DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

BMR Record 1978/10

A review of petroleum exploration and prospects in the Georgina Basin

by

J.J. Draper, J.H. Shergold, and K.A. Heighway

(with Appendix abstracted from Mathur and Bauer, 1977)

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Printed by C. J. THOMPSON, Commonwealth Government Printer, Canberra

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Plates 2-10 are from Mathur & Bauer, 1977.

SUMMARY

The Georgina Basin covers an area of 325 km^2 of western Queensland and the east central portion of the Northern Territory and consists of Late Proterozoic and Lower Palaeozoic sedimentary rocks deposited on part of an epicontinental shelf. Vendian to Lower Cambrian rocks forming the base of the sequence in the southern portion of the basin are siliciclastics with minor carbonate rocks of glacigene terrestrial and marine origin. Middle Cambrian sediments extend throughout the whole basin and consist largely of shallow marine carbonates with shales and (economically important) phosphorites. Shallow marine carbonates also form the bulk of Upper Cambrian sediments, but are restricted to the southern portion of the basin. Lower to Middle Ordovician sediments are progressively restricted in extent (southern margin to Toko syncline), become more siliciclastic with decreasing age and are of shallow marine origin. Minor terrestrial sedimentation occurred in the southern part of the basin during the Devonian.

Several exploratory and stratigraphic holes have found traces of hydrocarbons. Possible source rocks are present, particularly in the Middle Cambrian sequence. Water-flushing and biodegradation is apparent throughout most of the basin and hence prospectivity for petroleum must be restricted to the deeper portions of the Toko Syncline where flushing has not occurred. Other factors favouring the deeper part of the Toko Syncline are probable presence of source rocks, suitable reservoir rocks, known presence of hydrocarbons, and appropriate burial history. Other sequences worthy of further investigation are Vendian to Lower Cambrian sediments with a thickness of greater than 3700 m and a possible oil shale sequence in the Camooweal Undilla area.

Current investigations (1977) include stratigraphic field research seismic and aeromagnetic surveys and source rock evaluation. In view of these studies, it is recommended that a further review of the petroleum prospectivity of the Georgina Basin be carried out towards the end of 1978.

1. INTRODUCTION

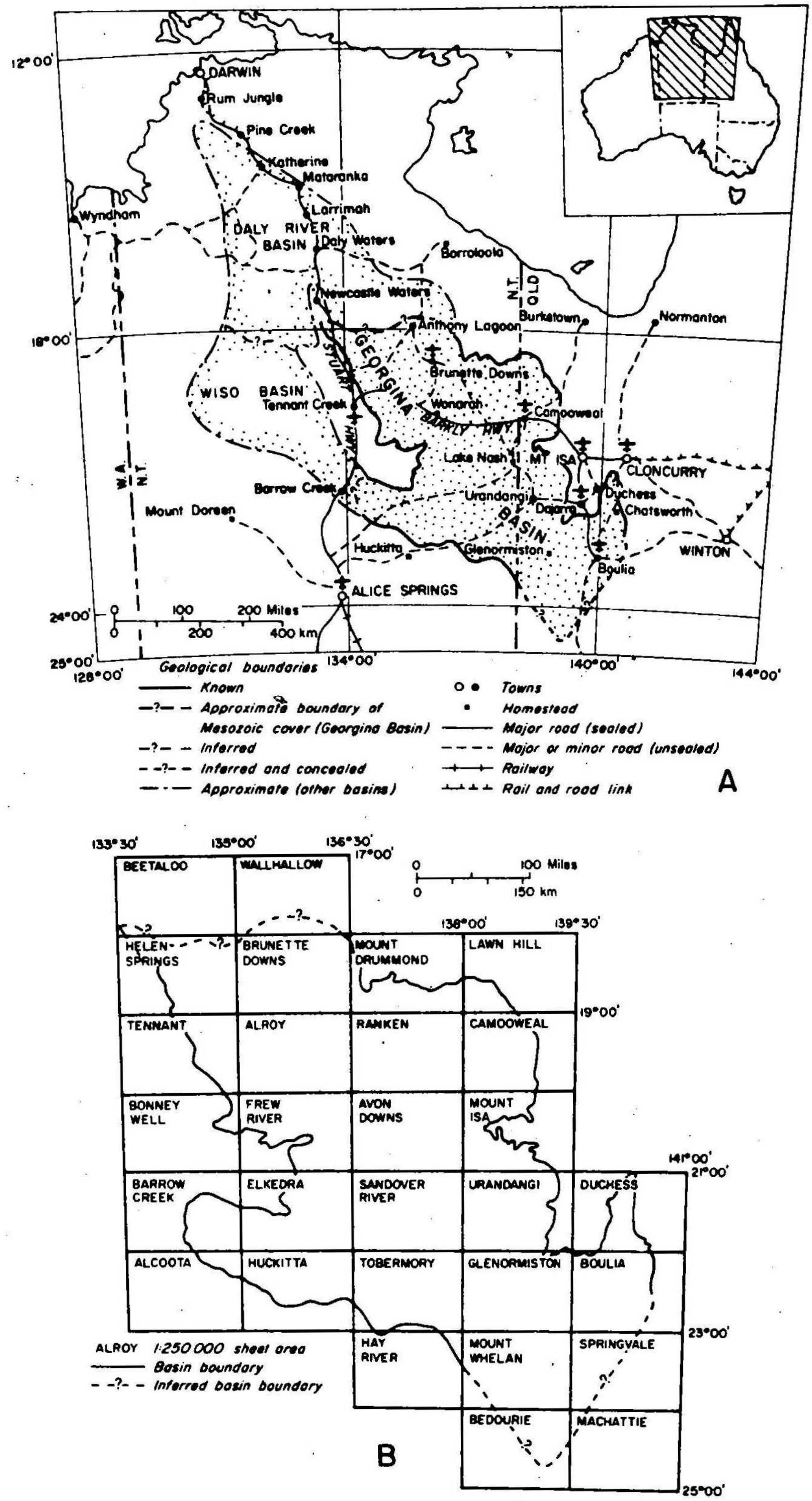
This report provides a general review of the geology, geophysics, and petroleum prospects for the Georgina Basin using information available to May 1977. It is intended that this summary be used as an evaluation of past petroleum exploration and in the formulation of future BMR investigations.

The Georgina Basin (Fig. 1) comprises a sequence of sedimentary rocks of Late Proterozoic to Devonian age (Shergold & Druce, in prep), which underlies an area of 325,000 sq km of western Queensland and the east central portion of the Northern Territory.

The Georgina Basin has been mapped at 1:250 000 scale and work is currently in progress to produce geological maps of selected areas at 1:100 000 scale. Gravity (7-mile grid) and aeromagnetic (two-mile interval traverses) surveys have been made over the whole basin but seismic surveys are mainly limited to the southeastern part.

Substantial stratigraphic information is available for the basin, principally as a result of joint mapping programs undertaken by BMR and the Geological Survey of Queensland (1950-54, 1957-65, 1974 to date). Twenty petroleum exploration wells have been drilled in the Georgina Basin, as well as numerous BMR stratigraphic holes. Stratigraphic information, mostly unpublished, has also accured from drilling for phosphorites and base metals.

Information gained prior to 1970 has been reviewed, and a map of the basin prepared, by Smith (1972). De Keyser (1973) provided more information on the northeastern part of the basin, and phosphatic units were reviewed by de Keyser & Cook (1973), who interpreted them with respect to the basin configuration. Additional stratigraphic information on units in the eastern portion of the basin, obtained since 1973, has been published by Shergold, Druce, Radke and Draper (1976). Shergold and Druce (in prep) summarised stratigraphic information available to the end of 1976.



A. Location, access and extent of the Georgina Basin (modified after Smith, 1972). B. 1:250 000 Geological Series Sheet areas relevant to the Georgina Basin (from Shergold, Druce, Radke & Draper, 1976)

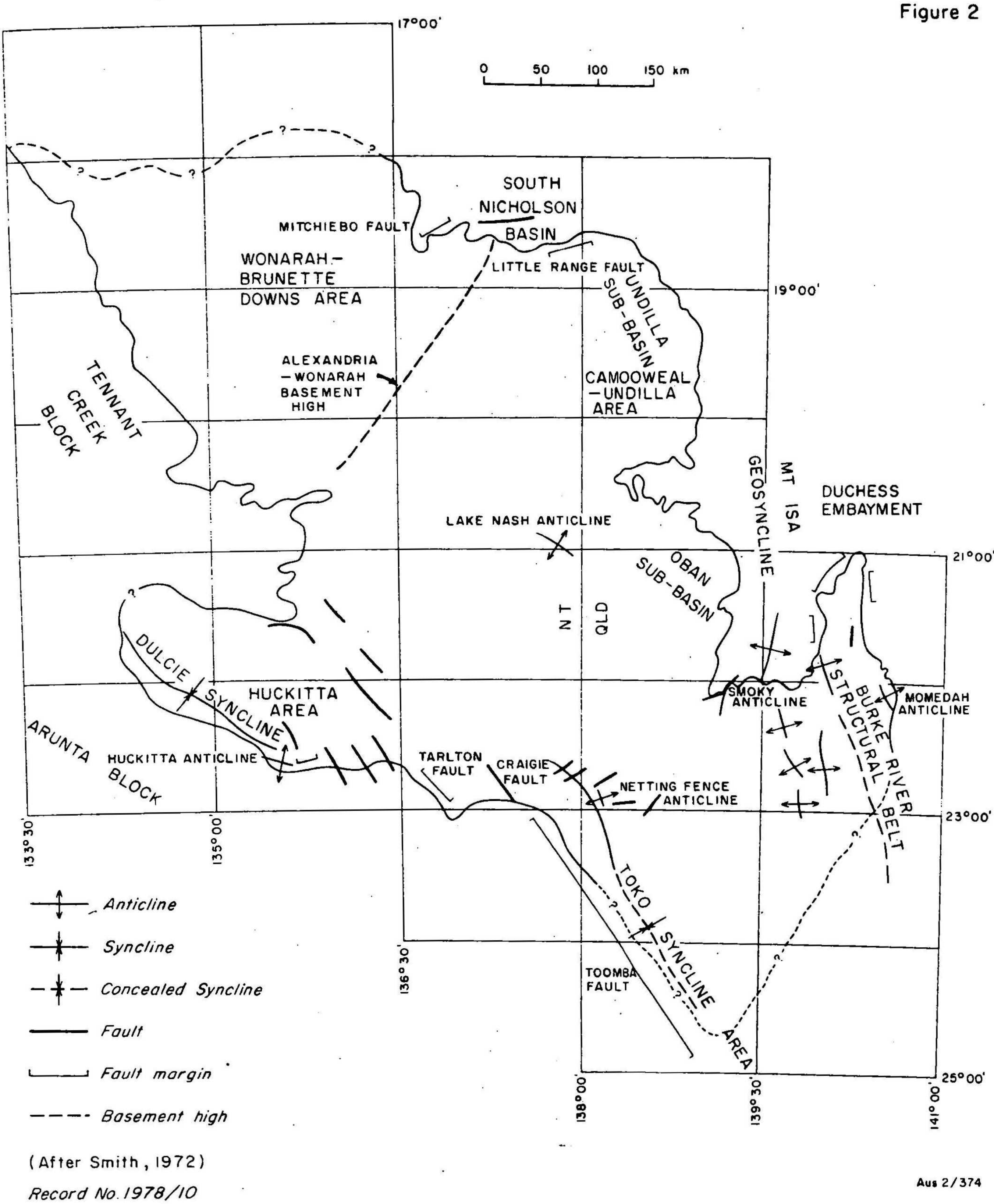
2. REGIONAL TECTONIC SETTING AND BASIN BOUNDARIES

The Georgina Basin comprises a succession of sediments which were deposited on a major segment of an epicontinental shelf. However, the only similarity to a basin shape results from the wedge-like thickening of the Lower Palaeozoic sequence south and southeast of Latitude 21° S, towards the inferred edge of the continental shelf.

Usage of the term 'basin' in the Australian geological literature is rarely qualified. Jack (1895) first used Georgina Basin in the title of a paper referring to the search for artesian water in western Queensland. Subsequently, various authors have used the name mostly for drainage or sedimentary basins, sometimes both (David, 1932), but it has also been applied to physiographical and geomorphological units. As a drainage basin the term has been used to describe the region drained by the Georgina River system, and as a sedimentary basin appears first to have been applied to the sediments of the Barkly Tableland (e.g. David, 1932, 1950; Reeves, 1951; Hossfeld, 1954; Condon, 1956). More rigorous definition of the Georgina Basin as a sedimentary basin followed the regional mapping activities of BMR (1957-65).

Smith (1965 a, 1972) regarded the inception of Middle Cambrian carbonate sedimentation as coincident with the initiation of the basin, a concept widely accepted by subsequent authors, e.g. de Keyser (1973), Shergold and others (1976), and compilers of the Tectonic Map of Australia (GSA, 1971). The latter show a Middle Cambrian and younger Georgina Basin resting on a Central Australian Platform Cover which comprises Upper Proterozoic and Lower Cambrian sediments and volcanics.

Such a definition is based partly on geological, and partly on economic observations. As a generalisation, the earliest sediments belonging to the Georgina Basin sequence north of latitude 21°S are Middle Cambrian carbonates, in places with associated variable basal clastic beds. Such carbonate sequences rest unconformably on mildly deformed Carpentarian or 'lower Adelaidean' sediments (the South Nicholson Group) in the north, the Carpentarian Mount Isa Orogenic Domain (Plumb & Derrick, 1975) in the east, or Lower Proterozoic to Carpentarian metamorphics, volcanics and sediments (Hatches Creek, and Warramunga Groups) of the Tennant Creek Block and Davenport Geosyncline in the west (Fig. 2). Locally, however, on the northern and western margins of the basin, Middle Cambrian carbonates overlie small areas



Main structural features, Georgina Basin of Lower or basal Middle Cambrian volcanics (Colless, Peaker Piker, and Helen Springs Volcanics), which themselves unconformably overlie the 'lower Adelaidean' sediments of the South Nicholson Basin, or the Lower Proterozoic to Carpentarian rocks of the Tennant Creek Block.

These Middle Cambrian sediments are recognised as the economic basement of the basin. Apart from containing enormous quantities of phosphate, they are the major aquifers in the region. With respect to hydrocarbons, their high organic content is encouraging, but inadequate burial and considerable subaerial erosion have reduced their prospectivity.

South of latitude 20^{o}S, Vendian and Lower Cambrian sequences, commonly commencing with arkose and glacigene sediments, rest unconformably on metamorphic rocks and granites of the Arunta Complex. In places, these dominantly clastic sequences grade conformably upwards, with increasing carbonate, into Middle Cambrian sequences. Elsewhere, an unconformity or disconformity exists. These clastic sequences possess minimal magnetic susceptibility, and thus the Arunta Complex forms the magnetic basement. If Smith's definition were followed, a natural base to the Georgina Basin in the form of a widespread unconformity, exists in its northern portion, but not in the southwest. Sequences older than, but conformable with, Middle Cambrian sediments are therefore included in the basin, as are their lateral equivalents which have non-conformable relationships. Thus the base of the basin is best considered to be diachronous, and to coincide with: (1) the inception of arkosic and glacigene sediments of Vendian to early Cambrian ages along the southern margin of the basin; (2) the unconformity at the base of volcanic sequences of early Cambrian or earliest Middle Cambrian age occurring locally on the northern and western margins; and (3) the unconformity below carbonates of Middle Cambrian age which extends over most of the basin north of latitude 21^{o}S.

The margins of the Georgina Basin (Fig 2) are thus often identified as an unconformity, commonly faulted, separating Lower Proterozoic, Carpentarian and 'lower Adelaidean' rocks from Vendian and later sediments. In the southeast, however, the margin is concealed beneath the Mesozoic Eromanga Basin, and to the northwest of Anthony Lagoon Mesozoic rocks conceal any connection between the Georgina and Daly River Basins. The latter may also be separated by a northward extension of the Carpentarian Tomkinson Creek Beds which form the Ashburton Range north of Tennant Creek. In the southwest, rocks of the Hatches Creek Group formed a high separating the Georgina and Wiso Basins. This barrier was intermittently submerged during early Middle Cambrian, latest Cambrian, early Ordovician, and Devonian times.

3. GEOPHYSICS

Geophysical investigations in the Georgina Basin commenced in the mid-1950's and have continued to the present day (Appendix 1).

Smith (1972) summarised geophysical activities until the late 1960's giving an account of the areas surveyed and the geophysical methods applied, including both BMR and exploration company results. Since the late 1960's, smaller areas of particular interest have been surveyed to investigate the nature and structure of the sequence and to further outline any major structures. During 1977, a seismic survey was undertaken by BMR in the Toko Syncline (Mathur & Bauer, 1977). A review of aeromagnetic data is planned for 1978. In view of these major revisions scheduled for completion by the end of 1978, only a brief resume of the geophysics is presented here. Appendix 2, abstracted from Mathur and Bauer (1977), presents a more detailed description for the Toko Syncline.

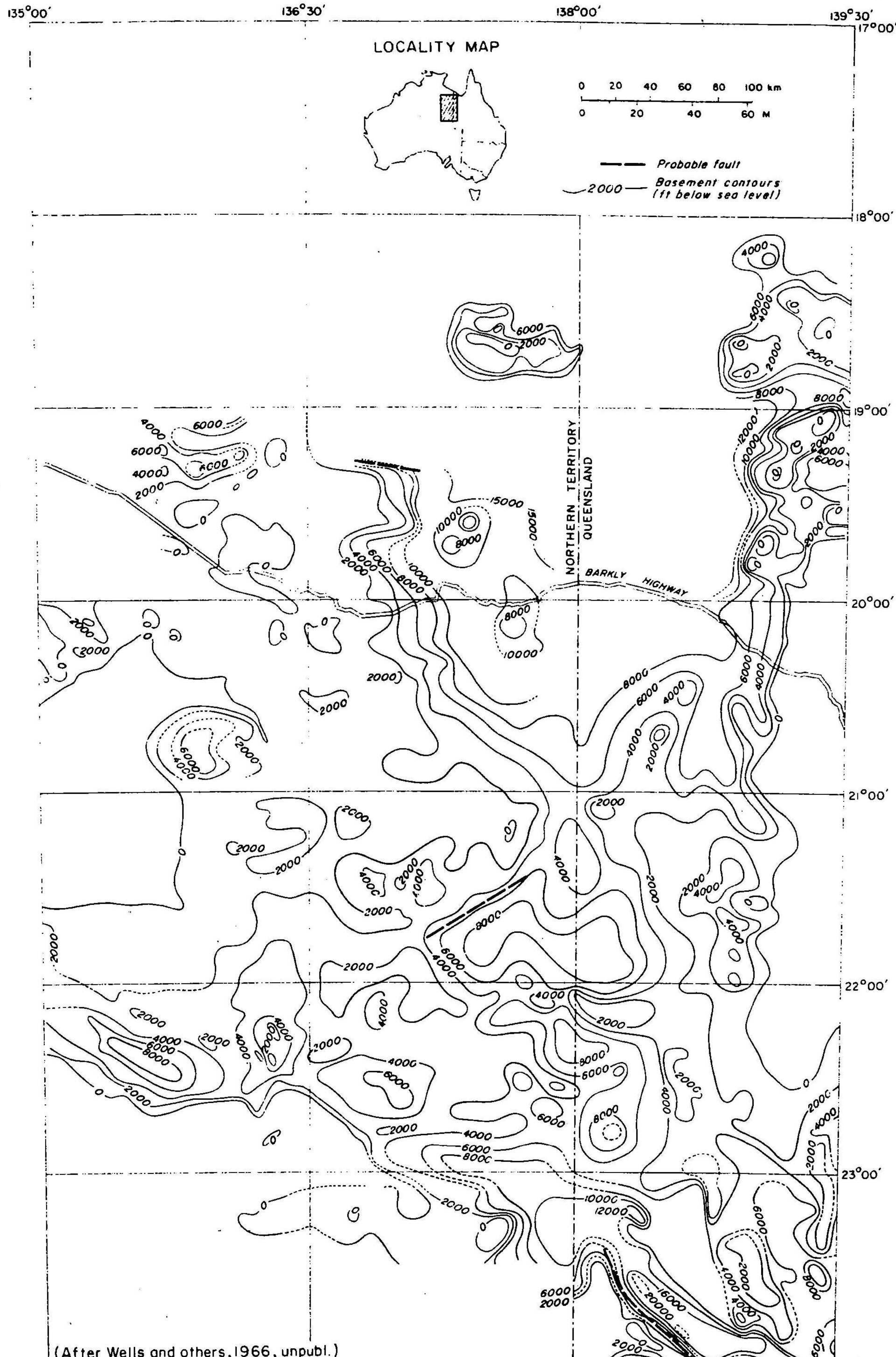
Aeromagnetic surveys

Aeromagnetic surveys have been conducted over the entire basin. The most comprehensive reports on the results are by Wells & Milsom (1965) and Wells, milsom, & Tipper (1966). These authors discuss results from individual 1:250 000 sheet areas, emphasising depth of magnetic basement and magnetic anomaly patterns. The results plus contributions from company surveys have allowed production of a depth to magnetic basement contour map (Fig. 3) and total magnetic intensity maps (Plate 1).

Gravity surveys

Gravity surveys cover the whole basin making it possible to illustrate its particular gravity features (Fig. 4 (a) & (b)). Detailed gravity surveys have been mainly centred in the southeastern part of the basin where petroleum prospectivity is greatest.

Figure 3



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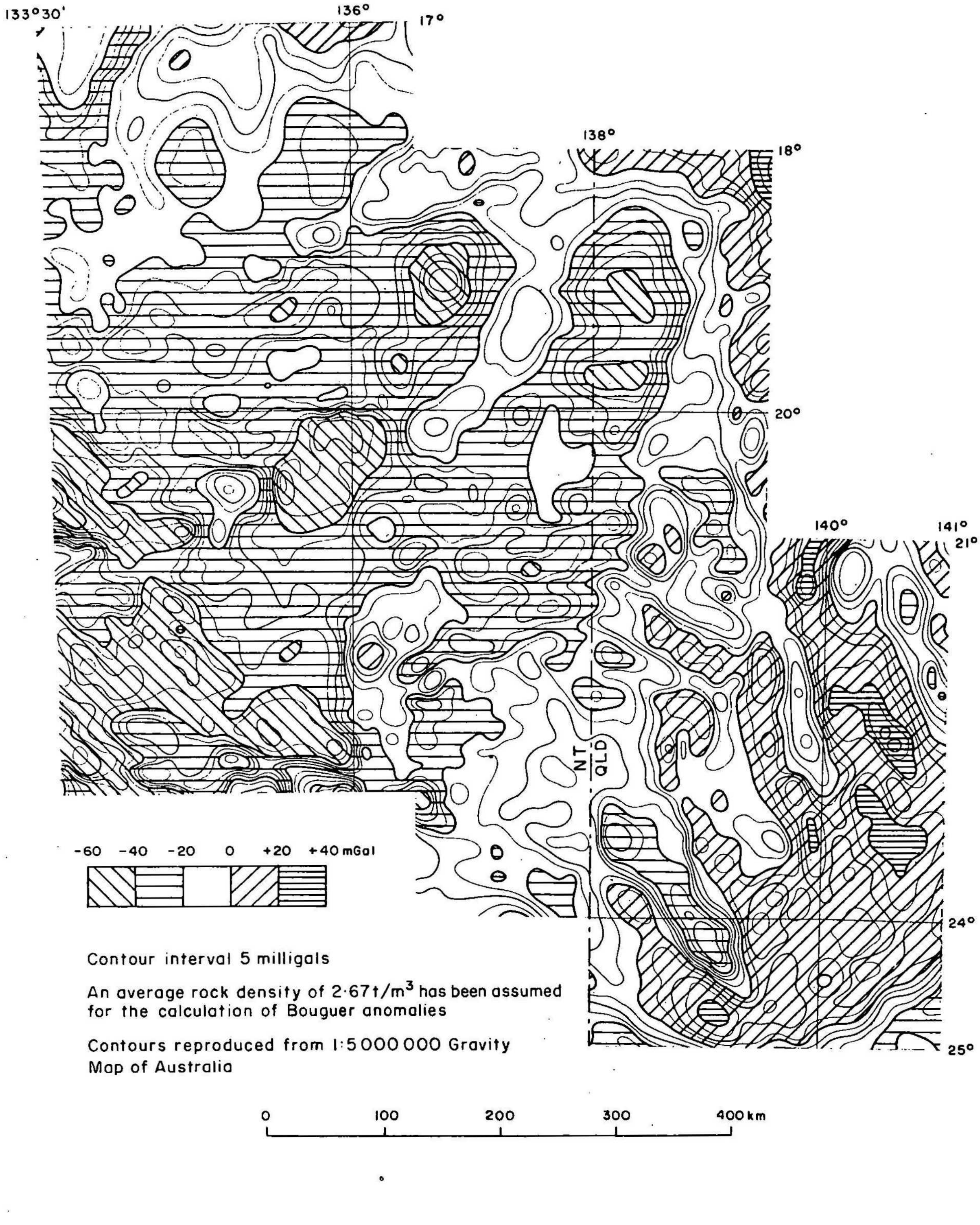
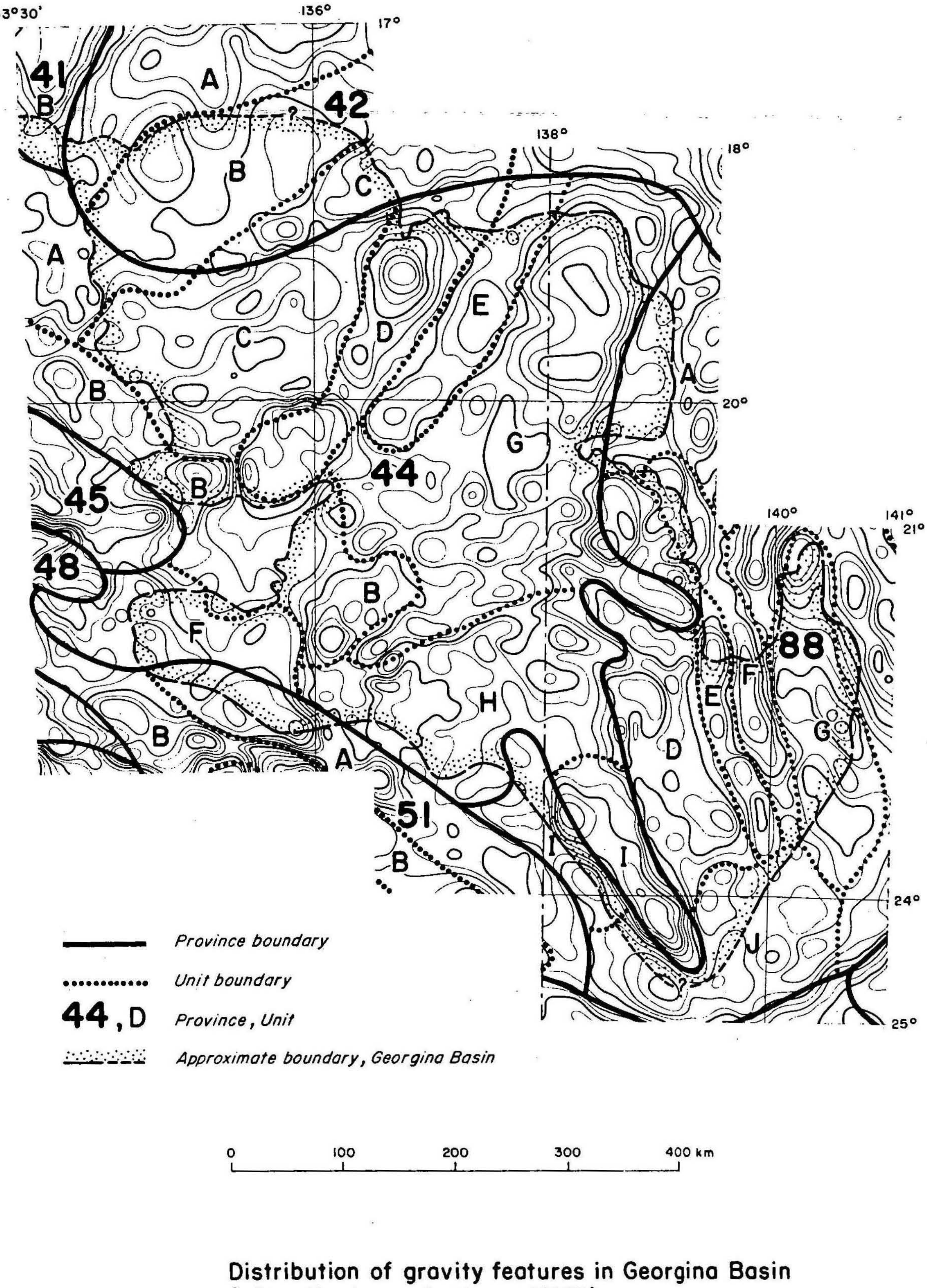
Magnetic basement contours



Gravity map of Georgina Basin area



Distribution of gravity features in Georgina Basin (after Fraser and others, 1977)

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Seismic surveys

The location of seismic surveys in the basin is given by Smith (1972). Little success was obtained from reflection traverses in areas of cavernous and fractured Palaeozoic carbonate rocks. Results from Toko Syncline prior to 1977 are discussed by Mathur and Bauer (1977), part of whose report is reproduced in Appendix 2.

4. GEOLOGY

The geology of the Georgina Basin is far simpler than the large number of stratigraphic units described to date would indicate. The complexity was compounded by an understandable failure of early workers to differentiate between lithostratigraphic and biostratigraphic units. Many of these so-called "units" are now recognised as facies variations and a picture of sedimentation in very shallow seas has emerged. Detailed discussion of the geology of the basin is presented by Smith (1972), and Shergold & Druce (in prep).

In this section, a general picture of sedimentation is given followed by a brief description of the stratigraphy of certain areas.

General patterns of sedimentation

Vendian to Early Cambrian

During the Vendian (late Adelaidean) to Early Cambrian, paralic, neritic and glacigene clastic sediments, and dolomites, were deposited along the southern margin of the Georgina Basin; at the same time, volcanic rocks were extruded along parts of the northern and western margins. Vendo-Cambrian sediments are of variable thickness; estimates for the HUCKITTA sheet area vary between 448-1455 m (Smith, 1972), and in excess of 3700 m in the HAY RIVER sheet area (M. Walter in Shergold & Druce, in prep). Such differences may reflect an extremely irregular pre-depositional terrain, and perhaps also the initiation of downwarping along the southern margin of the basin.

PROVINCE	UNIT
44-GEORGINA REGIONAL GRAVITY SHELF	A RENNER GRAVITY PLATEAU
	B OORATIPPRA GRAVITY HIGH
	C FREWENA GRAVITY SHELF
	D WONARAH GRAVITY LOW
	E LINGAREE GRAVITY RIDGE
	F AMMAROO GRAVITY DEPRESSION
	G SANDOVER GRAVITY LOW
	H TOBERMORY GRAVITY SHELF
	I TOKO GRAVITY TROUGH
88-CLONCURRY REGIONAL GRAVITY HIGH	A MOUNT OXIDE GRAVITY SHELF
	D GLENORMISTON GRAVITY SHELF
	E BOULIA GRAVITY RIDGE
	F KALKADOON GRAVITY LOW
	G BOURKE RIVER GRAVITY COMPLEX
	I FIELD RIVER SPUR
	J BEDOURIE GRAVITY RIDGE
	A BOOROOLOOLA GRAVITY HIGH

42-McARTHUR REGIONAL GRAVITY HIGH	B CRESWELL GRAVITY LOW
	C MURPHY GRAVITY RIDGE
41-DUMARA REGIONAL GRAVITY LOW	B AMUNGEE GRAVITY LOW
51-ILLOGWA REGIONAL GRAVITY HIGH	A HAY GRAVITY LOW

TABULATION OF GRAVITY PROVINCES & UNITS IN THE GEORGINA BASIN, AFTER FRASER AND OTHERS, 1977.

In general, Vendian sequences commence with glacigene sediments, of variable thickness and distribution, which unconformably overlie Carpentarian granites (minimum age, 1690 m.y., Rb-Sr, Compston & Ariens, 1968) and metamorphics of the Arunta Complex (1800-1700 m.y.). Shales from the glacial sequences in boreholes (Marduroo No. 1, Canary No. 1, Elizabeth Springs No. 1) are dated at 790-600 m.y. (ibid, p. 575); initial sedimentation along the southern margin of the Georgina Basin therefore coincides with that of the Pertataka Formation of the Amadeus Basin (Shergold & Druce, in prep.).

Early To Middle Cambrian

The geography of the Georgina Basin during the Early and Middle Cambrian was influenced by the development of two areas of carbonate banks or shoals. Dolomite was deposited in the southwestern corner of the basin during the later part of the Early Cambrian, through the Middle and much of the Late Cambrian. During the early Middle Cambrian (Ordian), an epicontinental sea began to transgress the Georgina Basin, and had flooded the greater part of it by the beginning of the Templetonian. Evidence from the Burke River area suggests that transgression continued at the eastern margin of the basin well into post-Templetonian time, when "upwards shallowing" sequences were being deposited elsewhere in the basin. As a result of this late Ordian transgression, a second area of dolomite deposition, the Camooweal Dolomite, was initiated over the former site of the South Nicholson Basin.

Late Cambrian

Upper Cambrian rocks are restricted to areas south of latitude 21^{o}S. No break in sedimentation is known at the epoch boundary. Late Cambrian geography, like that of the Middle Cambrian, is characterized by the development of carbonate banks, aligned roughly northeast-southwest (present geographic coordinates), which migrated to the south and southeast during Mindyallan through Payntonian time. A post-Idamean, but pre-Payntonian, break can be postulated to occur throughout the basin, except the Burke River Structural Belt where the event is recognised by the possible deposition of aeolian sediments (Radke in Shergold and others 1976:34).

Early to Middle Ordovician

Like the Upper Cambrian, succession Lower Ordovician rocks of the Georgina Basin are distributed south of latitude 21^{o}S. Possible Middle Ordovician rocks are restricted to the Toko-Toomba Ranges.

As a generalisation, Lower Ordovician rocks (Datsonian to early Arenigian) east of longitude 137^{o}E are dominantly carbonates, and rocks west of this meridian are dominantly clastics. Rocks younger than early Arenig are not yet identified in the Burke River area, and a mid-Arenig hiatus is apparent in the Toko-Toomba Ranges. Further west, in the Tarlton and Dulcie Ranges, a Warendian to mid-Arenig break has been recorded by Jones and others (1971: Chart 1). Late Arenig and younger strata are clastic sequences. Lower to Middle Ordovician rocks attain a maximum thickness of approximately 3200 m in the Toko-Toomba Ranges, and this total appears to thicken to the southeast.

Devonian

Shallow marine rocks of Early Devonian age (Draper, 1976b) are present in the Toko and Toomba Ranges. Middle to Upper Devonian rocks are present in the Toko, Toomba, and Dulcie Ranges. These latter sediments were deposited in alluvial fans, braided streams, and possibly in fresh water lakes.

Detailed stratigraphic sequences

For the purposes of this report, the Georgina Basin is divided into five areas: the Wonarah-Brunette Downs area, the Camooweal-Undilla area, the Huckitta area, the Toko Syncline area and the Burke River Structural Belt (Fig. 2). An exhaustive list of stratigraphic units will not be presented; only those relevant of this report will be discussed. For a more detailed discussion refer to Smith (1972), Shergold & others (1976) and Shergold & Druce (in prep).

Wonarah-Brunette Downs area

Volcanic units of Early Cambrian to early Middle Cambrian age are present overlying Proterozoic and early Adelaidean sediments. Middle Cambrian units include the Wonarah Beds (shale, limestone), Burton Beds (shale, limestone) and Anthony Lagoon Beds (red beds); all of which show some lateral facies relationships with one another. The Ranken Limestone may form a transitional unit between the Wonarah Beds and the Camooweal Dolomite of the Camooweal-Undilla area. The known maximum thickness of the Wonarah Beds is 312 m (Freweena No. 1), and of the Anthony Lagoon Beds is 320 m (Brunette Downs No. 1). No younger Palaeozoic units are known from the area.

Camooweal-Undilla area

In the Camooweal-Undilla area, Palaeozoic rocks younger than Middle Cambrian are unknown. The Middle Cambrian units and their relationships are summarised in Table 1. The rocks are predominantly carbonates with minor shale and siltstone, depositioned in generally very shallow marine environments, and the units mapped represent various facies. The maximum total thickness of units in the area is probably less than 500 m.

Huckitta area

The stratigraphy of the Huckitta area is shown in Table 2. The sequence consists of 910 m of late Adelaidean-Lower Cambrian arkose, sandstone and shale, with minor dolomite, and is of terrestrial and marine origin. The Middle Cambrian to Lower Ordovician sequence is 1550 m thick, and consists of limestone, dolomite, sandstone, and shale; it is also of shallow marine origin. It is overlain by 620 m of Devonian terrestrial sandstone and conglomerate.

Toko Syncline area

The stratigraphy of the Toko Syncline area is shown in Table 3. The Vendian-Lower Cambrian sequence consists of glacigene sediments, arkose, dolomite, sandstone, and siltstone, with a maximum thickness of 3700 m. The Middle Cambrian to Middle Ordovician sequence has a maximum thickness in excess of 3000 m and consists of shallow marine limestone, dolomite, sandstone and siltstone. This is overlain by 5 m of marine, and 420 m of terrestrial rocks, of Devonian age.

Burke River Structural Belt

The stratigraphy of the Burke River Structural Belt is shown in Table 4. The Vendian-Lower Cambrian sequence is relatively thin (75 m) and consists of glacigenic sediments, dolomite, sandstone, and shale. The Middle Cambrian-Lower Ordovician sequence is over 2000 m thick and is predominantly limestone and siltstone, generally representative of shallow marine environments.

Facies relationships - Southern Georgina Basin

Figure 5 is a diagrammatic representation of the relationship between the units in the southern part of the Georgina Basin. Only major depositional breaks are shown. The Huckitta and Toko Syncline areas appear to have been physically separated from the Burke River Structural Belt except during Late Cambrian and Early Ordovician times.

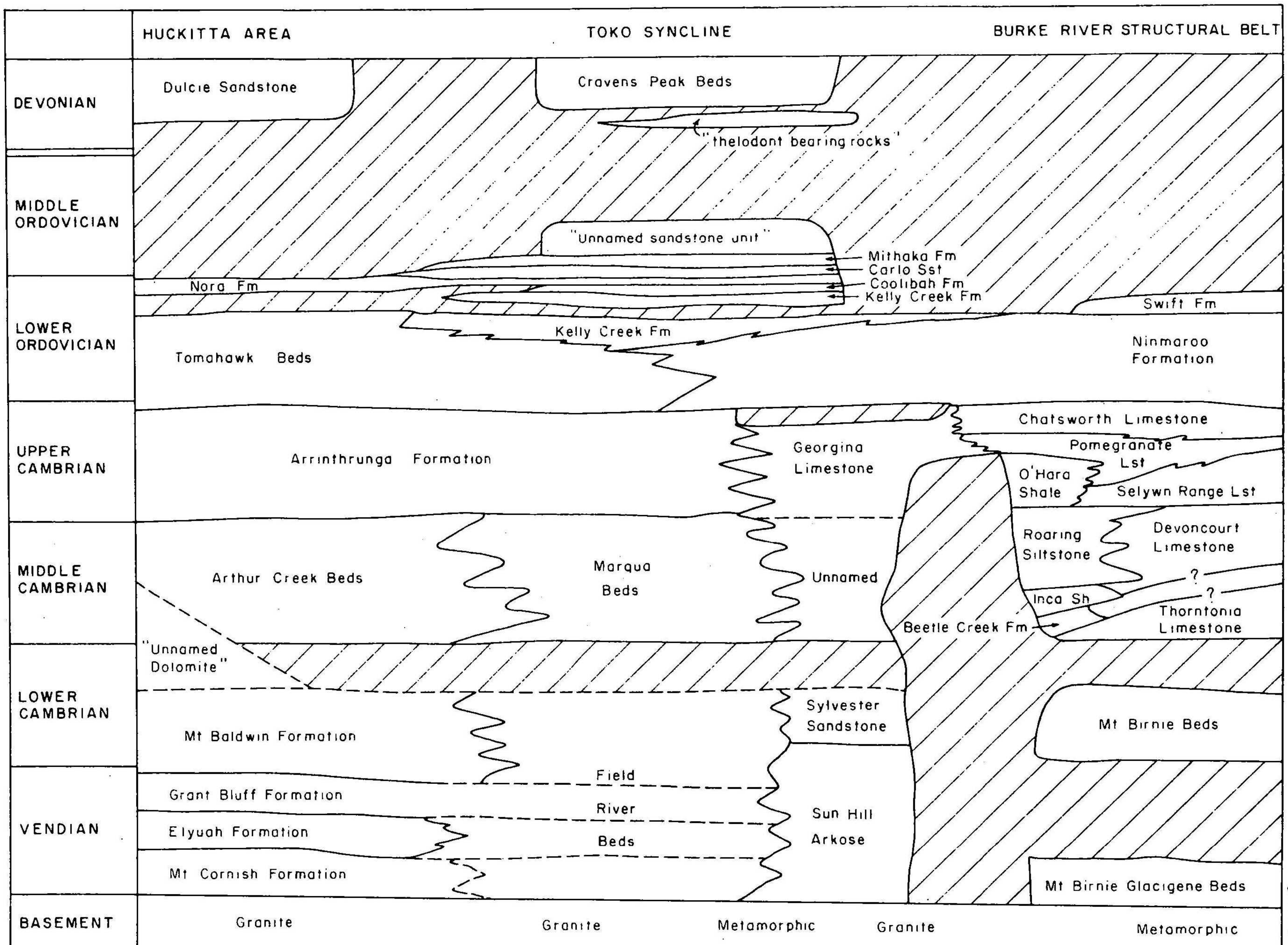

Figure 5

Diagrammatic representation of possible facies relationships, Southern Georgina Basin

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Table 1. Stratigraphy, Camooweal-Undilla area

Age	Unit	Estimated maximum thickness	Lithology	Stratigraphic relationships	Depositional environment	References
	Camooweal Dolomite	430 m	Dolomite (minor sandstone, limestone)		supratidal	de Keyser & Cook, 1973
	Split Rock Sandstone	30 m	Sandstone, calcareous sandstone		shallow subtidal	Shergold and others, 1976
	Mail Change Limestone	45+m	Limestone		shallow marine	Shergold and others 1976
	V-Creek Limestone	93 m	Silty limestone, limestone		subtidal-intertidal	Shergold and others 1976
Middle Cambrian	Currant Bush Limestone	150 m	Limestone (minor chert, shale)		intertidal-supratidal	Shergold & Druce, in prep.
	Age Creek Formation	?500 m	Dolomite		shallow marine	Shergold and others, 1976
	Inca Formation	160 m	Shale, siltstone, chert		transitional marine deep marine	Cook, 1977 de Keyser, 1973
	Beetle Creek Formation	15 m	Shale, chert, siltstone, limestone, phosphorite		shallow marine	de Keyser and Cook, 1973
	Thorntonia Limestone	?20 m	Limestone, dolomite, chert		sub-inter-supratidal	de Keyser and Cook, 1973
			UNCONFORMITY			
Adelaidean	Pilpah Sandstone	-	Sandstone			

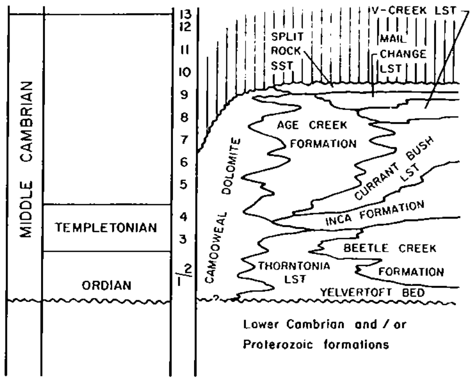

Table 2. Stratigraphy - Huckitta area

Age	Unit	Estimated maximum thickness	Lithology	Stratigraphic relationship	Depositional environment	References
Middle-Upper Devonian	Dulcie Sandstone	622 m	sandstone, conglomerate		lacustine and fluviatile	Gilbert-Tomlinson 1968
			U N C O N F O R M I T Y			
Lower Ordovician	Nora Formation	114 + m	siltstone, sandstone, shale		subtidal-intertidal	Shergold and others, 1976
	Tomahawk Beds	200 m	glauconitic sandstone, siltstone, dolomite limestone		shallow marine	Shergold and Druce, in prep.
Upper Cambrian	Arrinthrunga Formation	975 m	dolomite, sandstone, limestone		intertidal-supratidal	J. Kennard, personal communication, 1977
Middle Cambrian	Arthur Creek Beds	?263 m	siltstone, shale, sandstone, chert, limestone, dolomite	laterally equivalent to Marqua Beds and Sandover Beds	subtidal-intertidal	Shergold and Druce, in prep.
Vendian-Lower Cambrian	Mt Baldwin Formation	730 m	sandstone (minor dolomite)			
	Grant Bluff Formation	180 m	sandstone, dolomite, siltstone		marine	Shergold and Druce, in prep.
	Elyuah Formation	1265 m	arkose, shale			
	Mt Cornish Formation	365 m	boulder beds, sandstone, siltstone, dolomite		glacial	
Precambrian			granites, metamorphics			

Table 3. Stratigraphy - Toko Syncline area. *Thicknesses in Ethabuka No. 1.

Age	Unit	Estimated Maximum Thickness	Lithology	Stratigraphic Relationships	Depositional Environment	References
Devonian	U Cravens M Peak Beds	420 m	sandstone, conglomerate		Alluvial fan plain	Draper, 1977b
	L "thelodont bearing rocks"	5 m	limestone, siltstone, calcareous siltstone		shallow marine	Draper, 1977 b
			U N C O N F O R M I T Y			
Middle Ordovician	"Unnamed Sandstone unit"	*428 m	sandstone, minor siltstone conglomerate		subtidal-?	Shergold and others, 1976
	Mithaka Formation	*127 m	siltstone, sandstone	Toko Group	lagoon-bay	Draper, 1977a
	Carlo Sandstone	*189 m	sandstone		barrier	Draper, 1977a
Lower Ordovician	Nora Formation	*232 m	siltstone, sandstone, limestone		intertidal-subtidal	Shergold and others 1976
	Coolibah Formation	160 m	limestone, dolomite, chert		subtidal-intertidal	Shergold and others 1976
	Kelly Creek Formation	150 m	dolomite and sandstone		intertidal-supratidal	Shergold and others, 1976
	Ninmaroo Formation	335 m	dolomite, sandstone, limestone		intertidal-supratidal	
Upper Cambrian	Arrinthrunga Formation	975 m	dolomite, sandstone, limestone	?lateral equivalents	intertidal to supratidal	J. Kennard, personal communication, 1977
	Georgina Limestone	? 400 m	sandstone, siltstone, limestone		intertidal to subtidal	Henderson, 1976
Middle Cambrian	Marqua Beds	? 400 m	sandstone, shale, limestone, dolomite	laterally equivalent to Arthur Creek Beds in Huckitta Region	subtidal-intertidal-deep subtidal in part)	P. West, personal communication, 1977
Vendian -Lower Cambrian	Field River Beds	3700 m	arkose, dolomite, tillites		glacigene-marine	
Precambrian			granite	Age 1665 $\pm$ 10^{6} (K/Ar)		

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Table 4. Stratigraphy - Burke River Structural Belt

Age	Unit	Estimated maximum thickness	Lithology	Stratigraphic relationships	Depositional environment	References
Lower Ordovician	Swift Formation	20 m	chert, siltstone, sandstone	essentially the same primary unit	weathering profile on Ninmaroo Fm	Shergold and others 1976
	Ninmaroo Formation	950 m	limestone, dolomite		intertidal, supratidal	Shergold and others, 1976
	'Chatsworth Limestone'	535 m	limestone, calcareous siltstone	the same unit	shallow subtidal to intertidal	Shergold and others, 1976
	Gola Beds			unknown		
	Chatsworth Limestone	500 m	calcareous siltstone, limestone, calcareous sandstone		subtidal to shallow subtidal	Shergold and others, 1976
	Pomegranate Limestone	120 m	sandy shaly bituminous limestone	lateral equivalents	mainly subtidal	Shergold and others, 1976
	O'Hara Shale	60 m	lateritized shale and siltstone		regressive shallow marine	de Keyser, 1973
	Selwyn Range Limestone	40 m	micrite, limestone, dolomite, chert	part lateral equivalents conformable on Devoncourt Limestone	intertidal-supratidal	Shergold and others, 1976
	Roaring Siltstone	75 m	siliceous shale, siltstone, sandstone	part lateral equivalents	shallow to subtidal	Shergold and others, 1976
Middle Cambrian	Devoncourt Limestone	210 m	sandy bituminous limestone, calcareous shale		shallow subtidal to intertidal	Shergold and others, 1976
	Inca Formation	260 m	shale, siltstone, minor chert and limestone	conformable in part	transitional marine to estuarine; quite deep water	Cook, 1977; de Keyser, 1973
	Beetle Creek Formation	100 m	phosphatic siltstone and chert, phosphorite, limestone, sandstone	laterally equivalent in part	near shore, marine sub-basins	de Keyser and Cook, 1973
	Thorntonia Limestone	30 m	limestone, dolomite and dolomitic limestone		shallow subtidal, intertidal supratidal	de Keyser and Cook, 1973
			U N C O N F O R M I T Y			
Vendian-Lower Cambrian	Mount Birnie Beds	75 m	tilloid, dolomite, sandstone, shale, siltstone, conglomerate		glacial at base, marine towards top	Shergold and Druce, in prep.
			U N C O N F O R M I T Y			
Precambrian			granite, metamorphics			

Structure

The major structural features of the Georgina Basin are shown in some detail in Smith (1972). The structures are mainly faults with minor folds. The major structural features are the Burke River Structural Belt and and the Toko and Dulcie Syncline systems. In the Burke River Structural Belt movement is related to basement faults which have been periodically active up to the present. The Toko-Dulcie Syncline system is dominated by north-west-southeast trending faults and asymmetric synclines, the major formative event being Devonian (Draper, 1977b).

5. PETROLEUM PROSPECTS

Exploration to date

Traces of hydrocarbons have been found during exploratory, stratigraphic, and water-bore drilling, but to date no commercial quantities of hydrocarbons have been discovered in the Georgina Basin. Possible source rocks have been noted by many geologists, mainly within the Middle Cambrian sequence. Water flushing and lack of suitable reservoirs have been regarded as the main factors restricting the widespread occurrence of significant quantities. The most promising find to date has been in Ethabuka No. 1 (Fig 7) in the southeastern Toko Syncline where water flushing has not occurred.

Petroliferous odours were detected during drilling of water bores in the Georgina Limestone in 1910 (Reynolds, 1964; Smith, 1972). During World War II (1939-1945) the Main Roads Department of Queensland drilled water bores during road construction between Mount Isa and Camooweal. During the drilling of 40 mile Plain Bore (Figure 6) the drillers observed that some of the dark bituminous limestones burnt (Shepherd, 1945). The bore reached a depth of 263 m and bituminous limestone and shale were noted at several intervals. A sample from 62.5-62.8 m contained 67 litres/tonne of hydrocarbons on analysis (op. cit.). The limestone and calcareous shale sequence containing the oil shales may be part of the Currant Bush Limestone (Swarbrick, 1974). In 1956, during drilling of Cherry Creek Bore on Amaroo Station a piece of hot welding rod, accidently dropped down the hole and ignited gas which had accumulated there (Mackay & Jones, 1956): strong aromatic odour was noted.

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From 1957 to 1965 detailed mapping was undertaken by BMR and GSQ, during which time, 22 stratigraphic holes were drilled by BMR. From 1962-1966 (Figs. 6, 7), 15 exploratory or stratigraphic holes (Fig. 7) were drilled by oil companies.

During 1962, a core drilling program was undertaken by BMR (Milligan, 1963) and 19 holes were drilled in 16 localities (Fig. 6), ranging in depth from 51.8 m to 230 m (average 128 m) for a total of 2448 m. Approximately 1570 m of core was recovered. No hydrocarbons were observed except for asphalt in GRG 14. The drilling program did provide extremely useful stratigraphic information. During 1963/4 BMR drilled three deep stratigraphic holes (Smith, 1967). BMR 11 Cattle Creek (Fig. 7) was drilled to a depth of 457 m intersecting approximately 430 m of Camooweal Dolomite and bottoming in ?Adelaidean sandstone. No hydrocarbons were observed. Hydrocarbons were observed, however, in BMR 13 Sandover, which was drilled to a depth of 1015 m, intersecting Arrinthrunga Formation, Arthur Creek Beds, and Mount Baldwin Formation, and brttoming in Arunta Complex. Small quantities of bituminous material was noted in cuttings from both the Arrinthrunga Formation and the Arthur Creek Beds; show of gas was observed in Arthur Creek Beds in the interval 899.8-906.8 m; and some cuttings from this interval contained bituminous dolomite with globules of oil. BMR 12 Cockroach (Fig. 7) reached a total depth of 1219 m passing through Ninmaroo Formation, Arrinthrunga Formation and Marqua Beds: no hydrocarbons were observed.

Company drilling activity commenced in July 1962 with Black Mountain No. 1 (Phillips, 1963). Between July 1962 and January 1963 Phillips-Sunray drilled 4 holes in the Boulia area: Black Mountain No. 1, Canary No. 1, Beantree No. 1 and Elizabeth Springs No. 1 (Fig. 7) but no hydrocarbons were observed in any of these holes. During 1962, AP Lake Nash No. 1 (Amalgamated, 1963a) was drilled to test an anticlinal structure (Fig. 7). It reached a depth of 400 m through 303 m of Camooweal Dolomite, bottoming in ?Adelaidean sandstones and dolomites. Viscous tar or asphalt and small oil drops occurred throughout the interval 240.8-243.8 m. Porosity was vuggy and permeability low. Farmout-Place Ammaroo Nos. 1 and 2 (Farmout, 1963) were drilled from which gas had been earlier reported (see above). Ammaroo No. 1 (Fig. 7) reached a depth of 186.7 m in Sandover Beds (Arthur Creek Beds in Farmout (1963)). Fluorescence, often associated with fossils, petroliferous odours and bituminous material were noted throughout the Sandover Beds. Ammaroo No. 2

located 3 km south of Ammaroo No. 1, reached at depth of 256.8 m, bottoming in granite; fluorescence and petroliferous odours were again noted from the Sandover Beds. At 123.7 m a small flow of gas occurred, containing 1% hydrocarbons of both saturated and unsaturated types. The sequence was generally tight.

AP Morstone No. 1 (Amalgamated 1963b) was drilled in March-April 1963 to a total depth of 763 m: 326 m of Middle Cambrian, and 428 m of Proterozoic rocks. No hydrocarbons were observed, source rocks were lacking, and reservoirs were absent in the Middle Cambrian sequence. Between September and December 1964 PAP Brunette Downs No. 1 (PAP 1965a) and PAP Netting Fence No. 1 (PAP, 1965b) (Fig. 7) were drilled. Brunette Downs No. 1 reached a depth of 621.8 m through Middle Cambrian carbonates and ?Adelaidean sandstone and shale, but no hydrocarbons were observed. Netting Fence No. 1 reached a depth of 2031.8 m, bottoming in granite. It passed through a complete sequence from the Lower Ordovician Carlo Sandstone to the Middle Cambrian Thorntonia Limestone. Bituminous material was observed in the Nora Formation, Ninmaroo Formation, Georgina Limestone and in the Middle Cambrian rocks. Minor gas was also detected, but it was apparent that the sequence was water flushed. In 1964, Delhi-Santos-FPC(A) drilled Marduroo No. 1 and The Brothers No. 1 (FPC, 1965). Marduroo No. 1 (Fig. 7) went from Mesozoic into Adelaidean sediments, but no hydrocarbons were observed, although a total depth of 1176.8 m was reached. The Brothers No. 1 (Fig. 7) reached a depth of 1271.9 m and contains Mesozoic sediments overlying Upper Cambrian to Lower Ordovician limestone and shale. In 1965, Barkly Oil Company Pty Ltd drilled Frewena No. 1 (Barkly, 1965) to a depth of 312 m in Wonarah Beds. In August 1965, Alliance Mulga No. 1 (Alliance, 1965) was drilled to 915 m through Ninmaroo, Arrinthrunga Formations and Marqua Beds and bottoming in Adelaidean sandstone. No hydrocarbons were observed in any of these wells. Exoil Huckitta No. 1 (Exoil, 1966) was drilled in early 1966 and intersected Arrinthrunga Formation, Arthur Creek Beds, and Lower Cambrian to Adelaidean sediments before bottoming in granite at 1222.9 m. Minor fluorescence and oil staining were observed in the Arthur Creek Beds, but the sequence had been water flushed. In November 1966, Exoil Lucy Creek No. 1 (Exoil, 1967) was drilled to a depth of 1105 m before passing into granite basement intersecting the Tomahawk Beds, Arrinthrunga Formation and Marqua Beds. Fluorescence was observed in cuttings from the Arrinthrunga Formation and the Marqua Beds, and a petroliferous odour was detected in the Marqua Beds: again the sequence had been water flushed.

In the early 1970s Alliance Oil Development Australia N.L. became interested in the concealed part of the Toko Syncline and carried out a seismic survey in 1970. This survey delineated two possible closed structures, the Ethabuka Structure and the Mirrica Structure (Alliance, 1975). In 1973 Ethabuka No. 1, on the Ethabuka structure, a faulted anticline was drilled to a total depth of 1962 m and was abandoned at this depth owing to drilling difficulties. The hole intersected 640 m of Quaternary and Mesozoic sediments, 562 m of Middle Ordovician sandstone ("Ethabuka Beds" (in Alliance, 1975) - part of this sequence is attributed to the Devonian Cravens Peak Beds, but the subsequent positive identification by the Geological Survey of Queensland of a Middle Ordovician fossil near the top of the sequence does not support this), 126.5 m of Mithaka Formation, 189 m of Carlo Sandstone, 216.5 m of Nora Formation, 79 m of Coolibah Formation and 149+m of Kelly Creek Formation. The hole did not reach its target of possible reservoirs in the Ninmaroo, or possible source rocks in the Georgina Limestone and Marqua Beds (or their equivalents). Fluorescence and bitumen were observed in the Nora Formation between 1700.7-1734.3 m; the bituminous material impregnated fractures. At 1793 m, near the base of the Coolibah Formation, a flow of dry gas (70% Methane) of 250 MCF/D (open hole 12¼") was measured. Fresh water flushing appears to be restricted to the sequence above 1066 m, whereas the lower Ordovician and Cambrian rocks appear to be unflushed (Alliance, 1975).

Laboratory Investigations

Konecki (in Casey and others, 1960) tested 10 outcrop samples for porosity, permeability and fluid saturation: his results are summarised in Table 5. Residual oil values (obtained by toluene extraction) range from zero to 0.17% in light residual oil. Permeability in all cases is zero.

A number of cores have been analysed in the BMR Petroleum Technology Laboratory since 1960 (Appendix 3). Permeability is generally nil but some sandstones and vuggy dolomites have appreciable permeability.

As part of a geochemical study of many of the units in the southern part of the Georgina Basin, organic carbon contents have been determined (Table 6). The majority of samples are from surface outcrops and values are very low compared with average values (limestone 0.24 percent; shale 0.96 percent (Gehman, 1962)). Only the Pomegranate Limestone has values consistently in the range of the average value for limestones.

Two outcrop samples from the Ninmaroo Formation were analysed by BMR Petroleum Technology Laboratory in 1976 (File 76/780), and have Total Organic Carbon (TOC) values of 0.04 and 0.05 percent, extractable organic carbon values of 29 and 89 ppm, and hydrocarbon content of 6 and 34 ppm. McKirdy (see Appendix 5) suggests that one sample may have reached the oil generation phase of its diagenetic history.

Hydrocarbon analyses have been carried out on core from PAP Netting Fence No. 1 (McKirdy, 1977), the results indicating that the Marqua Beds have reached a stage of intense oil generation and that they are the probable source of reservoir bitumen in the overlying units. The reservoir zone has been subject to meteoric water circulation, resulting in water flushing and biodegradation.

Esso Australia (Metter, 1977) carried out source rock analyses on 9 samples from Netting Fence No. 1 and The Brothers No. 1. Although sample sizes were too small for detailed analyses, the results carried out do suggest marginal to good oil sources (4 samples). The Marqua Beds in Netting Fence No 1 and the Middle to Upper Cambrian sequence in The Brothers No 1 contain these possible oil sources.

Table 5. Residual oil contents of rocks in Burke River Structural Belt (data after Konecki in Casey and others (1960)

Stratigraphic Unit	Rock type	Porosity (%)	Permeability horizontal	vertical	Residual Oil (% wt.)
Pomegranate Limestone	fine-grained limestone	1.2	0	0	0
Pomegranate Limestone	dark limestone	1.44	0	0	0
Pomegranate Limestone	dark limestone	1.79	0	0	0
Pomegranate Limestone	sandy limestone	3.95	0	0	0.17
Pomegranate Limestone	fossiliferous crystalline limestone	1.16	0	0	0.17
Chatsworth Limestone	dense, dark limestone	1.06	0	0	0.096
Chatsworth Limestone	intraformational breccia	0.6	0	0	0.013
Chatsworth Limestone	crystalline limestone	1.7	0	0	0
Ninmaroo Formation	fine-grained limestone	0.94	0	0	0.113
Chatsworth Limestone	crystalline fossiliferous limestone	2.2	0	0	0.13
Chatsworth Limestone	dolomitic limestone	1.45	0	0	0.061
Ninmaroo Formation	crystalline fossiliferous limestone	2	0	0	0.04
Ninmaroo Formation	crystalline limestone	2.23	0	0	0

Table 6. Organic carbon values in various stratigraphic units

Formation	Surface / Subsurface	Mean (%)	Range	No. of samples
Arrinthrunga Formation (carbonate)	surface	0.03	0.01-0.08	(40)
Chatsworth Limestone (carbonate)	surface	0.05	0.03-0.09	(58)
	subsurface	0.12	0.03-0.25	(49)
Coolibah Formation (carbonate)	surface	0.06	0.02-0.13	(74)
Georgina Limestone (carbonate)	surface	0.07	0.05-0.11	(13)
Kelly Creek Formation (carbonate)	surface	0.05	0.02-0.05	(33)
Mithaka Formation (shale)	subsurface	0.16	0.12-0.22	(15)
Ninmaroo Formation (carbonate)	surface	0.06	0.02-0.32	(167)
	subsurface	0.04*	0.01-0.07	(24)
			*The majority of subsurface values are for dolomites	
Nora Formation (carbonate)	surface	0.04	0.01-0.08	(63)
Pomegranate Limestone (carbonate)	subsurface	0.18	0.06-0.38	(23)

5. PETROLEUM PROSPECTS

Hydrocarbons are present in the Georgina Basin and generation of oil has occurred. However, water flushing and biodegradation has affected most of the basin. The southern part of the Toko Syncline is the only region where water flushing has not occurred throughout the sequence and petroleum prospectivity is restricted to this area. The chances of finding hydrocarbons in economic quantities in this area is strengthened by the presence of gas in Alliance Ethabuka No. 1, the probable presence of source rocks in the Middle Cambrian, the burial history and the probable availability of reservoir and cap rocks. If suitable traps are present, the chances of finding large quantities of hydrocarbons are good.

One group of rocks, not considered to date, are worthy of further investigation. These are the Vendian to Lower Cambrian rocks along the southern margin of the basin. Thicknesses of up to 3700 m are present, dark shales may be suitable source rocks, suitable reservoirs are present in sandstone sequences, and structural traps are probable.

The presence of oil shales in the Camooweal-Undilla area should be investigated to determine their thickness, extent and quality.

6. CURRENT WORK & FUTURE EXPLORATION REQUIRED

A study of the Georgina Basin is currently underway by BMR and GSQ which involves detailed investigation of various stratigraphic units, geochemical investigation and some detailed mapping: field work will be completed in 1978. During the 1977 field season shallow stratigraphic drilling was undertaken by BMR, and deep stratigraphic holes were drilled by GSQ. A seismic survey was also carried out (Mathur & Bauer, 1977), the main aims being to link existing surveys, to link Netting Fence No. 1 and Ethabuka No. 1, and to examine the Toomba Fault in detail. Additional source rock investigations are being undertaken by the BMR Petroleum Exploration Branch for a number of holes in the basin. Results of these source rocks investigations should be available by the end of 1977. A review of magnetic data is programmed for 1978.

In view of the amount of work currently being undertaken in the Georgina Basin, a more accurate appraisal of the Georgina Basin hydrocarbon prospects should be made at the end of 1978 and a decision on future work should be made at that time.

7. CONCLUSIONS

Commercial hydrocarbon accumulations, if present in the Georgina Basin, are likely to be restricted to Palaeozoic rocks in the southern part of the Toko Syncline. The thick Vendian to Lower Cambrian rocks in the southern part of the basin may also be prospective. Oil shales in the Camooweal-Undilla area could be of economic interest in the future. In view of the large amount of current work being done in the basin, it is recommended that a re-appraisal be carried out at the end of 1978 with the aim of recommending what future activity is required.

APPENDIX 1

GEOPHYSICAL SURVEYS

Survey Name & Type	Year	Operator	Contractor	Reference
Regional Gravity Investigations In the Eastern & Central Commonwealth	1954	Univ. Sydney	-	Marshall, C.E. & Narian, H., 1954
Reconnaissance Gravity Survey in the Georgina Basin	1959	BMR	-	Neumann, F.J., 1959
Gravity Survey in the Toko Range Area, W-Qld.	1959	BMR	-	Neumann, F.J., 1959
Great Artesian Basin Aeromagnetic Reconnaissance Survey	1958	BMR	-	Jewell, F., 1959
Seismic Survey 1960 - Great Artesian Basin, SA & Qld.	1960	S.A. Mines Dept.		Milton, B.E. & Seedsman, K.R., 1960
Gravity Survey in Authority to Prospect 54P, Qld.	1960	Papuan Apinaipi Petroleum Co Ltd		Starkey, L.J., 1960
Boulia-Springvale, Marion Downs & Glenormiston areas Seismic Survey	1960	Phillips-Sunray		BMR File 62/1514 (unpubl.)
Great Artesian Basin Reconn-aissance Gravity Survey Using Helicopters	1961	BMR	-	Lonsdale, G.F., 1961
Gravity Survey, Boulia Area, Qld.	1959	Papuan Apinaipi Petroleum Co Ltd	-	BMR Petroleum Sub-sidiary ACT Publ. 37
Airborne Magnetic & Radiometric Survey Tennant Ck., N.T.	1962	BMR	-	Spence, A.G., 1962

APPENDIX 1 (CONT'D)

Survey Name & Type	Year	Operator	Contractor	Reference
Airborne Magnetometer Survey of Brunette Downs, NT	1963	Mines Administration	Adastra Hunting Geophysics Pty Ltd	Company Report (unpubl)
Annandale Seismic Survey	1963	French Petroleum Co. (Aust) Pty Ltd		BMR File 63/1514 (unpubl)
Electrical & Gamma-Ray Logging, Georgina Basin	1963	BMR	-	Unpubl. report
Tarlton Downs Gravity Survey,	1964	Alliance Petroleum Australia N.L.	- -	Completion Report (unpubl)
Coopers Creek Aeromagnetic Survey	1964	Delhi-Santos	Adastra-Hunting Geophysics	Unpubl. Report
Airborne Magnetometer Survey of Brunette Downs, NT	1964	Papuan Apinaipi Petroleum Co. Ltd	Adastra-Hunting Geophysics	Final Report
Aeromagnetic Survey Qld, NT	1964	BMR	-	Wells, R. et al., 1964
Alroy-Walhallow Aeromagnetic Survey	1965B	Barkley Oil Company	Adastra-Hunting Geophysics	Unpub. Report
Reconnaissance Gravity Survey NT, Qld	1959	BMR	-	Barlow, B.C., 1965
Contract Helicopter Gravity Survey, NT & Qld	1965	BMR	-	Flavelle, A., 1965
Bedourie Seismic & Gravity Survey	1964	French Petroleum Company (Aust) Pty Ltd		Unpubl. Final Report by C.G.G. 1965

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APPENDIX 1 (CONT'D)

Survey Name & Type	Year	Operator	Contractor	Reference
Cooper's Creek Aeromagnetic Survey (Oil leases OP 66 & 67, Qld)	1965	French Petroleum Company (Aust) Pty Ltd	Adastra-Hunting Geophysics	Unpubl. Report
Geophysical Results Across the Simpson Desert	1965			Laherrere, J. & Drayton, R.D., 1965
Sandringham Seismic Survey	1965D	French Petroleum Company (Aust) Pty Ltd		BMR File 65/4594 (unpubl)
Aeromagnetic Survey, Old & NT	1963	BMR	-	Wells, R. & Milsom, J.S. 1965
Georgina Basin Reconnaissance Gravity Survey Using Helicopters	1966	BMR	-	Barlow, B.C., 1966
Experimental Seismic Survey Cockroach Waterhole Area	1966	BMR	-	Chenon, C., 1966a
BMR 12 (Cockroach) Well Velocity Survey, NT	1964	BMR	-	Chenon, C., 1966b
Western Qld Reconnaissance Gravity Survey	1957-1961	BMR	-	Gibb, R.A., 1966
Southern Georgina Basin Seismic Survey	1965	BMR	-	Montecchi, P. & Robertson, C.S., 1966
Southeastern Georgina Basin Seismic Party Survey, Qld	1963-1964	BMR	-	Jones, P. & Robertson, C.S., 1967

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APPENDIX 1 (CONT'D)

Survey Name & Type	Year	Operator	Contractor	Reference
Georgina Basin Aeromagnetic Survey, Qld & NT	1963-1964	BMR		Wells, R., et al., 1966
Southern Georgina Basin Seismic Survey, NT & Qld	1965	BMR	-	Davies, J.S., 1974
Toko Range Seismic Survey, Qld	1970	Alliance Oil Development Australia N.L.	United Geophysical Corporation	Unpublished final report by United Geophysical Corporation
Results of Reconnaissance Gravity Survey of Aust.	1977	BMR	-	Fraser, A. and others, in press
Seismic Survey Southeastern Georgina Basin	1977	BMR	-	Mathur, S.P. & Bauer, J.A., 1977

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APPENDIX 2

PREVIOUS GEOPHYSICAL STUDIES

TOKO SYNCLINE

(abstracted from Mathur and Bauer, 1977)

PREVIOUS GEOPHYSICAL STUDIES

AEROMAGNETIC SURVEYS

The magnetic surveys over the Toko Syncline area were carried out by BMR north of 24°S, (Wells, Milson & Tipper, 1966), and by FPC (1963) south of 24°S. The magnetic pattern is dominated by a zone of relatively undisturbed field, which trends southeast and is associated with the Toko Syncline. On the map of interpreted depth to the magnetic basement, the syncline is represented as a broad asymmetric feature, dipping steeply on the southwestern side and more gradually on the northeast side (Pl. 3). North of 24°S maximum depths of over 7000 m are estimated in two small areas within a large depression bounded by the 5000 m contour. The steep southwestern flank of the syncline is faulted.

West of the syncline, a magnetically disturbed zone fringes a region of near-surface magnetic basement. The anomalies, up to 1500 nT in amplitude, are considered to be associated with basic rocks at shallow depths.

East of the syncline, two regions (A & B) of shallow magnetic basement with north-south trends are evident at longitudes 139°00' and 139°25'. The western region (A) corresponds to the outcrop of Late Adelaidean/Lower Cambrian Sylvester Sandstone or the Sun Hill Arkose; magnetic basement is shallow, estimated at about 500 m below sea level. The eastern region of shallow basement (B) has no surface expression, and Cretaceous sediments are seen in outcrop. Between these two regions a magnetic basement trough has a maximum depth of about 3000 m. The southeast-trending trough coincides with the southward extension of the Glenormiston Gravity Shelf (Pl. 4). These magnetic and gravity features could indicate a thickening of sediments, or may be caused by low density (granite) basement. The presence of Upper Cambrian Georgina Limestone cast of Sun Hill Arkose in outcrops separated by a fault, and located about 10 km southeast of Glenormiston (Pl. 2), supports the former interpretation.

GRAVITY SURVEYS

Reconnaissance gravity surveys in the area have been made by BMR on a 11-km grid. The resulting Bouguer anomalies are shown in Plate 4. The anomalies have been studied by Gibb (1967), and Fraser and others (in press). On the basis of the correlation of anomalies with the geology, several gravity features have been recognised (Pl. 4). The most predominant feature, the Toko Gravity Trough, trends southeast and shows anomalies ranging from 0 to -35 mGal. It corresponds at its northern end with the outcropping rocks of the Toko Syncline. Further north it disappears where the older and denser rocks of the syncline crop out. In the south, the anomalies suggest that the Toko Syncline plunges southeast under the Mesozoic cover. The steep gradient at the southwestern edge of the trough coincides with the Toomba Fault in the north, and suggests that the fault also extends under the Mesozoic cover in the south.

The Bedourie Gravity Ridge on the west and south of the Toko Gravity Trough shows small gravity features, with trends between northeast and northwest and anomalies between 0 and +25 mGal. It has been proposed by Fraser and others (in press) that this area is underlain by dense metamorphic rocks of the Mount Isa Geosyncline. The Glenormiston Gravity Shelf is located where the Georgina Basin sediments lap on to the Mount Isa Geosyncline. The gravity features here probably reflect both intra-basement density contrasts and the local thickening of sediments. The elongate northwesterly trending features on the southwest of the Toko Gravity Trough, viz., the Field Gravity Spur, Hay Gravity Low and Caroline Gravity Ridge are considered to represent intra-basement density variations within the Arunta Block.

SEISMIC SURVEYS

Several reconnaissance and detailed seismic surveys were made during 1960-70 by private companies and BMR, mostly in the southern part of the syncline. However, the seismic coverage of the syncline is not uniform (Plate 2). There are almost no data available in the Netting Fence No. 1 Well area; the northern traverses of the Toko Range Survey (Alliance, 1970) are not interconnected; and there are no direct ties across 24°S latitude between the Toko Range Survey and the Bedourie and Sandringham Surveys (FPC, 1965c, 1965d). Most surveys used reflection methods. The techniques used, and the quality of data and results obtained in individual surveys, are summarised in Table 2. A more detailed description of the results from each survey is given below.

Boulia-Springvale-Marion Downs-Glenormiston areas seismic survey, 1960 (Phillips-Sunray, 1962)

Only a small part of this survey extended into the area relevant to this report; the remainder lay further east and will not be considered here.

A line (G11 in Pl. 2) recorded from the Netting Fence area east towards Glenormiston, using spot-correlation shots up to 3 km apart, yielded fair record quality on the western end, but this rapidly deteriorated eastwards. Near the western end of the line a very doubtful seismic structure, corresponding closely with a definite surface feature (the Netting Fence Structure), was noted. Correlation between shotpoints on this line was very difficult.

A similar traverse (G9) from Marion Downs southwest towards the Toko Syncline generally yielded very poor data.

Table 2. Summary of recording parameters and results from previous seismic surveys

SURVEY	TYPE	SHOT PATTERN	CHARGE SIZE AND DEPTH	GEOPHONE TYPE	GEOPHONE PATTERN
Boulia-Springvale Marion Downs and Glenormiston areas Seismic Survey, 1960 (Phillips-Sunray, 1962)	Reflection (split-spread, spot correlation and single-fold)	1 to 5 holes/shot in line or X-pattern with holes 20 m apart	5 kg at 30 m	Electro-Tech EVS-2B 30 cps	4 to 32/litres, in line, X-pattern, or pallelogram
Seismic Survey, 1960, Great Artesian Basin, SA & QLD (Milton & Seedsman, 1961)	Refraction (probes) Reflection (split-spread, spot-correlation)	Single hole	10 kg at 20 m	-	10/trace, 3 m apart
Annandale Seismic Survey, 1963 (FPC, 1964)	Reflection (split-spread) Refraction (probes) Offset spreads	24/shot in two groups of 3x4 either side of traverse	27 to 55 kg/shot at 5 m	HSJ model K 20 cps (reflection) HS 4.5 cps (refraction)	36/trace in 3 lines
Bedourie Seismic and Gravity Survey 1964 (FPC, 1965b)	Reflection (Split-spread) Refraction (probes and continuous profiling) Offset spreads	23/shot in two groups of 3 x 4 either side of traverse	27 kg/shot at 5 m	HSJ	36/trace, in 3 lines 10 m apart, geophones 5 m apart
Sandringham Seismic and Gravity Survey, 1965 (FPC, 1965d)	Reflection (split-spread) Offset-spreads	36/shot in two groups of 3 x 6 either side of traverse	20 kg/shot at 5 m	HSJ 20 cps	36/trace, in 3 lines 20 m apart, geophones 5 m apart
South-Eastern Georgina Basin Seismic Survey, QLD 1963-1964 (Jones & Robertson, 1967)	Reflection (split-spread, some 6-fold CDP) Refraction (probes and continuous profiling)	Variable up to 12 holes/shot	1 to 23 kg/shot at 14 to 27 m	HSJ (reflection) Electro-tech 4.5 cps (refraction)	16 to 32/trace spacing and configuration variable
Toko Range Seismic Survey, QLD, 1970 (Alliance, 1970)	Reflection (split-spread)	Mainly single holes; some 3 and 5 hole patterns	15 kg/shot at 36 m for single holes 23 m for 3 holes 14 m for 5 holes	JSJ - K20 Hz	12/trace, 4-5 m apart

Seismic survey, 1960, Great Artesian Basin, S.A. & Qld (Milton & Seedsman, 1961)

This survey, conducted by the South Australian Department of Mines (SADM), consisted of a series of short refraction depth probes and some spot-correlation reflection profiling using 3 km spacing between shot-points. The results from only the Bedourie and Kamaran Downs No. 3 bore areas are relevant to the study of the syncline.

In the area to the north of Bedourie a refractor with velocity of 5450 m/s was recorded at a depth of 600 m. It was believed to be associated with early Palaeozoic limestone. Deep reflections down to a depth of 1500 m below this refractor was also recorded.

On the refraction line at Kamaran Downs Bore No. 3, a velocity of 5640 m/s was recorded at a depth of 450 m. This refractor must correspond to the granite met in the bore at 461 m.

Annandale seismic survey, 1963 (FPC, 1964)

This survey, carried out by Compagnie Generale de Geophysique, recorded 420 km of reflection and 110 km of refraction profiles. Much of the survey lay to the southwest of the Toko Syncline where only two horizons, 'C' (Transition Beds) and 'Z' (base of Mesozoic), were mapped. Refraction velocities of 5700-6050 m/s were found for the 'Z' horizon; below this horizon only very scattered and steeply dipping reflections were recorded.

However on line AQ (Pl. 2), the northernmost line of the survey, reflections down to 2.5 s on the northern side of a major fault showed the existence of a deep syncline. Eight reflection horizons were followed to a total depth of about 6000 m. The deepest refractor had a velocity of 5900 m/s and a maximum depth of 4600 m, and was thought to originate from the Ninmaroo Formation.

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Bedourie seismic and gravity survey, 1964 (FPC, 1965c)

This survey, also conducted by Compagnie Generale de Geophysique, followed the Annandale survey and was carried out mainly in the southern Toko Syncline (Pl. 2). It recorded 1360 km of reflection and 57 km of refraction profiles.

In the Toko Syncline good results were obtained, and reflections could be picked down to about 2.5-3.0 seconds. The shallow 'C' horizon (Transition Beds) was identified in the southern part of the area, but was too shallow to be followed further north. The 'Z' horizon (base of Mesozoic) is almost horizontal, and has a refraction velocity ranging from 3500 to 4550 m/s. Below the 'Z' horizon, several other horizons were picked, all dipping regularly to the southwest. The strongest of these is the 'N' horizon, thought at the time to correspond to the Ninmaroo Formation, but now tied to the Coolibah Formation.

The syncline is cutoff to the southwest by a major fault, which was mapped by the Annandale survey, and which has a displacement of over 4000 metres. The eastern margin of the syncline is also faulted, with the throw of the fault increasing from 1000 m in the northern part of the survey area to 2700 m in the south. This fault separates the main Toko Syncline from the eastern Border Zone (Pl. 6), a zone characterised by stronger southwesterly dips (up to 20°) on all horizons below 'Z'. It was possible to correlate the 'N' horizon across the fault; the 'N' and all horizons beneath it disappear in succession eastwards by truncation beneath the near-horizontal 'Z' horizon. It appears that much of the sequence overlying 'N' has been removed by erosion.

In the area immediately east of the Toko Syncline the 'N' horizon is not recognisable, but a horizon 'X' can be picked at reflection times ranging from 0.9 to 1.5 secs. It is not persistent over the whole area and is often hidden by multiples, possibly originating from the 'Z' horizon. The relationship of this area to the Toko Syncline edge is not known because a zone of poor quality reflections - possibly due to faulting - precludes any chance of relating the 'X' horizon directly to the 'N' horizon. The Brothers No. 1 Well, about 15 km northwest of Bedourie, indicated that the Mesozoic sediments were underlain by Upper to Middle Cambrian limestone. It is therefore possible that the 'X' horizon, which might be near the base of the Cambrian sediments, provides an indication of the extent of the Bedourie

(b)

GEOPHONE STATION	SPREAD	DATA QUALITY	DATA PRESENTATION	REMARKS
15 to 45 m	Split-spreads; 200-0-200 m 500-0-500 m; spot correlation: gaps of up to 3 km between shots	Poor to fair (difficult to correlate)	Wiggly-trace record sections, Time cross-sections	Limited usefulness due to difficulty in correlating between shotpoints
30 m (reflection) 60 m (refraction)	730-0-730 m (reflection) 0-1460 m (refraction)	Poor to fair	Time cross-sections	'Z' (base of Mesozoic) horizon mapped by reflection and refraction. Possibility of Cambro-Ordovician sediments in Breadalbane area indicated
50 to 60 m	600-0-600 m 720-0-720 m	Fair	Depth cross-sections all lines, VA sections all lines, Depth contour map on Horizon 'C'	SW of Toko Syncline only Horizons 'C' (top Blythesdale/Transition Beds) and 'Z' (base Mesozoic) picked. (Hor. Z refraction velocity 5700 to 6050 m/s) In Toko Syncline 8 reflections picked down to 2.5 sec. 'Ninmaroo' refractor velocity 5900 m/s, depth 4600 m.
50 or 60 m	600-0-600 m 720-0-720 m	Fair	Depth cross-sections all lines, VA sections some lines, Depth, contour maps on 'Z' 'N', 'X' horizons	'C', 'Z', and 'N' (?Ninmaroo) picked in Toko Syncline, 'C', 'Z', and 'X' (?base of Cambrian seds) picked on Bedourie Block
50 m	600-0-600 m	Fair (better than previous Bedourie survey)	Depth cross-sections all lines, VA sections all lines, Time contour maps on 'Z', 'MC', 'T_1', 'T_2' 'Pr' horizons	'Z' and 'MC' (middle Cambrian) horizonz picked over most of Bedourie Block 'T_1' and 'T_2' (Marqua Beds) and 'Pr' ?Upper Proterozoic) picked only in small area east of Brothers No. 1 well, 'X' horizon (?top of ?Tillite series) picked on most lines
15 or 45 m	183-0-183 m or 549-0-549 m	Fair to good	VA sections all lines	'Ninmaroo' reflection picked in Toko Syncline, reflections conformable with Ninmaroo indicate Palaeozoic sediments down to 4500 m. Possible Proterozoic Sediments underlie Palaeozoic, Overthrust faulting from south-west indicated at southwestern margin
34 or 67 m	402-0-402 m or 805-0-805 m	Poor to good	VA sections all lines, Time contour maps on Horizon "A" (?Ninmaroo) and Horizon "C" (? top Lower Cambrian or Proterozoic), "A-C" Isochron	Useful reconnaissance of Toko Syncline, One closed structure detailed and another indicated. Showed considerable fault-disturbance near south-western margin.

Block. The 'X' horizon also corresponds to the deepest refractor recorded in this area. The 'Z' horizon is a very strong reflector, and has a refraction velocity of 4500 to 5650 m/s, much higher than in the Toko Syncline.

With two exceptions, no continuous reflections were picked below the 'Z' horizon east of the Bedourie Block. The refraction velocity of the 'Z' horizon in this area is generally greater than 5800 m/s and is in agreement with the results from Marduroo No. 1 Well (FPC, 1965b) namely that this is an area where Mesozoic sediments rest directly on the Proterozoic.

Sandringham seismic and gravity survey, 1965 (FPC, 1965d)

The Sandringham survey was also conducted by Compagnie Generale de Geophysique, and recorded 182 km of reflection profiles (Pl. 2). It was carried out as a follow-up to the Bedourie survey to investigate in more detail the eastern margin of the Toko Syncline and the adjacent Bedourie Block. The French Petroleum Company considered that though the Toko Syncline contained potential source rock, the most likely place for suitable trap structures was in these areas.

Improved record quality over the Bedourie survey results allowed the mapping of additional reflection horizons. Apart from the 'Z' (base of Mesozoic) horizon, the survey mapped MC_1, MC_2, T_1, T_2 and Pr horizons. By tying to The Brothers No. 1 Well (FPC, 1965 a), MC_1 could be correlated with the top of the Pomegranate Limestone; MC_2, which is parallel to MC_1, with a layer in the Pomegranate Limestone; and T_2 tentatively with the lower Marqua Beds. T_1 is a marker picked east of The Brothers No. 1 Well which is truncated before the well. Pr was thought to originate in the Upper Proterozoic, and Horizon X, which was plotted on depth cross-sections but not contoured, was thought by FPC to originate from the top of the ?Tillite Series.

Horizon MC_1 or the horizon MC_2 was mapped over the central and southern parts of the Bedourie Block. In the east of this area only MC_2 exists, MC_1 is absent. Record quality was too poor in the northern part of the Block to allow mapping of any horizons below 'Z'; however weak reflections suggest that the top of the middle Cambrian series is eroded, the lower Cambrian still being present.

Horizons T_1, T_2 and Pr were picked only in a small area immediately east of The Brothers No. 1 Well. A small high with closures of 10 to 15 ms on the T_2 and Pr horizons was mapped.

Southeastern Georgina Basin seismic survey, Qld 1963-1964 (Jones & Robertson, 1967)

This BMR survey was a reconnaissance of the southern Toko Syncline to investigate the possible extension of a thick Lower Palaeozoic sequence from the outcrop area in the northwest part of the syncline southeastwards, as was suggested by a large southeasterly trending negative gravity anomaly. The survey also explored the area to the east to determine whether areas of low gravity could be related to thickened Lower Palaeozoic sediments.

The survey, conducted over two seasons, comprised 290 km mainly of single-fold reflection traverses (Pl. 2), and about 100 km of refraction, both as depth probes and continuous profiling. Some experimentation was carried out to determine optimum shooting parameters. Fair to good reflection results were obtained in the Toko Syncline, except near the disturbed south-western margin, but east of the syncline results were generally poorer. The refraction method was useful in identifying the 'Ninmaroo' reflection in the Toko Syncline, and the unconformity at the base of the Mesozoic to the east of the syncline; however there were few other persistent refractors and it was considered that the reflection method was more suited to the area.

The survey was successful in showing that the Toko Syncline extends southeast from the outcrop to 24°S latitude and beyond. The most persistent reflection recorded was thought to originate in the Lower Ordovician Ninmaroo Formation, but was later tied to the Coolibah Formation in Ethabuka No. 1 Well. This horizon reaches a maximum depth of over 3000 m on traverse BF, (Pl. 5), the main line across the syncline, but Lower Palaeozoic sediments conformable with this horizon probably extend to about 4500 m. Beneath the 'Coolibah' reflection, near the deepest part of the Palaeozoic syncline, there occurs a group of northeasterly dipping reflections in the 3-4 second range. These may correspond to the top of a probable Proterozoic sequence. Examination of the Bouguer anomalies along traverse BF shows that the Toko Gravity Trough minimum lies about 13 km northeast of the Palaeozoic structural low, as indicated by the Coolibah Formation reflection. This, together with the fact that the ?Proterozoic sequence appears to dip northeastwards towards the gravity minimum suggests that the gravity results may reflect the ?Proterozoic structure rather than the Palaeozoic syncline.

On the seismic section (Plate 5) there is an indication between SP 169 and 174, of a weak southwest-dipping reflection at times 1.0 to 1.4 s which is believed to from the plane of the overthrust Toomba Fault. The seismic section shows considerable similarity with that recorded at the northern overthrust margin of the Ngalia Basin (Wells, Moss & Sabitay, 1972). Additional evidence for the overthrust fault comes from the presence of a residual gravity high between SP 168 and 178 which has been interpreted by Jones & Robertson (1967) as a southwesterly dipping high-density slab, presumably brought up from the southwest by reverse faulting. This high-density and so high-velocity, slab is also considered to account for steep northeasterly dips seen on reflections between SP 173 and 176.

<u>Toko Range Seismic Survey, AP160P, Qld 1970</u>
<u>(Alliance, 1970)</u>

The Toko Range survey was carried out in the central part of the syncline. It consisted of 140 km of single-fold reflection profiles recorded by United Geophysical Corporation (Pl. 2).

The quality of the data which were recorded in analogue form and processed digitally varies from good to very poor. The main reflections, which can be followed over most of the surveyed area, were mapped, though jump correlations over large distances were required because of the absence of tie lines in the northern part. The shallower of the two horizons was believed to represent Ninmaroo Formation through ties to the BMR work (Jones & Robertson, 1967). The deeper horizon, the data for which are not very reliable, was thought to represent the erosional surface of either the Lower Cambrian or Proterozoic sequence. But on the basis of ties to Ethabuka Well No. 1, which was drilled subsequently and penetrated only the shallower horizon, this horizon was identified as the Coolibah Formation, and the deeper horizon re-interpreted as the Georgina Limestone (Alliance, 1974).

The two mapped horizons, which appear generally conformable to each other, show three structures which could form important traps for petroleum: A high with closure of more than 60 ms (230 m) where Ethabuka No. 1 Well was drilled and gas was encountered, and another two highs in which there is a possibility of closure greater than 250 ms (750 m) but, presently, insufficient seismic control - one to the southwest and the other against the Toomba Fault to the northwest of Ethabuka No. 1 Well.

Most of the seismic traverses ended some distance away from the Toomba Fault and therefore show little effects of the faulted margin. Only traverse AK crossed this margin, and shows overturning and complex faulting of the sediments with the suggestion of overthrusting at the southwestern margin similar to that seen on the BMR traverse BF.

SUMMATION

Geological, magnetic, and gravity data indicate the Toko Syncline to be a deep, southeasterly plunging, asymmetric synclinal sedimentary trough with significant faulting along its southwestern margin and gradual shallowing on its northeastern flank. These data also provide evidence for the presence of a small, partly faulted, relatively shallow trough of Lower Palaeozoic sediments southeast of Glenormiston (Plate 2), lying at the northeastern margin and separated by a ridge from the main part of the syncline.

In the northern part of the syncline the Netting Fence No. 1 Well was drilled through about 760 m of Middle Cambrian (Marqua Beds) sediments, most of which are absent from the outcrops on the northeastern flank, whereas the Late Adelaidean/Lower Cambrian (Sylvester Sandstone and Sun Hill Arkose) sediments which are absent in the well, are present in the outcrops ($23^{o}30'$S, $139^{o}00'$E; Pl. 2) below a thinner Middle Cambrian sequence. The relative thickness of the common formations (Carlo Sandstone, Nora Formation, Coolibah Formation and Kelly Creek Formation) penetrated both in the Netting Fence No. 1 and Ethabuka No. 1 Wells indicate a thickening of these formations to the southeast by a factor of at least 1.33 between the two wells. These data therefore suggest possibilities of stratigraphic pinchouts within the Middle and Lower Cambrian sequences along the axis, as well as across the northeastern flank of the syncline.

Although the seismic surveys provide useful information on the shallow sediments in the synclinal trough, the available seismic coverage in the area, and ties between the seismic traverses and with the wells and outcrops are limited. The quality of the seismic data varies from fair to poor, and is poorer in the deeper sediments, and in the structurally disturbed fault zones on the southwestern margin and the southern part of the southeastern margin of the syncline.

A number of significant reflectors are present within the sediments, and several horizons have been mapped over different parts of the area. North of 24°S, Alliance (1974) has mapped two horizons, the Lower Ordovician Coolibah Formation and Upper Cambrian Georgina Limestone. South of 24°S, FPC (1965c, 1965d) mapped several horizons which are believed to correspond to the base of Mesozoic cover, the Coolibah Formation, and boundaries within and at the base of the Cambrian sequence.

The general nature of the syncline is illustrated by the structure contour map of the Coolibah Formation (Pl. 6), a NW-SE section (Pl. 7) along the axis of the syncline connecting Netting Fence No. 1 Well, Ethabuka No. 1 Well, Bedourie Scout Hole No. 1, and The Brothers No. 1 Well, and three SW-NE sections (Pls 5, 8 & 9) across the northern, central and southern parts of the seismically surveyed area of the syncline. The structural map is a compilation of reflection - time contours from Alliance (1974) north of 24°S, and depth contours from FPC (1965c) south of 24°S. In the northern part the reflection is tied to the Coolibah Formation in the Ethabuka No. 1 Well. The reflection in the southern part has no direct ties with that farther north, but is believed to be the same on the basis of jump correlation across the 8 km gap. The sections in Plates 7, 8 and 9 are based on seismic reflection and well information.

The structural map and sections confirm the general finding of the earlier studies, that north of 24°S the syncline is asymmetric, plunging to the southeast, faulted on its southwestern margin, and gradually shallows on its northeastern flank. Although no faults have been shown on the structural map (Pl. 6) (Alliance, 1974), the seismic sections (e.g., Pl. 5) do show evidence of complex faulting accompanied by underthrusting, overturning and folding of sediments along the southwestern margin, which seem to have been caused by compression from the southwest.

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South of 24^{o}S, the structural map (Pl. 6) shows that under the Mesozoic cover, the syncline becomes a monoclinal feature. It is bounded on the southwest presumably by a southeast extension of the Toomba Fault, and faulted on the northeast by two northerly trending faults (French and Pippagitta Faults) which divide the feature into three structural parts: (1) the main Monocline, in which the sediment become shallow to the northeast, (2) the Border Zone, consisting of a narrow horst block where the Coolibah Formation rises steeply to the northeast and is truncated by the overlying Mesozoic sediments, and (3) the Bedourie Block where Upper Cambrian Chatsworth Limestone (presumably a partial equivalent of Georgina Limestone) was intersected below the Mesozoic cover in The Brothers No. 1 Well (Pls. 7 & 9).

The map also shows three closed anticlinal structures north of 24^{o}S; these could form important traps for petroleum: one was drilled by Ethabuka No. 1 Well in which gas was encountered, but the other two, showing much larger closures, are based on insufficient and poor data.

The seismic sections show several reflection events shallower and deeper than, and most conformable with the Coolibah Formation reflection, and suggest that the structure on the map (Pl. 6) is representative of that of most of the Palaeozoic sequence.

Only one of the deeper reflections, which is the strongest and most widespread in the surveyed area, can be followed along the traverse TA (Pl. 8) on to the northeastern flank of the syncline. Though it has been suggested by Alliance (1974) that it corresponds with the Ninmaroo Formation it was not penetrated by Ethabuka No. 1 Well, nor tied to the outcrops to the northeast. The interpretation of still deeper events is complicated by the presence of multiples that Jones & Robertson (1967) showed can be attenuated by the use of multiple-fold recording techniques. The steeply northeast-dipping events seen at times greater than 3.2 s on traverse BF, and at times greater than 2.0 s on traverses AX and AK, have been suggested as representing a horizon within the Proterozoic sequence, but the seismic data are not sufficient for a reliable interpretation.

The seismic reflectors plotted in Plate 7 do not support the south-eastern thickening of sediments indicated by the information from the Netting Fence No. 1 and Ethabuka No. 1 Wells. This, however, may be because the seismic data are available only for the Ethabuka No. 1 Well area, the lower reflector (?Georgina Limestone) is based on poorer quality data, and the same

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velocity function (curve B in Plate 10) was used to obtain depths over the mapped area.

As most of the seismic traverses on the southwestern flank of the syncline ended before the faulted margin was reached, the available seismic data are not adequate for studying the nature and structure of the Toomba Fault and the adjacent sediments.

It is apparent from the foregoing review that the following additional information is required:

- the nature and structure of the Lower Palaeozoic sediments and the underlying basement,
- the variation in thickness and character of the Palaeozoic sediments and the basement along the axis as well as across the flanks of the syncline,
- the nature and structure of the Toomba Fault along the southwestern margin, and of the adjacent sediments,
- ties between the previous seismic work, wells and outcrops for correlation of seismic reflections with lithological horizons.

It is considered that further seismic work using multiple-fold coverage and digital recording and processing techniques would help provide the additional information.

APPENDIX 3

Tabulations and reports of work carried out by Petroleum Technology Laboratory, BMR.

A. Core analysis results.
B. Porosity and permeability measurements - outcrop material Registered Number 74712658.
C. Analytical report. Ninmaroo Formation (L. Ord.), Georgina Basin.

A

Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. BMR, GEORGINA NO. 14

DATE ANALYSIS COMPLETED 26th June, 1963

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core	
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil				
61	638'3"	638'6"	Vugular Dolomite	12	41	27	2.55	2.90	Nil	10	-	Yellow Strang	Milky Opaque	Jet black, lustrous asphalt
61	638'6"	639'0"	"	18	593	1260	2.36	2.88	Nil	34	-	Orange Strang	Milky Opaque	Obvious in vugs. No fluorescence from this asphalt

Remarks: - Samples submitted by T. Milligan, Geological Section
Portion of Core 61 has been reserved for full core determination
Description of this core compares with description of core 3. 801'-811' of Lake Nash No. 1

General File No. 62/399
Well File No.

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CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. MORESTONE NO. 1

DATE ANALYSIS COMPLETED 10th July 1963

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core	
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil				
1	270'		Shale	6	N.	D.	2.59	2.74	33	Nil	-	Pale Yellow Trace	Trace	Carbonaceous Material present
2	636'		"	8	"	"	2.42	2.65	23	"	-	Pale Yellow Trace	Fair	As above
2	644'		"	1	"	"	2.55	2.58	37	"	-	Trace Fair	"	As above
3	938'0"	938'1"	Dolomite	3	"	"	2.70	2.78*	Nil	"	-	Nil	Nil	*Dolomite from Core 61
3	938'1"	938'2"	"	3	"	"	2.68	2.77*	"	"	-	"	"	Georgina Well 14 repeated
3	938'2"	938'4"	"	3	"	"	2.64	2.74*	"	"	-	"	"	Here to again give grain
3	942'2"	942'4"	"	2	"	"	2.67	2.73*	"	"	-	"	"	Density of 2.9
6	1765'		Sandstone & shale	10	"	"	2.46	2.77	25	"	-	"	Trace	

Remarks: - Only small pieces of the above cores remained and permeabilities could not be determined

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Well File No.

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CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. MORESTONE NO. 1

DATE ANALYSIS COMPLETED 10th July 1963

Core No.	Sample Depth From	Sample Depth To	Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy) V	Absolute Permeability (Millidarcy) H	Average Density (gm/cc.) Dry Bulk	Average Density (gm/cc.) Apparent Grain	Fluid Saturation (% pore space) Water	Fluid Saturation (% pore space) Oil	Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core	
6	1767'		Sandstone & shale	14.5	Nil	Nil	2.37	2.78	21	Nil	-	Nil	Trace	
6	1767'		"	13	N.	D.	2.36	2.73	25	"	-	"	"	Pieces only no permeability
6	1769'		"	9.5	Nil	Nil	2.48	2.74	14	"	-	"	"	
6	1771'		"	14.5	"	"	2.35	2.75	9	"	-	"	Fair	
6	1771		Repeat Extraction	-	-	-	-	-	7	"	-	"	Trace	2nd Extraction on selected black nodular shale
7	2127'0"	2127'4"	Red Sandstone	6	N.	D.	2.53	2.71	5	"	-	"	Trace	Small pieces
7	2129'4"	2129'8"	"	6	"	"	2.71	2.87	Nil	"	-	"	Nil	Only
7	2131'0"	2131'4"	"	13	"	"	2.38	2.73	Nil	"	-	"	"	No permeability determination

Remarks: -

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Well File No. ______

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CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. MORESTONE NO. 1

DATE ANALYSIS COMPLETED 10th July 1963

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core	
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil				
7	2133'0"	2133'2"	Sandstone	8	N.	D.	2.44	2.64	Nil	Nil	-	Nil	Nil	Small pieces only
7	2133'2"	2133'4"	Red Sandstone	3	"		2.65	2.73	23	"	-	"	"	No pieces suitable for permeability
7	2135'0"	2135'4"	"	4	"		2.59	2.71	23	"	-	"	"	Determination
8	2419'0"	2419'4"	"	13	Nil	Nil	2.39	2.74	Nil	Nil	-	"	"	
8	2421'0"	2421'4"	"	15	33	42	2.36	2.78	"	"	-	"	"	
8	2423'0"	2423'4"	"	13.5	31	24	2.36	2.74	"	"	-	"	"	
8	2425'0"	2425'4"	"	12.5	28	32	2.39	2.74	"	"	-	"	"	
8	2427'0"	2427'4"	"	11.5	Nil	Nil	2.43	2.75	"	"	-	"	"	

Remarks: -

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Well File No.

Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. BMR (COCKROACH)

DATE ANALYSIS COMPLETED 19th April 1966

Core No.	Sample Depth From	Sample Depth To	Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy) V	Absolute Permeability (Millidarcy) H	Average Density (gm/cc.) Dry Bulk	Average Density (gm/cc.) Apparent Grain	Fluid Saturation (% pore space) Water	Fluid Saturation (% pore space) Oil	Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core	
1	290'	300'	Limestone Vug	5	Nil	2*	2.58	2.70	Nil	Nil	N.D.	Nil	Nil	*Fine fracture evident
2	601'	611'	Limestone	3	"	Nil	2.75	2.82	N.D.	N.D.	"	N.D.	"	
3	915'	929'	Siltstone Calcareous	16	"	"	2.33	2.82	"	"	"	"	"	
4	1250'	1260'	Limestone	6	"	"	2.64	2.79	"	"	"	"	"	
5	1525'	1535'	Siltstone Calcareous	18	"	"	2.30	2.80	"	"	"	"	"	
6	1835'	1845'	Limestone Vugular	14	4	30	2.42	2.81	Nil	Nil	"	Nil	"	
7	2137'	2147'	Limestone	4	N.D.	Nil	2.65	2.76	N.D.	N.D.	"	N.D.	"	
8	2440'	2450'	"	7	Nil	"	2.60	2.79	N.D.	N.D.	"	N.D.	"	

Remarks: -

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Well File No.

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Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. BMR 12 (COCKROACH)

DATE ANALYSIS COMPLETED 19th April 1966

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil			
9	2730'	2740'	Sandstone Calcareous	10	N.D.	N.D.	2.38	2.65	N.D.	N.D.	N.D.	N.D.	Nil
10	2878'	2888'	Limestone	2	Nil	"	2.67	2.71	"	"	"	"	"
11	3139'	3149'	"	2	"	Nil	2.67	2.70	"	"	"	"	"
12	3375'	3385'	"	3	"	"	2.62	2.70	"	"	"	"	"
13	3630'	3646'	"	3	"	"	2.61	2.69	"	"	"	"	"
14	3996'	3998'	"	1	"	"	2.64	2.67	"	"	"	"	"

Remarks: -

General File No. 62/399
Well File No.

Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. LUCY CREEK NO. 1

DATE ANALYSIS COMPLETED 10th April 1967

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil			
1	296'0"	296'4"	Silic. Sandstone & Siltstone	4	Nil	Nil	2.74	2.83	N.D.	N.D.	N.D.	N.D.	N.D.
2	608'0"	608'4"	"	2	"	"	2.79	2.83	"	"	"	"	"
3	879'0"	879'4"	Shale	7	"	"	2.66	2.83	"	"	"	"	"
4	1149'0"	1149'4"	Sandstone	15	"	"	2.41	2.81	"	"	"	"	"
5	1504'0"	1504'4"	Limestone	4	"	"	2.58	2.70	"	"	"	"	"
6	1860'0"	180685"	"	14	"	"	2.44	2.82	"	"	"	"	"
7	2173'0"	2173'4"	"	4	"	"	2.65	2.76	"	"	"	"	"
8	2479'0"	2479'4"	Calc. Sandstone	14	Nil	3	2.35	2.73	Nil	Nil	"	Nil	Nil

Remarks: -

General File No. 62/399
Well File No. ____________

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Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. LUCY CREEK NO. 1

DATE ANALYSIS COMPLETED 10th April 1967

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil			
9	2695'0"	2695'5"	Limestone	5	Nil	Nil	2.60	2.71	N.D.	N.D.	N.D.	N.D.	N.D.
10	3204'0"	3204'4"	"	2	"	"	2.63	2.64	"	"	"	"	N.D.
11													
12	3520'0"	3520'4"	Shale	1	Nil	Nil	2.65	2.67	N.D.	N.D.	N.D.	N.D.	N.D.
13													
14	3624'0"	3624'5"	Igneous	2	Nil	Nil	2.68	2.71	N.D.	N.D.	N.D.	N.D.	N.D.

Remarks: -

General File No. 62/399
Well File No.

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Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. NETTING FENCE NO. 1

DATE ANALYSIS COMPLETED 31st May, 1972

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core	Fluorescence of sample "cut" in Tetrachlorethylene
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil				
17	5852'4"		Limestone	0.6	0.1	0.1	2.70	2.72	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
18	6178'4"		Slst; Calc Arg.	2.4	"	"	2.66	2.72	"	"	"	"	"	"
19	6416'4"		Sh; Pyr.	1.7	"	"	2.73	2.78	21	"	"	Neg.	Nil	Nil
20	6662'4"		Granite	3.1	"	"	2.63	2.72	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

Remarks: -

General File No. 62/399
Well File No.

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Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. GRG NO. 18

DATE ANALYSIS COMPLETED 3rd December 1963

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core	
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil				
5	305'	315'	Dolomite Rare Vugs	8.5	Nil	Nil	2.72	2.97	25	Nil	-	Nil	Nil	Some fine fractures in sample
6	"	"	As above	7.5	"	"	2.71	2.92	6	"	-	"	"	
7	"	"	Vugular Dolomite	6.5	"	"	2.76	2.93	4	"	-	"	"	
8	"	"	"	4.5	"	"	2.78	2.91	3	"	-	"	"	
9	"	"	"	7	"	"	2.76	2.96	Nil	"	-	"	"	
10	"	"	"	6.5	"	"	2.77	2.96	Nil	"	-	"	"	
11	"	"	"	8	"	"	2.70	2.91	25	"	-	"	"	

Remarks: -

General File No. 62/399
Well File No.

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Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. BMR 11 (CATTLE CREEK)

DATE ANALYSIS COMPLETED 14th April 1966

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil			
1	220'	229'	Limestone Vug.	14	Nil	Nil	2.42	2.81	Nil	Nil	N.D.	Nil	Nil
2	547'	560	"	8	"	"	2.57	2.80	"	"	"	"	"
3	701'	720'	Siltstone	14	"	"	2.43	2.88	N.D.	N.D.	"	N.D.	"
4	782'	783'	Limestone	4	"	"	2.70	2.82	"	"	"	"	"
5	784'	789'	Limestone Vug.	5	"	N.D.	2.68	2.82	Nil	Nil	"	Nil	"
6	885'	887'	Limestone	5	"	Nil	2.71	2.84	N.D.	N.D.	"	N.D.	"
7	940'	948'	"	5	"	N.D.	2.69	2.83	"	"	"	"	"
8	948'	951'	"	2	N.D.	"	2.63	2.68	"	"	"	"	"

Remarks: -

General File No. 62/399
Well File No.

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Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. BMR 11 (CATTLE CREEK)

DATE ANALYSIS COMPLETED 14th April 1966

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil			
9	1006'	1016'	Limestone	4	N.D.	N.D.	2.70	2.81	N.D.	N.D.	N.D.	N.D.	Nil
10	1075'	1085'	"	2	"	"	2.76	2.82	"	"	"	"	"
11	1136'	1139'	"	3	"	"	2.73	2.82	"	"	"	"	"
12	1202'	1205'	"	4	"	"	2.67	2.78	"	"	"	"	"
13	1256'	1257'	"	3	"	"	2.62	2.70	"	"	"	"	"
14	1308'	1318'	"	5	"	"	2.71	2.85	"	"	"	"	"
15	1390'	1400'	"	12	Nil	14	2.48	2.82	"	"	"	Nil	"
16	1450'	1452'	Silc Sandstone	10	N.D.	N.D.	2.40	2.67	"	"	"	Nil	"

Remarks: -

General File No. 62/399

Well File No.

Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. BMR 11 (CATTLE CREEK)

DATE ANALYSIS COMPLETED 14th April 1966

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil			
17	1495'	1500'	Silic Sandstone	9	Nil	53	2.46	2.69	Nil	Nil	N.D.	Nil	Nil
18	1500'	1502'	"	3	"	Nil	2.63	2.71	"	"	"	"	"

Remarks: -

General File No. 62/399
Well File No.

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Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. BMR 13 (SANDOVER RIVER)

DATE ANALYSIS COMPLETED 22nd July 1964

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core	Solvent After Extraction	
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil				Colour	Fluor
13	2975'	2980'	Limestone	2	Nil	Nil	2.63	2.69	84	16	-	Trace Fair	Nil	Yellow	Fair
13	"	"	"	2	"	"	2.64	2.70	91	9	-	Pale Yellow Trace	"	Bright Yellow	Fair

Remarks: - Acid solubility on above sample, 79%.
Only the very central pieces of core used for test.

General File No. 62/399
Well File No.

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Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

CORE ANALYSIS RESULTS

NOTE: (i) Unless otherwise stated, porosities and permeabilities were determined on two plugs (V&H) cut vertically and horizontally to the axis of the core. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively. (ii) Oil and water saturations were determined using Soxhlet type apparatus. (iii) Acetone test precipitates are recorded as Neg., Trace, Fair, Strong or Very Strong.

WELL NAME AND NO. BMR 13 (SANDOVER RIVER)

DATE ANALYSIS COMPLETED 3rd August 1964

Core No.	Sample Depth		Lithology	Average Effective Porosity two plugs (% Bulk Vol.)	Absolute Permeability (Millidarcy)		Average Density (gm/cc.)		Fluid Saturation (% pore space)		Core Water Salinity (p.p.m. NaCl)	Acetone Test	Fluorescence of freshly broken core	Extracted Oil
	From	To			V	H	Dry Bulk	Apparent Grain	Water	Oil				
1	2950'	2930'	Dolomite	37	N.D.	6	1.78	2.83	Nil	1	-	N.D.	Golden Strong	Light orange brown
2	"	"	"	33	"	8	1.87	2.80	72	?	-	"	"	Fluorescence. Bright greenish yellow

Remarks: - Porosities were confirmed using the gas expansion method. Neither sample showed fluorescence in the natural state.

General File No. 62/399
Well File No. 63/456

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POROSITY AND PERMEABILITY MEASUREMENTS - OUTCROP MATERIAL

REGISTERED NUMBER 7472658

As requested, we have carried out porosity and permeability (gas and liquid) tests on the sample plugs listed in the attached table. The plugs were drilled from an outcrop sample as per your instructions. Plug 1 was drilled from the massive material of the rock; plug 2 from the network of clay and dolomite; plug 3 was drilled perpendicular and parallel with respect to the veining in the sample.

It was not possible to measure any liquid flow (brine) in any of the samples because of the extremely low permeability, even though high differential pressure (300 psi) was applied across the samples for extensive periods.

(B.A. McKAY)
Pet. Tech. Cl. IV

20 December 1976

PETROLEUM TECHNOLOGY LABORATORY,

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, CANBERRA

CORE ANALYSIS RESULTS - POROSITY, PERMEABILITY AND DENSITY

NOTE: Unless otherwise stated, porosities and permeabilities were determined on two plugs (V & H) cut vertically and horizontally to the axis of the cores. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively.

WELL NAME & NO: 7472658 OPERATOR: DATE ANALYSIS COMPLETED:

Sample No.	Sample Depth (metres)		Lithology	Average effective porosity of two plugs (% Bulk Vol)	Absolute permeability (Md)		Average density (gm/cc)		Remarks
	From	To			V	H	Dry Bulk	Apparent Grain	
1			calcite, dolomite and cldy	3.60	N.D.	<0.1	2.64	2.74	
2			"	2.00	N.D.	<0.1	2.63	2.69	
3			"	5.80	<0.1	no flow	2.53	2.69	

N.D. = Not determined

General File No. - 76/1026

Well File No. -

APPENDIX 3C

ANALYTICAL REPORT: NINMAROO FORMATION (L. Ord), GEORGINA BASIN*

BMR Regd. no.	Sample type	TOC %	EOM ppm	EOM mg/gC	HYDROCARBONS ppm	HYDROCARBONS mg/gC	HYDROCARBONS %EOM	EOM COMPOSITION Saturates %	EOM COMPOSITION Aromatics %	EOM COMPOSITION Resins %	EOM COMPOSITION Asphalt %
74712635	Ls. (outcrop)	0.04	29	80	6	17	21.1	9.6**	11.5	44.2	34.6
74712636	"	0.05	89	190	34	72	37.9	19.5**	18.4	51.7	10.3

* Locality : B. Radke's section 202 (246 m & 249.5 m), Boulia 1:250 000 sheet area, Burke River Belt

** Analysed by gas chromatography

Analyst : I. Donald

Officer-in-charge : D.M. McKirdy

Date: 24.1.77

T.O.C. - Total Organic Carbon

EOM - Extractable Organic Matter

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COMMENTS

1. The analytical procedures followed are those outlined in McKirdy and Horvath (1976).

2. As the organic carbon content of these limestones is considerably less than the average for ancient carbonates (0.18% TOC), they can be regarded as having very poor source rock potential.

3. Being outcrop samples, the yield and composition of the EOM (bitumen) has probably been altered by weathering in the manner described by Leythaeuser (1973). The organic matter in sample 635 appears to be more weathered than that of sample 636.

4. GC analysis of the saturated hydrocarbons indicates considerable loss of lighter (C20) hydrocarbons from both samples.

5. If indigenous, the hydrocarbon content of the least altered sample (636, 37.9% EOM) is high enough to suggest that it has reached the oil generation phase of its diagenetic history.

(D.M. McKIRDY)

24 January 1977

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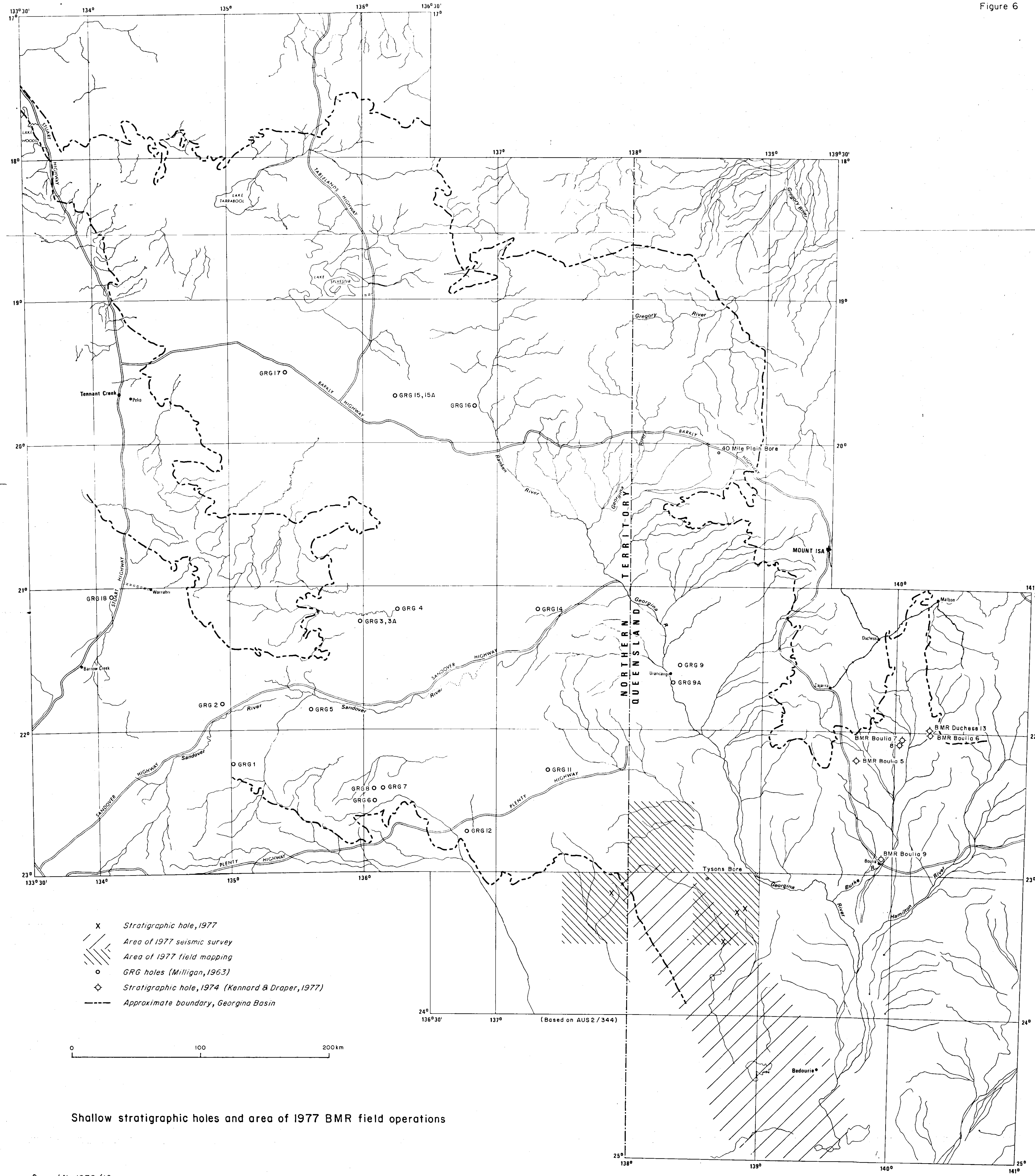
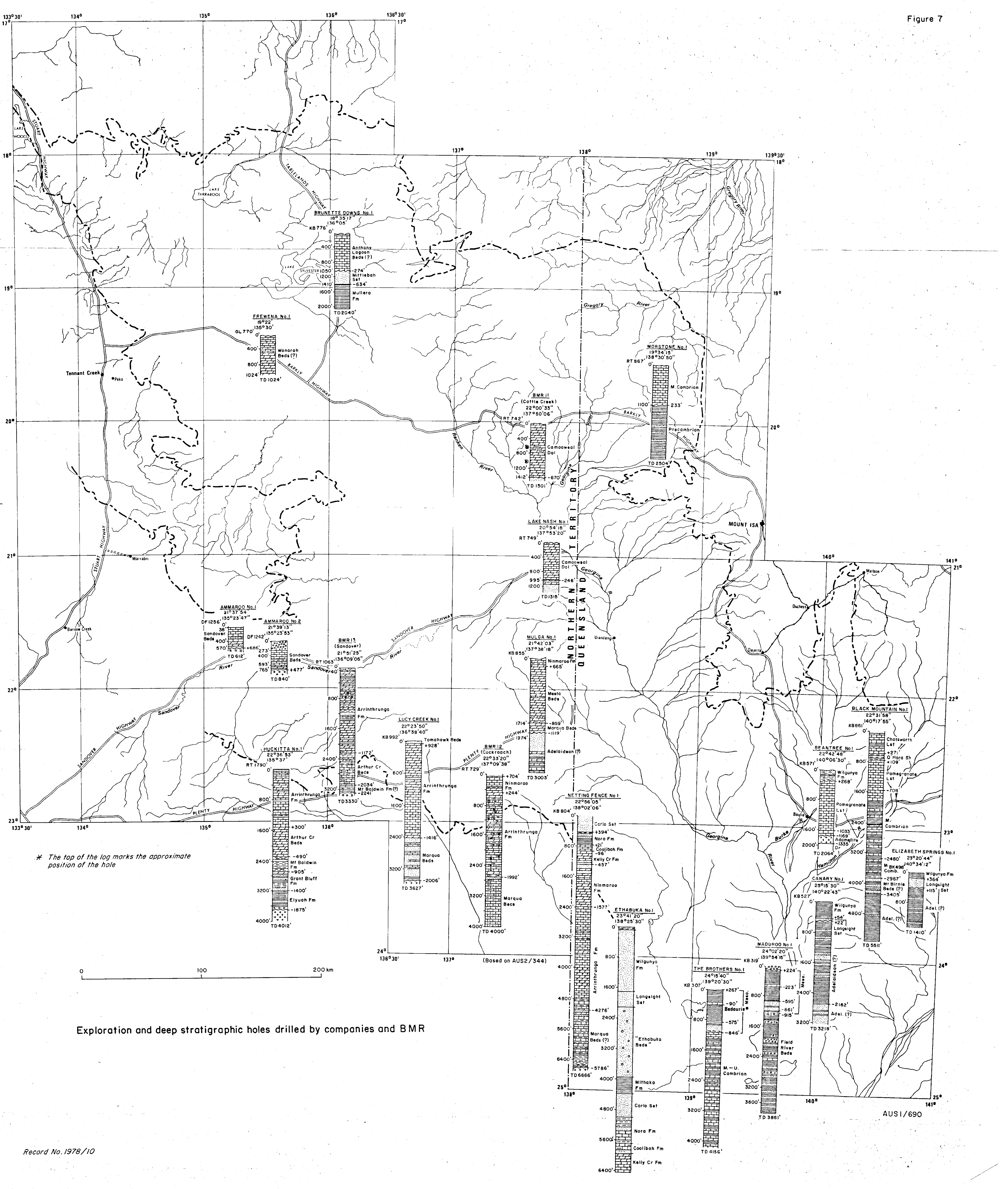


Shallow stratigraphic holes and area of 1977 BMR field operations

Figure 7



Exploration and deep stratigraphic holes drilled by companies and BMR

Record No. 1978/10

PLATE I

NOTES:

This map was compiled from various Total Magnetic Intensity contour maps available for purchase or reference at the Bureau of Mineral Resources, Canberra, A C T. Datums, contour intervals, scales of the original maps, and corrections for regional magnetic gradient commonly vary from one map sheet to the next. It is not practical to make adjustments for these differences; accordingly no attempt has been made to match the magnetic contours across the survey boundaries.

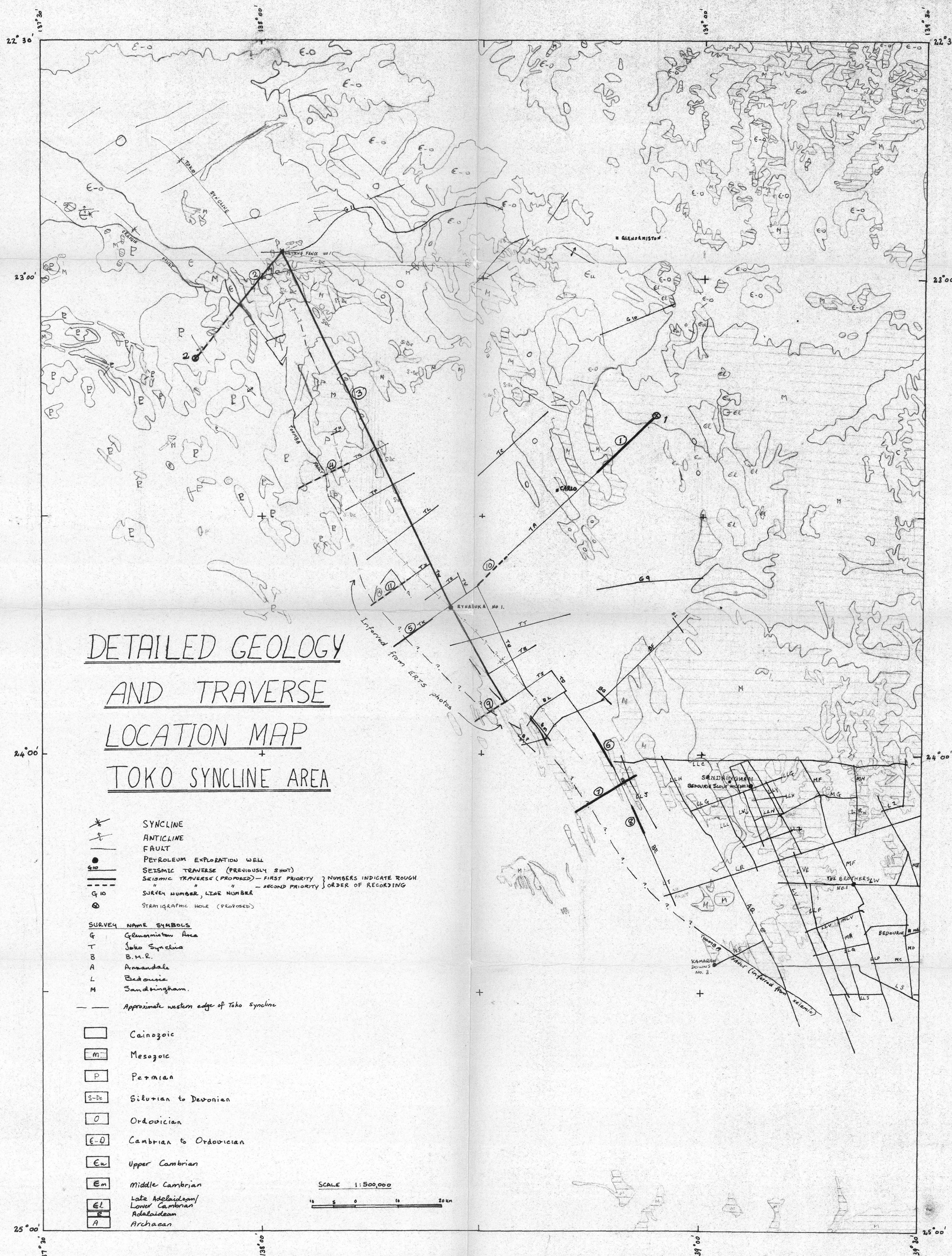
The information contained in this map has been obtained by the Department of National Development as part of the policy of the Commonwealth Government to assist in the exploration and development of mineral resources. It may not be published in any form, or used in a company prospectus or statement, without the permission in writing of the Director, Bureau of Mineral Resources, Geology and Geophysics.

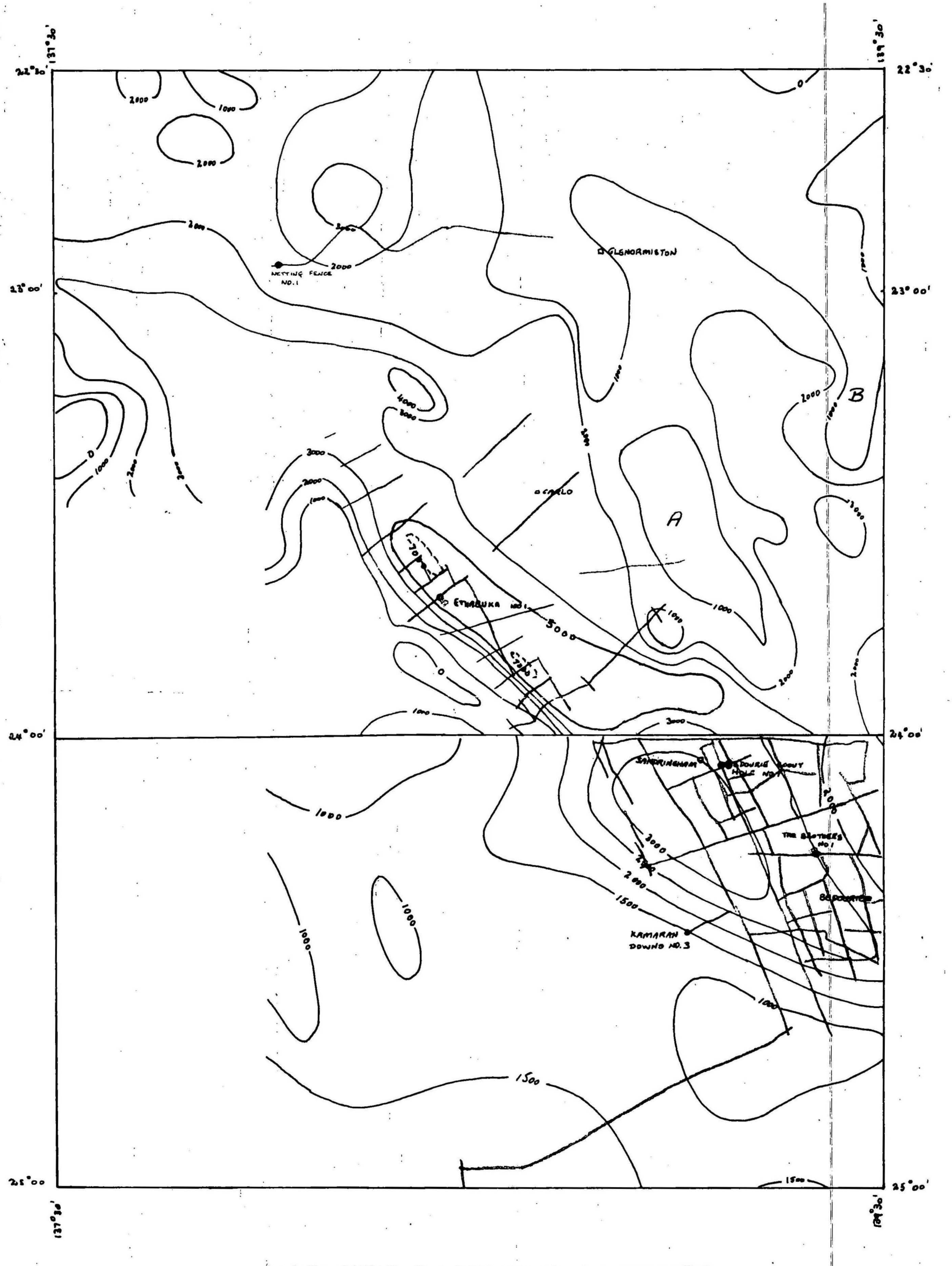
Preliminary edition

Total magnetic intensity

Record No. 1978/10

AUS 1/691


DETAILED GEOLOGY
AND TRAVERSE
LOCATION MAP
TOKO SYNCLINE AREA
SYNCLINE
ANTICLINE
FAULT
PETROLEUM EXPLORATION WELL
SEISMIC TRAVERSE (PREVIOUSLY SHOT)
SEISMIC TRAVERSE (PROPOSED) — FIRST PRIORITY
" " " — SECOND PRIORITY
NUMBERS INDICATE ROUGH ORDER OF RECORDING
SURVEY NUMBER, LINE NUMBER
STRATIGRAPHIC HOLE (PROPOSED)
SURVEY NAME SYMBOLS
G Glenormiston Area
T Toko Syncline
B B.M.R.
A Annandale
L Bedourie
M Sandringham.
Approximate western edge of Toko syncline
Cainozoic
Mesozoic
Permian
Silurian to Devonian
Ordovician
Cambrian to Ordovician
Upper Cambrian
Middle Cambrian
Late Adelaidean/ Lower Cambrian
Adelaidean
Archaean
SCALE 1:500,000
10 5 0 10 20 KM
TOKO SYNCLINE
CRAIGIE FAULT
TOOMBA FAULT
GLENORMISTON
CARLO
ETHABUKA NO 1.
NETTING FENCE NO 1
SANDRINGHAM
BEDOURIE SCOUT HOLE
THE BROTHERS NO.1
KAMARAN DOWNS NO. 3.
BEDOURIE
TOOMBA FAULT (inferred from seismic)
Inferred from ERTS photos
22° 30'
23° 00'
24° 00'
25° 00'
137° 30'
138° 00'
139° 00'
139° 30'



MAGNETIC BASEMENT CONTOURS

SCALE 1:1000 000

10 5 0 10 20 30 KM

CONTOURS NORTH OF 24°00' FROM WELLS, ET AL., (1966)

CONTOURS SOUTH OF 24°00' FROM F.P.C. (1965c)

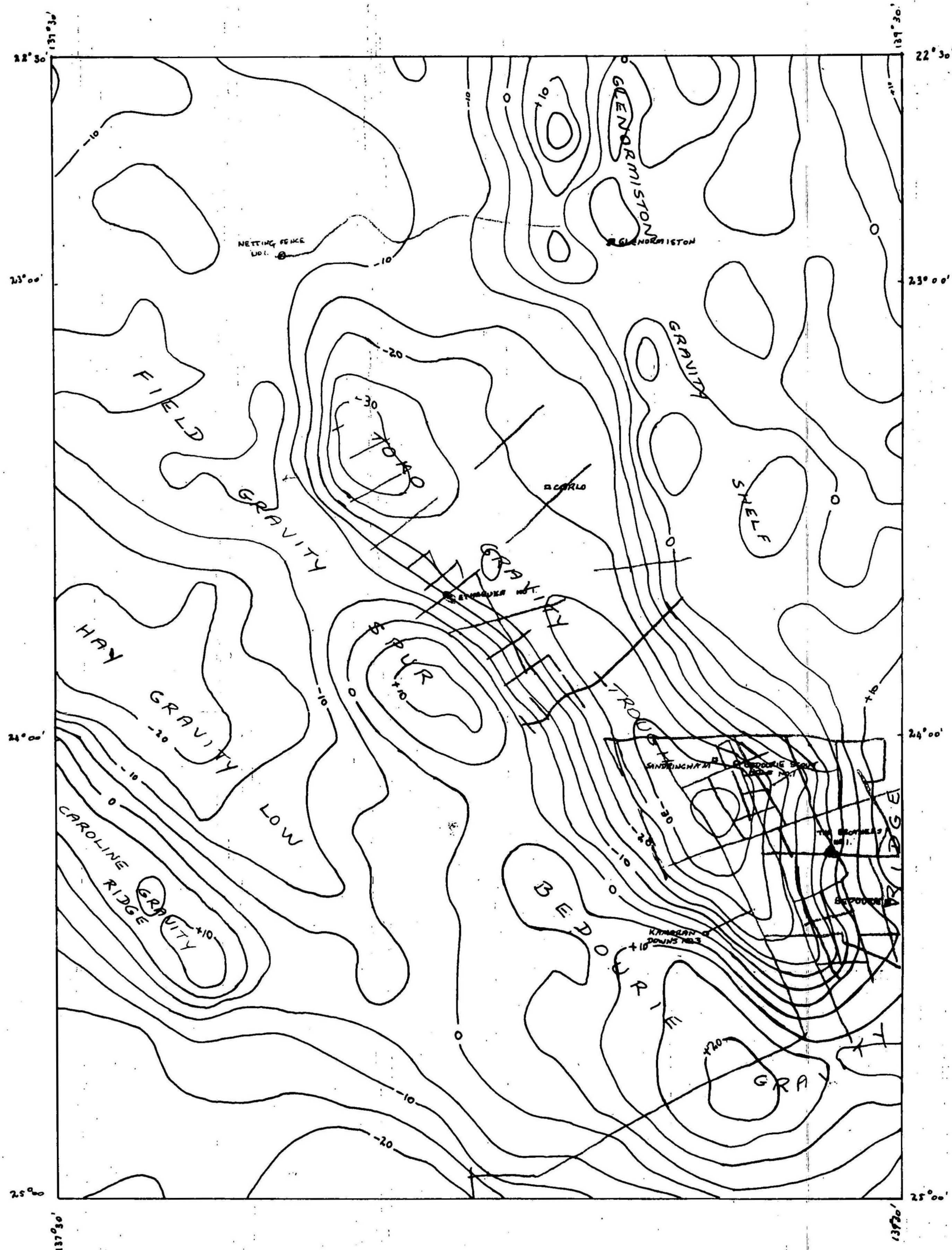
— 1500 — Magnetic basement depth (metres below msl)

——— Seismic line

Record No.1977/25 B 1978/10

F54/B3-271

PLATE 3



BOUGUER ANOMALIES

SCALE 1:1000000

10 5 0 10 20 30 Km

DENSITY 2.67 GM/CC

—— -20 —— Bouguer anomaly contours (mgals)

———————— Seismic line

Record No.1977/25 & 1978/10

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PLATE 4

CORRECTED RECORD SECTION

PLATE 5

RECORDING INFORMATION

Magnetic Recorder: DS7-7
Amplifiers: 7000 B
Filters: K18 - K160
A.G.C.: W.B.
Gain Initial: -55
Final: -10
Geophones: HSJ - 14 c/s
Geophone pattern:
16/trace, 20' apart in line
Station interval 150'

Shot-hole pattern:

25' · 50' or 25' · 50'

Depth 45'
Charge 2½ to 5 lb/hole

PLAYBACK INFORMATION

Filters: 1/20 - 1/60
A.G.C.: S.S.
Gain Initial: -40
Final: -20
Trip delay: 0
Compositing: Nil

VELOCITY INFORMATION

t;Δt analysis and
Expanded Spread Velocity Shoot
Traverses E, U, W, T, H

HORIZONTAL SCALE

FEET
0 1000 2000 3000 4000 5000
0 1800 3600

SOUTH-EASTERN GEORGINA BASIN
SEISMIC SURVEY 1963

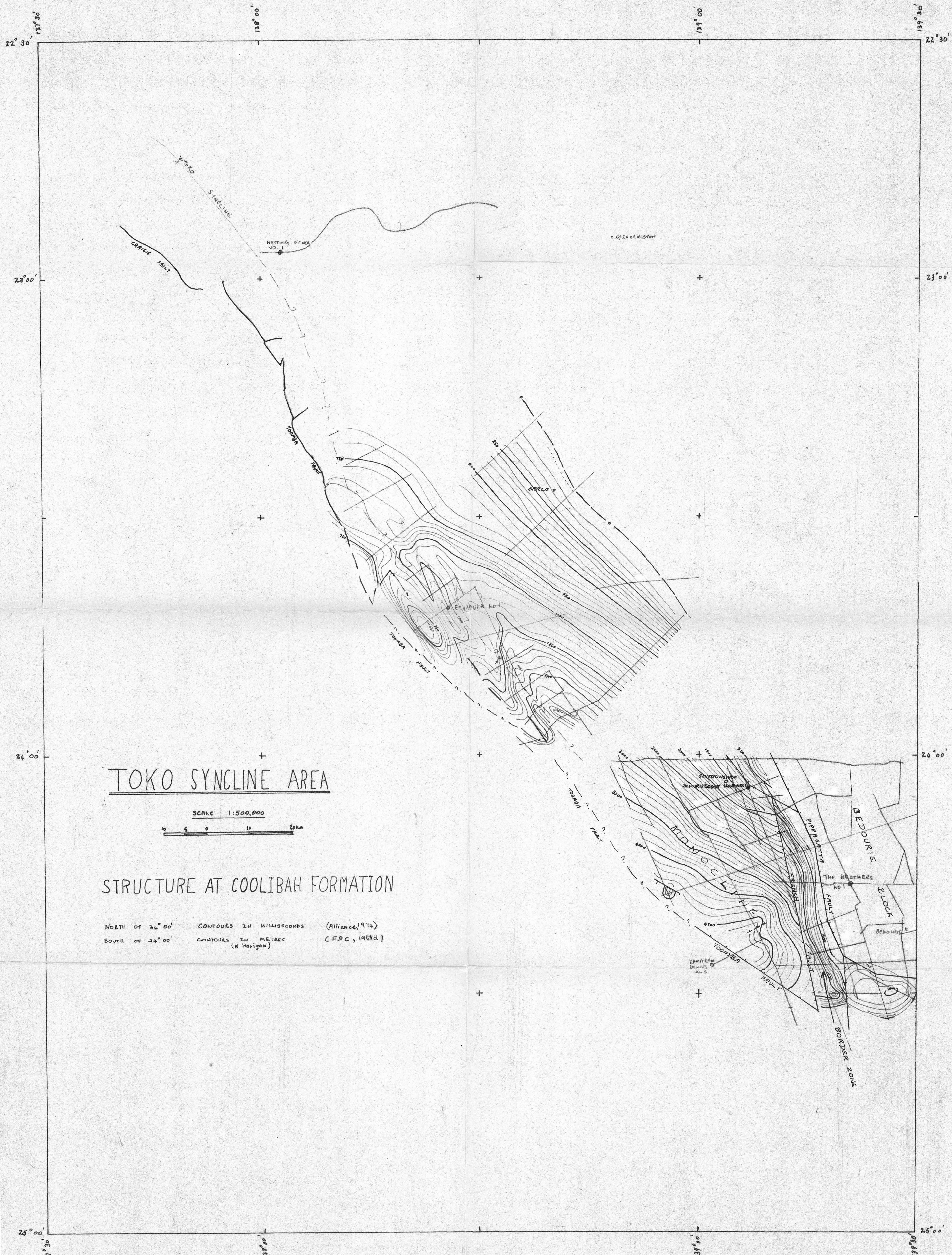
TRAVERSE BF

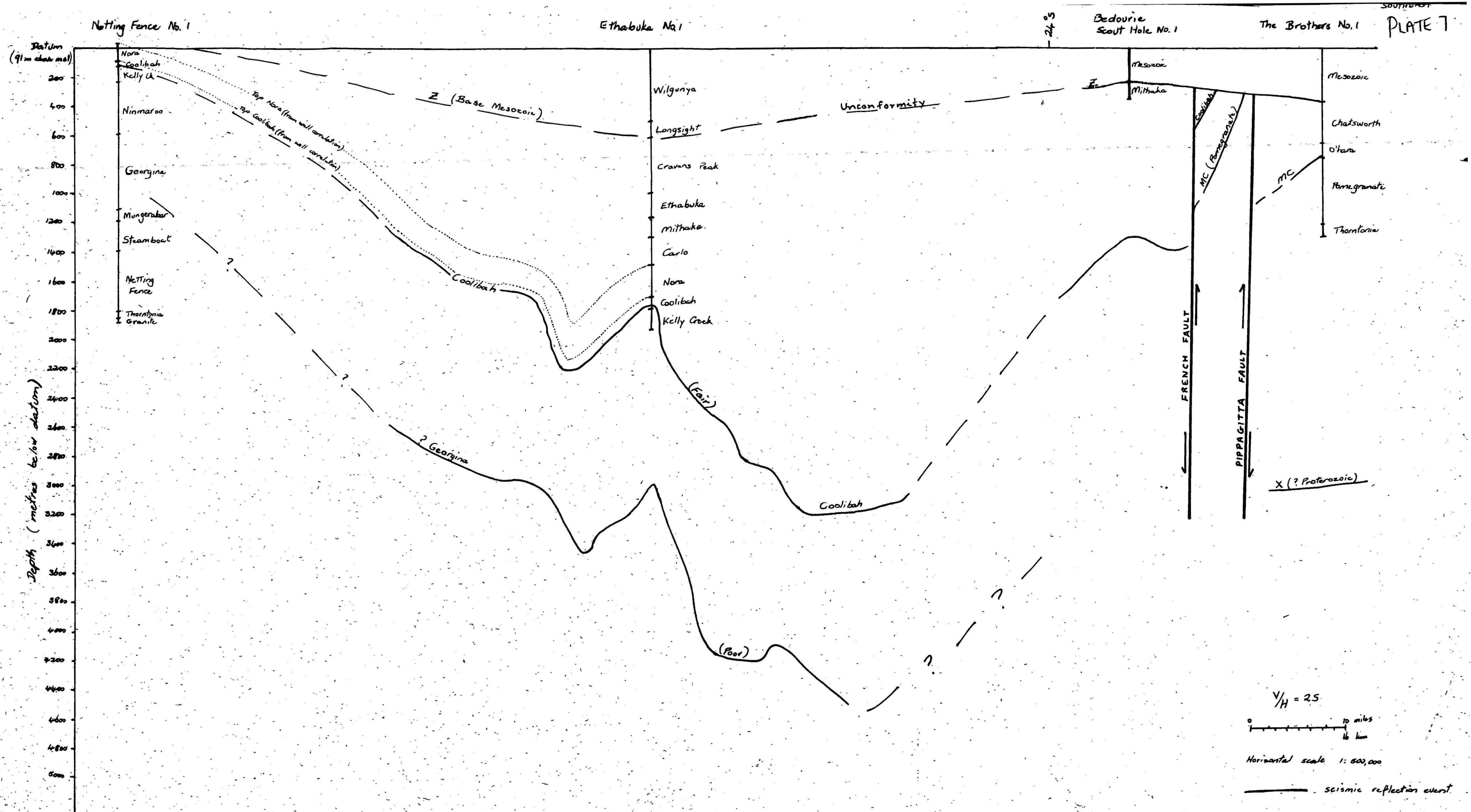
RECORDED BY: *Seismic Party No. 1*

SECTION BY: *Bureau of Mineral Resources Playback Centre SIE MS 42*

TO ACCOMPANY RECORD No. 1977/25
& Record No. 1978/10

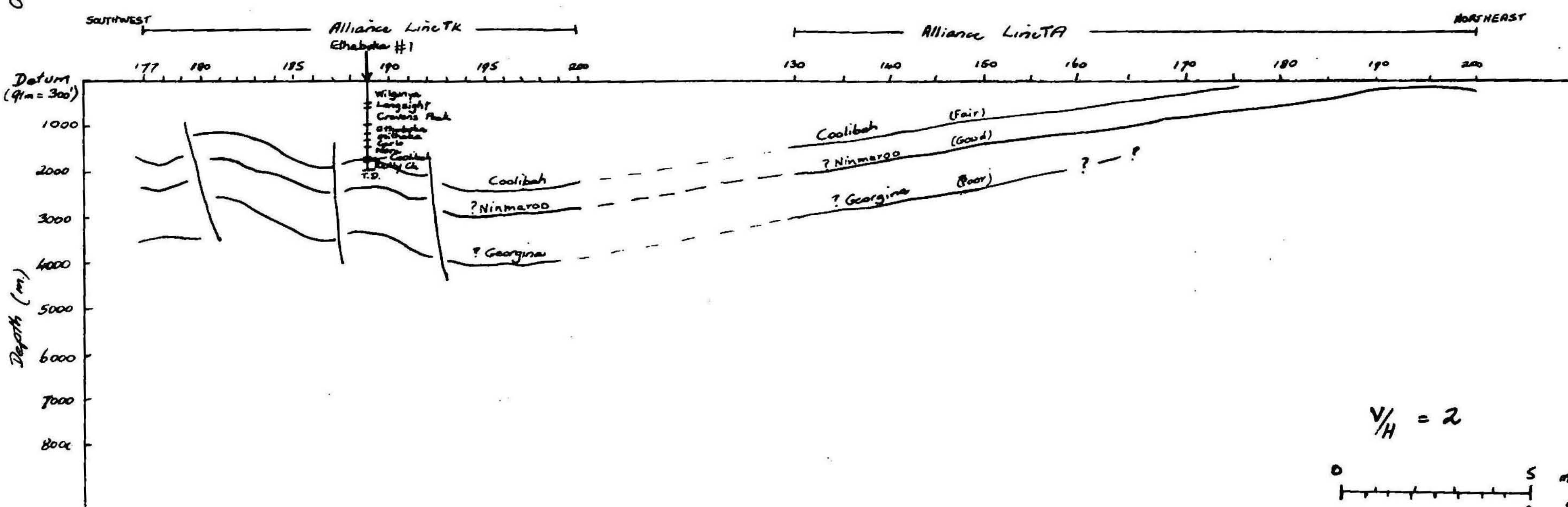
F54/B3-136-1


TOKO SYNCLINE AREA
SCALE 1:500,000
STRUCTURE AT COOLIBAH FORMATION
NORTH OF 24°00' CONTOURS IN MILLISECONDS (Alliance, 1974)
SOUTH OF 24°00' CONTOURS IN METRES (N Horizon) (FPC, 1965d)
TOKO SYNCLINE
CRAIGIE FAULT
TOOMBA FAULT
NETTING FENCE NO. 1
GLENORMISTON
CARLO
ETHABUKA NO 1
MONOCLINE
PIPPAGITTA FAULT
FRENCH FAULT
BEDOURIE BLOCK
THE BROTHERS NO 1
BEDOURIE
KAMARAN DOWNS NO. 3
BORDER ZONE
22°30'
23°00'
24°00'
25°00'
137°30'
138°00'
139°00'
139°30'



STRUCTURAL SECTION BETWEEN NETTING FENCE NO. 1, ETHABUKA NO. 1, BEDOURIE SCOUT HOLE NO. 1 AND THE BROTHERS NO. 1

Record No. 1977/25 & 1978/10



STRUCTURAL SECTION ALONG TRAVERSES TK AND TA

V/H = 2

0 5 miles

8 km

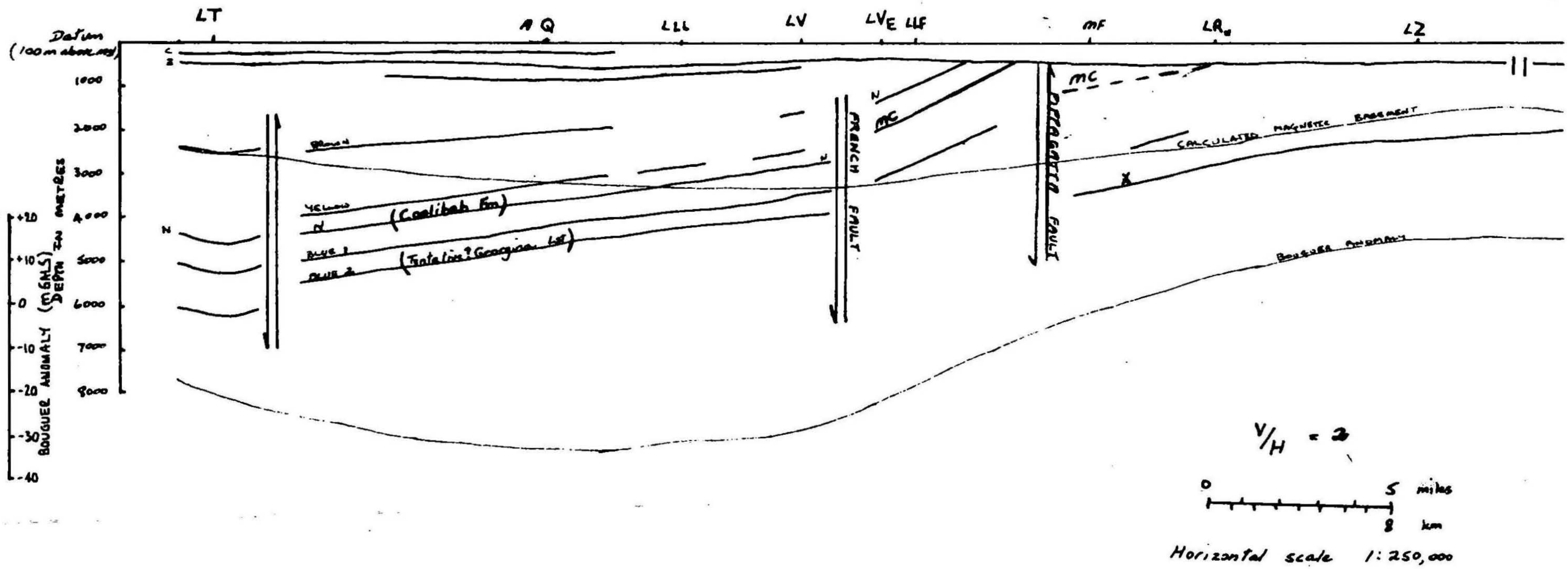
Horizontal scale 1:250,000

seismic reflection event

F54/B3-275A

PLATE 8

Record No. 1977/25 & 1978/10



MC — Seismic reflection event (Fair)

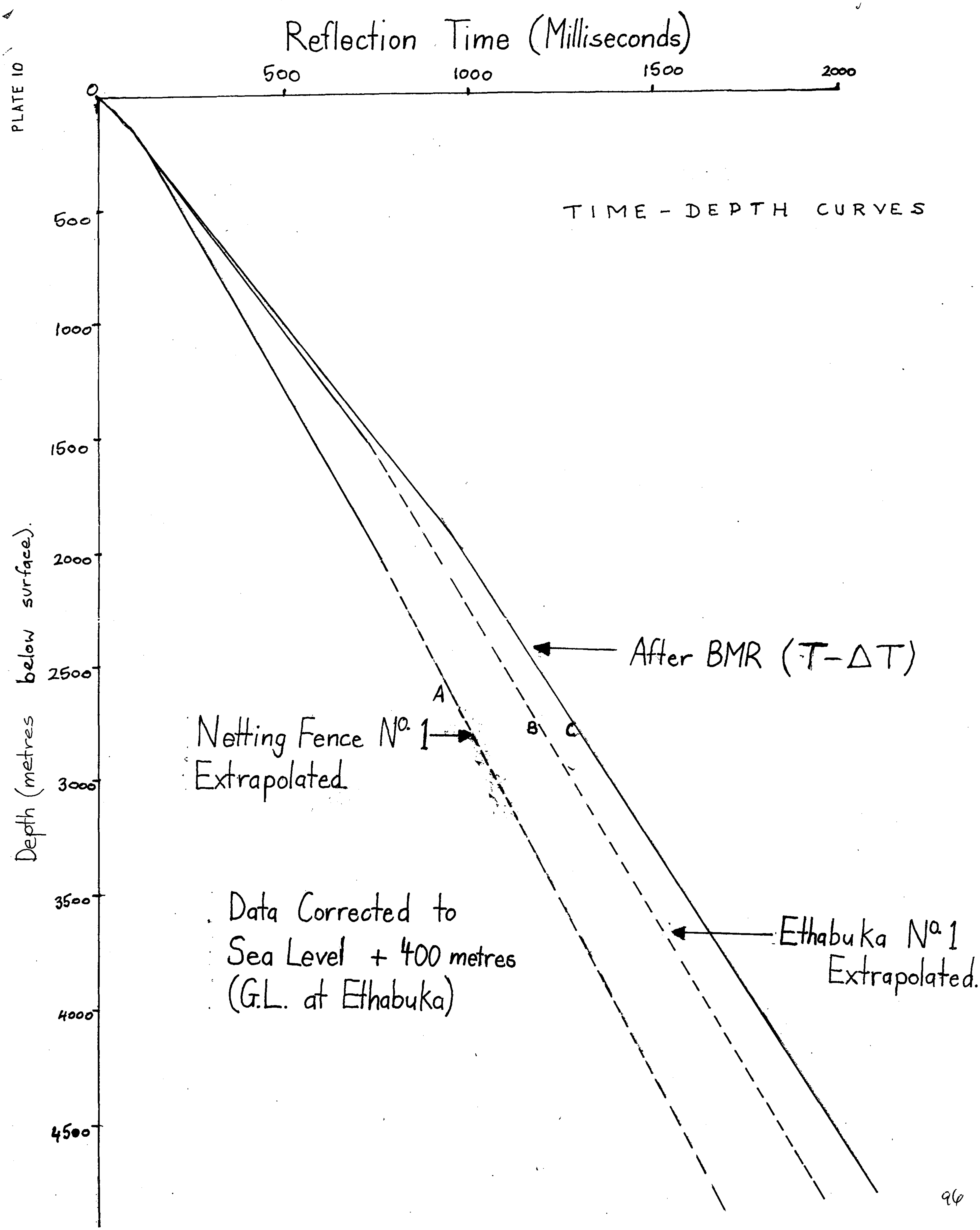
STRUCTURAL SECTION ALONG TRAVERSE LR

F54/B3-276A

PLATE 9

PLATE 10

F54/B3-277



Record No 1977/25 & 1978/10