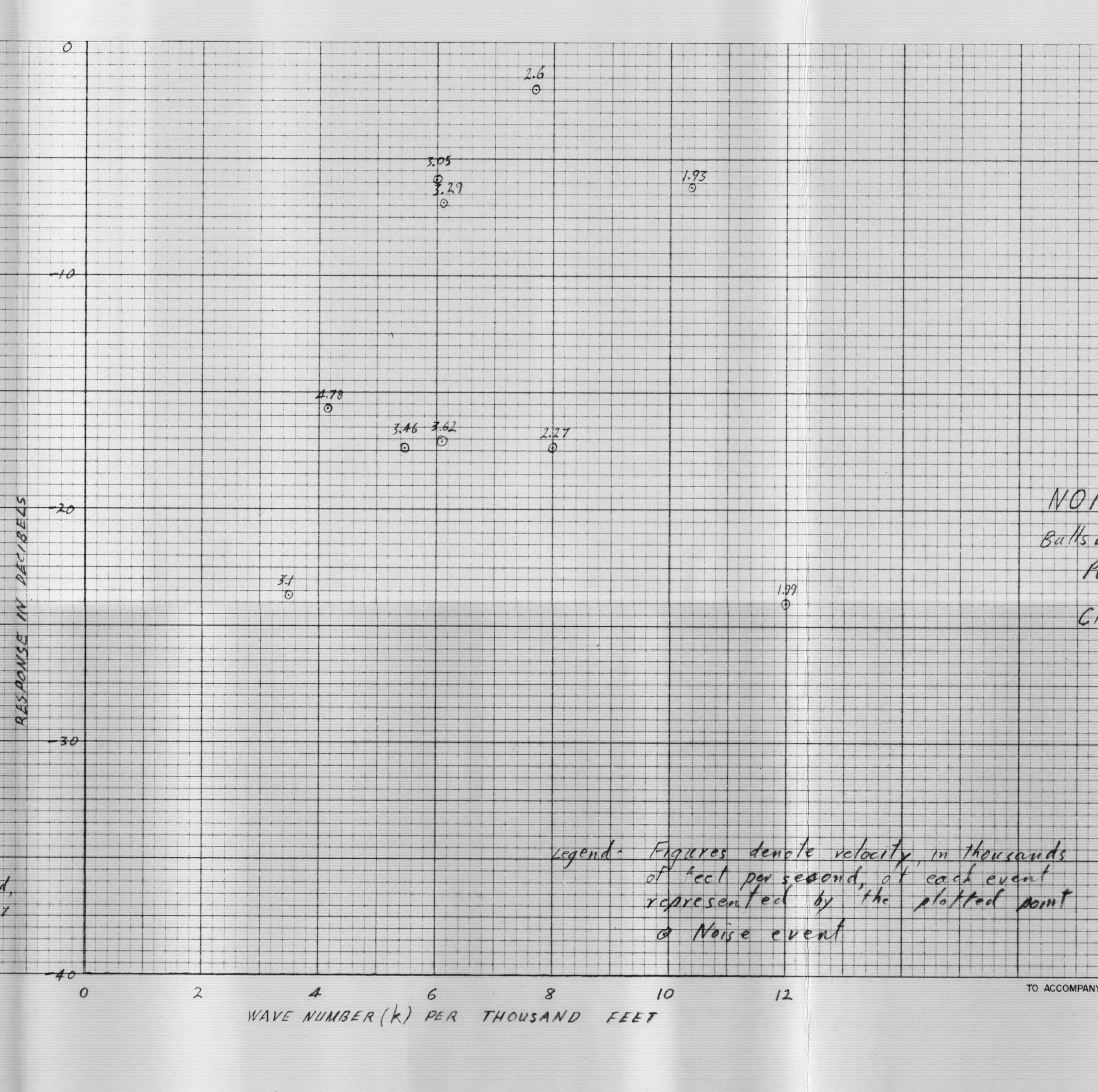
To accompany Record No 1966/203

H50/B3-27

PLATE 13







NOISE ANALYSIS E.F.
Bullsbrook. Traverse A
Perth Basin 1964
Charge: 5lb on surface.

TO ACCOMPANY RECORD No. 1966/203

H50/B3-16-1

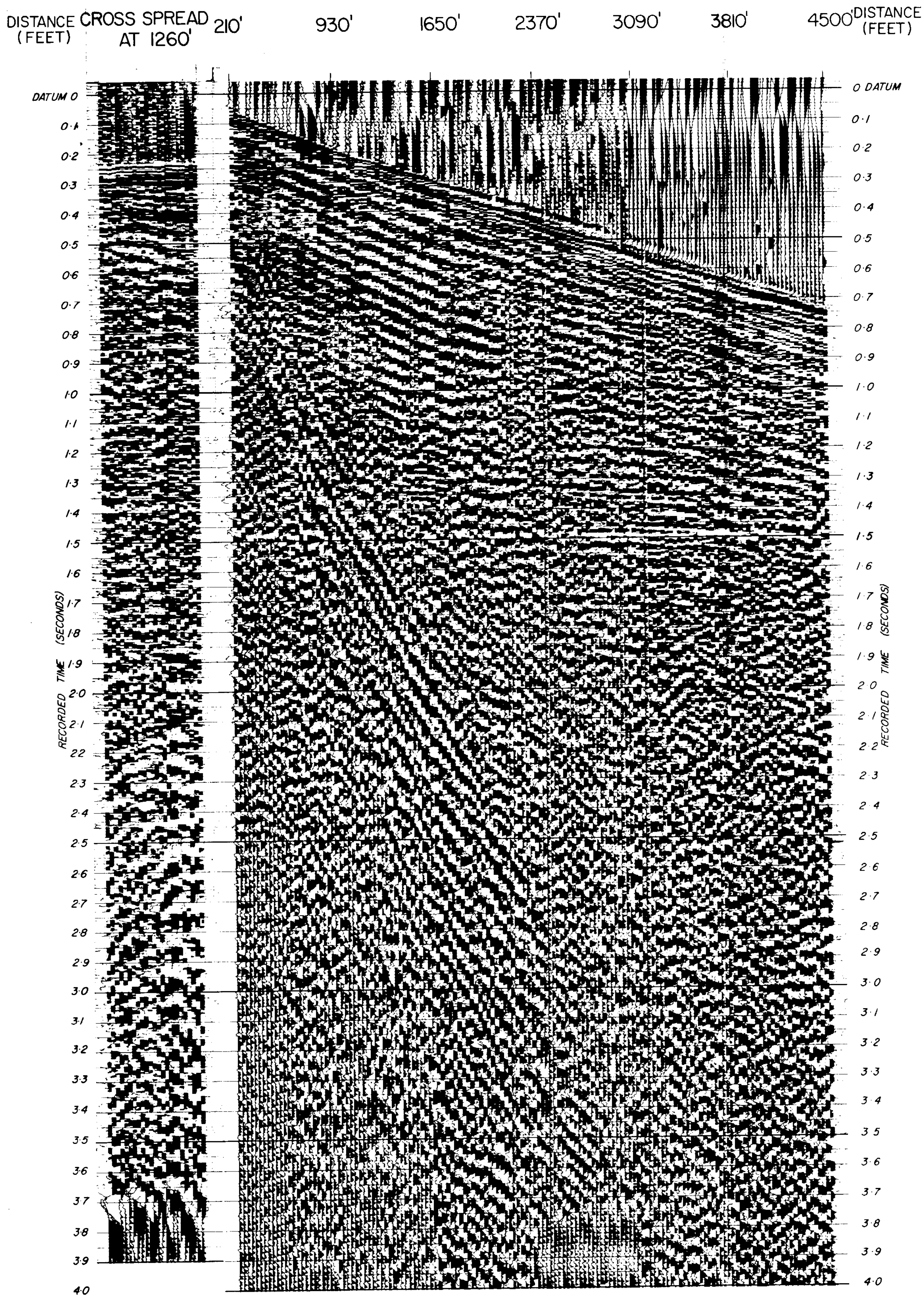


PLATE 14

RECORD SECTION

RECORDING INFORMATION

Magnetic Recorder ETL DS7/700

Amplifiers: 8000 Explorer

Filters: Out

A.G.C.: Off

Gain Initial: Varied

Final: Varied

Geophones: T.I.C – 20c/s

Geophone pattern: Single

Shot-hole pattern:

Charge: 15 lb at 25'

PLAYBACK INFORMATION

Filters: Out

A.G.C.: Off

Gain Initial: Programmed

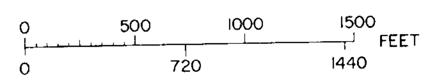
Final:

Trip delay: 0

Compositing: Nil

VELOCITY INFORMATION

HORIZONTAL SCALE



BULLSBROOK SEISMIC SURVEY 1964

PERTH BASIN WA

TRAVERSE B

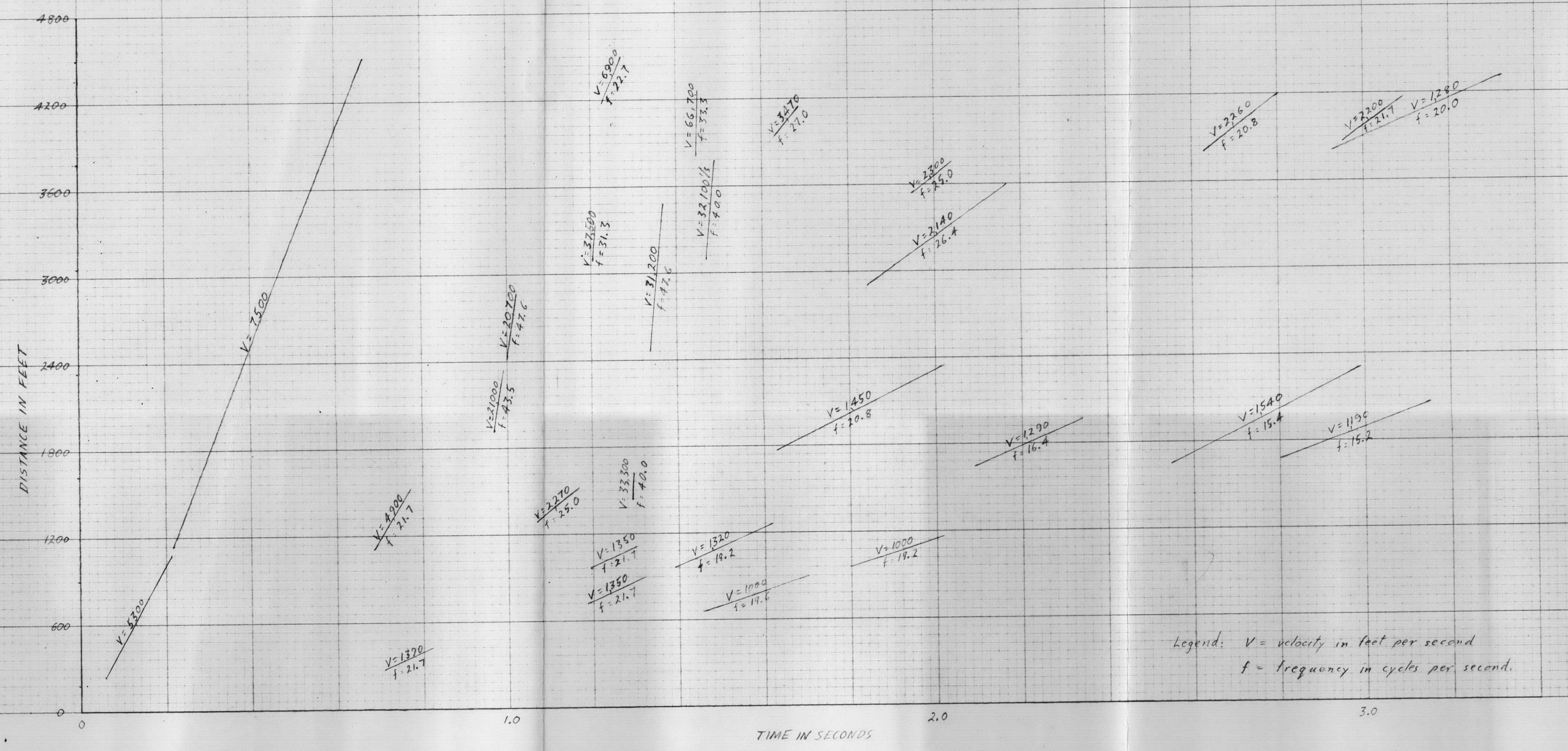
NOISE SHOOT CD

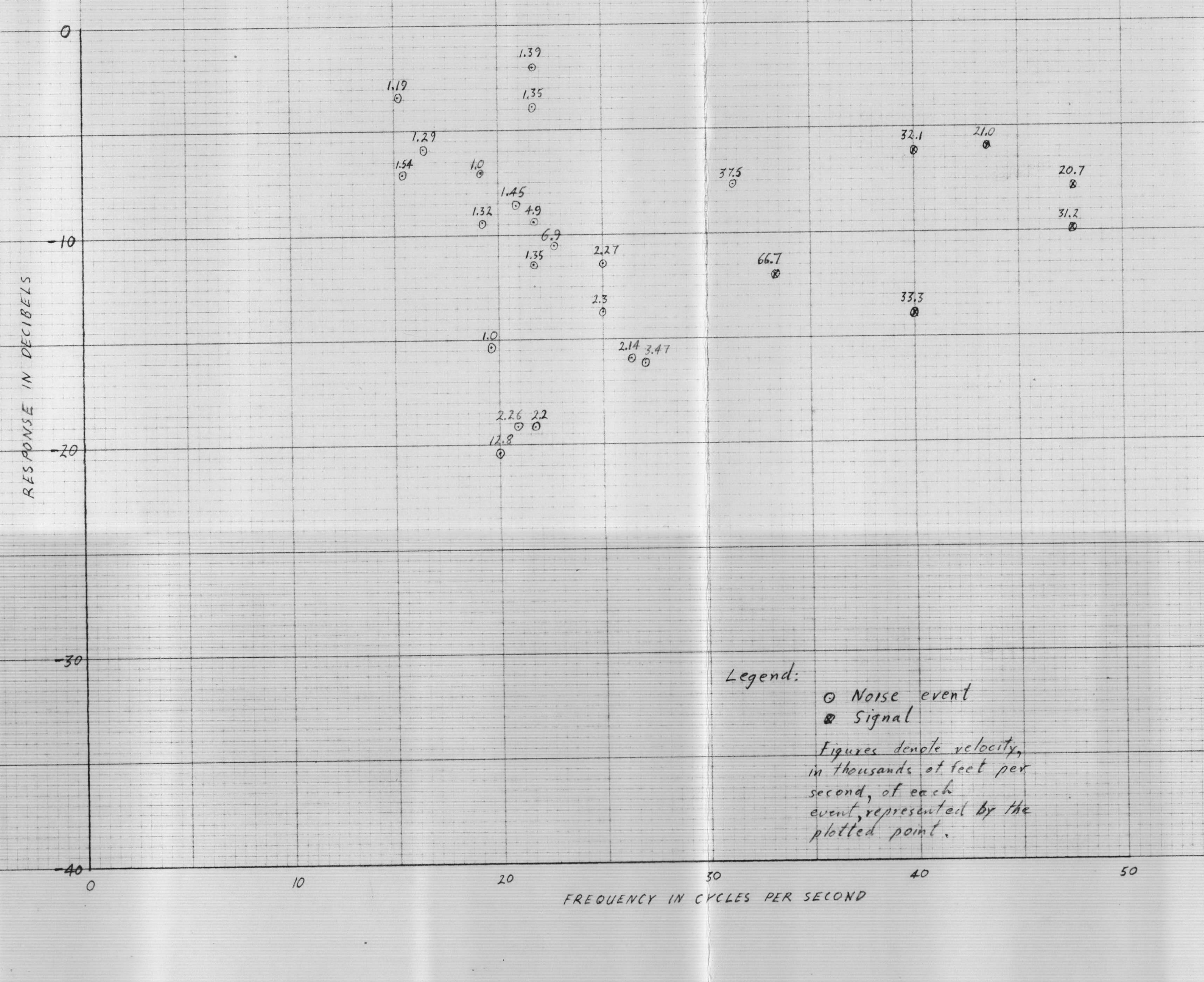
RECORDED BY: *Seismic Party No. 2*

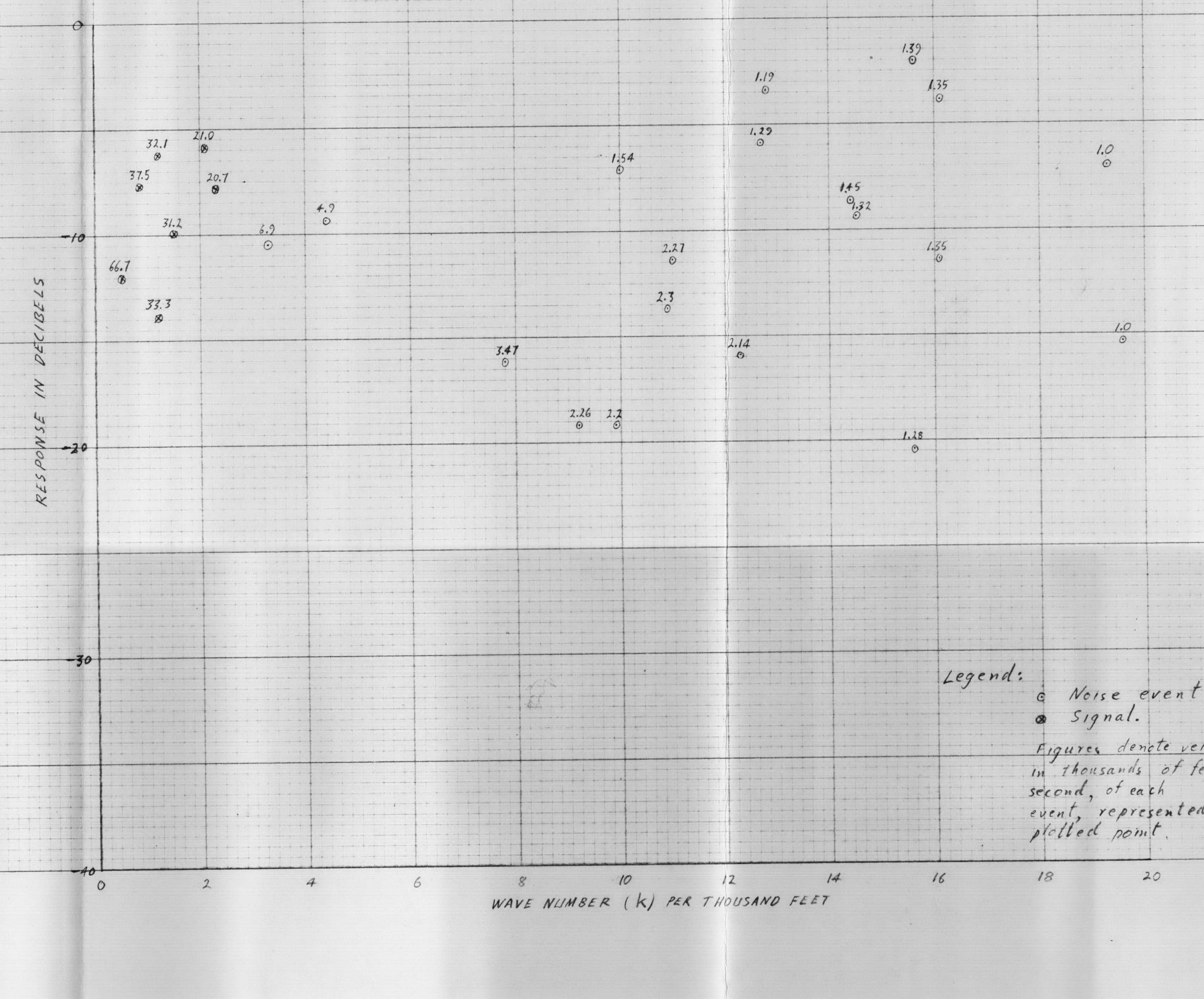
SECTION BY: *Bureau of Mineral Resources Playback Centre SIE MS 42*

TO ACCOMPANY RECORD No 1966/203

H50/B3–18







NOISE ANALYSIS CD
Bullsbrook. Traverse B.
Perth Basin 1964.
Charge: 15 lb
Shot Depth: 25 ft

20 TO ACCOMPANY RECORD No. 1966/203

H50/B3-18-1