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SOUTHERN GEORGINA BASIN SEISMIC SURVEY, NORTHERN TERRITORY AND QUEENSLAND 1965

by

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SUMMARY

Following a month of preliminary experimental seismic work in the latter part of 1964 the Bureau of Mineral Resources carried out a reconnaissance seismic survey of the southern part of the Georgina Basin, mainly in the Northern Territory, from April to October 1965. In most areas reflections proved very difficult to obtain. A number of different techniques were tried, including various shot and geophone pattern arrangements, noise testing, collinear offset shooting, airshooting and multiple coverage, but no technique was found which was generally successful in providing useful reflections. The seismic results tended to confirm gravity indications that there is a shelf area between BMR 12 Bore and Tobermory and provided no indications that there are deep Palaeozoic troughs similar to the Toko Syncline in the survey area.

1. INTRODUCTION

Since 1956, the Bureau of Mineral Resources has been carrying out reconnaissance geological and geophysical investigations of the Georgina Basin. The geological investigations have included a stratigraphic drilling program as well as the usual mapping, etc., and the geophysical investigations have consisted of aeromagnetic, gravity and seismic work.

Seismic work commenced in the Marion Downs - Toko Syncline area of the south-eastern part of the Georgina Basin in 1963 and continued through 1964. Objectives for these surveys had already been indicated by the previous geological and geophysical work; the main objectives were to investigate shooting conditions in an area where the Lower Palaeozoic formations are covered by a thin section of Mesozoic and Tertiary sediments, to investigate the extension to the south-east of the Toko Syncline as indicated by gravity work, and to make a stratigraphic tie between the supposed Upper Proterozoic sediments in the Canary Bore and the outcropping Upper Proterozoic sediments of the Sylvester Creek area.

The objective of the 1965 seismic survey was to obtain regional information on a large area in the southern part of the Georgina Basin which would assist in the interpretation of existing geological, gravity and aeromagnetic data in the area, with particular reference to petroleum prospects.

It was expected that seismic reflection or refraction traversing across the hard limestone and dolomite rocks of the Lower Palaeozoic formations, which cover a large portion of the Georgina Basin, would be difficult and might require unusual and involved techniques. For this reason it was decided that a seismic survey in this part of the Georgina Basin should commence with experimental work to develop a satisfactory technique for use in reconnaissance traversing. Therefore, in the last four weeks of the 1964 field season, experimental shooting was carried out on the Lower Palaeozoic carbonate rocks of the Georgina Basin near BMR 12 (Cockroach) Bore near the centre of the Tobermory 1:250,000 Series sheet to develop a useful technique for reconnaissance traversing in the Basin (Chenon, in prep). It appeared that, in the area where this experimental work was carried out, satisfactory results could be obtained using a fairly expensive technique.

In 1965 BMR Seismic Party No. 1 surveyed a number of reconnaissance traverses in the Southern Georgina Basin in the eastern portions of Tobermory and Sandover River 1:250,000 Series sheet areas and in the south-western corner of the Urandangi sheet. It was found that the area in which the experimental survey was carried out in 1964 was not typical of the region, but that useful reflection results were usually more difficult to obtain.

The survey commenced on 20th April 1965. Most of the survey was carried out from a camp 14 miles north-east of Cockroach Waterhole on the Tobermory sheet. For the last two months of the survey the party operated from a camp 5 miles south of Bulgera Waterhole on Gordon Creek. Field work was completed on 29th October 1965. Details of staff and equipment are given in Appendix A, and a number of statistics relating to the operation of the seismic party are presented in Appendix B.

2. GEOLOGY AND STRATIGRAPHIC DRILLING

Cambrian and Ordovician rocks occur over a large area of north-west Queensland and central-eastern Northern Territory. For the purpose of this report the Georgina Basin is understood to include all of those Lower Palaeozoic sediments occuring in the region of the Georgina River and its tributaries as well as in the Barkly Tableland to the north, and the Toko Range area to the south-east. It is bounded by areas of Proterozoic and Archaean rocks in the west, south-west and south, and the east, north-east and north. In the north-west and south-east the extension of the Georgina Basin Palaeozoic sediments are concealed below the Mexozoic cover.

The following discussion on the geology of the Georgina Basin is taken mainly from a report by Mulder 1961 which is based largely on work done by the Bureau of Mineral Resources and from Bureau reports.

Broadly speaking the Georgina Basin is a gentle north-west-trending elongated depression in the Precambrian basement filled with sediments ranging from lower Middle Cambrian to Ordovician age. The oldest predominantly elastic deposits crop out on the basin edges and are overlain and laterally replaced by mainly carbonate sediments in the more central parts.

Metamorphic rocks of the basement complex, presumably Archaean, occur south-west of the Georgina Basin as the Arunta Complex. Lower Proterozoic rocks form the more elevated parts of the country east and west of the Georgina Basin. In places they are metamorphosed due to the influence of larger granitic intrusions, but commonly they consist of non-metamorphosed quartzites, sandstones, arkoses and shales with minor intercalations of limestone and dolomite.

Upper Proterozoic sediments are separated from the Lower Proterozoic or Archaean rocks by a major unconformity. They consist mainly of arenaceous sediments which form pronounced topographical features. These sediments have been recognised in several areas of the Georgina Basin (Mulder, 1961), in particular along the southern edge of the Basin (Mt. Whelan, Hay River, Tobermory and Huckitta - 4 mile sheets). In this region, which is of interest to this report, various formations have been distinguished by B.M.R. geologists. The exact correlation of these formations has not always been established, and the sequence most probably includes several minor unconformities or disconformities. The presence of Collenia in some dolomite and limestone intercalations shows that the depositional environment was at least partly marine. A composite maximum thickness of about 7000 ft. of Upper Proterozoic and Lower Cambrian sediments is present in this area. Rapid changes in thickness, however, do occur. They are probably due to a strong relief of the erosional surface of the older Precambrian basement, and in most places the actual thickness is considerably less.

A major unconformity separates the Lower Cambrian rocks from the Cambro-Ordovician suite that is the main sedimentary sequence in the Georgina Basin. Petroleum accumulations are more likely to occur above, rather than below this unconformity, but the possibility of reservoirs within the Proterozoic sediments cannot be discounted. So far no Proterozoic source beds comparable to those known in the Amadeus Basin have been observed in the Georgina Basin region.

The Georgina Basin contains a considerable thickness of Cambrian and Ordovician sediments. The basal part of this sequence is formed by lower Middle Cambrian rocks. Three major rock-stratigraphic units have been distinguished (Mulder, 1961):-

(1) The Undilla Group : lower Middle - Upper Cambrian

(2) The Ninmaroo Group : upper Middle Cambrian - Lower Ordovician

(3) The Toko Group : Lower - Middle Ordovician

1. Undilla Group Within the Undilla Group Mulder recognised four lithological sequences which are to a large extent lateral equivalents. The first of these, the Thorntonia limestone, is the lowest stratigraphic unit of the Cambro-Ordovician sequence overlying unconformably Upper Proterozoic or older rocks. The Thorntonia Limestone which is confined to the eastern edge of the Sandover River and Boulia areas and is no more than 200 ft. thick consists of mainly greenish-brown dolomitized limestone, limestone and chert. The second unit, deposition of which occurred over most of the Georgina Basin, is the lower clastic facies of the Undilla Group consisting of basal conglomerates and breccias and thin-bedded, light-coloured siliceous shale or siltstone with minor intercalations of limestone in the higher parts. Bituminous calcareous shales have been reported in Isegam Bore and BMR 13. Thicknesses up to 865 ft. have been reported. The third lithological sequence, the main limestone facies of the Undilla Group, is generally exposed further away from the edges of the Georgina Basin and overlies and laterally replaces the lower clastic facies. The sequence consists of mainly well-bedded, locally dolomitic cream-and blue-coloured dense limestones which are in places dark and bituminous. Irregularly distributed chert nodules and stringers are abundant and in places more calcarenitic limestones

also alternate with calcilutites. Over 1000 ft. of section has been measured at the surface of Middle Cambrian Arthur Creek and Marqua Beds in the South Georgina Basin. In Tyson's Bore (South of Glenormiston), which started in Georgina Limestone, 1800 ft. of carbonate sequence was encountered without reaching its base. The fourth lithological sequence, the upper clastic facies of the Undilla group is known from the western rim of the Sandover River area and the northern part of the Boulia area. It is probably a local development wedging out basinward. This unit consists of reddish brown, weathered, thick-bedded impure sandstones and thin-bedded siliceous siltstones or shales. The thickness is probably less than 300 ft. Mulder estimates the total thickness of the Undilla Group as being in excess of 2000 ft.

2. Ninmaroo Group. The Upper Cambrian to Lower Ordovician Ninmaroo Group is characterised by predominantly dolomitic development as opposed to the limestone development of the Undilla Group. Cream-coloured saccharoidal dolomites and calcarenites replace the cream-and blue-coloured calcilutites of the Undilla Group. Sediments of the Ninmaroo Group occupy the more central parts of the Basin. They partly represent a lateral time equivalent of the upper part of the Undilla Group and partly overlie it. On top of the buried pre-Middle Cambrian highs the Ninmaroo may transgress directly on to the older rocks. The main carbonate facies of the group is characterised by the Ninmaroo Formation which outcrops in the Boulia and Sandover River areas and consists of well-bedded, alternate light cream-coloured saccharoidal dolomites, sandy dolomites, dolomitic sandstones, limestones and marls with local intraformational breccias. Dolomitization is highly irregular (Casey, 1960) and thicknesses up to 2200 ft. are known. The Arrinthrunga Formation which is known in the south Georgina Basin, is also characteristic, and consists of well-bedded, strongly-fractured dolomites, limestones and dolomitic limestones with interbedded sandstones and green siltstones up to 3000 ft. thick. A clastic facies development overlies the carbonate facies although in parts there is a lateral facies change from one to the other. These

consist of siltstones, sandstones, calcarenites, quartz sandstones, glauconitic sandstones, mudstones, siltstones, brown dolomites and limestones with a total thickness not in excess of 1000 ft. The total thickness of the Ninmaroo Group is probably not greater than 4000 ft.

3. Toko Group. The mainly clastic Middle Ordovician deposits of the Toko Group are known from the southern part of the basin in the Toko, Tarlton, and Dulcie Ranges. Like the underlying sequences it thickens to the south-east into the Toko Syncline. Sediments which are predominantly terrigenous and conformably overlie the Ninmaroo Group, consist of sandstone, siltstones mainly with some dolomite, shale, marl, coquinite and calcilutic limestone with a total thickness of about 1,000 feet.

A long period of stability followed the Middle Ordovician sedimentation and there is no further record of widespread deposition until the Upper Devonian. P.J. Jones (1963), however, reported the occurrence of coelolepid fish scales of Upper Silurian - Lower Devonian age in samples from shot holes in the Toko Range. About 2100 feet of Devonian Dulcie Sandstone, consisting of well-bedded, clean medium grained sandstone has been measured in the south-east-trending Dulcie Syncline. In the Huckitta area it overlies the Ordovician with a clear angular unconformity. The only direct evidence of this important erosional break which must occur at the base of the Dulcie Sandstone is loose blocks of conglomerate containing fossiliferous Ordovician sandstone found at the base of the capping sandstone. (K.G. Smith et al, 1960).

Seismic work by the Bureau of Mineral Resources in the south-eastern Georgina Basin (Robertson, 1964) showed the presence of up to 16,000 ft. of Ordovician - Devonian (?) sequence within the Toko Syncline. This indicates either a rapid thickening to the south-west of the known section or the occurrence of unknown Ordovician - Devonian section.

In the area between the Tarlton and Toko Ranges in the southern part of the basin (Tobermory and Hay River 1:250,000 series sheets) numerous mesas occur which consist of strongly laterised white siltstone and medium grained sandstone with scour and fill structures, some conglomerate and in places pale grey pebbly claystone with some boulders at the base (Smith and Vine, 1960). These beds which locally reach a thickness of more than 140 ft., unconformably overlie all older formations. Condon and Smith (1959) believed the formation to be partly of glacial origin (ground moraine) and on these grounds postulated a Permian age. This formation is called the Tarlton Formation.

Mesozoic rocks of both continental and marine origin occur as numerous laterite-capped mesas along the south-eastern margin of the Georgina Basin. In the Boulia area a coherent cover of Lower Cretaceous rocks is present, thickening rapidly towards the south and south-east into the Great Artesian Basin. These Mesozoic rocks form the main aquifer and the impermeable cap of the artesian sequence in the north-west of the Great Artesian Basin.

Tertiary sandstones and lacustrine limestones have been found scattered over most of the Georgina Basin area. They unconformably overlie Palaeozoic or Lower Cretaceous rocks.

The major fold axes in the Lower Palaeozoic sediments trend north-west. The folding appears to be stronger south of an east-west line running through Glenormiston Homestead, and minor and almost monoclinal cross folds run east-west. Both Palaeozoic and Mesozoic rocks have been folded and faulted although the main movements took place before deposition of the Cretaceous sediments. The minor structures which are common in the Lower Cretaceous beds in the Boulia and Glenormiston areas are generally reflections of displacements along the main structural trends of the older rocks below them. Major tectonic activity had been completed before the Tertiary, and the youngest rocks have only a slight regional tilt to the south.

The occurrence of bituminous carbonates and shales within the Lower Palaeozoic sequence has already been mentioned. Siltstone, soft argillaceous limestone, and dense limestone beds within the carbonate sequence could form cap rocks. Time breaks however occur within the carbonate sequence and in places the siltstone of the

Swift Formation and the Kelly Creek Formation overlies the carbonates disconformably. Hydrocarbons from the carbonates may thus have escaped before the siltstones were deposited. Apart from the Mesozoic sandstones the only possible reservoirs are in the older carbonate rocks, particularly in the dolomitized zones where vughs are numerous, in intraformational breccias and in limestones which have become sheared and faulted. Basal sands may occur at depth near the basement ridges over and along which the Lower Palaeozoic seas transgressed.

A few stratigraphic test bores have been drilled in recent years in the Georgina Basin. Lake Nash No. 1 Bore (Amalgamated, 1963) which was drilled on the Lake Nash Anticline, was plugged and abandoned at 1315 ft after penetrating 995 ft of Cambrian carbonate rocks and 320 ft of probable Proterozoic sedimentary rocks. A dolomitic unit from 790 ft to 995 ft contained viscous tar but no drill stem test was carried out over this interval.

B.M.R. 11 (Cattle Creek), on the Barkly Highway 23 miles west of Camooweal, was drilled by the Bureau to a total depth of 1501 ft after considerable trouble with loss of circulation. The succession drilled was mainly carbonates to 1420 ft after which a quartz sandstone and pebbly quartz sandstone ferruginised at the base was encountered. No velocity data was obtained, but electric, gamma ray and neutron logs were run.

B.M.R. 13 (Sandover River) was drilled to a total depth of 3330 ft. Precambrian gneiss was reported from 3300 ft and granite from 3328'. The section overlying this was Middle Cambrian to Upper Cambrian, mainly carbonate rocks. Oil shows were reported from a low velocity zone encountered on the sonic log between 2950 and 2980 ft and shown on the cuttings description log as a shale between 2950 ft to 2975 ft. Attempts to carry out a drill stem test were not successful. Electric, gamma ray, sonic, and microcaliper logs were successfully run to total depth.

B.M.R. 12 (Cockroach) was drilled in 1964 near Cockroach Waterhole on the main road 25 miles east of Tarlton Downs (see Plate 1) to a total depth of 4,000 feet. This bore first penetrated 500 feet of Upper Cambrian - Lower Ordovician Ninmaroo Formation then passed into the Upper Cambrian Arrinthrunga Formation (Ninmaroo Group) consisting largely of limestones and dolomites and finally into Middle (?) Cambrian Marqua Beds at 2720 feet. Electric, gamma ray and sonic logs were run to 3990 ft. A well velocity survey in B.M.R. 12 was carried out by BMR Seismic Party No. 1 in November, 1964 during the course of an experimental survey in the area. Velocities derived from the velocity survey and integrated sonic log are shown on Plate 5.

P.A.P. Netting Fence No. 1 was drilled by Mines Administration Pty. Ltd. on the small Netting Fence Anticline structure in the south-western corner of Glenormiston 1:250,000 Series sheet. The sediments penetrated were predominantly Cambro-Ordovician limestones and dolomites. Granite was encountered at about 6,600 ft. and the hole was abandoned at a total depth of 6,664 ft. Laterolog, microlaterolog, gamma ray and sonic logs were run in the hole to total depth.

Alliance Mulga No. 1 was drilled in 1965 on the Sandover River 1:250,000 Series sheet (see Plate 1) by Alliance Petroleum Australia N.L. to a total depth of 3003 ft. The bore is believed to have penetrated 16 feet of Quaternary deposits, 174 feet of Ninmaroo Formation, 1524 feet of Arrinthrunga Formation, 260 feet of Marqua Beds and 1029 feet of Upper Proterozoic sediments. Electric, gamma ray, neutron, sonic and caliper logs were run to a depth of about 2600 ft.

PREVIOUS GEOPHYSICS.

Aeromagnetic Surveys

The Bureau of Mineral Resources has carried out aeromagnetic reconnaissance surveys in 1958, 1963, and 1964 in the Georgina Basin and adjacent areas.

The 1958 survey (Jewell, 1960), consisted of a series of widely spaced traverses in the western part of the Great Artesian Basin and included the south-eastern part of the Georgina Basin. The results showed a good qualitative agreement with the known general structure of the basin and the main gravity anomalies.

In 1963 the Bureau of Mineral Resources started an aeromagnetic survey of the Georgina Basin with the object of obtaining the thickness of the sedimentary section (Wells and Milsom, 1965). The Mt. Isa, Elkedra, Sandover River, Urandangi, Glenormiston and Tobermory 1:250,000 sheets were completed using east-west flight lines spaced at two mile intervals. The remainder of the basin, covering the Mt. Drummond, Lawn Hill, Ranken, Camooweal, Frew River, Avon Downs, Huckitta, Mt. Whelan and part of Walhallow and Alroy 1:250,000 sheets, was completed in 1964. In addition the northern half of Illogwa Creek and Hay River 1:250,000 sheets to the south of the Georgina Basin were surveyed using flight lines of 4 mile spacing, to effect a tie between the Georgina Basin and Simpson Desert surveys.

There are problems in interpreting the aeromagnetic results in the Georgina Basin (Wells, Tipper and Milsom, 1964). Surveying of the basin margins has shown that much of the Proterozoic sedimentary sequence is magnetically indistinguishable from the Palaeozoic, and is considerably thicker in many places. Deep magnetic basement is considered to be variously the Archaean or overlying magnetic strata within the Lower Proterozoic. Magnetic basement contours therefore indicate depth to an uncertain stratigraphic level, above which are sediments of both Proterozoic and Palaeozoic age, which cannot be distinguished. Further, the regions of deeper basement yield few anomalies suitable for reliable depth estimation, consequently the control is inadequate for contouring in many places which might be of interest in the search for oil. Nevertheless the aeromagnetic results do provide some regional data which will assist in the planning of future geophysical investigations.

The eastern margin of the basin is clearly defined by shallow basement contours on the eastern edges of the Mt. Isa, Urandangi and Glenormiston 1:250,000 sheets. The shallow contours are parallel to the outcropping Lower Proterozoic sediments and the continuation of the contours to the south suggests the extension of the shallow basement below the Mesozoic and Palaeozoic cover.

The southern margin of the Georgina Basin in the extreme south of the Tobermory sheet, which is an area of outcropping granite, coincides with an east-west trending depression indicated on the magnetic basement contour map, the deepest part of which is shown to be 8000' below sea level. It is thought (Wells, Tipper and Milsom, 1964) that the smooth magnetic profile obtained in this area, which would normally indicate a deep sedimentary section in depth computations, is due to the granite having a highly uniform magnetisation near the surface.

Shallow basement is shown over most of the Elkedra sheet in the north-west of which there are granite and Lower Proterozoic outcrops. The magnetic basement deepens to 4000 feet below sea level in the extreme south-east corner of the Elkedra sheet. The depth to basement of approximately 3000 ft indicated on the contour map in this area at BMR 13 compares with the depth of 2240 ft below sea level at which Precambrian gneiss was encountered in the bore. Highly disturbed magnetic profiles, indicative of shallow basement, extend from the Elkedra sheet into the north-west of the Sandover River sheet. Further east, however, the magnetic field varies much more gently and the anomalies are generally of low amplitude. The boundary between these two provinces, which occurs on the Sandover River sheet, is sharply defined and characterised by a fall in the general magnetic level to the east. The boundary is roughly semicircular in shape, concave to the east and skirting the central and south-eastern portions of Sandover River sheet. To the west of the boundary anomalies are common and basement contours may be drawn with some confidence, although sources below the basement surface appear frequently. The basement here is considered to consist of Lower Proterozoic rocks similar to those outcropping in the Davenport Ranges, as the profile pattern from the ranges to the boundary discussed above is continuous. It is not considered likely that Upper Proterozoic sediments are developed in this area but they probably occur east of the boundary.

East of this boundary anomalies are more widely separated, are of lower amplitude and give widely fluctuating depth estimates. In many cases the sources are shallower than would be expected from the generally smooth profile pattern around the anomaly.

It is possible that these shallower sources are lenses of volcanic rocks occurring within a sedimentary sequence of considerable thickness, in which case two magnetic horizons are present. However, if such lenses exist it is unlikely that they are younger than Proterozoic, consequently depth estimates based on the anomalies to which they give rise would indicate the greatest possible thickness of Palaeozoic sediments. Another possible interpretation would be that these shallower sources are within the Palaeozoic sequence, in which case quite large thicknesses of prospective sediments might occur in areas where shallow basement depths are indicated. The latter possibility is unlikely since no volcanic rocks have so far been observed in the Palaeozoic.

The basement contours deepen steeply to the south-east on the Sandover River sheet across a north-east trending line where a possible fault has been interpreted. There is an alternate explanation of this steep gradient. Since the shallower anomalies mentioned above are not seen in the region of the trough in the south-east of Sandover River sheet, it could be concluded that the volcanic rocks forming the upper of the two magnetic horizons previously referred to have pinched out to the south-east. On the other hand if there is a genuine, abrupt increase in the thickness of the sedimentary sequence both magnetic horizons could still be present at depth. This latter hypothesis gains some support from the fact that there is evidence for more than one magnetic horizon within the trough. The steep gradient of the depth contours along the north-west wall of the trough could well represent a fault with a throw of about 2000 ft.

The deep basement development in the south-east of the Sandover River sheet is part of a large, irregularly-shaped depression extending into the south-west of the Urandangi sheet and into adjoining corners of the Glenormiston and Tobermory sheets in which magnetic basement is estimated to be at depths of 8000 ft. below sea level. It was expected that Upper Proterozoic sediments would be developed in the trough and Alliance Mulga No. 1 Bore appears to confirm this. Nevertheless the aeromagnetic results suggest that this large depression holds more promise of oil accumulations than any other area surveyed in the Georgina Basin, apart from the Toko Syncline.

This Sandover River - Urandangi Depression is separated in the south-east by an east-west trending basement ridge from two smaller depressions known as the Tobermory and Glenormiston Depressions. These two depressions, which are 8000 ft and 10,000 ft deep respectively, are separated by a small north-east-trending basement ridge. Netting fence No. 1 Bore was drilled near the south-western margin of the Glenormiston depression. Granite was encountered in the bore at a depth of 6,600 feet. This agrees fairly well with the basement depth estimate of about 6,000 feet from the aeromagnetic profiles in this area.

There is a small magnetic basement depression estimated to be 6,000 feet deep north-east of Tarlton Downs homestead on the Tobermory 1:250,000 sheet. B.M.R. 12 bore was drilled to 4,000 ft on the eastern side of this depression, where aeromagnetic results suggest magnetic basement is at about 4,000 ft. In B.M.R. 12, 1,280 ft of Middle Cambrian sediments were penetrated and the bore finished in these. The maximum known thickness of Middle Cambrian in the region is 1500 ft, so that it is likely that the base of the Palaeozoic section occurs at less than 4,500 ft. The aeromagnetic results therefore suggest that little or no Upper Proterozoic section is present in this area, as this generally behaves magnetically in a manner indistinguishable from the Palaeozoic.

Gravity Surveys

Gravity surveys were carried out in Western Queensland and south-eastern Northern Territory by the Bureau of Mineral Resources from 1957 to 1961 including both ground traverses and helicopter reconnaissance surveys. (Gibb, 1965?, Barlow, 1965?, in prep.). Mines Administration Pty Ltd in 1959 carried out a semi-detailed gravity survey in Western Queensland covering parts of the Georgina Basin on behalf of Papuan Apinaipi Petroleum Company Ltd (P.A.P., 1960). The results of these surveys, which cover much of the Georgina Basin and part of the Great Artesian Basin, have been compiled in the form of a composite Bouguer anomaly map (Barlow 1965? in prep.) In the following discussion the names of the gravity units are those revised by Vale (1965) except in cases where an author's name is quoted after the unit.

As noted by Gibb (1964) an overall assessment of the Bouguer anomaly picture of the Georgina Basin immediately indicates that the eastern boundary of the Georgina Basin is well expressed as a distinct north-north-west gravity gradient continuous over a distance of more than 200 miles along the western edge of the Cloncurry Regional Gravity High. Extending over an even longer distance is the north-west trend in contours which follows the south-west boundary of the basin. This trend described by Lonsdale and Flavelle (1962), is expressed in the Caroline Gravity Ridge and also in the Hay and Huckitta (Barlow, 1965) Gravity Lows which accompany this gravity ridge on its north-eastern side. The region bounded by these trends forms the southern portion of the Georgina Basin.

In the south-east corner of the region the Toko Syncline is well expressed as a gravity low which suggests the syncline extends well to the south-east of the outcrop area. This is bounded to the west by a gravity 'high' named the Field Gravity Spur, which diverges from the Caroline Gravity Ridge.

Further to the north, an area of low gravity relief, the

Tobermory Gravity Shelf, occupies nearly all of Tobermory four-mile sheet and extends over considerable portions of the neighbouring 4-mile sheets.

The Tobermory Gravity Shelf is bounded to the north-west by the Sandover Gravity Low, which covers most of Sandover River 4-mile sheet, and in turn is bounded to the west by the Ooratippra Gravity High which occurs mainly on the eastern part of the Elkedra 4-mile sheet.

The gravity relief in the western part of the Elkedra 4-mile sheet is not pronounced but there is evidence for the existence of a ridge of high values of gravity in the Davenport Range area. This ridge separates a region of low gravity values, the Frew River Gravity Low, (Barlow, 1965) in northern Elkedra sheet, and probably most of Frew River sheet, from the gravity low which is the expression of the Ammaroo Sub-basin centred in the Huckitta sheet area. This sub-basin is bounded to the south-west by the western-most extension of the Caroline Gravity Ridge.

The interpretation of gravity data in the Georgina Basin is complicated by the relatively small density contrast which can be expected to exist between the Cambrian limestones and the basement (2.7 to 2.8 gm/cc and 2.5 to 2.8 gm/cc respectively). The densities of Proterozoic sediments, Upper Cambrian sandstones and post-Cambrian sediments are lower, but in some cases only slightly lower, than these. Further difficulties arise because of the existence of numerous local gravity anomalies, bounded by strong gravity gradients, in areas of outcropping Precambrian rocks. For this reason lateral density variations of considerable magnitude must be inferred to occur within the basement rock complex, composed of metamorphics into which numerous types of basic and acid igneous rock have been intruded. Moreover the very dense dolomites of the region alternate with lighter sandstones, and these near-surface facies changes tend to mask effects due to basement features.

Notwithstanding these difficulties, which originate from complex lithology, the gravity data are of considerable value in delineating the geological margins of the Georgina Basin, in assessing the broader structure of the Basin and in establishing major structural features associated with sedimentary rocks which occur within the basin. Because of the considerable, though different, problems which apply to interpretation of the gravity and aeromagnetic results in the region, it is useful to compare the interpretations arrived at by these two methods, each of which serves as a check on the other.

The eastern margin of the Southern Georgina Basin is marked by a strong gravity gradient interpreted (Gibb, in prep.) as the gravity expression of the western limit of the Precambrian Cloncurry Fold Belt under transgressive Palaeozoic sediments of the Georgina Basin. Aeromagnetic results and gravity are in good agreement in this area in delimiting the Basin.

The distinct and persistent north-west gravity trend evident in the extensive zone of the Caroline Gravity Ridge and the group of gravity lows which accompany it to the north-east is tentatively interpreted as indicative of a major tectonic feature of a lineament type. In the westernmost portion of this gravity ridge the gravity 'highs' are known to occur over outcropping Archaean rocks of the Arunta Complex. The gravity 'low' north of the 'high' appears to be mainly caused by extensive intrusions of huge masses of granite into metamorphic rocks of Archaean age.

As a whole, the distorted zone comprising the Caroline Gravity Ridge and the adjacent chain of gravity lows is interpreted as the gravity expression of a major basement ridge of raised Archaean rocks occurring on a line of tectonic weakness, into which liquid masses of various types of magma, but mainly of granite, have been intruded. The north-eastern limit of the Hay Gravity Low, adjacent and parallel to the Caroline Gravity Ridge, agrees well with magnetic basement contours in defining the south-western margin of the Southern Georgina Basin.

The Tobermory Gravity Shelf covers a large part of the Tobermory 1:250,000 sheet. It is interpreted as a region of generally shallow basement with depth of basement of the order of 3,300 feet, a figure which agrees well with magnetic basement depth estimates for the region.

The Sandover Gravity Low covers much of the Sandover River 1:250,000 sheet, but notably reaches its maximum intensities in the northern half of the sheet. It is interpreted as a somewhat depressed area containing Palaeozoic sediments of increased thickness. However it has been suggested (Barlow, in prep.) that the gravity minima in the north-western and south-western corners of the Sandover River sheet in association with the Ooratippra Gravity High might be an expression of the margin of a high-standing complex of basement rocks rather than the result of sedimentary depressions.

In the south-east of the Sandover sheet, where the aeromagnetic results suggest a deep sedimentary depression bounded on the north-west by a possible fault, the gravity values are more similar to those on the Tobermory Gravity Shelf. In this area the most obvious gravity and aeromagnetic interpretations are in disagreement. However, Alliance No. 1 Bore in the south-east of the Sandover River sheet indicated that the Ninmaroo Formation, Arrinthrunga Formation and Marqua Beds were all considerably thinner than at BMR 12 on the Tobermory sheet, so that a northward extension of the Tobermory Gravity Shelf Area of shallow Proterozoic basement into this area seems likely.

There are two small gravity minima in the south-west of Urandangi sheet and north-west of Tobermory homestead which are overlapped by larger areas of magnetic basement depression. These are likely areas of increased thickness of sediments. However there is no gravity low corresponding to the Glenormiston magnetic depression north of Netting Fence No. 1 Bore. On the contrary the gravity results suggest an extension of the Tobermory Gravity Shelf into this area.

The Toko Syncline is well expressed in both gravity and aeromagnetic results. The Field Gravity Spur runs parallel to the Toko Syncline on its south-west margin on the Mt. Whelan and Hay River 1:250,000 sheets, but to the north, on the Tobermory and Glenormiston sheets, the Spur fans out across the projected axis of the Toko Syncline. Consequently, from gravity data it appears that, as a deeply depressed trough, the Toko Syncline does not extend beyond the north-west corner of Mt. Whelan sheet. Nevertheless, because of the high density of the Cambrian limestones, the gravity data would not exclude the possibility that a relatively shallow syncline with Cambrian sediments extends onto the south-east of the Tobermory sheet, as indicated by geological mapping. The gravity expression of the Toko Syncline on the Mt. Whelan sheet is much more pronounced because of the lesser density of the Middle and Upper Palaeozoic rocks which occur in that portion.

The aeromagnetic results indicate a continuous though weakening magnetic basement depression from the Toko Syncline proper across the Field Gravity Spur to the south-east corner of Tobermory sheet. This magnetic depression is somewhat south of the north-west extension of the Toko Syncline mapped by geologists, so that it is unlikely that it represents a sedimentary depression.

Seismic Surveys

Apart from the short experimental seismic survey carried out by the Bureau near B.M.R. 12 Bore in 1964 as a prelude to reconnaissance surveying in the region, no previous seismic work had been conducted in the region of the Southern Georgina Basin where the 1965 survey was carried out.

To the north of the survey area the Bureau of Mineral Resources in 1961 carried out experimental and reconnaissance seismic work in the Undilla Basin north-east of Camooweal, Queensland (Robertson, 1963).

A number of seismic surveys have been carried out in the south-east Georgina Basin. Papuan Apinaipi Petroleum Co. Ltd and Phillips Petroleum Co. conducted work in 1960-1961 in the Springvale, Boulia and Toko Range areas. (Phillips, 1961). Also in 1960 the South Australian Department of Mines conducted a Seismic Survey in the Great Artesian Basin in South Australia and in Queensland as far north as Boulia (Milton, 1961). In 1963 and 1964 surveys were carried out by the Bureau of Mineral Resources in the Springvale, Mt. Whelan and Bedourie 4 mile sheet areas (Robertson, 1965, Jones, 1965). In 1963 the French Petroleum Company (Aust.) Pty Ltd started a reconnaissance seismic survey which extended across the southern part of the Simpson Desert from South Australia to the Annandale - Sandringham region of Queensland. This survey was continued in 1964 as a semi-detailed seismic survey in the Bedourie area. (French Petroleum Co., 1964).

The Bureau of Mineral Resources seismic survey in the Undilla Basin in 1961 encountered a number of technical difficulties in applying the reflection and refraction seismic methods, due to the occurrence of Middle Cambrian limestones and Camooweal dolomite near the surface.

Reflection work in the area was difficult because of the large amount of surface noise generated by the shots and because the coherent noise waves generated have higher velocities and greater wave lengths than in most areas with the result that normal length multiple-geophone patterns are less effective in reducing them. Air-shot patterns were found to be quite effective in reducing high-frequency noise, particularly on the earlier part of the records.

It was considered, after experimentation, that single-deep hole shots and patterns of shallow shots should both be effective in improving record quality if they were offset about the same distance (2000') as the airshots were (Robertson, 1963). Patterns of holes about 150 ft deep drilled on the traverse line were also considered likely to be effective, but extremely hard drilling conditions would make progress slow with such deep holes.

The refraction method generally depends for its success on the occurrence of a number of rock layers whose refraction velocities become successively greater with depth. In the Undilla Basin refraction velocities of about 17,000 ft/sec are recorded from the Cambrian limestones close to the surface. The surface limestones act as a screen preventing useful information from being obtained below them by refraction methods unless refractors with unusually high velocities (e.g. 20,000 ft/sec) occur. Such refractors were apparently recorded in the area, but it was not certain what they represented. The most likely interpretation is that they represent an horizon near the top of Proterozoic rocks.

In the work carried out by Phillips Petroleum Co. in the Netting Fence area (Mt. Whelan sheet) of the Toko Syncline split spreads of 950'-0-950', between 4 and 32 geophones per trace, 1 to 5 shot holes per shot pattern, and shot point spacing of between a quarter of a mile and one mile were used. Correlation reflection shooting was reported to give satisfactory results where the surface outcrop was the Middle Ordovician Mithaka Shale formation, poor results over the Carlo Sandstone outcrops (only 6 shot points shot) and entirely unsatisfactory results over the Lower Ordovician Ninmaroo carbonate rocks.

A well-defined structural high in Cambrian and Ordovician rocks was indicated around 22°55' south and 138°02' east. The closed area covers about two square miles, and maximum closure is about 250 ft. About 6500 ft of section was suggested by seismic results. The seismic structure corresponds closely with a definite, surface feature (Netting Fence Structure). South-east of the above feature uniform south dip based on reliable data persists through the area surveyed. The Netting Fence Structure was drilled in 1964 with the results already indicated (see Section 2, Geology and Stratigraphic Drilling).

The greater part of the S.A. Department of Mines Seismic Survey in 1960 was carried out south of Breadalbane outside the area of interest of the present survey. One refraction line of interest however was shot at Boulia, north of the main survey, and a refractor of velocity 18,000 ft/sec at depth of 300 ft was obtained, which was interpreted as early Palaeozoic carbonate rocks.

The main objectives of the seismic surveys carried out by the Bureau of Mineral Resources in the south-eastern Georgina Basin in 1963 and 1964 were to investigate the possible extension of the Toko Syncline to the south-east beyond the Toko Range outcrop area, to attempt a tie between outcropping Upper Proterozoic sediments near the head of Sylvester Creek and supposed Upper Proterozoic sediments in Canary No. 1 Bore and to investigate shooting conditions and techniques required in areas where Lower Palaeozoic formations are covered by a thin section of Mesozoic and Tertiary sediments.

The investigation of the Toko Syncline was facilitated by the occurrence of a very good reflection which was identified, by cores from shot holes on the eastern flank of the syncline, with the Lower Ordovician Ninmaroo Formation. A sedimentary thickness in excess of 16000 ft near the axis of the Toko Syncline was demonstrated. In the Toko Syncline, with the exception of areas which were probably very disturbed tectonically, good results were obtained using 5 to 7 holes per shot drilled in line along the traverse to a depth of 45 feet and 16 geophones per trace in line. The surface formations were Mesozoic to Recent in age and easy to drill.

On the other hand no reflections were obtained using similar techniques on outcropping Lower Palaeozoic formations east of Herbert Downs. It was found from there southwards that the Lower Palaeozoic sediments under thin cover do not contain adequately thick and persistent high velocity layers which can be used as reliable refraction markers over appreciable distances. It was shown that it is possible to obtain reflections between Marion Downs and Canary, where there is a thin cover of several hundreds of feet of Mesozoic cover, using 5-hole shot patterns and 16 to 32 geophones per trace. It was also shown that a sedimentary section exists between Marion Downs and Canary but poor results at a few places made correlation across this interval very difficult.

The results of the 1963-1964 seismic survey carried out by the French Petroleum Co. (Australia) Pty Ltd in the Bedourie area are similar to those obtained by the Bureau during the above surveys. The good quality Ninmaroo reflection defines the southern extent of the Toko Syncline, and can be correlated up the eastern flank of the syncline to a possible north-south-trending boundary fault. This fault coincides with a similar trending steep gravity gradient. To the east of the fault reflections are confined mainly to the Mesozoic section and only occasional deeper reflections from within the possible Palaeozoic section are obtained.

The seismic survey of the most immediate interest to the 1965 programme is the Bureau's experimental seismic survey near B.M.R. 12 (Cockroach) Bore, undertaken in the last four weeks of the 1964 field season as a necessary preliminary to the broader programme of reconnaissance surveying to be carried out on large areas of outcropping Lower Palaeozoic sediments. The location of the 1964 experimental traverse is shown on Plate 1 near Traverse A. The main conclusions reached as a result of the experimental survey may be summarised as follows:-

(a) The character of seismic noise in the test area was unusual; there was much incoherent, high frequency noise but little low frequency organised noise.

(b) Noise tests and tests of various shot and geophone arrangements indicated that the best solution for improving reflection quality was to use large areal patterns of holes and geophones (e.g. 25 holes and 32 geophones) designed to reduce random noise.

(c) The optimum shooting depth seemed to be about 30 feet, or a few feet into the first high velocity layer.

(d) Using the optimum shot and geophone arrangement determined it was possible to obtain satisfactory reflections in the area tested from depths of up to about 4000 to 4500 feet, which probably represents the thickness of prospective sediments in this area.

(e) The spectrum of the records, including the reflected signals, was high frequency so that high pass filter bands were necessary both in recording and playback.

(f) Measurement of surface parameters indicated that the thickness of the weathered layer varied considerably over intervals of about a mile, despite only minor elevation changes.

(g) Drilling was very slow once the first layer of high velocity material was reached.

4. OBJECTIVES OF SURVEY AND PROGRAMME OF WORK PLANNED

The broad objectives of the Southern Georgina Basin Seismic Survey in 1965 were twofold. Firstly, to develop successful reconnaissance techniques for use in the area, and secondly to obtain regional information on the Southern Georgina Basin which would assist in the interpretation of existing geological, gravity and aeromagnetic data in the area, with particular reference to petroleum prospects.

As a result of the preliminary experimental work carried out in November 1964 it was hoped that, if the area tested was typical of the whole region, a suitable reconnaissance technique would be developed with little additional testing in 1965. It was planned to test the effects of offset shooting, which was not done in 1964, by shooting "expanded spreads". It was also planned to carry out further experimental work during the reconnaissance survey if (a) the results deteriorated or (b) if the surface conditions changed significantly. In the case of (a) it was planned to carry out a complete re-appraisal of all shooting parameters, while in the case of (b) it was planned to shoot noise profiles and carry out tests of modified shot-geophone arrangements with the object of improving results or economy.

It was proposed to pursue the objective of obtaining regional information by surveying a long reconnaissance seismic traverse across the southern part of the Georgina Basin approximately at right angles to the strike and following this with supplementary traverses whose priorities and locations would depend partly on the results of the main traverse. Five traverses were proposed with specific objectives in mind, although it was realised that it would not be possible to complete all of these traverses in 1965. It was considered that, if results warranted it, the proposed programme, or modifications of it, might be continued in 1966 or at a later date.

The detailed objectives of the survey and the seismic traverses proposed to achieve these objectives were as follows:-

(a) To investigate the large depression in magnetic basement south-west of Urandangi, also the Tobermory Depression and the relationship of these depressions to the Tobermory Gravity Shelf area, where both gravity and magnetic results suggest shallower basement.

Traverse proposed from B.M.R. 12 (Cockroach) Bore to Urandangi. Approximate distance 120 miles, time required 16 to 24 weeks.

(b) To investigate the north-western extension of the magnetic depression south-west of Urandangi, particularly its north-western boundary where the magnetic results suggest the possibility of a large fault. To resolve an apparent contradiction between the magnetic results and gravity results which suggest that there is an increase in thickness of sediments north-west of the supposed fault rather than a decrease.

Traverse proposed from the Tobermory-Urandangi traverse (a) in the south-east corner of Sandover River 1:250,000 sheet north-west at least to Gordon Creek near the centre of Sandover River sheet. Approximate distance 57 miles, time required 8 to 12 weeks.

(c) To complete a tie from the south-western end of Traverse (a) across areas of outcropping Upper and Middle Cambrian sediments to Proterozoic outcrops at the south-western margin of the Basin.

Traverse proposed from B.M.R. 12 Bore to Precambrian outcrop area about 8 miles south-east of Marqua. Approximate distance 36 miles, time required 5 to 7 weeks.

(d) To investigate the magnetic and gravity depressions near Tarlton Downs and to complete a tie from Traverse (a) across the northern end of the Tarlton Range to granite in the vicinity of Arthur Creek.

Traverse proposed from B.M.R. 12 Bore to Arthur Creek. Approximate distance 38 miles, time required 5 to 8 weeks.

(e) To investigate whether there is any thickening of sediments south-east of Tobermory in the area of the Tobermory Magnetic Depression and a small gravity low east of Tobermory.

Traverse proposed from Traverse (a) near Tobermory through Linda Downs. Approximate distance 20 miles, time required 3 to 4 weeks.

In practice drilling progress proved slower than anticipated and reflection results proved very difficult to obtain. Proposal (a) was commenced and about a half of the traverse was surveyed before slow progress and lack of results caused its abandonment. Several segments of traverse were surveyed in the Mulga Hill - Gordon Creek area to pursue the objectives of proposal (b) and to attempt a seismic tie to Alliance Mulga No. 1 Bore. For administrative reasons it was found desirable to terminate the survey at the end of Octover, a month earlier than originally planned. There was insufficient time to carry out proposals (c) to (e).

5. TECHNIQUES AND RESULTS.

Drilling

In general drilling presented considerable difficulties throughout the area, mainly because of the prevalence of hard layers of rock near the surface and because of the extreme variability of surface formations over short horizontal distances. The party was equipped with two Mayhew 1000 rigs and one lighter Carey rig. The Carey rig proved inadequate for drilling in the harder formations and was mainly used for advance exploratory drilling from the surface down to the first hard layer. The party frequently worked a total of three shifts per day on the two Mayhew rigs. Drilling rates were very variable but the average footage drilled per rig per 8½ hour shift was of the order of 300 feet. It was possible to drill with air on all traverses and it was only occasionally necessary to use water injection.

The locations of the various seismic traverses are shown on Plate 1. Drilling progress on Traverse A was frequently very slow, but in general it improved from west to east. As might be expected drilling was most difficult where hard limestone or dolomite outcropped, as between shot points 197 and 200 and in the vicinity of shot points 257 and 258. On the rest of the traverse formations presented an alternation of soft rocks, such as clayey sandstones and often siliceous limestone. In general drilling difficulties increased as a function of the thickness and number of limestone beds encountered.

The usual practice was to drill shotholes several feet into the first substantial hard layer encountered, so that the charges were placed within the hard rock. The average depth of shotholes so drilled was about 30 feet, although in isolated cases the soft formations extended much deeper. At SP. 228 two holes were drilled to 150 feet in sand, clay and shale without encountering hard bands of carbonates.

Limestone outcropped in places on Traverse B and drilling was consequently very slow. The depth to the limestone increased towards the south. Average hole depth on this traverse was about 50 feet.

Where limestone was not present near the surface the drills encountered a succession of hard shale layers and sticky clay, which made necessary the use of water injection.

On Traverse C hard limestone was generally encountered within about 35 feet of the surface. Above this sand, clay and hard shale were reported in the drill logs. Average depth of shotholes was about 30 feet, although at two shot points it was possible to drill to 138 ft and 195 ft respectively without penetrating any substantial hard layers. Surface conditions were similar on Traverse D, where average shothole depth was about 20 feet.

Drilling conditions down to the hard limestone were a little easier on Traverse E as sandy sediments predominated over the harder shale beds. Shothole depth was fairly constant at about 20 feet.

<u>Noise Tests</u>

As reflection results were difficult to obtain, at least one noise test spread was shot on each main segment of traverse to try to determine the reasons for the poor results. Standard noise test procedures were used throughout the survey and the following description of noise spread arrangements is generally applicable to noise tests carried out during the survey.

Each noise profile consisted of nine 24-trace spreads each 460 feet long, which were surveyed in line beginning from a point 100 feet from the common shot point. The whole profile covered a distance range of 100 ft to 4,400 ft from the shot point with a trace interval of 20 ft.

The shot point arrangement consisted of about a dozen holes drilled to normal shooting depth in a line perpendicular to the profile. The holes were fired singly using a constant charge. A single 20 c.p.s. geophone was used for each trace. No automatic gain control or electrical filtering were employed.

The gains were adjusted from spread to spread to obtain readable records at all distances using constant charge. Before each noise test a gain calibration test was carried out which allowed record amplitudes to be measured for a given input voltage and gain setting. As a result noise record amplitudes could be converted to millivolts input.

However it was found in this survey area that amplitudes varied greatly for similar size charges in the same hole or for similar charges in holes a few feet apart, so that relative amplitude measurements for events on different records were not always meaningful.

Traverse A.

Recording commenced on Traverse A at SP 200, which was located very close to BMR 12 (Cockroach) Bore (see Plate 1). The shot and geophone arrangements used for normal split spreads were those suggested by the experimental work in 1964, namely four rows of five holes 30 ft deep with 40 ft spacings between holes and rows and 24 geophones per trace in four rows of six with 22 ft spacings between geophones and 30 ft between rows.

Only poor quality reflections were obtained, the best one being a fairly high frequency event occurring at about 0.35 sec., which probably corresponded to a pronounced velocity discontinuity known from BMR 12 to occur near the boundary of the Arrinthrunga Formation and the Marqua Beds at a depth of 2720 feet. Record quality deteriorated further to the north-east of SP. 200 as the hard limestone layer became deeper. A number of other shooting and recording arrangements were therefore tried in an effort to improve results.

As the central traces on the 1800 ft split spread records appeared to be somewhat less disturbed by noise, 900 ft split spreads were tried. However improvement obtained was considered too slight to justify the extra work which this involved for a given length of traverse, particularly as it was necessary for the geophone groups to overlap one another to a considerable degree.

An expanded spread was shot and it was found that the best offset distance for recording pickable events was in the range 3600 to 7200 ft. Consequently, collinear offset shooting with the spread covering these distances from the shot was tried over an interval of about 6 miles using five hole shot patterns and 24 geophones per trace. It was found necessary to use charges of up to 400 lb per shot for this work. The sub-surface between shot points 188 and 216 was covered twice by this method by shooting "direct" and "reverse" offset shots in opposite directions.

A few events were recorded within 0.5 sec. of the first breaks using this method but unfortunately these appear to be either partly refracted events or reflections so confused by refracted events or irregularities as to be almost unusable. Variable area cross-sections from these shots, corrected only for normal moveout, showed a marked lack of continuity. The two cross-sections produced by shots in opposite directions showed little similarity in details both when placed in corresponding geophone positions and in similar subsurface coverage positions. This suggests that there may have been lenses or other bodies of discontinuous material between the surface and the main reflecting or refracting layers which interfered with the recording of continuous events. The results of the offset shots require more study before final conclusions can be drawn.

About six miles north-east of B.M.R. 12 Bore surface conditions became more similar to those encountered during the preliminary survey in 1964, with hard carbonate rocks at depths of 20 to 30 ft. Offset shooting was then abandoned and split spread shooting resumed. It became evident that,, where hard limestones or dolomites were encountered by the shothole rigs at shallow depths, a number of poor quality reflections, mostly at times less than half a second, could be recorded using a fairly heavy technique. Where the first high velocity layer was deeper it was virtually impossible to obtain any reflections using conventional means.

Plate 2, which is portion of a variable area record cross-section from Traverse A, shows the effect of surface conditions on reflection quality. The various near-surface layers indicated by first-break refraction times are shown plotted above the cross-section. On the left hand half of the cross-section, where the high velocity layer is close to the surface, some poor quality reflections are recorded. On the right hand side of the cross-section, where the high velocity layer is much deeper, the records are of lower frequency and reflections are absent.

In consequence of these observations and the slow drilling progress the party's light Carey rig was used to drill one or two exploratory holes at each shot point in advance of the main drilling crews to enable the selection of those portions of traverse where it appeared likely that reflection results could be obtained. Drilling of shothole patterns, which was difficult and slow, was then concentrated on the portions selected. Shallow refraction spreads, the same length as the normal reflection spreads and using one geophone per trace, were shot from each exploratory hole to assist in determining near-surface conditions.

The near-surface profile indicated by these shallow refraction spreads on Traverse A shows three main layers characterised by different velocity ranges. The surface layer, with a velocity range of 1700 ft/sec to 2500 ft/sec, appears to be continuous and not thicker than 45 ft. Average thickness is only about 20 ft. The high velocity layer, with velocities ranging from 16000 ft/sec to 19500 ft/sec, varies very much in depth as well as in velocity. The intermediate layer, which is not always present, varies very widely in thickness, velocity and probably also in rock type. Its velocity range is generally 5000 ft/sec to 8,500 ft/sec but between shot points 242 and 250 its range is 10,500 ft/sec to 13,500 ft/sec. Between shot points 254 and 264 it is apparently absent, with the low velocity surface layer resting directly on the high velocity layer. The various layers appear to be interrupted by numerous minor faults.

Of the 34 miles of traverse between BMR 12 Bore and No. 3 water bore to the north-east, 17 $^{1}/_{2}$ miles selected on the above mentioned bases were shot for reflections using 1800 ft split spreads. Poor to fair reflections were recorded over portions totalling about 7 miles of traverse, while the remaining portions were devoid of useful reflection results. It is notable that the best reflections were recorded near shot points 260 and 261 where the high velocity carbonate layer is at its shallowest depth.

Reflections obtained were mostly recorded in the first half a second. They indicated little or no dip. In some cases poor quality later events were recorded with reflection times up to 2 seconds or more.

The poor quality of results made it impossible to determine whether these later events were multiples or primary reflections. Likewise, it is impossible to estimate a maximum thickness for sediments in the area. On the basis that, where reflections were recorded they were usually observed up to at least 0.5 sec, it appears that the minimum thickness of sediments along the traverse is about 4000 ft, a fact already known at the south-western end of the traverse from BMR 12 Bore.

As a result of a noise test at SP. 228 the geophone pattern used on most of Traverse A consisted of 24 geophones in two rows of 12 parallel to the traverse. The spacing between geophones was 14 ft and the distance between the rows was 30 ft. The shothole pattern consisted of 20 holes in two rows of 10 parallel to the traverse, with 17 ft between holes. For recording an electrical filter pass band between 18 and 160 c.p.s. with filter slopes of 18 lb per octave was used, while for playback a pass band from 33 to 92 c.p.s. was generally used.

In an effort to improve results where some poor reflections had been recorded, six fold multiple coverage was carried out on Traverse A between shot points 258 $^{2}/3$ and 270. For this work split spreads extending 3600 feet on either side of the shot were used. This was twice the length of the split spreads used for single coverage. Five hole shot patterns were employed, with 30 ft spacings between holes. The geophone patterns were similar to those used for single coverage.

Unfortunately the multiple coverage work did not result in any improvement to reflection quality. This was possibly due to poor static corrections resulting from rapidly varying surface conditions. It may also have been due in part to the increased length of the spread used. An expanded spread shot in the area indicated that the reflection signal to noise ratio was best in the range 0 to 900 ft from the shot and decreased considerably at larger distances.

Because of slow drilling experiments were tried with air shooting on Traverse A and other traverses. Charges of up to 200 lb were usually distributed over 13 stakes arranged in a star pattern and detonated about six feet above the ground. Recording spreads similar to those used for hole shots were employed. Air shots sometimes produced results not much inferior to the hole shots, but in no case did they produce better results.

The easternmost segment of Traverse A, which extends over a distance of about 11 miles from SP. 350 to SP. 383, was surveyed for the purpose of investigating an aeromagnetic "low" centred south-east of Tobermory homestead. Three miles of the traverse were shot for reflections near the Northern Territory - Queensland border and one mile was shot near the Tobermory-Marqua road, but then work on the traverse was abandoned because of lack of reflections.

Complete noise profiles of the type described earlier were shot on Traverse A at shot points 228 and 270. A noise test covering shot to geophone distances of 1060 to 2000 ft was shot at SP. 350. In general the surface noise recorded was in the medium to high frequency range and was not very highly organised. Probably about 30% to 50% of the noise recorded could be regarded as coherent for the 20 ft trace interval employed. The noise events were fairly evenly distributed in time after the first breaks and no distinct noise-free "window" was observed.

Traverse B.

Traverse B, about 4 miles in length, was surveyed along the Northern Territory - Queensland border a few miles south of Manners Creek homestead (see Plate 1). A noise test profile recorded at SP. 1009 on this traverse indicated that the geophone pattern of 2 rows of 12 geophones in use on the greater portion of Traverse A was suitable for use on this traverse. However the shot pattern was reduced to five holes in line at 38 ft intervals to increase the party's rate of progress. As on Traverse A, single holes at each shot point were shot into 1800 ft refraction spreads on either side of the shot point to provide information on near-surface layers.

A few poor shallow reflections were recorded on this traverse and also a number of moderately strong deeper events with reflection times of up to 2.75 sec. Some of the latter indicated strong southerly dip, but their importance is decreased by the lack of continuity between records. These deep events may indicate the presence of a deep Proterozoic sedimentary section in this area.

Traverse C.

Traverse C (see Plate 1) was surveyed in two segments, the southern segment for the purpose of allowing correlation of seismic results with the nearby Alliance Mulga No. 1 Bore and the northern segment to attempt seismic investigation of a gravity "low". However the records from both segments were so devoid of useful reflections that neither of these aims were fulfilled.

A noise test profile was shot on each segment, one at SP. 2404 and the other at SP. 2368. The results of these did not suggest that the shooting and recording arrangements adopted on Traverse B as a compromise with speed of operation should be varied for Traverse C. As on Traverses A and B refraction shots were fired at each shot point and recorded on single geophones to investigate surface layers. A 20 hole shot pattern was fired at SP. 2408 where some very poor reflections were recorded using a 5 hole pattern. The larger pattern produced a slight but significant improvement in reflection quality. Experiments with air shooting were carried out at shot points 2365, 2366 and 2367 with the shot offset 2000 ft perpendicular to the traverse. The results were generally a little, but not greatly, inferior to those with shot holes.

Traverse D.

About 9 miles of reflection profile were shot on this traverse, which extended southwards from near Gordon Creek (Plate 1). Traverse D was surveyed in an attempt to find seismic evidence for the existence of a major fault postulated on the basis of aeromagnetic results. No useful reflections were recorded over the greater part of the traverse. However some poor reflections were recorded at SP. 3819 towards the northern end of the traverse and reflection quality improved up to SP. 3822 where a fair quality reflection was recorded at about .260 sec and several other poor reflections were recorded at times up to 0.5 sec. These reflections were observed on the southern half of the record from SP. 3823, which was the last shot point on the traverse, but not on the northern half. Reflections mostly indicated little or no dip, except for those on the records from shot points 3822 and 3823 which indicated southerly dips of a few degrees. Termination of the reflections to the north on the record from SP. 3823 was sufficiently abrupt to suggest that faulting occurs in this area. A major fault with north-east-south-west trend has been postulated on aeromagnetic evidence (see section 3) to exist in this area. It is possible that Gordon Creek itself follows such a fault line.

Techniques for reflection and shallow refraction shooting on Traverse B were similar to those employed on Traverses B and C. Shot points 3819, 3820 and 3821 at the northern end of Traverse D, originally shot with 5 hole patterns drilled into the hard limestone layer at about 20 feet, were re-shot for comparison using 20 hole patterns drilled to the same depths and also airshot patterns. The results using 20 hole patterns were only very slightly better than those using five holes, while the airshots were noticeably poorer. At shot points 3819, 3820 and 3821 one hundred hole patterns were drilled to the rig kelly depth of 15 ft to test the effect of large numbers of energy sources located above the top of the first high velocity layer. The results of the 100 hole patterns at shot points 3819 and 3820 were poor compared with the 5 hole patterns drilled a few feet deeper to locate charges partly in the hard limestone layer. At SP. 3821 the 100 hole pattern produced a record comparable to the 5 hole pattern. It appears that record quality is highly dependent on the charges being placed in contact with the hard layer.

Noise test profiles shot at shot points 3810 and 3821 on Traverse D indicated that approximately half of the noise recorded was of the organised or coherent type while about half was random. Noise frequencies were somewhat higher than those recorded on previous traverses.

Traverse E.

Traverse E consisted of four miles of reflection traverse surveyed near the centre of a large aeromagnetic "low" in the south-western corner of Urandangi 1:250,000 Series sheet (see Plate 1). Techniques for reflection and shallow refraction shooting on Traverse E were again similar to those used on the previous traverses. A noise test profile indicated fairly high noise frequencies and predominantly incoherent noise events.

Using 5 hole shot patterns and 24 geophones per trace, the results were very poor. Only at SP. 4511 were some reflections recorded. Poor events at about half a second indicated gentle dips to the north.

6. CONCLUSIONS

In terms of new geological information supplied the survey proved very disappointing. The main conclusion to be drawn is a negative one, namely that in the region surveyed the seismic method indicated no areas where there might be considerable thicknesses of prospective oil-bearing sediments readily mappable by seismic means. This is a conclusion resulting mainly from the poor quality of seismic results obtained and it does not exclude the possibility that petroliferous sediments exist in the area. However the likelihood that deep troughs of Palaeozoic sediments such as the Toko Syncline occur in the survey area has been much reduced by this survey, since it is very likely that such troughs would have produced some persistent reflections.

The reflections which were recorded on Traverse A indicated little or no dip and were distributed similarly in time to those recorded near BMR 12 Bore. The seismic results therefore tend to confirm indications from gravity results that there is a shelf area between BMR12 and Tobermory. Alliance Mulga No. 1 Bore to the north indicated that the Palaeozoic sediments were less than 2000 ft thick and were underlain by Upper Proterozoic sediments. No useful reflections were recorded in this area. However, 15 miles north-west of Mulga No. 1, near Gordon Creek, fair reflections were recorded to about 0.5 seconds as in the vicinity of BMR 12. It is possible that 4000 ft of Palaeozoic sediments may be present at Gordon Creek as at BMR 12. The seismic work indicated the likely presence of a fault in this area, but there was no indication of its magnitude or strike.

During the course of the survey a considerable amount of experimentation and testing was carried out to try to improve results and to determine the reasons for the poor results generally obtained. This work has not been fully analysed at the time of writing, but some conclusions can be drawn regarding field techniques. It was found that in general the best results were obtained where limestones and dolomites were encountered at shallow depths. Such areas can be readily located by shallow refraction shooting. It does not appear then, that noise as a result of the presence of a surface layer with high velocity was the main reason for the poor reflections, although reflection of shot energy from the top of the high velocity layer might have been a factor where the charge was not placed in the high velocity layer.

Drilling on all traverses was slow and difficult. The poor signal to noise ratios generally observed require high multiplicity of energy sources and geophones. Since large shothole patterns are expensive in the survey area, consideration should be given to the use of some other type of energy source, such as weight dropping or "Vibroseis", for any future seismic surveys in the region. However there is no certainty that methods using surface energy sources would be successful since the 1965 survey demonstrated that results were invariably poor where the charges were not in contact with the first high velocity layer. Air shooting is not as effective as hole shooting but could be useful in areas where signal to noise ratio is better than on the traverses surveyed in 1965, if such areas exist.

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APPENDIX A

Staff and Equipment

Staff

Party leader	J.S. Davies
Geophysicist	P. Montecchi
Surveyors	J. Cameron
	P. Pullinen
Observer	R. Krege
Shooter	H. Pelz
Toolpusher	B. Findlay
Drillers	A. Zoska
	E. Cherry
Drilling Assistant, acting driller	E. Lodwick
Mechanics	T.H. Clark
	B. Ingram
Party clerk	S. Wright

Fourteen wages employees were also employed for the duration of the survey. These included cooking staff, field hands, and drill helpers.

Equipment

Seismic amplifiers	T.I. 8000 "Explorer"
Seismic oscillograph	S.I.E. TR06
Magnetic recorder	Electro - Tech. DS7 - 7 PP7 Junction box
Geophones	E.V.S. 2B, 20 c.p.s. (approx. 900), for reflection work.
Cables	Vector 2000 ft. and 1500 ft.
Transceivers	Traeger T.M. 2 (3) and Pye F.M.(3)
Recording truck	International A.B. 120, 4 x 4, 1 ton utility with B.M.R. - Ansair cab.
Shooting Truck	Bedford RLHC3, 4 x 4 with 600 - gallon cylindrical tank.
Drills	Two Mayhew 1000, one Carey shot-hole rig.

Water tankers	Three Bedford RLHC3, 4 x 4 with 600 - gallon cylindrical tanks.
	One Bedford RLHC3, 4 x 4 with 800 - gallon flat tank.
Geophone trucks	Two Landrovers, L. W. B.

Three more Landrovers, a one-ton utility, a three-ton supply truck, a workshop truck, an office caravan, a kitchen caravan, one electric generator mounted on a two-wheel trailer, and five four wheel trailers completed the party's mobile equipment.

APPENDIX B

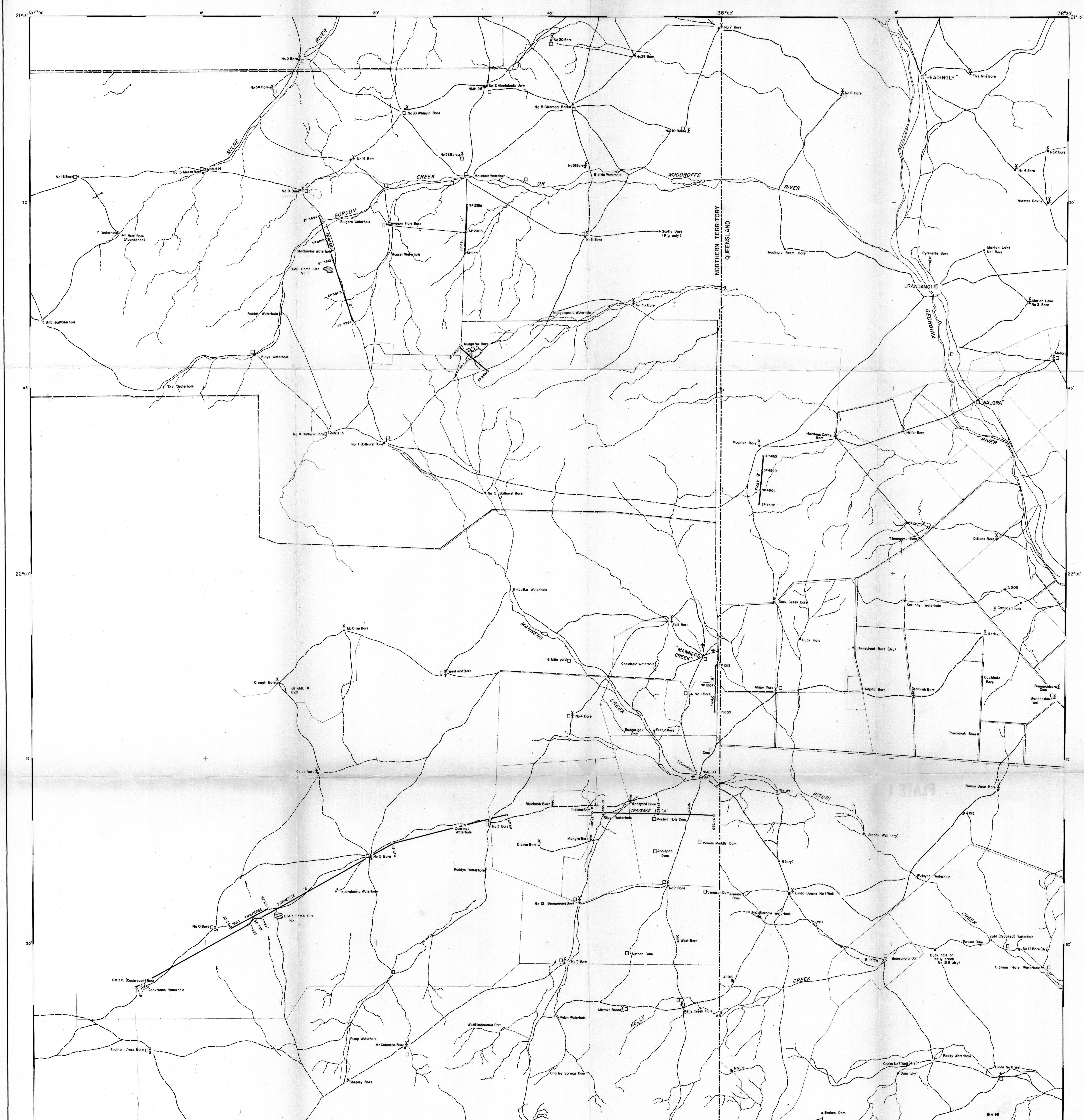
Table of operations

General Information

Sedimentary basin	Southern Georgina Basin
Area of survey	Tobermory, Sandover River and Urandangi 1:250,000 Series sheets.
Camp sites near	Cockroach Waterhole, Gordon Creek
Established first camp	13th April 1965
Surveying commenced	13th April 1965
Drilling commenced	20th April 1965
Shooting commenced	20th April 1965
Miles surveyed	83
Topographic survey control	Division of National Mapping 4-mile series and air photos. Department of Interior bench marks, Queensland State datum.
Total footage drilled	98,282 (mainly 20 and 5 hole reflection patterns)
Explosive used	Geophex = 44,312 lbs. Ligdyn = 1,450 lbs. Ammonium Nitrate = 640 lbs.
Datum level for corrections	500 ft. A.S.L.
Weathering velocities	1700 - 3000 ft/sec.
Sub-weathering velocity	mainly 16,000 ft/sec.
Method for weathering corrections	Uphole times checked by first breaks.
Source of velocity distribution	B.M.R. 12 Bore sonic log

Reflection shooting data

Shot-point interval	1,800 ft.
Geophone group interval	150 ft.
Number of miles traversed	80
Number of shot-points fired	240
Common shooting depth	20 - 30 ft.
Usual recording filters	18 - 160 K
Usual playback filters	33 - 92 K
Common total charge per S.P.	100 lbs. (split spreads)
	200 lbs. (offset shooting)
	130 lbs. (air-shooting)

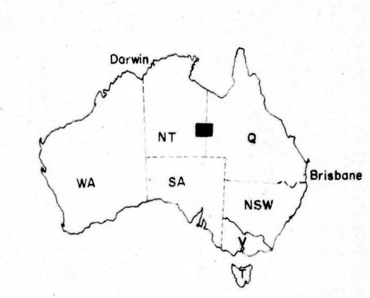


LEGEND

- State Boundary
- Track and Road
- River and Creek
- Fence
- Waterhole
- Waterbore
- Yard
- BMR Camp Site
- Landing Strip
- Oil Search Bore
- Seismic Traverse

5 0 5 10 15 20 MILES

5 0 5 10 15 20 KILOMETRES

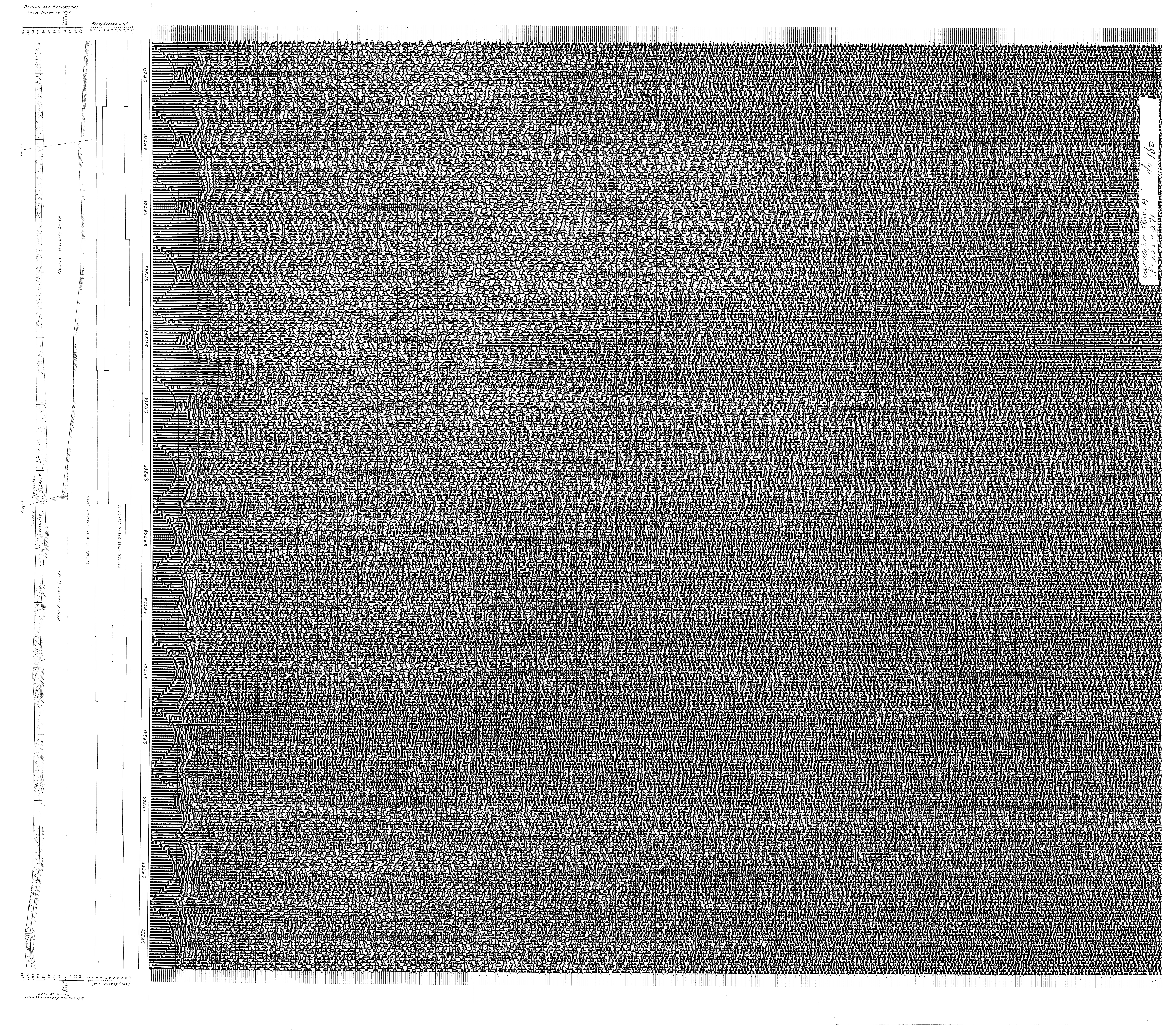


SOUTHERN GEORGINA BASIN SEISMIC SURVEY 1965

POSITION OF TRAVERSES

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

F53/B3-121


DEPTHS AND ELEVATIONS FROM DATUM IN FEET
FEET/SECOND × 10³
Medium Velocity Layer
High Velocity Layer
Low Velocity Layer
Surface Elevations
Fault?
Average Velocity of Surface Layer
S.P. 271
S.P. 270
S.P. 269
S.P. 268
S.P. 267
S.P. 266
S.P. 265
S.P. 264
S.P. 263
S.P. 262
S.P. 261
S.P. 260
S.P. 259
S.P. 258