COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1961-150

EMERALD-DUARINGA SEISMIC SURVEY, QUEENSLAND 1960

by

C.S. Robertson

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ABSTRACT

The Bowen Basin, in Central Queensland, is one of the sedimentary basins in which the search for oil is being pursued. In the second half of 1960 the Bureau of Mineral Resources, Geology and Geophysics did a seismic survey lasting four months in the central portion of the Bowen Basin. This Record describes briefly the work done and the principal results obtained. A single, discontinuous seismic traverse was surveyed across the Basin in an east-west direction. The results provided information on the structure and minimum thicknesses of sediments in the area.

1. INTRODUCTION

From 30th July to 23rd November 1960 the Bureau of Mineral Resources, Geology and Geophysics did a reconnaissance seismic survey in the central portion of the Bowen Basin, where the search for oil is being pursued. The objectives of the survey were to determine the structure of the basin and the thickness of sediments by traversing the basin from the western margin of the Basin near Anakie to the eastern margin east of Duaringa (see Plates 1 and 2). This location for an east-west traverse across the Basin was chosen because of its central position in the Basin and because of the excellent access provided by the highway from Rockhampton to Emerald.

In this area the Basin is approximately 130 miles wide. It was decided that the best way of attaining the objectives of the survey in the four-month period available was to survey a series of reflection traverses at intervals across the Basin and refraction profiles at several selected locations. The portions of the traverse on which seismic work was done are shown on Plate 2.

The greater portion of the Bowen Basin, including those areas in which seismic work has been done, is covered by Authority to Prospect 56P, held by Associated Freney Oil Fields N.L.

Prior to the survey described here, seismic work in the Bowen Basin had been done by the Bureau in the Comet area in 1951 (refraction work only - Smith, 1951) and in the Cooroorah-Mt Stuart area in 1959 (Morton and Moss, 1961) and by Austral Geo Prospectors Pty Ltd for Associated Freney Oil Fields N.L. in the Banana area in 1960.

Gravity work in the Comet-Rolleston area was done by Oldham (1958) and regional gravity work covering the whole of the Emerald-Duaringa seismic traverse was done by Starkey (1959) (See Plate 4). A positive Bouguer anomaly (+ 5 milligals) was located near Comet, while negative anomalies were obtained west and east of Comet in the Emerald region (- 18 milligals) and Blackwater-Bluff region (- 16 milligals).

2. GEOLOGY

The Bowen Basin is a large depositional area which received sediments from the beginning of the Permian to the Triassic. The basal sediments in the Basin unconformably overlie Carboniferous and older volcanics, and other igneous rocks.

In the north of the Basin, the earliest Permian rocks are a thick sequence of volcanics, mainly flows, interbedded with conglomerate, sandstone, and siltstone; they are overlain locally by the Collinsville Coal Measures, and elsewhere by a thick marine sequence which overlaps the coal measures. The marine sequence is overlain by thick freshwater sediments containing coal measures in places, of mainly Upper Permian age, which overlap the Anakie Metamorphics of the Anakie Structural High at Blair Athol. Triassic sedimentation includes conglomerate, sandstone, and siltstone.

To the south, the Basin plunges under the unconformably younger strata of the Great Artesian Basin, and at the western junction of the two basins a shelf area (Springsure Shelf) of sedimentation extended around the southern plunging end of the Anakie Structural High into the southern Drummond Basin.

Derrington and Morgan (1959a) recognise a number of structural zones in the area traversed during the 1960 seismic survey. Near the eastern margin of the Basin is the Dawson Tectonic Zone, which is believed to be about 40 miles wide and which is marked by steep isoclinal folds, minor basic intrusions, quartz veining and mineralisation, and low-grade metamorphism. Near the centre of the Basin is the Comet Ridge, a structural "high" varying in width from 20 to 50 miles. Characteristic of this "high" are broad anticlines with gently dipping flanks and sigmoidal axes, and sediments indicative of shallow-water sedimentation. East of the Comet Ridge is an Intermediate Zone approximately 10 miles wide and parallel to the western margin of the Dawson Tectonic Zone. The types of sedimentation and folding in this zone are intermediate between those of the Comet Ridge and the Dawson Tectonic Zone. West of the Comet Ridge is a structural depression which Derrington and Morgan called the "Carnarvon Trough", containing a considerable thickness of Permian sediments.

The only deep bore near the seismic traverse is A.F.O. No. 1 Bore (Cooroorah) drilled in 1959 about 30 miles north of the traverse. A stratigraphic log from this bore is shown on Plate 3. Stratigraphic cross-sections compiled for several other parts of the area are also shown on Plate 3. In the Springsure region, Carboniferous and Permian sediments are found in both continental and marine-paralic facies. Sediments of the continental or "Western Facies" may be expected to occur near the western end of the 1960 seismic traverse, adjoining the western margin of the Basin formed by the Anakie Structural High. On the other hand, sediments a short distance to the east in the Emerald-Yamala area are likely to resemble those of the marine or "Eastern Facies" known from the Springsure area to the south. The stratigraphic column for the Emerald-Yamala area shown on Plate 3 is a generalized one compiled from information from six bores south of Springsure (Webb, 1956). Also shown on Plate 3 is a stratigraphic column showing the relationship of rocks known from outcrop in the Comet-Mt Stuart-Bluff area (Derrington and Morgan, 1959b).

It will be noted that sediments expected to occur in the 1960 traverse area are principally Permian, overlain in some localities by possible Triassic sediments and lesser thicknesses of Tertiary sediments, laterite, and volcanics. Over most of the region, the presence of pre-Permian sediments is doubtful.

3. FIELD WORK

The Bureau's No. 1 seismic party set up camp near Comet township on 30th July 1960 and did reflection and refraction work on the western portion of the traverse across the Basin from this camp until 24th October 1960. The party then moved camp to a site near Dingo, and reflection work was done on the eastern portion of the traverse until 23rd November 1960, when the party left the area. Despite frequent storms in the latter part of the survey, no working time was lost through wet weather. Altogether, 60 miles of reflection profiling was completed on a series of traverses spaced at intervals across the Basin.

The survey was conducted by geophysicists C.S. Robertson (party leader) and J.S. Davies assisted by nine staff members of the Bureau and ten wages employees. Two surveyors were provided by the Department of the Interior. The staff members and the main items of equipment used are listed in Appendix A.

For reflection shooting the normal split-spread method of continuous profiling was used. For refraction shooting the "depth probing" method described by Vale and Smith (1961) was employed. The spread dimensions, recording parameters, and many statistics relating to the survey are set out in Appendix B. Appendix C gives shot-hole drilling statistics.

4. RESULTS

(a) Presentation of results

The results of the reflection and refraction work done during the 1960 seismic survey are summarised in a diagrammatic cross-section along the traverse (Plate 3). On this cross-section, reflections that can be correlated from record to record have been plotted as continuous lines (not migrated to their correct positions) but other reflections are plotted only roughly as short dashes to indicate the approximate dip along the traverse. Recorded refractors also are shown, and are labelled with their respective velocities. It should be noted that for convenience in presentation, the vertical scale has been exaggerated to 5.28 times the horizontal scale.

In the absence of any bore-hole velocity information it has been necessary to base the depth scale on t, Δ t Analyses. These analyses indicate that there is a significant difference in the average vertical velocities on either side of the Comet Ridge. Down to depths of about 5000 ft the average vertical velocities are assumed to be given approximately by the following linear functions:-

$$v_a = 9000 + 4300t \quad \text{(east of Comet)}$$

and $$v_a = 8500 + 1800t \quad \text{(west of Comet)}$$

where t = reflection time.

Below 5000 ft the interval velocity is assumed to increase progressively less rapidly until west of Comet it finally reaches a constant value of 21,000-ft/sec at a depth of 30,000 ft, and east of Comet at a depth of 25,000 ft. It should be noted that, apart from a single deep refractor recorded on Traverse A near Blackwater, no velocity information is available from below about 5000 ft. The depths of the deeper reflections plotted on Plate 3 may therefore be in error by as much as 20 per cent. Velocities on the Comet Ridge are probably different from those in the sedimentary troughs on either side. In the absence of more reliable information the velocity distribution for the eastern trough was used for Traverse B on the Comet Ridge, as velocities on the Ridge may be expected to be relatively high.

t, Δ t Analysis of reflections on Traverse M near Duaringa indicates much lower vertical velocities for sediments there; it is assumed that the average vertical velocity down to 4000 ft is given by:-

$$v_a \quad = \quad 5000 + 1500t \quad \text{(Duaringa area)}$$

where t = reflection time.

Below 4000 ft an arbitrary interval-velocity curve was adopted, such that a constant vertical velocity of 21,000-ft/sec was reached at 24,000 ft.

Below the diagrammatic seismic cross-section on Plate 3 a regional Bouguer gravity anomaly curve (Starkey, 1959) with the same horizontal scale has been drawn. Below this is geological information that has already been discussed and a possible cross-section illustrating all the information at an approximately natural scale.

In a later report the reflection results will be presented in the form of corrected variable-density record sections and migrated sections and the refraction results will be presented in detail.

(b) Discussion of results

It is convenient to consider the seismic results by starting at the western end of the series of traverses and proceeding towards the eastern end.

West of Emerald: Traverses E and H (see Plate 3) were surveyed partly to locate the western margin of the Bowen Basin in this area and partly to see if there were any indications of older sediments beneath the Permian ones. On Traverse H, immediately east of Taroborah, refraction work indicated the presence of refractors with velocities of 12,350-ft/sec and 19,000-ft/sec at depths of about 600 and 3000 ft respectively, while near the western end of Traverse E a refractor with a velocity of 19,400-ft/sec was recorded only a few hundred feet from the surface. No shallow reflections were recorded on either of these traverses but many deeper reflections were recorded on both. These mainly indicated steep but erratic dips and the reflections can rarely be correlated from one record to the next. On Traverse E, reflections were sometimes of fair quality but dips were erratic. Reflections continued to arrive for as long as 6 seconds. This is in marked contrast with results at most localities within the Basin, where reflected energy rarely lasted beyond 2.5 seconds even when heavy charges were used.

It is concluded that Traverse E is close to the margin of the Bowen Basin and that it is underlain mainly by strongly folded metamorphic and predominantly crystalline rocks in which seismic energy is not attenuated as rapidly as in most of the sediments of the Bowen Basin. There is a low-velocity 6500-ft/sec layer several hundred feet thick at the surface on Traverse E. This may represent a thin layer of Permian or even Tertiary sediments, or it may be a deeply weathered layer of metamorphic rocks. The 19,400-ft/sec refractor evidently represents the top of the metamorphic rocks; i.e. the "Anakie Metamorphics". This refractor has a very irregular surface and may be faulted.

Because of the closeness of Traverse H to Traverse E it is reasonable to correlate the 19000-ft/sec refractor at a depth of about 3000 ft on Traverse H with the 19,400-ft/sec refractor of Traverse E. It may be concluded that the western margin of the Basin lies somewhere between the two traverses.

On Traverse D, reflections with fairly constant slopes were recorded from near the surface down to depths corresponding to a reflection time of about 2 seconds. These reflections suggest that there is a considerable thickness of sediments there (probably about 8000 ft) and hence that the Basin deepens rapidly east of Traverse H. Near the western end of Traverse D reflections are very poor or absent altogether. Reflection quality improves towards the east and in the central portion of the traverse moderately steep dip components to the east are indicated. At a point on the traverse about 3½ miles west of Emerald there is an abrupt change in reflection slope and quality. East of this discontinuity, reflections are of better quality and indicate nearly horizontal sediments. It is proposed at this stage that the discontinuity in reflection slope is caused by a fault, although the existence of this fault is very doubtful. There is no indication of the amount of throw or of which is the down-thrown side. The fault does not appear to have any surface expression.

Sediments of the Colinlea Formation, of Lower or Middle Permian age, outcrop on the western end of Traverse D and, according to the report by Shell (Queensland) Development Pty Ltd (1952), extend in outcrop as far west as Taroborah. This Formation is thought to have a maximum thickness of 4500 ft. It is probable that many of the east-dipping reflections on Traverse D are from the Colinlea Formation. Unfortunately, reflection quality on the western and central portions of Traverse D was too poor to establish whether any more-or-less conformable beds may be present beneath the Colinlea Formation. Consequently the 19,000-ft/sec refractor recorded on Traverse H may represent the base of the Colinlea Formation or, less likely, the base of some older sediments.

<u>Emerald-Yamala area</u>: Seismic reflection and refraction work between the supposed fault on Traverse D and Comet indicated the presence of a trough or sub-basin of relatively undisturbed sediments whose maximum thickness (at least 10,000 ft) is located about half way between Emerald and Yamala. Seismic work indicated gentle easterly dip components along Traverse C towards the deepest part of the sub-basin. A short cross-traverse surveyed at right angles to Traverse C, 2 miles west of Yamala, indicated little or no north-south dip component.

The sediments in the Emerald-Yamala area are believed to be Permian, probably corresponding to the "Eastern Facies" sediments of the Springsure region. About 25 ft of gravel was encountered by shot-hole drills at the surface on the western portion of Traverse C. This is thought to be of Tertiary age. Similarly, Tertiary basalt was encountered in shot-holes west of Emerald.

On Traverse C, between Emerald and Yamala, seismic energy usually lasted for only about 1.5 seconds and reflections were recorded as long as the energy persisted (i.e. to 10,000 ft). It is impossible, therefore, to place any upper limit on the thickness of Permian sediments present or to say whether pre-Permian sediments exist in this area.

Refraction work centred about 2 miles west of Yamala indicated the presence of a refractor with a velocity of 17,380 ft/sec at a depth of about 5000 ft below M.S.L. This refractor has a very gentle westerly dip component. At a distance of 9½ miles west of Yamala a refractor with a velocity of 16,010 ft/sec was recorded from a depth of about 3500 ft. This refractor indicated a very small easterly dip component. The thickest sediments in this sub-basin evidently occur between these two refraction profiles.

Comet Ridge: The Bureau of Mineral Resources carried out a refraction survey on the Comet Ridge in 1951 (Smith, 1951), the main results of which are shown on Plate 3. An 18,150-ft/sec refractor was recorded from a depth of only about 2200 ft. A similar refractor was recorded by the Bureau in 1959 (Morton and Moss, 1961) from about the same depth near Mt Stuart, about 30 miles to the north. It is most probable that these refractors represent the same horizon. Drilling of A.F.O. No. 1 Bore (Cooroorah) indicated that this horizon is the top of a very hard sandstone. As in the trough west of the Comet Ridge, refraction work east of the Comet Ridge indicated that refractors with velocities of about 18,000 ft/sec are at much greater depth than 2200 ft.

During the 1960 seismic survey, reflection work was done on the central part of the 1951 traverse (Traverse B). As single-hole shooting proved ineffective, about 3 miles of traverse was surveyed using nine-hole pattern shots. At times less than 2 seconds (about 12,000 ft) only a few poor reflections were recorded, and these indicated moderately steep easterly dip component (see Plate 3). Reflections later than 2 seconds were common; they mostly indicated steep and erratic dips, but reflections recorded at about 2.2 to 2.4 seconds indicated consistent westerly dips and could in many cases be correlated from record to record.

The relatively shallow depth of the 18,150-ft/sec refractor on the Comet Ridge, together with the fact that reflection and refraction work on either side indicated dips away from the Ridge, confirms geological and gravity evidence that sediments are thinner on the Comet Ridge. However, the actual thickness of sediments in this area is still open to question. In the troughs either side of the Ridge conformable reflections were considerably deeper than refractors having velocities of about 18,000 ft/sec. If these refractors in the troughs can be correlated with the 18,150-ft/sec refractor on the Comet Ridge, then sediments may extend well below 2200 feet in this area.

The persistent reflections at about 2.3 seconds on Traverse B indicate that there is a marked discontinuity with a westerly dip component at about 14,000 ft, but what this represents is uncertain. The variable dips indicated by deeper reflections probably result from the fact that the rocks below the 14,000-ft discontinuity are strongly folded. They may correlate with the metamorphics that give rise to similar reflections on Traverses E and H. It is notable that reflected energy later than about 2.3 seconds is of predominantly higher frequency than that preceding 2.3 seconds.

Traverses F and G, which were surveyed on the eastern and western flanks of the Comet Ridge respectively, produced only a few poor reflections, from relatively shallow depths.

Blackwater-Bluff area: Traverse A was a continuous reflection traverse 11 miles long between Blackwater and Bluff. A complete refraction "depth probe" (Vale and Smith, 1961) was made near its western end to record all possible refractors. The reflections obtained on this traverse were the best for the whole survey and could frequently be continuously correlated from record to record for some miles. The principal reflection recorded on the eastern portion of the traverse was exceptionally strong.

Reflections on Traverse A invariably indicated easterly dip component. A one-mile cross-traverse at right angles to the main traverse near its centre produced good reflections which indicated southerly component. Hence the true direction of dip in this area is south-east and the magnitude of dip is 6 or 7 degrees.

Seismic energy was generally recorded until 1.5 to 2 seconds after the shot and reflections were often recorded for as long as the energy persisted. Consequently it is again impossible to place an upper limit on the thickness of sediments present. However, it is likely from reflection results that the thickness of sediments is at least 12,000 ft at the eastern end of the traverse, and may be much greater in the area south-east of Traverse A.

Five refractors were recorded near the western end of the traverse, including a 17,500-ft/sec refractor at about 3900 ft and a 19,700-ft/sec refractor at 7700 ft. Only very few and poor reflections were recorded from below the deeper refractor at the western end of the traverse, although poor reflections apparently from below this horizon were recorded farther east. The high velocity of 19,700-ft/sec suggests that rocks below this refractor are metamorphic or igneous. However, all refraction velocities in this area are unusually high, and the 19,700-ft/sec refractor could represent the top of pre-Permian sediments, as a total of at least 12,000 ft of sediments is suggested by reflection work.

At the eastern end of Traverse A near Bluff and at the western end of Traverse J there is good evidence of faulting at depth. Numerous faults in the Bluff area are known from surface geological mapping. It is probably because of these faults that the very strong reflections on Traverse A cannot be correlated across the 1½-mile gap between Traverses A and J.

Reflections on Traverse J are much more confused than on Traverse A. At about two to three thousand feet, reflections at its western end indicate east component of dip as on Traverse A but these become more nearly horizontal on the eastern half of Traverse J. The deeper reflections indicate dips in both easterly and westerly directions.

<u>Dawson Tectonic Zone</u>: On Traverse K near Dingo and Traverse L near Tryphinia, no shallow reflections were recorded but many deep reflections were. The latter mainly indicated steep dips in both easterly and westerly directions. The reflections could not generally be continuously correlated from record to record. They suggested the presence of strongly folded rocks such as had been expected in the Dawson Tectonic Zone. Beyond about 3 seconds many horizontal reflections were recorded, especially on Traverse L. Similar reflections to these were also recorded beyond about 3 seconds on Traverse H. These evidently come from within a basement of igneous rocks or granitised sediments; in the Dawson Tectonic Zone this basement is apparently overlain by some 20,000 ft of folded rocks.

<u>Duaringa area</u>: On Traverse M, surveyed south-westerly from Duaringa, a number of continuously correlatable reflections from relatively shallow depths were recorded over a distance of 1½ miles. These indicated a small south-westerly dip component and a thickness of about 3000 ft of undisturbed sediments. On the western half of Traverse M no reflections were recorded from single shot-holes. However, two nine-hole pattern shots were fired on this part of the traverse and they indicated that the reflecting layers may persist along the whole of the traverse although they are more difficult to record on the south-western half. Two shots a quarter of a mile apart were fired about half way between Traverses L and M but no shallow reflections were recorded. There were a few very weak events which indicated steep dips, evidently from folded rocks at depth. It is believed that the shallow reflections on Traverse M come from Tertiary sediments.

Traverse N was surveyed for 3 miles east from the Dawson River. The very few shallow reflections recorded on this traverse indicated westerly dip component. A 17,060-ft/sec refractor with westerly dip was recorded in the centre of this traverse at a depth of about 1100 ft. This probably represents the top of the undifferentiated Lower Palaeozoic rocks which outcrop a little to the east of Traverse N. Many scattered deep reflections were recorded which indicated fairly steep westerly dip component.

Comparison of seismic and gravity results: A Bouguer anomaly map prepared from maps by Starkey (1959) is shown on Plate 4. In broad outline the regional Bouguer anomaly curve along the seismic traverse line (see Plate 3) appears to agree with the structure as revealed by seismic work and geological mapping assuming that the gravity anomalies are due to basement relief. The Comet Ridge is clearly shown as a gravity "high", supporting the view that basement is relatively shallow in this area. On either side of the Comet Ridge are gravity "lows" corresponding to portions of the traverse line where seismic work indicates the presence of considerable thicknesses of sediments. At each end of the traverse are gravity "highs" produced by older and denser basement rocks near the surface. Across the Dawson Tectonic Zone the Bouguer curve is almost horizontal and slightly positive, suggesting that basement rocks are shallower than in the Blackwater-Bluff area which lies west of it.

The postulated cross-section at the bottom of Plate 3 is based on both seismic and gravity results. Basement depth on the cross-section is derived from the estimated depth on Traverses H, K, and L of the top of the horizontal reflectors that produce reflections beyond 3 seconds. Calculations of depth differences, based on the Bouguer gravity anomaly curve, have been used to interpolate between Traverses H, K, and L; in these calculations it was assumed that the anomalies are due to relief on a boundary with density contrast of 0.2 g/c.c.

Structures shown on the cross-section are consistent with the seismic results but because of the many gaps between seismic traverses, and the poor results on some traverses, it must be emphasised that the cross-section is largely hypothetical.

5. CONCLUSIONS

The 1960 seismic survey confirmed the existence of structural features previously believed to exist; namely, the Comet Ridge, sediment-filled troughs on each side of the Comet Ridge, and the Dawson Tectonic Zone. It also revealed the presence of a small trough or sub-basin of relatively undisturbed sediments near Duaringa. A number of possible or probable faults were located and a considerable amount of information was obtained on dip of the sediments and on seismic velocities at various depths.

It was determined that the western margin of the Bowen Basin is near Taroborah and the eastern margin several miles east of the Dawson River. Seismic results indicated that the sedimentary trough west of the Comet Ridge contains at least 10,000 ft of sediments and the trough east of the Comet Ridge contains at least 12,000 ft of sediments. In both cases the sediments appear to be gently down-warped except on the eastern side of the eastern trough, near Bluff, where there is evidence of extensive faulting. South-west of Duaringa it was shown that there are 3000 ft or more of relatively undisturbed sediments which are probably Tertiary. Although the seismic results gave no indication of the presence of sizable structural traps, such traps would not necessarily have been revealed by a survey of this kind.

Reflection quality varied but near the Basin margins and near the Comet Ridge the quality was usually very poor below 5000 ft. It is not known, therefore, whether there are sediments older than, and more or less conformable with, the Permian sediments. This question might be resolved by detailed, continuous refraction profiling to plot the eastward extension of the refractors recorded on Traverses E and H. Deep reflections obtained in the Dawson Tectonic Zone indicate that folded rocks there persist to a depth of about 20,000 ft; just east of Taroborah it was shown that metamorphic rocks, which are presumably folded, also persist to a depth of about 20,000 ft. Basement below these folded rocks gives rise to consistently horizontal reflections and is almost certainly igneous.

In the sedimentary troughs on each side of the Comet Ridge no refractor of 18,000 ft/sec was recorded within several thousand feet of the surface. Therefore the very hard sandstone encountered at about 1600 feet in the Cooroorah bore either does not extend into the troughs owing to a facies change, or is much deeper.

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APPENDIX "A"

STAFF AND EQUIPMENT

STAFF

Party leader	C.S. Robertson
Geophysicists	J. Davies
Surveyors	W. Richards, R. Mathews or N. Wilson
Clerk	W. Rossendell
Observer	G. Abbs or L. Vliegenthart
Shooter	E. Cherry
Toolpusher	J. Halls
Drillers	B. Findlay, J. Lambert
Drilling assistants	J. Chandler, F. Blackwell
Mechanics	I. Pirie, H. Robertson

EQUIPMENT

Seismic amplifiers	T.I.C. 621
Seismic oscillograph	T.I.C. 50-trace
Magnetic recorder	Electro-Tech DS-7
Geophones	T.I.C. 20-cycle and 6-cycle
Drills	1 Failing 740, 1 Carey
Water tankers	2 International 700-gallon, 1 Bedford 700-gallon
Shooting truck	1 Bedford 700-gallon

APPENDIX "B"

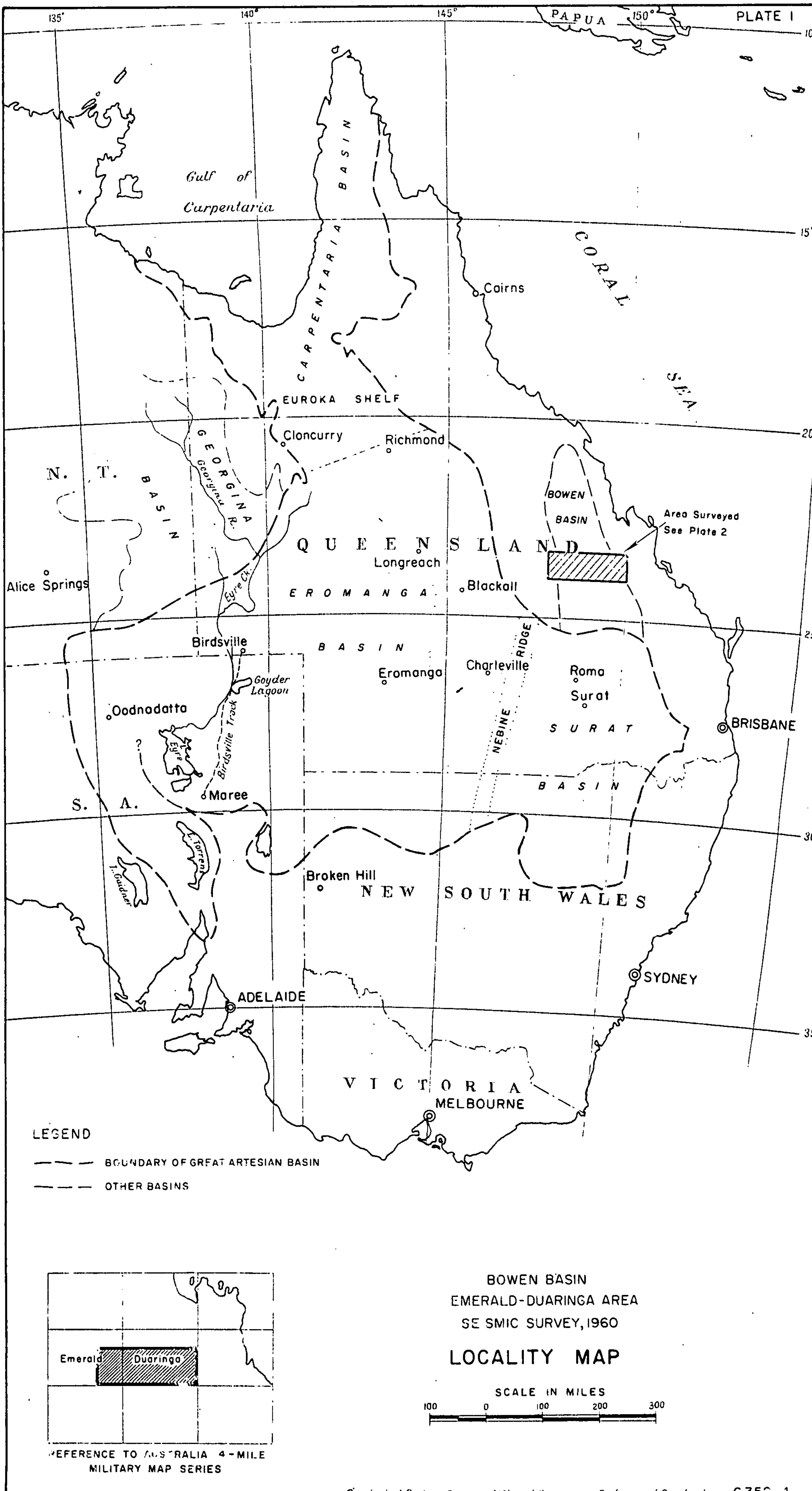
TABLE OF OPERATIONS

Sedimentary basin	Bowen Basin
Area	Emerald-Duaringa
Camp sites	Near Comet and near Dingo
Established camp	30/7/60
Surveying commenced	1/8/60
Drilling commenced	1/8/60
Shooting commenced	2/8/60
Miles surveyed	95
Topographic survey control	Horizontal and vertical control from main roads bench marks
Total footage	35,536
Explosives used	$8\frac{3}{4}$ tons Geophex and 1092 detonators
Datum level for corrections	500 ft above M.S.L.
Weathering velocities	2000 to 3000 ft/sec
Sub-weathering velocities	8000 to 10,500 ft/sec
Source of velocity distribution	t, Δ t Analysis and refraction shooting
Reflection shooting data	
Shot-point interval	1320 ft
Geophone group	6 per trace at 22-foot intervals (20-cycle geophones)
Geophone group interval	110 feet
Holes shot	250 single and 20 9-hole patterns
Miles traversed	58
Common shooting depths	85 to 105 ft
Usual recording filter	L2H2
Usual playback filter	L2H4
Common charge sizes	20 lb
Weathering corrections	After Vale (1960)
Grading system	Gaby's system (Gaby, 1947)
Refraction shooting data	
Geophone group	2 6-cycle geophones close together
Geophone group interval	220 ft
Holes shot	39
Usual recording filter	LOH4
Number of refraction traverses	7
Charge sizes	20 to 400 lb
Maximum shot-to-geophone distance	12 miles
Weathering control	From reflection results or weathering spreads
Weathering and elevation corrections	After Vale (1960)

APPENDIX "C"

SEISMIC SHOT-HOLE DRILLING

Total footage drilled	35,536
Number of holes drilled	468
Deepest hole	150 ft
Average depth of hole	76 ft



BOWEN BASIN
EMERALD-DUARINGA AREA
SEISMIC SURVEY, 1960

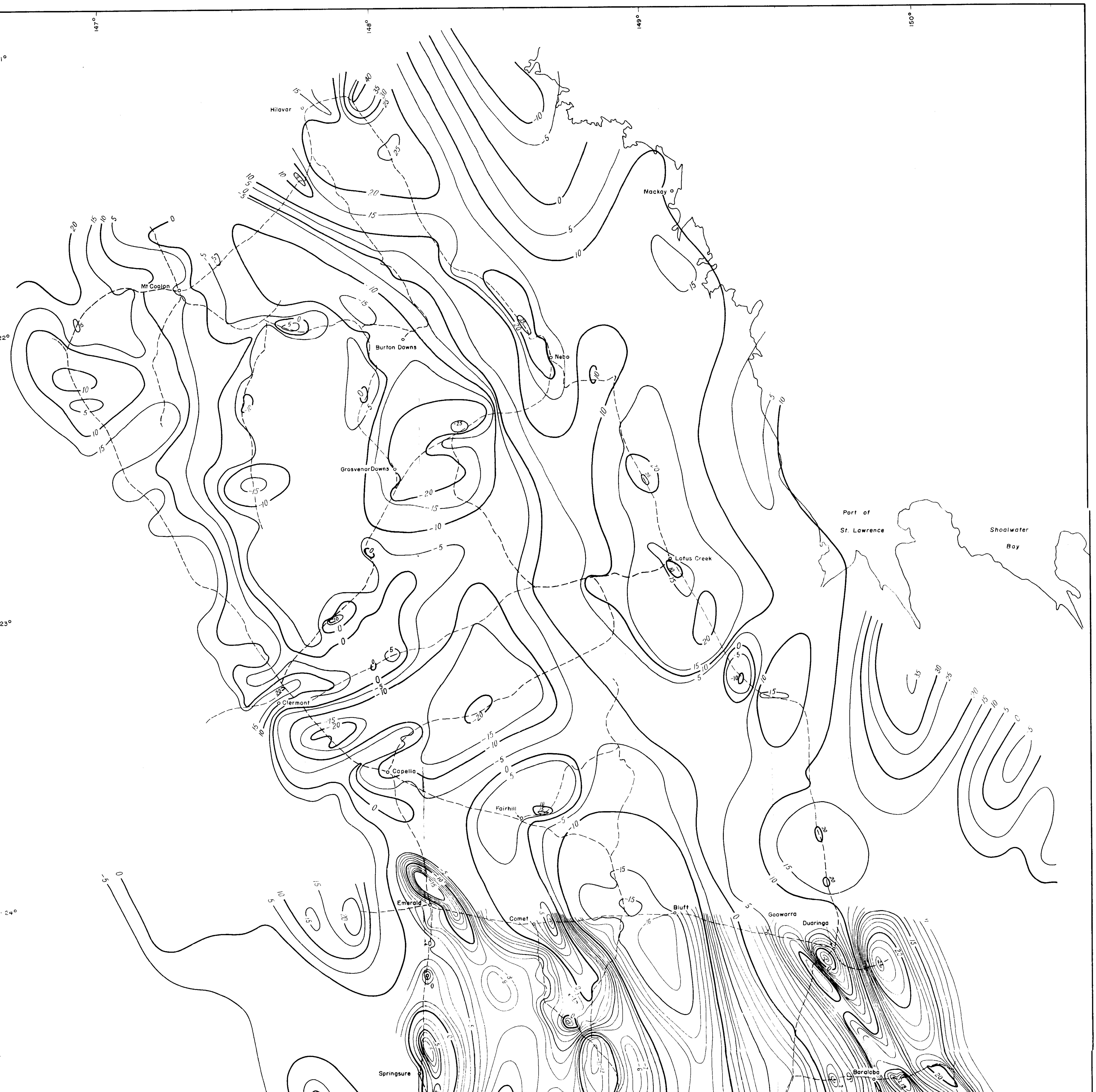
LOCALITY MAP

To Accompany Record No. 1961-150

To Accompany Record No 1961-150

EMERALD-DUARINGA, 1960

PLATE 4



REGIONAL BOUGUER GRAVITY MAP
OF THE CENTRAL PORTION
OF THE BOWEN BASIN, QUEENSLAND

To Accompany Record No 1961-150