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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1963/63

UNDILLA BASIN SEISMIC SURVEY, QUEENSLAND 1961

by

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SUMMARY

The Undilla Basin, in north-western Queensland, is a small sedimentary basin containing Cambrian limestones which adjoin the widespread but undated Camooweal Dolomite to the west. In the latter part of 1961 the Bureau of Mineral Resources, Geology and Geophysics did a brief reconnaissance seismic survey lasting about seven weeks in the Undilla Basin. This Record describes briefly the work done and results obtained. The occurrence of limestone near the surface throughout the basin presented difficult problems in the application of the reflection and refraction seismic methods but some progress was made towards the solution of these problems.

1. INTRODUCTION

From 6th October to 22nd November 1961 the Bureau of Mineral Resources, Geology and Geophysics did a reconnaissance seismic survey in the Undilla Basin, north-east of Camooweal, Queensland. The objectives of the survey were:

(a) to determine the thickness of relatively unmetamorphosed strata in the Undilla Basin,

(b) to determine the relation between the Middle Cambrian sediments of the basin and the undated Camooweal Dolomite to the west, and

(c) to determine the existence or otherwise of a sandstone sequence between the Middle Cambrian limestone strata and metamorphic basement.

It was considered that although all the necessary conditions for oil occurrence might be present in the Undilla Basin, its limited size made it unlikely that it would itself represent a large and important oil province. However, the importance of the seismic survey was believed to lie chiefly in the possibility of demonstrating the contemporaneity of the fossiliferous Middle Cambrian limestones of the Undilla Basin and the apparently unfossiliferous Camooweal Dolomite. The latter is believed to extend over a large area of north-west Queensland and the Northern Territory, although much of it is soil-covered. It was believed that the Camooweal Dolomite might be of Proterozoic Age and that it was a poor prospect for oil occurrence. However, if it could be demonstrated that the Camooweal Dolomite was deposited simultaneously with highly fossiliferous limestone of the Undilla Basin then the oil prospects of a large region would be greatly enhanced.

Prior to the Bureau's 1961 seismic survey, no seismic work or other geophysical work had been done in the Undilla Basin although the area had been geologically mapped by the Bureau (see 1:250,000 series Geological Sheet E/54-13, Camooweal, 1961). Because of the widespread occurrence of limestone and dolomite it was foreseen that the area would be a difficult one for seismic work and the Bureau's Seismic Party No. 1 went prepared to spend a considerable amount of the time available for the survey doing experiments to improve the quality of results. Such experimentation was later found to be necessary.

2. GEOLOGY

Cambrian and Ordovician rocks occur in the region of Queensland within the meridians 138 and 141 degrees east and the latitudes 18 and 24 degrees south (Opik, 1960). These rocks, including the Camooweal Dolomite, cover an area of about 30,000 square miles and about one-third of the surface of the region. The larger part of the region belongs to the outcropping basement and to Mesozoic and Tertiary deposits. The lower Palaeozoic rocks extend from Queensland into the Northern Territory, where they cover an even larger area. North of the latitude 22 degrees south the Cambrian and Ordovician rocks are preserved as numerous outliers. The largest of these is situated between Lawn Hill and the Pilpah Range near Camooweal, and includes the Undilla Basin.

The Undilla Basin region has been considered as having been a hypothetical stable foreland or high craton now covered by late Proterozoic and Cambrian sediments. Originally, these Cambrian rocks formed a continuous blanket over the whole region but a considerable portion was eroded away before the marine Mesozoic inundation. The complete Middle Cambrian sequence is preserved in the Undilla Basin but the Upper Cambrian is missing. A large part of the Cambrian sequence in the Basin is concealed under a thin blanket of Cretaceous shale that forms an undissected low plateau with shrubs and timber. The plateau is surrounded by scarps 100 to 200 ft high.

North of the Undilla Basin a veneer of Middle Cambrian Thorntonia Limestone is present, which along its southern edge dips southwards into the Undilla Basin. At the Border Waterhole the Camooweal Dolomite and Cambrian rocks are down-faulted against Precambrian rocks to the north. The dolomite is horizontal and younger than the folded but unmetamorphosed late Precambrian Constance beds north of the fault.

In the Pilpah Range, which is the southern limit of the Undilla Basin, only residuals of Middle Cambrian formations occur. Consequently, a sedimentational break during the Middle Cambrian is apparent here, indicating that the Range itself was only temporarily submerged during the continuous sedimentation in the Undilla Basin to the north. The Cambrian rocks of the Undilla Basin either rest on Precambrian rocks consisting of sediments or igneous or metamorphic rocks, or abut the Camooweal Dolomite in the west.

The Camooweal Dolomite is about 800 to 1000 feet thick, its base being below sea level. It appears to be a uniform blanket extending into the Northern Territory. Within this large area of dolomite, pockets of Middle Cambrian rocks may still be present unnoticed under the soil cover. The Camooweal Dolomite consists of dolomite with interbeds of calcareous dolomite and with chert nodules. It is unfossiliferous. It was formerly thought that the Camooweal Dolomite was unconformably overlain by the Middle Cambrian Age Creek Formation but there is, at the present time, considerable doubt about the relation between the two.

The following, which is based on Opik (1960) and Randal & Brown (1962), is a summary of the characteristics of the principal Middle Cambrian formations present in the Undilla Basin area (see also 1:250,000 series Geological Sheet E/54-13, Camooweal 1961):

Thorntonia Limestone. Dolomitic limestone, dolomite, and limestone with chert layers and nodules. The thickness is about 200 ft, but usually far less is preserved.

Current Bush Limestone. Bituminous, smelly, flaggy limestone with marly interbeds. Thickness is variable but in the Border Waterhole area it attains its maximum of 500 ft.

Age Creek Formation. A calcareous formation consisting of sandy clastic dolomite and limestone with interbeds of calcareous sandstone. Slumping is common; dips towards the basin observed may be foreset dips. The Age Creek Formation is the slope deposit of the Undilla Basin. Its thickness is greater than 4000 ft (Randal & Brown, 1962, p.6).

<u>V-Creek Limestone</u>. A well-bedded, laminated marly limestone with banks of siliceous limestone and fine-grained calcilutitic interbeds in its lower levels. Thickness is between 100 and 120 ft.

<u>Mail Change Limestone</u>. Two-coloured, thick-bedded, fine-grained limestone restricted to the Undilla Basin. A resistant rock forming low and extended mesas. Thickness is small, not exceeding 20 ft.

3. FIELD WORK

The Bureau's Seismic Party No. 1 set up camp near the Camooweal-Burketown road about 35 miles north-east of Camooweal on 6th October 1961. Camp was dismantled on 22nd November 1961. High temperatures were general during the period of the survey. During November, afternoon thunderstorms were common, but not more than a few hours fieldwork were lost owing to these as they usually occurred late in the afternoon. A number of windy periods were experienced in which winds of 10 to 20 m.p.h. continued for several days, both in the daytime and at night. Wind must be ranked with the hard drilling conditions experienced as a major hindrance to seismic work in the area.

Within the Undilla Basin area the terrain is not generally rugged, although there are some areas of rugged limestone ridges. About half the area was moderately well timbered, requiring a considerable amount of traverse cleaning by the surveying crew; the other half consisted of open black-soil terrain. The latter was more difficult of access than most black-soil areas because of the large number of limestone boulders that usually littered the ground.

Practically without exception, drilling in the Undilla Basin on the Proterozoic sediments to the east and on the Camooweal Dolomite was very difficult. Penetration rate was generally about 5 ft/hr, using hard-rock bits and drilling with either water or air. The deepest hole drilled by the seismic party in the area took five 8½-hour shifts to reach a depth of 150 ft. Rig breakdowns were abnormally frequent because of the hard conditions.

Despite the hard formations drilled there was a tendency for shot-holes to collapse after the first shot particularly in black-soil areas where caving-in occurred near the surface. This was partly overcome by the use of short lengths of casing near the surface. Loss of drilling mud circulation was also a recurrent problem for the party's Failing-750 rig which is only equipped for water drilling. A tractor-mounted Proline drill using 3-ft auger flights was successfully used for drilling shallow holes through the soil on top of the hard limestone. This soil cover ranged up to 6 ft in the black-soil areas.

The survey was conducted by geophysicists C.S. Robertson (party leader), K.B. Lodwick, and J.S. Davies assisted by eight staff members of the Bureau and fourteen wages employees. A surveyor and assistant were provided by the Department of the Interior. The staff members and main items of equipment used are listed in Appendix A.

spread

For reflection shooting the normal split-spread method of continuous profiling was used. Up to 36 geophones (20 c/s) per trace were employed for reflection shooting and a number of noise tests were made. For refraction shooting the 'depth probing' method described by Vale and Smith (1961) was employed. The spread dimensions, recording parameters, and many statistics relating to the survey are set out in Appendix B. Appendix C gives shot-hole drilling statistics.

4. RESULTS

Refraction

Traverse E. Near the beginning of the survey a one-mile traverse was surveyed on the Lower Proterozoic Ploughed Mountain Beds about five miles west of Thorntonia Homestead (see Plate 2). This traverse was shot from both ends to record the refraction velocity, which it was hoped might prove to be typical of Proterozoic basement rocks underlying the Undilla Basin. The results obtained are shown on Plate 3. The principal velocity recorded was about 17,300 ft/sec. There is evidence of faulting or other structural irregularity on the western end of the traverse. Because of this, and the rather large scatter of some points on the graph, the velocity measurements can only be regarded as approximate.

The velocity of 17,300 ft/sec is reasonably close to the velocities recorded from near-surface limestone within the Undilla Basin. It is thus evident that if the Ploughed Mountain Beds or similar Proterozoic rocks extend beneath the limestones of the Undilla Basin, it may be difficult or impossible to distinguish them from the Cambrian limestone by means of refraction velocity measurements. It would have been desirable to extend the length of Traverse E and attempt to record from deeper refractors in which the velocity was higher but the ruggedness of the terrain made this impossible in the time available.

Traverse B. This traverse was located near Mailchange Ruins, about half way between Undilla and Morstone Homesteads (see Plate 2). It was surveyed in a north-south direction near what is considered to be the deepest part of the Undilla Basin. Refraction work was carried out following procedure similar to that outlined by Vale and Smith (1961) to record from as many refractors as possible. The results are shown on Plate 4.

With shot-to-geophone distances of up to four miles a first-break velocity of about 16,500 ft/sec was recorded. This is the velocity in the Middle Cambrian limestone near the surface, as intercept times were in all cases small. Beyond the shot-to-geophone distance of four miles it was found to be extremely difficult to obtain enough seismic energy at the geophones to produce satisfactory records, even though large explosive charges were used.

However, with shot-to-geophone distances of over two miles a later refracted arrival was usually recorded after the first breaks. This later event was quite definite and indicated a refractor in which the velocity is about 20,000 ft/sec and which has a small component of dip to the south. The depth to this refractor is not known with any accuracy for two reasons. Firstly, refracted events recorded from it did not have sharp beginnings, so that first-break times had to be estimated, with considerable chance of error. Secondly, very little information is available concerning the vertical velocities in the rocks overlying the 20,000-ft/sec refractor. From t:Δ t analysis of meagre seismic reflection data on Traverse B the average vertical velocity in the Cambrian limestones appears to be about 13,000 ft/sec. This appears to be a reasonable value for horizontally bedded rocks in which the refraction velocity is 16,500 ft/sec. Using an average vertical velocity of 13,000 ft/sec in the rocks overlying the 20,000-ft/sec refractor, its depth is estimated to be 4500 $\pm$ 1000 ft below the surface.

Traverse C. This traverse was surveyed for a distance of five miles and was situated a short distance east of Undilla Homestead (Plate 2). Refraction shots were fired from beyond both ends of the spreads using shot-to-geophone distances of $2\frac{3}{4}$ to $3\frac{3}{4}$ miles and $2\frac{1}{2}$ to $3\frac{1}{2}$ miles for the two shots. It was found that much smaller charges were required on this traverse than on Traverse B in order to obtain adequate refracted energy.

When shooting from the western end of the traverse, an apparent velocity of 16,700 ft/sec was recorded on most geophones and a higher velocity was probably recorded on a number of the more distant ones (Plate 5). Similarly, when shooting from the eastern end of the traverse apparent velocities of 17,200 ft/sec and 19,000 ft/sec were recorded on the near and more-distant halves of the spread respectively. Following experience on Traverse B, where a high-velocity refractor was recorded as a distinct 'second event' it was decided to fire a third shot on Traverse C (from Shot-point 345) after reducing the shot-to-geophone distance to $1\frac{1}{2}$ to $2\frac{1}{2}$ miles. This attempt to separate the two refracted arrivals, which were apparently recorded at about the same time on the first two records, was not successful as no sign of a second event was observed on the third record.

The results of this traverse indicate the presence of a near-surface refractor in which the velocity is about 16,900 ft/sec and the probable occurrence of a refractor at a depth of about 1800 ft, in which the velocity is about 19,500 ft/sec.

Traverse D. This traverse, which was situated south-west of Thorntonia Homestead near the eastern margin of the basin (Plate 2), was surveyed for eight miles. Two pairs of refraction shots were fired, using shot-to-geophone distances of $1\frac{1}{4}$ to $2\frac{1}{4}$ miles and 4 to 5 miles. Only one refractor was recorded (see Plate 6). The velocity of this refractor was 18,300 ft/sec and its depth about 400 ft below datum (datum = 700 ft A.S.L.). This is approximately the depth expected to the Proterozoic rocks at this point, which is only about six miles from their outcrop (see Camooweal 1:250,000-series Geological Sheet E/54-13 for cross-section through the Undilla Basin). Therefore, it is possible that this refractor, in which the velocity is significantly higher than in the Mail Change Limestone on Traverses B and C, represents the top of the Proterozoic sediments. It is also possible that it represents an unweathered layer of the Currant Bush Limestone formation, which includes chert layers in which the velocity could well be 18,300 ft/sec.

The main problem in interpreting the refraction results is to decide whether the 20,000-ft/sec refractor recorded on Traverse B and the 19,500-ft/sec refractor which can safely be assumed to represent the same horizon, recorded on Traverse C, can be correlated with the Proterozoic rocks outcropping at the eastern margin of the Basin. The refraction velocity in the latter is about 17,300 ft/sec below Traverse E and possibly 18,300 ft/sec below Traverse D. It is possible that the velocity in the Proterozoic rocks increases towards the west because of increasing depth of burial under Cambrian rocks until it reaches a value of 20,000 ft/sec near the deepest part of the Basin (Traverse B). If this is so the Cambrian rocks must have a thickness of about 4500 ft beneath Traverse B. If this is not the case it is difficult to explain why the 20,000-ft/sec refractor was not recorded on Traverse D. On the other hand, if the 20,000-ft/sec refractor cannot be correlated with the top of the Proterozoic rocks, it evidently represents a horizon within the Proterozoic rocks. In any case it is possible to conclude with reasonable certainty that the maximum thickness of the Cambrian limestone sequence in the Undilla Basin is about 4500 ft. However, it must be emphasised that this figure is accurate only within ± 20 percent.

Reflection

Because of the limited time available and the proportion of that time spent on experimentation, only about six miles of reflection profiling was completed. However, this work was sufficient to give some indication of the problems encountered in the area and to suggest some possible solutions to these problems. The interpretation of reflection results in terms of depth below ground surface is of course dependent on a knowledge of seismic velocities at various depths. The velocity information available is very sketchy because there are no deep bores in the Undilla Basin nor has an extensive seismic reflection survey been made there. Insufficient reliable reflections were recorded in this survey to permit the carrying out of a reliable $t:\Delta t$ analysis. However, the sketchy reflection information available suggests that the average vertical velocity down to a depth of about 8000 ft is about 13,000 ft/sec. A constant vertical velocity of 13,000 ft/sec has been assumed for depth calculations in this Record but it is emphasised that this is only a rough figure and depth estimates can therefore be subject to considerable error.

Reflection work was commenced on Traverse B near Mailchange Ruins. Some poor-to-fair reflections were recorded at about 1.2 sec but it was soon evident that good shallow reflections (from within the Cambrian limestones or from near the top of the Precambrian basement rocks) would be difficult to obtain. For this reason it was decided at first to use 36 geophones per trace for reflection shooting. These were arranged in a diamond pattern with a spacing of 22 ft between geophones. It was also obvious that shot-hole patterns should be used, but unfortunately the very hard drilling conditions made this impracticable except for very shallow holes and for one or two locations where drilling conditions were easier than usual and permitted deeper patterns to be drilled. At Shot-point 251 on Traverse B a comparison was made between results obtained with the 36-geophone pattern and a pattern using 12 geophones in two lines of six at 45 degrees to the traverse, the lines cutting the traverse at points 110 ft apart. It was found that there was no significant difference in the results.

A series of noise tests was carried out on Traverse B in an attempt to determine the nature of the seismic noise present on the records so that means might be devised to improve record quality. Plate 7 shows a series of noise records obtained using bunches of geophones spaced 10 ft apart along the traverse at distances from the shot ranging from 110 ft to 1440 ft. No automatic gain control or presuppression was used. Amplifier settings were made so as to filter as little of the low frequencies as possible, although some filtering of very high frequencies was used because of the prevalence of wind noise. Explosive charges of a quarter of a pound to two and a half pounds were placed at a depth of 3 ft.

It is clear from Plate 7 that a considerable amount of noise is generated by shots in this area and that much of this noise is of the 'coherent' or 'organised' type as opposed to 'random' noise. The explosive charges used for these tests were considerably smaller than those used for reflection shots (30 to 40 lb.). The larger charges used for reflection shots might be expected to produce noise of greater amplitude and perhaps of longer duration, while the greater shot depths used might tend to reduce the noise at the surface to some extent. However, the noise velocities and frequencies are likely to be similar for all types of shots.

Following close on the first breaks, a noise event with velocity of about 8000 ft/sec and frequency of about 35 c/s was recorded. At a distance of 660 ft from the shot (half the normal geophone spread used) this event occurred at about 0.2 sec. Normally this event will be too early on the record to cause any interference to the reflected energy. It can be determined from Plate 7 that the predominant noise waves have a phase velocity of about 5500 ft/sec and frequencies ranging from 30 c/s near the shot-point to 18 c/s about a quarter of a mile away. These waves persist for over a second on the record made with geophones farthest from the shot. They would probably be observable for longer periods if larger shots were used. It is therefore obvious that these noise waves will have a profound effect on all but the deepest reflections and particularly on those shallower reflections that might be recorded from within the Middle Cambrian limestone. The slow-velocity event that appears last on the records is due to the direct air waves.

From these noise tests, it was determined that 12 geophones at 13-ft intervals would give a significant attenuation of the organised noise. This arrangement was later used for Traverse A1 where the hole shots were employed, but no direct comparison was obtained between the 36-geophone diamond pattern and the 12-geophone in-line pattern.

Traverse B. Shot-points 248 to 251 inclusive on Traverse B were shot using single holes and 36 geophones per trace arranged in diamond patterns. The results are shown as a corrected record cross-section on Plate 8. Shot-point 251 was shot at depths of 150ft, 120ft, 70ft, and 40ft. The best records were obtained from the shots at 120 ft and 150-ft depths. These records show a number of poor-quality reflections. An uphole survey here indicated a weathering depth of 70 ft. Unfortunately, the other three holes were only shot at depths ranging between 40 and 60 ft, because the hole depths were limited by the abnormally hard drilling conditions.

The only persistent reflected energy recorded from these shots is at times between 1.2 and 1.4 sec. Assuming an average vertical velocity of 13,000 ft/sec this corresponds to a depth of about 8000 to 9000 ft. This is far in excess of the geological estimates of the depth of the base of the Cambrian limestone and also the depth suggested by the refraction work (4500 ft), so that it is most probable that these reflections are from strata well below the top of the Proterozoic rocks. As it is the Cambrian cross-section that is of primary interest, it is necessary to record reflections at times less than 0.7 sec. However, as Plate 8 shows, shallow reflections do not appear on these records. The reflections recorded between 1.2 and 1.4 sec, although poor, indicated that the Proterozoic strata have little or no dip component in the traverse direction.

Shot-points 248 to 251 on Traverse B were also shot using air shots. Ten-pound charges were placed on stakes about 8 ft above the ground. Thirteen stakes were arranged in a star pattern so that each was at an apex of an equilateral triangle with 60-ft sides. The centre stake was offset 2220 ft from the traverse, where 36 geophones per trace were used as for the hole shots. The results obtained are shown on Plate 9. The air shots are much more free of high-frequency noise than the hole shots, as one would expect. There are also some shallow events recorded before 0.6 sec. However, these are probably not reflections, as their move-out due to spread length appears too great. No noise tests were made using air shots, but if it is assumed that air shots produced similar noise to the shallow-hole shots used for noise tests, then the predominant seismic noise waves from the air shots would not reach the geophones until about 0.4 sec after the shot was fired. Moreover, after travelling more than 2000 ft in the horizontal direction any noise disturbances would be expected to be substantially attenuated by the ground before they reached the geophones. At the same time the increased multiplicity of charges would tend to reduce horizontally-travelling noise near the source by cancellation in the usual way.

It is possible that 13-hole patterns in the same positions as the air-shot patterns may have produced results equally as free of noise, but because of the slow drilling rate this possibility is mainly of academic interest, as far as reasonably deep holes are concerned. Single deep holes offset say 2000 ft at right angles to the traverse might also produce better records than those obtained using hole shots on the traverse. This was not tried, although hole shots located at one end of a half-mile geophone spread were tried without success.

Shallow-pattern shots of up to 25 holes were tried on Traverse B, the patterns being at the centres of normal split spreads. The holes were drilled to the base of the soft soil and clay overlying the limestone, a depth of about 6 ft. The results were poorer than those obtained using a single hole about 60 ft deep.

A nine-hole pattern shot was fired at Shot-point 232 on Traverse B as well as a single-hole shot for comparison. The pattern was shot with charge depth 36 ft using a diamond pattern with 50 ft spacing. As expected the nine-hole pattern gave better results than the single hole but the records obtained were still of poor quality, comparable to those of Shot-points 248 to 250 on Plate 8. At Shot-point 201 on Traverse B a direct comparison of a nine-hole pattern shot and a 13-stake air shot was attempted. Unfortunately the lack of reflections on both records made the comparison useless.

Traverse A2. In order to determine the relation between the Camooweal Dolomite and the limestones of the Undilla Basin, two short reflection traverses, A1 and A2, were surveyed across the boundary between the two formations. On Traverse A1, hole shots were used. During the considerable time required for the drilling of shot-holes on Traverse A1 the recording crew was engaged in shooting Traverse A2, using air-shot patterns.

Traverse A2 was surveyed for three miles across the eastern boundary of the Camooweal Dolomite about a mile north of the Camooweal-Burketown road (see Plate 2). Thirteen-stake air-shot patterns were used as on Traverse B. The offset distance was 2000 ft from the centre of the pattern to the traverse and the total charge for each shot was 130 lb of Geophex. For the first few spreads on this traverse, 36 geophones per trace were used in diamond patterns with 22-ft spacing. Later the geophone arrangement was altered to 12 geophones per trace in line with the traverse with a spacing of 13 ft. Two air-shot patterns at different shot-points were shot twice on Traverse A2, using 36 and 12 geophones per trace and in successive shots for comparison. In both cases the records were indistinguishable as far as quality of reflections was concerned. Twelve geophones per trace were used for the remainder of the survey.

Reflection results obtained on Traverse A2 are shown as a record cross-section in Plate 10. It will be seen that air-shooting was successful in producing reflections that were occasionally of fair quality. A reflection which persisted over most of the traverse was recorded at about 1.4 sec. Some shallower reflections were recorded, notably at Shot-point 147 about 0.9 and 1.0 sec, but if the thickness of Cambrian sediments on this traverse is similar to, or less than, that on Traverse B, these reflections are from within the Proterozoic rocks. The few shallow events with large Δt recorded at less than 0.5 sec are probably refractions. The reflections obtained generally indicated little or no dip component along the direction of the traverse.

The traverse site was selected so that the traverse was surveyed close to outcrops of Camooweal Dolomite and the Middle Cambrian Age Creek Formation. The boundary at the surface between the Camooweal Dolomite and the Middle Cambrian sediments is believed to cross Traverse A2 between Shot-points 141 and 142, although the exact location of the boundary is uncertain owing to soil cover. The seismic records near the boundary are of very poor quality but the few deep reflections recorded in this vicinity indicate virtually horizontal strata. There are no obvious diffraction patterns or any other indications of the presence of a fault or abrupt structural change in this vicinity.

If the Undilla Basin sediments increase rapidly in thickness eastwards from the boundary with the Camooweal Dolomite, reflections from the strata below them might be expected to show some evidence of the downwarping of Precambrian rocks that must have taken place to cause sedimentation in Cambrian times. The seismic results indicate that there is no pronounced downwarping of the deeper rocks on Traverse A2.

Traverse A1. This traverse was surveyed for 2$\frac{1}{2}$ miles across the boundary of the Camooweal Dolomite and the Middle Cambrian Age Creek Formation, less than a mile north of Morstone Homestead (see Plate 2). Starting at the western end single shot-holes were drilled to 100 ft at the first few shot-points. Charges of 30 lb were used in these comparatively deep holes. Because of the excessive drilling time required to drill the holes to this depth, patterns of shallow holes drilled to 8 ft were also tried. The patterns consisted of one or two lines of 15 holes spaced at 10-ft intervals in the traverse direction. The results using 30-hole patterns were generally comparable to those obtained with a single 100-ft hole while the 15-hole patterns gave slightly poorer results. However, drilling of a 30-hole pattern to a depth of 8 ft was at least twice as quick as drilling a single 100-ft hole. Twelve geophones per trace at 13-ft intervals were used on Traverse B. The results obtained are shown as a corrected record section in Plate 11.

The eastern boundary of the Camooweal Dolomite at the surface is believed to cross Traverse A1 in the vicinity of Shot-point 51, near the centre of the traverse. No shallow reflections were recorded near this shot-point so that the traverse provided no direct information regarding the nature of the boundary between the Camooweal Dolomite and the Cambrian rocks to the east. Reflections recorded at Shot-point 51 beyond 0.9 sec, which probably corresponds to a depth of about 6000 ft, indicate the presence of strata with practically no dip in the traverse direction. The most persistent reflection recorded on this traverse was a deep one at about 1.4 sec which evidently corresponds to a similar reflection recorded on Traverse A2. This reflection was difficult to correlate over the whole length of the traverse as it was poorly recorded on several records. However, it appears from character correlation of this reflection from Shot-point 47 to the central portion of the traverse, and also from dip observed on the record from Shot-point 50, that there may be a small increase in thickness of the sedimentary rocks from the western to the central portion of the traverse. Whether such an increase in thickness is accompanied by easterly dips at shallow depths is not known, but this leaves open the possibility that the Camooweal Dolomite dips eastwards under Cambrian limestones. There is no evidence of faulting near the boundary of the Camooweal Dolomite on Traverse A1.

The seismic results are inconclusiveconcerning the possible existence of an unconformity at the western boundary of the Undilla Basin. If the Middle Cambrian rocks increase in thickness from zero at the boundary they would not be expected to have a thickness of more than about 1000 ft at the eastern ends of Traverses A1 and A2, which are only two or three miles from the boundary. Reflections from 1000 ft would be expected at about 0.24 sec. These would not be sufficiently separated from 'first breaks' to be recognisable on the air-shot records and would be difficult to record on the hole shots because of the high noise level at this time. Extension of the traverse farther east was desirable but unfortunately there was insufficient time available for this.

5. CONCLUSIONS

Achievement of the geological objectives of the survey was largely prevented by the technical difficulties encountered in applying the refraction and reflection seismic methods in the Undilla Basin area. The survey served as a useful first attempt to obtain seismic results in this area since the problems involved were discovered and some attempts were made to solve them.

Reflection work in the area is difficult because of the large amount of surface noise generated by the shots and because the coherent noise waves generated have higher velocities and greater wavelengths than those in most areas, with the result that multiple-geophone patterns are relatively ineffective in reducing them. Air-shot patterns were found to be quite effective in reducing high-frequency noise, particularly on the earlier part of the records. However, refracted events appear to have been recorded up to about 0.5 sec. These may obscure any shallow reflections if they are present. The air-shot patterns were located about 2000 ft from the traverse and it is considered that improvement in the earlier parts of the records was at least partially due to simple attenuation of surface noise as a result of the increased travel path to the geophones. If this is so then single deep-hole shots and patterns of shallow shots should both be effective in improving record quality if they are offset about the same distance as the air shots were. Patterns of holes about 150 ft deep drilled on the traverse line in the usual way are also likely to be effective but the hard drilling conditions would make this type of pattern very expensive.

The refraction method generally depends for its success on the occurrence of a number of rock layers whose refraction velocities become successively greater with depth. In the Undilla Basin, refraction velocities of about 17,000 ft/sec are recorded from the Cambrian limestones close to the surface. Velocities are as high as this in only a few sedimentary rocks, and the velocities in igneous rocks are not much in excess of this. The surface limestones therefore act as a 'screen', preventing useful information from being obtained below them by refraction methods unless refractors with unusually high velocities (e.g. 20,000 ft/sec) occur. Such refractors were recorded below TraversesB and C, but it is not certain what these refractors represent. The most likely interpretation is that they represent an horizon near the top of the Proterozoic rocks. If this is so, then the Cambrian sediments have a thickness of about 4,500 ft at Traverse B and the thickness decreases fairly rapidly eastwards to about 1800 ft at Traverse C.

The Limited amount of reflection work done near the western margin of the basin proved inconclusive regarding the relation between the Camooweal Dolomite and the Cambrian limestone of the Undilla Basin. However, this work did show that there is no major downwarping or faulting of the underlying Proterozoic rocks at a depth of about 10,000 ft in the vicinity of the western margin of the Undilla Basin.

Unfortunately no time was available to attempt to determine whether a sandstone sequence existed between the limestones of the Undilla Basin and metamorphic basement. Experience showed that this would probably have been very difficult to do because refraction velocities in such sandstones would not be likely to be higher than those in the Undilla Basin limestones and hence could not be distinguished by refraction methods.

6. REFERENCES

OPIK, A.A.	1960	Cambrian and Ordovician geology. In THE GEOLOGY OF QUEENSLAND. Melbourne University Press, 89-109.
RANDAL, M.A. and BROWN, G.A.	1962	Additional notes on the geology of the Camooweal 4-mile sheet area. Bur. Min. Resour. Aust. Rec. 1962/49 (unpubl.)
VALE, K.R. and SMITH, E.R.	1961	The 'depth probing' technique using seismic refraction methods. Bur. Min. Resour. Aust. Rec. 1961/79.
VALE, K.R.	1960	A discussion on corrections for weathering and elevation in exploration seismic work, 1959. Bur. Min. Resour. Aust. Rec. 1960/1

APPENDIX A

STAFF AND EQUIPMENT

STAFF:

Party leader	C.S. Robertson
Geophysicists	J.S. Davies K.B. Lodwick (four weeks)
Surveyors	J. Ransom) Department of the R. Wenholz) Interior
Clerk	W.E. Rossendell
Observer	L. Vliegenthart (three weeks) R. Krege
Shooter	E. Cherry
Toolpusher	B.G. Findlay
Drillers	K. Suehle F. Reith
Mechanics	T.H. Clark J. Maxwell

EQUIPMENT:

Seismic amplifiers	TIC Model 621
Seismic oscillograph	TIC 50-trace
Magnetic recorder	DS7-7
Geophones	TIC and Electro-Tech EVS2 (20-c/s) TIC (6-c/s)
Drills	Failing 750 Carey H1
Water tankers	3 x 600 gallon
Shooting truck	1 x 600 gallon

APPENDIX B

TABLE OF OPERATIONS

Sedimentary Basin	Undilla Basin
Camp site	Wim Well
Established camp	5th October 1961
Surveying commenced	6th October 1961
Drilling commenced	6th October 1961
Shooting commenced	9th October 1961
Miles surveyed	$26\frac{3}{4}$
Topographic survey control	1:250,000 series and Dept of Main Roads bench marks
Total footage drilled	3830 ft
Explosives used	6800 lb
Datum level for corrections	700 ft above M.S.L.
Weathering velocities	6500 ft/sec
Sub-weathering velocities	14,000 ft/sec
Source of velocity distribution	t: Δ t analysis

REFLECTION SHOOTING DATA

Shot-point interval	1320 ft
Geophone group	Up to 36 per trace (20 c/s) at 22ft & 15ft
Geophone-group interval	110 ft
Holes shot	26
Miles traversed	6
Common shooting depths	6ft (for patterns), 40ft
Usual recording filter	L_2H_3 (23 to 75 c/s)
Common charge sizes	130 lb for air-shooting, 50 lb for hole-shooting
Weathering corrections	After Vale (1960)

REFRACTION SHOOTING DATA

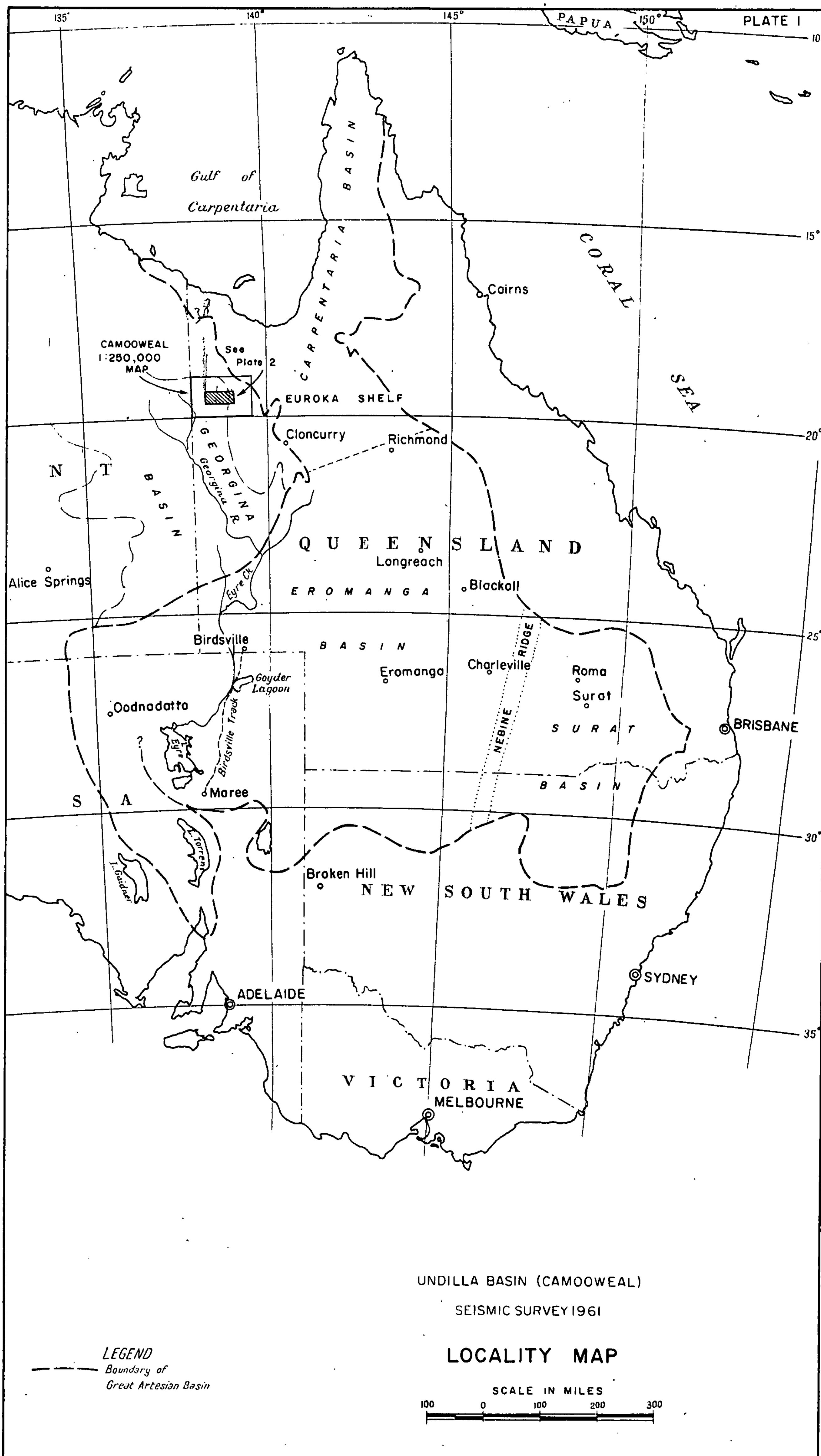
Geophone group	Two TIC 6c/s, close together
Geophone group interval	220 ft.
Holes shot	12
Usual recording filter	L_2H_3 (8 to 75 c/s)
Number of refraction traverses	4
Charge sizes	400 lb
Maximum shot-to-geophone distance	5 miles
Weathering control	Reflection shooting
Weathering and elevation corrections	After Vale and Smith (1961)

APPENDIX C

SEISMIC SHOT-HOLE DRILLING STATISTICS

9/10/61 to 21/11/61

	Failing 750	Carey H1
Total footage drilled	1811 ft	2019 ft
Total number of holes drilled	32	143
Average depth of holes	56 ft	14 ft
Deepest hole drilled	100 ft	65 ft
Travelling time and rigging up	60 hr	$42\frac{3}{4}$ hr
Time lost repairs to drill	$14\frac{1}{2}$ hr	43 hr
Time lost repairs to rig engine		$3\frac{1}{2}$ hr
Drilling time	226 hr	$153\frac{1}{2}$ hr
No. of shifts worked	35	30
Maintenance to drill	28 hr	29 hr
Bentonite used	37 bags	
Drilling rate	8ft/hr	13ft/hr
Loading holes		$3\frac{1}{4}$ hr



UNDILLA BASIN (CAMOOWEAL)

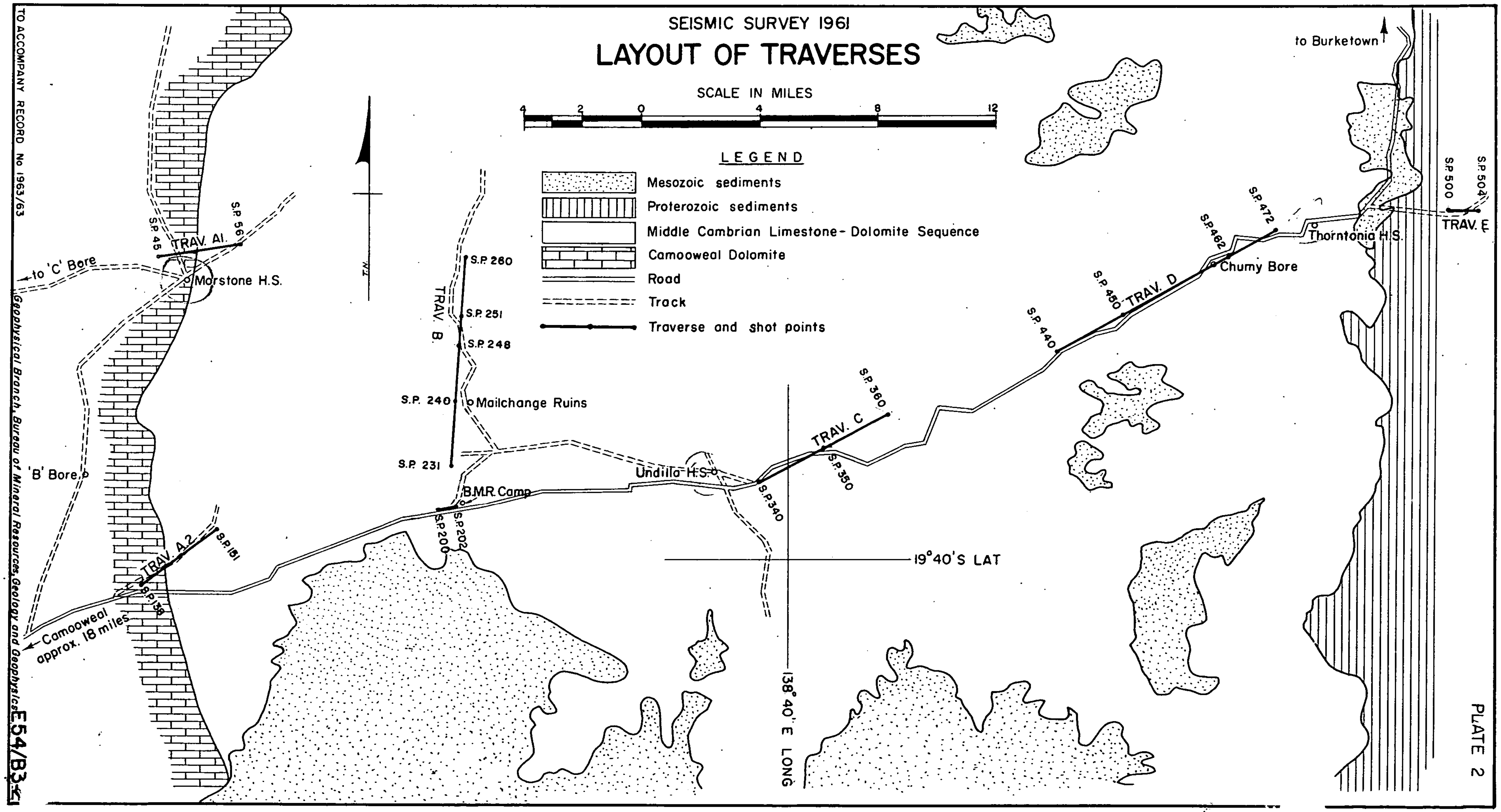
SEISMIC SURVEY 1961

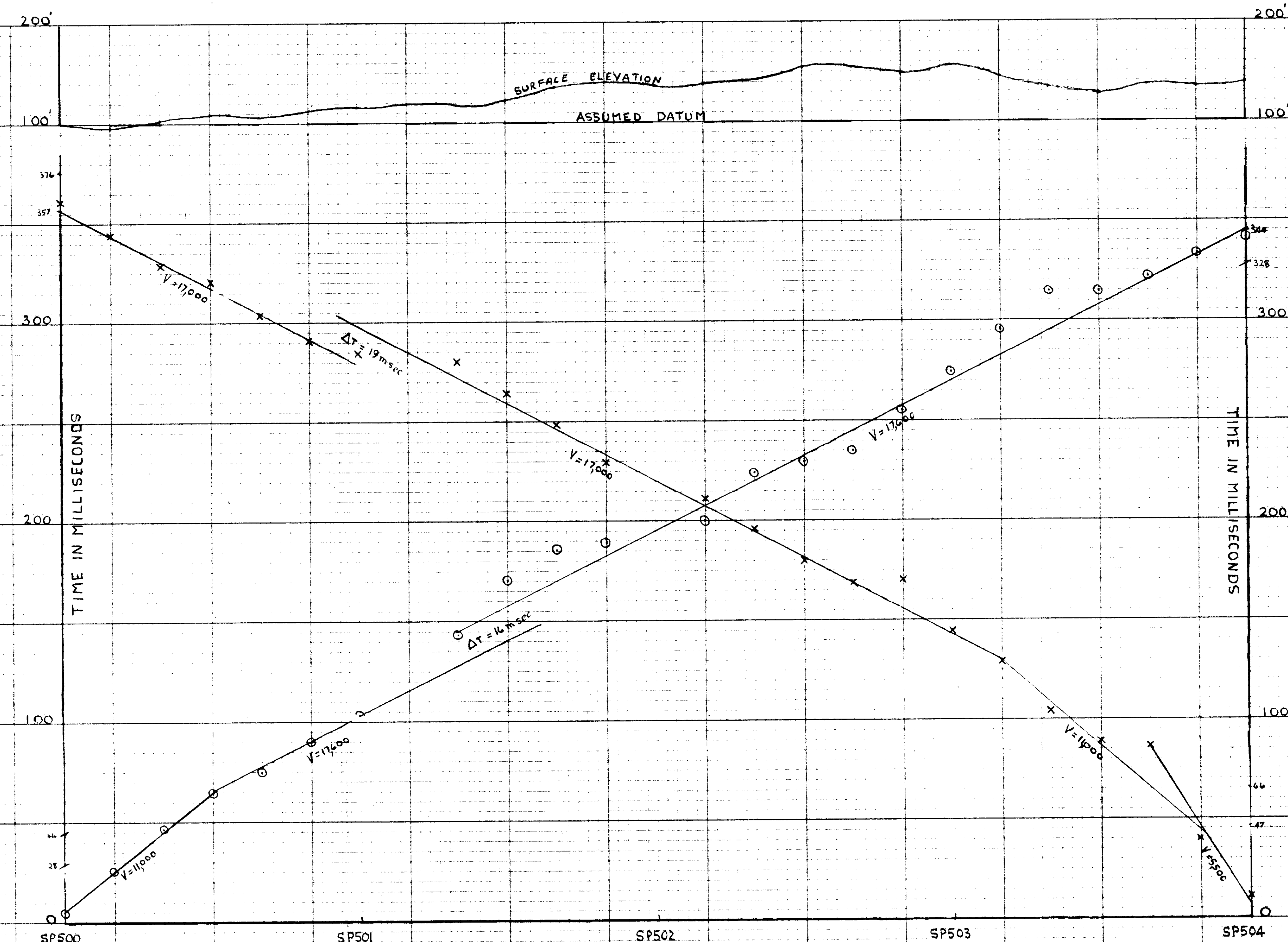
LOCALITY MAP

TO ACCOMPANY RECORD No 1963/63

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. E54/B3-1

UNDILLA BASIN, CAMOOWEAL AREA, QLD.





CAMOOWEAL - UNDILLA BASIN QLD

SP504

t_o	370	352	336	331	311	301	293	–	291	276	261	248	–	227	212	197	–	189	162	147	124	108	87	40	12
W_c+E_c	8	8	8	10	8	9	9	10	10	12	13	14	–	15	15	17	17	18	18	19	20	20	–	–	–
t_c	362	344	328	321	303	292	284	–	281	264	248	229	–	212	197	180	168	171	144	128	104	88			

500 501 502 503 504

SP500

t_o	13	34	55	73	79	95	109	–	150	180	196	199	–	212	236	243	249	271	289	312	330	329	338	350	359
W_c+E_c	8	8	8	9	5	6	6	7	7	9	10	11	–	12	12	14	14	15	15	16	15	15	16	17	17
t_c	5	26	47	64	74	89	103	–	143	171	186	188	–	200	224	229	235	256	274	296	315	314	322	333	342

500 501 502 503 504

Note: Velocities shown in feet/sec

SCALES

HORIZONTAL 440 0 440 880 1320 FEET

(Vertical scales as shown)

TRAVERSE E

REFRACTION TIME/DISTANCE CURVES

E 54/B3-3

TO ACCOMPANY RECORD No 1963/63

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

PLATE 4

TRAVERSE B

REFRACTION TIME/DISTANCE CURVES

SCALES

HORIZONTAL 1100 0 1100 2200 3300 FEET

(Vertical scales as shown)

Note: Velocities shown in feet/sec

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics E 54/B3-4

TO ACCOMPANY RECORD No. 1963/63

SP360

t_o	1132	1121	1114	1095	1087	1075	1063	1046	1038	1028	1013	1004	–	950	938	922	914	902	880	873	861	850	836	827	820
W_c+E_c																									
t_c																									

346 347 348 349 350

SP340

926	942	954	966	985	995	1004	1021	1033	1047	1058	1074	–	1098	1114	1127			1187	1193	1205	1210	1220	1131	1243	t_o
																									W_c+E_c
																									t_c

351 352 353 354 355

SP345

495	509	521	534	553	562	571	589	601	615	625	641	–	667	683	695	711	721	733	749	761	773	787	800	812	t_o
																									W_c+E_c
												–													t_c

351 352 353 354 355

TRAVERSE C

REFRACTION TIME/DISTANCE CURVES

SCALES

HORIZONTAL 1100 0 1100 2200 3300 FEET

(Vertical scales as shown)

Note: Velocities shown in feet/sec

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

E54/B3-5

TO ACCOMPANY RECORD No 1963/63

SP472

	452						453						454						455						456
t_o	1430	1416	1393	1382	1378	1369	1364	1349	1339	1332	1312	1305	-	1285	1271	-	1241	1234	1214	-	1190	1184	1177	1165	1150
W_c+E_c	25	24	25	26	27	27	27	27	28	29	28	28	-	29	29	29	28	29	29	28	28	29	30	31	32
t_c	1405	1392	1368	1356	1351	1342	1337	1322	1311	1303	1284	1277	-	1256	1242	-	1213	1205	1185	-	1162	1156	1147	1134	1118

SP462

	453						454						455						456						457
t_o	-	699	685	677	657	649	642	628	617	605	587	576	-	558	528	521	511	500	486	468	471	457	455	432	421
W_c+E_c	29	29	30	31	30	30	31	31	31	31	30	31	-	30	30	31	32	33	34	35	36	36	38	38	38
t_c	-	669	655	646	626	619	611	597	586	574	557	545	-	528	498	490	479	467	452	433	435	421	417	394	383

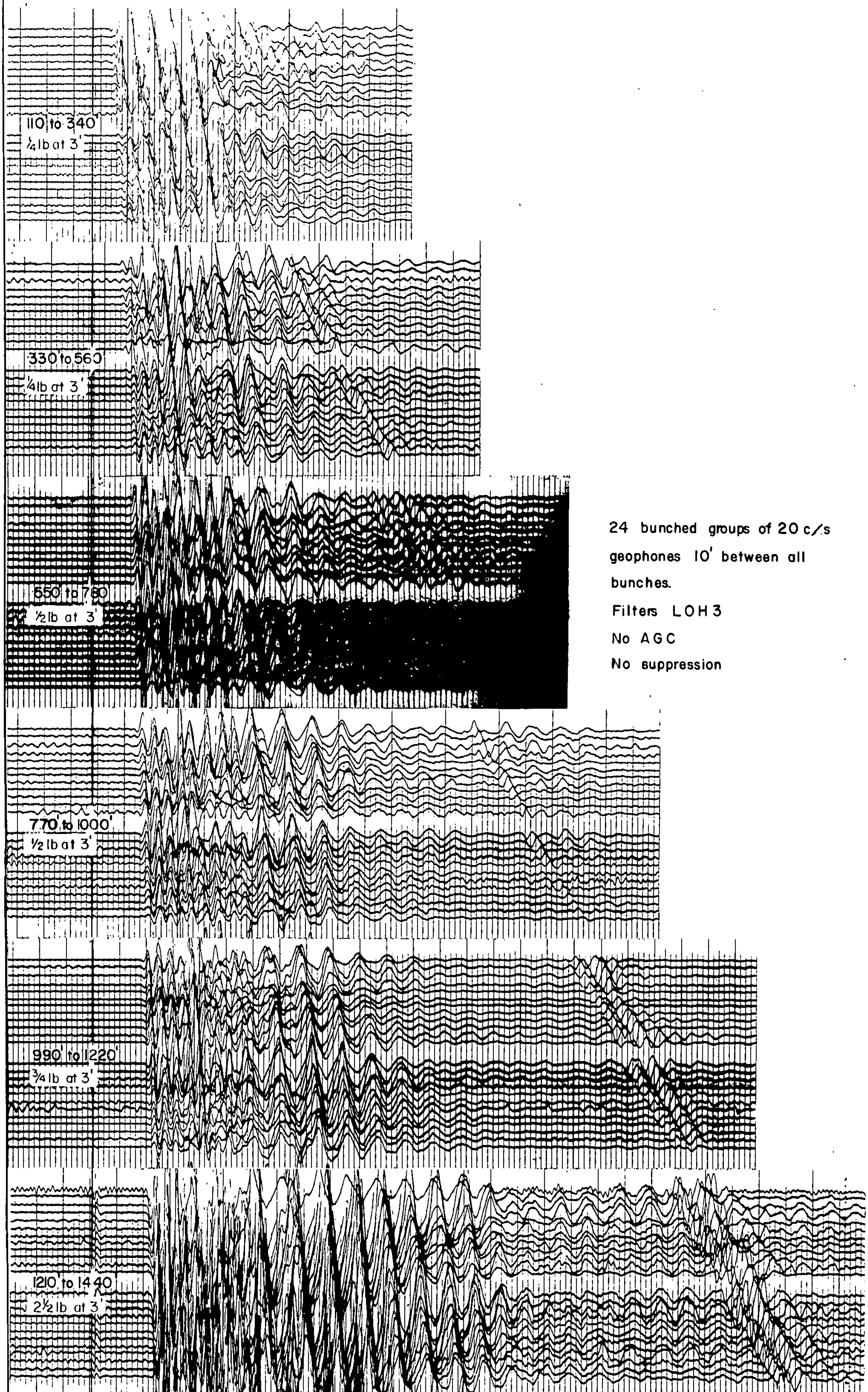
SP440

	456						457						458						459						460
t_o	1213	1235	1268	1272	1300	1288	1307	1306	1311	1322	1327	1328	-	1354	1362	1377	1391	1403	1412	1429	1437	1446	1466	1474	1479
W_c+E_c	41	42	43	43	45	45	45	45	45	46	45	45	-	45	45	45	45	44	44	44	44	43	42	42	41
t_c	1172	1193	1225	1229	1255	1243	1262	1261	1266	1276	1282	1283	-	1309	1317	1332	1346	1359	1368	1385	1393	1403	1424	1432	1438

SP450

	455						456						457						458						459
t_o	-	455	460	479	498	509	518	-	557	-	600	600	-	620	638	644	651	657	663	681	690	706	721	731	742
W_c+E_c	-	29	29	30	31	32	33	34	35	35	37	37	-	37	37	38	37	37	37	37	37	37	37	36	36
t_c	-	426	431	449	467	477	485		522	-	563	563	-	583	601	606	614	620	626	644	653	669	684	695	706

NOISE TESTS TRAV. B MAILCHANGE S.P 250



24 bunched groups of 20 c/s geophones 10' between all bunches.

Filters LOH 3

No AGC

No suppression

TO ACCOMPANY RECORD No 1963/63 GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS E54/B3-7

UNDILLA BASIN, QLD

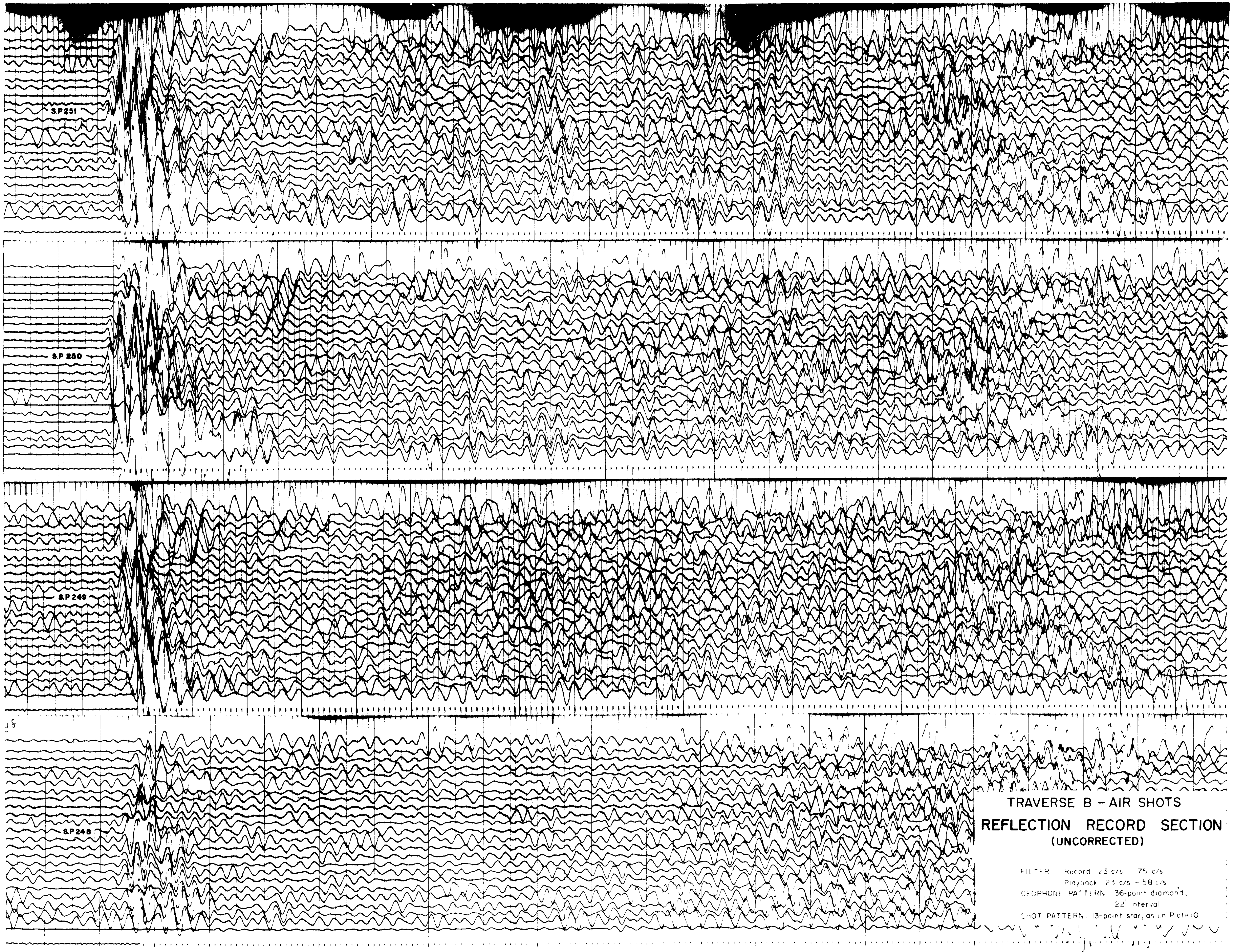
PLATE 8

TRAVERSE B — HOLE SHOTS
REFLECTION RECORD SECTION
(CORRECTED)

FILTER : 25 c/s — 70 c/s
GEOPHONE GROUP : 36 point diamond
22' interval.
SHOT GROUP : Single Hole

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics E 54/B3-8
TO ACCOMPANY RECORD No 1963/63

UNDILLA BASIN (CAMOOWEAL) QLD.

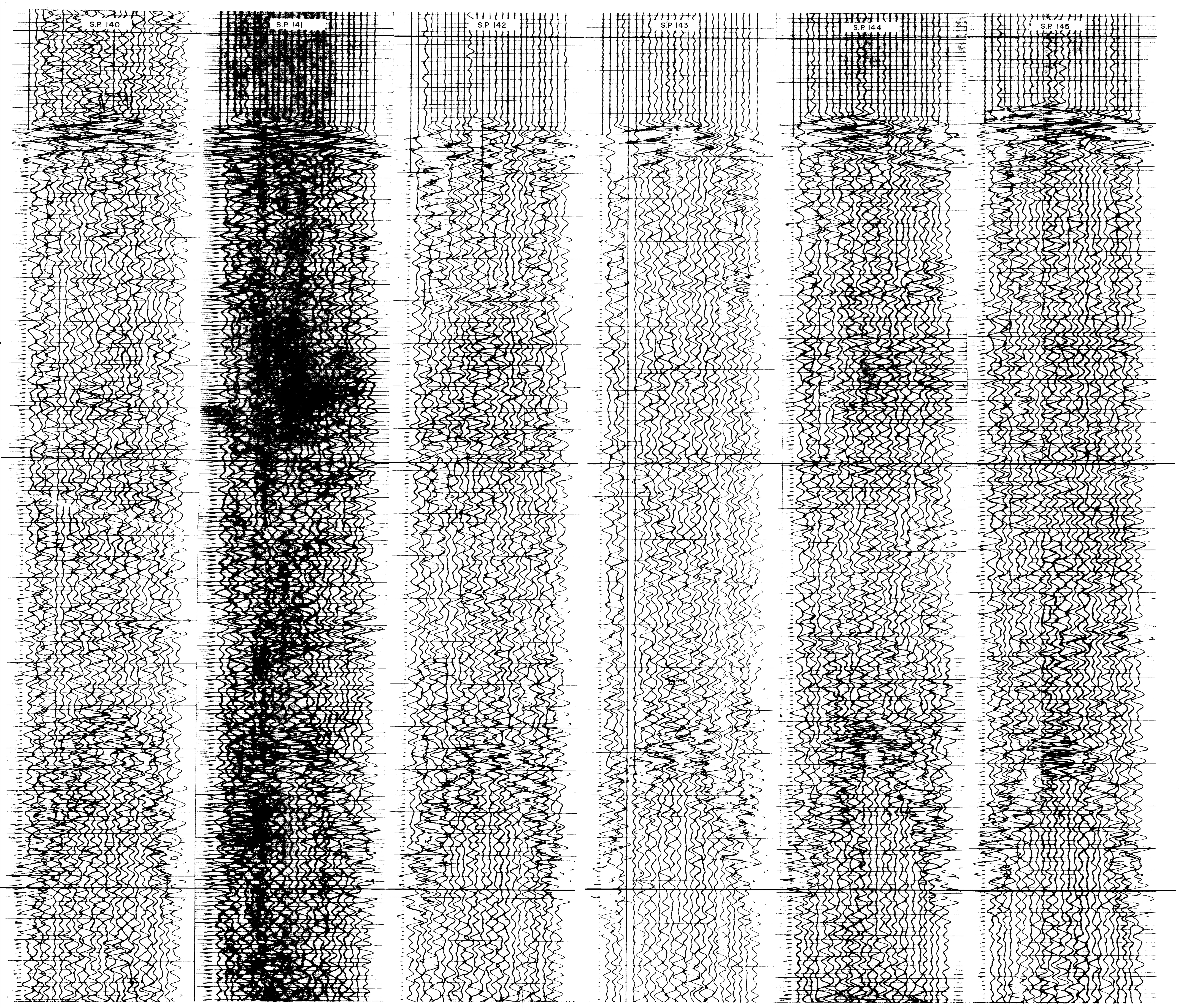


TRAVERSE B - AIR SHOTS

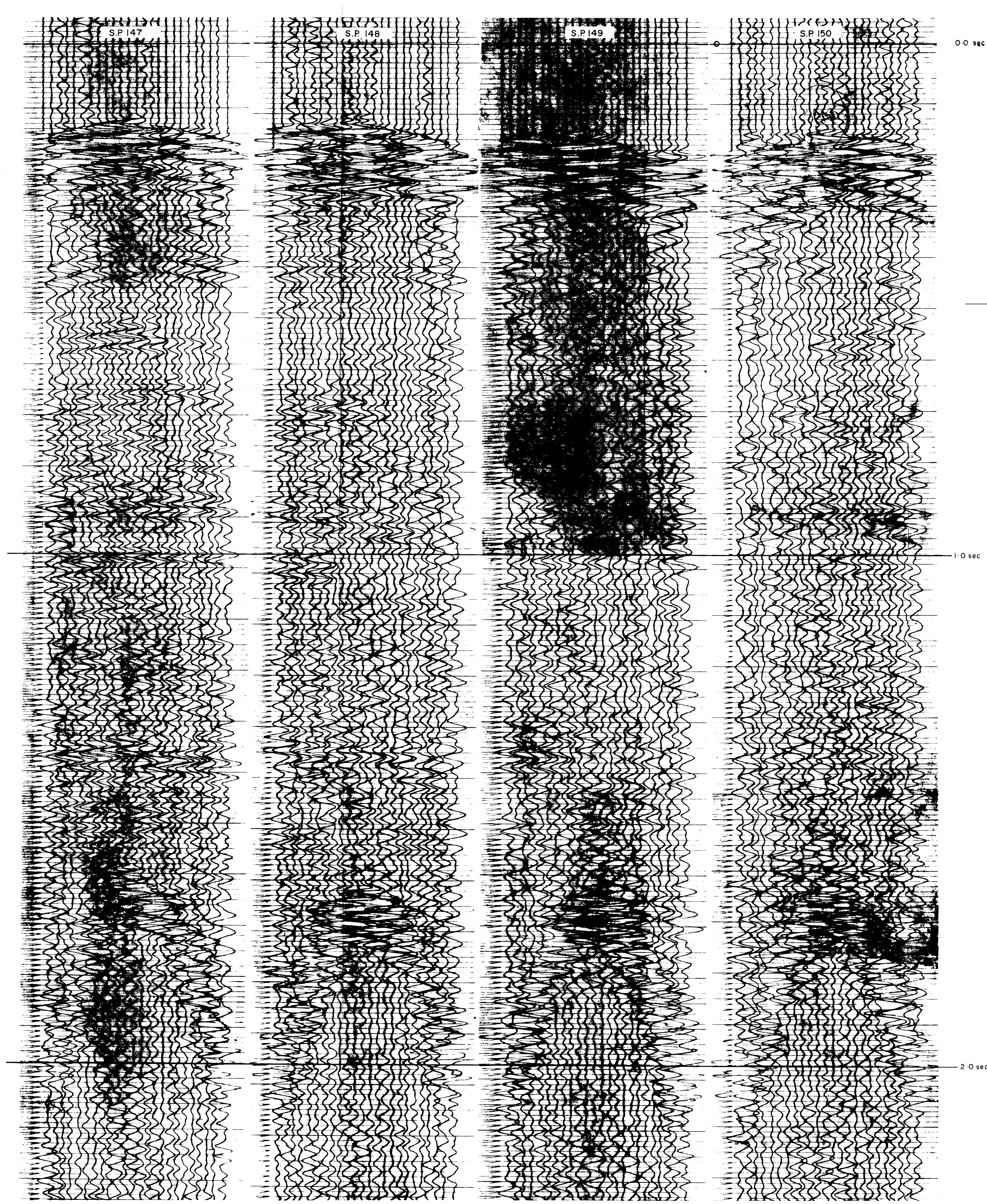
REFLECTION RECORD SECTION

(UNCORRECTED)

FILTER : Record 23 c/s - 75 c/s
Playback 23 c/s - 58 c/s
GEOPHONE PATTERN 36-point diamond, 22' interval
SHOT PATTERN 13-point star, as on Plate 10



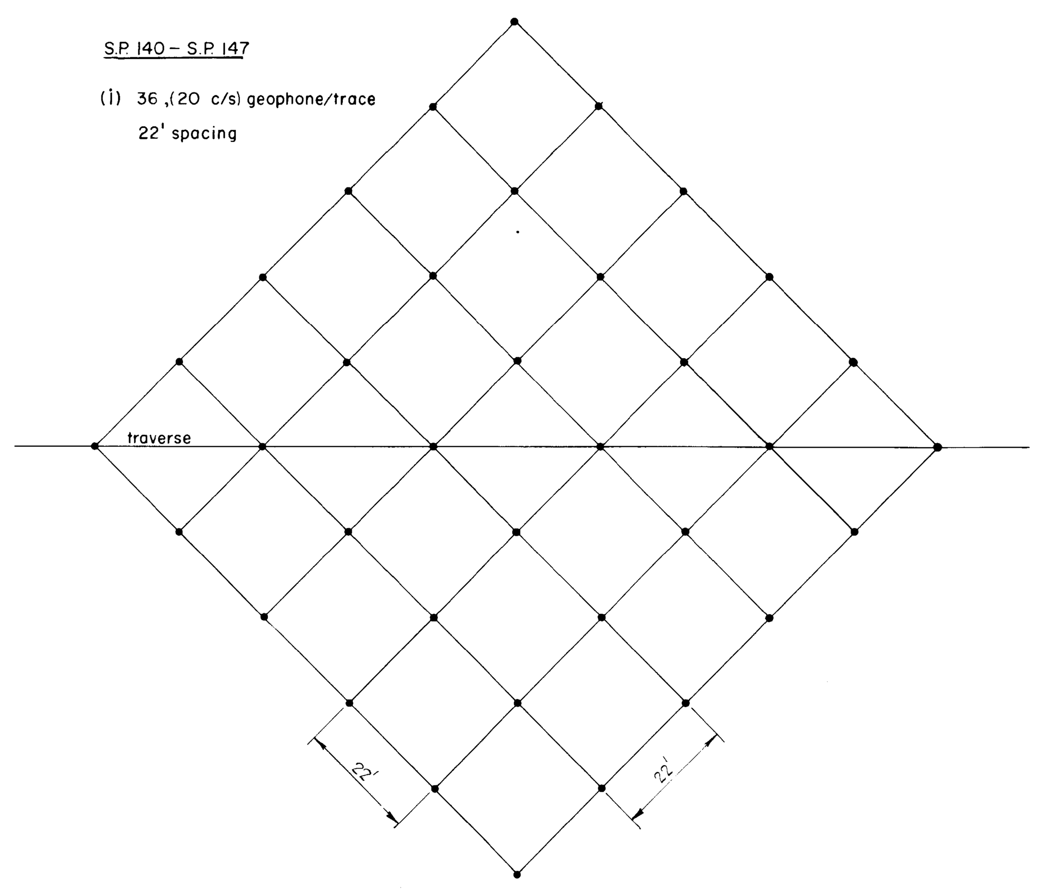
S.P. 146
TAPE NOT RECORDED



GEOPHONE PATTERNS

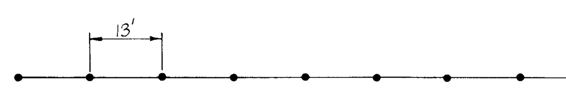
S.P. 140 – S.P. 147

(i) 36 ,(20 c/s) geophone/trace
22' spacing



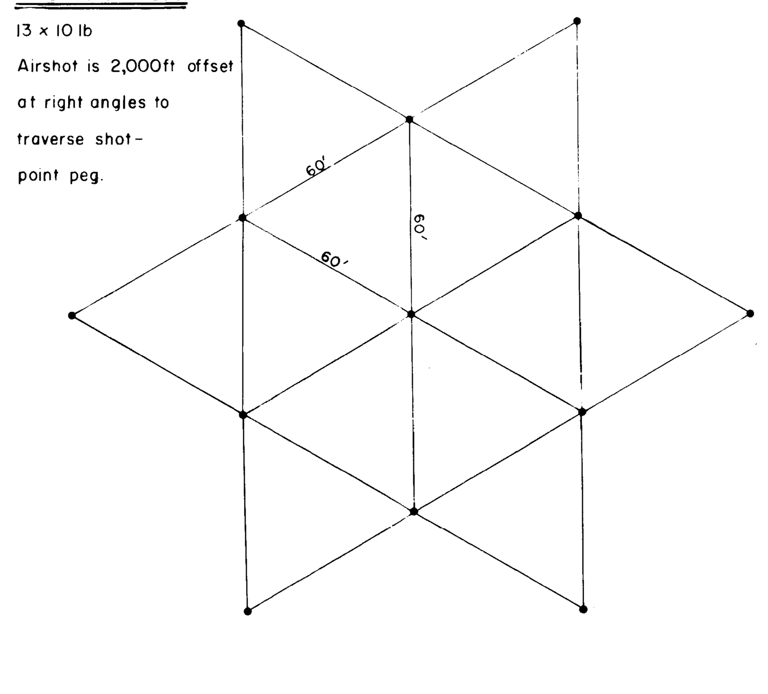
S.P. 147 – S.P. 150

(ii) 12 ,(20 c/s) geophones / trace in line
13' spacing



AIRSHOT PATTERN

13 x 10 lb
Airshot is 2,000ft offset
at right angles to
traverse shot-
point peg.



TRAVERSE A2 – AIRSHOTS

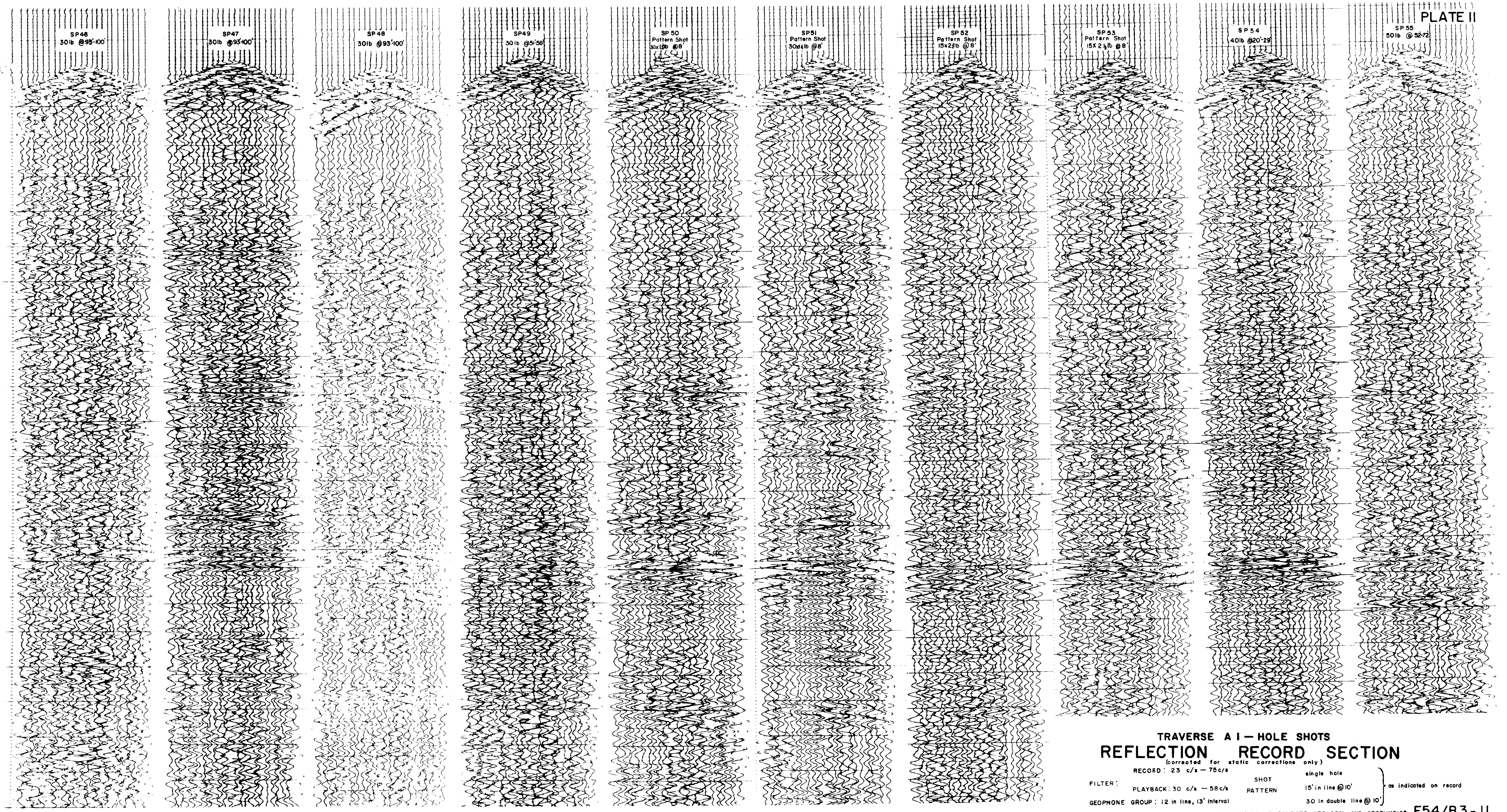
REFLECTION RECORD SECTION
(UNCORRECTED)

FILTER : Record : 23 c/s – 75 c/s
Playback : 23 c/s – 58 c/s
GEOPHONE PATTERN : as above
SHOT PATTERN : as above

E 54/B3-10

To accompany Record No. 1963/63 *Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.*

PLATE II



UNDILLA BASIN (CAMOOWEAL) QLD

TRAVERSE A I — HOLE SHOTS

REFLECTION RECORD SECTION

(corrected for static corrections only)

FILTER: RECORD: 23 c/s — 75c/s
PLAYBACK: 30 c/s — 58c/s

SHOT PATTERN: single hole; 15' in line @10'; 30 in double line @ 10' — as indicated on record

GEOPHONE GROUP: 12 in line, 13' interval

TO ACCOMPANY RECORD No 1963/63

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS E54/B3-11