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Denison Trough seismic survey,

Queensland, 1978:

Preview Report

by

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SUMMARY

The Bureau of Mineral Resources plans to conduct a seismic survey in the southern Denison Trough, in the western part of the Permo-Triassic Bowen Basin in Queensland, between July and November 1978.

A considerable amount of exploratory work has been carried out in the southern Denison Trough and this has led to the discovery of four significant but presently non-commercial gas fields. The existing geological, geophysical and drilling data provides much information on the upper part of the prospective Permian sequence, but the lower part of the Permian sequence, and the structural configuration of the trough at basement level, are poorly understood.

The BMR survey is aimed at delineating the configuration of the Trough, in particular that of the lower part of the Permian sequence and of basement. It is also expected to provide stratigraphic information which may assist in the solutions of problems which have important implications for the hydrocarbon potential of the trough, in particular that of the distribution of potential reservoir sands.

The proposed survey will consist of approximately 300 kilometres of multifold reflection traverses, recorded digitally. It is also planned to make gravity observations along the seismic traverses.

INTRODUCTION

A seismic survey is planned by the Bureau of Mineral Resources, Geology and Geophysics (BMR) in southern Queensland from July to November 1978. The survey will be conducted in the southern part of the Denison Trough, which forms the western part of the Bowen Basin, and its main objectives are to investigate the configuration of the trough down to the base of the prospective Permian sequence, and to determine the nature of the western margin of the trough. This information will assist in a more accurate evaluation of its hydrocarbon potential.

A large amount of geological mapping, petroleum exploration and stratigraphic drilling, and geophysical work particularly seismic surveying, has been carried out in the area. This has provided much information on the structure and stratigraphy of the upper part of the Permian sequence, but sparse data on the lower part. In answer to a circular letter asking for suggestions on future BMR seismic programs, Mines Administration Pty Ltd (MINAD), proposed that the BMR conduct a program of regional seismic work in the Denison Trough. This proposal was supported by the Geological Survey of Queensland (GSQ) who have been conducting a stratigraphic drilling program in the area since 1972, and who are carrying out a detailed stratigraphic study based on this data plus that from petroleum exploration wells.

The Denison Trough has proven hydrocarbon potential. As a result of petroleum exploration drilling to date, small gas fields have been discovered at Glentulloch, Rolleston, Arcturus, and Westgrove, though none of these has been brought into production. Many other gas shows have been encountered throughout the trough, but only traces of oil have been found. The presence of good hydrocarbon source rocks, limited reservoir rocks, adequate cap rocks, and numerous structural traps has been demonstrated. The two main problems with regard to hydrocarbon potential are the limited development of good reservoir rocks, and the timing of the major phase of structuring, which is thought possibly to have post-dated the migration of hydrocarbons. If it can be shown that conditions favourable to the development of reservoir rocks existed during the Permian, and that structures are present which existed during the migration of hydrocarbons, the potential of the area will be greatly up-graded.

The existing seismic coverage, though extensive, dates mostly from the early 1960s and low-effort techniques were used. The resultant data quality, although reasonable for the techniques in use at the time, is poor by current standards, and since much of the data was not recorded on magnetic tape it cannot be improved by modern data processing.

In general the existing seismic coverage shows fair data down to the top of the Lower Permian Reids Dome Beds, but, beneath this, reflection data is either non-existent or of poor quality. In addition, since most work has been directed at locating structures suitable for the accumulation of hydrocarbons, the seismic work tends to be concentrated along the major anticlinal trends, with very sparse coverage in between. With few exceptions the surveys had not been planned with the definition of the overall configuration of the trough in mind.

The proposed BMR survey will use CDP and digital recording and processing techniques, and should obtain data of significantly better quality than that recorded by past surveys. It is proposed in addition to take gravity readings along the seismic traverses to allow the additional constraints of gravity to be applied to the seismic interpretation.

The location of seismic traverses is constrained by the topography, which is extremely rough in parts of the survey area, particularly in the west where there is a deeply dissected plateau capped by Tertiary basalt, and in the central part where Jurassic sandstones outcrop at the northern eroded edge of the Surat Basin. Although the traverses have been designed to avoid very rough terrain, it is expected that bulldozing will be required in places to improve access. Dense timber cover in some areas will also necessitate the use of a bulldozer for clearing of lines.

Drilling progress, which is expected to govern the rate of progress of the survey operation, will probably be slow in the northern part of the survey area where basalt and river gravels are prevalent. Elsewhere, however, drilling conditions are expected to be fair.

The main supply centre for the operation will be Roma, which lies to the south of the survey area. Roma, with a population of 6000, has direct road and rail links with Brisbane, and a commercial air service which operates four days a week. The main access into the survey area is the Carnarvon Developmental Road which connects Roma with Injune and Rolleston.

GEOLOGY

The Denison Trough is a northerly trending Lower Permian downwarp along the western margin of the Permo-Triassic Bowen Basin. It contains over 4000 metres of marine and non-marine clastic sediments. It is flanked to the west by the Springsure Shelf and the Nebine Ridge, to the east by the Comet Platform which separates it from the Taroom Trough element of the Bowen Basin, and to the south by the Roma Ridge. A major structure, the Merivale Fault, separates the western margin of the trough from the Springsure Shelf and Nebine Ridge. The structural setting of the trough is illustrated in Fig. 1.

Geological mapping of the Permian rocks outcropping along the western margin of the trough commenced in 1926, and much work has been done in the area since in the search for hydrocarbons. The area was systematically mapped as a joint project by the Bureau of Mineral Resources and the Geological Survey of Queensland in 1963-64 (Mollan, Dickins, Exon and Kirkegaard, 1969, and Mollan, Forbes, Jensen, Exon and Gregory, 1972). The outcrop geology is shown on Plate 1.

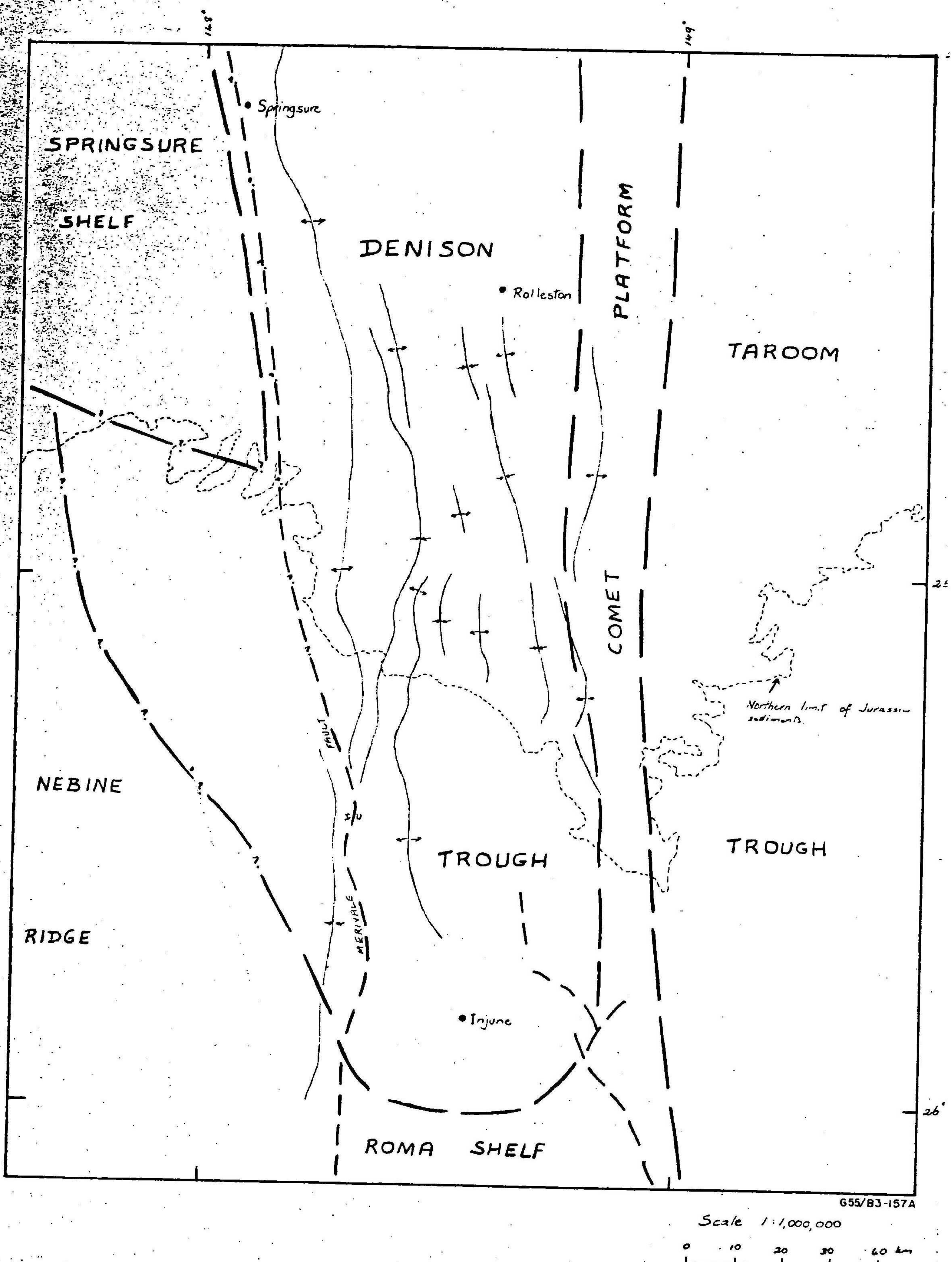

FIG 1. REGIONAL SETTING OF SOUTHERN DENISON TROUGH

Approximately 50 petroleum exploration wells and 17 GSQ stratigraphic bores have been drilled in and around the Denison Trough. Appendix 1 lists these wells with the thickness of Permian sediments penetrated, the formation that the well bottomed in, and any hydrocarbons found. Basement was reached in several wells drilled on the eastern and southern flanks of the trough, and in four wells within the trough, in particular SQDI (Morella), PEC Warrinilla 3, OSL 2 (Hutton Creek), and OSL 3 (Arcadia). In most of these wells prospective basement consisted of indurated sediments and metasediments, of probable Devonian age, which have been assigned to the Timbury Hills Formation. However andesitic volcanics were intersected at OSL 3 (Arcadia) and SQDI (Morella), and at PEC Warrinilla 3 a 260 metre thick volcanic sequence was intersected before the well bottomed in the Timbury Hills Formation. No wells have reached basement in the deep western part of the trough adjacent to the Merivale Fault.

Stratigraphy

The general stratigraphic sequence of the Denison Trough is given in Table 1. A more detailed description of the Permian section, including the maximum thickness, depositional environment, and lithology of each unit is given in Table 2. There are some variations, which cannot be discussed in this brief summary, in the nomenclature used by various workers for the Permian sequence. The nomenclature used here is that of Power (1967).

The Permian sediments of the Denison Trough fall into three broad divisions. These are a lower terrestrial sequence (the Reids Dome Beds), a middle mainly marine sequence (Cattle Creek Formation to Black Alley Shale), and an upper terrestrial sequence (The Bandanna Formation). The Reids Dome Beds are a very thick sequence of carbonaceous shales, siltstones and sandstones containing numerous coal seams. The middle marine sequence consists of a series of alternating shale and sandstone units deposited during several transgressive-regressive phases. The upper terrestrial group is a predominantly coal measure sequence.

The Permian sequence is unconformably overlain by a Triassic sequence consisting of three non-marine formations, which are considered to be largely unprospective.

In the south, the Triassic sequence is overlain with marked angular unconformity by Jurassic rocks of the Surat Basin. In the north and west, Tertiary basalt flows obscure much of the Permian and Triassic sequences.

TABLE 1. GENERAL STRATIGRAPHY, SOUTHERN DENISON TROUGH

AGE		UNIT		
	QUATERNARY	Soil, alluvium, gravel		
	TERTIARY	Basalt		
SURAT BASIN	CRETACEOUS	GRIMAN CREEK FORMATION		
SURAT BASIN	CRETACEOUS	SURAT SILTSTONE		
SURAT BASIN	CRETACEOUS	WALLUM-BILLA FMN	COREENA MEMBER	
SURAT BASIN	CRETACEOUS	WALLUM-BILLA FMN	DONCASTER MUDSTONE	
SURAT BASIN	CRETACEOUS	BUNGIL FORMATION		
SURAT BASIN	CRETACEOUS	HOORAY SANDSTONE	MOOGA SANDSTONE	
SURAT BASIN	JURASSIC	HOORAY SANDSTONE	ORALLO FORMATION	
SURAT BASIN	JURASSIC	HOORAY SANDSTONE	GUBBERAMUNDA SANDSTONE	
SURAT BASIN	JURASSIC	Injune Creek Group	WESTBOURNE FORMATION	
SURAT BASIN	JURASSIC	Injune Creek Group	ADORI SANDSTONE	SPRINGBOK SANDSTONE
SURAT BASIN	JURASSIC	Injune Creek Group	BIRKHEAD FORMATION	WALLOON COAL MEASURES
SURAT BASIN	JURASSIC	Injune Creek Group	EUROMBAH FORMATION	
SURAT BASIN	JURASSIC	HUTTON SANDSTONE		
SURAT BASIN	JURASSIC	EVERGREEN FORMATION	Westgrove Ironstone M	
SURAT BASIN	JURASSIC	EVERGREEN FORMATION	Boxvale Sandstone Mbr	
SURAT BASIN	JURASSIC	PRECIPICE SANDSTONE		
BOWEN BASIN (DENISON TROUGH)	TRIASSIC	MOOLAYEMBER FORMATION		
BOWEN BASIN (DENISON TROUGH)	TRIASSIC	CLEMATIS SANDSTONE		
BOWEN BASIN (DENISON TROUGH)	TRIASSIC	REWAN FORMATION		
BOWEN BASIN (DENISON TROUGH)	LATE PERMIAN	BANDANNA FORMATION		
BOWEN BASIN (DENISON TROUGH)	LATE PERMIAN	BLACK ALLEY SHALE		
BOWEN BASIN (DENISON TROUGH)	LATE PERMIAN	PEAWADDY FORMATION	Mantuan Productus Bed	
BOWEN BASIN (DENISON TROUGH)	EARLY PERMIAN	CATHERINE SANDSTONE		
BOWEN BASIN (DENISON TROUGH)	EARLY PERMIAN	INGELARA FORMATION		
BOWEN BASIN (DENISON TROUGH)	EARLY PERMIAN	PREITAG FORMATION		
BOWEN BASIN (DENISON TROUGH)	EARLY PERMIAN	ALDEBARAN SANDSTONE		
BOWEN BASIN (DENISON TROUGH)	EARLY PERMIAN	CATTLE CREEK FORMATION		
BOWEN BASIN (DENISON TROUGH)	EARLY PERMIAN	REIDS DOME BEDS		
BOWEN BASIN (DENISON TROUGH)	EARLY PERMIAN	VOLCANICS		
DEVONIAN		TIMBURY HILLS FORMATION		

(Permian-Triassic stratigraphy as in Power, 1967; Jurassic-Cretaceous stratigraphy after Exon, 1976).

AGE	GROUP	SUB-GROUP	UNIT	MEMBER	MAXIMUM THICKNESS (m)	ENVIRONMENT	LITHOLOGY
UPPER PERMIAN	BLACKWATER		BANDANNA FORMATION		300 aprox.	Paludal, lacustrine and fluviatile	Calcareous, lithic sandstone, siltstone, shale, coal, and minor tuff and oil shale. Coal seams significant in upper part of unit.
UPPER PERMIAN	BACK CREEK GROUP	BLENHEIM SUB-GROUP	BLACK ALLEY SHALE		200 approx.	Marine grading upwards to paludal	Dark grey to black shale and siltstone, interbedded tuff, bentonite, and minor fine sandstone.
UPPER PERMIAN	BACK CREEK GROUP	BLENHEIM SUB-GROUP	PEAWADDY FORMATION	Mantuan Productus Bed	210	Shallow marine and paludal, partly fluviatile and possibly deltaic	Carbonaceous siltstone, shale, and lithic quartzose sandstone, commonly calcareous. Upper part dominantly sandstone, lower part mainly siltstone and shale. Mantuan Productus Bed is prominent marine fossil shell horizon at or near top of unit.
	BACK CREEK GROUP	GEBBIE SUB-GROUP	CATHERINE SANDSTONE		115	Shallow marine and paralic, possibly in part sand bars	Fine to medium grained, well sorted, feldspathic, lithic and quartzose sandstone with interbedded siltstone, minor pebble and conglomerate beds.
	BACK CREEK GROUP	GEBBIE SUB-GROUP	INGELARA FORMATION		200 approx.	Marine	Siltstone, silty sandstone, sandy siltstone, with "erratic" pebbles. Thin calcareous sandstones, limestones and coquinites.
	BACK CREEK GROUP	GEBBIE SUB-GROUP	FREITAG FORMATION		95	Marginal marine, parts paludal	Interbedded quartz sandstones, conglomeratic sandstones, and mudstones. Minor coal.
	BACK CREEK GROUP	GEBBIE SUB-GROUP	ALDEBARAN SANDSTONE		650	Fluviatile, deltaic, marginal marine, parts may be neritic	Sandstone, conglomerate, lesser siltstone, shale and coal.
LOWER PERMIAN	BACK CREEK GROUP	TIVERTON SUB-GROUP	CATTLE CREEK FORMATION	Sirius Mudstone Member Staircase Sandst Member Middle Mudstone Member Riverstone Sandst. Member Lower Mudstone Member	800 approx.	Mainly marine, some littoral and fluviatile. Periods of restricted circulation.	Marine siltstone, sandstone, shale, minor limestone. Staircase and Riverstone Sandstone Members partly fluviatile. Gypsum, small amounts of phosphate.
LOWER PERMIAN	REIDS DOME BEDS			Orion Formation	2770+	Shallow freshwater, swampy	Upper unit: Coal measure sequence - fine to coarse carbonaceous sandstone, dark carbonaceous siltstone, shale, coal. Middle unit: Black to grey carbonaceous micaceous shale, siltstone, sandstone, minor coal, thin beds dolomite, conglomerate. Basal unit: Black shale and mudstone, coal seams, anhydrite layers, interbeds of hard carbonaceous anhydritic sandstone and orthoquartzite.

TABLE 2. DETAILED PERMIAN STRATIGRAPHY

(After Power 1967 and Dickins and Malone 1968)

Structure

The present-day Denison Trough consists of a series of folds along approximately north-south axis. Some of these are evident in outcrop e.g. the Springsure, Serocold, and Consuelo Anticlines and the Rewan and Nuga Nuga Synclines. Others, e.g. the Warrinilla, Rolleston and Purbrook Anticlines, have been mapped by seismic surveys. Numerous culminations occur along the anticlinal trends. There is a decrease in the intensity of the folding from west to east, from the Springsure and Serocold Anticlines which have amplitudes of over 1000 metres and dips of up to 40 degrees, to the broad and ill-defined Purbrook Anticline. The Springsure and Consuelo Anticlines in particular display marked asymmetry, with the steeper flank on the western side, and there is thrust faulting associated with the Springsure Anticline in the northern part of the Trough.

A major feature, the Merivale Fault, marks the western limit of lowermost Permian deposition. This fault is believed to have undergone displacement of several thousand metres during the early Permian, with the eastern side downthrown, but later movements reversed the direction of this throw and the Merivale Fault is now downthrown on the western side, with a displacement of a few hundred metres.

The location of the Merivale Fault in the southern part of the trough is well established by seismic control. The nature of the fault is not completely clear but it appears, in this area at least, to be a high angle reverse fault. The structure is believed to continue northwards in the zone west of the Serocold Anticline and east of the Springsure Shelf.

There is some evidence for faulting within the trough associated with the folding of the Permo-Triassic sequence. For example, seismic data clearly shows a fault with a throw of over two hundred metres on the eastern side of the Morella Anticline.

Geological History

Deposition in the Denison Trough commenced in the earliest Permian with the accumulation of a thick sequence of terrestrial sediments, the Reids Dome Beds, in a rapidly subsiding trough adjacent to the Merivale Fault. Subsequent encroachment of the sea from the east resulted in a period of marine deposition during which the Cattle Creek Formation was laid down; this was interrupted in the west by two regressions of the western shoreline which gave rise to two sandstone bodies, the Riverstone and Staircase Sandstone Members. A major regressive phase followed during which the marginal marine, deltaic and fluviatile rocks of the Aldebaran Sandstone were laid down. In parts of the trough a marked unconformity separates these rocks from overlying units. A thin marginal marine unit, the Freitag Formation, marked a return to marine conditions during which the siltstones of the Ingelara Formation were deposited. This was succeeded in the northwestern and central parts of the trough by a sandstone unit, the Catherine Sandstone, representing a limited regression from the west.

At the beginning of the Late Permian the Denison Trough no longer formed a distinct downwarp and the area became part of the western limb of a broad downwarp (the Mimosa Syncline) whose axis lay to the east (Mollan et al., 1969). Shallow marine and paludal sediments of the Peawaddy Formation and Black Alley Shale were deposited.

In the latest Permian the region was cut off from the sea and the Bandanna Formation, consisting of freshwater and paludal sediments with coal seams, was deposited over a large area.

Minor tectonic movements near the close of the Permian resulted in minor unconformities between the Permian and Triassic sediments in some areas. In the Triassic, non-marine deposition with several local breaks continued with the area of most rapid subsidence lying to the east. The red-beds of the Rewan Formation were succeeded by the fluvial Clematis Sandstone and the shallow water labile sediments of the Moolayember Formation.

Compressional forces, which may have commenced much earlier but which reached a peak in the late Triassic, folded the Permo-Triassic rocks into the parallel north-south asymmetric anticlines and synclines evident today. Reactivation of the Merivale Fault resulted in a relative upward displacement of the eastern side of the fault by several hundred metres.

Widespread erosion occurred during the late Triassic and the anticlines formed during the compressional phase were breached to varying degrees.

Freshwater sandstones, siltstones, and some coal were laid down over much of the area during the Jurassic. These rocks are draped over older structures and the fact that underlying anticlines are reflected in the Jurassic rocks is probably a result of differential compaction.

Epeirogenic uplift in the Tertiary increased the basinward (southward) tilt of the Surat Basin sequence. Associated with this was the extrusion of widespread basalt flows.

Hydrocarbon potential

To date, non-commercial gas fields have been discovered in the Denison Trough at Glentulloch, Rolleston, Arcturus and Westgrove, and numerous gas and oil shows and indications have been encountered elsewhere (see Appendix 1). The producing horizons were the Aldebaran Sandstone at Glentulloch and Westgrove, the Mantuan Productus Bed (Peawaddy Formation) and the Freitag Formation at Rolleston, and the Peawaddy Formation at Arcturus.

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Source. Rocks with good hydrocarbon source potential occur throughout the Permian section. In particular the carbonaceous shales and siltstones of the Reids Dome Beds, the marine siltstones of the Cattle Creek and Ingelara Formations, and shaley sections of the Aldebaran Sandstone and Freitag Formation should contain suitable source material.

Reservoir. The general shortage of good reservoir sands is a major problem in the Denison Trough. Porosity and permeability of the sandstone units is on average low due to the presence of clay matrix or siliceous overgrowths, and is extremely variable within relatively small areas. Limited permeability has been found in the Reids Dome Beds, in particular in the lower part of the sequence at AAO Westgrove 3. The sandstone members of the Cattle Creek Formation also offer some potential. The Aldebaran Sandstone is a proven reservoir, but the development of porosity and permeability is variable. The Freitag Formation and Mantuan Productus Bed also have proven reservoir potential, but once again the development of good porosity and permeability is sporadic.

Seal. The alternation of transgressive siltstones with the sandstone bodies provides adequate potential for the sealing of any reservoir.

Structure and timing. Seismic surveys have revealed the presence of many structural traps of substantial proportions. Nearly all of these occur as closed culminations on the major anticlinal trends. As most of the closure on these structures resulted from movements in the late Triassic, generation and migration of hydrocarbons may have occurred prior to the formation of traps.

Thus the two main limitations to the hydrocarbon potential of the area are the poor development of good reservoir sands and the possible lateness of the main phase of structuring with respect to hydrocarbon migration. The potential of the trough will be greatly up-graded if it can be shown that conditions conducive to the development of reservoir sands existed in the Permian, and if the existence of structures of Permian age can be established.

PREVIOUS GEOPHYSICAL SURVEYS

Aeromagnetic Surveys

The BMR conducted an aeromagnetic survey over much of the Bowen Basin, including the Denison Trough, between 1961 and 1963 (Wells and Milsom, 1966).

Wells and Milsom found that interpretation of the results was made difficult by interference between the effects of deep and superficial magnetic horizons (such as Tertiary basalts, present over much of the central and northern Denison Trough), and that much of the area was devoid of anomalies suitable for depth estimation. However determinations of magnetic basement depths were carried out where possible, and the resultant contours on magnetic basement are shown in Fig. 2.

There is very limited correlation between the magnetic basement contours and the configuration of the Denison Trough and its environs. In most areas the magnetic basement is correlated with rocks of unknown age which are below prospective sedimentary basement, and for this reason the magnetic results cannot be used for delineating structures within the Denison Trough.

Gravity Surveys

A helicopter reconnaissance gravity survey was done over the area by BMR in 1964 (Lonsdale, 1965). The Bouguer anomalies were re-computed during the production of the Gravity Map of Australia (Anfiloff, Barlow, Murray, Denham and Sandford, 1976). The Bouguer anomalies for the Denison Trough and surrounding areas are shown in Fig. 3.

The map can be divided into three general areas. These are a zone of high gravity in the west, reflecting the shallow basement of the Nebine Ridge and Springsure Shelf, an area of low gravity in the south, corresponding approximately with but not necessarily related to the occurrence of Jurassic sediments, and an area of intermediate Bouguer anomaly values corresponding approximately to the Permo-Triassic outcrop area in the north.

It was noted by Fraser, Darby and Vale (1977) that the Denison Trough has no appreciable gravity expression. Close examination reveals that some minor correlations can be found between the Bouguer anomalies and the known geology, for example the gradient between the relative gravity low at Westgrove in the deeper part of the trough and the relative gravity high at Arcadia on the Comet Platform. In general however the correspondence is poor, possibly due in part to a small density contrast between the Permo-Triassic rocks and the underlying metasediments of the Timbury Hills Formation.

The joint modelling of seismic data and gravity data from readings to be taken along the seismic traverses, may help to ascertain what geological boundaries the Bouguer anomalies reflect, and thus perhaps enable the use of previous gravity information to clarify the structure of the whole area.

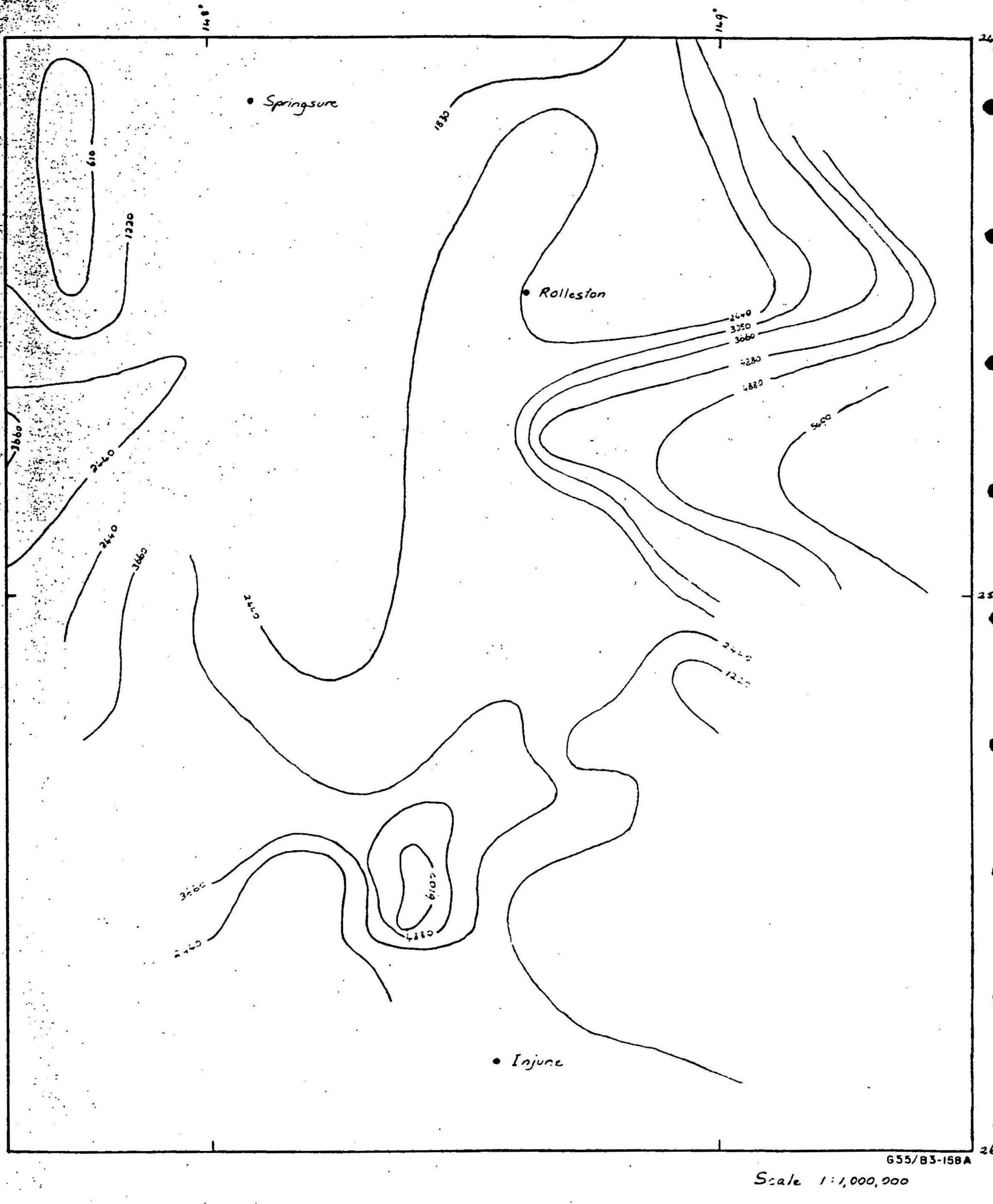

FIG 2. MAGNETIC BASEMENT DEPTH

metres below m.s.l.

From Wells & Milsom, 1966

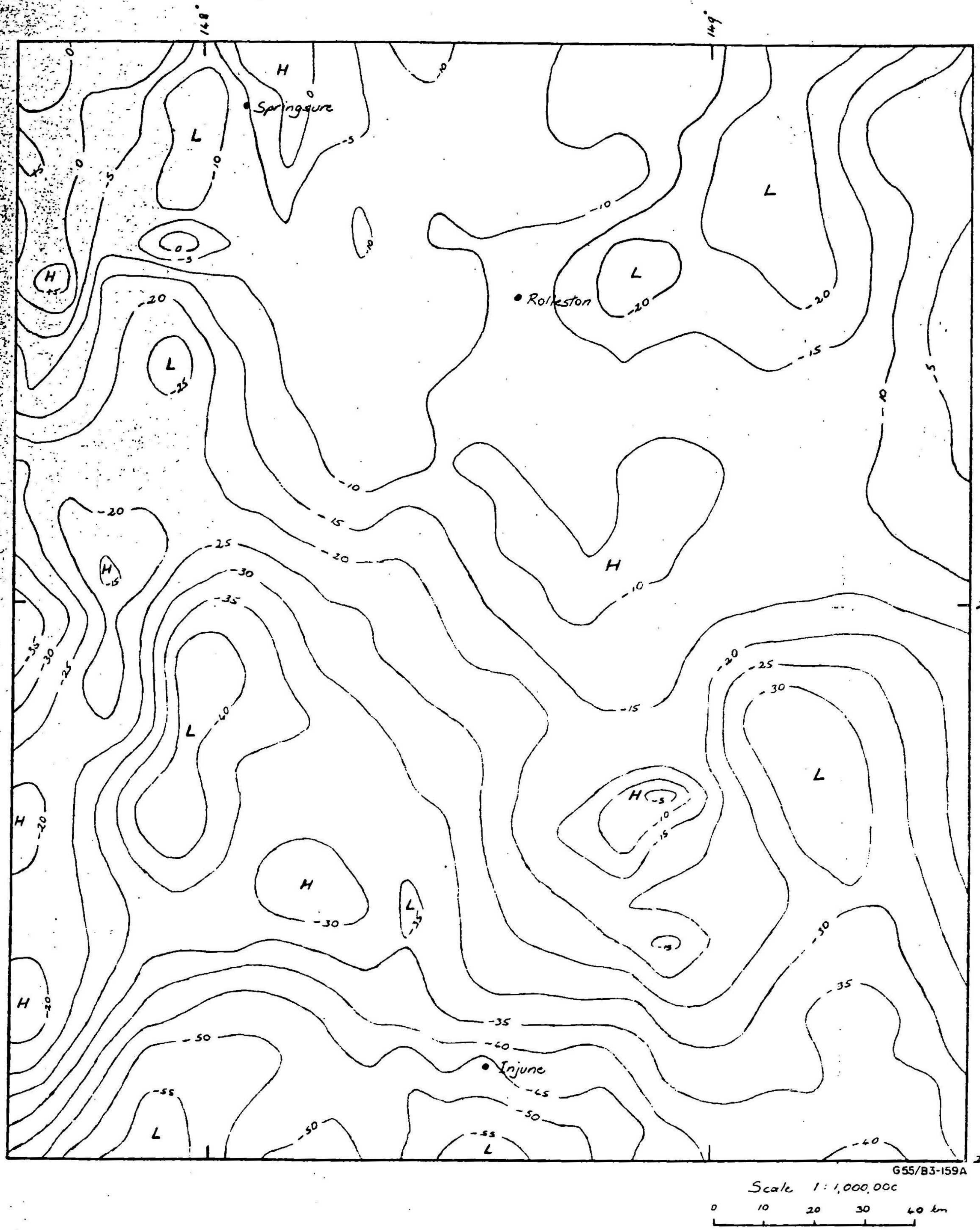

FIG 3. BOUGUER ANOMALIES

Contour interval 5 milligals

$\rho = 2.67\ t\,m^{-3}$

Seismic Surveys

Over 4000 km of reflection seismic traverses has been recorded by private companies in the southern Denison Trough in attempts to define drilling targets for petroleum exploration. The distribution of these traverses is shown in Plate 1.

Over three-quarters of this seismic work was recorded in the early 1960's, using mainly single-fold coverage and generally low effort techniques. Almost half of the total coverage was not recorded on magnetic tape.

Pertinent facts relating to the ten main seismic surveys, including the techniques used and the quality of the data obtained, are summarized in Table 3. A more detailed discussion of each survey is given below.

Merivale Area seismic survey, 1961-62 (Associated Australian Oilfields N.L.)

The Merivale Area survey, conducted in the southernmost part of the Denison Trough, consisted of both singlefold and "spot-correlation" recording aimed at establishing drillsite locations on suitable structures. AAO Glentulloch 1, AAO Killoran 1, and AAO Westgrove 1 to 4 were drilled on structures located by the survey.

Two main reflection horizons were mapped, identified by ties to AAO Westgrove 1 and AAO Glentulloch 1 as (1) near the base of the coal seams of the Bandanna Formation, and (2) near the top of the Reids Dome Beds. At Glentulloch there is evidence of a very weak event at the expected time for a basement reflection, but in the deeper part of the trough to the north, any evidence for reflections from below the top of the Reids Dome Beds is very sparse.

Several lines from this survey cross the Merivale Fault. Only one horizon was picked west of the fault and since it is impossible to correlate events across the fault, its identification is difficult. The only well tie is to AAO Womblebank 1, for which no velocity information is available. Using the velocity function from AAO Glentulloch 1, the nearest well with velocity data, this horizon falls a little above basement, so could originate either from basement or from within the thin Permian section overlying basement. Further north and just west of the Merivale Fault, where the Permian section is expected to be thicker, the mapped horizon originates from above basement and probably from within the Permian section.

The nature of the Merivale Fault is difficult to ascertain on the unmigrated seismic sections, however dip migration reveals that the fault is a high angle feature, with a near conformable Permian to Lower Triassic sequence east of the fault upthrown against the Permian to mid-Triassic sequence west of the fault. Due to the lack of well control west of the fault and the inability to correlate reflections across it, the seismic data is unable to indicate how much Permian section exists west of the fault. It does, however, show that the Triassic section is substantially thicker on the western side than on the eastern side. This agrees with the results of GSQ Eddystone 2-3RA, which indicated a thick sequence of the mid-Triassic Moolayember Formation west of the Merivale Fault, as opposed to its complete absence, presumably through erosion, at Westgrove east of the

Survey	C'wealth Subsidy	Location	Type	Amount of Coverage	Shot pattern	Av. Charge Size and Depth	Geophone type and pattern	Station Interval	Spread	Presentation of data	Data quality
Merivale Area (A.A.O.,1961-62)	Yes	Southern Denison Trough	Spot-correlation and single fold reflection	913 km	Single	5 kg 35 m	Electro-Tech EVS-2B, 14 Hz 5/trace, in line, 9 m apart	33 m	396-0-396 m	Uncorrected wiggle-trace	Fair for upper part of section, very poor for lower part
Rolleston-Springsure (A.F.O., 1962)	Yes	Central and northern Denison Trough	Spot correlation and single fold reflection	627 km	Single	20 kg 22 m	S-32, 27 Hz 12/trace, in line, 7 m apart	34 m	402-0-402 m	Uncorrected wiggle-trace	Poor to fair
Rolleston Area (Planet, 1962)	Yes	Central southern Denison Trough	Singlefold reflection	406 km	Single	14 kg 45 m	Electrotech, 30Hz 8/trace, in line, 9 m apart	34 m	402-0-402 m	Corrected wiggle-trace, some variable area	Fair
Purbrook-Arcadia (A.A.O.,1962-63)	Yes	Eastern Denison Trough	Singlefold reflection and minor refraction	300 km reflection 14 km refraction	Single	33 kg 27 m	Electrotech 20 or 27 Hz. 12/trace, in line, 7 m apart	34 m	402-0-402 m	Uncorrected wiggle-trace	Fair
Emerald (Part 1) (A.F.O. 1963-64)	Yes	Central, eastern and northern Denison Trough	Singlefold reflection	820 km	Single	25 kg 46 m	S-32, 27 Hz. 12, 24 or 36/trace 5 or 7 m apart	22 to 45 m	268-0-268 m to 536-0-536 m	Variable area	Poor to very poor in north, fair in south
Emerald (Part 2) (A.F.O., 1964)	Yes	Central Denison Trough (Rolleston area)	Singlefold reflection, Vibroseis source	94 km	Vibrator pattern length 122 m	No. of sweeps/trace :10, frequency range:20-57 Hz	HSJ 14 Hz. 300-400/trace in 122 x 111 m or 122 x 122m arrays	27 or 40 m	268 or 402 m	Variable area	Very poor to fair
Warrinilla (Planet, 1967)	Yes	Central southern Denison Trough	3-fold CDP reflection	17 km	Single	16 kg 41 m	Electrotech EV-S, 20 Hz. 16/trace, in line, 5 m apart	67 m	805-0-805 m	Variable area	Fair
Westgrove (A.A.O., 1968)	No	Southern Denison Trough	6-fold CDP reflection	87 km	Single	45 kg 45 m	24/trace, in two rows of 12, in line approx 7 m apart	83 m	0-419-2347 m	Variable area	Fair for upper part of section, very poor for lower part
Warrinilla West (Planet, 1970)	Yes	Central southern Denison Trough	3-fold CDP reflection	18 km	Single	25 kg 45 m	HSJ 14 or 20 Hz. 12/trace, in line, 6 m apart	61 m	701-0-701 m	Variable area	Fair
Denison Trough (Planet, 1969-70)	Part	Eastern Denison Trough	Singlefold to 12-fold CDP reflection	127 km subsidized; approx 670 km un-subsidized	Single	25 kg 36 m	HSJ 20 Hz 12/trace in line, 6 m apart	45 m (singlefold) 61m (CDP)	536-0-536 m (singlefold) 732-0-732 m (CDP)	Variable area	Poor to very poor in north, fair in south

TABLE 3. SEISMIC SURVEYS, SOUTHERN DENISON TROUGH

fault. The seismic sections also show that Jurassic sediments cross the fault zone with a small amount of flexure but no fault displacement.

This survey was conducted using a very low-effort technique, with 5 kg charge sizes and 5 geophones/trace. Although fair quality reflections were obtained from the Bandanna Formation and the top of the Reids Dome Beds, the almost total absence of energy return from basement renders this survey useless as an indicator of the thickness and distribution of the Lower Permian Reids Dome Beds, and therefore also as an aid to establishing the Early Permian history of the area.

Rolleston - Springsure Area seismic survey, 1962 (Associated Freney Oilfields N.L.)

This survey in the central and northern Denison Trough consisted of singlefold and "spot-correlation" recording aimed at locating drilling targets.

Four reflection horizons were mapped throughout most of the survey area. From ties to exploration wells by means of lines of the later Purbrook - Arcadia and Emerald surveys, these horizons are identified, in the southern part of the survey area at least, as Horizon A, near the base of the coal seams of the Bandanna Formation, Horizon B, near the base of the Aldebaran Sandstone, Horizon C, near the base of the Cattle Creek Formation, and Horizon D, possible basement, unconformable with the other three horizons.

The generally poorer record quality in the northern part of the survey area makes correlation more difficult there, thus reducing the reliability of the horizon maps and making identification of the reflection horizons mapped questionable.

Two noise shoots were recorded during the course of the survey to analyse the properties of coherent noise in the area. These indicated that there were noise events with the same frequency and wave-number characteristics as signal, which would therefore interfere with signal events, and that the wavelength of many of these noise events was too long for them to be effectively attenuated by geophone and shot arrays. A high low-cut fitter (30 to 36 Hz) with a sharp cut-off slope was used on recording to attenuate noise events (the data was not recorded on magnetic tape, hence the need for severe filtering during recording).

In general, useful data was obtained in the southern part of the survey area, which is the part most relevant to this study, using relatively light techniques. Noise problems, apparently associated with the near-surface basalt layer, resulted in a serious deterioration in record quality north of Rolleston.

The Rolleston - Springsure survey showed that the north-south structural trends evident in outcrop in the Springsure - Serocold and Consuelo Anticlines persist to the north and east where the Permian sequence is concealed by younger sediments and Tertiary volcanics. Several major anticlinal trends were outlined, and closure on numerous features along these anticlinal trends was indicated.

Rolleston Area seismic survey, 1962 (Planet Exploration Company Pty Ltd)

The Rolleston Area survey in the central southern Denison Trough was conducted for the purposes of mapping subsurface structure and selecting drillsite locations. It mapped two major anticlinal trends, the Morella and Warrinilla Anticlines. PEC Warrinilla 1 and 2, and PEC Warrinilla North 1 were drilled on the Warrinilla Anticline on features defined by the Rolleston Area survey.

The survey mapped three reflection horizons throughout the whole of the area, plus seven intermediate horizons in varying parts of the area. The shallower two of the three main horizons are identified by ties to the above wells as near the base of the coal seams of the Bandanna Formation, and within the Cattle Creek Formation. The reflection quality of these horizons is fair throughout the whole area, and the Bandanna horizon in particular is a very strong reflection event. The deepest of the three horizons, however, is weaker, much less continuous, and complexly faulted, makihg its correlation from area to area difficult and unreliable. This horizon originates from a major angular unconformity believed to represent basement. Its reflection time agrees with the expected basement time as indicated by PEC Warrinilla 3, which intersected the Devonian Timbury Hills Formation beneath the Permian sequence.

The survey provided good coverage over the Warrinilla Anticline and partial coverage of the Morella Anticline to the west. The Warrinilla Anticline is a broad north-south trending high which plunges and narrows northwards. It has gentle dip on the eastern flank and steeper dip on the western flank. There are several culminations along its length.

The Morella Anticline is apparently a parallel feature west of and structurally higher than the Warrinilla Anticline. It is separated from the area to the east by a major down-to-the-east fault which is probably of post-Permian origin. It was noted that several of the intermediate mapping horizons appeared to pinch out over the Morella Anticline, indicating that this area was structurally high at the commencement of Permian deposition and possibly also at certain periods throughout the Permian. There is similar evidence that the PEC Warrinilla North 1 culmination may have been a pre-Permian uplift.

A major phase of folding was indicated in post-Permian time which imposed a system of north-south folds throughout this and surrounding areas.

The Rolleston Area survey used relatively light techniques with 14 kg charges, 8 geophones/trace, and singlefold coverage. These methods gave fair data on shallow horizons and poor data on basement. It is considered that standard modern techniques should yield much improved records in this area including fair data on basement.

Purbrook-Arcadia seismic survey, 1962-63 (Associated Australian Oilfields N.L.)

The main part of this survey was conducted in the Purbrook-Arcadia area on the eastern flank of the Denison Trough. Smaller surveys were done in the Bandanna area in the west and the Inderi and Laleham areas to the north.

The objective in the Purbrook-Arcadia area was to map structures suitable for drilling. Mapping was done on three reflection horizons, which were identified by ties to several wells as Horizon A, near the base of the Bandanna Formation, Horizon B, near the top of the Cattle Creek Formation, and Horizon C, correlated at OSL 3 (Arcadia) with the base of the Cattle Creek Formation, but corresponding in the Rolleston area with the Emerald survey Horizon D, believed to represent basement. At the time of doing the survey a miscorrelation between lines leading to this situation could easily have occurred, as the traverses were unconnected. After the Emerald survey, carried out the year after the Purbrook-Arcadia and Rolleston - Springsure surveys, a re-interpretation of data from all three surveys was carried out and incorporated in a single set of contour maps.

The survey mapped the western flank of the broad, north-south trending Purbrook Anticline. No certain closures were mapped but several were indicated. The siting of AP Cometside 1, AP Motley 1, and AP Purbrook South 1, drilled after the follow-up work during the Emerald survey, was based mainly on mapping by the Purbrook-Arcadia survey.

Data quality in the Purbrook-Arcadia area was generally fair. The charge sizes used for this survey, averaging 33 kg/shot, were larger than those used by other surveys carried out at about this time.

The small survey carried out in the Bandanna area was designed to prove closure on the Bandanna culmination of the Springsure - Serocold Anticline. It succeeded in doing this, and AFO Bandanna 1 was subsequently drilled. The quality of the reflection data obtained was fair. The dominant reflection event in the area originates from the top of the Reids Dome Beds; there are reflections from below this level but they are fairly weak. The position of basement is completely unknown as this work is not tied to a basement well.

Two small reflection and refraction surveys were recorded at Inderi and Laleham, northwest and north of Rolleston respectively, in areas of Tertiary basalt cover. The quality of the data obtained was generally poor.

<u>Emerald seismic survey, 1963-64 (Associated Freney Oilfields N.L.)</u>

This survey was conducted in the central, eastern, and northern parts of the Denison Trough. Its purpose was to locate and map structures favourable for the accumulation of hydrocarbons, including the detailing of structures indicated by the Rolleston - Springsure and Purbrook-Arcadia surveys. AFO Rolleston 1 to 10, AFO Arcturus 1 to 4, AFO Purbrook 1 and AFO Yandina 1 were drilled on structures detailed by the Emerald survey.

The survey consisted of two parts. The first, comprising the majority of the survey, consisted mainly of single fold reflection recording using a conventional explosive source. The second part was a much smaller survey carried out in the Rolleston area using the Vibroseis method. It was done to evaluate in more detail the Rolleston gas field, and to enable a comparison of the results of the Vibroseis and conventional methods.

The contour maps presented by the Emerald survey incorporate reinterpreted data from the previous Rolleston - Springsure and Purbrook-Arcadia surveys. Four reflection horizons were mapped where record quality permitted. These were Horizon A, identified by ties to outcrop on the Consuelo anticline and to wells at Rolleston, Purbrook, Inderi and Arcturus as near the base of the coal seams of the Bandanna Formation; Horizon B identified at AFO Rolleston 1 as near the base of the Aldebaran Sandstone, but at AFO Purbrook 1 as a horizon within the Cattle Creek Formation; Horizon C, identified at AFO Rolleston 1 as near the base of the Cattle Creek Formation, but at AFO Purbrook 1 as from within the Timbury Hills Formation, and Horizon D, possible basement. At AFO Rolleston 1 Horizon D originates approcimately 60 metres below the total depth of the well, and as the well bottomed in the lower part of the Reids Dome Beds it is reasonable to surmise that this horizon represents basement in this area. It is almost certain however that the stratigraphic position of the horizon varies throughout the survey area.

Reflection quality varies from fair to extremely poor. In general it is best in the southern part of the survey area, and deteriorates to the north where surface and near surface basalt is widespread. Of the four reflections mapped, Horizon A is the strongest. It could be mapped fairly reliably in the south, but less so in the north. Horizon B is of poor to fair quality in the south, and very poor quality in the north. Horizon C could not be mapped at all in the northern area. Horizon D could be mapped reliably only in the Rolleston - Purbrook area, elsewhere it was mapped as a phantom horizon based on discontinuous reflection segments.

Considerable effort was put into experimentation with shot and geophone patterns, shot depths, charge sizes, spread lengths, recording filters etc in an attempt to improve record quality. Despite this no techniques were evolved which gave a satisfactory signal-to-noise ratio in basalt-covered areas. The Vibroseis recording in the Rolleston area produced records of comparable to slightly better quality than those obtained using conventional techniques. In particular the Vibroseis records showed better resolution of the presumed basement reflection.

The poor quality of much of the data recorded by the Emerald survey limits its usefulness. However it did indicate the general structural configuration of the area, namely one of sub-meridional folding, and it was successful in either proving or indicating closure on numerous structures.

Warrinilla seismic survey, 1967 (Planet Exploration Company Pty Ltd)

This was a small survey on the Warrinilla Anticline aimed at confirming an anomaly indicated by reinterpretation of data from the Rolleston area survey, with a view to drilling an exploratory well. It was hoped to prove that a structure in existence now was structurally high during Permian deposition, thereby forming a trap for migrating hydrocarbons.

The survey was conducted using 3-fold CDP coverage, relatively small charge sizes (16 kg/shot) and 16 geophones/trace. Fair quality data was obtained. Three reflection horizons were mapped, which have been identified, using an inferred velocity function, as near the base of the Bandanna Formation, near the top of the Reids Dome Beds, and near the top of the volcanic sequence (in PEC Warrinilla 3).

The survey indicated the existence of a small closure over which thinning of the Lower Permian sequence occurred. PEC Warrinilla 3 was subsequently drilled on this site.

Westgrove seismic survey, 1968 (Associated Australian Oilfields N.L.)

This was an unsubsidized survey conducted in the southern Denison Trough. A high effort recording technique including 6-fold CDP coverage, large charge sizes (45 kg/shot) and 24 geophones/trace was used. Good reflection data was obtained from the top of the Lower Permian Reids Dome Beds, but virtually no reflections were recorded from lower in the sequence.

Warrinilla West Seismic Survey, 1970 (Planet Exploration Company Pty Ltd)

This small survey was aimed at outlining part of the Morella anticlinal trend and determining the structural relationship with the Warrinilla anticlinal trend to the east, with a view to locating a test-site.

The survey was conducted using mainly 3-fold CDP coverage, moderate charge sizes (25 kg/shot) and 12 geophones/trace. Fair quality data was obtained.

Mapping was carried out on two reflection horizons which were identified, using inferred velocity data, as near the top of the Ingelara Formation, and near the top of the Cattle Creek Formation. Other reflection events were present, including one which probably originates from basement.

The survey confirmed the existence of a major down-to-the east fault on the eastern side of the anticline. It also proved closure against this fault at the site of SQD1 (Morella), but showed the high point of this closure to be over a kilometre south of the well. A second closure on the Cattle Creek mapping horizon was indicated further south, but curtailment of the program prevented its complete assessment. It also prevented the recording of a line linking the Morella and Warrinilla Anticlines.

Denison Trough seismic survey, 1969-70 (Planet Exploration Company Pty Ltd)

This was an extensive survey carried out in the eastern part and on the flank of the Denison Trough. Most of the survey did not qualify for exploration subsidy because of proximity to the Rolleston and Arcturus gas fields. Of the two small parts which did qualify for subsidy, the most relevant one to this study lies on the Purbrook Anticline immediately east of Warrinilla. The other part lies further north near AAO Sunlight 1. The subsidized part of the Denison Trough survey has been called the Denison East seismic survey.

The Denison East survey had as its objective the detailing of structural anomalies. The subsidized lines on the Purbrook anticlines were recorded with mainly singlefold but some 3-fold CDP coverage. Moderate charges (25 kg/shot) and 12 geophones/trace were used. The record quality achieved was generally fair. Two reflection horizons, identified as the tops of the Peawaddy and Ingelara Formations were mapped, and deeper reflections were evident on the record sections. The contour maps show two northward-plunging anticlines; on each of these a small structural closure was delineated.

The small area of subsidized work around AAO Sunlight 1 lay in an area of near-surface basalt. Despite the use of 6 and 12-fold CDP recording, the reflection quality achieved was poor to very poor.

OBJECTIVES AND PROGRAM

The existing seismic coverage in the Denison Trough has been successful in locating numerous drilling targets including four which resulted in significant gas finds but is not of sufficient quality nor of the right distribution to answer the following two important questions.

1. What is the depth and configuration of pre-Permian basement?

2. What is the nature of the western margin of the trough?

In addition to these fundamental questions, there are others more directly related to the Trough's hydrocarbon potential, in particular:-

3. What is the distribution of reservoir sands?

Pre-Permian basement has been recorded at some locations in the northern part of the survey area, however the generally poor record quality, the irregular distribution of seismic lines, and in places the faulted nature of the basement have made it impossible to map the basement horizon throughout the area and thus to obtain a clear picture of its configuration. In the southern part of the survey area, previous seismic surveys have failed, because of the presence of thick coal seams, to record reflections from beneath the top of the Reids Dome Beds. Thus the depth and configuration of basement are completely unknown in this area.

The Merivale Fault, the western limit of the majority of Lower Permian sediments, is believed to have been a controlling factor in the development of the Denison Trough. Geological mapping and stratigraphic drilling suggest that it was a growth fault during the Lower Permian, but present seismic data is not of sufficient quality to confirm this. If the growth fault theory can be confirmed by good quality seismic data, the prospects for good reservoir - source relations adjacent to the fault are up-graded. In addition, the present structural configuration of the more intensely folded western part of the trough cannot be determined below the top of the Reids Dome Beds due to the inability of seismic surveys so far to record reflections from this zone. Determination of the style of structuring at depth, for example anticlinal folding or thrust faulting, would allow better assessment of the trap possibilities in the Reids Dome Beds.

The Reids Dome Beds, the lowermost unit in the Denison Trough, is a thick terrestrial sequence of carbonaceous shales, siltstones and sandstones containing numerous coal seams. The sequence is considered to have good source rock potential and modest reservoir potential in some areas. Its distribution is largely governed by basement configuration. The sequence is known to be very thick in the Westgrove area in the south-western part of the Trough, and could be of similar thickness elsewhere particularly in the western part of the trough adjacent to the Merivale Fault. It has been suggested (Brown, 1977) that sedimentation in Reids Dome time was controlled not only by the Merivale Fault, but also by several parallel faults to the east, resulting in a system of meridional half-grabens in which thick sequences of lower Permian sediments were deposited. If this is the case, greater thicknesses of Reids Dome Beds than previously thought may exist in parts of the Denison Trough. In addition, the existence of several active faults increases the chances of good reservoir beds having formed in association with such faults.

As has been pointed out elsewhere, the limited development of adequate reservoirs is one of the main problems with regard to the hydrocarbon potential of the Denison Trough, and evidence indicating their existence is required to enhance the prospectivity of the area. The most likely places for reservoir sands to occur are adjacent to the trough margins, in particular margins such as the Merivale Fault which are thought to have been active during deposition, adjacent to intra-basin highs such as the Morella High, and associated with ancient shorelines such as that believed to have existed in Aldebaran time in the southeastern part of the trough. To date information on potential reservoirs has been derived almost entirely from drilling results. It is considered that good quality seismic data can, in conjunction with drilling data, assist in the mapping of lateral facies variations across the trough and thus the distribution of potential reservoir sands.

The BMR survey is aimed at overcoming these deficiencies in the present understanding of the Denison Trough, and at providing a framework of good quality seismic traverses for future reviews. The lines planned are as follows:-

Traverses 1 and 2. These lines will be recorded from the Arcadia anticline near the eastern flank of the trough. The lines will tie to PEC Warrinilla 1 exploration well and GSQ Taroom 8, 9 and 10 stratigraphic boreholes, and will connect to Traverse 3 (below). The aims of these traverses are (1) to investigate the existence and location of an important facies change suggested by GSQ stratigraphic drilling, and (2) to investigate the depth and configuration of basement.

Traverse 3. This line will be recorded from the eastern flank of the Warrinilla Anticline west to the Serocold Anticline. It will tie to PEC Warrinilla 3 and 4, SQD 1 (Morella) and AFO Bandanna 1. The main aim of the line is to obtain depth and structural information from basement. Control on the position of the basement horizon for this traverse and Traverses 1 and 2 will be obtained from PEC Warrinilla 3 and SQD1 (Morella), both of which intersected basement.

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Traverse 4. This is an east-west trans-trough line designed to map the basement depth and configuration from the Comet Platform in the east to the Merivale Fault in the west. It will tie to AFO Purbrook 1, AFO Rolleston 1, and AOE 3 (Consuelo); control on the basement horizon will be obtained from AFO Purbrook 1.

Traverse 5. (second priority). This line will be recorded if time permits. It will constitute a tie line between Traverses 3 and 4, and would assist in the mapping of reflection horizons on all existing seismic data in the region.

Traverse 6. This line is designed to obtain data from within the Reids Dome Beds and from basement, in an area where previous seismic surveying has failed to do so. The line will be recorded from the Hutton Dome in the east to west of the Merivale Fault, and will tie to OSL 2 (Hutton Creek) GSQ Taroom 11-11A, AAO Kia Ora 1, and AAO Westgrove 3. It is hoped that this line will solve the problems of the depth and configuration of basement, the type of structuring at depth in the Westgrove area, and the nature of the Merivale Fault.

Traverse 7. (second priority). This line will be recorded, if time permits, between AAO Glentulloch 1 where basement was intersected at shallow depth, and the Westgrove area, with the main aim of tracing the basement horizon from Glentulloch into the deeper part of trough. The line will tie to AAO Glentulloch 1 and 2, AAO Kildare 2, AAO Kildare North 1, and AAO Westgrove 3, 2 and 1.

Optimum shooting and recording parameters for each area will be determined by means of noise tests, uphole shoots and charge size experiments. Optimum shot hole depths will be determined by recording weathering shots at intervals along the traverses in advance of the drilling team, and by reference to data from the existing seismic coverage. Multiple-coverage recording, mainly 6-fold, will be used. A geophone station interval of 42 metres will be used to obtain data of high enough resolution to show detailed stratigraphic information and to adequately map structurally complex zones. Expanded spreads may be recorded if considered necessary to supplement velocity information obtained from exploration wells and from the analysis of the CDP data. The data will be recorded digitally, using 48 input channels.

The proposed program consists of approximately 300 km of coverage, which is the amount considered possible based on production rates achieved by recent BMR surveys.

In addition to the seismic work, it is proposed to make gravity observations at approximately ½ kilometre intervals along the seismic traverses, and possibly on extensions of the traverses if this is considered necessary to enable a proper interpretation of the gravity data to be made.

The survey team will leave Canberra in late June. Drilling operations will commence in early July, and recording in mid-July. The party will return to Canberra in late November. The personnel, vehicles and equipment to be employed are listed in Appendix 2.

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APPENDIX 1. PETROLEUM EXPLORATION AND STRATIGRAPHIC WELLS, DENISON TROUGH

Well	Location	Year	Total depth (m)	Thickness Permian (m)	Formation bottomed in	Hydrocarbons
AAO 7 (Arcadia)	25 17 54 S, 148 47 43 E	1957	1000	894 +	Reids Dome	Gas show
OSL 3 (Arcadia)	25 17 00 S, 148 45 00 E	1939	1840	1691	Volcanics	Tr. oil
AFO Arcturus 1	24 03 40 S, 148 30 00 E	1964	1891	1685 +	Cattle Creek	Gas well
AFO Arcturus 2	24 01 10 S, 148 24 42 E	1964	1113	Not available		-
AFO Arcturus 3	24 04 30 S, 148 31 05 E	1964	645	Not available		Gas well
AFO Arcturus 4	24 05 20 S, 148 31 05 E	1964	1113	Not available		-
AFO Bandanna 1	25 06 40 S, 148 17 20 E	1963	1232	1232 +	Reids Dome	Gas show, tr. oil
AOD Comet River 1	24 37 46 S, 148 38 04 E	1970	1910	1471 +	Cattle Creek	Gas show
AP Cometside 1	24 39 30 S, 148 48 06 E	1964	1695	1427	Timbury Hills	-
AOE 3 (Consuelo)	24 33 40 S, 148 23 20 E	1955	1352	1352 +	Reids Dome	-
PEC Crystalbrook 1	25 29 03 S, 147 59 35 E	1964	628	0	Timbury Hills	-
*GSQ Eddystone 1	25 20 00 S, 148 18 00 E	1976	1220	880 +	Reids Dome	-
*GSQ Eddystone 2-3 RA	25 19 00 S, 148 06 00 E	1977	679	0 +	Moolayember	-
MPA Glenhaughton 1	25 12 30 S, 149 07 45 E	1964	2871	800	Volcanics	-
AAO Glentulloch 1	25 47 17 S, 148 22 47 E	1961	1245	708	Timbury Hills	Gas well
AAO Glentulloch 2	25 46 17 S, 148 22 47 E	1968	949	439 +	Reids Dome	Gas well
AAO Glentulloch 3	25 46 42 S, 148 23 30 E	1968	957	399 +	Reids Dome	Gas show
OSL 2 (Hutton Creek)	25 42 00 S, 148 42 00 E	1938	1429	1149	Timbury Hills	Gas show
AFO Inderi 1	24 17 00 S, 148 29 00 E	1963	1656	1629 +	Reids Dome	Gas show
AAO Kia Ora 1	25 38 44 S, 148 36 49 E	1966	1655	870 +	Reids Dome	Gas show
AAO Kildare 1	25 43 16 S, 148 24 46 E	1963	1745	1010 +	Reids Dome	Gas show
AAO Kildare 2	25 43 09 S, 148 23 00 E	1963	2336	1786 +	Reids Dome	Gas show
AAO Kildare North 1	25 40 43 S, 148 22 30 E	1968	1389	663 +	Reids Dome	-
AAO Killoran 1	25 54 00 S, 148 19 00 E	1962	716	134	Timbury Hills	-
SQD 1 (Morella)	25 00 46 S, 148 29 04 E	1951	1412	1170	Volcanics	-
AP Motley 1	24 38 52 S, 148 46 23 E	1964	1276	991 +	Cattle Creek	-
AFO Purbrook 1	24 37 10 S, 148 48 20 E	1963	1508	1343	Timbury Hills	-
AP Purbrook South 1	24 49 30 S, 148 46 40 E	1964	1701	1021 +	Cattle Creek	-
AOE 1 (Reids Dome)	24 47 23 S, 148 19 18 E	1955	2762	2762 +	Reids Dome	Gas show
AOE 2 (Reids Dome)	24 51 00 S, 148 19 00 E	1955	1238	1238 +	Reids Dome	-
AFO Rolleston 1	24 33 47 S, 148 37 52 E	1964	2898	2686 +	Reids Dome	Gas well, tr. oil
AFO Rolleston 2	24 32 58 S, 148 38 48 E	1964	1442	1128 +	Aldebaran	Gas show
AFO Rolleston 3	24 32 55 S, 148 37 52 E	1964	992	778 +	Aldebaran	Gas well
AFO Rolleston 4	24 34 39 S, 148 37 52 E	1964	1064	785 +	Aldebaran	-
AFO Rolleston 5	24 33 47 S, 148 36 55 E	1964	1108	715 +	Aldebaran	-
AFO Rolleston 6	24 35 27 S, 148 37 52 E	1964	1673	1316 +	Cattle Creek	-
AFO Rolleston 7	24 32 53 S, 148 37 24 E	1964	1067	836 +	Aldebaran	Gas show
AFO Rolleston 8	24 33 47 S, 148 38 48 E	1964	1037	786 +	Aldebaran	Gas well
AFO Rolleston 9	24 32 02 S, 148 38 48 E	1966	1098	796 +	Aldebaran	Gas show
AFO Rolleston 10	24 34 39 S, 148 36 55 E	1966	1076	717 +	Freitag	Gas show
*GSQ Springsure 1	24 39 00 S, 148 28 00 E	1972	366	281 +	Black Alley	-
*GSQ Springsure 2	24 38 00 S, 148 27 00 E	1972	275	275 +	Catherine	-
*GSQ Springsure 3	24 38 00 S, 148 26 00 E	1972	365	365 +	Aldebaran	-
*GSQ Springsure 4	24 38 00 S, 148 25 00 E	1972	366	366 +	Aldebaran	-
*GSQ Springsure 5	24 34 00 S, 148 23 00 E	1972	917	917 +	Cattle Creek	-
*GSQ Springsure 6	24 14 00 S, 148 14 00 E	1972	457	457 +	Cattle Creek	-
*GSQ Springsure 7	24 16 00 S, 148 14 00 E	1972	457	457 +	Cattle Creek	-
*GSQ Springsure 8	24 16 00 S, 148 13 00 E	1973	455	455 +	Cattle Creek	-
*GSQ Springsure 9	24 16 00 S, 148 12 00 E	1973	453	453 +	Reids Dome	-
*GSQ Springsure 10	24 25 00 S, 148 10 00 E	1973	500	463 +	Aldebaran	-
AFO Struan 1	24 07 30 S, 148 37 15 E	1965	1839	1809 +	Reids Dome	-
AFO Sunlight 1	24 16 00 S, 148 51 15 E	1966	1522	1115	Volcanics	-
*GSQ Taroom 8	25 02 00 S, 148 34 00 E	1974	892	412 +	Peawaddy	-
*GSQ Taroom 9	25 07 00 S, 148 37 00 E	1975	1095	558 +	Ingelara	-
*GSQ Taroom 10	25 13 00 S, 148 47 00 E	1975	1230	1018 +	Cattle Creek	-
*GSQ Taroom 11-11A	25 42 00 S, 148 42 00 E	1976	1306	1097 +	Reids Dome	-
*GSQ Taroom 12-12A	25 46 00 S, 148 3[illegible] 00 E	1977	379	233 +	Black Alley	-

APPENDIX 1 (CONTINUED)

PEC Warrinilla 1	25 06 49 S, 148 33 14 E	1963	2042	1582 +	Reids Dome	Gas show
PEC Warrinilla 2	25 03 33 S, 148 33 10 E	1964	1770	1273 +	Reids Dome	Gas show
PEC Warrinilla 3	24 57 42 S, 148 35 53 E	1968	2250	1357	Timbury Hills	Tr. oil
PEC Warrinilla 4	24 58 25 S, 148 33 55 E	1958	1528	1031 +	Cattle Creek	Gas show
PEC Warrinilla 5	25 00 02 S, 148 34 25 E	1968	2051	1562 +	Reids Dome	Gas show, tr. oil
PEC Warrinilla North 1	24 52 49 S, 148 31 50 E	1963	2096	1489 +	Reids Dome	Gas show
PEC Warrong 1	25 09 46 S, 147 53 37 E	1964	1091	219	Timbury Hills	-
AAO Westgrove 1	25 32 00 S, 148 26 00 E	1962	1964	1459 +	Reids Dome	Gas show, tr. oil
AAO Westgrove 2	25 33 00 S, 148 26 00 E	1962	1693	1278 +	Reids Dome	Gas well
AAO Westgrove 3	25 34 00 S, 148 26 00 E	1963	3859	3434 +	Reids Dome	Gas well, tr. oil
AAO Westgrove 4	25 33 00 S, 148 25 00 E	1963	947	472 +	Aldebaran	Tr. oil
AAO Womblebank 1	25 47 35 S, 148 11 35 E	1968	1348	204	Timbury Hills	-
AAO Yandina 1	24 11 00 S, 148 30 00 E	1965	780	713 +	Aldebaran	-

*Stratigraphic bore

Company name abbreviations

AAO - Associated Australian Oilfields N.L.
AFO - Associated Freney Oilfields N.L.
AOD - Alliance Oil Development N.L.
AOE - Australian Oil Exploration
AP - Amalgamated Petroleum Exploration Pty Ltd
GSQ - Geological Survey of Queensland
MPA - Marathon Petroleum (Australia) Ltd
OSL - Oil Search Ltd
PEC - Planet Exploration Company Pty Ltd
SQD - Shell (Queensland) Development Pty Ltd

APPENDIX 2. PROPOSED PERSONNEL, VEHICLES AND EQUIPMENT

PERSONNEL

Party leader	J. Bauer	
Party manager	P. Flanagan	
Geophysicists	F. Brassil (part-time)	
	W. Anfiloff (part-time)	
	O. Dixon (GSQ)	
Observer	J. Grace (part-time)	
	G. Jennings (part-time)	
Technical officers (science)	D. Pfister	
	T. Hegvold (part-time)	
	G. Price (part-time)	
Technical officer (engineering)	D. Gardiner (part-time)	
Shooters	R. Cherry	
	L. Rickardsson	
Mechanic	D. McIntyre	
Toolpusher	E. Cherry	)
Drillers	T. Shanahan	)
	K. Reine	) Petroleum
	K. Huth	)
	E. Lodwick (part-time)	) Technology
Assistant driller	J. Henry (part-time)	)
Wages mechanics	T. Johnson	) Section
	A. Crawford (part-time)	)
Cook	1	
Cook's offsider	1	
Wages hands	16	
Surveyor	1	) Dept of
Technical officer (surveying)	1	) Administrative
Chainmen	2	) Services, Brisbane

VEHICLES

Recording truck	International D1610, 3 tonne, 4 x 4
Shooting truck	" " " "
Workshop truck	" " " "
Flat-top trucks	2 x " " " "
Water tankers	3 x " " " "
Stores truck	International D1310, 30 cwt, 4 x 4
Geophone carriers	3 x Landrover, L.W.B.
Personnel carriers	3 x Landrover S/W
Drilling rigs	3 x Mayhew 1000/Mack 6 x 8 trucks
	1 x " " " " " (part-time)
Drill tankers	3 x A.E.C. Militants
	1 x " " (part-time)
Office caravan	4 - wheel
Kitchen caravan	"
Ablutions caravan	"
General purpose trailers	3 x 4-wheel
Workshop trailer	4-wheel
Generator trailer	2-wheel
Drill trailer	4-wheel, 6 tonne
Drill mechanics trailer	2-wheel

EQUIPMENT

Recording system	TI DFS-IV
Cameras	SIE TRO-6
	Geospace 1801
Switch gear	I/O Rota-long
Radio firing unit	I/O R.F.U.
Cables	18 x 265 m, SCG-5 24 - channel
	5 x 539 m, 48 - channel
	5 x " " " (due Sept '78)
	2 x 146 m, weathering cables
Geophones	1280 x GSC 20D 8 Hz
Tranceivers	5 x CODAN 6924
	8 x PHILLIPS FM828
Gravity meter	1 Worden

PLATE I. GEOLOGICAL AND SEISMIC TRAVERSE LOCATION MAP, SOUTHERN DENISON TROUGH

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