COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

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GEOPHYSICAL EXPLORATION
IN THE
CARNARVON (N.W.) BASIN,
WESTERN AUSTRALIA

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INTRODUCTION

This report describes the geophysical surveys made by the Geophysical Section of the Bureau to assist in the search for oil in the Carnarvon (North-west) Basin of Western Australia.

When the geophysical surveys commenced in September, 1950, with the inception of the gravity reconnaissance programme, much geological work had already been done in the Basin and investigations by geologists of the Bureau were still in progress. (Condon, 1954). All the geophysical work has been planned and done in close co-operation with the Geological Section. Close co-operation has also been maintained with the West Australian Petroleum Pty. Ltd., since its formation in 1952. The exploration permits held by that Company cover the entire area dealt with in this report. The assistance given by this company to the field parties is gratefully acknowledged.

The geophysical work completed to the present time consists of gravity and seismic surveys.

The application of the gravity method in exploration of the Basin depends on the justifiable assumption that the density of the pre-Cambrian rocks, which form the basement and crop out to the east of the Basin, is higher than that of the late Palaeozoic to Recent sediments within the Basin. Differences in thickness of the sedimentary section resulting from troughs or ridges in the basement should therefore produce anomalies in the gravity pattern. Furthermore, if density differences occur within the sediments (for example, in general an increase in density with depth would be expected), gravity anomalies will be caused by folding and faulting within the sediments. Such folding and faulting may or may not be related to basement structure. The gravity survey of the Basin could be expected to give information on the configuration of the basement and on structures which might be present in the overlying sedimentary rocks.

In the interpretation of the gravity results, difficulties arise from uncertainty with regard to the density difference between the basement and the sediments and also with regard to the possible density variations within both the basement and the sedimentary section. Inherent in the gravity method is also the difficulty in distinguishing between anomalies due to causes at shallow and greater depths. In the Carnarvon Basin there is undoubtedly a large regional effect, which, however, at the present stage cannot be accurately evaluated.

On the other hand, the seismic method is suitable for direct measurement of the depths to subsurface rock boundaries, provided that reflection or refraction of seismic waves takes place at such boundaries. Compared with that used in gravity surveys, the equipment required for seismic surveys is more elaborate and the operating costs much higher, and the use of seismic methods is most appropriate for the detailed investigation of particular areas where geological mapping or gravity work has shown the probable existence of favourable structures.

The gravity reconnaissance surveys have covered the whole of the continental part of the Carnarvon Basin, i.e. the large area lying between the Murchison River in the south and the town of Onslow in the north and bounded in the west by the coast and in the east approximately by the 117th meridian. The distribution of the gravity stations throughout this area was largely controlled by the need for siting them along roads and tracks accessible to motor vehicles. The average station interval is about 5 miles. In addition to the reconnaissance surveys the gravity work included a detailed traverse between Wandagee Hill and Williambury Homestead, and other detailed traverses in the Cape Range, Giralia and Rough Range areas.

The gravity field work was done during the following periods:- October to December, 1950; June to December, 1951; March to May and October to December, 1953.

All the gravity readings have been tied to the Bureau's pendulum stations at Onslow, Carnarvon and Geraldton, and it has therefore been possible to express the anomalies relative to the theoretical values on the International Ellipsoid. During the second part of the 1953 field season, systematic checks were made on the earlier work in places where loop misclosures showed such checks to be necessary.

The accurate determination of the position and elevation of the gravity reconnaissance stations scattered over such a large and sparsely settled area as the Carnarvon Basin presented considerable difficulties. In general, the existing maps were not accurate enough for plotting stations and determining station latitudes, and provided little or no topographical information. It was necessary therefore to fix the position of stations from air photographs. Strip maps covering the routes followed were prepared from the air photographs and the strip maps were located by means of astro-fixes and existing trig. stations. Along some of the traverses, station elevations were obtained by the usual levelling method with suitable ties made to sea level. This work provided control for the levelling on the other traverses, which was done with an elevation meter or by barometric methods. The assistance of surveyors from the Department of Interior in the essential surveying work required by gravity reconnaissance is gratefully acknowledged.

The gravity reconnaissance described in this report completes the initial phase of the gravity exploration of the Basin. However, the distribution of the gravity stations is such that only an interpretation on broad lines is possible and cannot be regarded as final. The interpretation will undoubtedly be modified when more detailed gravity work has been completed and when control information becomes available from drilling results. In order to use the gravity method in the search for favourable drilling sites it would be necessary to make detailed gravity surveys throughout the Basin and particularly over the geologically mapped structures.

The seismic field work in the Carnarvon Basin was confined to one field season, i.e. from April to December 1951, and consisted of surveys on the Cape Range and Giralia Anticlines. Both refraction and reflection methods were used. The purpose of the seismic work was to determine if the structures at surface extended to depth and thus establish if a suitable site for a deep exploration drill hole exists.

The seismic surveys on the Giralia Anticline indicated that the structure at the surface does not extend below the major unconformity and confirmed the value and applicability of seismic methods in the exploration of the area.

GRAVITY SURVEYS.

OPERATIONS.

A gravity reconnaissance survey was made in the Carnarvon Basin in September to December 1950, and was continued during 1951. The first phase of this survey was described by Thyer (1951b). Four detailed traverses were run during 1951. In conjunction with the Bureau's seismic work, a gravity traverse was run along Shot-hole Canyon on the east flank of the Cape Range Structure, and two gravity traverses were run across the Giralia Structure, one along seismic traverse A (Giralia-Bullara), and the other along seismic traverse C (near Remarkable Hill). Another detailed traverse was run from Williambury Homestead to Wandagee Hill. The location of these traverses is shown on Plate 1.

A Norgaard gravity meter was used during the 1950 and 1951 surveys, and station elevations were determined by the use of aircraft altimeters. Station locations were determined by spotting on air photographs. The stations in the detailed surveys along the seismic traverses were levelled by spirit level and staff.

After the 1951 survey, large misclosures were discovered in both gravity and elevations. It was subsequently realised that the Norgaard meter is unsuitable for use at high temperatures, as it has a large variation of reading with temperature, except near its compensated temperature (about 20°C), and there is also a tendency for bubbles to form in the oil in which the moving parts are suspended. These bubbles occasionally cling to the beam, causing large discrepancies in the readings. It was therefore decided to re-survey part of the area with a Worden and a Western meter. This was done during 1953, and a sufficient network of traverses was re-surveyed to reduce the errors considerably, and to enable them to be distributed over the remaining traverses. Elevations were also re-determined with greater accuracy, along some traverses by spirit level and staff, and along other traverses by a vehicle-borne elevation meter of the slope-integrator type. Enough control was established by these surveys to permit a distribution of errors over the remaining traverses. The re-surveyed stations are indicated on Plate 1.

Also during 1953, a detailed gravity survey was made over the Rough Range structure. To avoid the need for surveying, readings were taken at seismic shot-points which had been laid out by West Australian Petroleum Pty.Ltd.

Further reconnaissance work was done during 1953 in the southern part of the Basin, between the Gascoyne and Murchison Rivers, more particularly between the Gascoyne and Wooramel Rivers. A traverse to Geraldton ties this work to the previous survey of the Western Australian coastal plain (Thyer, 1955). (Magnetic work was carried out in conjunction with this survey, but the magnetic results are not discussed in this report). A Worden gravity meter was used and levels were obtained by precise microbarometers used in a "leap-frog" method, in which two barometers were read simultaneously at successive stations of the survey. Radio communication was used to ensure simultaneity of readings, and the barometers were read at one station interval (3-5 miles) apart. A surveyed line of levels between Carnarvon and Geraldton was used as a control for the elevation.

The reconnaissance surveys were confined to traverses along existing roads and tracks with stations at about 5-mile intervals. The detailed surveys were along seismic traverses (generally across country) with stations at $\frac{1}{4}$ to $\frac{1}{2}$-mile intervals, except the traverse from Williambury Homestead to Wandagee Hill, which followed the road, stations being at about $\frac{1}{2}$-mile intervals.

REDUCTION AND PRESENTATION OF RESULTS.

Errors in loop closures in gravity and elevation were distributed after the 1952-3 re-surveying programme was completed. The errors were distributed around the re-surveyed loops first, as these were considered to be more accurate than the previous work. These values were then accepted and used as a basis for distributing errors in the previous work which had not been re-surveyed.

Elevation corrections were made using a correction factor of .067 mg/ft., corresponding to a mean density of the surface material of 2.3 gm/cc.

The gravity values shown on Plates 1 and 2 are Bouguer anomalies. Free air anomalies have also been calculated but are not included in this report. Isostatic corrections were calculated for the initial reconnaissance survey (Thyer 1951b) and an isostatic anomaly map was prepared. However, the isostatic anomalies have not yet been calculated for the revised and extended results. The discussion in this report is based on Bouguer anomalies, though occasional reference is made to the effect of isostatic corrections. It is believed that the major features on each type of anomaly map are substantially the same. The main difference between the maps is in the regional gradient of gravity from west to east.

The reconnaissance survey results are shown as a contour plan on Plate 1. The detailed survey results are plotted on Plate 2. The results of the Rough Range survey are shown as a contour plan. The traverse along Shot-hole Canyon, the traverse across the south end of Cape Range and Rough Range structures, two traverses across the Giralia structure, and the traverse from Williambury to Wandagee Hill, are shown as profiles, with corresponding geological sections.

DISCUSSION OF RESULTS.

Reconnaissance Survey.

In the area covered by the reconnaissance survey, the range of the Bouguer values is very large, namely from -55 to +55 milligals. For convenience in discussing the various features of the gravity contour map, the term anomaly will not be used to mean the conventional Bouguer value but will be restricted to the relative "highs" and "lows" in the contour pattern. These relative "highs" and "lows" will be referred to as positive and negative anomalies and as such are indicated by the appropriate + and - signs on the contour plan.

Along the eastern margin of the Basin, the gravity values in general rise towards the east, that is, towards the outcrop of the pre-Cambrian rocks. From near Wogoola to Eudamulla, the gravity gradients are moderate to steep over the boundary between the pre-Cambrian and Palaeozoic sediments. In the area immediately south of Eudamulla there are no gravity observations, but further south, between Coordewandy and Narryer, the gradients are particularly steep and the gravity contours appear to follow closely the boundary of the pre-Cambrian outcrop. However, the gravity values over the pre-Cambrian rocks east of the boundary are by no means uniformly high; an eastward decrease in gravity values is indicated towards Edmund Homestead, Mount Augustus and Yinnietharra.

The major gravity features over the Basin have a general north-north-west trend in the central part of the area, changing to northward in the northern part. The Basin is separated into two parts by a positive gravity feature or "ridge" which extends from about 30 miles east of Meedo Homestead, through Binthalya, Hill Springs, Wandagee Hill, Mia Mia, Marilla and east of Giralia Homestead. On each side of this central "ridge" there is an extensive negative anomaly, i.e. a large area of relatively low gravity values. The axis of the eastern negative anomaly extends from Towrana Homestead to near Middalya Homestead, thence almost due north to Yanrey Homestead. The axis of the western negative anomaly can be traced from Coburn Homestead, through Yaringa South Homestead, Ellavalla Homestead and Minilya to Remarkable Hill and then between Giralia and Bullara Homesteads. North of Remarkable Hill the axis is slightly to the west of the surface axis of the Giralia Anticline. The anomaly broadens considerably between Ellavalla and Minilya and may include Salt Lake, over which there are no gravity observations. West of the anomaly, there is a general increase in gravity values to the west and north-west with the highest values on the west side of the Cape Range where the gravity value reaches +55 milligals.

Superimposed on the anomalies described above there appears to be a regional increase in gravity to the north.

The isostatic corrections calculated by Thyer (1951b) are about 45 milligals in the North-West Cape Peninsula, 30 milligals at Carnarvon and Onslow, and zero at Gascoyne Junction. These corrections are negative and, when applied to the Bouguer values, reduce the regional rise of gravity to the north, and tend to introduce a regional decrease to the west. The corrections were calculated on the Hayford system, using a depth of compensation of 113.7 km. Isostatic corrections have not yet been calculated for any other type of compensation.

In the western part of the Basin, there are no bores to basement, or basement outcrops, which could give control for the gravity interpretations. Thus it is not possible to make any estimates of the thickness of sediments in the western part on the basis of the gravity information alone. The magnitude of the isostatic corrections shows that there could be large gravity effects due to deep-seated causes. However, there is no certainty that the best method of isostatic compensation has been adopted for the area, or that the area is in isostatic equilibrium.

The gravity anomalies within the Basin, apart from regional and isostatic effects, may be due to variations in density within the basement, or to variations in the thickness or density of the sediments in the basin. At the present stage of investigation, the relative magnitudes of these different effects are not known with certainty and consequently the interpretation of the gravity anomalies is tentative to a large extent.

Although there is evidence for variations in density in the pre-Cambrian rocks and it is likely that variations in density also occur in the sediments, it is nevertheless considered that the major anomalies within the Basin are mainly due to variations in the thickness of the sediments. The present interpretation of the gravity results is based mainly on the assumption that, in general, the basement is denser than the sediments and that negative anomalies occur where the sediments thicken locally.

Evidence in support of this assumption is provided by the gravity results in the eastern and south-eastern portions of the Basin. In most of the eastern marginal portion of the Basin the gravity values rise towards the east as the outcrop of pre-Cambrian rocks is approached. This rise is most pronounced in the area between Coordewandy and Narryer, where the gravity contours agree closely with the mapped boundary of the pre-Cambrian outcrop. A positive anomaly is associated with the pre-Cambrian inlier, east of Carey Downs and forming the Carrandibby Range.

The lowest gravity values in the eastern part of the Basin occur near Merlinleigh Homestead where there is a Bouguer value of -54 milligals. This value represents a drop of over 40 milligals from the outcropping pre-Cambrian 15 miles to the east. The thickness of the sedimentary sequence near Merlinleigh Homestead, as deduced from the outcrops of the sediments and their dips, is approximately 12,000 feet (Condon, 1954). This thickness of sediments provides an entirely satisfactory explanation of the observed negative anomaly. If the density of the basement is between 0.2 and 0.3 higher than that of the sediments, the anomaly would correspond to a thickness of 10,000 to 15,000 feet of sediments.

It is necessary to consider whether the interpretation made by assuming that the basement is denser than the sediments could be invalidated by density variations within the basement. Considerable variations in gravity occur along the traverses over the pre-Cambrian rocks east of the Basin, and it is possible that the gravity values over the Basin are affected by density variations in the basement. It is believed that such density variations cause only a secondary contribution to the observed anomalies within the Basin and that the major gravity features previously described are caused by variations in depth to basement.

The reason for this belief is that the gravity anomalies over the pre-Cambrian rocks show no regular trend and differ in this respect from the major anomalies over the Basin. The negative anomaly near Nanutarra Homestead and the positive anomaly south-west of Uaroo Homestead both appear to strike east. The positive anomaly north-east of Mangaroon and Lyndon, which coincides with a narrow belt of pre-Cambrian sediments outcropping amongst the schists (Condon, 1954) strikes south-east, then turns eastwards towards Mt. Augustus. The major gravity anomalies over the Basin show a north-north-west to northerly trend, which is roughly parallel to the western boundary of the pre-Cambrian outcrop and roughly parallel to the coastline and the edge of the continental shelf. There is no evidence of a similar trend in the anomalies observed over the pre-Cambrian rocks.

If the main anomalies over the Basin are interpreted as due to variations in depth to basement, there appear to be two large elongated troughs in the basement separated by a north-south basement ridge. The eastern trough may correspond to the main axis of sedimentation of the Palaeozoic basin. The western trough may correspond to a thick sequence of Palaeozoic sediments or to the axis of the Cretaceous-Tertiary basin. All the anticlines mapped in Mesozoic and Tertiary rocks lie in the western part of the Basin, as divided on the basis of the gravity results. North of Remarkable Hill, the axis of the western trough lies slightly to the west of the Giralia Anticline at the surface. The synclinal structure at depth indicated by the seismic survey across Giralia Anticline (see p. 9) confirms the existence of a trough in the basement.

Geological evidence indicates that if the folding which occurs in the Basin is of mechanical origin, the folding must be the result of major faulting in the pre-Cambrian basement and Palaeozoic sediments (Condon, 1954). All the anticlines in the Basin are considered to be due to high-angle upthrust faulting of the basement and Palaeozoic rocks and located over two large thrust wedges. It would be expected that the faulting described would produce observable gravity effects in the form of gradients over the faults and positive anomalies over the upthrust wedges. The gravity anomalies over the Cape Range and Giralia Anticlines (discussed in the section on the detailed gravity surveys) may be due in part to faults in the basement and Palaeozoic rocks. South of the Giralia Anticline there appears to be no evidence in the gravity results to support the existence of two large upthrust wedges beneath the surface anticlines. If such wedges are present their throws must be too small to be detected by the reconnaissance survey.

Devonian sediments have been identified recently at a depth of 1,400 feet (Thomas and Dickens, 1954) in the Pelican Hill Bore, 8 miles north of Carnarvon. It seems very unlikely that the presence of Devonian sediments at this depth is due to an upthrust with a throw of about 10,000 feet, as a structure of this magnitude would be expected to give an anomaly of about 30 milligals. No large positive anomaly has been observed in the vicinity of the Pelican Hill Bore. The gravity evidence suggests that a large thickness of Devonian or older sediments may be present below this bore. Even admitting that the basement may be at a relatively shallow depth in this area, with the low gravity values related to relatively low density basement rocks or to regional effects due to deep-seated causes, the absence of any zones of large gravity changes in a fairly short distance almost certainly precludes the possibility of faulting on the scale suggested.

The gravity survey is not sufficiently detailed to show whether small gravity anomalies are associated with the anticline south of the Giralia Anticline, except that there appears to be a small positive residual anomaly associated with the Chargoo Anticline. More detailed work would be required to define this anomaly. It is probably associated with a feature at moderate depth.

In the eastern part of the Basin, the lowest gravity values observed are near Merlinleigh Homestead. There are no gravity traverses across the Kennedy Range and it is impossible to say whether gravity continues to decrease west of Merlinleigh, before rising to the higher values observed along the traverse between Hill Springs and Binthalya. The gravity results are interpreted to indicate a trough in the basement with its deepest part near, or to the west of, Merlinleigh Homestead. This interpretation conflicts with the picture of the basin structure deduced from the geological evidence (Condon, 1954). The geological evidence is considered to indicate that the westerly dip of the basement continues to the west beyond the central positive gravity anomaly and that the deepest part of the basin is in the vicinity of Salt Lake.

The negative gravity anomaly in the eastern part of the Basin can be traced northwards to Yanrey and Glenroy Homesteads, but it becomes narrower towards the northern end. The contour pattern is disturbed east of Yanrey Homestead by a positive anomaly which lies just west of the pre-Cambrian outcrop, and which is probably due to density variations within a shallow basement. To the east of this there is a negative anomaly which may represent another variation in shallow basement.

The southward decrease in gravity along the central positive zone is reversed to give a local positive anomaly near Binthalya Homestead. It is suspected that basement is near the surface in the vicinity of this anomaly, although the geological evidence indicates a thick sedimentary sequence. South of the Gascoyne River there is a belt of positive and disturbed anomalies from Pimbie to east of Carey Downs, which is interpreted as an east-west belt of shallow basement. This belt includes the north-east striking anomaly near Carey Downs, which is associated with the pre-Cambrian outcrop forming the Carrandibby Range.

On the gravity contour map, the western negative anomaly is a very broad feature between the Wooramel River and the north end of Salt Lake. North of this it narrows considerably near the Giralia Anticline. The northward narrowing of the negative anomaly appears to be related to an extension to the south-west of the positive anomaly observed in the Rough Range area. A detailed gravity survey in the area south-west of Rough Range would be needed to investigate the possible extension of the Rough Range anomaly in this direction.

The rise in gravity to the north-west across the North-West Cape Peninsula may mean that the basement is approaching the surface; however, this explanation is contrary to the geological evidence, on which a thickness of more than 20,000 feet of sediments is estimated (Condon et al, 1953). Large gravity anomalies due to deep-seated features are common near continental margins. The margin here approaches close to the coast and this anomaly may be associated with a deep-seated feature. The general rise to the west of the gravity values is shown to continue by the readings on Bernier Island, Dirk Hartog Island and Peron and Edel Peninsulas. A local positive anomaly occurs on the west coast of Edel Peninsula.

Vening Meinesz (1948) established a few submarine pendulum stations off the coast, and these were used by Thyer (1951b) in preparing the isostatic anomaly map. They have not been used in the plan in Plate 1, as the Bouguer values in the present work have not been corrected for topography. Without this correction, particularly for the nearby variation in ocean depth, it is inadvisable to draw conclusions from a comparison with the off-shore gravity values. However, the isostatic anomalies measured by Vening Meinesz may be compared with those on land given by Thyer (1951b). The comparison shows that gravity continues to increase off-shore west of Carnarvon. Further north, two gravity stations of Meinesz, one 50 miles north-west of Cape Cuvier and the other 80 miles west of Point Cloates, both show that there is a decrease in gravity going west from the coast to these stations.

South of the Wooramel River and east of the Coastal Highway there is a large area without gravity stations. Observations have been made along a traverse between Hamelin Pool and Narryer Homestead. This shows a positive anomaly centred at station 20-7, 14 miles north-east of Meadow Homestead, which may be a continuation of the main central positive anomaly. There is a fairly sharp drop of about 30 milligals east of station 20-7, and further east along the traverse a rise of over 50 milligals occurs between stations 20-14 and 20-16. These steep gradients have been tentatively correlated with the decrease in gravity south-east of Callatharra Homestead, and the decrease north-west from Byro Homestead. They suggest major faults and the presence of a down-faulted block trending approximately south-west. The negative anomaly immediately to the west of Narryer Homestead, involving a substantial decrease in gravity between Narryer and station 20-25, suggests a possible echelon displacement of the supposed eastern fault line. The zone of low gravity values which is centred approximately midway between Callatharra and Byro Homesteads and which is tentatively assumed to continue south-westwards to include the low values at stations 20-13 and 20-14 (40 miles west-south-west of Narryer Homestead), may indicate one of the deepest parts of the Basin. The -40 milligal contour represents a value 40 to 50 milligals lower than the values on the out-cropping pre-Cambrian to the east.

The gravity values on the traverse northwards from Geraldton along the Coastal Highway show some fluctuations over the pre-Cambrian, culminating in a maximum of +58 milligals at station 1-23, 8 miles north of Galena. Further north, gravity decreases with several small fluctuations to station T-23, 16 miles east-north-east of Hamelin Homestead, where the value is about -20 milligals. There is no sign of the negative zone referred to in the previous paragraph, which would be expected to cross the highway if its trend is south-west and if that trend continued. The zone must either terminate before the highway is reached or swing southwards and continue east of the highway. This zone may extend southwards to join the negative anomaly which has been observed between Geraldton and Mullewa and may thus link the Carnarvon Basin with the Perth Basin. Field work now in progress should establish whether this is so.

The northward decrease in gravity along the Coastal Highway is most pronounced between stations 1-27 and 1-28 where a drop of 16 milligals occurs. The strike of this feature cannot be ascertained from the single traverse. Geological evidence indicates Permian sandstone unconformably overlying pre-Cambrian gneiss in this area (Condon, personal communication) and the gradient observed between stations 1-27 and 1-28 may be caused by the gneiss dipping steeply to the north beneath the sandstone. Alternatively, the gradient may be due to a substantial fault with downthrow to the north.

Detailed Surveys.

The results of the detailed gravity surveys are plotted on Plate 2. The geological sections which accompany the gravity profiles are not to be considered as a rigid interpretation of the gravity results. They are based on the geology as described in the geological report on this Basin (Condon, 1954), but modified where necessary to be consistent with the gravity information. In drawing the sections across the Giralia Anticline, attention has also been paid to the seismic information. The geological sections are to be considered not so much as interpretations, but rather as a possible geological background against which the gravity results should be considered.

The locations of the detailed traverses and the area covered by the Rough Range survey are shown on the regional gravity plan (Plate 1). The profiles have been plotted with the horizontal co-ordinate representing distance along the traverses as shown on the map, and no attempt has been made to project the results on to a straight line.

The detailed surveys are discussed below under the following headings:- (1) Shot-hole Canyon Traverse; (2) Traverse A1, Cape Range; (3) Giralia Anticline, Traverses A and C; (4) Wandagee Hill-Williambury Traverse; (5) Rough Range Area.

1. Shot-hole Canyon Traverse.

The short traverse, from SP1 to SP14, on the eastern flank of the Cape Range Anticline, is the only gravity work that has been carried on to the structure near the apex. The profile is incomplete and not of much value. It has been extended tentatively to include the gravity values at station 19-10, beyond the eastern end of the traverse, and station 9-12, beyond the western end. Between SP14 and SP1 the profile shows a rise in gravity to the west. The regional gravity shows a rise in the same direction, as can be seen on Plate 1. However, the rise towards the west as SP1 is approached is steeper than the regional gradient and therefore there must be at least a residual positive anomaly between SP1 and station 9-12. The maximum of this residual anomaly may nearly coincide with the anticlinal axis. The rise in gravity westwards from station 19-10 may be due in part to a fault with down-throw to the east and if so would tend to confirm the theory (Condon, 1954) that the Cape Range Anticline was produced as a result of an upthrust fault block in the basement.

2. Traverse A1, Cape Range.

This follows seismic traverse A1 of the West Australian Petroleum Pty. Ltd. across the southern end of the Cape Range and Rough Range Anticlines.

It is noteworthy that the Rough Range Anticline gives a large gravity anomaly as far south as this traverse, although the surface geological axis is not shown continuing to the south (Condon et al., 1953). There is a gap in the gravity readings from SP58 to SP70 and consequently the profile does not show whether or not there is a positive anomaly near the axis of the Cape Range Anticline.

The profile provides no definite evidence that the Rough Range Anticline has been formed over a high-angle upthrust fault in the basement. From examination of the results of the detailed survey of the Rough Range area (p. 10) it is considered that the most likely interpretation of the residual positive anomaly is a sub-surface feature at a depth less than 5,000 feet. If a fault in the basement exists, the throw must be too small to produce a significant gravity effect at the surface. If the gradient of the profile at the eastern end of the traverse is due to a basement effect, a fairly uniform easterly dip of the basement surface is suggested rather than a fault.

A gravity traverse across the Cape Range near the apex of the anticline should be of considerable interest, and this would be the next logical step in any further exploration planned on this structure.

3. Giralia Anticline, Traverses A and C.

Two gravity traverses were surveyed across this structure. They follow the Bureau's seismic traverses A and C. The gravity profile along traverse A was discussed by Thyer (1951a) and the seismic work by Vale (1951).

The gravity profile along traverse A shows a broad negative anomaly with the minimum at G20-G24, that is about $2\frac{1}{2}$ miles west of the surface axis of the Giralia Anticline and about 11 miles east of the Bullara Syncline. The average gradient is greater on the eastern side than on the western side. The profile shows several small irregularities, some of which may have been incorrect readings due to the erratic behaviour of the Norgaard gravity meter. The total anomaly is about 13 milligals with a half-width of about $2\frac{1}{4}$ miles, which means that it could be due to a sub-surface feature at a depth of about 10,000 feet. A broad shallow feature could produce the anomaly, but a change of about 3,000 feet in the thickness of sediments would be required.

The seismic section shows that the upper sedimentary layers - presumably Cretaceous and Tertiary - above the unconformity at a depth of about 3,000 feet, do not change in thickness by more than a few hundred feet and that there is a syncline below the unconformity. It seems fairly certain, therefore, that the cause of the gravity anomaly lies below the unconformity. The gravity anomaly is probably due to a trough in the basement. Such a trough would result in thickening of the Palaeozoic sediments. Although the seismic evidence of a synclinal structure at depth supports the view that the gravity anomaly is due to a basement trough, the position of the gravity minimum does not correspond exactly with the syncline. The trough of the syncline is approximately below SP16, which is about 2 miles east of the lowest point of the gravity anomaly. Furthermore, the seismic section shows no evidence of a slope of the synclinal axis.

The seismic results show evidence of a fault between SP6 and SP8, where a zone of steep easterly dips has been observed at the surface. A fault with a downthrow to the east has been inferred from those dips (Condon, 1954). A small disturbance of the gravity profile near SP5 could be due to such a fault, but only if the fault were at a shallow depth and had a throw of only a few hundred feet.

If the eastern half of the main anomaly shown by the profile is considered as being due to a fault, it can be estimated that the fault would be centred at a depth of about 8,000 feet. The fault would have a down-throw to the west, possibly of 2,000 feet or more. Such a fault is a possible interpretation of the gravity anomaly, but clearly a fault of this type would not provide an explanation of the origin of the Giralia Anticline in terms of the theory suggested by Condon (1954), as the down-throw is to the west and not to the east.

The profile along traverse C shows a general rise in gravity eastwards from SP51. A reversal of this trend between SP3 and SP6 correlates with the seismic evidence for a shallow fault with a down-throw to the east of a few hundred feet. The reversal of the trend results in the appearance of a residual positive anomaly corresponding approximately to the Giralia Anticline. Further investigation of this residual positive anomaly would be justified, as it may be related to the anticlinal structure mapped at the surface. However, on the present available gravity data, it is considered that the residual positive anomaly is produced by the effect of a shallow fault superimposed on the broader anomaly resulting from a basement feature. There is a rise in gravity from SP51 to the reconnaissance station 31-7, about 6 miles to the west, thus suggesting a broad negative gravity anomaly with the minimum near SP49. The negative anomaly is considered to be due to a basement trough.

4. Wandagee Hill - Williambury Traverse.

This traverse extends across the major negative anomaly in the eastern part of the Basin. From station G149, one mile west of Middalya Homestead, there is a steady increase in gravity to the western end of the traverse. A smaller increase occurs from Station G120, 12 miles east of Middalya Homestead, to the eastern end of the traverse. It has not been possible to reconcile the structure of the basin deduced from the geological evidence with the broad negative anomaly shown by the profile along this traverse. The regional westerly dip of the sediments in outcrop is considered to indicate that the thickening, of the sedimentary sequence continues westwards to, and beyond, Wandagee Hill, except where it is interrupted by faults with downthrow to the east. The gradual rise in gravity to the west towards Wandagee Hill suggests rather a gradual rise in the basement and a thinning of the sedimentary section in this direction. A substantial rise in gravity occurs from G145 to G147 at the eastern end of the traverse where the pre-Cambrian outcrop is approached.

Many faults are shown by geological mapping along this traverse but most of them cannot be satisfactorily correlated with features on the gravity profile. One exception is the upthrust fault block from G136 to 16-2, (near the eastern end of the traverse) which appears to have a small anomaly associated with it, although the anomaly is not as large as would be expected from such a large throw. A possible exception is the fault outcropping near G106, four miles east of Middalya, which may be related to the gravity drop from G107 to G109. The gravity profile is not consistent with the major fault with downthrow to the east near Wandagee Hill, which is indicated by geological mapping, as there is no gravity gradient steep enough.

5. Rough Range Area.

The results of the survey are shown as a contour plan on Plate 2. The feature of most interest is the positive gravity anomaly striking approximately north-north-east and passing through A-1/26, A-21/10, A-22/8, A-5/2, A-20/3 and A-18/2. There is a closure of about 1 milligal, with the highest value at A-22/8.

Owing to the limitations of time and surveying facilities, gravity observations were made at the seismic shot-points only. The resulting distribution of gravity stations does not give a good coverage of the anomaly. It would have been desirable to have two or three additional east-west traverses between traverses A-22 and A-23, and more stations are required to the east of traverse A-22 to define the anomaly more accurately. Further observations are required to establish whether the anomaly continues to the south of traverse A-1.

It is apparent that the axis of the anomaly is approximately parallel to the surface axis of the Tertiary anticline (Condon et al., 1953) but about one mile to the east. This suggests a considerable migration of the axis of the structure with depth, or a displacement at an unconformity.

The regional map (Plate 1) shows an increase in gravity to the north-west of Rough Range. To the south-east, gravity continues to decrease and passes through a minimum between Bullara and Giralia Homesteads. No gravity information is available to the east, in Exmouth Gulf.

As the structure lies near the large change in gradient it is difficult to separate the local anomaly from the regional anomalies. However, an attempt has been made to do this and to make an estimate of the maximum depth to the subsurface feature causing the residual anomaly (Dooley & Everingham, 1954). The maximum depth to the top of the feature was estimated for two possible values of the regional gradient. A density contrast of 0.3 was assumed in both cases. The depths obtained were about 3,700 feet and 4,300 feet for the two alternative interpretations of a cross-section through station A-5/2 near the centre of the anomaly.

In Rough Range No.1 Bore, the unconformity between the Cretaceous and the Permian rocks was met at a depth of 3,995 ft. It is highly probable that the Permian rocks are substantially denser than the Cretaceous, and that a density contrast sufficient to account for the observed anomaly would be found at the unconformity. The density contrast is not likely to be more than 0.3. If it is less, then the maximum depths will be less than those calculated.

On this hypothesis, the positive residual gravity anomaly should represent a high feature on the unconformity between the Cretaceous and the Permian rocks. It is likely that the depth to the top of the feature would be less than the maximum depth estimate of 3,700-4,300 ft., and therefore would probably be less than the depth to the unconformity as found in the bore. However, the bore is situated on the flank of the gravity anomaly, and therefore if the hypothesis is true, the unconformity must be shallower at the axis of the anomaly. In any case, maximum depth estimates of this nature are necessarily approximate, and could be in error by a few hundred feet.

CONCLUSIONS.

At the present stage of the investigation of the Carnarvon Basin, the control information does not provide an entirely satisfactory basis for interpretation of the results of the reconnaissance gravity survey. Difficulties in interpretation arise from the presence of large regional gradients and from the possibility of horizontal variations in the density of the basement and the sedimentary rocks.

The interpretation of the reconnaissance survey has been attempted only on broad lines and depends on the assumption that, in general, the density of the sediments is less than that of the basement rocks. This interpretation shows two major troughs in the basement, separated by a roughly north-south zone of relatively shallow basement. All the anticlines mapped at the surface in Mesozoic and Tertiary rocks lie in the western part of the Basin as divided on the basis of the gravity results.

The central north-south ridge in the basement conflicts with the structure of the Basin inferred from geological mapping, which has been interpreted to indicate that the westerly dip of the basement continues from the eastern edge of the Basin, nearly to the coast-line, except where interrupted by major faults with downthrow to the east.

The gravity results show little evidence of major faulting, except in the eastern margin of the Basin. There may be faults with smaller throws (of the order of a few hundred feet) which would not be revealed by the reconnaissance survey. It seems unlikely that the presence of Devonian sediments at a depth of 1,400 feet in the Pelican Hill Bore near Carnarvon, is due to a major upthrust wedge of basement and Palaeozoic rocks.

Additional gravity observations are required in many parts of the Basin that have not been adequately covered by the reconnaissance survey. In particular, additional gravity observations are required over the Kennedy Range and in the area between the Kennedy Range and the boundary of the pre-Cambrian outcrop to the east; also, in the area south of the Wooramel River and east of the Coastal Highway, an area which, from present gravity data, may include one of the deepest parts of the Basin. Additional gravity observations in the latter area should indicate whether or not the Carnarvon Basin is linked with the Perth Basin to the south. The gravity survey of the Carnarvon Basin will not be complete without observations off-shore over the continental shelf.

It is considered that additional gravity data would assist in reconciling the points of difference between the interpretations of the geological and geophysical work.

The Rough Range Anticline is the only structure in the Basin over which a fairly complete detailed gravity survey has been made. A positive anomaly with a closure of about 1 milligal was observed. The axis of the anomaly is parallel to, and about one mile to the east of, the surface axis of the anticline. The relation between the gravity anomaly and the accumulation of oil discovered in Rough Range No. 1 Bore is not clear at present.

Two east-west traverses across the Giralia Anticline show a broad negative anomaly, believed to result from a trough in the basement below the anticline. The only possible correlation between the gravity results and the geologically mapped surface structure is a small positive feature superimposed on the broader negative anomaly on the southernmost traverse.

Although limited in scope, the detailed surveys indicate the need for further detailed gravity surveys over the known anticlines in the Basin.

SEISMIC SURVEYS

LOCATION.

The seismic surveying carried out by the Bureau in the Carnarvon Basin has been confined, except for an inconclusive traverse on the Cape Range, to the Giralia Anticline which has been mapped at the surface in Mesozoic and Tertiary rocks. The seismic survey was done during 1951 and consisted of three traverses. These were :-

(1) Traverse "A", an east-west reflection traverse across the northern end of the anticline.

(2) Traverse "B", a north-south refraction traverse along the surface axis of the anticline near traverse "A".

(3) Traverse "C", an east-west reflection traverse across the apex of the anticline.

The locations of these traverses are shown on Plate 1.

PURPOSE.

The object of the above traverses was to show, as far as possible, which one of three alternatives represented the tectonic nature of the major anticlines in the area. The three alternatives were proposed and expressed by Dr. Schneeberger (1950) who was, at the time, a Supervising Geologist with the Bureau. The three alternatives were expressed as follows :-

(1) It is assumed that the Palaeozoic sediments are developed in at least the same thickness as measured in outcrop sections farther east. They are faulted in a similar pattern to the Palaeozoic sediments near the eastern margin of the basin. The folding of the Mesozoic-Tertiary sediments, which overlie the Palaeozoic rocks unconformably, is the result of the block-faulting of the Devonian-Permian sequence in depth. This should result, in a seismic reflection picture, in two independent sets of dips, the higher set appertaining to the folded Mesozoic-Tertiary sequence, the deeper one to the block-faulted Palaeozoic strata.

(2) The Palaeozoic and Mesozoic-Tertiary sediments are harmoniously folded, although incipient folding movements might have taken place in pre-Mesozoic time. Dips in the younger strata should in this case be of approximately the same magnitude as those in the Palaeozoic beds. A deep-seated basement core might, however, be present, but would presumably be out of reach of the seismic investigation.

(3) The Cape Range and Giralia Anticlines contain basement cores (buried hills), flanked and partly overlapped by Palaeozoic sediments. As in the case of other well known structures of this type, differential compaction would be an essential factor for their origin. The zones of steep dips in the Mesozoic-Tertiary sequence would in this case be caused by faulting in the basement complex. A solution of this alternative should be possible with refraction shooting, provided the Palaeozoic cover of the basement ridge is not too thick.

TECHNICAL MATTERS.

Along reflection traverses "A" and "C", initial tests were made by the conventional shot hole technique and also by the air shooting technique. Air shooting was adopted as the main method for the two traverses, but along Traverse "C" it was supplemented by hole shooting.

Cross sections obtained along the reflection traverses have been plotted in depth, i.e. the reflection times have been multiplied by the appropriate velocity to convert them to depth (plate 3). The reflections have been plotted according to calculated angles of dip. The dips have been taken into account when plotting the position of the reflections and the reflections are shown in the positions from which they appear to come if it is assumed that the section is normal to the strike of the reflecting horizon and that the velocity is uniform. A correction has been made for elevation effects. The air shooting technique, in which the shot points were off-set by 2,400 - 3,000 feet normal to the traverse from the ends of the geophone spreads, did not provide the necessary data for making weathering corrections, but special shooting to obtain these data was not considered justified. Velocities used for the depth plotting have a probable error of 10 per cent, but this can have little effect on the structural picture obtained as an error of 10 per cent in relief is not important at this stage.

The refraction traverse is open to several interpretations, particularly in relation to the number and value of observed velocities of minor refractors. Only the more definite refractors are listed in the discussion of results and an estimate of their velocity, depth, and apparent dip in the north-south direction is given. A basic assumption for the interpretation given is that the beds below the traverse have a practically constant dip along the traverse. Substantial departures from this assumption would cause gross errors.

DISCUSSION OF RESULTS;

Reflection Traverse "A".

Generally, throughout the length of the section, the shallow data are abundant and good, particularly in the zone between 2,000 and 3,000 feet, with notable exceptions in the region between SP's 6 and 8 and immediately to the west of SP24. The reflecting horizons conform generally with the surface structure. Below this zone there is good evidence of an unconformity, but the number and the quality of the reflections below the unconformity are not as good as in the zone above. The upper part of the section above the unconformity is believed to correspond to Mesozoic and Tertiary rocks which are separated from underlying Palaeozoic rocks by the unconformity.

The following is a detailed description of the section from east to west. Between SP's 40 and 34 the reflecting horizons dip slightly to the west and the shallow and deep horizons appear conformable. To the west of SP34, at about 2,750 feet depth, an unconformity becomes apparent. The reflecting horizons immediately below the unconformity dip about 6° to the west between SP's 34 and 27 and at about 4° to the east between SP's 27 and 1, thus forming a syncline with its axis near SP27. The reflecting horizons above the unconformity are relatively flat and slightly synclinal. Under SP's 27, 26, 1 and 2, a second unconformity is suggested at about 4,000 feet, as the beds below this depth dip much more gently than those immediately above.

From SP2 to SP6 the unconformities are not apparent and all beds continue either flat or with slight westerly dips, the most significant exception being the reflection under SP5 with different phases at 1.945 and 1.973 seconds respectively, which was actually recorded from SP11. This reflection dips at about 55° to the west and its significance in indicating faulting will be discussed later. From SP6 to the west of SP7 there is a complete absence of reliable reflections and this also indicates faulting. The shallow reflections from SP8 westward and the steeply dipping reflections which are shown between SP's 7 and 8 are conformable with surface dips.

SP14 coincides with the axis of the anticline. The shallow reflections show gentle east dips east of it and west dips to the west. To the west of SP8 the first high grade deep reflections, i.e. from below the major unconformity, are recorded from SP10 and they show westerly dips in contrast to the easterly dips of the shallow horizons above them. Below a depth of approximately 4,000 feet, these westerly dips continue to SP16 which appears to be on the axis of a syncline. At a depth of between 3,000 and 4,000 feet, however, the beds appear relatively flat and may be unconformable with both the shallow anticline and the deeper syncline.

From SP20 westward the quality of the records is poor and a considerable amount of conflicting data is shown. However, the unconformity between the deeper and shallow zones is still apparent. SP's 41 and 42 were not used and SP45 gave no reflections whatever. Three experimental shot points, A, B and C, were placed a further seven miles westward. The dips above 3,000 feet differ slightly from those below, but the evidence of an unconformity is not conclusive. There appears to be a reversal in dip in the deeper beds which suggests the presence of a syncline centred at shot point B.

Reflection Traverse "C"

Shallow events (less than 2,500 feet).

Seismic events returning from less than 2,500 feet are in general strong and clear. They include both reflections and refractions and the classification of an event is not always clear at first. Refractions usually show a "wash board" effect when plotted on the cross-section as reflections. Individual events of this type are of no use for indicating the value of the dip of the strata they represent, but when a number form a continuous sequence they have qualitative value in that they then indicate the direction of dip. This is so between SP's 33 and 5.

The section across the western flank of the anticline shows west dip of 3° from SP55 to SP48, no dip between SP48 and SP38 and west dip of 6° between SP38 and SP34. On the eastern flank, between SP's 5 and 6, there is a definite break in the continuity of the shallow events, those to the east of SP6 arriving about 0.08 sec. later than those to the west of SP5. This indicates the presence of a fault between SP5 and SP6, with an estimated down-throw to the east of about 500 ft. The change in the elevation of the recorded horizons is sufficient to alter the character of the events from refractions on the west to reflections on the east. The fault can be correlated with the probable fault indicated on traverse "A" between SP's 5 and 8. From SP6 to SP18 the profile of the shallow beds is fairly flat.

The shallow reflections recorded when shooting from SP18 to the east and SP19 to the west are similar in character, but arrive about 0.05 sec. later at SP19 than at SP18. This indicates another fault, with an estimated down-throw to the east of about 300 ft. on the eastern side of the Marilla Anticline.

From SP19 to the end of the traverse at SP35, the profile is generally flat, with exceptions between SP's 40 and 42, where west dip of 3° is recorded, and between SP's 43 and 45, where east dip of $2\frac{1}{2}^{\circ}$ is recorded.

Deep events (Greater than 2,500 feet).

Both the air shooting and the hole shooting show an almost complete lack of reflections immediately west of SP6 from depths greater than 2,500 ft., while from SP6 to SP9 there is an abundance of reflections. Some reflections from hole shooting at SP7 come from as deep as 11,000 ft. and are of good quality. The sharp change from numerous reflections to no reflections is evidence that the suggested fault between SP5 and SP6 in the shallow beds continues through the sections. SP's 6 and 8 provide the only reliable dip information for the beds below 2,500 ft. The events on these records consistently show east dip throughout the section from 2,500 ft. to 11,000 ft., the average dip value being approximately 5°. The shallow beds under these shot points are reasonably flat.

Elsewhere along the traverse, although many events have been plotted below 2,500 ft., the dips are so inconsistent that no definite conclusions can be drawn. The nature of many of the events is not known, since they do not appear to fulfil necessary conditions for either refractions or reflections. G.F. Francis, United Geophysical Company (1951) suggests that they may be due to reverberations within a relatively low-velocity layer.

Refraction Traverse "B".

The following table sets out the results obtained from this traverse. Possible errors, other than gross errors due to wrong assumptions, are velocity 5%, depth $\pm$ 20%, dip $\pm$ 20%.

Velocity of Refractor	Depth below SP.R1	Apparent Dip
6,330	10 ft.	
9,250	600 ft.	0.7° N.
11,600	3,340 ft.	4.8° N.
14,900	5,030 ft.	2.6° S.
17,600	7,160 ft.	1.4° S.
19,900	13,860 ft.	5.4° N.

CONCLUSIONS.

In relating these results to the main object of the survey, namely the nature of the structure underlying the Giralia anticline, it is seen that :-

(a) A shallow anticline corresponding to the Giralia Anticline exists to a depth of approximately 3,000 feet.

(b) There is a marked unconformity below this depth where, on Traverse "A", there is actually a syncline underlying the shallow anticline.

(c) There is an absence of reflections beneath S.P's 6 and 8 along Traverse "A" which is marked in the surface geology as an area of steep dips, and the absence of reflections is considered to be evidence of faulting.

(d) The results of Traverses "B" and "C" indicate that a section of at least 11,000 feet exists below the Giralia Anticline.

It is thus possible to offer the following comments on the alternatives to the tectonic nature of the structure. The surface structure is not repeated at depth and the Palaeozoic and Mesozoic-Tertiary sediments are not harmoniously folded. There is no obvious relation between deep and shallow structures. The seismic results do not indicate a basement core to the Giralia Anticline.

The seismic results indicate that the zone of steep dips shown at the surface on the eastern flank of the anticline is underlain by a deeper fault or a series of faults confined to a relatively narrow region.

On Traverse "A", faulting is indicated by the absence of reflections (a normal feature of a fault zone) and is also suggested by the steeply dipping reflection below SP5, which was recorded from SP11. This steeply dipping reflection could possibly be a reflection from a fault plane which, however, may have been misplotted owing to errors inherent in the plotting technique and in the velocity assumptions. Such evidence as there is suggests that there may be a fault plane dipping at approximately 55° to the west below the area of steep dips, but its exact location cannot be determined.

On Traverse "C", there is evidence of two relatively shallow faults between SP's 5 and 6 and between SP's 18 and 19.

Further information on the nature of the faulting might be obtained from refraction shooting along north-south traverses on each side of the supposed fault to obtain the depths to prominent refracting horizons which could be correlated, and along east-west traverses across the supposed fault to determine the throw.

The seismic work has shown that seismic methods are applicable in the investigation of possible oil-bearing structures in the Carnarvon Basin. It is clear from the results obtained on the Giralia Anticline, that investigation with a view to the selection of deep drilling sites cannot be carried out thoroughly without seismic surveys of selected areas.

REFERENCES

Condon, M.A., 1954 - Condensed progress report on the geology of the Carnarvon (N.W.) Basin, Western Australia. Aust. Bur. Min. Resour., Records 1954, No. 36.

Condon, M.A., Johnston, D., Perry, W.J., and Crespin, I., 1953 - Cape Range Structure, Western Australia. Aust. Bur. Min. Resour., Bull. 21.

Dooley, J.C., and Everingham I.B., 1954 - Detailed gravity survey of Rough Range Structure, near Learmonth, Western Australia. Aust.Bur.Min.Resour., Record in preparation.

Francis, G.F., 1951 - Personal communication.

Nettleton, L.L., 1940 - GEOPHYSICAL PROSPECTING FOR OIL, McGraw-Hill, New York and London.

Schneeberger, W.F., 1950 - Aust.Bur.Min.Resour., internal minute.

Thomas, G.A. and Dickens, J.M., 1954 - Discovery of Upper Devonian rocks in the Pelican Hill Bore. Aust. J. Science., 17(2),47.

Thyer, R.F., 1951a - Detailed gravity traverse, northern end Giralia Structure, N.W. Basin, Western Australia. Aust.Bur.Min.Resour., Records 1951, No. 68.

__________, 1951b - Gravity Reconnaissance (1950), N.W.Basin, Western Australia. Aust.Bur.Min.Resour., Records 1951 No.69.

__________, 1955 - Gravity Survey of the Coastal Plain Basin, Western Australia. Aust.Bur.Min.Resour., (Report in preparation).

Vale, K.R., 1951 - Report on Giralia-Bullara seismic reflection traverse, Western Australia. Aust.Bur.Min.Resour., Records 1951, No.62.

Vening Meinesz, F.A., 1948 - GRAVITY EXPEDITIONS AT SEA, 1923-1938 Vol IV Drinkerij Waltman (A.J. Mulder), Delft.

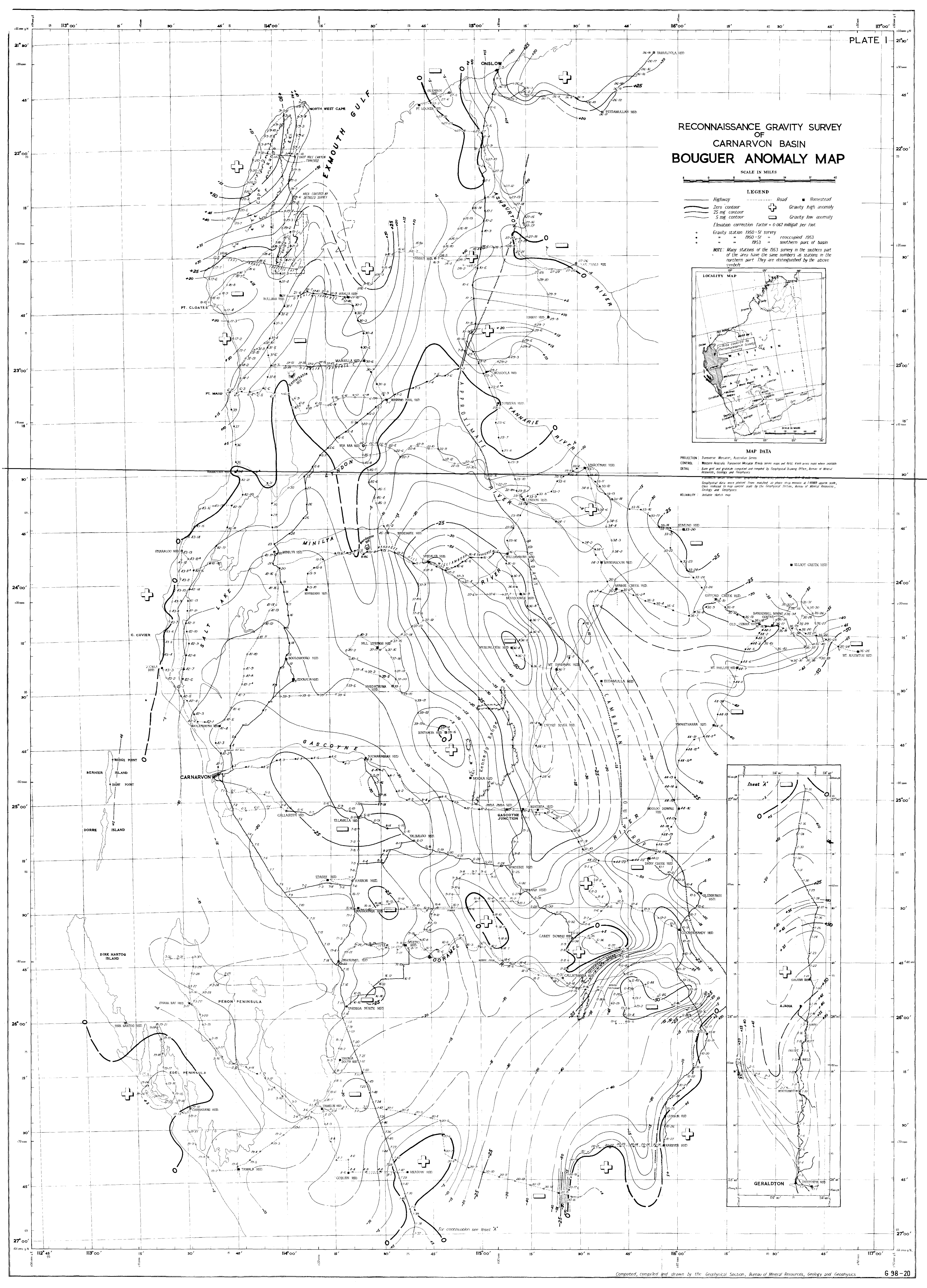
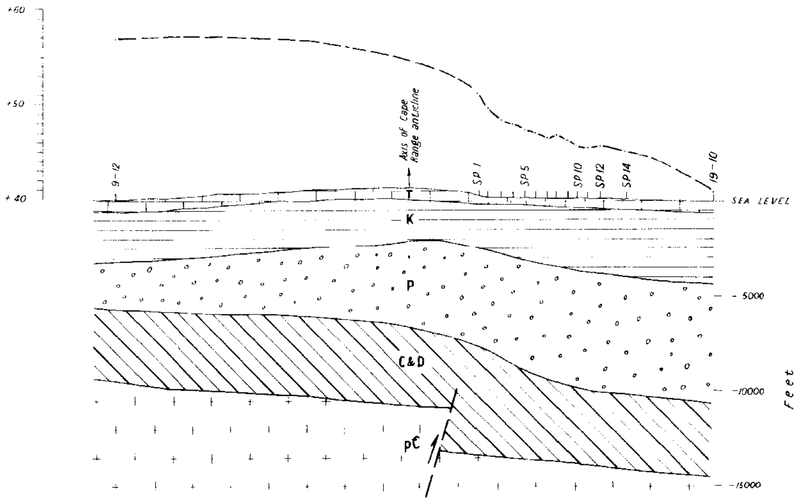


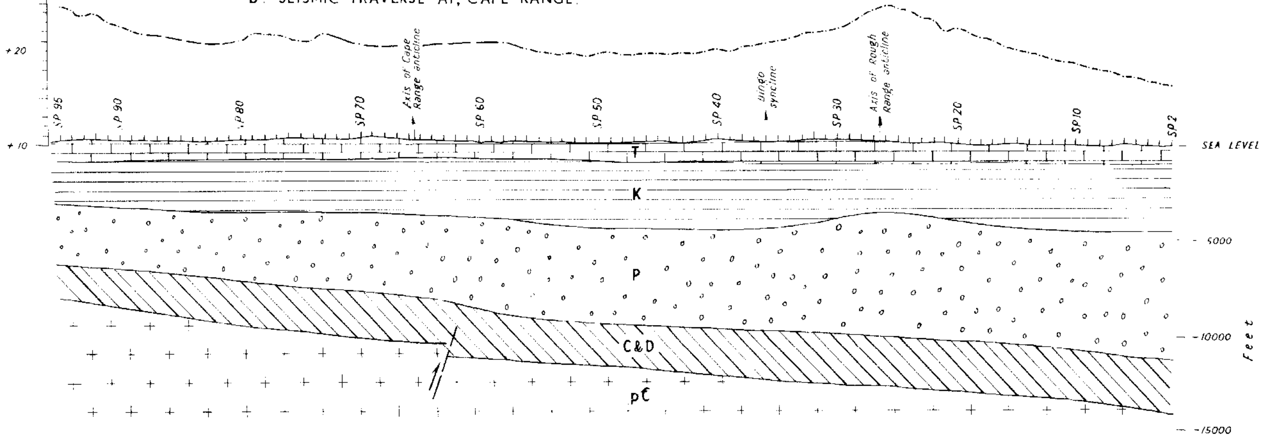
PLATE I
RECONNAISSANCE GRAVITY SURVEY
OF
CARNARVON BASIN
BOUGUER ANOMALY MAP
SCALE IN MILES
LEGEND
Highway
Road
Homestead
Zero contour
25 mg contour
5 mg contour
Gravity high anomaly
Gravity low anomaly
Elevation correction factor - 0·067 milligall per foot
Gravity station 1950-51 survey
" " 1950-51 " reoccupied 1953
" " 1953 " southern part of basin
NOTE: Many stations of the 1953 survey in the southern part of the area have the same numbers as stations in the northern part. They are distinguished by the above symbols
LOCALITY MAP
MAP DATA
PROJECTION: Transverse Mercator, Australian Series
CONTROL: Western Australia Transverse Mercator 10 mile series maps and R.A.S.C. 4 mile series maps where available.
DETAIL: Base grid and graticule computed and compiled by Geophysical Drawing Office, Bureau of Mineral Resources, Geology and Geophysics
Geophysical data were plotted from matched air photo strip mosaics at 1:49889 approx. scale, then reduced to map control scale by the Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics.
RELIABILITY: Reliable sketch map.
ONSLOW
EXMOUTH GULF
NORTH WEST CAPE
PT. CLOATES
PT. MAUD
C. CUVIER
CARNARVON
BERNIER ISLAND
DORRE ISLAND
DIRK HARTOG ISLAND
PERON PENINSULA
EDEL PENINSULA
ASHBURTON RIVER
YANNARIE RIVER
LYNDON RIVER
MINILYA RIVER
SALT LAKE
GASCOYNE
GASCOYNE JUNCTION
WOORAMEL
Inset 'A'
AJANA
GERALDTON
For continuation see Inset 'A'
Computed, compiled and drawn by the Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics
G 98-20

PLATE 2

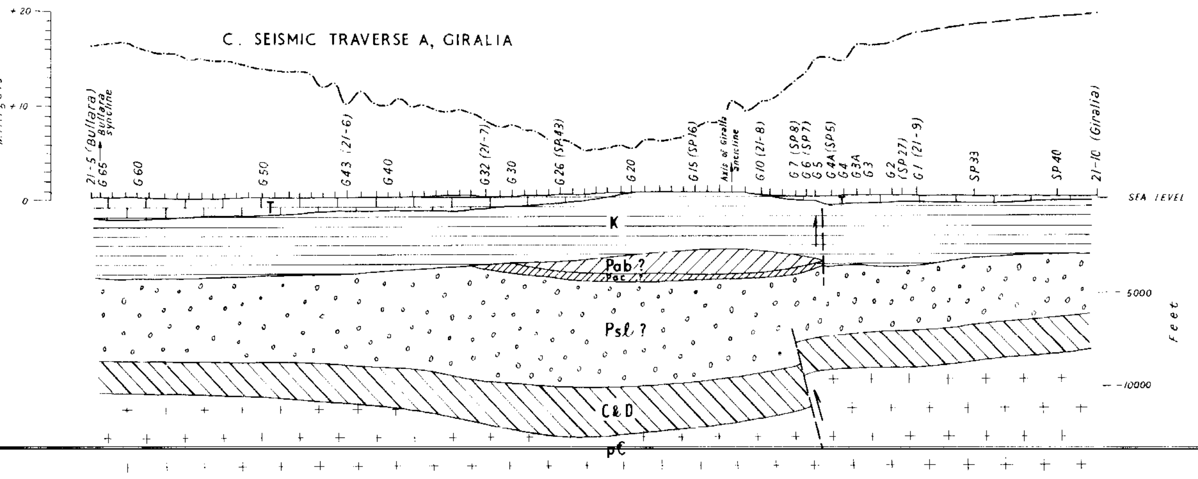
A. SHOT HOLE CANYON TRAVERSE, CAPE RANGE.



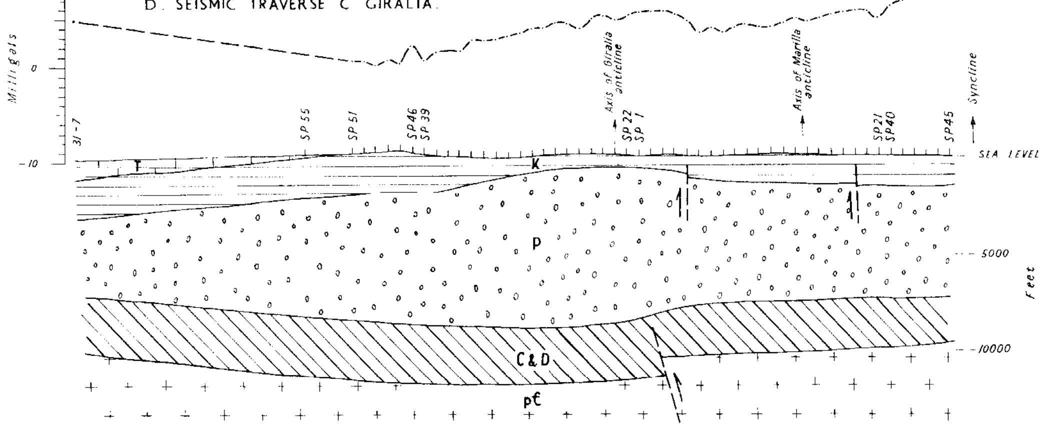
B. SEISMIC TRAVERSE A1, CAPE RANGE.



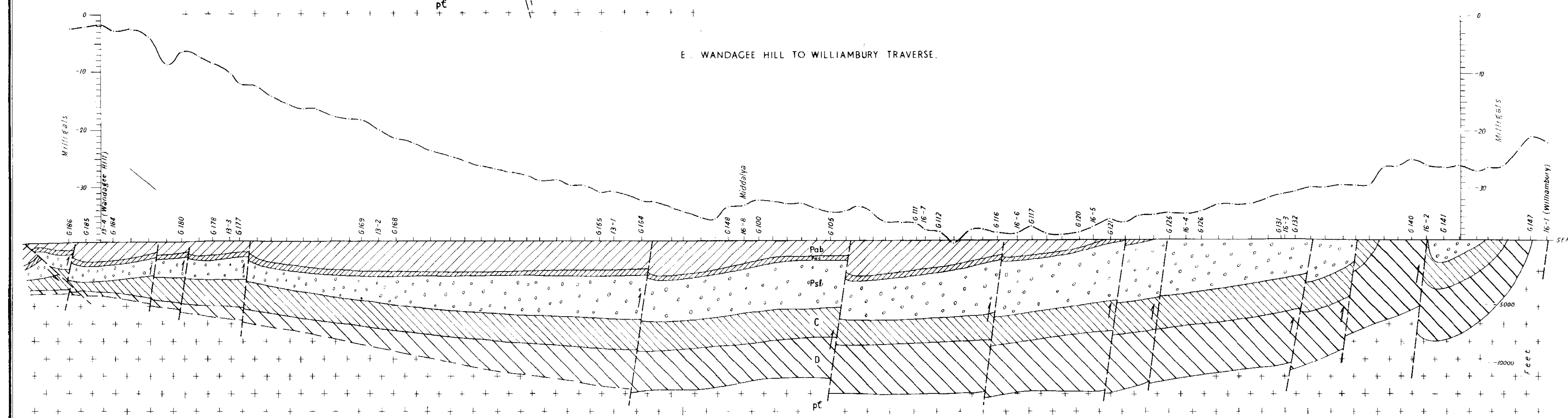
C. SEISMIC TRAVERSE A, GIRALIA

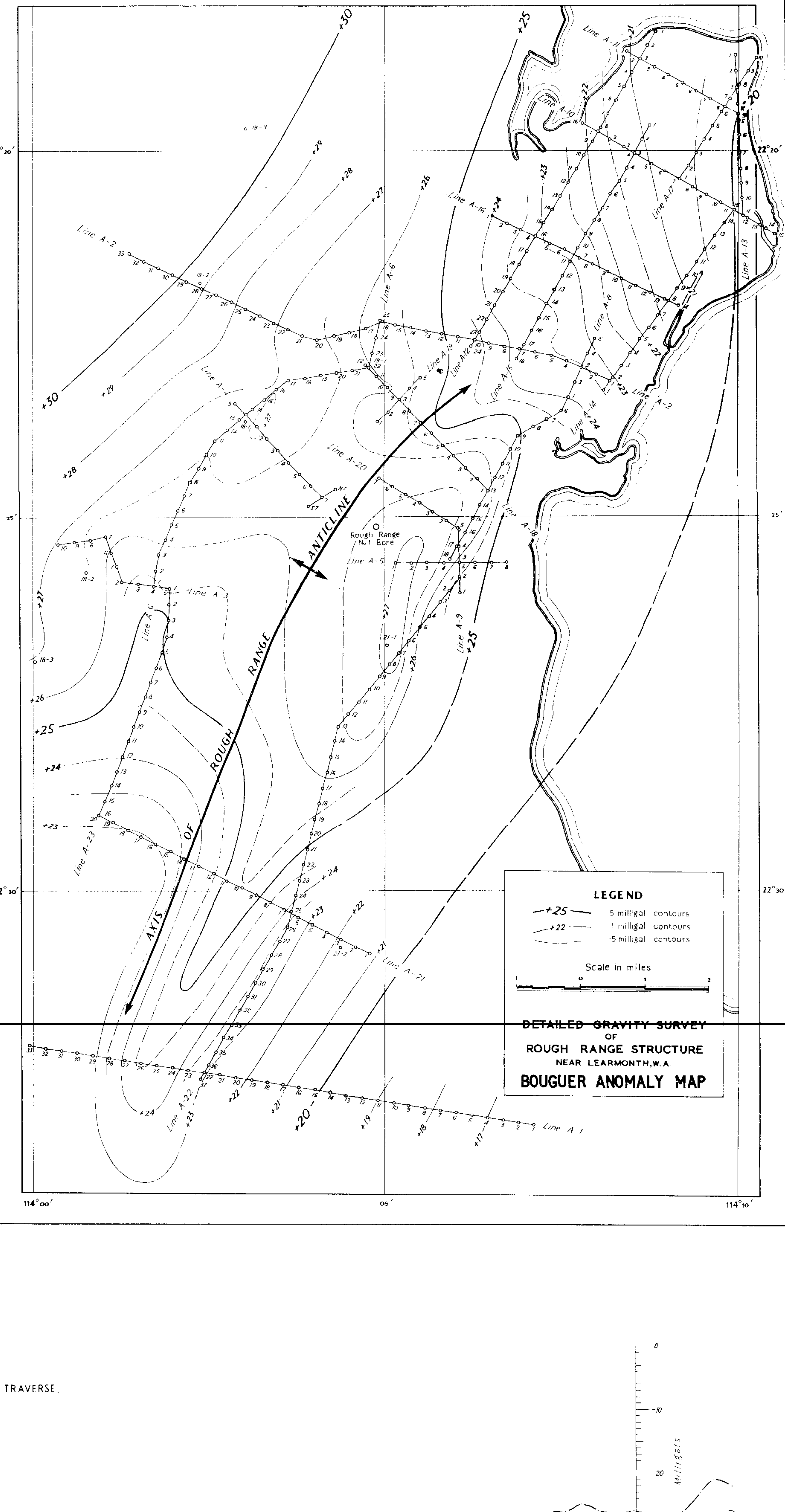


D. SEISMIC TRAVERSE C GIRALIA.



E. WANDAGEE HILL TO WILLIAMBURY TRAVERSE.





LEGEND

T	Tertiary
K	Cretaceous
C&D	Carboniferous & Devonian
C	Carboniferous
D	Devonian
P — Permian: Pab	Byro Group
P — Permian: Pac	Callytharra Formation
P — Permian: Psl	Lyons Group
pC	PRE-CAMBRIAN

NOTE:

Positions of detailed surveys are shown on Plate I.

The geological sections shown with the gravity profiles are not intended as strict interpretations of the gravity results. They are based mainly on the geological report (Rec. 1954/36), but have been modified to conform with gravity and seismic information. The modifications are not necessarily the correct interpretation, but should be regarded as suggestions.

HORIZONTAL SCALE IN MILES

2 0 2 4 6 8

CARNARVON BASIN
DETAILED GRAVITY SURVEYS

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics

G98-19


PLATE 3
DATUM LEVEL (100' ABOVE M.S.L.)
DEPTH BELOW DATUM LEVEL
5,000'
10,000'
7 MILE BREAK
TRAVERSE "A"
REFLECTIONS FROM AIR-SHOOTING
WITH ALL SHOT POINTS OFFSET 2400 FEET
GOOD
POOR
NOVEMBER 1951
K. R. Vale
Geophysicist
DATUM LEVEL (400' ABOVE M.S.L.)
TRAVERSE "C"
REFLECTIONS FROM AIR-SHOOTING
WITH SHOT POINTS OFFSET 3000 FEET
AND HOLE SHOOTING WITH SHOT POINTS
ON TRAVERSE
REFLECTIONS FROM HOLE SHOOTING
GOOD REFLECTIONS FROM AIR SHOOTING
POOR REFLECTIONS FROM AIR SHOOTING
JULY 1952
Geophysicist
SEISMIC REFLECTION SURVEY,
GIRALIA ANTICLINE, CARNARVON (N.W.) BASIN, W.A.
REFLECTION CROSS SECTIONS
SCALES
HORIZONTAL
VERTICAL
1000 0 1000 2000 3000 4000
FEET
Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics
G 98-23