COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

RECORDS 1958, No. 48

FINAL REPORT ON A SEISMIC REFLECTION SURVEY, IN THE SYDNEY BASIN, N.S.W.

FEBRUARY-MAY, 1957

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ABSTRACT

Between February and May, 1957, an experimental seismic reflection survey was made in the Sydney Basin by the Bureau of Mineral Resources to test the applicability of the method in that area and to investigate the sedimentary section. The work done at four different locations is described and the seismic results obtained are discussed in relation to the known geology. In general, the seismic method proved applicable in the Sydney Basin. The use of multiple geophone and shot-hole techniques proved desirable in some areas, notably on the Hawkesbury Sandstone. The seismic work indicated the existence of sediments up to 15,000 feet thick. Insufficient seismic work was done to prove the existence of individual structures suitable for the accumulation of oil or gas.

1. INTRODUCTION

The Sydney Basin seismic survey was undertaken by the Bureau of Mineral Resources on the application of the Australian Oil and Gas Corporation, supported by the New South Wales Department of Mines. The Bureau made the survey with the object of determing whether the seismic reflection method of prospecting is applicable to the Sydney Basin. This involved the following :-

(i) Testing of shooting conditions on the various formations encountered in the Sydney Basin.

(ii) Experimenting with different shooting techniques, particularly with the use of multiple arrays of geophones, in areas of poor-quality reflections.

(iii) Investigation of the sedimentary section in the Sydney Basin.

Tests were made between 25th February and 13th May, 1957, in the Llandillo, Dural, Maroota and Singleton (or Camberwell) areas of New South Wales. These tests showed that, in general, the seismic reflection method of prospecting is applicable to the Sydney Basin, but special techniques are required in some areas to obtain useful results. Reflections of fair quality were obtained in the Llandillo area from depths of up to 15,000 feet, even when using standard techniques.

The Sydney Basin includes an area of Permian and Triassic rocks which extends for about 100 miles north, south and west from Sydney. It is bounded on the east by the Pacific Ocean and extends in a north-westerly direction from Sydney and Newcastle up the Hunter River Valley. The following columnar section of Permian and Triassic rocks of the Sydney Basin (Raggatt, 1954) gives a general outline of the sedimentary section in the area.

	WIANAMATTA GROUP (800 FT)	Upper half mainly sandstone, lower half mainly shale.
	HAWKESBURY SANDSTONE (900 FT)	Predominantly sandstone
TRIASSIC	NARRABEEN GROUP	Sandstone and shale at top; red and green claystone and sandstone in middle; mainly conglomerate and sandstone at base.

PERMIAN	UPPER COAL MEASURES	NEWCASTLE COAL MEASURES (1500 FT)	Mainly sandstone, conglomerate and coal seams.
		TOMAGO COAL MEASURES (2000 FT)	Mainly sandstone, shale and coal
	UPPER MARINE	MULBRING SHALE (3000 FT)	Predominantly shale
		MUREE (400 FT)	Sandstone and conglomerate
		BRANXTON (3000 FT)	Sandstone, sandy shale and Fenestella shales
		GRETA COAL MEASURES (300 FT)	
	MARINE	FARLEY (1000 FT)	Sandstone and tuff
		RUTHERFORD (1150 FT)	Sandy shale and mudstone; minor limestone; basalt

LOWER		ALLANDALE (1000 FT)	Sandstone, basalt, tuff and conglomerate.
		LOCHINVAR (2750 FT)	Sandstone, basalt and sandy shale mainly; some shale

Conditions for seismic surveys were tested by surveying traverses on a shale area of the Wianamatta Group, on the Hawkesbury Sandstone and on the Newcastle (or Upper) Coal Measures. A few spreads were also shot on rocks of the Maitland Group (Upper Marine Series). Throughout the survey, the conventional split-spread, continuous profiling technique of shooting was employed. Traverses were surveyed with shot holes at every quarter-mile and geophone stations every 110 feet, except where obstacles necessitated the shortening of spreads. Different techniques of employing ten 6-cycle-per-second geophones per trace were tried on the first traverse at Llandillo, and a system was developed which was used on the three succeeding traverses with some success. Results obtained using multiple shot holes were compared with those using multiple geophones.

The plotted sections obtained from the seismic survey were generally in agreement with results inferred from geological investigations, as regards both thickness of sedimentary section and geological structure at depth. However, it should be emphasised that insufficient seismic traversing was done to establish the fact that surface geological mapping is a reliable guide to structure at depth in the areas considered. The seismic method proved valuable in indicating geological structure. It could be particularly useful, in those areas in which little information can be obtained from geological mapping, and in those places where test drilling sites must be critically located with respect to some specific structural feature such as the apex of an anticlinal structure.

The seismic party employed by the Bureau consisted of either 2 or 3 geophysicists, a radio technician as observer, a drilling "toolpusher", two drillers, a shooter and 7 field hands. Two university students on vacation were employed with the party for about half of the survey. The Australian Oil and Gas Corporation supplied an assistant surveyor and chainman who worked full time with the party. The seismic party's working week averaged 42½ hours, but staff members worked additional time as required.

The seismic equipment used (T.I.C. 621) was a 24-channel set made by the Technical Instrument Company of Houston, Texas. The party was equipped with 250 6-c.p.s and 150 20-c.p.s. T.I.C. geophones. Shot-hole drilling was carried out using two Failing"750" drills mounted on 3-ton Commer 4-wheel-drive vehicles. The party's vehicles included also 4 Commer 750-gallon water tenders, 3 Land-Rovers and a panel van.

2. SEISMIC WORK ON THE WIANAMATTA GROUP NEAR LLANDILLO.

(a) Programme of Work.

Eight and a half miles of traverse were surveyed in an east-west direction immediately south of Llandillo, 30 miles west of Sydney (see Plate 1). The seismic survey along this traverse (Traverse A) was commenced on 25th February and completed on 21st March.

The locations of shot points on Traverse A are shown on Plate 2. Commencing at shot point (S.P.1) near the middle of the traverse, the traverse was surveyed in a westerly direction to S.P.17, near Cranebrook. A short cross traverse (Traverse B), half-a-mile in length, at right angles to Traverse A, was surveyed between shot points 6 and 7. S.P.20 was ¼-mile east of S.P.1 and the traverse was continued in an easterly direction from there to S.P.35 near RIchmond-Blacktown Road. The depth of weathering on the traverse was usually about 35 feet and shot holes were drilled to about 85 feet. Drilling was moderately fast along the traverse; 60 holes were drilled and the total footage was 5,355 feet. Explosive charges of 15 lbs. of Geophex were used in several shot holes at first, but 25-lb. charges were found necessary in the majority of holes on this traverse.

Reflections of reasonable quality were obtained on the western half of the traverse, using single shot holes and the T.I.C. 20-c.p.s. multiple-four geophones, which were spaced at intervals of 5 feet. Only a few reflections of very poor quality were obtained from S.P. 20 to S.P. 27, so it was decided to experiment on this portion of the traverse with different shot and geophone arrangements.

At S.P. 22, 6-c.p.s. T.I.C. geophones were used in multiples of 10 per trace and placed in line along the traverse with 5 geophones on each side of each geophone peg. This arrangement was tried with the geophones at intervals of 10 feet, 30 feet and

50 feet. The first test (10-foot intervals) resulted in a small improvement on the record obtained with the multiple-four geophones. The second test (30-foot intervals) resulted in a marked improvement. The third test (50-foot intervals) gave only a slight improvement on the second test. The geophones were used in multiples of 10 because this was the greatest number available per trace. It is probable that the use of larger groups would have further improved the results. Reproductions of records obtained at S.P.22 using different geophone arrangements are shown on Plate 9.

In addition to the geophones being placed in line they were tried in square grid patterns about the geophone pegs, i.e. each group of 10 geophones was arranged so that there were 3 rows of 3 geophones, 50 feet apart, with an additional geophone at the central point. The result using this arrangement was of similar quality to the result obtained when the geophones were used at 50-feet intervals in line.

Nine-hole diamond pattern shots, with 50-foot spacing between holes and using $2\frac{1}{2}$ lb. of Geophex in each hole, were fired for comparison with the results obtained using single 25-lb. shots. The pattern shots resulted in marked improvements both when using the geophones at 50-feet intervals in line and in grid patterns. The record obtained using a 9-hole pattern shot and multiple-ten geophones in line at 50-foot intervals is reproduced on Plate 10.

As a result of these experiments, a workable system for using multiples of 10 geophones was developed and used extensively during the remainder of the Sydney Basin survey. In this system, the geophones were laid along the traverse line at intervals of 24.5 feet with 5 geophones on either side of each geophone peg and take-out point on the Vector geophone cable. The interval of 24.5 feet was selected so that the farthest geophone from each take-out point fell on the next geophone peg, thus enabling first-break times at the geophone pegs to be obtained. In the case of the two groups of geophones nearest the shot, the geophone interval was reduced to 6 feet so that the geophones nearest the shot would not receive excessive shot-hole noise. Pattern shots were used whenever the rate of progress of the drilling crews permitted. By varying the number of holes drilled at each shot point, the rate of progress of the drilling crews could be readily adjusted to that of the recorder crew using the geophones in multiples of 10.

Shot points 20 to 27 were re-shot using the multiple-ten geophones and one, two or three shot holes. Much improved results were obtained. This technique was also employed at shot points 28 and 29. Shot points 30 to 34 were shot using the multiple-four geophones.

Copies of records from S.P.11 and S.P. 29 are included on Plate 10 as typical records from Traverse A.

(b) Position of the Traverse in Relation to Geology.

The Llandillo traverse is located on the Triassic Wianamatta Group, which consists mainly of freshwater shales in the Llandillo area, and on small patches of alluvium. The terrain in the area is gently undulating and as rock outcrops are sparse, little is known of the detailed structural geology. Exposures of shale in road cuttings and creeks indicate that the strata are generally horizontal or nearly so.

In 1935, Gas Drillers Ltd., commenced drilling on a geologically closed structure on the eastern bank of the Nepean River near Mulgoa, about 8 miles south-west of Penrith and 11 miles from the western end of the Llandillo traverse. This bore (Mulgoa Bore) was commenced on the Hawkesbury Sandstone and reached a depth of 3,125 feet. From the surface to 190 feet, sandstones of the Hawkesbury Group were encountered. From 190 feet to 2,070 feet the bore passed through shales and sandstones of the Narrabeen Group. At 2,080 feet, the first of several coal seams interbedded with shales and sandstones of the Newcastle (or Upper) Coal Measures was encountered. There is some doubt about the identity of the beds in which the bore bottomed.

(c) Method of Plotting.

Since the preliminary report on the seismic survey in the Sydney Basin was issued (Robertson, 1957), the seismic records from the Llandillo traverse have been re-examined. Reflection times have been revised and some reflections have been regraded. Weathering and elevation corrections have been re-calculated. The reflection cross-section has been replotted using the correlation method and a slightly different velocity distribution with respect to depth. In the later distribution the velocity increases rapidly from 13,000 feet per second at sea level, to 16,000 feet per second at 4,000 feet. Thereafter, the velocity increases only very slowly with depth. This velocity distribution is based on "first-break" or near-surface refraction velocities and on a T. ΔT analysis (Dix, 1952, p.124) of all reflections recorded on the Llandillo traverse.

(d) Results and Interpretation.

The results from the Llandillo traverse are shown on Plate 5 in the form of a correlation cross-section.

Many reflections of quality ranging from very poor to good were recorded on the traverse from estimated depths down to 23,000 feet. These give a fairly good indication of the geological structure in the area. The outstanding feature of the cross-section plotted from the seismic results is a series of persistent reflections from about 4,000 feet. These reflections can be correlated across almost the whole length of the traverse. A second, slightly less persistent series of reflections was obtained from about 6,000 feet. Reflections were also fairly numerous from between 12,000 and 14,000 feet over about half of the traverse but there were none in the central part. Few reflections were obtained from above 4,000 feet and from below 15,000 feet.

Reflections from above 15,000 feet indicate dips of only a few degrees, except for the deeper reflections near the western end of the traverse, which indicate components of dip along the traverse of up to 10 degrees to the east. On the western half of the traverse, reflections from above 8,000 feet indicate a general easterly component of dip of the order of 150 feet per mile. From S.P. 17, at the western end of the traverse, to S.P.11, reflections from between 12,000 and 14,000 feet indicate a consistent easterly component of dip of about 500 feet per mile.

Between S.P. 20 and S.P. 25, the traverse line was moved 600 feet to the north to avoid thick scrub. As a result, spreads 20- 21 and 24- 25 did not lie in the east-west direction (see plan of traverse on Plate 2.) Considering only the component of dip along the direction in which the traverse as a whole was surveyed (approximately east-west), there is a weakly defined synclinal axis between S.P.1 and S.P. 23, where reflections indicate ore or less horizontal strata. From S.P.23 to S.P. 25 reflections indicate a westerly component of dip of about 300 feet per mile. On the eastern side of S.P. 25 and S.P. 26, reflections indicate easterly dip of similar magnitude. This easterly component of dip is substantiated by numerous reflections from between 4,000 and 15,000 feet, including some of fair and good quality. There is thus a reasonably well-established anticline near S.P. 25. The deeper reflections indicate a synclinal axis near S.P. 27 and gently westerly slopes from there to S.P.28. From S.P. 28 to the eastern end of the traverse (S.P.34), reflections indicate horizontal strata.

Reflections from the short cross traverse (Traverse B) at right angles to the main traverse between S.P. 6 and S.P.7 indicate a northerly component of dip of about 200 feet per mile. Reflections from spread 20-21, which was oriented in a north-east/ south-west direction, also show evidence of this northerly component of dip.

Reflections from below 15,000 feet are not numerous and there are none in the central portion of the traverse. Near both ends of the traverse, the deep reflections indicate dips of 10 to 20 degrees, towards the centre. There is evidence of an unconformity at about 15,000 feet, the reflections from below this depth indicating generally steeper dips than those above it. These reflections are fairly well scattered and could be reflections from within the basement. Alternatively, they may be multiple reflections with arrival times not directly related to depth. They are not sufficiently numerous or consistent to permit detailed analysis of this aspect. Bearing this in mind, and also the fact that the velocities used have a fairly large probable error, it may be stated that the seismic results indicate a sedimentary section of about 15,000 feet.

3. SEISMIC WORK ON THE HAWKESBURY GROUP NEAR DURAL

(a) Programme of Work.

The second traverse in Sydney Basin was surveyed from near Kenthurst in a south-easterly direction to the Australian Oil and Gas Corporation's Dural No. 1 Bore (see Plate 3a). This traverse (Traverse C) passed through several small farming properties and was 3½ miles in length. The seismic survey of Traverse C was commenced on 21st March and completed on 9th April.

From S.P.1, at the western end of the traverse, to S.P. 8 the best shooting depth was from 150 to 200 feet and shot holes were therefore drilled to 200 feet. To the south-east of S.P. 8, reflections of comparable quality were also obtained when shooting at depths between 50 and 100 feet; drilling of deep holes was therefore discontinued from S.P. 10 onwards. Drilling in the hard Hawkesbury Sandstone was slow. The total footage drilled on the Dural traverse was 3,165 feet, distributed over 32 holes. A 7-hole pattern shot was fired at S.P.2. The 6-c.p.s. T.I.C. geophones were used in multiples of 10 along the whole length of the traverse. Charges of 25 lbs. of Geophex per hole were used in the single holes.

(b) Position of the Traverse in Relation to the Geology.

Along the greater portion of the traverse, the Hawkesbury Sandstone is overlain by 5 to 20 feet of Wianamatta shale, but some shot points, notably near the south-eastern end of the traverse, were directly on Hawkesbury Sandstone or derived soil. Structural contours, derived by mapping the base of the Wianamatta Group, are shown for the Dural area on Plate 3a (geology by the Australian Oil and Gas Corporation). The structural contours indicate a domal structure of low relief about 2 miles east of Dural township. The Australian Oil and Gas Corporation's Dural East No. 1 Bore was drilled to a depth of more than 5,000 feet near the crest of this structure.

It was hoped that the seismic traverse, in addition to testing shooting conditions on the Hawkesbury Group, would provide information regarding the structure. However, the position of the traverse was determined largely by the feasibility of access. The traverse was surveyed approximately at right angles to the structural contours on the western flank of the structure but rough terrain on the eastern side prevented the traverse from being continued past the crest and on to the eastern flank.

(c) Method of Plotting.

A cross-section showing the seismic results obtained on Traverse C is shown on Plate 6. Since the preliminary report (Robertson, 1957) was issued, all reflections have been repicked, retimed and regraded.

Weathering and elevation corrections have been re-calculated. The cross-section has been replotted using the correlation method, as in the preliminary report.

The velocity distribution with respect to depth used in the preparation of the cross-section was the same as that derived by T.ΔT analysis for Traverse E (see Section 5). Insufficient reflections were recorded on the Dural traverse to allow determination of a separate velocity distribution for this area. No well velocity information has been obtained from the Dural East No.1 Bore. The first-break velocities recorded at Dural (see Plate 6) were closer in magnitude to those recorded on Traverse E, near Singleton, than to those recorded near Llandillo.

(d) Results and Interpretation

The plotted results of the Dural traverse on the Hawkesbury Sandstone provide a much less complete picture of subsurface structure than was obtained on the Wianamatta Group near Llandillo. Few reflections were obtained and these have been graded mainly as poor quality or doubtful reflections. Reflections were obtained from depths down to about 6,000 feet and were most numerous from between 3,000 and 5,000 feet. None were recorded from above 2,500 feet. Two sample records from Traverse C are included on Plate 10.

Along most of the traverse, 50-c.p.s. A.C. interference from power lines presented a problem. As the level of this interference was above that of the reflected energy after about 1.0 to 1.5 seconds on most records, reflections from below about 8,000 feet would have been masked by the 50 c.p.s. oscillations. However, at shot points 1, 2 and 14, where there was little A.C. interference, no reflections were recorded after 1.0 seconds. It is possible therefore that absence of A.C. interference would not have resulted in much better results.

Near the south-eastern end of the traverse several reflection from depths of 3,000 to 4,000 feet can be correlated for more than half a mile. These indicate strata with a north-westerly component of dip similar to that indicated by the structural contours on the base of the Wianamatta Group, namely about 100 feet per mile.

On the central portion of the traverse, between shot points 5 and 10, only a few scattered reflections were recorded. These give no reliable indication of dip. For about a mile at the north-western end of the traverse reflections are a little more numerous and these also agree with the structural contours in indicating a north-westerly component of dip of the order of 100 feet per mile.

A phantom horizon derived from the slopes of all reflections recorded on Traverse C is plotted on the cross-section. The slopes of all reflections plotted in the same 660-foot horizontal interval have been averaged to obtain the slopes on the phantom horizon.

It may be concluded that the limited seismic evidence indicates that structure mapped at the surface probably extends to a depth of at least 4,000 feet near the Dural traverse.

Near Dural East No.1 Bore, the two main reflection horizonts were at 3,100 feet and 4,000 feet below sea level, i.e. about 3,780 feet and 4,680 feet below ground surface. The descriptions of rock samples from the bore (Crespin, 1957) do not reveal any major changes in rock type at these depths which could be correlated with the reflection horizons with any degree of certainty. From 3,295 feet below surface level, carbonaceous shale with fragments of coal was encountered in the bore. From 4,393 feet to 4,805 feet, carbonaceous and calcareous shales and sandstones were reported. From 4,665 feet to 4,700 feet, large fragments of coal were reported. It is possible that energy was reflected at the interfaces between coal seams and shale or sandstone and that the "reflections" as they appear on the seismic record represent the resultant reflected energy from a group of these interbedded layers.

4. SEISMIC WORK ON THE HAWKESBURY GROUP NEAR MAROOTA

(a) Programme of Work

Two miles of seismic traverse were surveyed in a north-westerly direction east of Maroota, which is 15 miles north of Dural on the road to Wiseman's Ferry (see Plates 1 and 3). The seismic survey at Maroota was commenced on 10th April and was completed on 24th April.

On this traverse (Traverse D), there was no A.C. interference such as was experienced at Dural. The 6-c.p.s. geophones were used in multiples of 10 (at 22.5 foot intervals) on all spreads on Traverse D except at the northernmost end (S.P. 24). Shot-hole patterns were used along the traverse, the number of holes per shot point ranging from 2 to 9. The depth of weathering ranged from 25 to 45 feet and most holes were drilled to about 65 feet. Drilling was faster than on the Dural traverse. A total of 41 holes was deilled and the total footage was 3,018 feet.

(b) Position of the Traverse in Relation to Geology

The Maroota traverse was surveyed as an additional test of shooting conditions on rocks of the Hawkesbury Group, as difficult terrain and access problems had made the traverse near Dural considerably shorter than had originally been intended. Moreover, it was considered that the known structural conditions at Dural might affect the quality of reflections and it was desired to make tests in an area more representative of the Hawkesbury Group.

It was difficult to select an additional traverse location near Dural because of the settled nature of the area. Possible locations on the Hawkesbury Group further north were very limited because of the rugged topography and the lack of suitable roads. Two miles of bush track following a telephone line near Maroota were selected as the most suitable traverse site for additional work.

To the writer's knowledge, no detailed geological mapping has been done in the Maroota area. The traverse was surveyed, for the greater part at least, on rocks of the Hawkesbury Group. No Wianamatta Shale was recorded on the drilling logs, although the presence of small orchards near shot points 19 to 21 (Plate 3b) suggests the presence of soil similar to that of Wianamatta Shale orchard areas. As this traverse descended into two valleys, some of the seismic shots were fired at considerably lower horizons in the Hawkesbury Group than at Dural, where shooting was confined to the top of the Hawkesbury Group.

(c) Method of Plotting.

As for the Dural traverse, the reflections from the Maroota traverse have been completely re-assessed since the preliminary report was issued. Many of the most doubtful reflections have been omitted after further consideration. The correlation method of plotting was used in preparation of the cross-section on Plate 7. The velocity distribution used was the same as that for Traverse E near Singleton.

(d) Results and Interpretation

It can be seen from Plate 7 that few reflections were obtained on the Maroota traverse. The quality of the reflections obtained was without exception poor and in nearly all instances the reflection grading assigned was RP, which indicates a questionable reflection. As on the Dural traverse, reflections were most numerous from about 3,000 feet. Doubtful reflections were recorded from depths down to 17,000 feet. Because of the lack of reliable reflections, it is not possible to draw any conclusions regarding detailed geological structure, but reflections on the whole indicate strata which are horizontal or nearly so. Two sample records from Traverse D are included on Plate 11.

5. SEISMIC WORK ON THE NEWCASTLE COAL MEASURES NEAR SINGLETON (CAMBERWELL ANTICLINE)

(a) Programme of Work

Five and a half miles of seismic traverse were surveyed on the Newcastle Coal Measures from the New England Highway, 3 miles north of Singleton, in a westerly direction to the Hunter River (Traverse E). The traverse crossed the Australian Oil and Gas Corporation's proposed drilling site on the Camberwell Anticline. A cross-traverse (Traverse F) about one mile long was surveyed approximately at right angles to the main traverse at S.P. 34, ½-mile east of the proposed drilling site (see Plate 4). The seismic survey was commenced on 29th April and was completed on 13th May.

The 6-c.p.s. geophones were again used in multiples of 10 along the main traverse, as the majority of reflections obtained were poor in quality. The 20-c.p.s. geophones were used in multiples of 4 on the cross traverse. Single shot holes were used except at shot points 36,38 and 39, where 3-hole pattern shots were fired. The depth of weathering on the Camberwell traverses is mostly about 30 to 40 feet and the best shooting depth is 60 to 70 feet. Charges of 25 lbs. of Geophex per hole were used.

The majority of the holes were drilled to 75 feet. On the western half of the main traverse, two holes were drilled to twice this depth. Shallow coal seams were encountered on the westernmost two miles of the traverse. Drilling was mostly moderately fast, but hard bands of material were encountered at several shot points near the eastern end of Traverse E. Water circulation was lost at two shot points. Forty-one holes were drilled and the total footage was 3,036 feet.

(b) <u>Position of the Traverse in Relation to Geological Structure.</u>

It is generally desirable that any seismic reflection survey consisting of a single traverse should be at right angles to the strike of the geological strata in order that the reflections recorded should take place in a single, vertical plan. Because of marked changes in the direction of the strike and the hilly topography in the area surveyed this was not practicable over the whole length of the traverse.

It can be seen from the map on Plate 4, on which the geology as mapped by Booker (1953) is superimposed, that Traverse E crosses the axis of the Camberwell Anticline approximately at right angles, passes close to the Australian Oil and Gas Corporation's proposed drill site and extends for 2 or 3 miles on either side of the anticline. The traverse is approximately at right angles to the strike near the eastern end and from S.P. 36 to the western end, but from S.P. 31 to S.P. 34 where the strike is almost at right angles to the regional trend, the seismic traverse is approximately parallel to the strike. It should be noted that over this portion of the traverse, seismic reflections will have taken place in planes other than the vertical. As these reflections have been plotted on the cross-section as though they took place in the vertical plane, depths and dip angles as plotted for this portion of the traverse are less accurate than elsewhere.

(c) Method of Plotting

Cross-sections showing the seismic results from Traverses E and F are shown on Plate 8. Since the preliminary report was issued (Robertson, 1957) the records have been re-assessed and the least square method has been applied in the determination of dip angles. The reflections have been plotted in the apparent position of the reflecting interface, assuming that the reflections take place in the vertical plane and that the ray paths are linear.

The velocity distribution used is based on a T.ΔT analysis (Dix, 1952, p.124) of all reflections obtained in the Singleton area. This distribution differs only slightly from that used in the preliminary report. "First-break" refraction data and the T.ΔT analysis indicate very high seismic velocities in the area. In the velocity distribution assumed, datum velocity is 12,000 ft/sec. and velocity increases steadily to a depth of about 4,000 feet, below which a constant velocity of 16,000 ft/sec. is assumed.

It is evident from Plate 8 that the reflection slopes show some similarity to the surface topography. The large difference in vertical scales used to plot surface elevation and reflection data should be noted. This similarity is not due to incorrect elevation corrections. If the elevation velocity used (10,500 ft/sec.) were in error by as much as 2,000 ft/sec., the error in elevation correction at the highest point on the traverse would be less than 20 milliseconds. It is probable that any error is considerably less than this. It is possible that the geological structure has influenced the development of surface topography to produce the above-mentioned similarity.

(d) Results and Interpretation

Strong reflections were recorded at about 0.6 seconds at many points, but apart from these, reflections were generally poor. Copies of three selected records from Traverse E are shown on Plate 11 to illustrate the quality of the records. Many reflections were obtained from S.P. 27 at the eastern end of Traverse E to S.P. 39, the only notable gap in the reflections being below S.P. 36, near the proposed drill site. The traverse crosses the Newcastle Coal Measures (formerly known as "Upper Coal Measures"), but rocks of the Maitland Group (formerly known as the "Upper Marine Series") were encountered in shot holes 36 and 37. Crespin (1957), after an examination of shot hole drilling samples from Singleton, notes :-

> "Two holes, S.P. 36 and S.P. 37, on the Singleton Traverse penetrated the marine Permian beds, the dark grey siltstones containing numerous foraminifera and ostracoda. The assemblage of species is characteristic of that found in subsurface sections of the Maitland Group in the Hunter River District and is most probably referable to the Mulbring Sub-group."

From S.P. 39 to S.P. 45, there is an almost complete lack of reflections. Reflections were recorded from S.P. 45 to S.P. 48.

A cross traverse consisting of 4 shot points was surveyed approximately at right angles to the main traverse through S.P. 34 (Plate 4). The cross traverse was not surveyed through the proposed drilling site (S.P. 36), as would have been desirable from the geological point of view, because of the lack of reflections recorded from that shot point.

Reflections were recorded from depths down to about 13,000 feet on the Singleton traverses and were most numerous between 3,000 and 8,000 feet. From S.P. 27 to a point between S.P.29 and S.P. 30, reflections indicate a moderately steep and consistent westerly component of dip of the order of 1000 feet per mile.

Further west, the shallower reflections indicate an easterly component of dip of about 300 feet per mile to S.P. 32. From S.P. 32 westwards, reflections indicate generally increasing easterly dips to a point between S.P. 35 and S.P. 36. Between this point and S.P. 34, easterly dips are of the order of 1000 feet per mile. Over this eastern portion of the traverse, between S.P. 27 and S.P. 36, reflections from depths below 5,000 feet agree with the shallower reflections in indicating westerly and easterly dips at the eastern and western ends respectively.

The seismic results from the eastern half of the traverse are in fair agreement with the geological structure as mapped by Booker (1953) and indicated on Plate 4. On geological grounds, the Rix's Creek Syncline, whose axis trends north-north-west, is believed to divide into two parts near the traverse, so that two minor synclinal axes cross the traverse near shot points 30 and 33. The seismic results indicate a single broad syncline with no evidence of two separate synclinal axes.

West of the proposed drill site, the majority of the reflections from depths above 5,000 feet between S.P. 36 and S.P. 39 indicate a westerly component of dip of about 700 feet per mile. These reflections are of poor to fair quality. A group of five doubtful reflections of the lowest grade on the eastern side of S.P. 37 indicates easterly dip. The seismic results on the whole support the existence of an anticlinal axis crossing the main traverse near S.P. 36 and S.P. 37. Seismic evidence of easterly dip on the eastern flank between S.P. 36 and S.P. 33 and westerly dip on the western flank between S.P. 37 and S.P. 39 is fairly strong. The position of the anticlinal axis cannot be determined accurately from the seismic section because of the paucity of reflections in the axial region. The absence of reflections near an anticlinal axis is a phenomenon commonly encountered in seismic reflection surveying.

A group of eight poor to fair reflections from depths between 8,000 and 10,000 feet was recorded from between S.P. 37 and S.P. 38, and indicates more or less horizontal strata. It is possible that these reflections indicate the position of the crest of the Camberwell Anticline at those depths.

The absence of reflections to the west of S.P. 39, together with an abrupt change of some 2,000 feet per second in the near-surface refraction or "first-break" velocity (see bottom of Plate 8), is strongly indicative of a fault near S.P. 39. This is supported by the fact that coal was encountered in drilling shot holes from S.P. 40 westwards but not to the east of S.P. 40 (see drill logs at bottom of Plate 8).

There may likewise be a fault near S.P.45, on the western side of the region of no reflections, although the change in first-break velocities there is more gradual and the drill logs show no obvious changes in near-surface lithology.

From S.P. 45 to S.P. 48, at the extreme western end of the traverse, all reflections, ranging in quality from very poor to good, indicate a consistent westerly component of dip of about 800 feet per mile regardless of depth.

Reflections from the two southernmost shot points on the short north-south cross traverse (Traverse F, Plate 8) indicate a southerly component of dip of about 200 feet per mile. Reflections from the next shot point (S.P. 34A) indicate a much steeper component of dip in the opposite direction, i.e. towards the north. However, although a considerable amount of definite reflected energy was recorded at this shot point the dips indicated are regarded as doubtful, as most of the reflections show an abnormal degree of curvature across the seismic record and there is evidence of phase changes between adjacent traces. This could be due to the presence of a fault beneath the spread or to some other irregularity beneath the weathered layer. No reliable reflections were recorded from the northernmost shot point on Traverse F.

6. CONCLUSIONS

(i) In the areas investigated, seismic shooting conditions are moderately good on shale of the Wianamatta Group and on some parts of the Newcastle Coal Measures. The seismic method of prospecting proved fairly successful when used on these strata. The traverses surveyed at Dural and Matoota demonstrated that useful results can also be obtained on Hawkesbury Sandstone, although the results are generally much poorer than those from the shale and coal measure areas.

(ii) The use of geophones in multiples of 10 proved successful in areas of poor reflections. In this survey, 10 geophones per trace was the maximum number available, but it is probable that larger numbers would be even more successful. The multiple-10 geophone array gave much better results than the multiple - 4 array. Surveying with multiple - 10 array progressed at approximately half the speed of normal surveying when using multiple -4. However, a faster technique could undoubtedly be developed. In the Sydney Basin, the multiple -10 geophone array proved just as effective when used in-line along the traverse as when used in square grid patterns about the geophone points. It was found that a convenient and effective interval at which to space the 10 geophones was 24.5 feet. Reflection quality can be much improved by using patterns of, say, 9 shot holes instead of a single hole with the same total amount of explosive charge. The technique of using shallow pattern shots with a very large number of holes was not tried but may well prove economical and effective in the Sydney Basin.

(iii) The seismic survey indicates that anticlinal structures may exist at depth at Llandillo Dural and Singleton. Much more seismic work would be needed, however, to confirm the existence of these structures and to determine whether closed structures, suitable for the accumulation of oil or gas, exist. The limited amount of reflection data obtained at Dural confirms the gentle north-westerly dip mapped on the surface to the north-west of Dural East No.1 Bore. The seismic work indicates that this dip extends to a depth of at least 4,000 feet. It was unfortunate that rough terrain prevented the seismic traverse from being continued any appreciable distance to the east of the Bore, where surface mapping indicates south-easterly dip. Near Singleton, there is evidence from the seismic results that an anticlinal axis crosses the Camberwell traverse near shot points 36 and 37, although the absence of sufficient reliable reflection data from these shot points leaves the exact location of the axis open to conjecture. Results from the short cross-traverse through S.P. 34. indicate a southerly dip south of the main traverse, but results were inconclusive north of that traverse. The seismic work suggests that a fault may exist near S.P. 39.

On the basis of the seismic work so far done near Singleton, it would appear that a more intensive and detailed seismic investigation would be desirable before an expensive deep drilling programme is carried out. This investigation should aim at clarifying the structure near the southern end of the Camberwell Anticline and further work should be done at the eastern end of the seismic traverse, where strong, consistent reflections indicate westerly dips of about 12 degrees.

7. REFERENCES.

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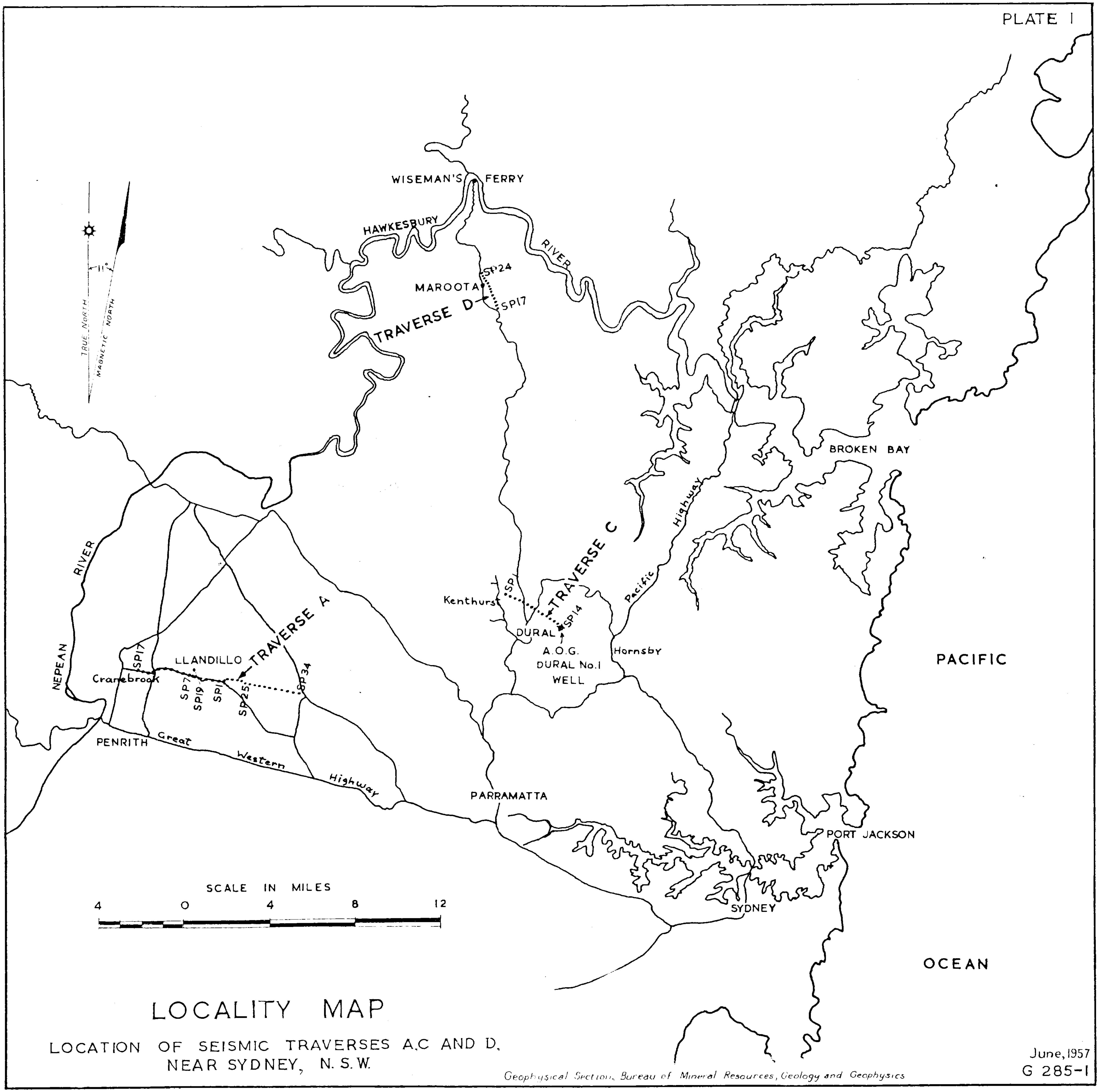
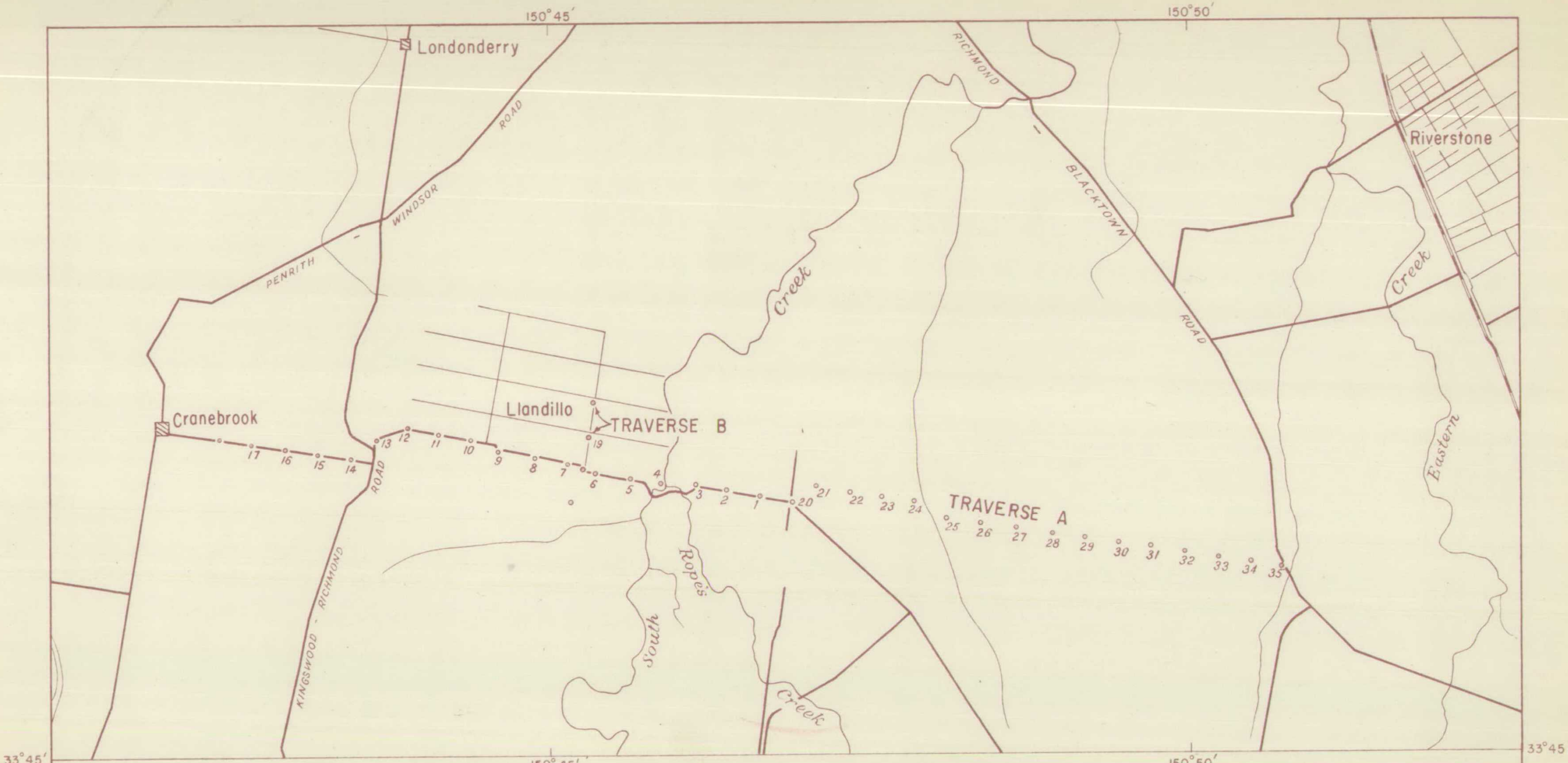


PLATE I
WISEMAN'S FERRY
HAWKESBURY
RIVER
MAROOTA
SP24
SP17
TRAVERSE D
TRUE NORTH
MAGNETIC NORTH
11°
BROKEN BAY
NEPEAN
RIVER
TRAVERSE C
SP1
Kenthurst
SP14
DURAL
A.O.G.
DURAL No. I
WELL
Hornsby
Pacific
Highway
PACIFIC
TRAVERSE A
LLANDILLO
SP17
Cranebrook
SP7
SP19
SP1
SP25
SP34
PENRITH
Great
Western
Highway
PARRAMATTA
PORT JACKSON
SYDNEY
SCALE IN MILES
4
0
4
8
12
OCEAN
LOCALITY MAP
LOCATION OF SEISMIC TRAVERSES A,C AND D,
NEAR SYDNEY, N.S.W.
Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics
June, 1957
G 285-1



SEISMIC REFLECTION SURVEY IN THE SYDNEY BASIN, N.S.W.

POSITION OF TRAVERSES A AND B, NEAR LLANDILLO

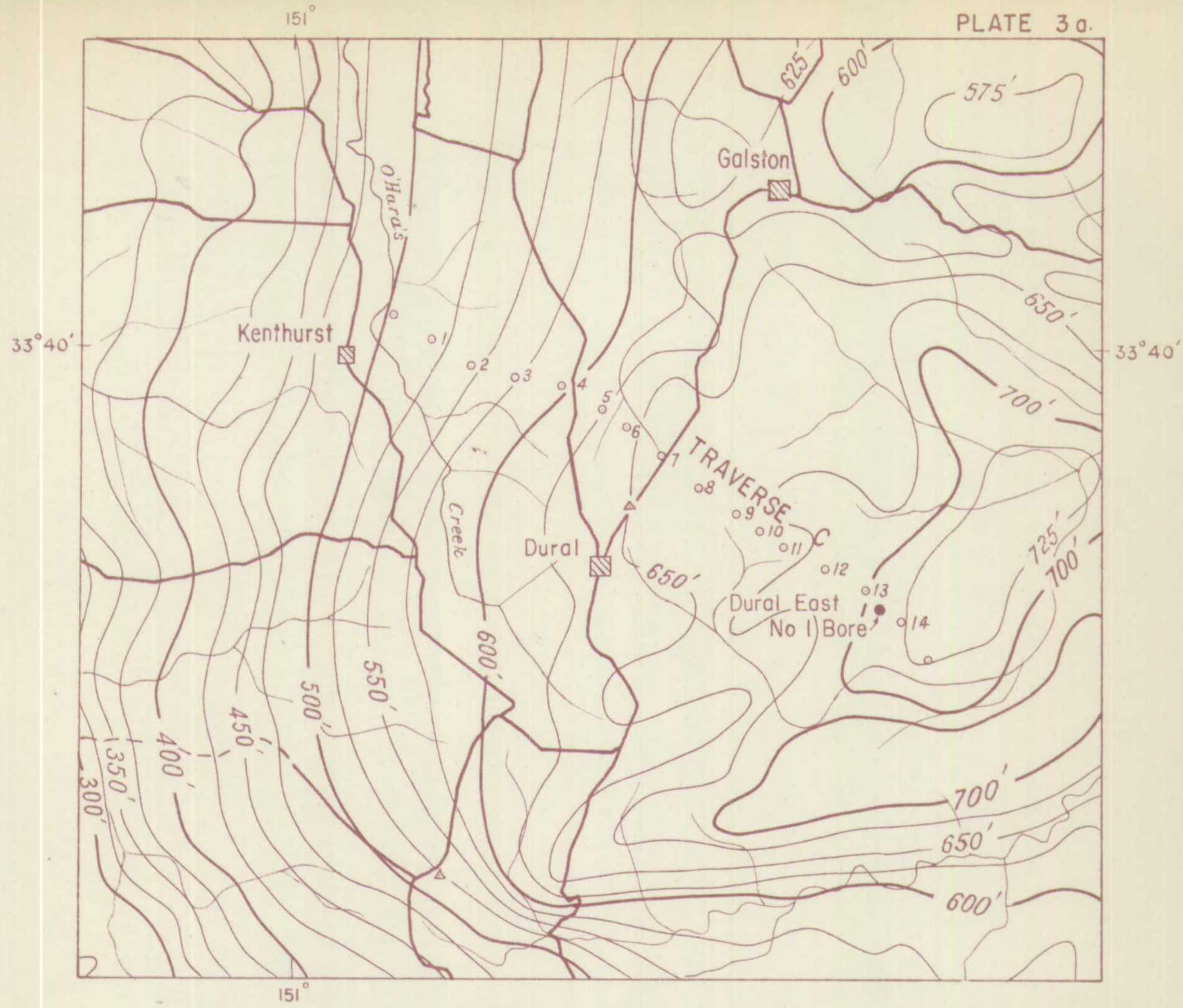
SCALE IN MILES

1 0 1 2 3

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics. G 285 - 12

PLATE 2

PLATE 3a.

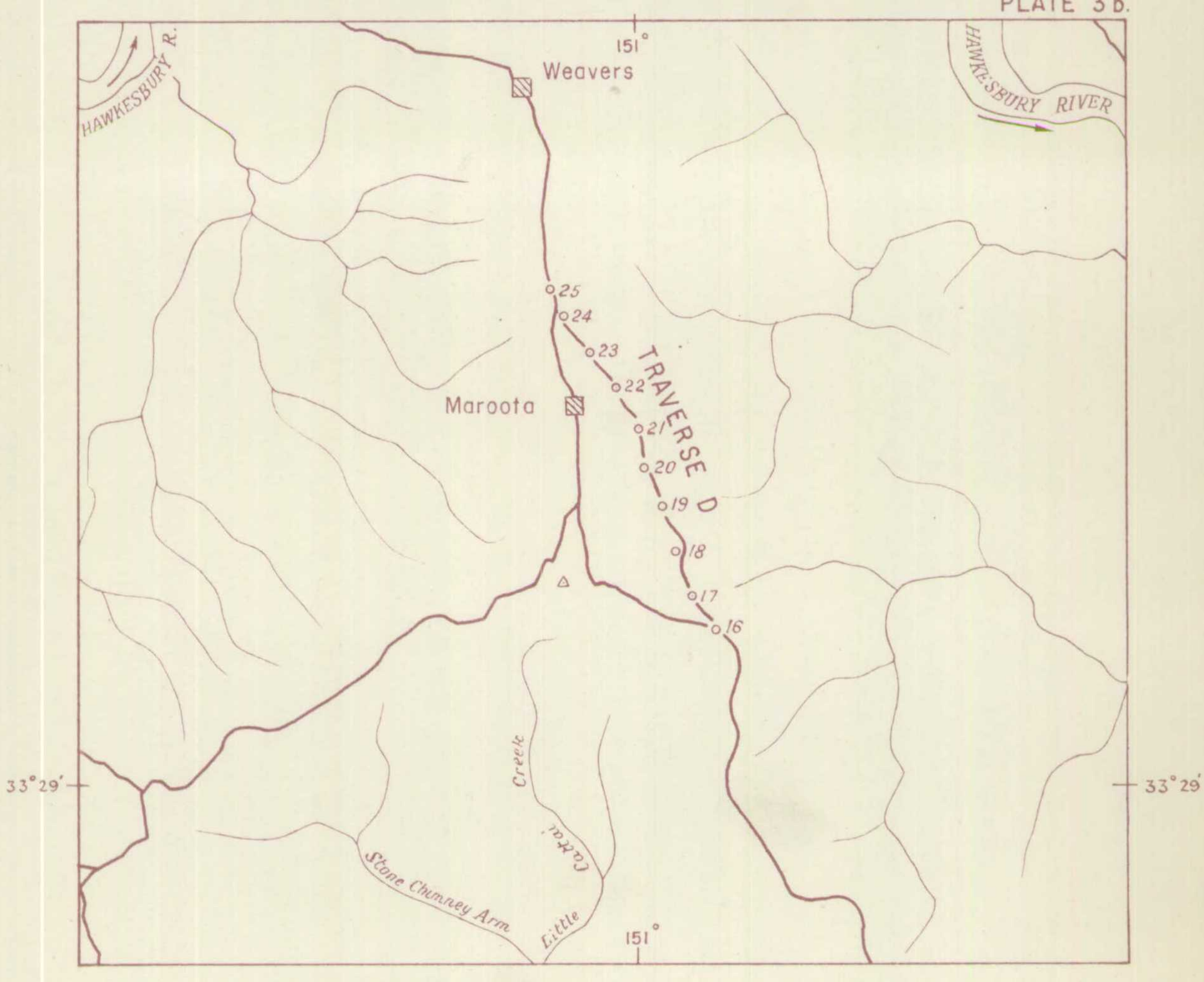


POSITION OF TRAVERSE C NEAR DURAL IN RELATION TO STRUCTURAL CONTOURS OF WIANAMATTA GROUP

SCALE IN MILES (BOTH PLANS)

1 0 1 2 3

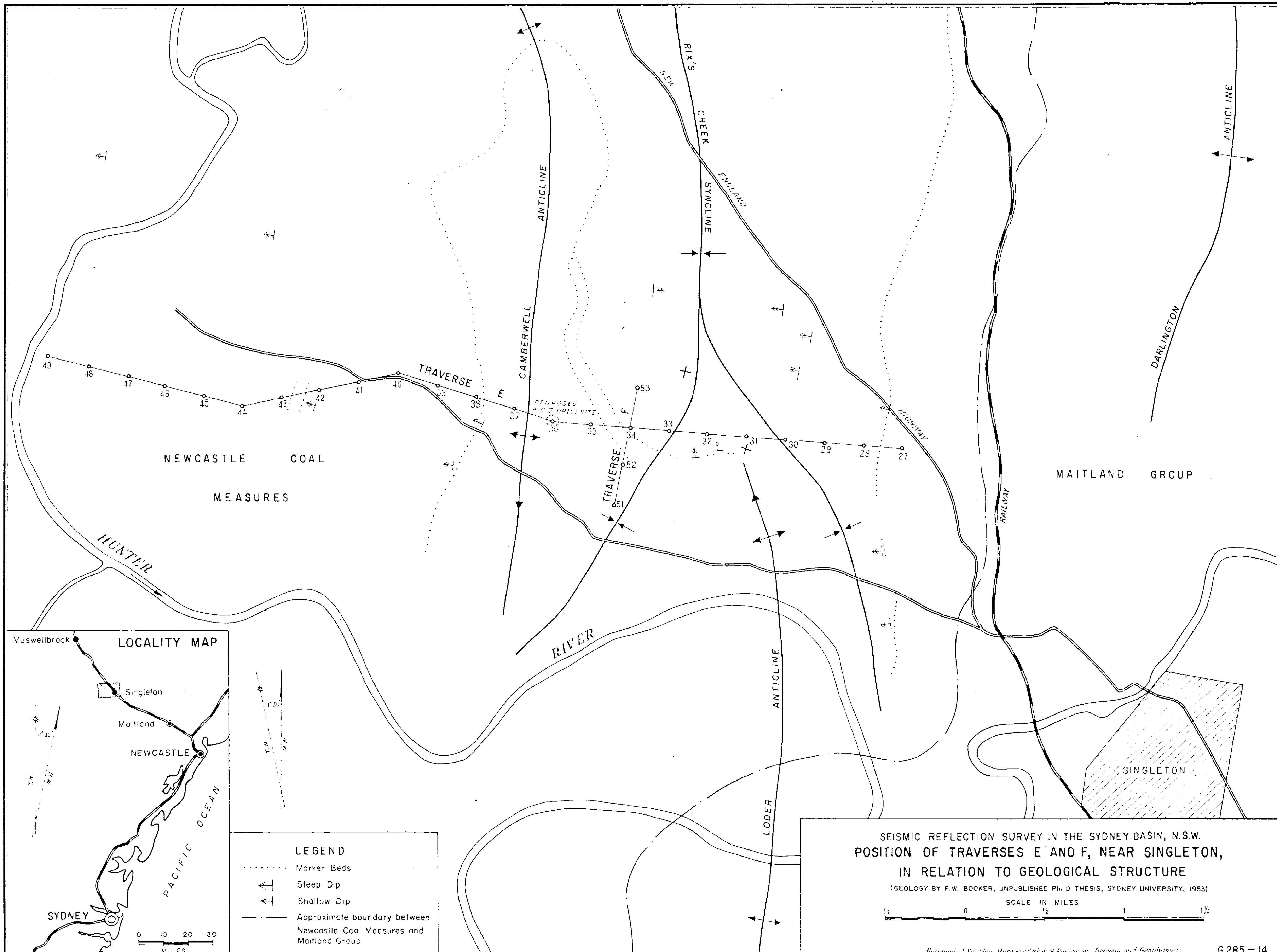
PLATE 3b.



POSITION OF TRAVERSE D NEAR MAROOTA

SEISMIC REFRACTION SURVEY IN THE SYDNEY BASIN. N.S.W.

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics. G 285 – 13



SEISMIC REFLECTION SURVEY IN THE SYDNEY BASIN, N.S.W.

POSITION OF TRAVERSES E AND F, NEAR SINGLETON, IN RELATION TO GEOLOGICAL STRUCTURE

(GEOLOGY BY F.W. BOOKER, UNPUBLISHED Ph. D THESIS, SYDNEY UNIVERSITY, 1953)

SCALE IN MILES

½ 0 ½ 1 1½

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics

G285-14

SEISMIC REFLECTION TRAVERSE, LLANDILLO
SYDNEY BASIN N.S.W.

CORRELATION CROSS SECTION ALONG
TRAVERSE A

REFLECTION TIMES CORRECTED TO DATUM LEVEL (S.L.)
AND PLOTTED DIRECTLY UNDER THE
SHOT POINT FROM WHICH RECORDED

GEOPHYSICIST: C. S. Robertson

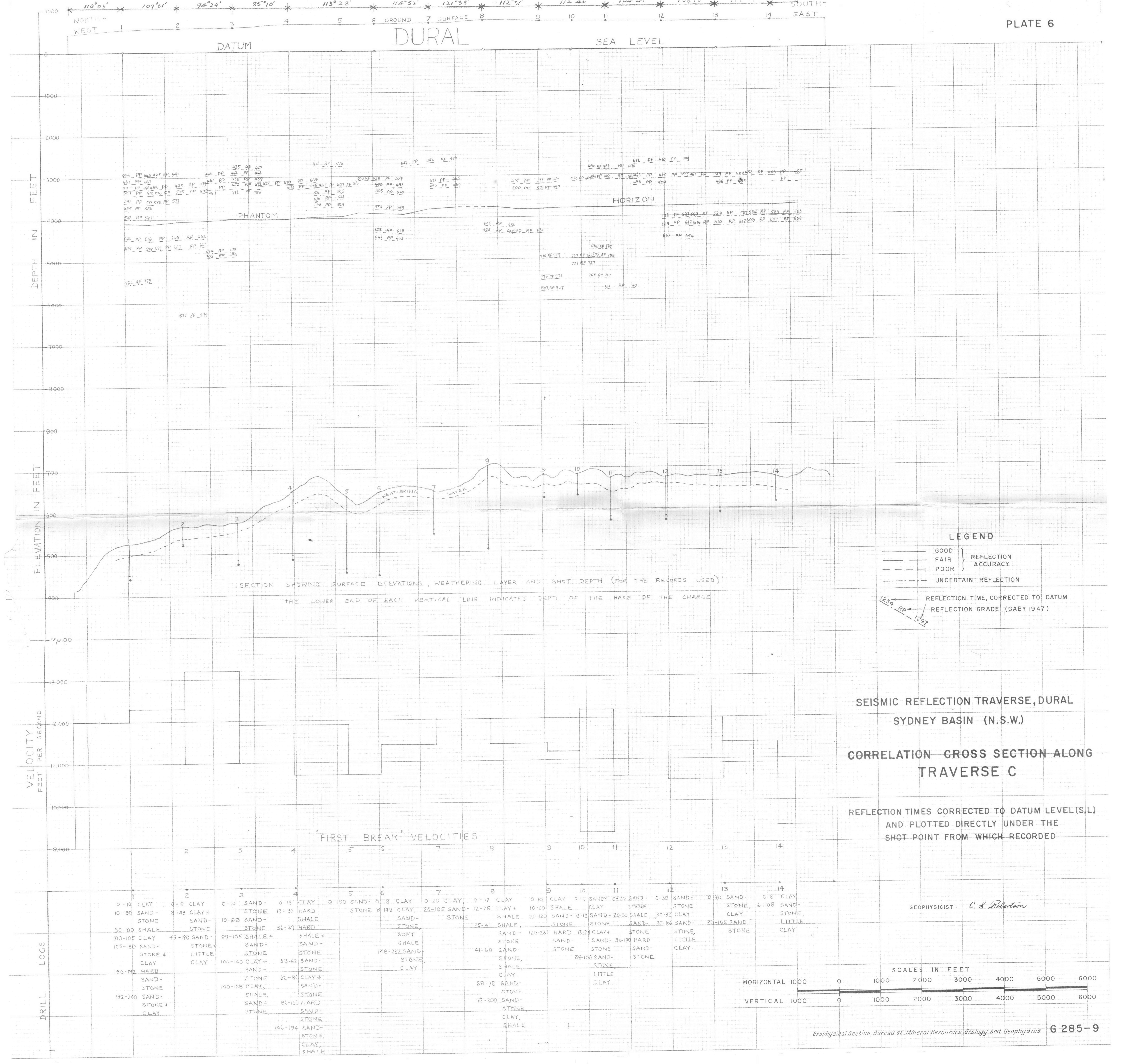
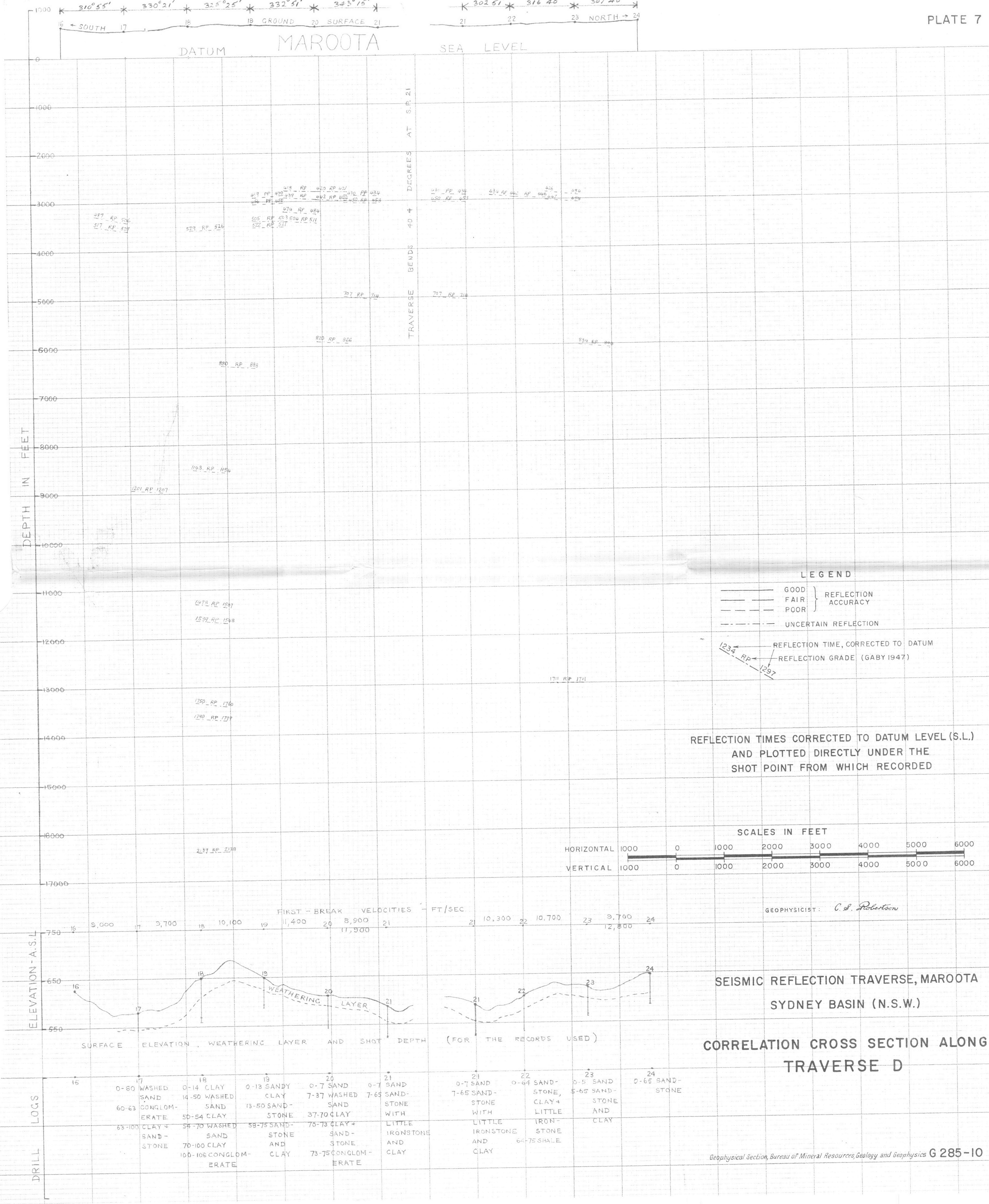


PLATE 6
NORTH-WEST
SOUTH-EAST
GROUND SURFACE
DURAL
DATUM
SEA LEVEL
PHANTOM
HORIZON
DEPTH IN FEET
ELEVATION IN FEET
WEATHERING LAYER
SECTION SHOWING SURFACE ELEVATIONS, WEATHERING LAYER AND SHOT DEPTH (FOR THE RECORDS USED)
THE LOWER END OF EACH VERTICAL LINE INDICATES DEPTH OF THE BASE OF THE CHARGE
LEGEND
GOOD
FAIR
POOR
REFLECTION ACCURACY
UNCERTAIN REFLECTION
REFLECTION TIME, CORRECTED TO DATUM
REFLECTION GRADE (GABY 1947)
VELOCITY FEET PER SECOND
"FIRST BREAK" VELOCITIES
DRILL LOGS
SEISMIC REFLECTION TRAVERSE, DURAL
SYDNEY BASIN (N.S.W.)
CORRELATION CROSS SECTION ALONG
TRAVERSE C
REFLECTION TIMES CORRECTED TO DATUM LEVEL (S.L)
AND PLOTTED DIRECTLY UNDER THE
SHOT POINT FROM WHICH RECORDED
GEOPHYSICIST: C. S. Robertson.
SCALES IN FEET
HORIZONTAL 1000 0 1000 2000 3000 4000 5000 6000
VERTICAL 1000 0 1000 2000 3000 4000 5000 6000
Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics
G 285-9

PLATE 7


MAROOTA
DATUM SEA LEVEL
SOUTH
GROUND SURFACE
NORTH
TRAVERSE BENDS 40 DEGREES AT S.P. 21
DEPTH IN FEET
LEGEND
GOOD
FAIR
POOR
REFLECTION ACCURACY
UNCERTAIN REFLECTION
REFLECTION TIME, CORRECTED TO DATUM
REFLECTION GRADE (GABY 1947)
REFLECTION TIMES CORRECTED TO DATUM LEVEL (S.L.) AND PLOTTED DIRECTLY UNDER THE SHOT POINT FROM WHICH RECORDED
SCALES IN FEET
HORIZONTAL
VERTICAL
GEOPHYSICIST: C. S. Robertson
FIRST - BREAK VELOCITIES - FT/SEC
ELEVATION - A.S.L.
WEATHERING LAYER
SURFACE ELEVATION, WEATHERING LAYER AND SHOT DEPTH (FOR THE RECORDS USED)
DRILL LOGS
17 0-60 WASHED SAND 60-63 CONGLOMERATE 63-100 CLAY + SANDSTONE
18 0-14 CLAY 14-50 WASHED SAND 50-54 CLAY 54-70 WASHED SAND 70-100 CLAY 100-106 CONGLOMERATE
19 0-13 SANDY CLAY 13-50 SANDSTONE 50-75 SANDSTONE AND CLAY
20 0-7 SAND 7-37 WASHED SAND 37-70 CLAY 70-73 CLAY + SANDSTONE 73-75 CONGLOMERATE
21 0-7 SAND 7-65 SANDSTONE WITH LITTLE IRONSTONE AND CLAY
22 0-64 SANDSTONE, CLAY + LITTLE IRONSTONE 64-75 SHALE
23 0-5 SAND 5-65 SANDSTONE AND CLAY
24 0-65 SANDSTONE
SEISMIC REFLECTION TRAVERSE, MAROOTA
SYDNEY BASIN (N.S.W.)
CORRELATION CROSS SECTION ALONG
TRAVERSE D
Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics G 285-10


WEST
EAST
SOUTH
NORTH
DATUM = S.L.
SURFACE ELEVATION, WEATHERING LAYER AND SHOT DEPTH (FOR THE RECORDS USED)
SURFACE ELEVATION IN FEET ABOVE DATUM
DEPTH IN FEET
NOTE: IT SHOULD BE NOTED THAT THE NORTHERLY DIPS INDICATED BY THE REFLECTIONS RECORDED AT S.P. 34A ARE REGARDED AS VERY DOUBTFUL, SINCE MOST OF THOSE REFLECTIONS SHOW AN ABNORMAL DEGREE OF CURVATURE ACROSS THE SEISMIC RECORD. THERE IS EVIDENCE OF PHASE CHANGES BETWEEN ADJACENT TRACES AND THE EVIDENCE OF DIP FROM THESE REFLECTIONS CONFLICTS WITH THAT FROM MORE RELIABLE REFLECTIONS.
LEGEND
GOOD
FAIR
POOR
REFLECTION ACCURACY
UNCERTAIN REFLECTION
REFLECTION TIME CORRECTED TO DATUM
REFLECTION GRADE (GABY 1947)
TANGENT OF DIP ANGLE
SCALES IN FEET
HORIZONTAL
VERTICAL
TRAVERSE F
(SEE TRAVERSE E)
"FIRST BREAK" VELOCITIES
VELOCITY - FEET PER SECOND
REFLECTION TIMES CORRECTED TO DATUM LEVEL (S.L.)
REFLECTIONS MIGRATED AND PLOTTED
IN APPARENT CORRECT POSITIONS.
SEISMIC REFLECTION TRAVERSE, CAMBERWELL ANTICLINE,
SINGLETON AREA (N.S.W.)
CROSS SECTION ALONG
TRAVERSE E
LEAST SQUARE DIP PLOTTING
GEOPHYSICIST:
DRILL LOGS
Geophysical Section, Bureau of Mineral Resources Geology and Geophysics
G 285-11

PLATE 9

Plate 9(A)

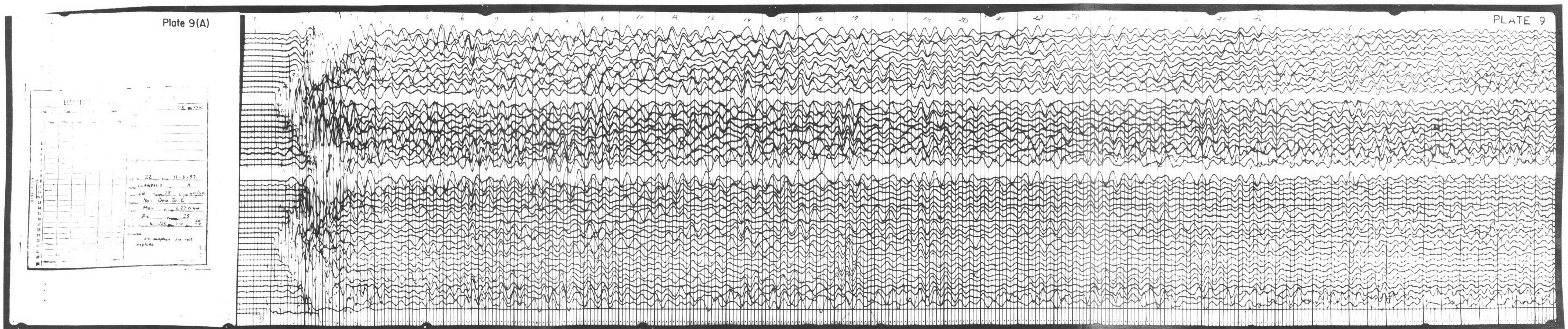


Plate 9(B)

Plate 9(C)

Plate 9(D)

Plate 9(E)

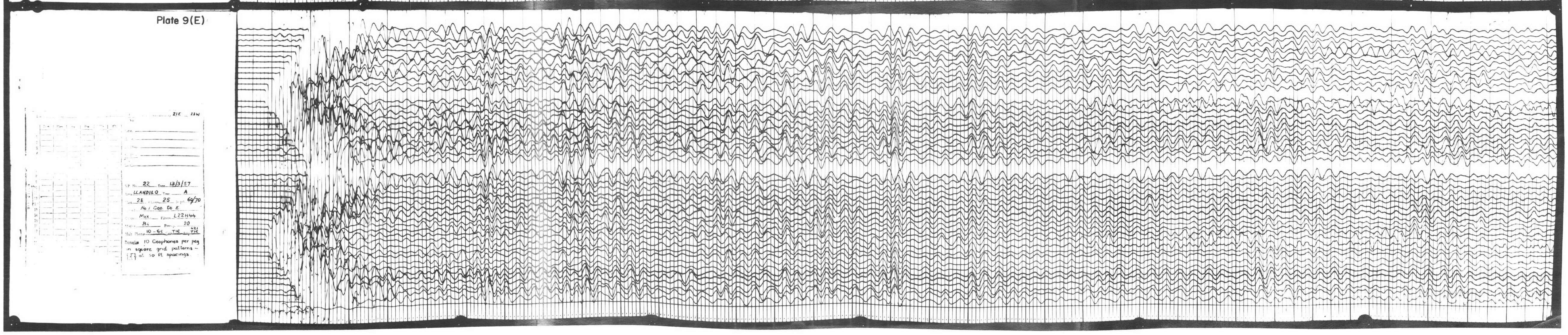
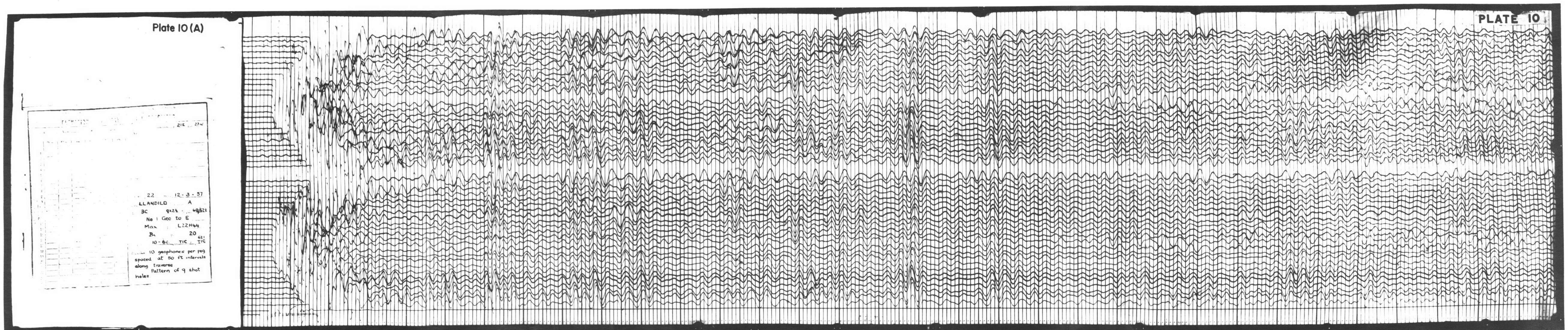


PLATE 10

Plate 10 (A)



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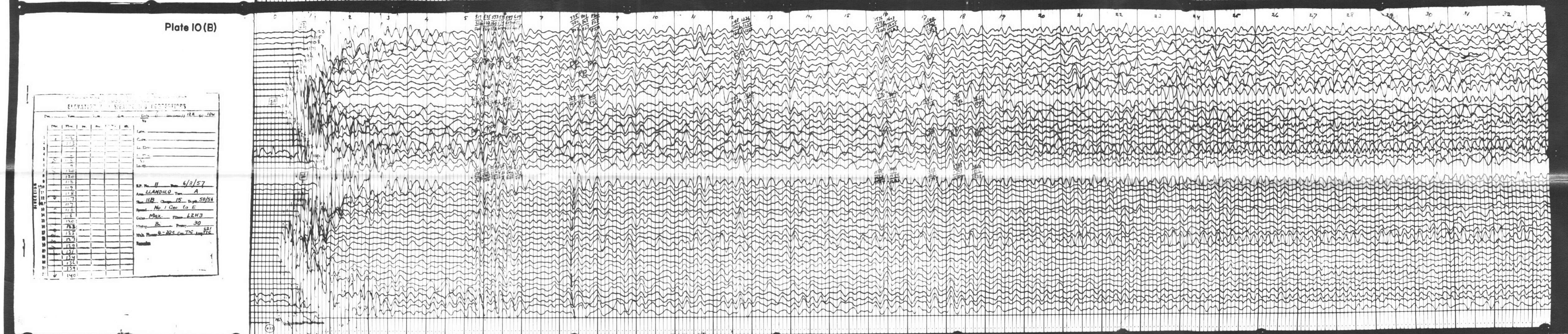

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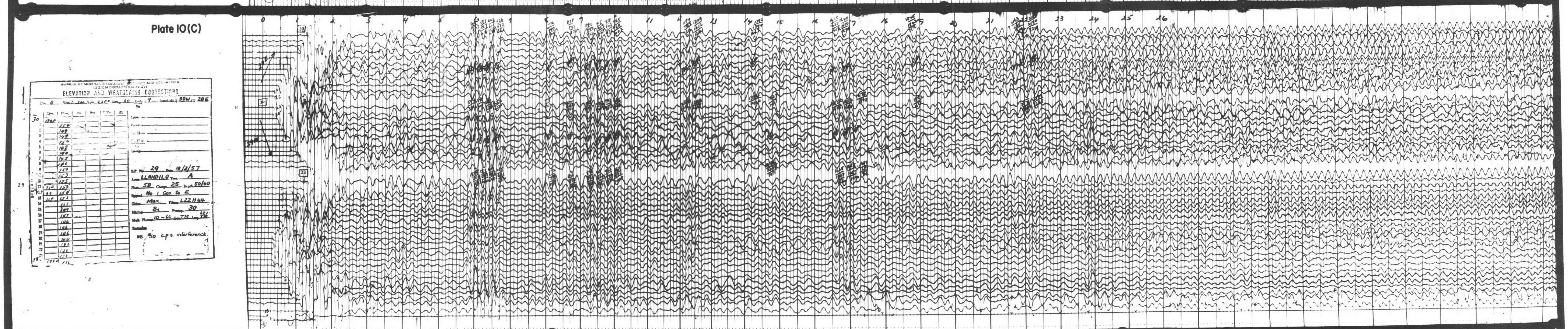
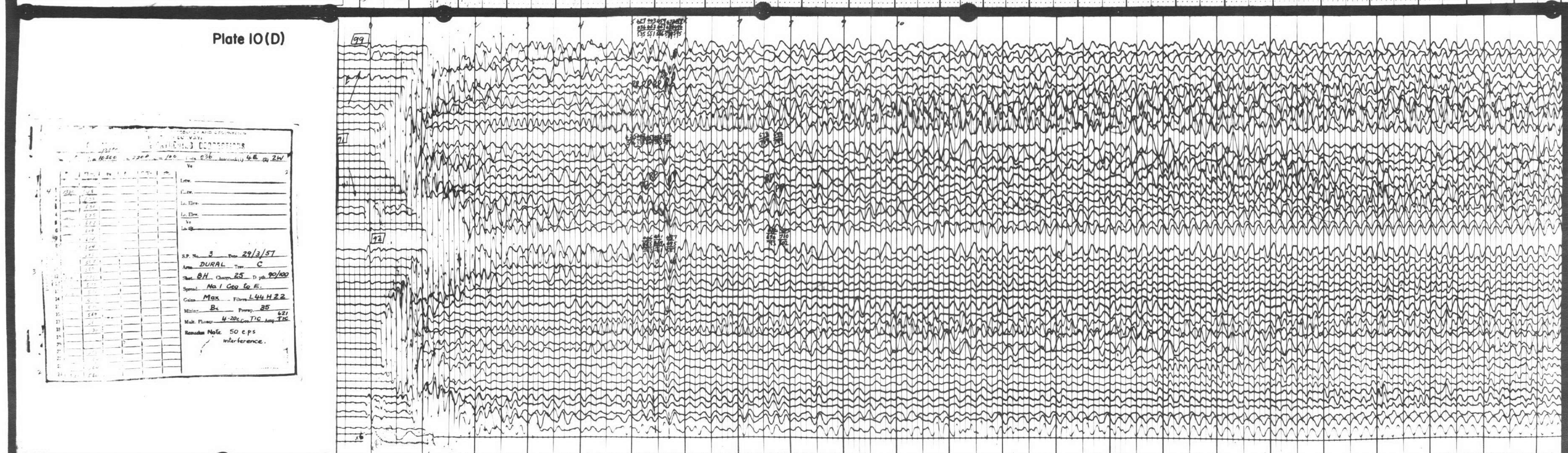


Plate 10 (D)



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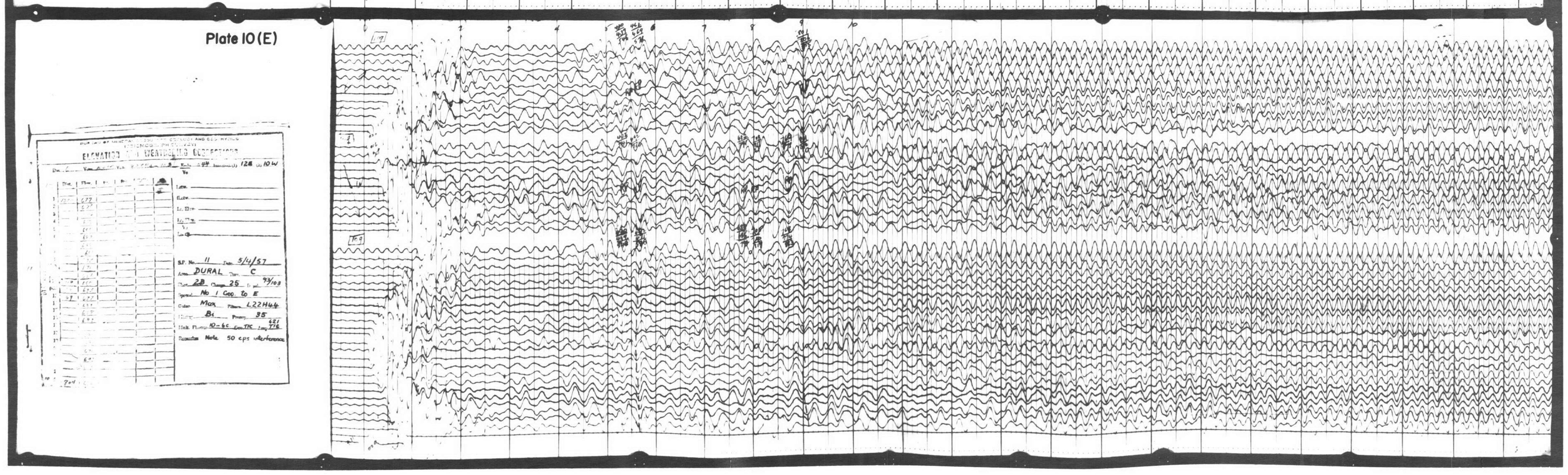
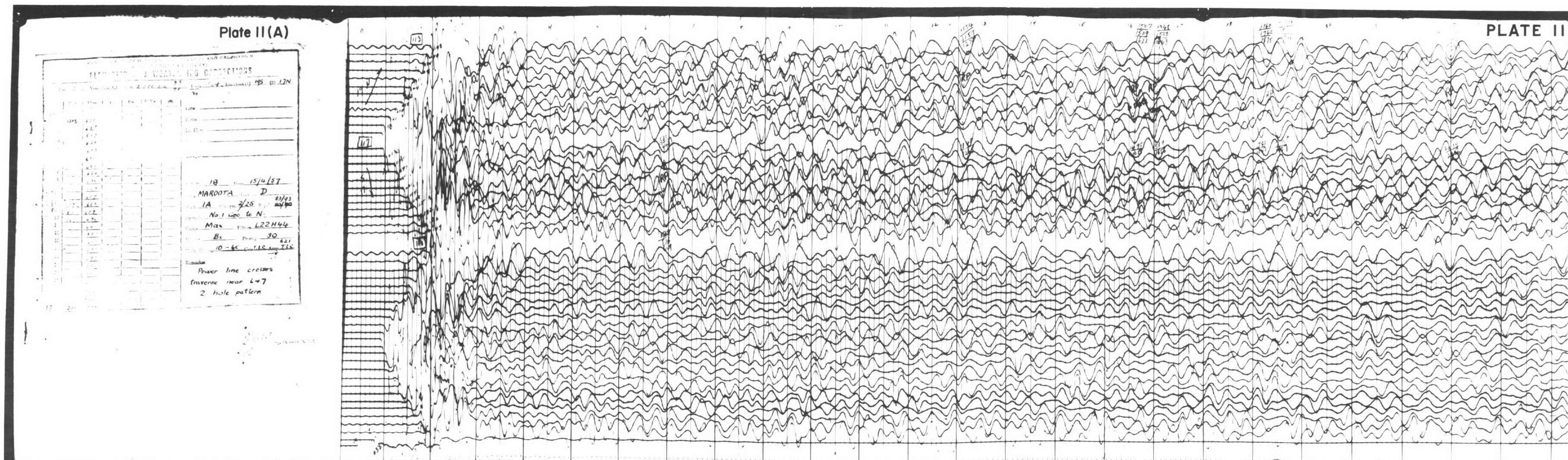


PLATE II

Plate II(A)



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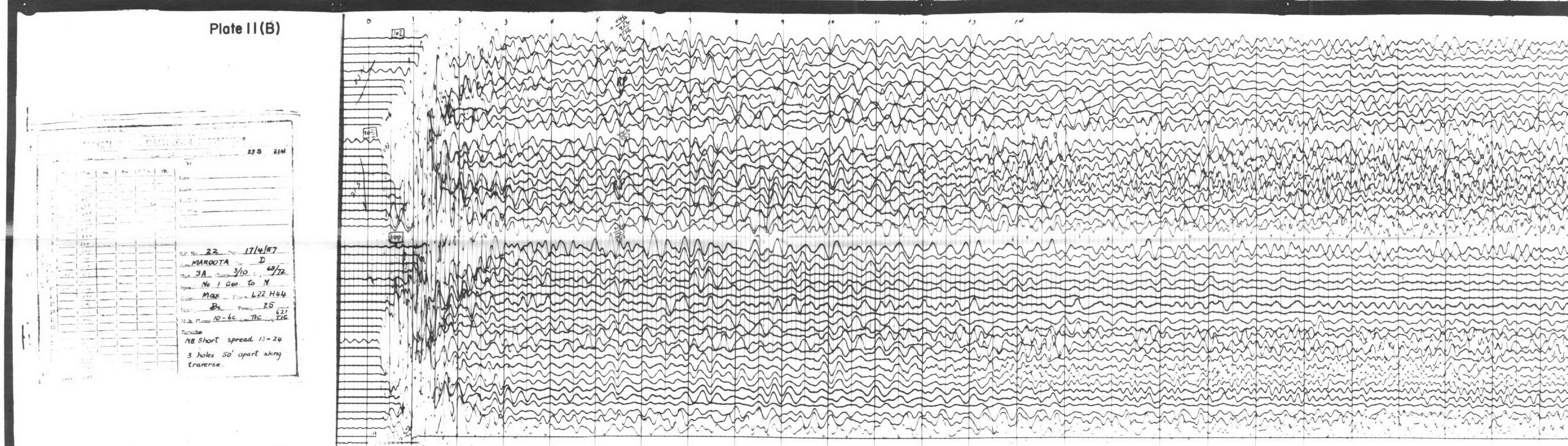

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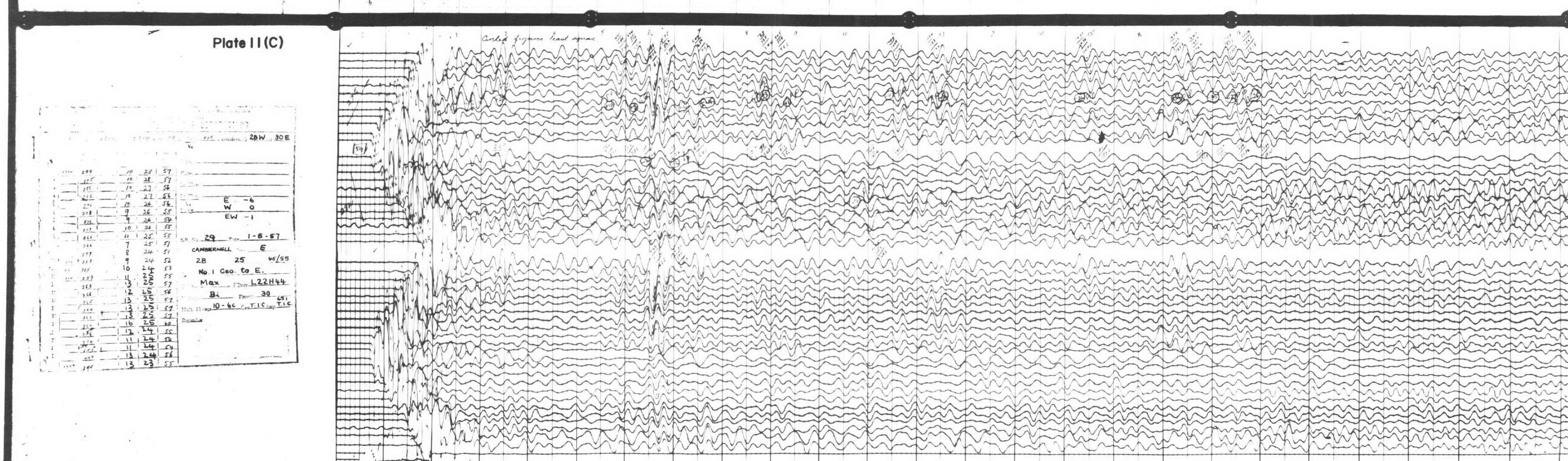

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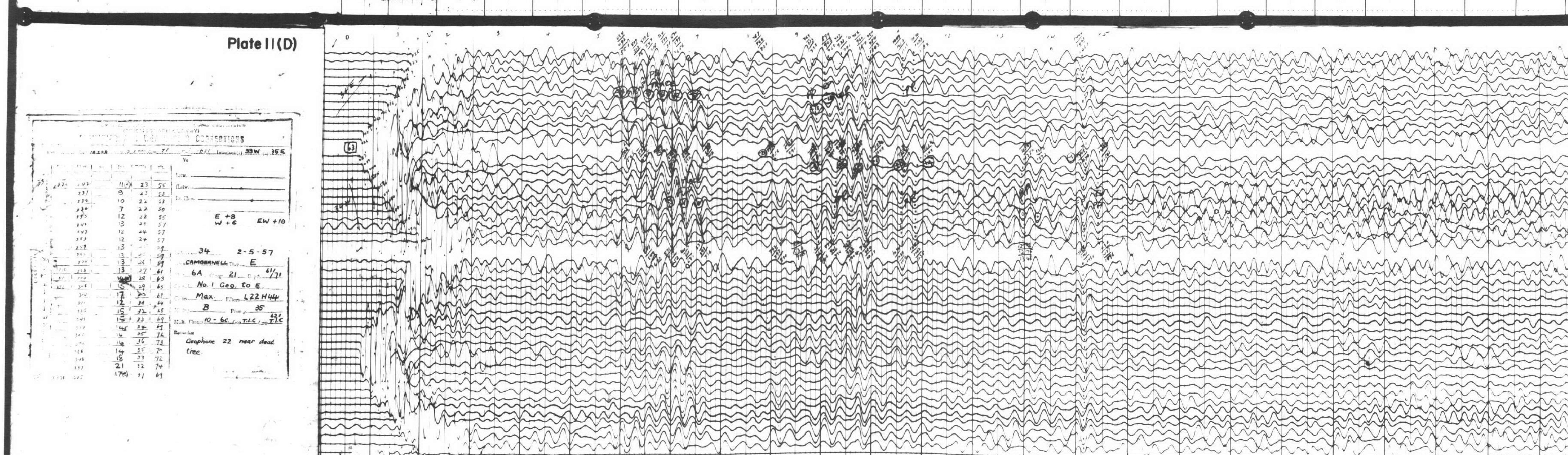

Plate II(E)