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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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QUILPIE-EROMANGA SEISMIC REFLECTION SURVEY, QUEENSLAND, 1959

by

A. L. BIGG-WITHER and A. G. MORTON

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SUMMARY

A reconnaissance seismic survey was made in the area of Quilpie and Eromanga in south-western Queensland.

Traverses crossed the Harkaway, Pinkilla, and Tallyabra Domes. Reflection horizons were correlated with horizons within the Mesozoic sediments, and one persistent reflection was correlated with a horizon near the top of the Palaeozoic sediments. A thickness of sediments of up to 15,000 ft, including up to 11,000 ft of Palaeozoic rocks, was indicated on the flanks of the Harkaway and Pinkilla Domes.

Results were compared with existing gravity data. Suggestions of faulting are based on seismic and gravity evidence taken together and also on gravity evidence alone in locations not covered by the seismic work.

1. INTRODUCTION

Geological reconnaissance work by Geosurveys Ltd, on behalf of L.H. Smart Oil Exploration Pty Ltd, has disclosed the presence of numerous well-exposed anticlines in the Quilpie/Eromanga area of south-west Queensland, most of which appear to have been unrecognised previously. A broad reconnaissance gravity survey was also made and there was generally good correlation between these surface structures and the observed Bouguer anomalies, suggesting that the structures continued at depth. To investigate the area further, the Bureau of Mineral Resources carried out a seismic survey.

The objectives of the seismic survey were:

(a) to determine the thickness of sediments,

(b) to find out whether these anticlinal structures continue at depth,

(c) to determine the usefulness of gravity work for investigating subsurface structure in the area (in particular, to investigate the possible cause of the very steep gravity gradient on the north-western flank of the Pinkilla Dome)

To obtain the desired information, the following seismic reflection and refraction work was done:

(1) a complete refraction traverse to record all measurable velocities, located about eight miles east of Eromanga, in the broad synclinal area of the Kyabra/Tallyabra swamp complex; associated with this, three miles of continuous reflection profiling at the centre of the traverse to obtain weathering, and dip, control,

(2) a refraction depth-probe, for significant velocities recorded in (1), and three miles of reflection profiling, on the Grey Range (near the Pinkilla Dome) about 20 miles west of Quilpie.

(3) a refraction depth probe as in (2), and 10 miles of reflection profiling on the Harkaway Dome trend, about 20 miles west of Eromanga,

(4) about two miles of reflection traverse, located along the Quilpie/Windorah road in the region of the steep gravity gradient referred to in objective (c) above.

The locations of the traverses are shown on Plate 1. A summary of the personnel, equipment, and general statistics of the survey is given in appendices A, B and C.

2. GEOLOGY

The area of the present survey is situated in the south-eastern portion of the Eromanga Basin which forms the western part of the Great Artesian Basin. The geology of the Great Artesian Basin has been described by many authors including, in recent years, Mott (1952 a and b), Whitehouse (1954), and Sprigg (1958). The following summary is taken chiefly from these sources.

In the Quilpie/Eromanga area, the stratigraphic sequence known from outcrop and from bores extends from Quaternary to Jurassic times. However, the Tertiary and Quaternary sediments are present only as thin veneers, the Tertiary consisting in the main of freshwater conglomerate and sandstone. An important feature of the formation of Tertiary soils, according to Sprigg, is the associated formation of a siliceous duricrust, occurring principally on gently-eroded surfaces in Cretaceous shale. The resistance to erosion of this duricrust has helped to maintain escarpments and to give topographic expression to fold structures.

The Mesozoic sequence is known fairly well in the area, only the lower Cretaceous sediments being marine in origin. Typically, the Mesozoic sequence is as follows:

		Name	Lithology	Thickness(ft)
upper Cretaceous		(Winton (Formation (	Freshwater shale	about 2000
lower Cretaceous	Rolling Downs Group	(Tambo & (Roma (formations	Dark fossiliferous Shale (Marine)	1000 - 2000
Transition Beds	Blythesdale Group		Typically freshwater sand with plant remains, but may be marine or paralic in some areas.	?
Jurassic	Walloon Coal Measures		Coal measures	?

The Winton, Tambo, and Roma Formations crop out widely in the core regions of eroded anticlines exposed in the area. Only two bores in the area, viz. Eromanga No. 2 and Bulgroo, are reported to have penetrated the Mesozoic sequence, and Permian rocks have been tentatively identified in these at 4230 ft and 5372 ft respectively. Permian freshwater and glacigene sediments crop out around the eastern margin of the Basin in Queensland and New South Wales and their equivalents could be present in this area.

Older rocks, some of which crop out at considerable distance from the area, may be present at depth. Extensive Precambrian sediments are known in South Australia and New South Wales. Fossiliferous Cambrian and Ordovician limestone, etc., are present to the north-west in the Georgina Basin around Boulia and plunge under the Artesian Basin. Granites, associated with slates similar to the Ordovician and Silurian slates in New South Wales, occur in the Eulo/Hungerford region. It is not known what formations are below the Mesozoic in the Eromanga area. The identification of the Permian in the Eromanga and Bulgroo bores is only tentative.

In a sketch plan accompanying an article by Dr Dorothy Hill on the Geology of Queensland (ANZAAS Handbook of Queensland, 1951) the probable boundary between the craton and the Tasman Geosyncline in early Palaeozoic times is shown east of the Eromanga area. If this is correct, no great thicknesses of early Palaeozoic rocks can be expected in this area. However, suggestions have been put forward by others that the area of the Great Artesian Basin may have been within the Tasman Geosyncline from early Palaeozoic times until at least the Permian, and consequently, the deeper troughs within the Basin may contain large thicknesses of Palaeozoic sediments.

Until a few years ago it was generally accepted that the Great Artesian Basin was broadly saucer-like and without surface expression of geological structure. Sprigg's survey showed the area to be one of excellent structural development with a number of closed anticlines clearly reflected in the local topography. Moreover, reconnaissance gravity results suggest the continuation of the structures at depth.

The Quilpie/Eromanga area can be considered broadly as an association of two gentle anticlinoria with general northerly axes of folding. The western group constitutes the McGregor Range trend, and the eastern group, the Grey Range trend. Between the two systems lies the synclinal area of the Kyabra/Tallyabra swamp complex.

The domes and anticlines within the McGregor and Grey Range trends can be of considerable size, e.g. the Canaway and Mount Margaret Domes are about 30 miles long by 10 to 15 miles wide and have about 200 to 300 ft of vertical closure in outcrop.

The purposes of the survey, were to investigate some of these structures, particularly the Pinkilla and Harkaway structures, and to find out whether, as the Bouguer anomalies suggest, the structures observed at the surface continue at depth.

3. SHOOTING CONDITIONS

The shooting conditions were variable throughout the area, but could broadly be related to three types of surface conditions:

(a) on Traverse B and Traverse C the shot-hole drills encountered relatively consolidated rocks. Best shooting depths ranged between 110 ft and 175 ft, and seismic record quality was generally fair to good.

(b) Traverse A was on an area of very thick alluvium and, when using a single-hole shooting technique, good records could be obtained only by drilling deep holes. At the commencement of the survey, Shot-point 23 was drilled to 375 ft so that the vertical velocity could be measured and some experimental shooting could be done to determine the best shooting depth. The drill was still in unconsolidated clay and silt at 375 ft.

Although the depth of weathering was only 80 ft, it was found that the best seismic record was obtained when shooting at the bottom of the hole (375 ft). The record quality deteriorated gradually as the shot depth was reduced to 200 ft; for shot depths less than 150 ft, reflections were almost non-existent. With the existing drilling arrangements it was unreasonable to drill to 375 ft along the whole traverse, so a compromise was adopted by using 200-ft shot-holes. For comparison a 25-hole pattern was shot at Shot-point 23, with holes 20 ft deep, spaced 50 ft apart and using 1 lb of explosive in each. The results obtained were not any better than those from the single, deeper shot. However, no systematic investigation of the possibilities of pattern shooting was made,

(c) on the north-western end of Traverse D (Shot-points 151 to 155), the duricrust presented a problem. The conventional arrangement of one shot-hole per record and six geophones per trace produced virtually NR (no reflection) records whereas south-east from Shot-point 159, where there was no duricrust, quite good reflections were obtained by conventional methods.

An experimental shot was made on the duricrust using four shot-holes in line with the spread and 24 geophones per trace, arranged in four lines of six geophones. This showed considerable improvement over the conventional record, but because of the time consumed and the extreme difficulty of 'planting' geophones satisfactorily on the hard duricrust surface these experiments were not continued.

4. DISCUSSION OF RESULTS

Reflection results

Correlation cross-sections of the reflection results from Traverses A, B, C, and D are shown on Plates 2, 3, 4, and 6 respectively. The locations of all traverses are shown on Plate 1. With a few exceptions, reflection quality was fair to good. Individual traverses are discussed separately. Cross-sections on a reduced scale, along with the observed Bouguer-anomaly profiles, are shown on Plates 11, 12, and 13.

Reflection zones (A, B, C, D, and E) are shown on each cross-section. They are tentatively correlated on the basis of refraction velocities or reflection character or both, and their approximate stratigraphic positions are considered to be:

ZONE		
A	-	undifferentiated Cretaceous
B	-	Blythesdale
C	-	undifferentiated Jurassic
D	-	Lower Mesozoic
E	-	near top of Palaeozoic

The correlation and identification are far from certain but they provide a useful hypothesis for further discussion and for the direction of future exploration.

Traverse A (Tallyabra) - Plate 2 This east-west traverse, three miles long, is located seven to ten miles east of Eromanga.

Scattered shallow reflections were observed down to a time of about 0.9 seconds (roughly 3300 ft) when the first continuous band of reflected energy was recorded. This has been called Zone B and appears to correlate with the 13,020-ft/sec refractor recorded on this traverse (see refraction results). The Eromanga No. 2 bore is reported to have entered the Blythesdale Group at 3100 ft so this zone is tentatively correlated with that Group. Another almost-continuous reflection band was recorded at about 1.4 sec or near 6000-ft depth and is called Zone E. This appears to correlate with a refractor in which the velocity is 17,230 ft/sec (see below). This velocity is probably too high to represent a Mesozoic formation, so this zone is tentatively assumed to be near the top of the Palaeozoic formations. Although this reflection is not very characteristic on this traverse, elsewhere in the area a very strong reflection was recorded that has been assumed to be the top of the Palaeozoic. This strong reflection is well exhibited on Traverse C, and comparison of refraction results between the two traverses tends to justify the approximate correlation of the two zones, in spite of the difference in character of the reflections. This zone has been referred to as the P horizon by Geosurveys Ltd.

Between zones B and E, two other zones called C and D can be recognised, which are continuous over distances of 3000 to 7000 ft.

Only scattered reflections are recorded below the zone E, but there are a sufficient number of them to suggest a continuation of the sediments to at least 8500 ft.

The shallow Zone B (Blythesdale ?) is generally flat over the length of the traverse.

The deeper Zone E (Palaeozoic ?) is relatively flat also, but does suggest a synclinal axis below Shot-point 21.

There is no pronounced unconformity apparent in the cross-section. From the few scattered reflections, a slight unconformity could be present below Zone E but the evidence for this is weak.

Traverse B (Pinkilla) Plate 3 This traverse, three miles long, was shot in an east-west direction on the Pinkilla Dome. The results indicate five zones of more-or-less continuous reflections, viz. A, B, C, D, and E. Zones B and E are continuous across the entire length of the traverse and, from the refraction results and reflection character, they correlate with the Zones B and E on Traverse A. This correlation suggests that Traverse B is situated on a structural 'high' as Zone B is about 1200 ft shallower and Zone E about 2600 ft shallower than on Traverse A.

All zones indicate relatively flat-lying sediments, but there is reliable evidence of a fault near the western end of the traverse. The disturbed reflections near the eastern end of the traverse might also be attributed to faulting, but the overall deterioration of seismic record quality, due possibly to shooting at too shallow a depth, precludes any reliable interpretation.

Between Shot-points 76 and 80, only scattered reflections were recorded from below Zone E and, with one exception, there is no evidence of any reflections from below 7000 ft. Towards the western end of the traverse, however, reflections were recorded from as deep as 15,000 ft.

Moving from east to west across the traverse, a noticeable feature of the cross-section is the progressive increase in depth from which reflections continued to be recorded.

A surface (Z) below which reflections are virtually absent, is drawn across the cross-section. This hypothetical surface could be near the boundary between sediments and altered basement rocks. However, a possible basement refractor is recorded well above this surface.

Phillips Petroleum Co. has shot traverses east of Traverse B (see Plate 12) and the results showed evidence of a similar surface which the company has interpreted in a similar manner as marking the base of a trough of Palaeozoic sediments. It will be seen that on Traverse D, which was shot in a north-west direction across the Pinkilla Dome, a similar surface (Z) was found, below which reflections are very few or absent. Gravity results support the hypothesis of a basement 'high' beneath the Pinkilla Dome.

Traverse C (Harkaway) Plates 4 and 5. This traverse, eight miles long, was shot in an east-west direction across the Harkaway structure. From the trend of the Bouguer-anomaly contours, the traverse appears to be surveyed at an angle of 50 degrees to the strike of the structure. Therefore the dips indicated are probably component-dips only. Five reflection zones (A, B, C, D, and E) of varying reflection continuity were recorded. Zone A is almost continuous and Zone E is continuous over the entire traverse. Zone A is at an average depth of about 1500 ft below datum while the deepest zone, Zone E,is at an average depth of about 6000 ft. The other zones are more-or-less evenly spaced between these two zones. Zone E appears as a very strong continuous band of reflections across the reflection records and is almost coincident with the 18,000-ft/sec refractor. It is assumed to represent the top of the Palaeozoic, and to be equivalent to the horizon traced by Geosurveys Ltd. Reflections continue to be recorded from below Zone E, from depths as great as 15,000 ft on the flanks of the structure but only from depths as great as 2000 ft below the crest. Between Shot-points 116 and 132, all zones show constant westerly components of dip which decrease upwards from about 2¼ degrees for the deep Zone E, to about 1 degree at Zone A. A single record taken at Shot-point 109 (refraction Shot-point) indicates that this westerly dip continues and possibly increases slightly in rate of dip. The dip of Zone E between Shot-points 131 and 116 is estimated to be about 3 degrees.

At Shot-point 132 there is a definite reversal in the direction of dip, with east components of dip to Shot-point 136 beyond which the stratigraphic horizons are more-or-less flat-lying. A sharp change in weathering velocity was measured at Shot-point 136, a value of 3000 ft/sec being obtained to the east and 2000 ft/sec to the west of Shot-point 136. This change in weathering velocity is presumably related to the structure.

A curved-path, migrated-dip cross-section is shown on Plate 5; this cross-section uses a velocity distribution expressed by the relation $v_i = (6000 + 0.9d)$ ft/sec, where v_i = interval velocity and d = depth. This shows the structure more clearly and indicates the strong possibility of a fault in Zone E below about Shot-point 134 or 135, but the evidence is not entirely conclusive. Above Zone E it is considered that the beds are more likely to be continuous than faulted.

There is reflection evidence that the sediments continue for several thousand feet below Zone E.

<u>Traverse D (Pinkilla flank) Plates 6 and 7</u>. This traverse, 5½ miles long, was shot in a north-west direction across the north-western flank of the Pinkilla Dome.

The reflection cross-section shows four fairly continuous zones within 4000-ft depth of the datum. These zones are shown on Plate 6 as A, B, C, and D all with gentle north-westerly dip. None of the above zones can be the cause of the steep gravity gradient on the north-western flank of the Pinkilla Dome (see gravity interpretation). As they are conformable and show gentle structure, they are all assumed to be within the Mesozoic sediments. Zone E is unconformable with Zone D as the former indicates much steeper north-westerly dips. Between Shot-points 159 and 166, reflections were recorded from below Zone E down to a depth of 12,000 ft, and these showed an increasing dip with depth. From Zone E down, the reflections give the impression that the beds are abutting an erosional surface (possibly basement) at the south-eastern end of the line. The possible outline of such a surface is shown on the cross-section.

The quality of the deep reflections from Zone E, and below, is fairly good and some are continuous over a distance of 5000 to 7000 ft. The structure of Zone E would appear to be largely responsible for the gravity anomaly observed. This is discussed further in the section on gravity.

A curved-path, migrated-dip cross-section is shown on Plate 7; this cross-section used a velocity distribution represented by v_i = (6000 + 0.9d) ft/sec. The angular unconformity is clearly seen at Zone E with truncated beds below it.

Refraction results

Time/distance curves and interpretation for refraction traverses A (Tallyabra), B (Pinkilla), and C (Harkaway) are shown on Plate 8, 9, and 10. The refractors as interpreted are also shown on the reflection cross-sections for Traverses A, B, and C for comparison.

It might be mentioned here that the refraction traverses were not always straight lines (see Plate 1) and in some cases this caused considerable difficulty in interpretation. The time/distance curves shown on Plates 8, 9, and 10 are partly estimated for equivalent straight-line traverses and are consequently not as accurate as may be desired. It also means that subsurface overlap was not always achieved although the time/distance curve may indicate that it was. However, it is considered that the interpretation would not be markedly different for an actual straight-line traverse.

The interpretation of the refraction results was difficult because of the large number of refractors recorded, and because of the bends in the traverses. Final interpretation has differed greatly from the initial field interpretation. It is now apparent that additional shooting would have been desirable to ensure that, when shooting from opposite directions, refractors were recorded from overlapping portions of the refractor, and also to establish with more certainty which refraction recordings from opposite directions corresponded to each other. In the interpretation shown below the time/distance curves, the only refractors plotted are those that the authors confidently believed exist roughly as shown. On Traverse C the authors were not sufficiently confident of the refractor profiles to plot them. Consequently the diagram on Plate 10 is intended only to represent the approximate depth and velocity of refractors.

The velocity and depth of the refractors recorded on each traverse are summarised in the table below:

Reflection Zone	Traverse A		Traverse B		Traverse C	
	Velocity (ft/sec)	Depth (ft)	Velocity (ft/sec)	Depth (ft)	Velocity (ft/sec)	Depth (ft)
	6500	sub-weathering				
	7230	80				
	8090	700	8410	300		
B	13,020	3250	12,640	2000	12,570	3000
					14,865	3800
					16,150	4800
E	17,230	5700	17,520	3000	18,000	5850
	20,900	8600	21,700	3800		

There is good correlation between the refractors recorded on Traverses A and B, and the depth measurements show that all are considerably shallower on B than on A. As pointed out above, the Eromanga No. 2 bore suggests that the 13,020-ft/sec refractor recorded on Traverse A should be correlated with the Blythesdale Group; and because of its high velocity, the 17,230-ft/sec refractor should be regarded as a Palaeozoic formation. The depths of these two refractors are approximately the same as reflection zones B and E on Traverse A and hence are correlated, as is shown in the table. The correlation between these refractors and the two reflecting zones also appears reasonable on Traverse B, although the depth to the 17,520-ft/sec refractor diverges from Zone E towards the eastern end of the traverse. The possible faulting indicated by the reflection cross-section at this eastern end may be the cause of this, as it has not been allowed for in the refraction interpretation.

Because of the bends in the traverse and the complicated subsurface structure (as shown by the reflection cross-section), interpretation of refraction Traverse C was very difficult. The final interpretation arrived at is by no means certain. When compared with Traverses A and B, the correlation of refractors is not as obvious either. The most reasonable correlation appears to be that shown in the table, and this means that two refractors have been recorded on Traverse C, viz. 14,865-ft/sec and 16,150-ft/sec refractors, which have not been recorded on Traverses A and B. Failure to record these refractors would not be surprising on Traverse B, where there is a large decrease in thickness of sediments compared with the other two traverses, and those refractors recorded are too close together to allow the recording of others between them if they did exist. On Traverse A when shooting from the west with a shot-to-geophone distance of 4 to 5 miles, an apparent velocity of 14,060 ft/sec was recorded. This shooting distance was omitted in the reverse direction, so no complementary velocity has been recorded. It seems probable that this velocity is a real one and correlates with the 14,865-ft/sec refractor on Traverse C. The 16,150-ft/sec refractor has only been recorded as a later event in one direction of shooting on Traverse C, so it may be that on Traverse A it has never become a first arrival and consequently has been 'missed' in the shooting. Alternatively, the relatively steep dip of the subsurface formations below the geophone spreads on Traverse C, and the monocline or fault of 1000-ft relief that lies between the geophone spreads and the eastern shot-points, may have complicated the shooting so much that the interpretation does not represent the true facts.

The depths calculated for the refractors on Traverse C do not correspond to the depth of the main reflection zones (see Plate 4). However, the very strong reflection (Zone E) is generally taken to be near the top of the Palaeozoic sediments in this area, and to be consistent in our correlations, it should correspond to the 18,000 ft/sec refractor, to which it is closest in depth. A velocity of 16,150 ft/sec appears high for the Mesozoic sediments (although velocities like this were measured in the lower Mesozoic formations in the Cabawin No. 1 bore in the Surat Basin), but in view of the uncertainty in the refraction interpretation on this traverse, this has been accepted. The 12,570-ft/sec refractor could correspond to either Zone B or Zone C marked on the cross-section.

5. COMPARISON OF SEISMIC RESULTS WITH GRAVITY ANOMALIES

In discussing the interpretation of the seismic results obtained in the area in relation to the Bouguer gravity anomalies, use is made of seismic work carried out by Phillips Petroleum Co. (Phillips and Sunray Mid-Continent, 1961). The reflection Traverses A, B, C, and D along with the company seismic data are shown at a reduced scale on Plates 11, 12, and 13. Depths have been adjusted using the same velocity function as was used for the Bureau's traverses. Bouguer-anomaly profiles and gravity interpretation are also plotted, and refraction horizons and velocities indicated. Reflection Zone E appears as a continuous band of energy across all reflection cross-sections and is currently interpreted as a horizon near the top of the Palaeozoic. Velocities of 17,230 ft/sec, 17,520 ft/sec and 18,000 ft/sec appear to correlate with this zone. A qualitative correlation between seismic cross-sections and the Bouguer profiles along individual traverses will be discussed first.

Harkaway, Traverse C (Plate 11)

The Bouguer anomaly is observed to increase from Shot-point 116 to Shot-point 124 after which it begins to decrease, reaching its lowest value above Shot-point 147. The structure as shown by Zone E rises from west to east, shows reversal in direction of dip between Shot-point 132 and 137, and reaches its lowest level between Shot-points 140 and 147.

Tallyabra, Traverse A (Plate 11)

The Bouguer profile is more-or-less flat between Shot-points 17 and 23 beyond which it falls towards the east. The structure indicated by the E zone is more-or-less flat.

Pinkilla Dome, Traverse B (Plate 12)

The sediments down to Zone E appear quite flat. The point of inflexion on the Bouguer-anomaly curve between Shot-points 68 and 70 appears to support the existence of a fault as shown on the western end of this traverse. However, the Bouguer anomaly can also be accounted for theoretically by a large basement uplift, beneath the Pinkilla Dome, coinciding with the surface marked Z. It is not possible to differentiate between the possible causes of the anomaly.

Pinkilla Dome, Traverse D (Plate 13)

Zone D shows slight north-westerly dip and cannot be the cause of the very steep gravity gradient observed along this traverse. Zone E, however, is a very steeply dipping zone, which could account for the observed Bouguer anomaly. The difference in density of the beds above and below Zone E may not be the only factor. Surface Z, which is possibly basement surface, could be a contributory factor. The sudden change in gradient of the Bouguer profile between Shot-points 159 and 167 is possibly due to a density contrast that may exist between beds above and below the Surface Z. The gradient of the Bouguer-anomaly profile is seen to return to its former value at Shot-point 168 at a point where the Surface Z probably levels out.

It is apparent from the above that a quantitative interpretation of the gravity data is likely to be very complex. Here there are possibly important density contrasts at three levels:

(a) at the Mesozoic/Palaeozoic boundary,

(b) at Zone E (a zone within, and possibly near the top of, the Palaeozoic sediments),

(c) at the Palaeozoic/ (?) Archaeozoic boundary - Surface Z.

Bulloo Syncline Cross-section by Phillips Petroleum Co. Ltd (Plate 12)

A quantitiative interpretation of the gravity data is given later. The gravity profile across the Bulloo Syncline shows a pronounced 'low'. The seismic cross-sections show that this could be due to (a) thickening of the Mesozoic sediments or (b) an increase in thickness of the Palaeozoic sediments towards the centre of the syncline.

From the above it is seen that along all traverses there is a good qualitative correlation between the seismic cross-sections and the observed Bouguer profiles. Therefore, gravity work in the area is a useful preliminary to more detailed surveys. It is clearly demonstrated that gravity 'highs' are frequently associated with subsurface relief.

A quantitative interpretation of the Bouguer profile across the Harkaway Dome (Plate 11)

The Bouguer profile across the Harkaway Dome indicates a fault. The half-width of the anomaly indicates a depth of about 5500 ft below sea level to the centre of the fault. The model selected is that of a vertical fault at 'A', which approximates the displacement shown by zone E. The estimated depth to centre of the fault block (5500 ft below sea level) suggests that a density contrast between beds above and below Zone E is responsible for the observed Bouguer anomaly. If the throw of the fault is taken to be the difference in depths to Zone E under Shot-points 132 and 140, which are situated on either side of the monoclinal flexure, then a density contrast of 0.44 g/cm^3 is required to account for the total anomaly between the maxima and minima on the Bouguer profile. It is seen that the calculated curve fits the observed curve fairly well.

The above analysis strongly suggests that the monoclinal flexure at a depth of about 5500 ft below sea level (i.e. 5800 ft below datum) is the major cause of the observed relief in the Bouguer-anomaly profile.

Attempt to correlate Traverse C (Harkaway) with Traverse A (Tallyabra) (Plate 11)

If the geological conditions that appear to give rise to the observed Bouguer-anomaly profile across Harkaway Dome exist as far east as Tallyabra Dome, it may be possible to correlate the seismic cross-sections on gravity evidence. Zone E is extrapolated eastwards on the basis of gravity as far as Tallyabra using the 'plate formula':

$$\Delta g = 2 \pi \rho G \Delta d$$

G = universal constant of gravitation

ρ = density contrast

d = thickness of plate

The points 'B' and 'C' of the Bouguer-anomaly curves suggest two faults. Depths to the centres of these faults or monoclinal flexures which can, as at Harkaway, be represented approximately as vertical faults, are suggested by the half-width of the Bouguer anomalies. If the throws of the faults are assumed to be such as to account for the total anomalies between maxima and minima on the curves (assuming a density contrast of 0.44 g/cm^3 and that the locations of the faults are directly below the points of inflexion on the Bouguer profile), it is seen that in both cases the calculated curves for faults assumed to be at 'B' and 'C' give very reasonable fits to the observed Bouguer-anomaly profile. They also lie on the extrapolated Zone E based on the 'plate formula'. Thus the extrapolation of Zone E from Harkaway to Tallyabra on the above assumptions appears reasonable. However, eastwards the extrapolated Zone E is found to deviate more and more from the seismic Zone E and this suggests that there could be an alternative correlation of seismic refractions.

The above is based on the simple assumption that the conditions that give rise to the Bouguer profile across Harkaway (a density contrast of 0.44 g/cm^3 at Zone E) extend as far as Tallyabra. It is doubtful that such a simple assumption could be applied eastwards as far as the Bulloo Syncline. However, the extrapolation of Zone E eastwards on gravity evidence as far as the Bulloo Syncline is instructive.

To attempt a correlation between Harkaway Dome and the Bulloo Syncline on gravity evidence would be complex for there appear to be several factors which give rise to the anomalies on the individual traverses. However, as a step towards such a correlation, the Bouguer profile across the Bulloo Syncline is now analysed quantitatively.

<u>A quantitative interpretation of the Bouguer profile across the Bulloo Syncline</u> (Plate 12)

The interpretation is based on the following assumptions which give a reasonable fit between the model used for the gravity interpretation and the seismic cross-section :

(a) there is a density contrast of 0.17 g/cm^3 at the Mesozoic/Palaeozoic boundary,

(b) there is a density contrast of 0.20 g/cm^3 either within the Palaeozoic sediments or at the Palaeozoic/Archaeozoic boundary.

The models used are illustrated and the calculated Bouguer-anomaly curves are shown on Plate 12.

It is seen that (including the effect of the Mesozoic sediments in each instance) the calculated curve for the density contrast at Surface A (i.e. within the presumed Palaeozoic sediments) gives a much better fit to the actual curve than that calculated for the density contrast at Surface B.

It is felt that the above quantitative studies over Harkaway Dome and the Bulloo Syncline and the attempts to extrapolate seismic Zone E by gravity show that there are substantial areas where a more-or-less quantitative assessment of gravity is possible, particularly in terms of structure and thickness of Palaeozoic sediments. However, it should be emphasised that gravity interpretation is not unique and that the degree of reliability of the interpretation depends on the amount of control available. Checking would normally be done by seismic traverses so located as to provide well-distributed control for improving the gravity interpretation.

6. CONCLUSIONS

The following conclusions may be drawn from this survey:

(a) in the area of the Tallyabra Syncline, the sediments probably exceed 12,000 ft. This conclusion is drawn from the results on Traverse D, where the thickness of sediments is indicated to be 12,000 ft and increasing to the north-west.

(b) the Pinkilla Dome is proved to be a structurally high area, with the basement probably between 4000 and 6000 ft deep. As shown on Traverse D, the deeper sediments, which are probably Palaeozoic, appear to abut a possible basement core on the western side of this Dome. It is possible that there are no Palaeozoic sediments on the top of the Dome.

(c) the existence of an anticlinal fold, probably faulted on the eastern flank in the deeper sediments, is proved to a depth of 7000 ft below the Harkaway Dome. Although the absence of deep reflections below the crest of this structure could indicate a shallow basement (i.e. roughly 7000 ft), there is no indication of truncation or abutment of the deeper sediments on either the faulted eastern flank or the gently-sloping western flank. It is possible in this case that the absence of reflections does not indicate lack of sediments on top of the structure and that Palaeozoic sediments exist right across this anticline. The fact that Zone E, which is assumed to be near the top of the Palaeozoic sediments, is continuous across the structure supports this view. It has certainly not been proved yet that this structure is a completely similar one to the Pinkilla Dome.

(d) there appears to be good correlation between the semi-regional basin structure and the general Bouguer gravity anomalies, and also between the surface, the Mesozoic, and the Palaeozoic structures and the more detailed Bouguer anomalies. Important density contrasts have been indicated:

(a) between Mesozoic sediments and Palaeozoic sediments at Harkaway,

(b) within the Palaeozoic sediments in the Bulloo Syncline,

(c) between the Palaeozoic sediments and the basement at Pinkilla.

7. REFERENCES

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MOTT, W.D.	1952	Oil in Queensland Ibid. No. 612.
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VALE, K.R. and SMITH, E.R.	1961	The 'depth probing' technique, using seismic refraction methods. Bur. Min. Resour. Aust. Rec. 1961/79.
WHITEHOUSE, F.W.	1954	Artesian water supplies in Queensland; Appendix G - The geology of the Queensland portion of the Great Australian Artesian Basin. Govt Printer, Brisbane.

APPENDIX A

STAFF AND EQUIPMENT

STAFF:

Party Leader:	A.G. Morton	
Geophysicists:	K.B. Lodwick	
	K.F. Fowler	
Surveyors:	C.R. Samundsett	Provided by Department of the Interior.
	J.T. Coman	
Observer:	G.L. Abbs	
Shooter:	H. Wischmann	
Drilling team		
Toolpusher	L. Sprynskyj	Provided by Petroleum Technology Section of the Bureau.
Drillers	B.G. Findley	
	K. Suehle	
Mechanics	G. Bennett	
	I.D. Pirie	
Clerk	W.E. Rossendell	

Up to 10 assistants (including cooks, drill helpers, and field hands) were employed as required.

EQUIPMENT:

Seismic amplifiers:	TIC model 521 - Filter curves are shown on Plate 15.
Seismic oscillograph:	TIC 50-trace, 10 in., mixing
Magnetic recorder:	Electro-Tech DS 7.
Geophones:	TIC 20 c/s and 6 c/s
Drills:	2 Failing 750, with $4\frac{1}{2}$ x 5 mud pumps
Water Tankers:	Four, 700-gallon, vacuum filling
Shooting Truck:	One, 700-gallon, vacuum filling

An office caravan, recording truck, 4 Land Rovers, workshop truck, 3-ton supply vehicle, 1-ton utility, light tractor, and a number of trailers completed the party's mobile equipment.

APPENDIX B

TABLE OF OPERATIONS

Established camp:	6.8.59
Camp site:	Approximately 3 miles west of Eromanga.
Surveying commenced:	1.8.59
Drilling commenced:	7.8.59
Shooting commenced:	7.8.59
Total footage drilled:	20,472 (See Appendix D for drilling analysis)
Miles levelled:	80
Topographic ties:	Bench marks
Explosive used:	10,563 lb Geophex.
No. of Detonators used:	457
Datum level for corrections:	300 ft above sea level
Weathering velocities:	Variable, 2000 to 3500 ft/sec
Sub-weathering velocities:	Variable, 6000 to 6500 ft/sec
Velocity distribution used:	Mean curve between that obtained by

Geosurveys Ltd from t : Δt analysis and by the BMR Haddon Downs survey.

$$v_i = 6000 + 0.9d \text{ ft/sec}$$ (See Plate 14).

REFLECTION SHOOTING DATA

Shot-point interval	¼ miles
Geophone group:	6 geophones, 20 c/s, 22 ft apart in line of traverse
Geophone group interval:	110 ft
No. of holes shot:	81
Common shooting depths:	
	Traverse A 190 ft
	Traverse B 175 ft
	Traverse C 110 ft
	Traverse D 105 ft
Usual recording filter:	L2H2
Usual playback filter:	L3H3
Miles traversed:	20¼
Common charge sizes:	
	Traverse A 20 lb
	Traverse B 20 lb

	Traverse C 10 lb
	Traverse D 25 lb
Weathering corrections:	Graphical, and adjacent geophones; after Vale (1960)
Grading:	After Gaby (1957)

REFRACTION SHOOTING DATA:

Geophone group:	Two geophones, 6 c/s, together
Geophone group interval:	220 ft
No. of holes shot:	22
Usual recording filter:	LOH3
Charge Sizes:	100 lb (for shot/geophone distances up to $1\frac{1}{2}$ miles) to 600 lb (for shot/geophone distances up to 9 miles)
Maximum shot/geophone distance:	47,280 ft
Weathering control:	From reflection shooting (for remote shot-points, from uphole time only)
Weathering and elevation corrections:	After Vale & Smith (1961)

APPENDIX C

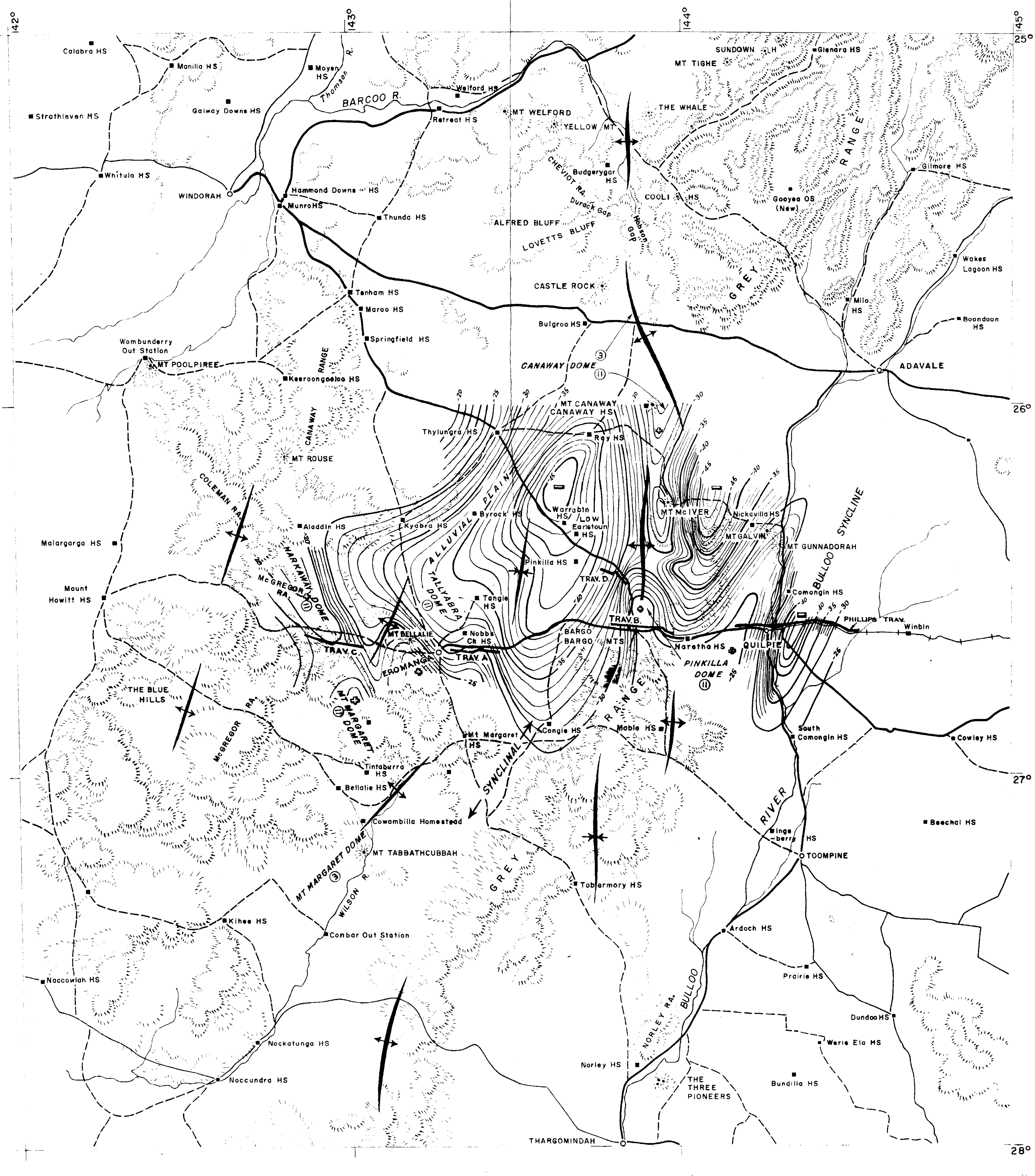
NOTES ON DRILLING TIMES OF SEISMIC SHOT-HOLES - 7/8/59 to 25/9/59.

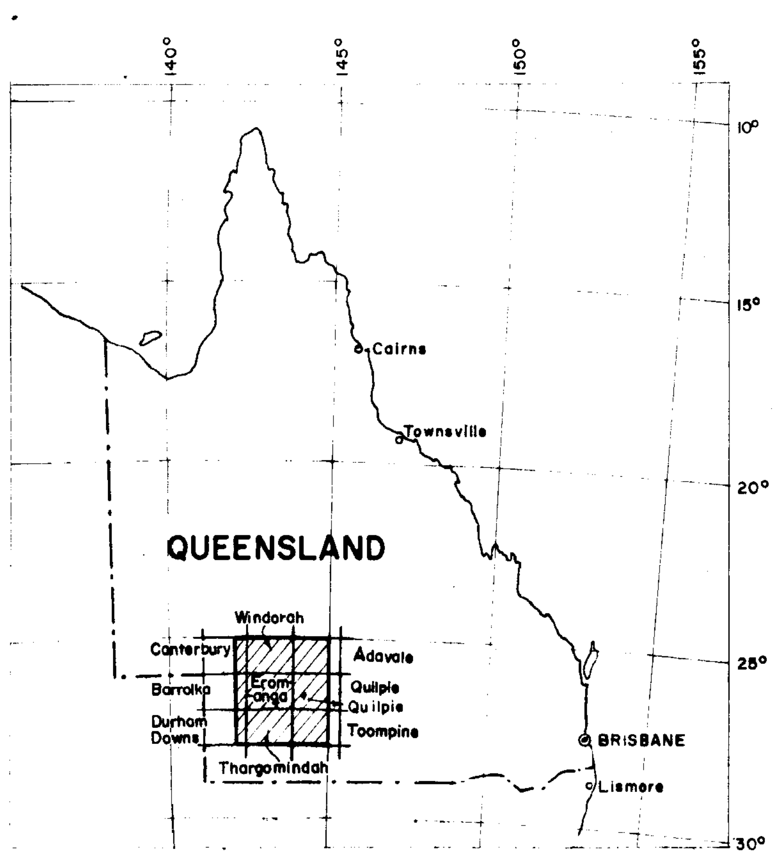
No. of operation shifts:	62
Total time for operation shifts:	527 hr
Overtime (maintenance):	70½ hr
Overtime (drilling):	nil
Total overtime:	70½ hr
Drilling time:	301½ hr
Travelling & rigging time:	182 hr
Time lost because of rain:	31 hr
Time lost waiting for water:	31 hr
Time lost by repairs to rig and equipment:	29 hr
Time lost standing by for recorder:	17 hr
Total drilling time lost	108 hr
No. of holes drilled:	162
Total footage drilled:	20,472 ft
Highest footage drilled per day by two rigs:	1035 ft
Lowest " " " " " "	284 ft
Average " " " " " "	649.6 ft
Deepest hole drilled:	375 ft
Average depth of holes	126 ft
Bentonite used:	nil

Note: Although drilling generally was not difficult, it proved to be rather slow because

(a) fairly deep holes were needed in most places, and

(b) in refraction shooting the 'bulling' charge frequently caused the hole to collapse, necessitating a re-drill. For these reasons it was sometimes necessary to operate three drill-shifts per 24 hours to avoid holding up the recording crew.





REFERENCE TO AUSTRALIA STANDARD MAP SERIES

SEISMIC SURVEY

QUILPIE-EROMANGA AREA 1959, EROMANGA BASIN Q'LD

STRUCTURAL GEOLOGY AND BOUGUER ANOMALIES, TRAVERSE LOCATIONS

Geological Structures after Geosurveys Ltd Plans LHS 3, 10 and 11
Bouguer Anomaly contours after BMR Plans G69-47 and 51
and include the work of the Bureau (1959), Shell (Q'ld)
Development Pty Ltd (1942), H. Narain (1956-57),
and Geosurveys Ltd (1958-59)

SCALE IN MILES

10 0 10 20 30 40 50

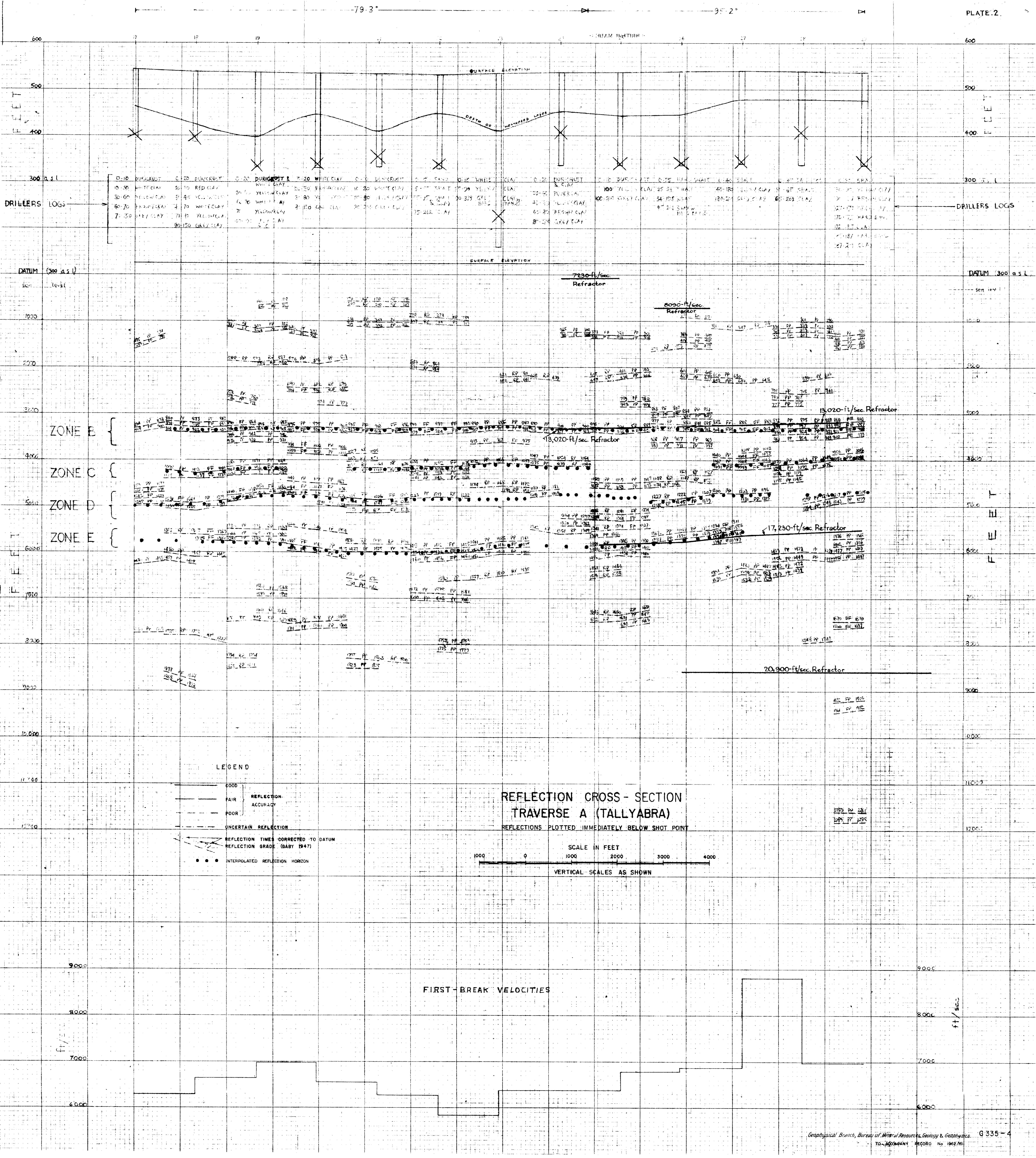
(AFTER 1:1,000,000 I.C.A.O. CHARTS COOPER CK AND CHARLEVILLE)

Geophysical Branch Bureau of Mineral Resources, Geology and Geophysics.

G335-1-1

To Accompany Record No 1962/161

PLATE. 2.



79·3°
35·2°
SURFACE ELEVATION
DEPTH OF WEATHERED LAYER
DRILLERS LOGS
DATUM (300 a.s.l.)
7230-ft/sec. Refractor
8090-ft/sec. Refractor
13,020-ft/sec. Refractor
17,230-ft/sec. Refractor
20,900-ft/sec. Refractor
ZONE B
ZONE C
ZONE D
ZONE E
FEET
LEGEND
GOOD
FAIR
POOR
REFLECTION ACCURACY
UNCERTAIN REFLECTION
REFLECTION TIMES CORRECTED TO DATUM
REFLECTION GRADE (GABY 1947)
INTERPOLATED REFLECTION HORIZON
REFLECTION CROSS - SECTION
TRAVERSE A (TALLYABRA)
REFLECTIONS PLOTTED IMMEDIATELY BELOW SHOT POINT
SCALE IN FEET
1000 0 1000 2000 3000 4000
VERTICAL SCALES AS SHOWN
FIRST - BREAK VELOCITIES
ft/sec
Geophysical Branch, Bureau of Mineral Resources, Geology & Geophysics.
TO ACCOMPANY RECORD No 1962/161
G 335 - 4

PLATE. 3.

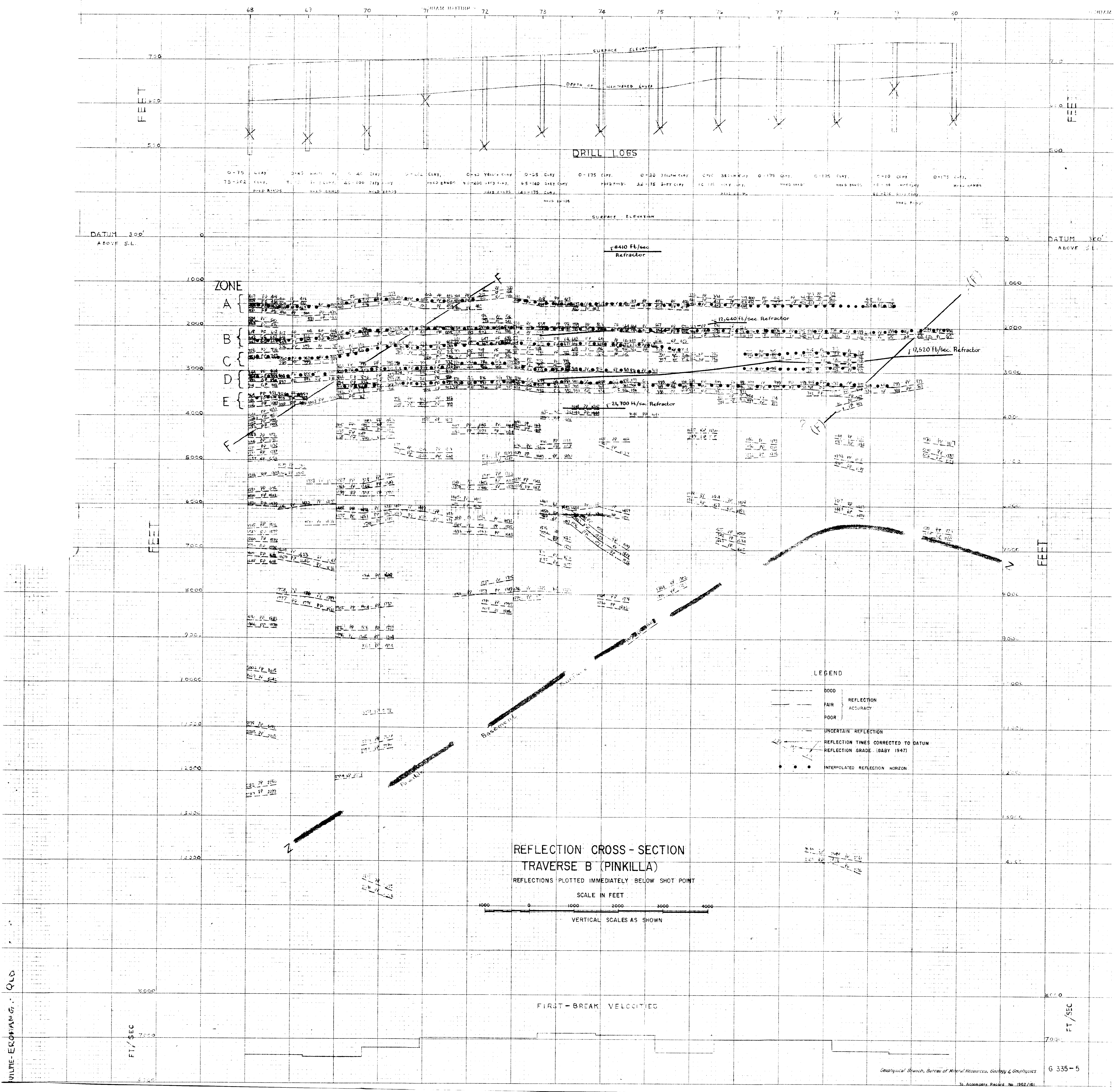

104.5°
94.8°
86.7°
SURFACE ELEVATION
DEPTH OF WEATHERED LAYER
FEET
DRILL LOGS
DATUM 300' ABOVE S.L.
8410 ft/sec Refractor
ZONE
A
B
C
D
E
12,640 ft/sec. Refractor
17,520 ft/sec. Refractor
21,700 ft/sec. Refractor
Basement
LEGEND
GOOD
FAIR
POOR
REFLECTION ACCURACY
UNCERTAIN REFLECTION
REFLECTION TIMES CORRECTED TO DATUM
REFLECTION GRADE (GABY 1947)
INTERPOLATED REFLECTION HORIZON
REFLECTION CROSS-SECTION
TRAVERSE B (PINKILLA)
REFLECTIONS PLOTTED IMMEDIATELY BELOW SHOT POINT
SCALE IN FEET
1000 0 1000 2000 3000 4000
VERTICAL SCALES AS SHOWN
FIRST-BREAK VELOCITIES
FT/SEC
Geophysical Branch, Bureau of Mineral Resources, Geology & Geophysics
G 335-5
To Accompany Record No 1952/161

PLATE 4.

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. G 335-6

To Accompany Record No 1962 / 161

PLATE 5

TO ACCOMPANY RECORD No 1962/161

PLATE. 6.

G 335-7

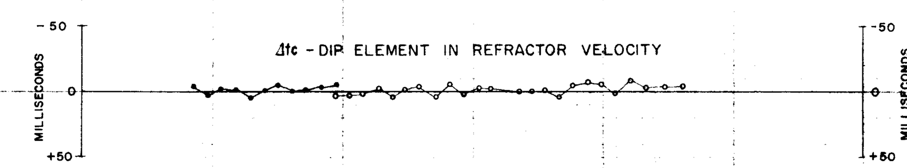
Geophysical Branch, Bureau of Mineral Resources, Geology & Geophysics.

TO ACCOMPANY RECORD No. 1962/161

TO ACCOMPANY RECORD No 1962/161

SP 38

t_n	2178	2167	2147	2129	2117	2097	2077	2063	2046	2027	2006
Wc + Ec	-57	-58	-58	-58	-58	-59	-60	-59	-60	-59	-59
t_c	2121	2109	2088	2071	2059	2038	2017	2004	1986	1968	1947

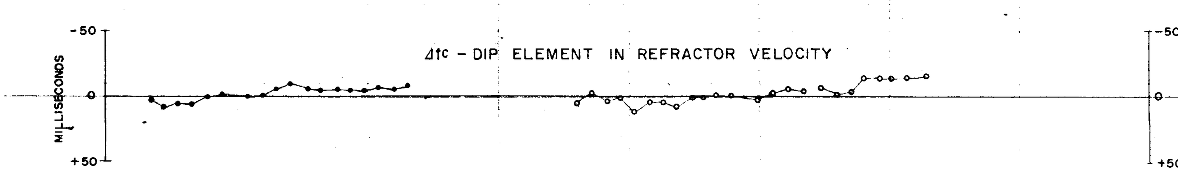


SP 14

	SP 26						SP 27						SP 28						SP 29						SP 30
t_n	1987	2001	2015	2030	2053	2066	2080	2101	2110	2135	2149	2168	—	2200	2217	2234	2254	2263	2279	2295	2319	2327	2349	2366	2393
Wc + Ec	-60	-58	-56	-57	-58	-58	-56	-56	-57	-57	-57	-58	—	-55	-55	-55	-55	-54	-54	-54	-54	-54	-54	-54	-54
t_c	1927	1943	1959	1973	1995	2008	2024	2045	2053	2078	2092	2110	—	2145	2162	2179	2199	2209	2225	2241	2265	2273	2295	2312	2339

SP 45

	SP 22						SP 23					SP 24							SP 25
t_n	2997	2995	2976	2963	2943	2928	—	2904	2884	2871	2854	2844	2836	2823	2807	2800	2782	2771	2756
Wc + Ec	-62	-68	-66	-65	-62	-63	—	-61	-55	-57	-61	-60	-61	-62	-60	-62	-63	-62	-62
t_c	2935	2927	2910	2898	2881	2865	—	2843	2829	2814	2793	2734	2775	2761	2747	2738	2719	2709	2694

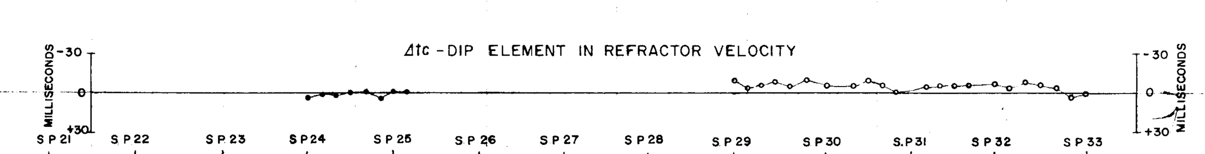


SP 7

	SP 27						SP 28						SP 29						SP 30						SP 31
t_n	2773	2782	2800	2810	2823	2839	2850	2867	2872	2887	2897	2909	—	2940	2946	2955	2969	2980	2999	3009	3013	3025	3035	3050	3060
Wc + Ec	-58	-58	-59	-69	-58	-59	-57	-57	-57	-58	-57	-58	—	-58	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57	-57
t_c	2715	2724	2741	2751	2775	2780	2793	2810	2815	2829	2840	2851	—	2882	2889	2898	2912	2923	2942	2952	2956	2968	2978	2993	3003

SP 101

	SP 24				SP 25			
t_n	3959	3949	3941	3929	3920	3909	3899	3889
Wc + Ec	-63	-63	-62	-65	-65	-64	-64	-64
t_c	3896	3864	3879	3864	3856	3845	3835	3825



SP 150

	SP 29						SP 30						SP 31						SP 32						SP 33
t_n	3719	3736	3744	3752	3766	3773	3786	—	—	3814	3829	3846	—	3863	3872	3882	3881	—	3911	3901	3932	3945	3958	3973	3933
Wc + Ec	-60	-60	-60	-60	-60	-60	-60	—	-60	-60	-60	-60	—	-60	-60	-60	-60	—	-60	-60	-60	-60	-60	-60	-60
t_c	3659	3676	3684	3692	3706	3713	3726	—	3748	3754	3769	3786	—	3803	3812	3822	3831	—	3851	3867	3872	3885	3898	3913	3923

REFRACTION TIME/DISTANCE PLOT AND INTERPRETATION TRAVERSE A (TALLYABRA)

HORIZONTAL SCALE IN FEET

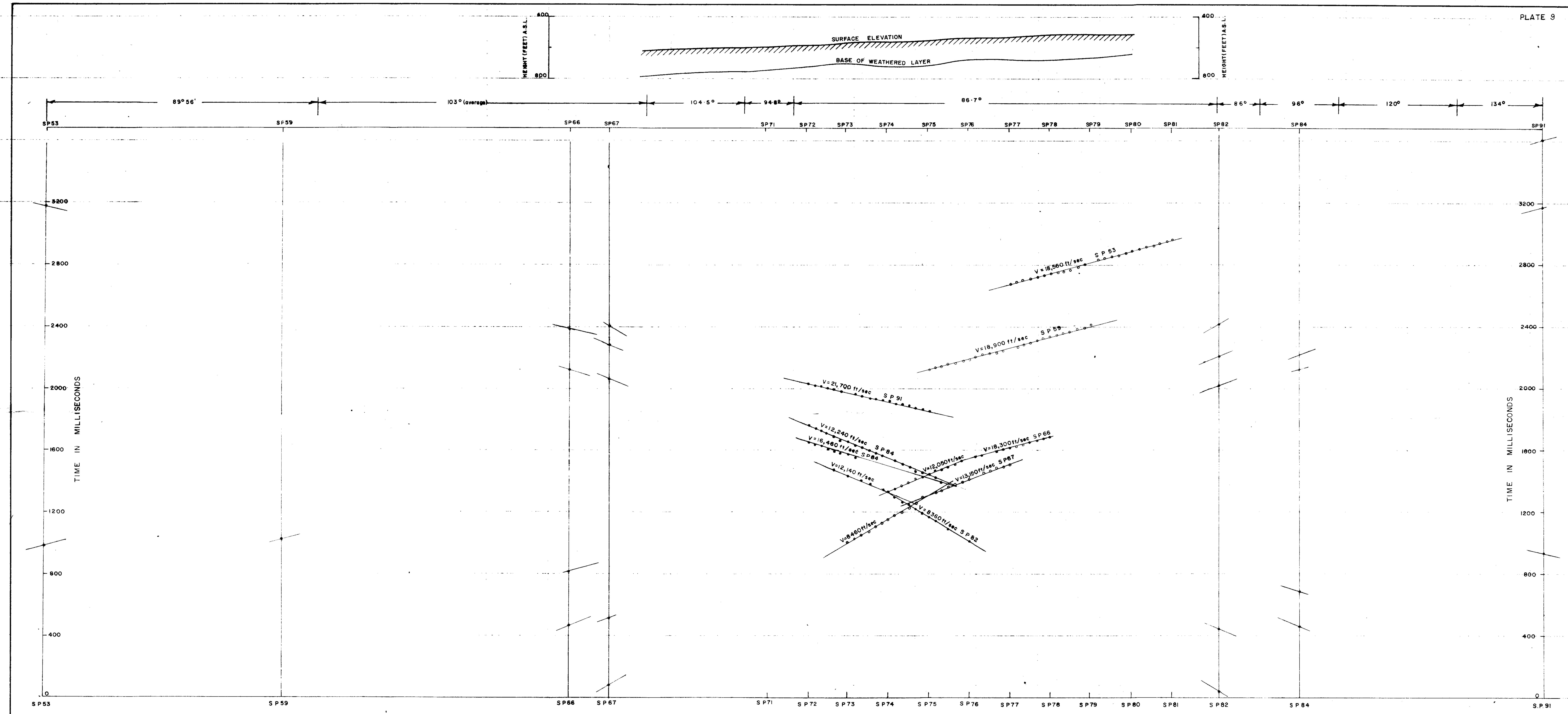
2000 0 2000 4000 6000

VERTICAL SCALES AS SHOWN

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. G 335-11

TO ACCOMPANY RECORD No 1962/161

EROMANGA, QLD.



REFRACTION TIME/DISTANCE PLOT AND INTERPRETATION TRAVERSE B (PINKILLA)

HORIZONTAL SCALE IN FEET
2000 0 2000 4000 6000
VERTICAL SCALES AS SHOWN

SP 82

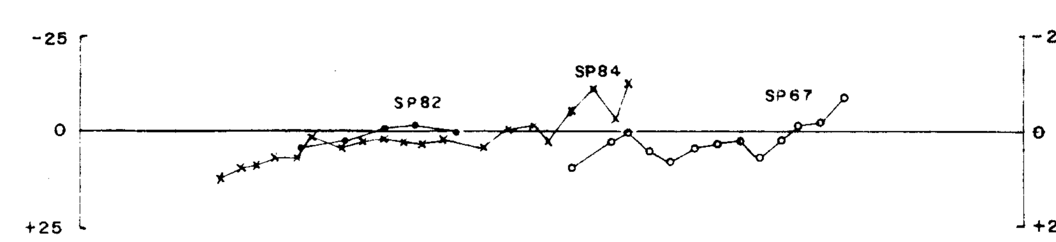
tn	1485	–	1518	1533	–	1569	–	1607
Wc + Ec	-139	–	-138	-136	–	-134	–	-134
tc	1546	–	1380	1397	–	1435	–	1473

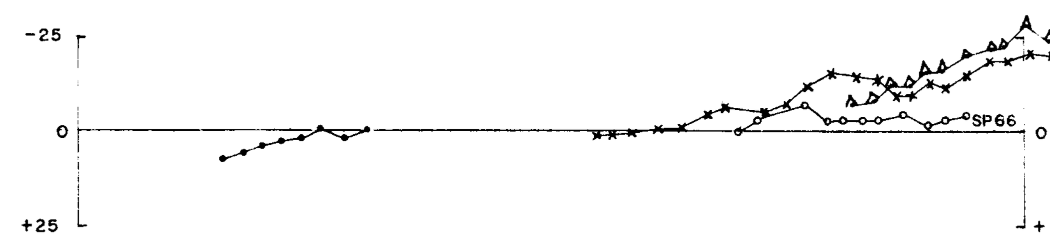
SP 84

tn	1901	1880	1862	1842	1825	1801	1788	1770	1754	1638	1724	1706	—	1671	1648	1632	1616	1593	1572	1558	1528
Wc + Ec	-139	-139	-138	-138	-138	-137	-138	-138	-140	-141	-144	-143	—	-142	-141	-143	-141	-143	-145	-141	-138
tc	1762	1741	1724	1704	1687	1664	1650	1632	1614	1497	1580	1563	—	1529	1507	1489	1475	1450	1427	1417	1390

SP 84

tn	1728	1741	1750	1766	1779	1794	1807	1821
Wc + Ec	-137	-138	-157	-138	-138	-138	-139	-139
tc	1590	1603	1613	1628	1641	1656	1668	1682





SP 67

tn	1424	–	1456	1470	1494	1512	1525	1504	1563	1583	1598	1611	1630	1638
Wc + Ec	-123	–	-127	-127	-128	-127	-125	-128	-130	-128	-128	-129	-130	-129
tc	1301	–	1329	1343	1366	1385	1400	1416	1433	1455	1470	1482	1500	1509

SP 53

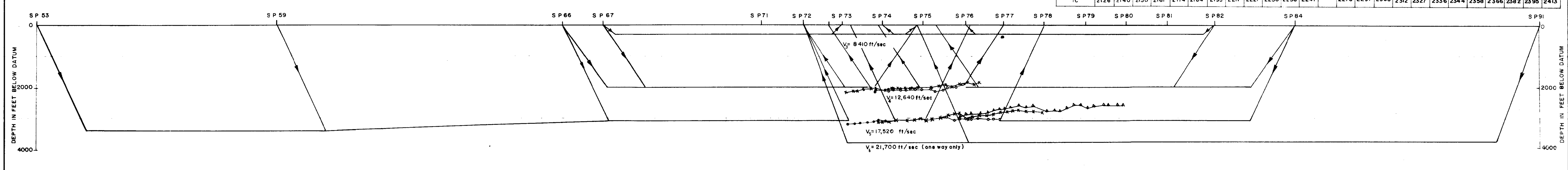
tn	2808	2819	2830	2843	2853	2863	2875	2885	2897	2904	2921	2928	—	2960	2971	2983	2989	3001	3013	3030	3041	3051	3066	3079	3087
Wc + Ec	-123	-123	-125	-125	-128	-126	-128	-128	-129	-129	-128	-124	—	-125	-125	-125	-120	-122	-123	-123	-122	-123	-123	-126	-123
tc	2685	2696	2705	2718	2725	2737	2747	2757	2768	2775	2793	2804	—	2835	2846	2858	2869	2879	2890	2907	2919	2928	2943	2953	2964

SP 66

tn	1674	1688	–	1709	1725	1736	1750	1762	1772	1790	1799	1812
Wc + Ec	-116	-120	–	-122	-121	-121	-123	-125	-123	-125	-124	-125
tc	1588	1568	–	1587	1604	1615	1627	1639	1649	1665	1675	1686

SP 59

tn	2253	2263	2273	2286	2298	2305	2319	2335	2343	2353	2362	2372	—	2400	2417	2429	2440	2454	2465	2473	2448	2496	2511	2520	2538
Wc + Ec	-127	-123	-123	-125	-124	-121	-124	-124	-122	-123	-124	-125	-124	-124	-126	-126	-128	-127	-129	-129	-130	-130	-129	-125	-125
tc	2126	2140	2150	2161	2174	2184	2195	2211	2221	2230	2238	2247	—	2276	2291	2303	2312	2327	2336	2344	2358	2366	2382	2395	2413



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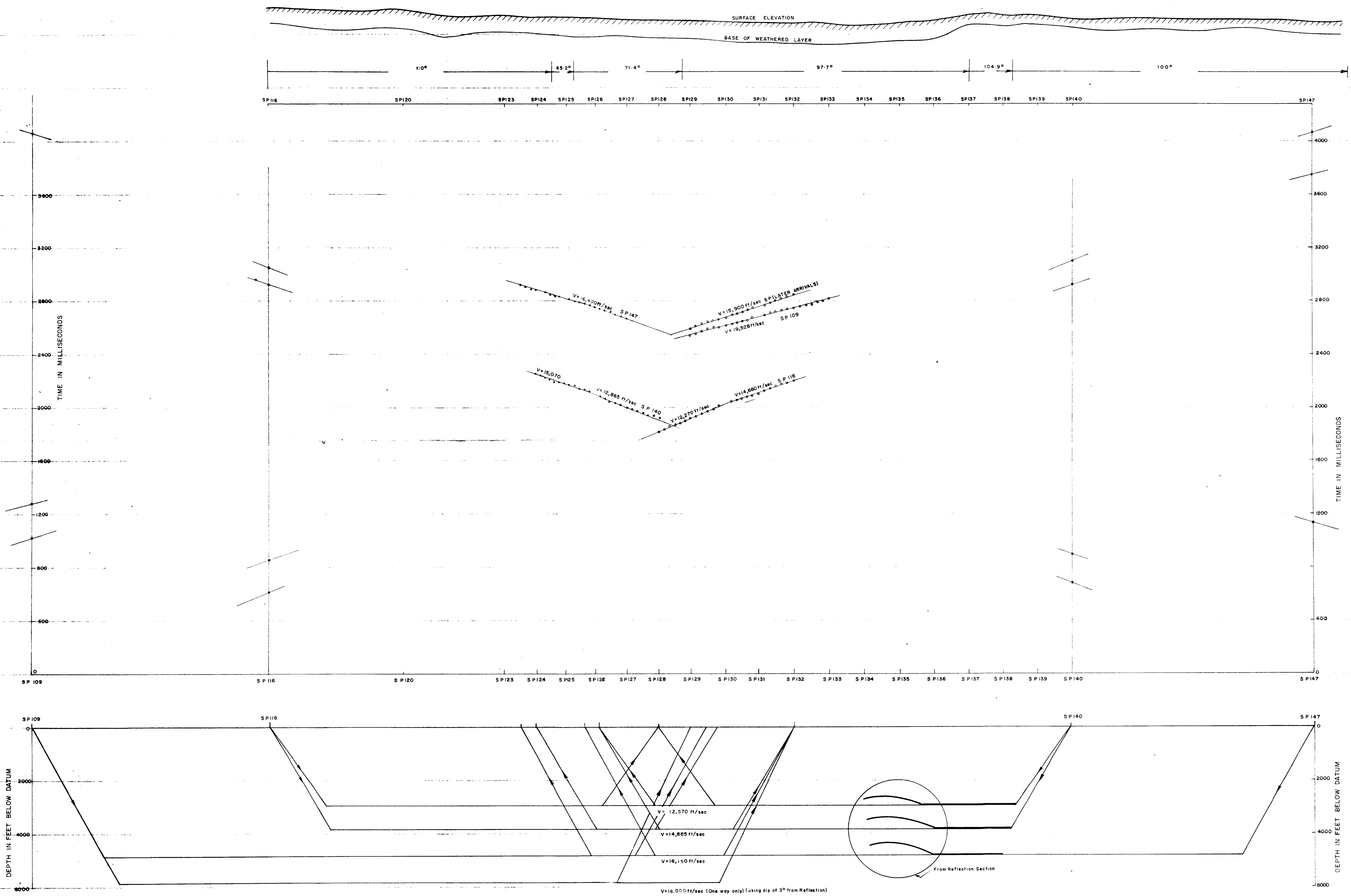
TO ACCOMPANY RECORD No 1962/161

EROMANGA, QLD.



REFRACTION TIME-DISTANCE PLOT AND INTERPRETATION TRAVERSE C (HARKAWAY)

HORIZONTAL SCALE IN FEET

2000 0 2000 4000 6000

VERTICAL SCALES AS SHOWN

EROMANGA, QLD.

PLATE II

REFLECTION CROSS-SECTIONS,
TRAVERSES C AND A
WITH OBSERVED AND CALCULATED GRAVITY PROFILES

SCALE IN MILES
VERTICAL SCALES AS SHOWN

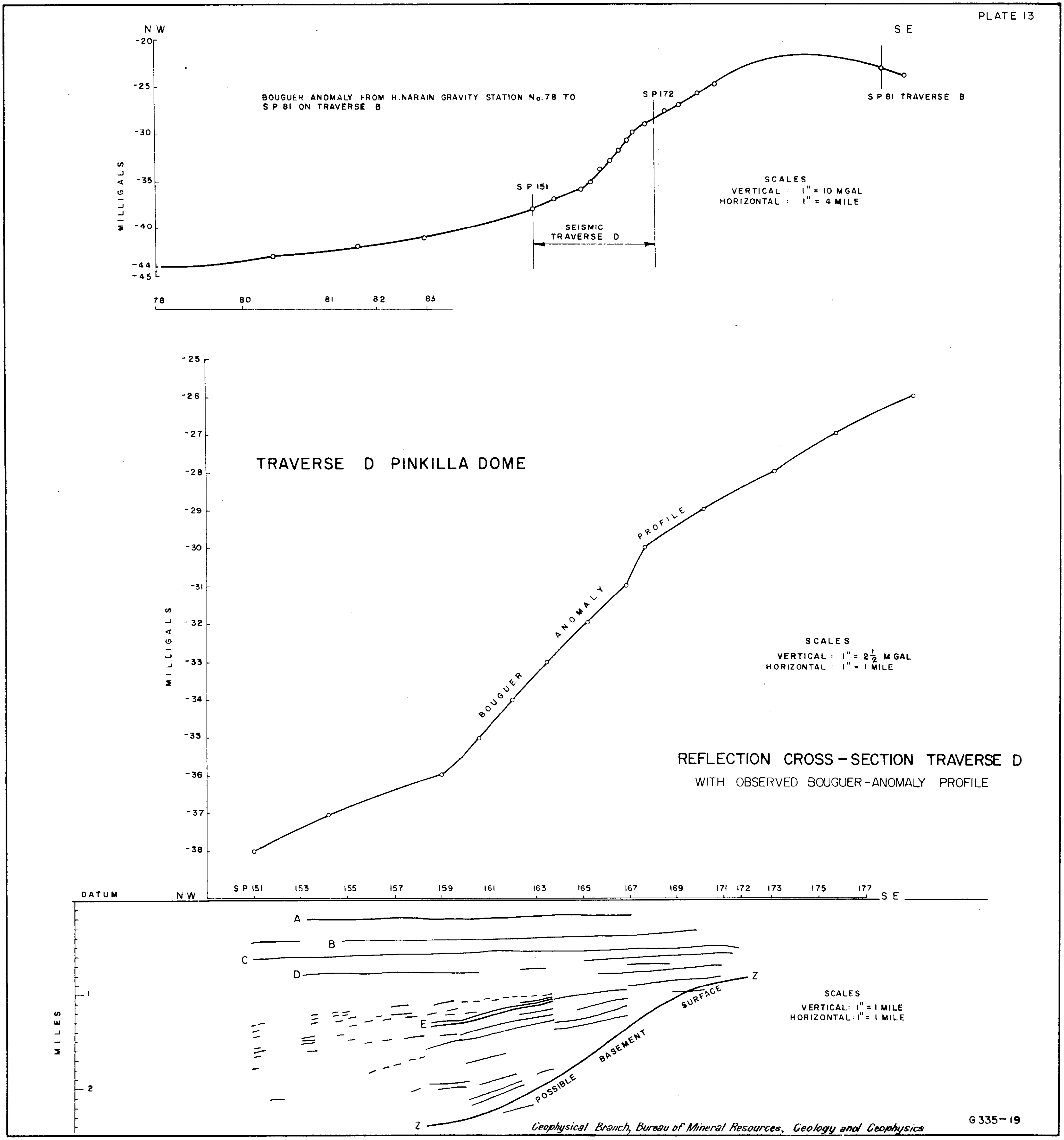
Geophysical Branch, Bureau of Mineral Resources, Geology & Geophysics G335-9

TO ACCOMPANY RECORD No 1962/161

REFLECTION CROSS – SECTION,
TRAVERSE B AND CROSS – SECTION BY
PHILLIPS PETROLEUM CO. LTD,
WITH OBSERVED AND CALCULATED GRAVITY PROFILES

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics. G. 335 – 10

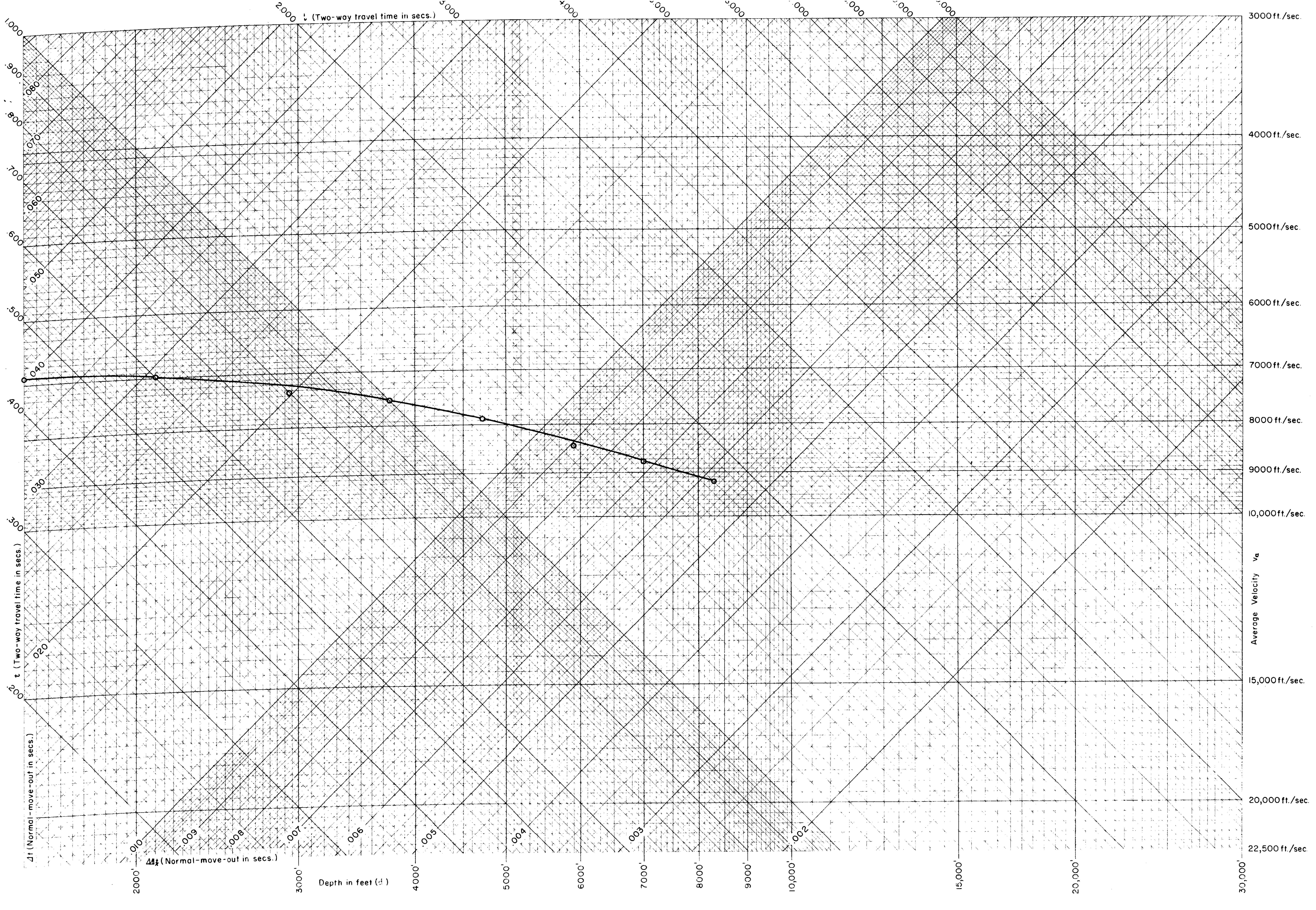
TO ACCOMPANY RECORD No 1962/161



QUILPIE — EROMANGA Q'LD.

TO ACCOMPANY RECORD No 1962/161

QUILPIE – EROMANGA 1959.



NOMOGRAM

TIME - DEPTH - AVERAGE VELOCITY - SPREAD CORRECTION

x = 1320'

In use, this nomogram will provide for the value of x above, a single point for any two of the other four parameters defined below. From this point, the values of the other two parameters may be read off directly.

BASIC EQUATIONS

$$\Delta t_x = t \left[\left(\frac{x^2}{4d^2} + 1 \right)^{\frac{1}{2}} - 1 \right] \quad \text{......... (1)}$$

$$d = \frac{1}{2} V_a t \quad \text{......... (2)}$$

PARAMETERS

t = Two-way travel time to horizontal reflecting interface

Δt_x = Spread correction at a distance x from shot-point

Va = Average Velocity

X = Distance from shot-point to geophone

d = Depth of horizontal reflecting interface

SOURCE OF VELOCITY DISTRIBUTION

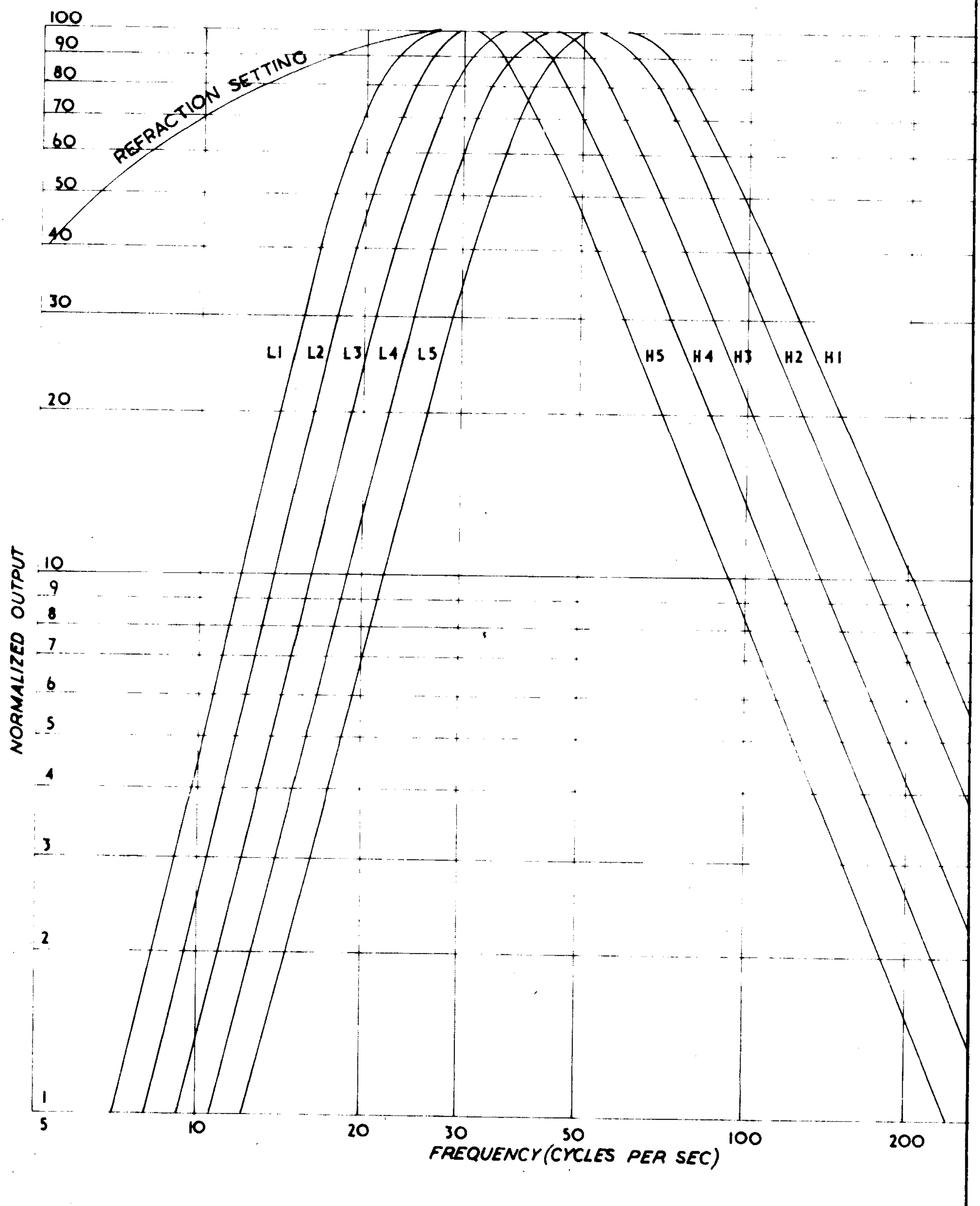
ASSUMED MEAN CURVE BETWEEN THAT OBTAINED BY GEOSURVEYS LTD, from t : Δt analysis and the Haddon Downs Survey

v_i = 6000+0·9d ft/sec
(Datum Velocity)

v_i = Instantanous Velocity

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics G 335-20

To Accompany Record No 1962 / 161



FILTER CURVES

TIC AMPLIFIER TYPE 521

QUILPIE — EROMANGA Q'LD.

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics G335-18

TO ACCOMPANY RECORD No 1962/161