BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

Record 1981/12

STRATIGRAPHIC DRILLING IN THE CRETACEOUS TOOLEBUC FORMATION IN THE SOUTHERN AND EASTERN EROMANGA BASIN, 1980 - A CONTRIBUTION TO BMR/CSIRO NERRDC PROJECT 78/2616

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SUMMARY

Fifteen shallow stratigraphic holes were drilled during 1980 in the southeast of the Eromanga Basin as part of the BMR/CSIRO NERDDC Oil Shale Methodology Project. The holes were drilled to obtain stratigraphical, structural, petrophysical, geophysical, and geochemical information about the Toolebuc Formation and its oil shale. With minor exceptions the formation was fully cored in each hole.

BMR Urisino No. 1 (Appendix 1) was drilled and wire-line logged by BMR. It is located 130 km east of Tibooburra, NSW, on the southern margin of the basin (Fig. 1). The remaining fourteen holes (Appendixes 2-14) were drilled by a contractor to the northeast, in central Queensland (Fig. 2), between Barcaldine and Charleville; they were also wire-line logged by BMR.

The Urisino hole intersected a unit thought to be equivalent to the Toolebuc Formation. It contained no oil shale. Ten of the other holes intersected the complete Toolebuc Formation, which contained oil shale in all cases. Two holes did not reach the Toolebuc Formation, and in the remaining two the presence of the formation is as yet uncertain.

In seven of the Queensland holes a kerosene-like fluid flowed to the surface from the Toolebuc Formation along with the drilling medium. Geochemical analysis showed the fluid to be a mature hydrocarbon of probable terrigenous origin not related to the normal Toolebuc Formation marine-type kerogen.

The drilling results and data already available lead to the hypothesis that oil shale is absent from the Toolebuc Formation roughly south of a line joining Bedourie and Charleville in Queensland (Appendix 15).

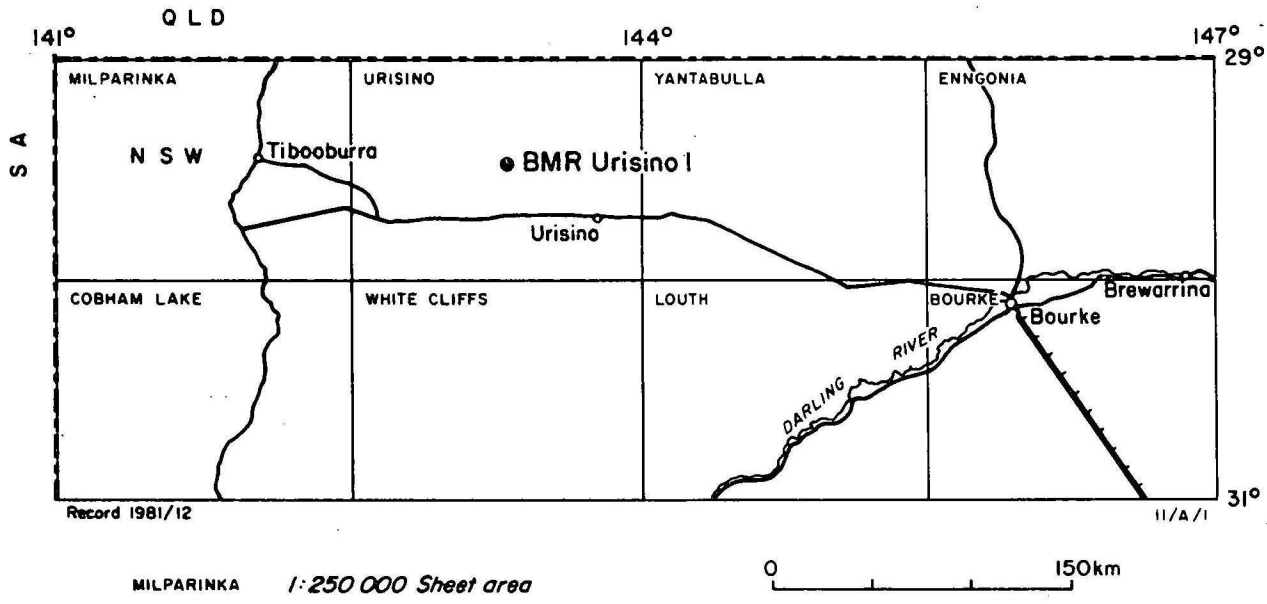

Fig. 1 Location map, BMR Urisino 1 stratigraphic hole

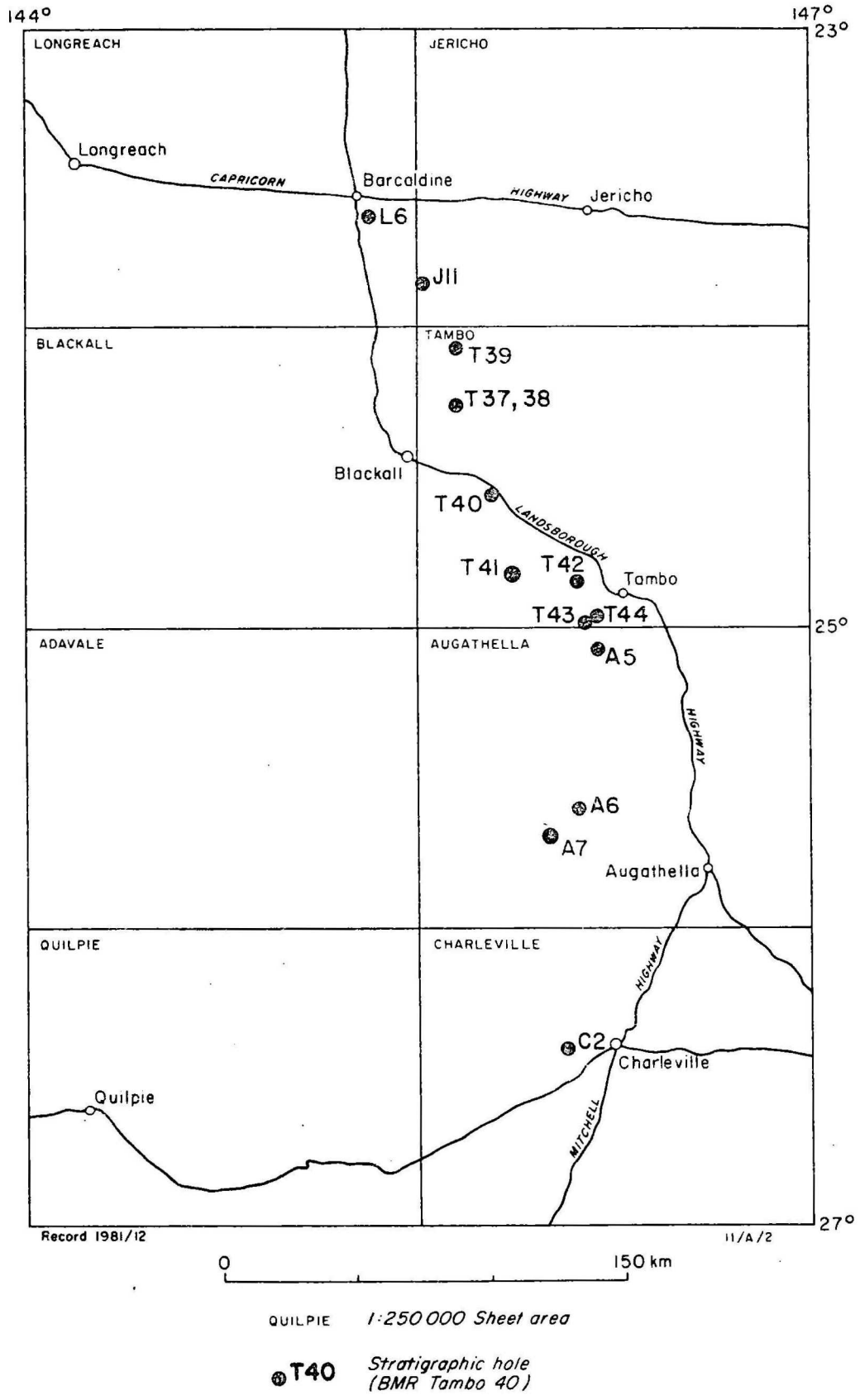

Fig. 2 Location map, stratigraphic holes drilled in Queensland

INTRODUCTION

The NERDDC Oil Shale Methodology Project is being carried out jointly by the Bureau of Mineral Resources and CSIRO's Fossil Fuel Division. H.F. Doutch (BMR) and Professor G.H. Taylor (ANU) are the Project Leaders.

Work in BMR on the project began at the end of February 1980, with S. Ozimic as principal investigator collecting information on the Toolebuc Formation from companies and State geological surveys, and carrying out a drilling program.

The 15-hole drilling and wire-line logging program completed in 1980 is the subject of this report. One hole was drilled in northwestern New South Wales and 14 in central Queensland. All cores and cuttings have been megascopically examined and are here briefly described and their lithologies correlated with wire-line logs and other information. Composite borehole logs are presented in Appendixes 1-14, and correlations between the holes in Plate 1.

GEOLOGICAL SETTING

Basin setting of Toolebuc Formation

The Eromanga Basin is a large basin of irregular outline containing flat-lying to gently folded Jurassic and Cretaceous sedimentary rock up to 3200 metres thick. It covers about 1 200 000 km^2 in Queensland, Northern Territory, South Australia, and New South Wales. The basin connects with the Carpentaria Basin across the Euroka Arch and with the Surat Basin across the Nebine Ridge and the Cunnamulla Shelf. Elsewhere, the boundary is an unconformity separating basin sediments from older rocks.

The older part of the basin sequence contains up to 1200 m of Jurassic fluviatile, lacustrine, and deltaic sandstone, siltstone, and thin coal seams. Volcanic detritus within the upper part of this sequence was probably derived from volcanoes within the drainage basins of the streams. The Jurassic sediments are overlain conformably by up to 2000 m of Cretaceous deltaic, marine, and lacustrine sandstone, mudstone, siltstone, limestone, and minor coal, deposited during major marine advances and regressions.

Minor oscillations during the middle to late Albian provided varied depositional environments reflected in the lithologies of the Toolebuc Formation e.g. fossiliferous and non-fossiliferous limestones, siltstone, shale, and bituminous shale.

Drape folds occur over basement ridges and blocks; local monoclines in the upper part of the sequence grade down into faults. Over large areas the sequence dips at angles less than 7°.

Lithostratigraphic setting of Toolebuc Formation

The Toolebuc Formation (Fig. 3) is part of the Cretaceous Rolling Downs Group, which consists of several marine, paralic, and freshwater units. The geology of the Group is summarised in Table 1.

The type section of the Toolebuc Formation has been defined by Senior & others (1975) as a sequence between 25.3 and 35.8 metres in stratigraphic drill-hole BMR Boulia No. 3A (Fig. 4). The hole was drilled 13.7 km east of Hamilton Hotel, about 100 metres north of the Boulia-Winton Highway. The hole is located at 22°47'00"S and 140°43'30"E. The type section consists of black mudstone, with a few thin limestone beds and shell fragments down to 30.5 metres, and a hard concretionery limestone and thin crystalline limestone beds interbedded with soft black mudstone down to 35.8 metres. The cores from the hole are available for inspection at the BMR Core and Cuttings Laboratory, Fyshwick, ACT.

The strata thought to be the Toolebuc Formation in the 15 holes drilled are broadly similar to the type section. However, in definition of the type section, the authors have not defined criteria for the top and bottom of the formation. Further, in BMR Boulia No. 3A the Allaru Mudstone is considerably more calcareous than the Wallumbilla Formation and is less readily distinguished from the Toolebuc Formation. Ramsden (1980) considered the boundary between the Toolebuc Formation and Allaru Mudstone to be probably transitional.

In most places the formation is associated with a very strong gamma-ray anomaly or is thought to be; such an anomaly is almost nowhere exhibited by the Wallumbilla Formation or Allaru Mudstone. This anomaly has been recorded in water bores and petroleum exploration wells in Queensland, South Australia, and New South Wales, and its character has been illustrated for the Eromanga Basin by Senior & others (1978).

However, the association has yet to be proved in many places, although anomalies recorded from otherwise unsampled water bores have up to now provided reliable targets for drilling for the formation.

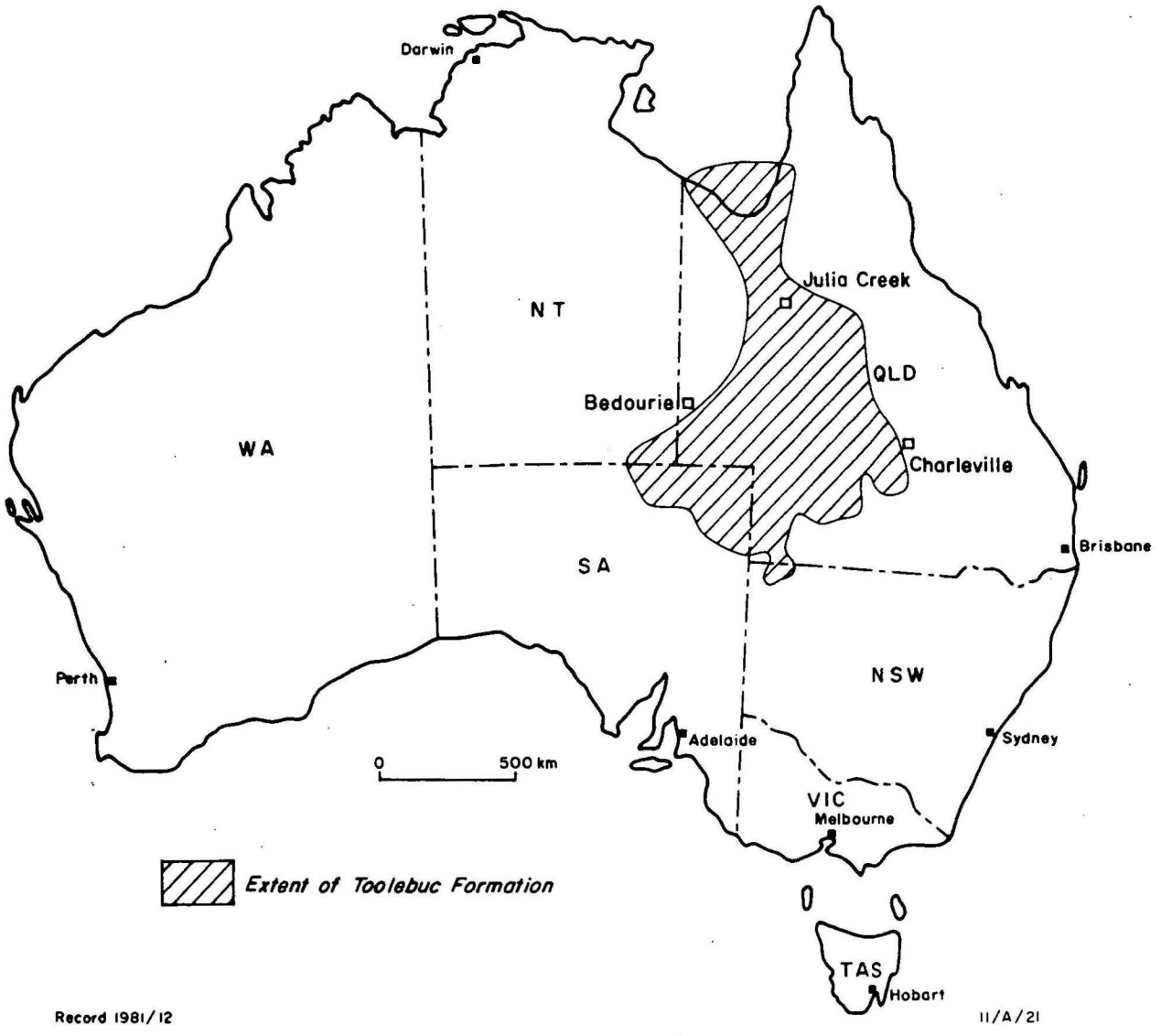

Fig. 3 Extent of Toolebuc Formation

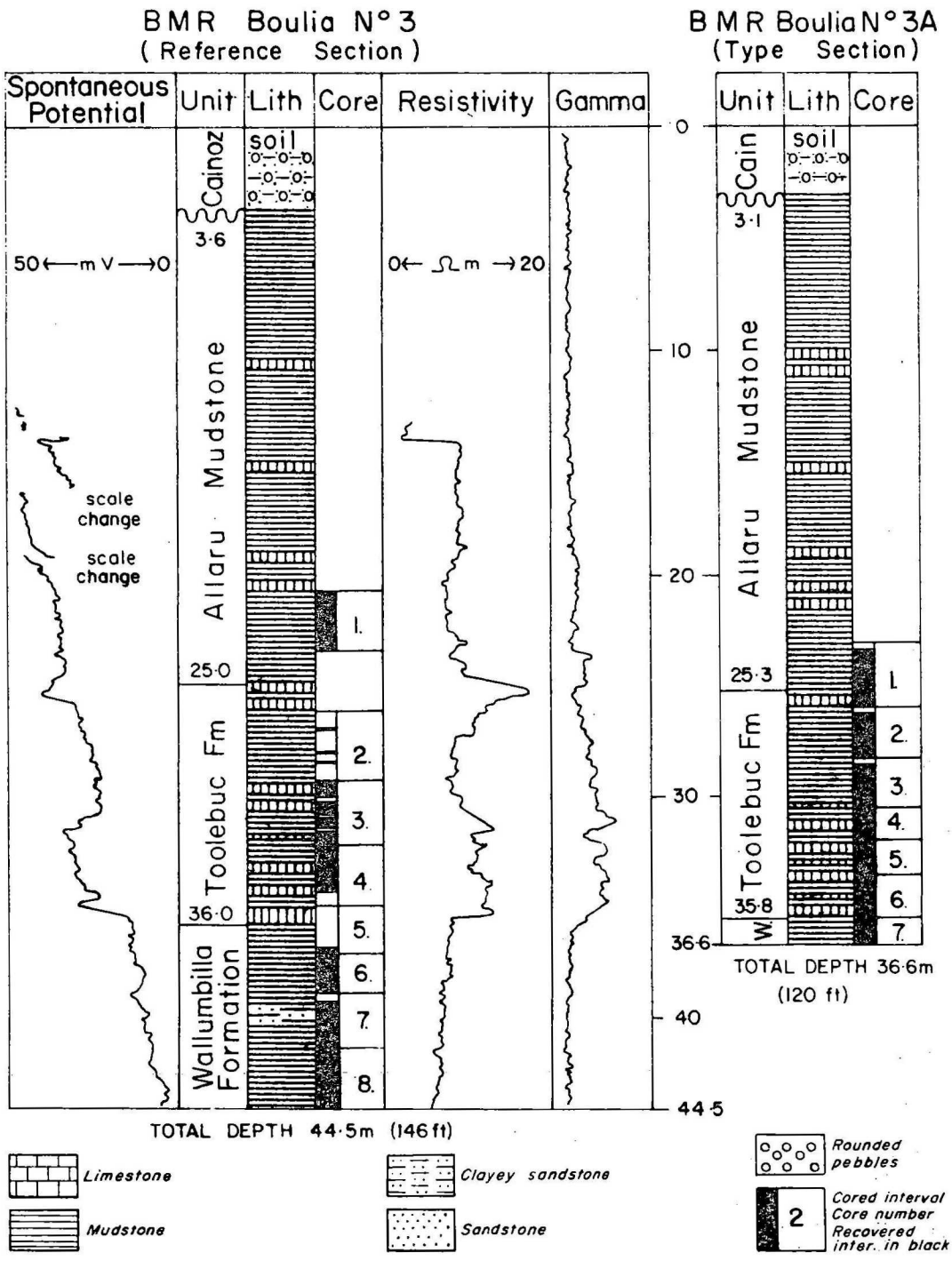

Fig. 4 Type Section of Toolebuc Formation in B M R Boulia N° 3A Stratigraphic Drill Hole and reference sec B M R Boulia N° 3
(After Senior & others, 1975)

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Record 1975/67, Fig. 8 ; 1981/12, Fig. 4

Table 1 - Eromanga Basin, rock units of the Rolling Downs Group
(From Exon & Senior, 1976)

Age	Unit		Maximum Thickness(m) Average	Lithology and Palaeontology	Environment	Relationships
Cenomanian	Rolling Downs Group	Winton Formation	1100 500	Labile sandstone, siltstone, mudstone, calcareous in part; mudclast conglomerate, minor coal. Freshwater molluscs, plants, spores and pollen. Reptile tracks.	Plains: streams, swamps, lakes. Wide river flats and local development of short-lived streams.	Restricted to Eromanga Basin.
Late Albian		Mackunda Formation	200 60	Labile sandstone, siltstone, mudstone, coquina limestone, mudclast conglomerate, cone-in-cone limestone. Glauconie-bearing. Marine molluscs, fish and sharks teeth, forams. Plant fragments, spores and pollen.	Marine regression. Deposition in paralic environments.	Restricted to Eromanga Basin.
		Allaru Mudstone	270 200	Blue-grey mudstone, siltstone, minor fine labile sandstone, calcareous in part. Molluscs, with ammonites and pelecypods dominant, forams. Minor plant fragments, spores and pollen, microplankton.	Shallow seas, largely below wave base. Good connection with open sea.	Restricted to Eromanga and Carpentaria Basins.
		Toolebuc Formation	75 15	Bituminous and calcareous shale, black siltstone, fine grained limestone, coquinite, labile sandstone. Richly fossiliferous; relatively few genera of pelecypods, gastropods ammonites and belemnites. Fish remains, planktonic forams, spores, pollen and microplankton.	Shallow seas, with shoals. Good connection with open sea.	Restricted to Eromanga and Carpentaria Basins.
Early and Middle Albian		Wallumbilla Formation — Coreena Member	220 150	Siltstone, mudstone, labile sandstone, mudclast conglomerate. Glauconie-bearing and calcareous in part. Locally rich marine fauna of pelecypods, gastropods, belemnites, scaphopods, and rare ammonites; forams. Plant fragments, spores, pollen and microplankton.	Shallow marine and paralic gives way to coastal plain.	Continuous with Coreena Member of Surat Basin.
		Wallumbilla Formation — Ranmoor Member	310 250	Grey to black mudstone, siltstone, carbonaceous in part. Upper part rich in kerogen (oil shale). Marine fossils, near Hughenden only, from near base and top. Fauna of ammonites, belemnites and pelecypods. Spores, pollen and microplankton.	Shallow marine, paralic (possibly enclosed basins or lagoons).	Northeastern marginal facies of Eromanga Basin. Correlate of Coreena Member.
Late Aptian		Wallumbilla Formation — Jones Valley Member	10 5	Siltstone, calcareous siltstone, and limestone, and very fine labile sandstone. Minor glauconie. Fossils only at a few localities. Pelecypods, belemnites, scaphopods, burrows, crinoids, and brachiopods. Spores, pollen and microplankton.	Paralic (possibly lagoons and coastal plains)	Northeastern marginal facies of Eromanga Basin. Correlate of upper part of Doncaster Member.
		Wallumbilla Formation — Doncaster Member	220 150	Blue-grey mudstone, siltstone, glauconie-bearing and calcareous in part. Minor sandstone. Minor limestone, some cone-in-cone. Fossiliferous concretions containing marine fauna. Pelecypods dominant; also ammonites, belemnites, gastropods, crinoids, brachiopods, decapods, crustacea and algae. Spores, pollen and varied microplankton.	Shallow seas, locally above wave base.	Continuous with Doncaster Member of Surat Basin.

According to Exon & Senior (1976), the Toolebuc Formation was probably deposited in a shallow sea, with connections to the ocean in the north; the shales were laid down in reducing conditions in sheltered areas, and the limestone beds probably developed as bioherms during periods of open sea ingression. The genesis of the formation is further discussed later in this report.

DRILLING OPERATIONS

An important part of this project is sampling the Toolebuc Formation to investigate variations of sedimentary environment and to establish models to which variations in grade and areal extent of oil shale can be related.

One area selected for a possible model was on the southern margin of the Eromanga Basin east of Tibooburra, New South Wales. BMR Urisino No. 1 stratigraphic hole was drilled by BMR using a Mayhew 100 mobile rig (for details see Appendix 1). Drilling commenced at Owen Downs homestead, 130 km east of Tibooburra, NSW, on 7 May 1980 and was completed on 15 May 1980. The drilling site for BMR Urisino No. 1 was chosen on the basis of gamma-ray anomalies in many wire-line logged water bores in the Bulloo Embayment of the Eromanga Basin, NSW, and on the assumptions made by Herbert (1980) that there is a strong possibility that oil shale beds correlated with the anomalies (related or unrelated to the Toolebuc Formation) may occur in the NSW portion of the Eromanga Basin.

The 14-hole drilling operation in Queensland commenced on 26 August 1980 with BMR Tambo No. 37 and was completed on 20 September with BMR Charleville No. 2. All holes were sited along roads or tracks, most of which are shown on the 1:250 000 topographic and geological maps covering the areas. Where possible, holes were sited close to water bores in which gamma-Ray logs run some years ago suggested the presence of the Toolebuc Formation, and so provided some control for coring. The drilling was carried out by Amalgamated Drillers Co. Pty Ltd, of Brookvale NSW, using a Mobile B80 Top Drive Combination Rig. Three-man crews operated two 12-hour shifts per day for the majority of the program. Air-drilling was carried out from surface to top of cored intervals; coring was carried out using drilling fluid mixed with potassium chloride (KCl) to reduce swelling of clays. Hole diameter was $4\frac{1}{2}$ inches. A standard HQ triple-tube core barrel 3.0 metres long, with bottom discharge bits and a stationary, split steel inner tube was used in all holes.

Before drilling, Mines Departments were informed of the proposed program and permission was sought from property owners.

WIRE-LINE LOGGING OPERATIONS

A suite of wire-line logs was run in each of the holes either in the course of drilling or on completion of each hole. The logging was carried out by a two-man crew from the Geophysical Branch of BMR, using BMR slim-hole tools and a density sonde hired from SIE Inc. of Brisbane. Gamma-ray, long and short spaced density, caliper, neutron, spontaneous potential, resistivity, and temperature were recorded at a scale of 5 inches per 100 feet from surface to total depth. Copies of the logs, together with gross lithologies, are shown in Appendixes 1-14.

The original copies of wire-line logs are held by the BMR Geological Branch.

HANDLING OF CUTTINGS AND CORES

During the drilling of the 15 holes a total of 220 cutting samples were collected at 2-metre intervals from the surface to the top of cored intervals in each hole; 503.25 metres were cored, of which 74.7 percent was recovered from the BMR Urisino No. 1, and 98.7% from the 14 holes in Queensland (Table 2).

Cuttings and cores were washed and air-dried if necessary, and packed into standard BMR plastic bags and wooden boxes. They have been deposited in the BMR Core and Cuttings Laboratory, Fyshwick ACT, where they have been registered and slabbed, and are available for examination subject to approval by the Director, BMR.

Table 2. Cuttings and Core Recovery

	Cuttings (m)	Recovery %	Cores (m)	Recovery %
BMR Urisino No. 1	50.00	100	119.00	74.7
QLD holes	446.80	100	384.25	98.7

DISCUSSION OF RESULTS

Data on rock units intersected in the drilled holes are presented in Table 3 and Plate 1. Composite lithological and wire-line logs for all holes are shown in Appendixes 1-14 inclusive. All interpretations in this report are based on observations made on the core and cutting material from the current drilling. Units are discussed in sequence from the surface downwards.

Superficial deposits

In BMR Urisino No. 1 hole, a sequence of reddish sandy soil, grey silcrete, and claystone was intersected before entering the Allaru Mudstone. In most holes in Queensland unconsolidated grey and reddish brown soil and sand horizons were penetrated in most holes down to 30 metres depth (Plate 1).

Allaru Mudstone

In the course of this drilling program only the lower part of the Allaru Mudstone was penetrated. The maximum thickness of 76.0 metres was obtained in BMR Urisino No. 1 hole. The lower part of the formation as drilled consists of a massive homogeneous brown to dark grey claystone grading in part to grey siltstone. The thickness of the weathered zone intersected in the drilled areas varied considerably. Fragments of cone-in-cone limestone and hard siltstone were recognised in cuttings. Carbonaceous material (mainly plant remains) is present throughout. Megafossils (bivalves) are abundant in places. Fine-grained pyrite and laminae of calcite are common. Burrowing, slump and scour structures, and micro-crossbedding were observed in cores.

Depositional environment of lower part of formation: The marine fossils together with burrow structures, lamination and micro-crossbedding suggest deposition below wave-base in a sea in which bottom currents operated with varying velocities. The development of pyrite is interpreted as being a result of probable reducing conditions below the water/sediment interface.

Table 3 - Tops of formations penetrated (All depths below ground level)

	Total depth (m)	Base weathering	Top Allaru Fm	Top Toolebuc Fm	Top Coreena Mbr	Coring interval	Core recovery %
BMR Urisino No. 1	149.0	26	26	102	122	8-78 120-149	74.7
BMR Charleville No. 2	49.0	30.0	Surface	-	-	3.0-49.0	99
BMR Augathella No. 7	99.3	23.0	Surface	72.5	84.0	24.0-99.3	99
BMR Augathella No. 6	99.4	12.0	Surface	54.5	65.0	30.0-99.4	95
BMR Augathella No. 5	31.7	5.0	Surface	14.6	15.8	12.0-31.7	99
BMR Tambo No. 44	33.2	10.3	Surface	15.2	21.0	15.0-33.2	99
BMR Tambo No. 43	72.0	28.0	Surface	54.0	Undifferentiated	36.0-72.0	99
BMR Tambo No. 42	36.3	15.0	3.0	16.7	19.5	16.8-36.3	99
BMR Tambo No. 41	47.85	15.0	Surface	35.9	44.2	32.0-47.85	99
BMR Tambo No. 40	70.20	15.0	Surface	64.0	Undifferentiated	36.0-70.20	99
BMR Tambo No. 37/38	73.25 65.60	18.0	1.0	58.0	63.4	67.0-73.25 54.0-65.60	99 99
BMR Tambo No. 39	99.10	21.0	2.0	-	-	54.0-99.1	99
BMR Jericho No. 11	71.15	9.7	Surface	55.9	65.2	42.0-71.15	99
BMR Longreach No. 6	41.0	12.0	-4-	25.0	31.0	25.0-41.0	99

Toolebuc Formation

The thickness of the Toolebuc Formation ranges from 20.0 metres in BMR Urisino No. 1, to 1.2 metres in BMR Tambo No. 42 (Table 3).

In BMR Urisino No. 1 recrystallised, non-fossiliferous limestone beds mark both the top and the bottom of the Toolebuc Formation time equivalent. Carbonaceous silty shale containing plant remains, pyrite, and minor siderite make up the remainder of the formation. Burrow mottling is the commonest trace fossil throughout the intersected sequence. No megafossils were observed.

In the 14 Queensland holes the formation consists of recrystallised fossiliferous limestone, bituminous shale, and calcareous silty and pyritic shale beds. Marine fossils, mainly pelecypods, are abundant in the northern holes but rare in the south.

Boundary criteria: the upper boundary is here taken to be the top of the top recrystallised limestone bed in BMR Urisino No. 1 and the top of the recrystallised fossiliferous beds in the Queensland holes when present. Elsewhere it is determined on lithological contrast and on the character of wire-line logs; particularly the gamma-ray log, which usually shows a marked increase in radiation on entering the Toolebuc Formation.

Depositional environment: In BMR Urisino No. 1 hole the overall paucity of marine microplankton in the assemblages suggest that a brackish-marine, nearshore environment prevailed in the depositional area (Burger, 1980). This is supported by the presence of carbonaceous material (mainly plants), and diagenetic minerals (pyrite and siderite) which are indicative of reducing nearshore (sheltered) conditions. Micro-crossbedding, lamination, and burrow structures together with predominant silt- and clay-sized detrital material suggest that this formation was deposited below wave base where weak to moderate currents operated.

In the Queensland holes the diminishing content of marine fossils (mainly pelecypods) in the southern holes would suggest deposition in a more restricted and only occasionally open marine environment. Presence of pyrite throughout the area suggests reducing conditions below or at water/sediment interface.

Coreena Member

The maximum thickness intersected was 34.4 metres in BMR Augathella No. 6 hole. (Appendix 12). The base of the member was not penetrated by any of the holes and the formation as drilled is a massive, generally homogeneous volcanic sandstone, light grey to greenish, in places calcareous. It is glauconite and glauconite-bearing, carbonaceous, pyritic, and sideritic. Notable variations in the makeup of this formation from south to north are:

- diminishing grainsize (coarse to fine),
- diminishing size of cross-bedding (macro to micro),
- diminishing content of argillaceous matrix,
- diminishing content of siderite and carbonaceous material,

and

- increasing calcite cement.

Figure 5

Photo 1: Kerosene-like fluid flowing from the Toolebuc Formation in BMR Jericho No. 11 Shotigraphic hole.

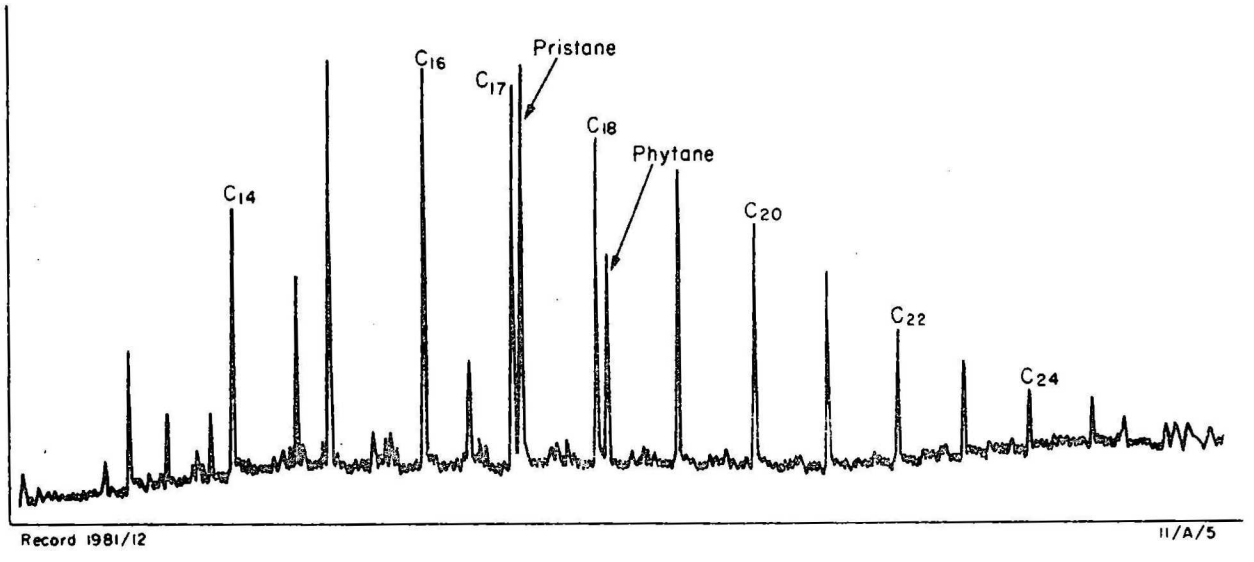

Fig. 6 Gas chromatogram of kerosene-like fluid from BMR Jericho II

Boundary criteria: The upper boundary of this formation is taken as the top of a sandstone bed which is conformably overlain by either a limestone bed (eg. BMR Tambo Nos. 37 & 38, Appendix 2) or a bituminous shale (eg. BMR Jericho No. 11, Appendix 4). In addition the character of wire-line logs was also used, particularly the gamma-ray log, which normally shows a marked decrease in radiation on entering the Coreena Member from the Toolebuc Formation.

Depositional environment of upper part of member: The northward diminishing grainsize, cross-bedding, and content of argillaceous matrix suggest deposition in an environment affected by a northward decrease in current activity probably towards a more open sea. The abundance of early-burial diagenetic minerals, however, reflects considerable reducing conditions at or below the water/sediment interface.

Further, a northward increase in calcite cement, interpreted as having been precipitated directly from calcium-rich marine waters, supports the suggested depositional setting.

Presence of kerosene-like fluid

In some of the Queensland holes a kerosene-like fluid with a distinct petroliferous odour flowed to surface along with the drilling medium (Fig. 5). Samples of this fluid were analysed in BMR's Petroleum Technology Laboratory and interpreted as being related to a mature hydrocarbon of probable non-marine origin. A gas chromatograph curve obtained in the analysis is shown in Figure 6.

CSIRO's Fossil Fuel Section also carried out similar analysis which agreed with the Petroleum Technology Laboratory results. The information available on the organic diagenesis (maturity) of the Toolebuc and associated formations from the drilled area (Ramsden & others, 1980; J. Saxby & A.C. Cook, pers. comm. 1980), suggests that these hydrocarbons could not have been formed in simu but have most likely migrated up dip from a more mature oil-generating zone of the Eromanga Basin.

Expenditure

A total of $78 454.18 has been spent on the 14-hole drilling program in central and southern Queensland (Table 4). The expenditure incurred for the one hole in NSW is as yet not available.

Table 4. Drilling expenditure, Queensland holes

Stratigraphic Hole	Drilling Costs
Tambo No. 37	$5 106.30
" No. 38	3 304.07
" No. 39	6 096.00
Jericho No. 11	5 561.63
Longreach No. 6	3 104.39
Tambo No. 40	5 298.15
" No. 41	3 033.15
" No. 42	3 166.65
" No. 43	7 079.33
" No. 44	4 205.65
Augathella No. 5	2 543.15
" No. 6	9 367.91
" No. 7	8 207.60
Charleville No. 2	4 380.20
Total	$70 454.18

Depositioning fee	$4 000.00
Repositioning fee	4 000.00
Drilling costs	70 454.18
	$78 454.18
Total expenditure	$78 454.18

GAMMA-RADIATION

In the subsurface the presence of the Toolebuc Formation has in the past been suspected from a marked isolated peak or set of peaks on gamma-ray logs. The anomaly is easily recognised, and can be correlated throughout the Eromanga Basin (Smart, 1972; Exon & Senior, 1976; Senior & others, 1978), although detailed correlations with specific lithologies have not been attempted.

Senior & others (1978) attributed the anomaly to uranium-bearing phosphate minerals associated with shell debris. Recent detailed studies at Julia Creek and Boulia (Ramsden, 1980; Ramsden & others, 1980) have confirmed that uranium associated with both carbonaceous matter and phosphatic fish remains is responsible for the gamma-ray anomaly.

An anomaly was recorded associated with the Toolebuc Formation in ten of the project holes drilled in Queensland. In BMR Urisino No. 1 hole an anomaly occurs in the upper part of the Coreena Member equivalent but not above in the Toolebuc Formation equivalent. Burger (1980) found the age of sediments giving the gamma-ray anomaly in BMR Urisino No. 1 to be slightly older than is the Toolebuc Formation in central and northern Queensland.

The source of the anomaly in BMR Urisino No. 1 is attributed primarily to the increase in potassium associated with an argillaceous bed in the upper part of the Coreena Member equivalent, but uranium associated with carbonaceous matter also contributes to the activity (Ramsden & others, 1980).

Examination of the logs of a number of petroleum exploration wells and water bores in South Australia, New South Wales, and Queensland and those of this report shows that the gamma-ray anomaly possibly rises continuously in the succession from the southern to the northern margins of the Eromanga Basin, from the upper part of the Coreena Member or its equivalent to the upper beds of the Toolebuc Formation. A possible explanation for this rise from south to north could be related to the following palaeogeographic controls: climate, provenance, tectonics, depositional basin tectonics, and eustacy.

CONCLUSIONS

The preliminary results presented in this report are based on megascopic examination of cores and cuttings, and interpretation of wireline logs from the drilling program.

A first examination of cores and cuttings provided generalised evidence on environment of deposition and provenance, and on diagenetic processes which modified the Toolebuc and associated formations. Wireline logs in conjunction with data on lithology and sedimentary structures provided the necessary information for identifying lithofacies.

Integration of these preliminary results with data from petroleum exploration wells, stratigraphic holes, and water bores provided a basis for establishment of a working hypothesis that oil shale is probably absent from the Toolebuc Formaton roughly south of a line joining Bedourie and Charleville in Queensland.

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APPENDIX 1: BMR Urisino No. 1 Stratigraphic Hole

Summary

The drilling site for BMR Urisino No. 1 was chosen on the basis of the presence of a gamma-ray anomaly in several wire-line logged water bores in the Bulloo Embayment of the Eromanga Basin, NSW, and on the assumptions made by Herbett (1980) that there is a strong possibility that oil shale beds either related or unreleated to the Toolebuc Formation may occur in the NSW part of the Eromanga Basin.

The hole was drilled by BMR in co-operation with the Geological Survey of NewwSouth Wales. It penetrated 6 m of Quaternary superficial deposits, 20 m of Tertiary silcrete and claystone, 76 m of Cretaceous Allaru Mudstone, 20 m of Toolebuc Formation equivalent, and 27 m of Coreena Member of the Wallumbilla Formation before reaching total depth at 149 m below ground level. On completion it was found that the Toolebuc Formation equivalent contained no oil shale component, and that the gamma-ray characteristic anomaly occurred in the underlying Coreena Member of the Wallumbilla Formation.

Stratigraphic hole history

Location : Urisino 1:250 000 Sheet area 130 km E. of Tibooburra NSW, 2 km S. of Owen Downs homestead.
Lat.: 29°28'27"S
Long: 143°17'52"E

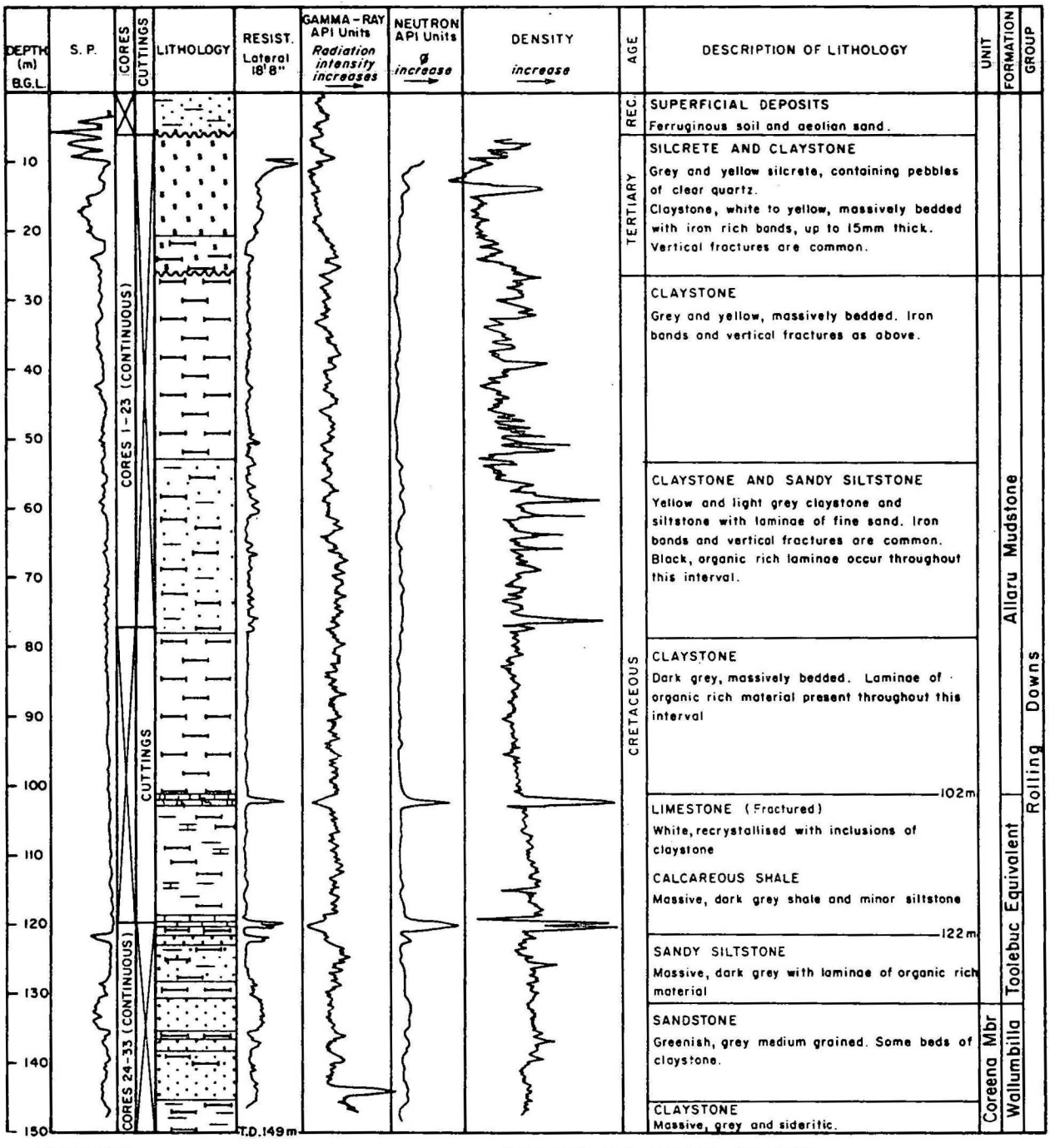
Elevation : 161 m above sea level.

Commenced drilling : 7 May 1980

Drilled by : BMR Petroleum Technology Section

Total depth : 149 m below ground level

Well-site Geologist: S. Ozimic



LOCATION
Urisino 1:250 000 Sheet
130 km east of Tibooburra, N S W.
2 km south of Owen Downs
Lat: 29° 28' 27" S
Long: 143° 17' 52" E

DRILLED AND LOGGED BY BMR
Commenced drilling: 7 May 1980
Completed drilling: 15 May 1980

Record 1981/12

11/A/6

Fig. 7 Composite well log, BMR Urisino 1

Wire-line log record

Spontaneous potential	4 - 149 m
Resistivity (lateral) log	10 - 149 m
Gamma-ray	Surface - 147 m
Neutron	10 - 148 m
Density	8 - 147 m

Cutting samples and cores

Cutting samples were collected from surface to 8 m and from 78-120 m at 2-m intervals during drilling. Cores were cut as required and a total of 33 cores were recovered from this hole.

Methods used

All cores and cuttings were examined under low-power binocular microscope. The results were plotted, with wire-line logs and stratigraphic information, on a composite well log (Fig. 7).

Stratigraphy

The rock units penetrated in Urisino No. 1, and their thicknesses, are listed below.

Rock Unit	Interval	Thickness
Superficial deposits	surface to 6 m	6 m
Silcrete and claystone	6 to 26 m	20 m
Allaru Mudstone	26 to 102 m	76 m
Toolebuc Formation equivalent	102 to 122 m	20 m
Coreena Member	120 to 149 m	29 m

The lithological characteristics of the units penetrated are described on Figure 1.

Palynological notes by Dr D. Burger (BMR Professional Opinion Geol. 80.016) on the age and correlation of the Toolebuc Formation are attached to this Appendix.

PROFESSIONAL OPINION GEOL. 80.016

PRELIMINARY PALYNOLOGICAL NOTES ON BMR URISINO 1 N.S.W.

by

D. BURGER

INTRODUCTION

BMR Urisino 1 borehole was drilled in the southern Eromanga Basin of northwestern New South Wales (Urisino 1:250 000 Sheet area), as part of the Toolebuc Oil Shale Project. In this region the Toolebuc Formation is no longer recognised as a lighologic unit in outcrop and subsurface. Nevertheless, a marked positive gamma-ray anomaly which in Queensland is characteristic of the formation has been found in the logs of several drilled sections in the southern and western sectors of the basin. Palynological data from BMR Urisino 1 confirm the view held in the Geological Survey of New South Wales that the gamma-ray anomalies are not restricted to the Toolebuc Formation, and contribute to the efforts of correlating the rock nomenclature developed in South Australia and Queensland.

STRATIGRAPHY

The Eromanga Basin overlaps four states, namely Queensland, New South Wales, South Australia, and Northern Territory. Over the years, field work and stratigraphic interpretation of the rock sequence have resulted in independent rock nomenclatures being developed in South Australia and Queensland; partly to identify different facies provinces in the basin, and partly through lack of coordination of the mapping programs.

One of the casualties of this development is the Toolebuc Formation, which is a well-defined rock unit in Queensland (Casey, 1959; Smart, 1972; Senior et al., 1975). Southern and western limits of occurrence of the formation were outlined by means of the disappearance of a marked gamma-ray anomaly associated with the formation in the logs of water bores and commercial wells. There is no evidence that the disappearance of the formation is connected with a gap in the sequence, and Vine et al. (1965) suggest that the formation represents a brief evaporitic episode at the time that a "Toolebuc sea" covered parts of northern and central Queensland.

Over the years several suggestions have been made as to where the Toolebuc Formation fitted in the sequence in northern South Australia. Ludbrook (1966) correlated the "unnamed greensand member" in the Oodnadatta area with the base of the "Tambo Series", which in Queensland includes the Coreena-Toolebuc-Allaru-Mackunda interval (Exon et al., 1972). Freytag (1966) formally named the greensand member as the Coorikiana Member of his Oodnadatta Formation, and tentatively correlated this member with the Toolebuc equivalent in FPC Purni 1

well further to the north. This suggestion was partly based on a possible radioactive maximum in the Coorikiana Member. Recently, the presence of a highly radioactive interval within the Wallumbilla Formation in the Tibooburra area gave rise to the speculation that the Toolebuc Formation is present also in the Bulloo Embayment in northwestern New South Wales. There the situation is now complicated by the presence of a "lower" and an "upper" gamma-ray anomaly within the Rolling Downs Group (Herbert, 1980). The palynological aspects of these anomalies are being investigated by A. McMinn of the Geological Museum in Sydney.

BMR Urisino 1 was drilled in the same general area and intersects a rock sequence equivalent in time to the upper part of the Coreena Member of the Wallumbilla Formation, the Toolebuc Formation, and the Allaru Mudstone. Lithologically, the sequence closely corresponds to the uppermost Bulldog Shale and the lower part of the Oodnadatta Formation, including the Coorikiana and Wooldridge Limestone Members in the Oodnadatta region (Fig. 1). However, formal nomenclature of the section will be decided in consultation with the Geological Survey of New South Wales.

A gamma-ray anomaly is associated with the lower part of the glauconitic sandstone at about 142 m, and its relationship vis-a-vis the Toolebuc anomaly is made clear by palynological examination of core samples at critical intervals in the borehole.

PALYNOLOGICAL CORRELATIONS

Many samples taken from the cored interval of BMR Urisino 1 yielded moderately to richly species-varied assemblages of spores and pollen grains. The assemblages in the 129-149 m interval represent the Coptospora paradoxa zone, and those in the 50-126 m interval the Phimopollenites pannosus zone (Fig. 1). One sample taken from the 126.2-129 m interval yielded very few and inconclusive palynomorphs, and this assemblage could be part of either zone. Occurrences of species and details of the marine (dinoflagellate) sequence will be presented in a future paper.

These two palynological zones are well known in the Albian of eastern Australia. Dettmann & Playford (1969) reported the Coptospora paradoxa zone from the Murray Basin (New South Wales), the Eromanga Basin (South Australia), and the Otway and Gippsland Basins in South Australia and Victoria. Burger (1980) studied the zone in many boreholes drilled in the Surat Basin, and

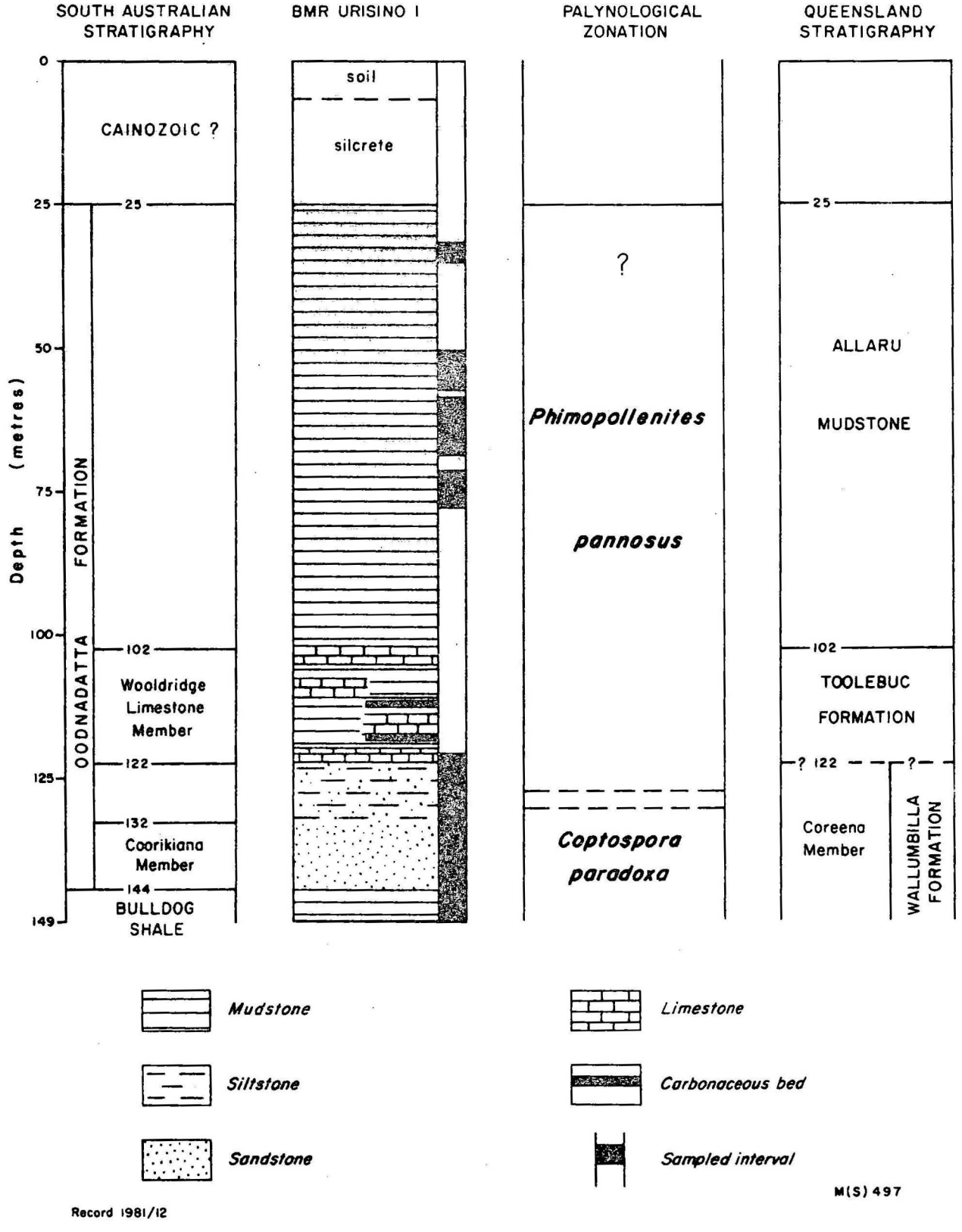


Fig. 1 Stratigraphy of BMR Urisino 1 (NSW)

concluded that it was of middle Albian age. Dettmann & Playford (op. cit.) described the Phimopollenites ("Tricolpites") pannosus zone from the Otway Basin and the Oodnadatta region.

In Santos Oodnadatta 1 well (South Australia) the Coptospora paradoxa zone occurs between 596 feet and 407 feet and is associated with the upper part of the Bulldog Shale and the Coorikiana Member of the Oodnadatta Formation. The Phimopollenites pannosus zone occurs between 407 feet and 87 feet and is associated with the Oodnadatta Formation, including the Wooldridge Limestone Member (Dettmann & Playford, 1969; Wopfner et al., 1970; Playford et al., 1975).

A sidewall core shot in a greensand interval in Delhi Betoota 1 well at 2758 feet yielded a spore and pollen assemblage which I determined as representing the Coptospora paradoxa zone (to be published). This means that glauconite sands typical of the Coorikiana Member mapped in the Oodnadatta region may extend into northwestern New South Wales and southwestern Queensland and that they formed a restricted shallow marine facies at the end of the Coptospora paradoxa zone.

In Queensland this part of the sequence is poorly known palynologically. The Toolebuc Formation, as interpreted by Smart (1972) and Senior et al. (1975), is a very poor pollen-producing unit, as is also the upper part of the Coreena Member in many areas. The overlying Allaru Mudstone in the Longreach area includes assemblages of palynological unit K2b+ (Burger, 1968) and which are now recognised as the Phimopollenites pannosus zone. Similar assemblages have been described also from the formation in the Dobbyn area, further northwest (Playford et al., 1975). At the time the Toolebuc Formation was thought to be associated with palynological unit K2a, which precedes units K2b+, but recent data from the Carpentaria Basin (study in progress) made it clear that the formation actually lies within the Phimopollenites pannosus zone.

On the basis of this evidence it is suggested that the basal interval in BMR Urisino 1 within the Coptospora paradoxa zone is equivalent in time to the Coreena Member, and that the predominantly argillaceous section between 25 m and 122 m within the Phimopollenites pannosus zone is equivalent in time to the Toolebuc-Allaru interval. From the palynological evidence of Santos Oodnadatta 1 the Toolebuc Formation can be broadly correlated with the Wooldridge Limestone Member, and the upper part of the Coreena Member with the Coorikiana Member (see Fig. 1).

PALAEO-ENVIRONMENTS

Marine microphytoplankton is present in very low quantities in several samples and indicates that the sequence was deposited in marginal and brackish, near-shore conditions. McMinn (pers. comm.) placed the dinoflagellate sequence between 52 m and 124 m in Morgan's (1977) late Albian Endoceratium ludbrookiae zone. He indicated a marked proportional increase of dinoflagellates in assemblages between 120 m and 124 m, and this suggests that the sediments in that interval represent brief offshore, open marine conditions.

CONCLUSIONS

1. BMR Urisino 1 borehole penetrated a section which is tentatively compared with the uppermost Bulldog Shale and the lower part of the Oodnadatta Formation, including the Coorikiana and Wooldridge Limestone Members.
2. On palynological evidence the section compared with the Bulldog Shale and the Coorikiana Member is correlated with the upper Coreena Member, and the section compared with the Wooldridge Limestone Member and the overlying argillaceous interval of the Oodnadatta Formation with the Toolebuc Formation and the Allaru Mudstone, respectively.
3. The gamma ray anomaly at about 142 m depth is slightly older in time than the well-known Toolebuc anomaly in Queensland, and its relationship to other anomalies found in the region around Tibooburra should be more closely examined.
4. The overall low presence of marine microplankton in the assemblages suggests that brackish-marine, nearshore environments prevailed, with possibly a brief marine incursion between deposition of the Coorikiana Member and the Wooldridge Limestone Member equivalent intervals.

D. BURGER

14 August 1980

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APPENDIX 2: BMR Tambo Nos. 37 and 38 Stratigraphic Holes

Stratigraphic hole history

On completion of BMR Tambo No. 37 hole, it was found that the cored interval did not include the area of pronounced gamma-ray anomaly (thought to be associated with the Toolebuc Formation). A second hole, Tambo No. 38, was drilled only 4 metres west from No. 37 so as to obtain complete core coverage over the interval of the pronounced gamma-ray anomaly.

General data

	BMR Tambo No. 37 (NERDDC-1)	BMR Tambo No. 38 (NERDDC-2)
Sheet area	TAMBO 1:250 000	TAMBO 1:250 000
General location	4 km along road from Glenusk H.S.	same as for Tambo No. 37
Latitude	24°15'00"	24°15'00"
Longitude	145°49'07"	145°39'07"
Commenced drilling	26-8-80	27-8-80
Completed drilling	27-8-80	29-8-80
Drilled By	Amalgamated Drillers Co. Sydney	Amalgamated Drillers Co. Sydney
Total depth	73.25 m B.G.L.	65.60 m B.G.L.
Wire-line logs		
- Gamma-ray	Surface to 72.0 m	Surface to 63.0 m
- Neutron	"	"
- Resistivity	"	"
- Density	"	"
- Caliper	"	"
- Spont. Potential	"	"
Cores	6 cores (67-73.25 m)	8 cores (54.00-65.60 m)
Cuttings	Surface to 67 m	Surface to 54.00 m

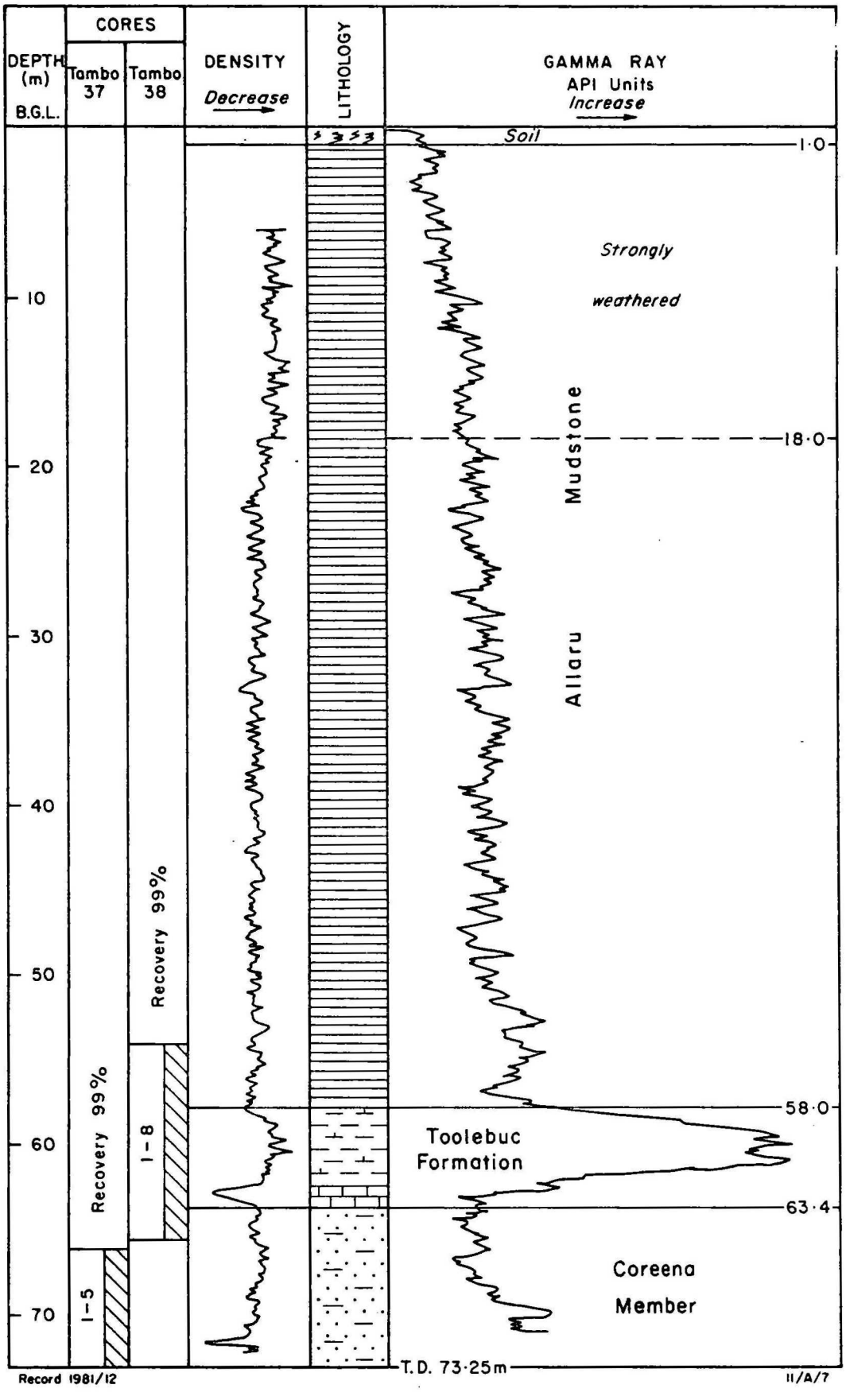

Fig. 8 Composite well log, BMR Tambo 37 & 38

Stratigraphy

The rock units penetrated in the Tambo No. 37 and 38, and their thicknesses, are listed below.

Rock Units	Interval (m)	Thickness (m)
Soil	0 - 1	1
Allaru Mudstone	1 - 58	57
Toolebuc Formation	58 - 63.4	5.4
Wallumbilla Formation	63.4 - 73.25	10.25

The lithological units penetrated are correlated with the wire-line logs and shown in Figure 8.

APPENDIX 3: BMR Tambo No. 39 Stratigraphic Hole

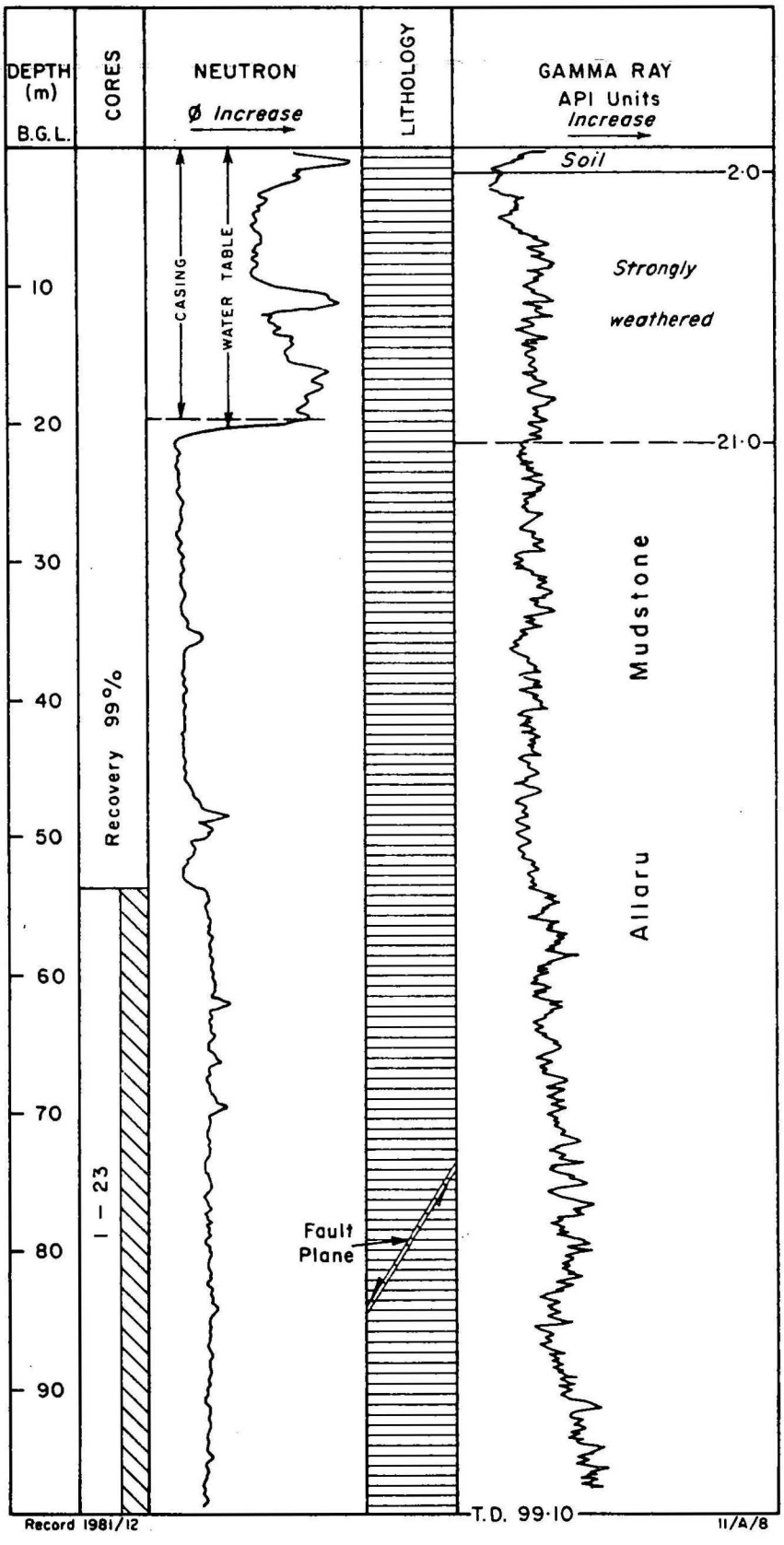

Fig. 9 Composite well log, BMR Tambo 39

General data

Sheet area	TAMBO 1:250 000
General location	7 km west along road from Yalleroi to Darracourt Homestead
Latitude	24°04'11"S
Longitude	145°39'16"E
Commenced drilling	29-8-80
Completed drilling	1-9-80
Drilled by	Amalgamated Drillers Co. Sydney, NSW
Total depth	99.10 m B.G.L.

Wire-line logs

- Gamma-ray	Surface to 97.5 m
- Neutron	" to 98.8 m
- Resistivity	-
- Density	" to 98.8 m
- Caliper	" to 98.8 m
- Spon. potential	-
Cuttings	Surface - 54.00 m
Cores	(23 cores) 54.00 m - 99.10 m T.D.

Stratigraphy

BMR Tambo No. 39 penetrated 2 metres of superficial deposits and 97 m of monotonous blue-grey shale (Allaru Mudstone). At 82 m a steep fault plane was intersected.

The rock units intersected are correlated with the wire-line logs and shown in Figure 9.

The reason for this hole not reaching the Toolebuc Formation is attributed to a local depression, possibly a syncline on the downthrown side of a fault zone.

APPENDIX 4: BMR Jericho No. 11 Stratigraphic Hole

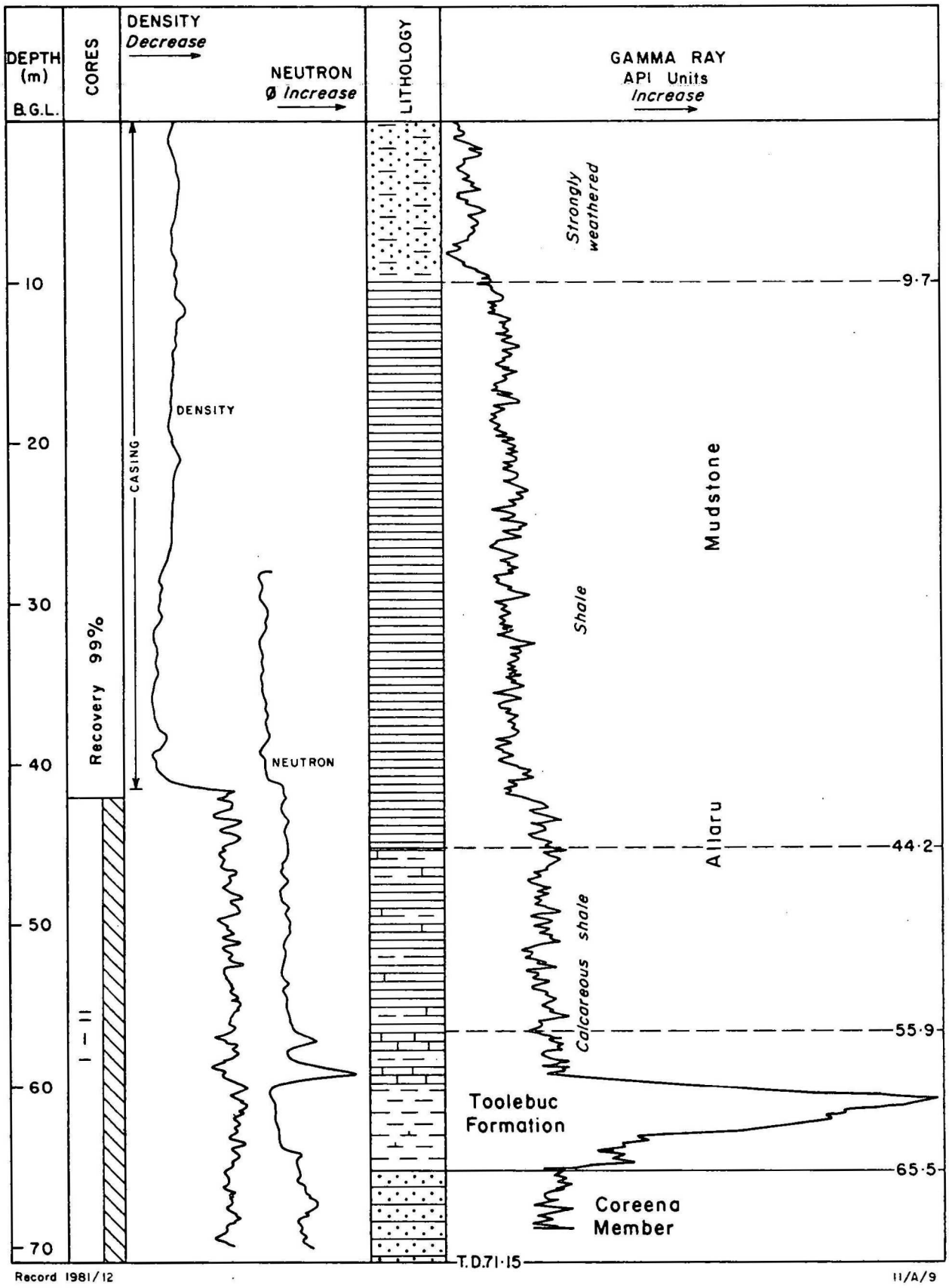

Fig. 10 Composite well log, BMR Jericho 11

General data

Sheet area	JERICHO 1:250 000
General location	1.0 km NW of Delta South homestead
Latitude	23°51'30"S
Longitude	145°31'18"S
Commenced drilling	1-9-80
Completed drilling	2-9-80
Drilled by	Amalgamated Drillers Co. Sydney, NSW
Total Depth	71.15 m B.G.L.

Wire-line logs

- Gamma-ray	Surface to 69.0 m
- Neutron	" to 69.0 m
- Resistivity	2 to 70.0 m
- Density	2 to 70.0 m
- Caliper	2 to 70.0
- Spon. potential	2 to 70.0 m
Cuttings	Surface to 42.05 m
Cores	42.05 to 71.15 m

Stratigraphy

The rock units intersected in Jericho No. 11, and their thicknesses, are listed below.

Rock units	Interval	Thickness
Superficial deposits	Surface to 28.0	28.00
Allaru Mudstone	28.0 to 55.9	27.09
Toolebuc Formation	55.9 to 65.2	9.03
Coreena Member	65.2 to 71.15 T.D.	5.95

The lithological units penetrated are described and correlated with the wire-line logs in Figure 10.

When coring from 58.30 m a kerosene-like fluid flowed to surface with the drilling medium. Geochemical analyses of the fluid are discussed in main text.

APPENDIX 5: BMR Longreach No. 6 Stratigraphic Hole

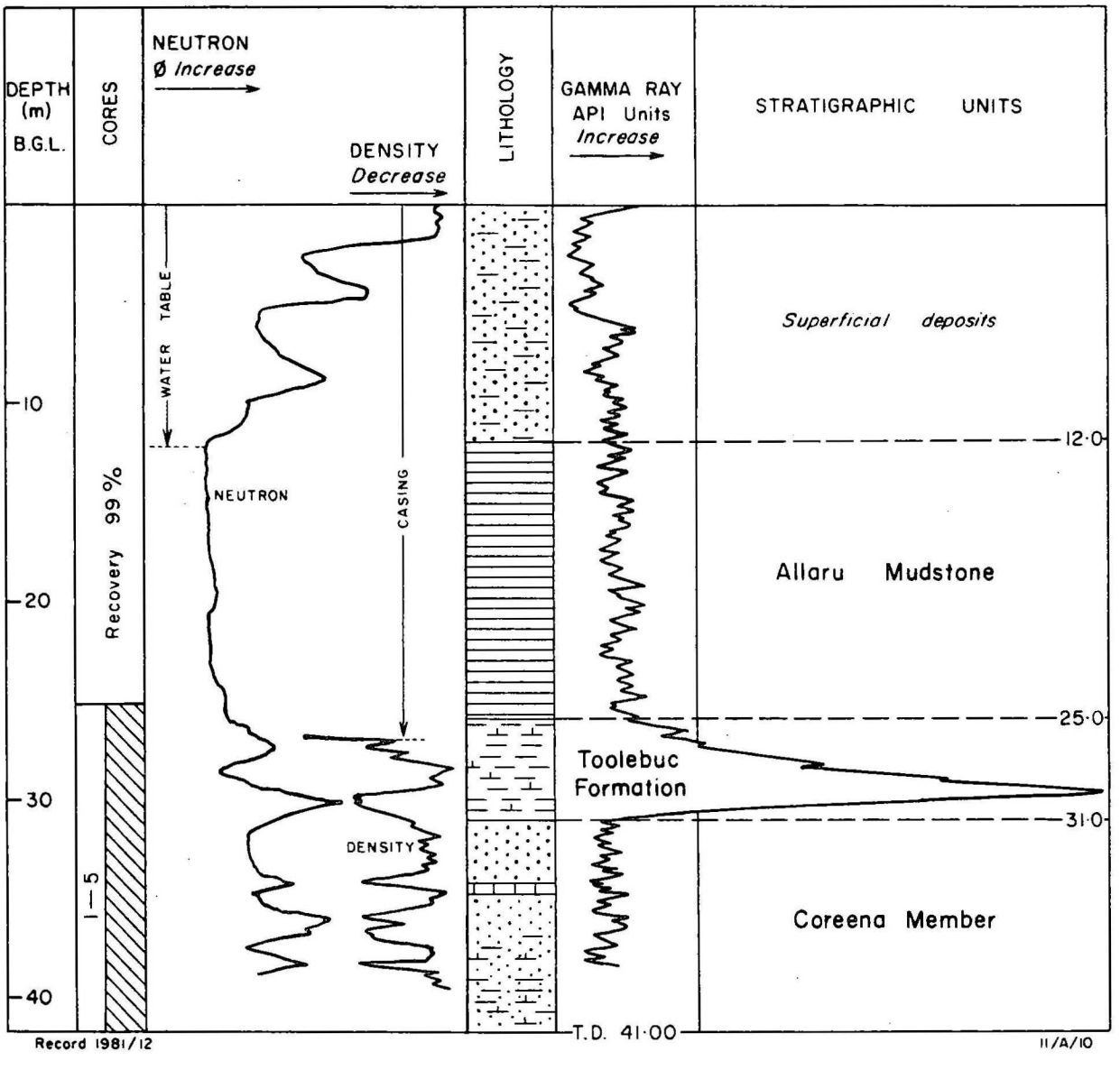

Fig. 11 Composite well log, BMR Longreach 6

General data

Sheet area	LONGREACH 1:250 000
General location	200 m E from Farmout Drillers Alice River No. 1
Latitude	23°37'35"S
Longitude	145°19'16"E
Commenced drilling	3-9-80
Completed drilling	4-9-80
Drilled by	Amalgamated Drillers, Sydney, NSW
Total depth	41.00 m B.G.L.

Wire-line logs

- Gamma-ray	Surface to 38.0 m
- Neutron	" 38.0 m
- Resistivity	2.0 to 39.0 m
- Density	2.0 to 39.0 m
- Caliper	2.0 to 39.0 m
- Spon. potential	2.0 to 39.0 m
Cuttings	Surface to 25 m
Cores	25 to 41 m T.D.

Stratigraphy

The rock units penetrated in Longreach No. 6, and their thicknesses, are listed below.

Rock units	Interval (m)	Thickness (m)
Superficial deposits	Surface to 12	12
Allaru Mudstone	12 to 25	13
Toolebuc Formation	25 to 31	5
Coreena Member	31 to 41 T.D.	11

The lithological units penetrated are described and correlated with the wire-line logs in Figure 11.

APPENDIX 6: BMR Tambo No. 40 Stratigraphic Hole

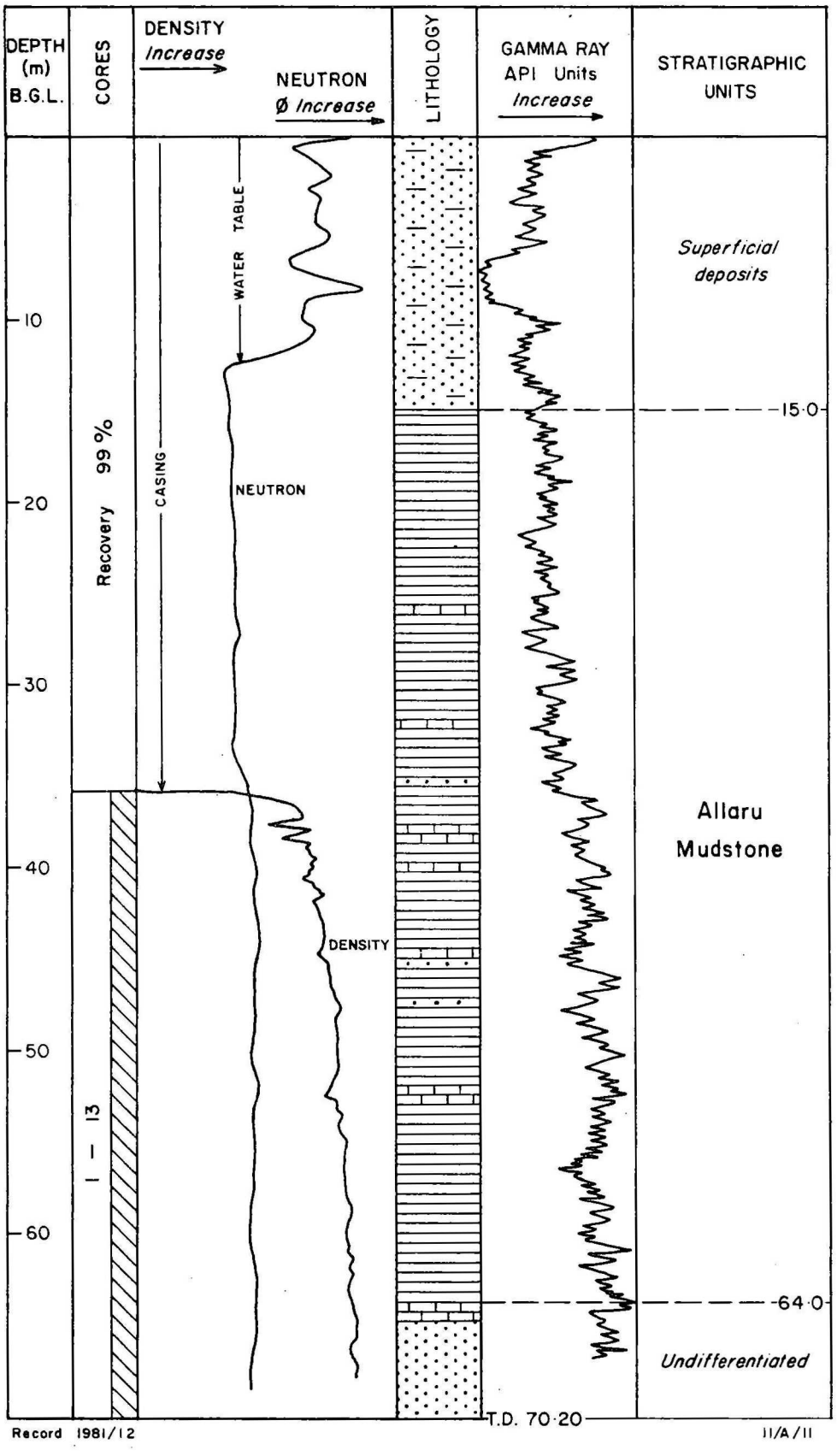

Fig. 12 Composite well log, BMR Tambo 40

General data

Sheet area	TAMBO 1:250 000
General location	Northampton Downs Water Facility
Latitude	24°32'58"S
Longitude	145°47'04"E
Commenced drilling	5-9-80
Completed drilling	6-9-80
Drilled by	Amalgamated Drillers Co. Sydney, NSW
Total depth	70.20 m B.G.L.

Wire-line logs

- Gamma-ray	Surface to 65.0 m
- Neutron	" 65.0 m
- Resistivity	2.0 to 66.0 m
- Density	2.0 to 66.0 m
- Caliper	2.0 to 66.0 m
- Spon. potential	2.0 66.0 m
Cuttings	Surface to 36.00 m
Cores	36.00 to 70.20 m

Stratigraphy

The rock units penetrated in the Tambo No. 40, and their thicknesses, are listed below.

Rock unit	Interval (m)	Thickness (m)
Superficial deposits	Surface to 15.0	15.0
Allaru Mudstone	15.0 - 64.0	49.0
? Undifferentiated	64.0 - 70.20	6.20

The lithological units penetrated are described and correlated with the wire-line logs in Figure 12. This hole had to be abandoned at 70.20 m because of water encroachment problems.

APPENDIX 7: BMR Tambo No. 41 Stratigraphic Hole

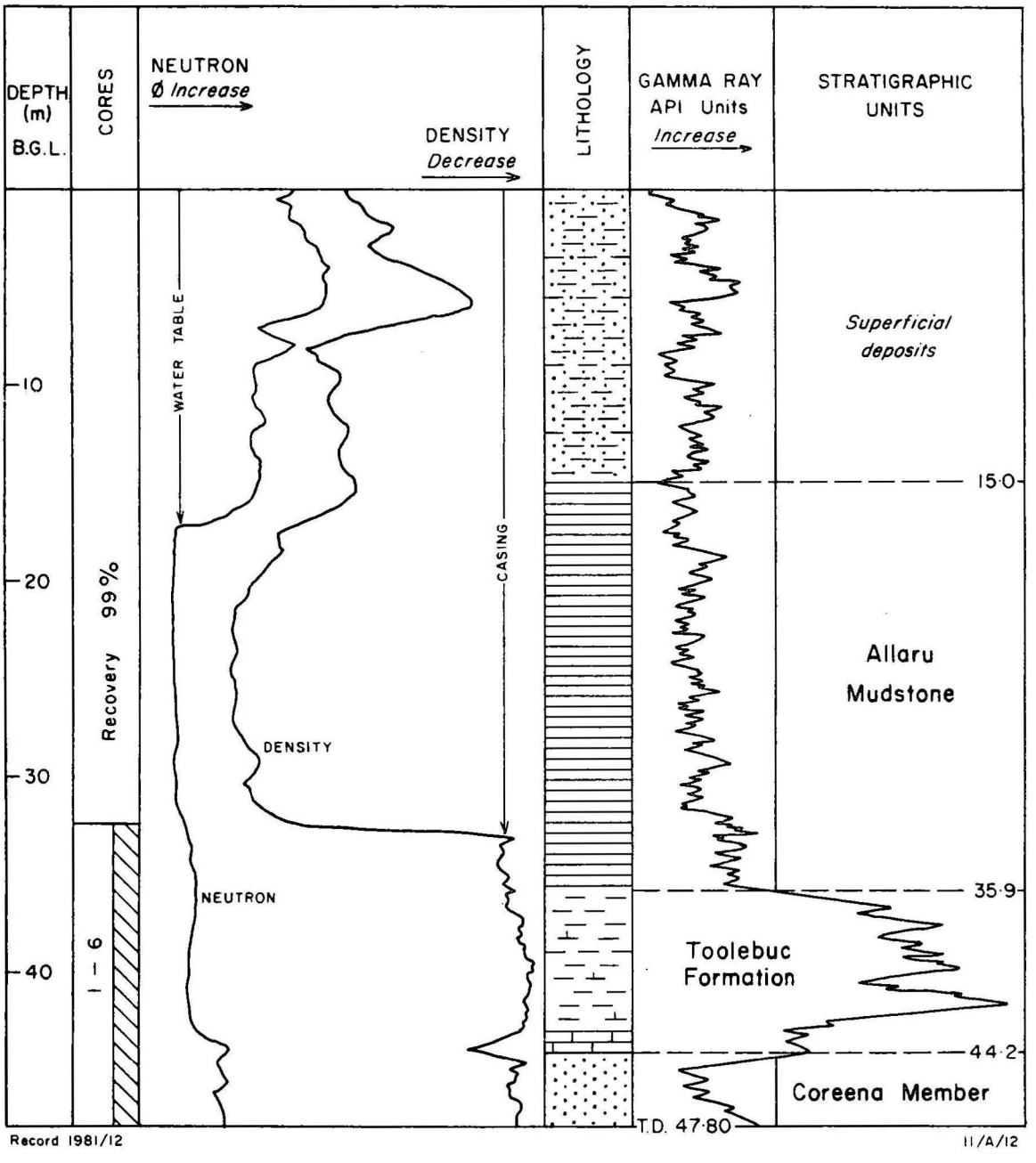

Fig. 13 Composite well log, BMR Tambo 41

General data

Sheet area	TAMBO 1:250 000
General location	Boxhill homestead
Latitude	24°29'56"S
Longitude	145°56'46"E
Commenced drilling	7-9-80
Completed drilling	7-9-80
Drilled by	Amalgamated Drillers Co. Sydney, NSW
Total depth	47.85 m B.G.L.

Wire-line logs

- Gamma-ray	Surface to 46.0 m
- Neutron	" 46.0 m
- Resistivity	2.0 to 47.0 m
- Density	2.0 to 47.0 m
- Caliper	2.0 to 47.0 m
- Spon. potential	2.0 to 47.0 m
Cuttings	Surface to 32.0 m
Cores	32.0 to 47.85 m

Stratigraphy

The rock units penetrated in the Tambo No. 41, and their thicknesses, are listed below.

Rock unit	Interval (m)	Thickness (m)
Superficial and weathered rocks	Surface to 15.0	15
Allaru Mudstone	15.0 to 35.9	20.9
Toolebuc Formation	35.9 to 44.2	3.3
Coreena Member	44.2 to 47.85	3.7

The lithological units penetrated are described and correlated with the wire-line logs in Figure 13.

APPENDIX 8: BMR Tambo No. 42 Stratigraphic Hole

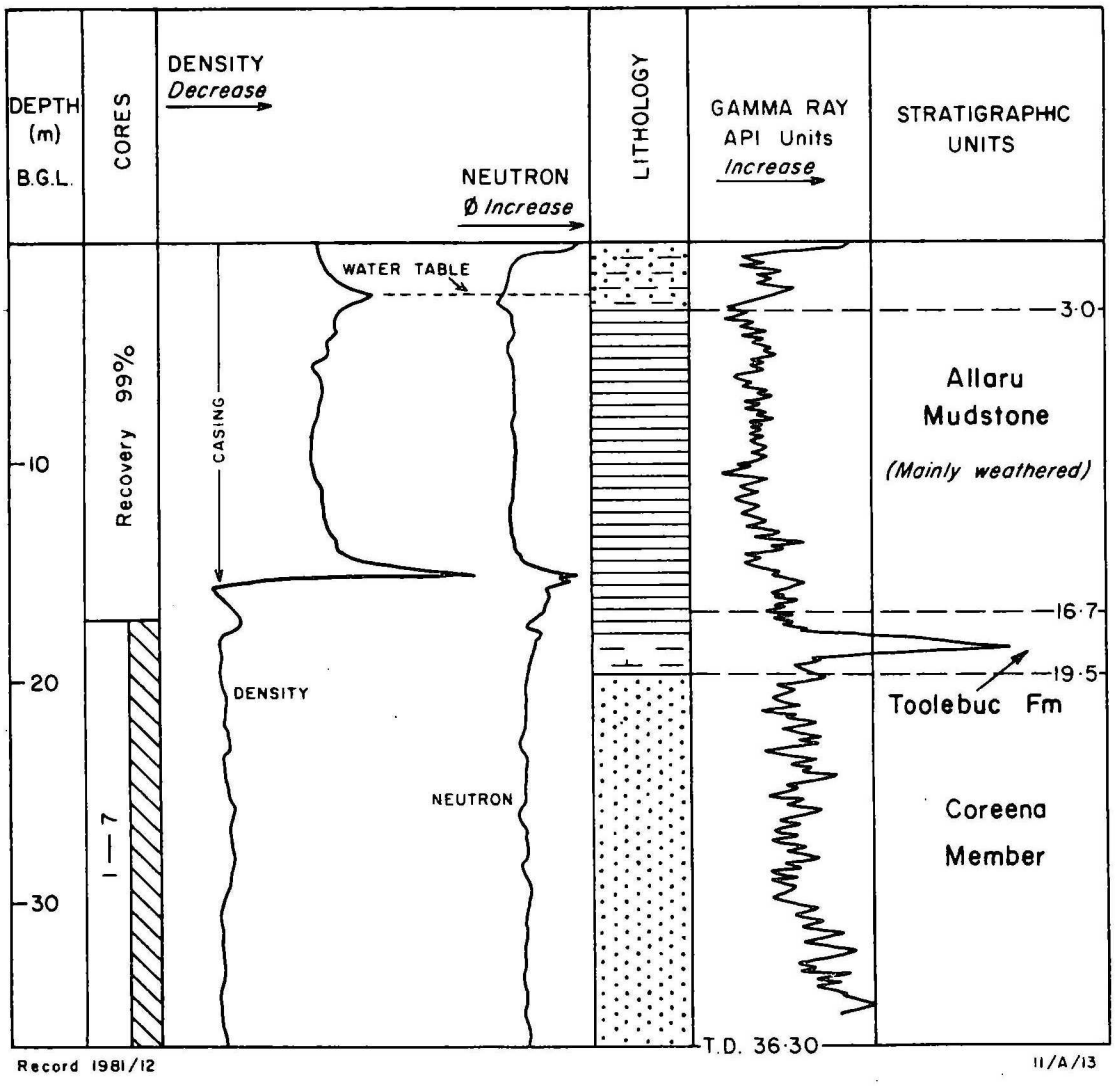

Fig. 14 Composite well log, BMR Tambo 42

General data

Sheet area	TAMBO 1:250 000
General location	Next to Reg. Water Bore 2885
Latitude	24°51'21"S
Longitude	146°06'19"E
Commenced drilling	8-9-80
Completed drilling	8-9-80
Drilled by	Amalgamated Drillers Co. Sydney, NSW
Total depth	36.30 m B.G.L.

Wire-line logs

- Gamma-ray	Surface to 35.0 m
- Neutron	" 35.0 m
- Resistivity	2.0 to 36.0 m
- Density	2.0 to 36.0 m
- Caliper	2.0 to 36.0 m
- Spon. potential	2.0 36.0 m
Cuttings	Surface to 16.80 m
Cores	16.80 to 36.30 m

Stratigraphy

The rock units penetrated in the Tambo No. 42, and their thicknesses, are listed below.

Rock units	Interval (m)	Thickness (m)
Superficial weathered rock	3 to 15	15.0
Allaru Mudstone	15 to 16.7	17.0
Toolebuc Formation	16.7 to 19.51	2.81
Wallumbilla Formation	19.51 to 36.30	16.79

The lithological units penetrated are described and correlated with the wire-line logs in Figure 14.

APPENDIX 9: BMR Tambo No. 43 Stratigraphic Hole

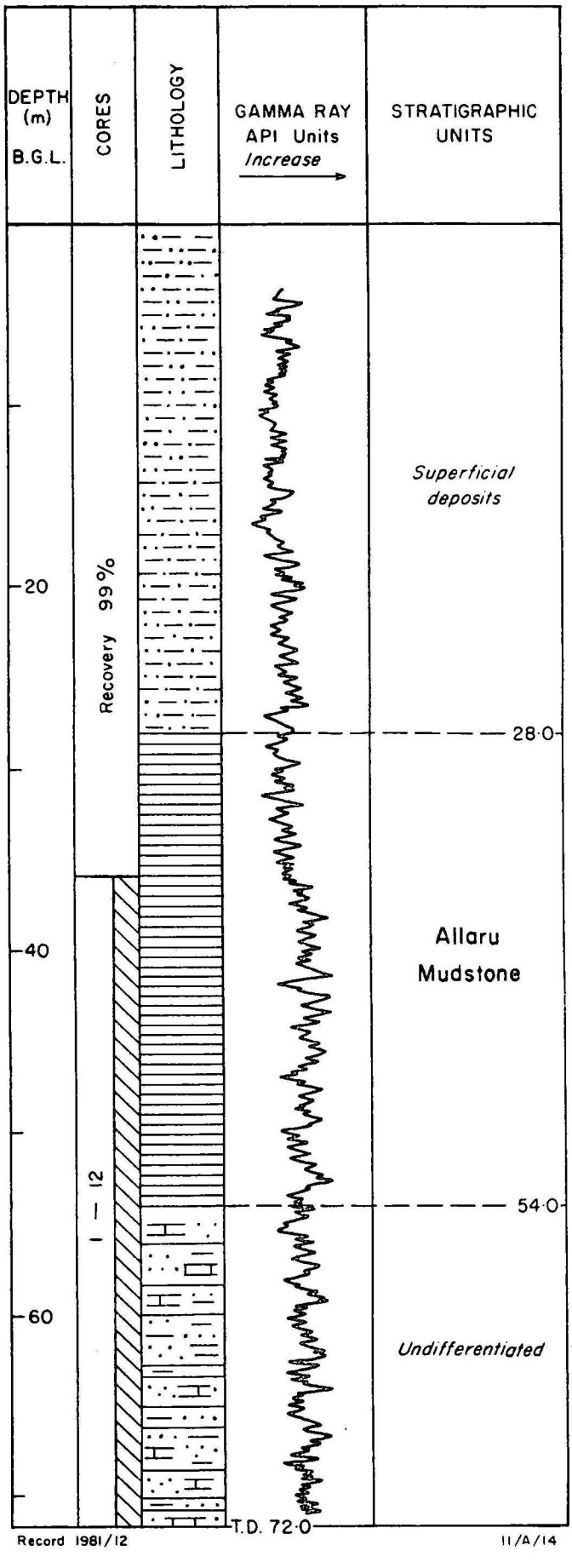

Fig. 15 Composite well log, BMR Tambo 43

General data

Sheet area	TAMBO 1:250 000
General location	South of Isoroy homestead
Latitude	24°59'35"S
Longitude	146°07'47"E
Commenced drilling	9-9-80
Completed drilling	10-9-80
Drilled by	Amalgamated Drillers Co. Sydney, NSW
Total depth	72.00 m B.G.L.

Wire-line logs

- Gamma-ray	Surface to 71.0 m
- Neutron	-
- Resistivity	-
- Density	-
- Caliper	-
- Spon. potential	-
Cuttings	Surface to 36 m
Cores	36.0 to 72.0

Stratigraphy

The rock units penetrated in Tambo No. 43, and their thicknesses, are listed below.

Rock units	Interval (m)	Thickness (m)
Superficial deposits	Surface to 28	28
Allaru Mudstone	28.0 to 54	26
? Undifferentiated	54 to 72	18

The lithological units penetrated are described and correlated with the wire-line log in Figure 15.

The hole was abandoned at 72.0 m B.G.L. due to extensive water encroachment.

APPENDIX 10: BMR Tambo No. 44 Stratigraphic hole

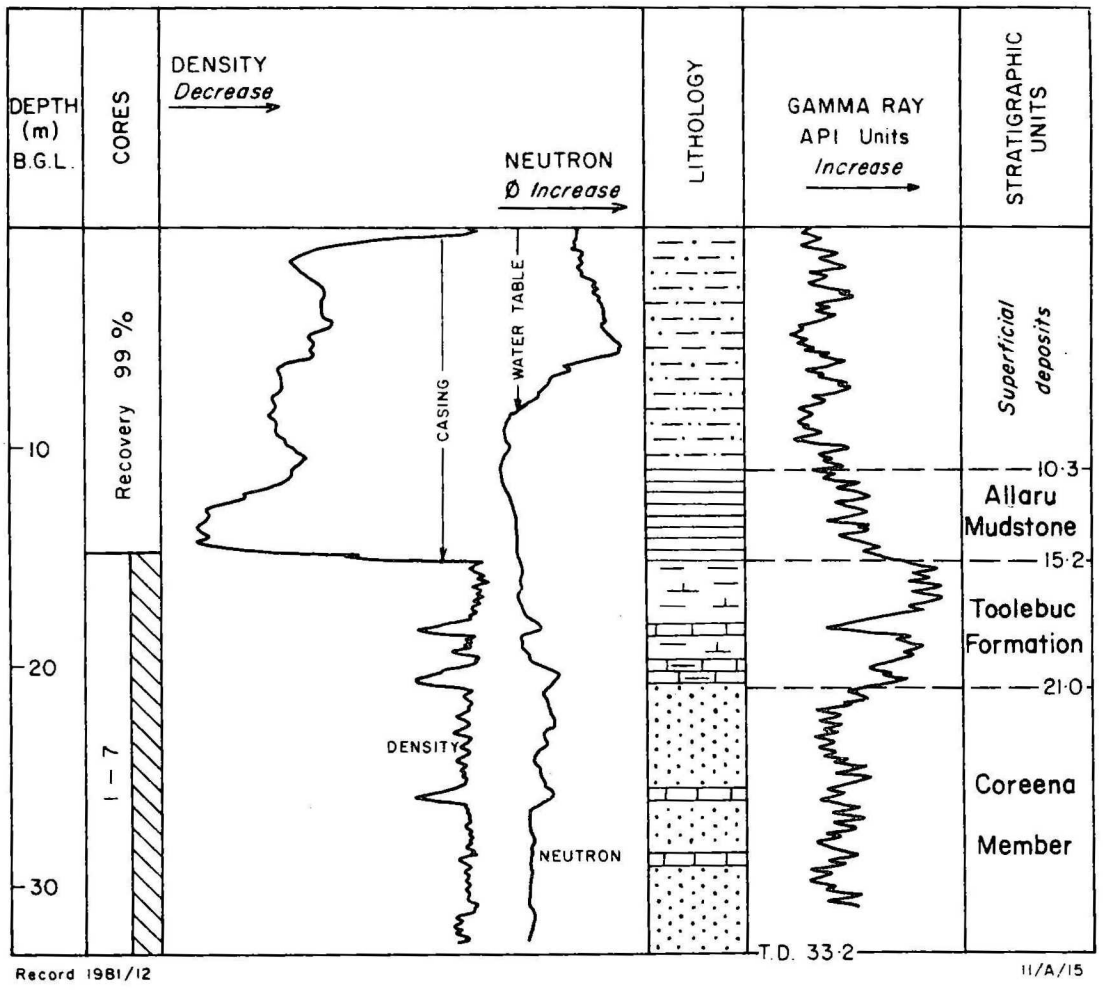

Fig. 16 Composite well log, BMR Tambo 44

General data

Sheet area	TAMBO 1:250 000
General location	3.5 km southeast of Isoroy homestead
Latitude	24°58'22"S
Longitude	146°09'25"E
Commenced drilling	10-9-80
Completed drilling	11-9-80
Drilled by	Amalgamated drillers Co. Sydney, NSW
Total depth	33.20 m B.G.L.

Wire-line logs

- Gamma-ray	Surface to 31.5 m
- Neutron	" 31.5 m
- Resistivity	2.0 to 32.5 m
- Density	2.0 to 32.5 m
- Caliper	2.0 to 32.5 m
- Spon. potential	2.0 to 32.5 m
Cuttings	Surface to 15 m
Cores	15.0 to 33.20 m

Stratigraphy

The rock units penetrated in the Tambo No. 44, and their thicknesses, are listed below.

Rock unit	Interval (m)	Thickness (m)
Weathered rock	Surface to 10.3	10.3
Allaru Mudstone	10.3 to 15.2	4.9
Toolebuc Formation	15.2 to 21.0	5.8
Coreena Member	21.0 to 33.2	12.2

The lithological units penetrated are described and correlated with the wire-line logs in Figure 16.

APPENDIX 11: BMR Augathella No. 5 Stratigraphic Hole

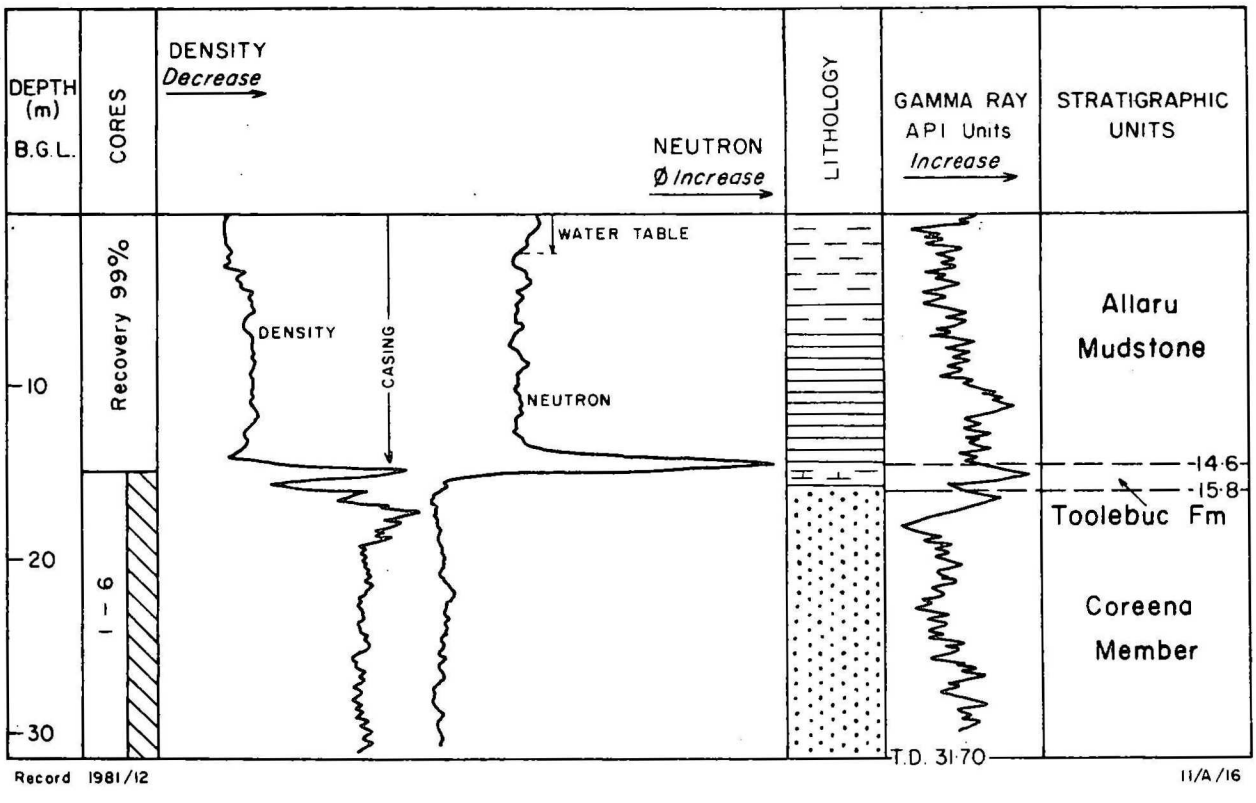

Fig. 17 Composite well log, BMR Augathella 5

General data

Sheet area	AUGATHELLA 1:250 000
General location	Next to Registered Water Bore 3336
Latitude	25°03'55"S
Longitude	146°11'10"E
Commenced drilling	11-9-80
Completed drilling	12-9-80
Drilled by	Amalgamated Drillers Co. Sydney, NSW
Total depth	31.70 m B.G.L.

Wire-line logs

- Gamma-ray	Surface to 30.0 m
- Neutron	" 30.0 m
- Resistivity	2.0 to 31.0 m
- Density	2.0 to 31.0 m
- Caliper	2.0 to 31.0 m
- Spon. potential	2.0 to 31.0 m
Cuttings	Surface to 12.0 m
Cores	12.0 to 31.70 m

Stratigraphy

The rock units penetrated in the Augathella No. 5, and their thicknesses, are listed below.

Rock units	Interval (m)	Thickness (m)
Allaru Mudstone	Surface to 14.6	14.6
Toolebuc Formation	14.6 to 15.8	1.2
Coreena Member	15.8 to 31.70	15.9

The lithological units penetrated are described and correlated with the wire-line logs in Figure 17.

APPENDIX 12: BMR Augathella No. 6 Stratigraphic Hole

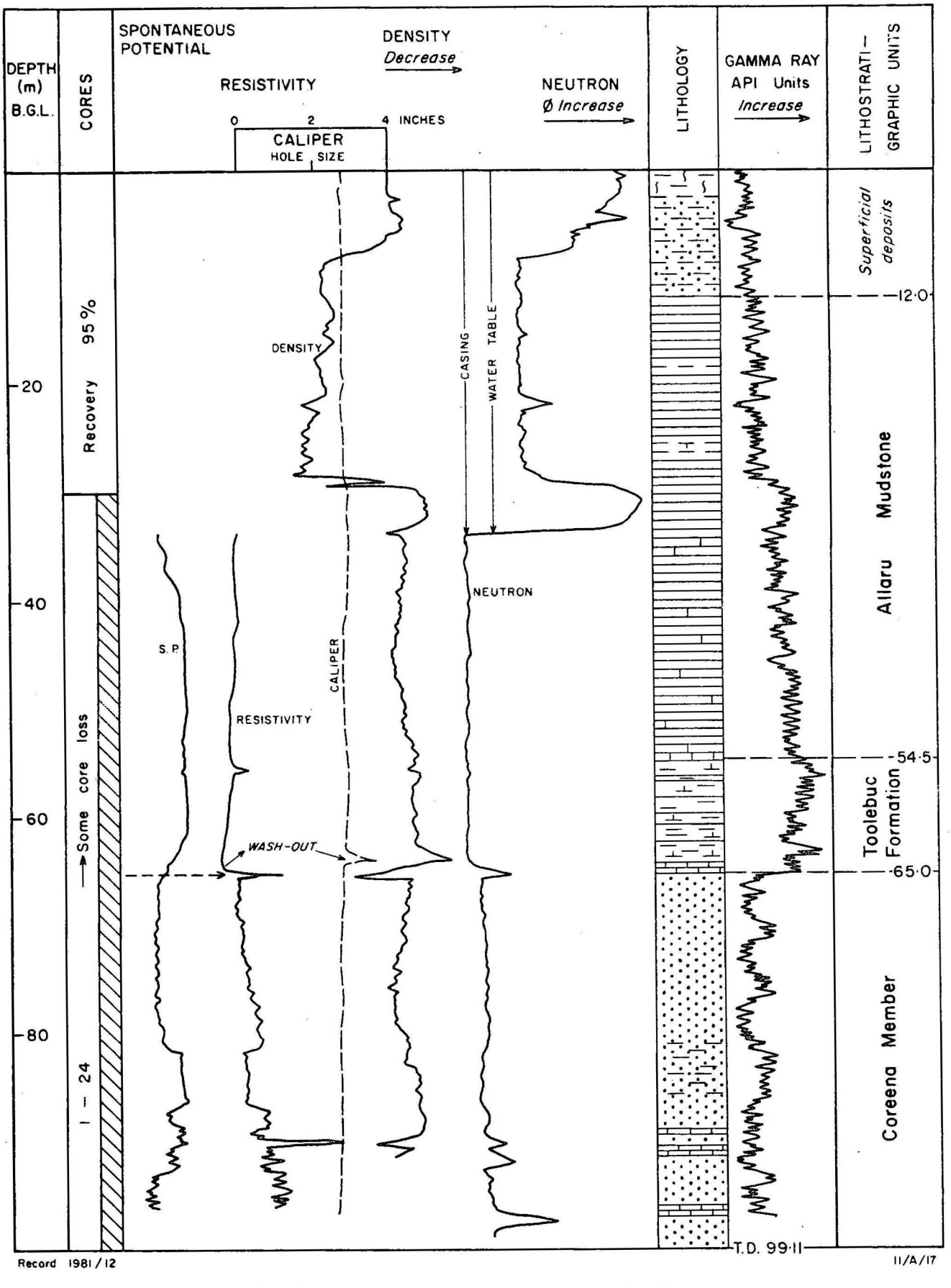

Fig. 18 Composite well log, BMR Augathella 6

General data

Sheet area	AUGATHELLA 1:250 000
General location	Next to Registered Water Bore 4033
Latitude	25°36'13"S
Longitude	146°05'35"E
Commenced drilling	14-9-80
Completed drilling	15-9-80
Drilled by	Amalgamated Drillers Co. Sydney, NSW
Total depth	99.4 m B.G.L.

Wire-line logs

- Gamma-ray	Surface to 98.0 m
- Neutron	" 98.0 m
- Resistivity	2.0 to 99.0 m
- Density	2.0 to 99.0 m
- Caliper	2.0 to 99.0 m
- Spon. potential	2.0 to 99.0 m
Cuttings	Surface to 30 m
Cores	30.0 to 99.4 m

Stratigraphy

The rock units penetrated in the Augathella No. 6, and their thicknesses, are listed below.

Rock unit	Interval (m)	Thickness (m)
Superficial deposits	Surface to 12.0	12
Allaru Mudstone	12.0 to 54.5	42.5
Toolebuc Formation	54.5 to 65.0	10.5
Coreena Member	65.0 to 99.4	34.4

The lithological units penetrated are described and correlated with the wire-line logs in Figure 18.

APPENDIX 13: BMR Augathella No. 7 Stratigraphic Hole

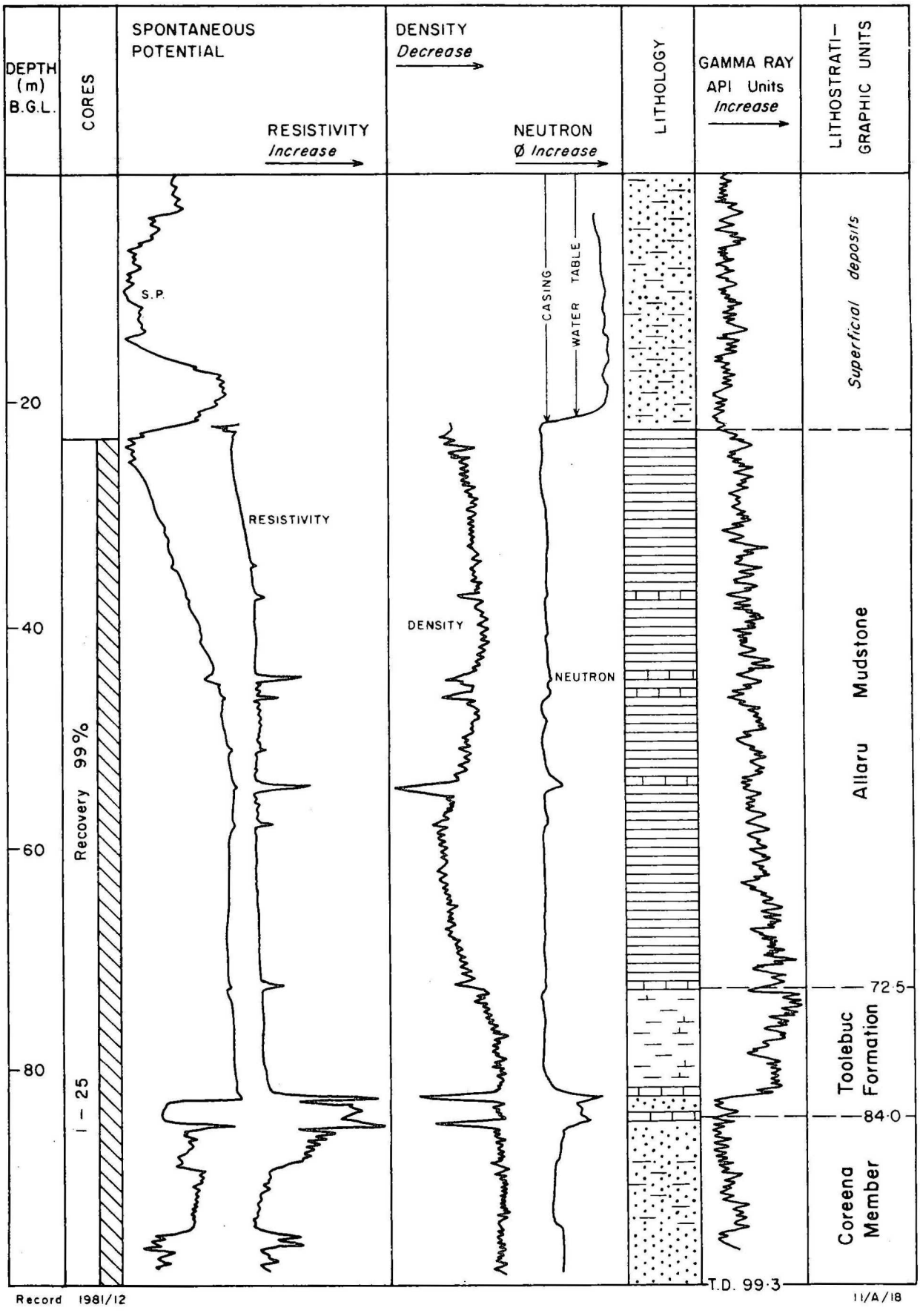

Fig. 19 Composite well log, BMR Augathella 7

General data

Sheet area	AUGATHELLA 1:250 000
General location	Next to Registered Water Bore 4090
Latitude	25°01'45"S
Longitude	146°42'02"E
Commenced drilling	16-9-80
Completed drilling	17-9-80
Drilled by	Amalgamated Drillers Co. Sydney, NSW
Total depth	99.3 m B.G.L.

Wire-line logs

- Gamma-ray	Surface to 98.5 m
- Neutron	" 98.5 m
- Resistivity	2.0 to 99.0 m
- Density	2.0 to 99.0 m
- Caliper	2.0 to 99.0 m
- Spon potential	2.0 to 99.0 m
Cuttings	Surface to 24.6 m
Cores	24.0 to 99.3 m

Stratigraphy

The rock units penetrated in Augathella No. 7, and their thicknesses, are listed below.

Rock unit	Interval (m)	Thickness (m)
Soil	Surface to 2.00	2.0
Allaru Mudstone	2.00 to 72.5	70.5
Toolebuc Formation	72.5 to 84.0	11.5
Coreena Member	14.0 to 99.3	15.3

The lithological units penetrated are described and correlated with the wire-line logs in Figure 19.

APPENDIX 14: BMR Charleville No. 2 Stratigraphic Hole

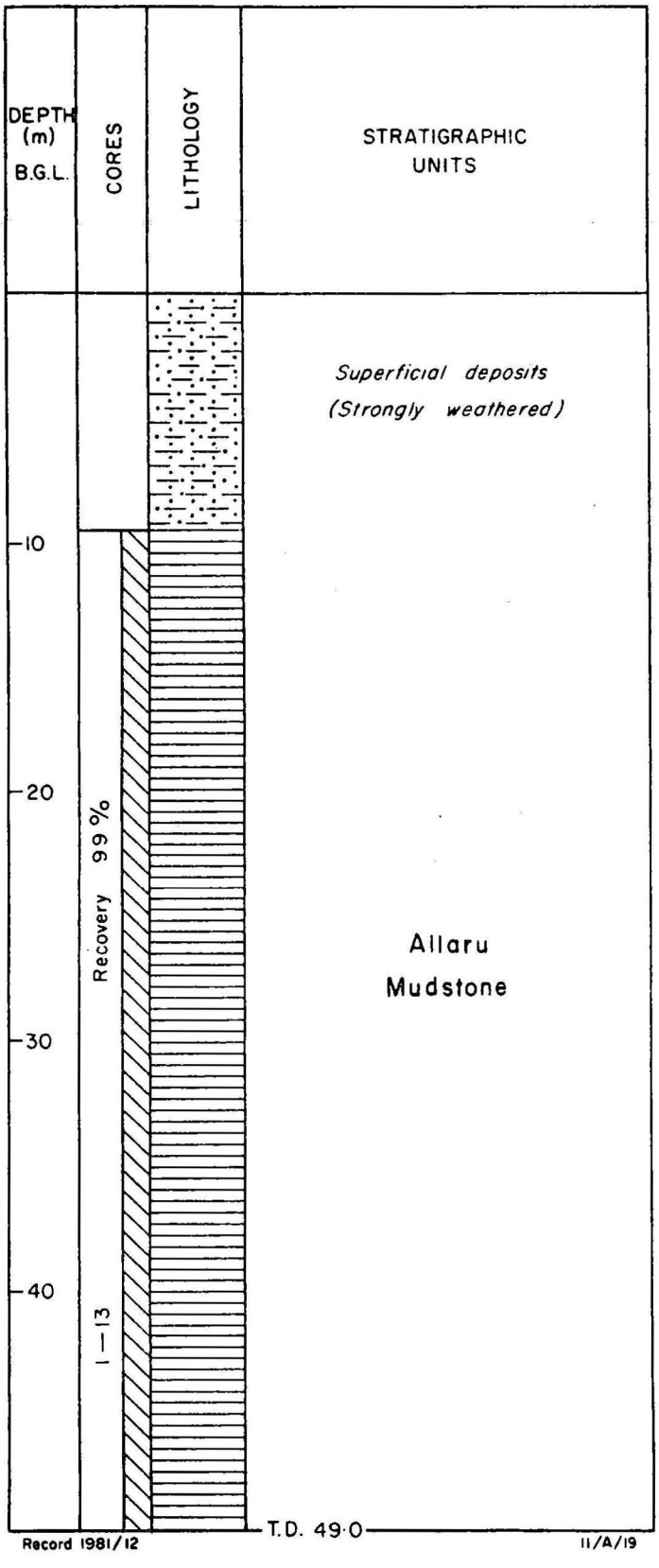

Fig. 20 Composite well log, BMR Charleville 2

General data

Sheet area	CHARLEVILLE 1:250 000
General location	Next to Registered Water Bore 2000
Latitude	25°24'52"S
Longitude	146°03'23"E
Commenced drilling	19-9-80
Completed drilling	20-9-80
Drilled by	Amalgamated Drillers Co. Sydney, NSW
Total depth	49.0 m B.G.L.

Wire-line logs

- Gamma-ray	-
- Neutron	-
- Resistivity	-
- Density	-
- Caliper	-
- Spon. potential	-
Cuttings	Surface to 9.0 m
Cores	3.0 to 49.0 m

Stratigraphy

The rock units penetrated in the Charleville No. 2, and their thicknesses, are listed below.

Rock unit	Interval (m)	Thickness (m)
Superficial deposits	Surface to 10	10
Allaru Mudstone	10 to 49.00	39.00

The lithological units penetrated are shown in Figure 20.

The hole was abandoned at 49.0 m B.G.L. due to extensive caving.

APPENDIX 15: Re-assessment of Oil Shale and Shale Oil in Toolebuc Formation

Re-evaluation of petroleum exploration well information and results from this drilling program lead to the conclusion that oil shale is absent from the Toolebuc Formation roughly south of a line joining Bedourie and Charleville in Queensland (Fig. 21). The northern limit of oil shale (Fig. 21) in the formation is taken as the supposed northern limit of the formation as shown in Plate 2, of BMR Bulletin 202 (on the Carpentaria and Karumba Basins).

For the purpose of calculating resources these limits were plotted on the Geological Map of Queensland, 1975, scale 1:2.5 million. On this map, eastern and western limits are shown in a generalised way only for larger outcrops and for amalgamations of smaller ones; the continuous boundary adopted was based on these, on likely variations of the formation, and on structural patterns. For calculating resources apparently available for open-cut mining a line was roughly plotted indicating the position of the formation 100 m below ground level; this line is more approximate than the boundaries plotted. The map plot was digitised and areas were calculated by computer.

Parameter values used in the calculations were:

(1) average thickness of oil shale 5 m
(2) average yield of oil shale 60 litres/tonne (Fisher assay)
(3) SG of oil shale 1.9

Results (All figures rounded off conservatively)

Total area of Toolebuc Formation thought to contain oil shale:
423 000 km^2.

Area in which oil shale is at a depth of 100 m or less:
39 000 km^2.

Total volume of oil shale, average 5 m thick, in Toolebuc Formation (less volume of shale less than 50 m deep, as it is likely that this is oxidised and uneconomic);
2020×10^9 m^3.

Volume of oil shale between 50 m and 100 m depth:
95×10^9 m^3.

Total volume of shale oil in Toolebuc (SG 1.9, yield 60 litres/tonne):
230×10^9 kl

Volume of shale oil between 50 m and 100 m:
11×10^9 kl

Summary of Toolebuc Formation oil shale resources

	Sept. 1977	Oct. 1980
Production area (km^2)	700 000	423 000
Average thickness (m)	10	5
Average yield (L/t)	45	60
Specific gravity	1.5	1.9
Inferred resources of oil ($\times 10^9 m^3$)	455	230

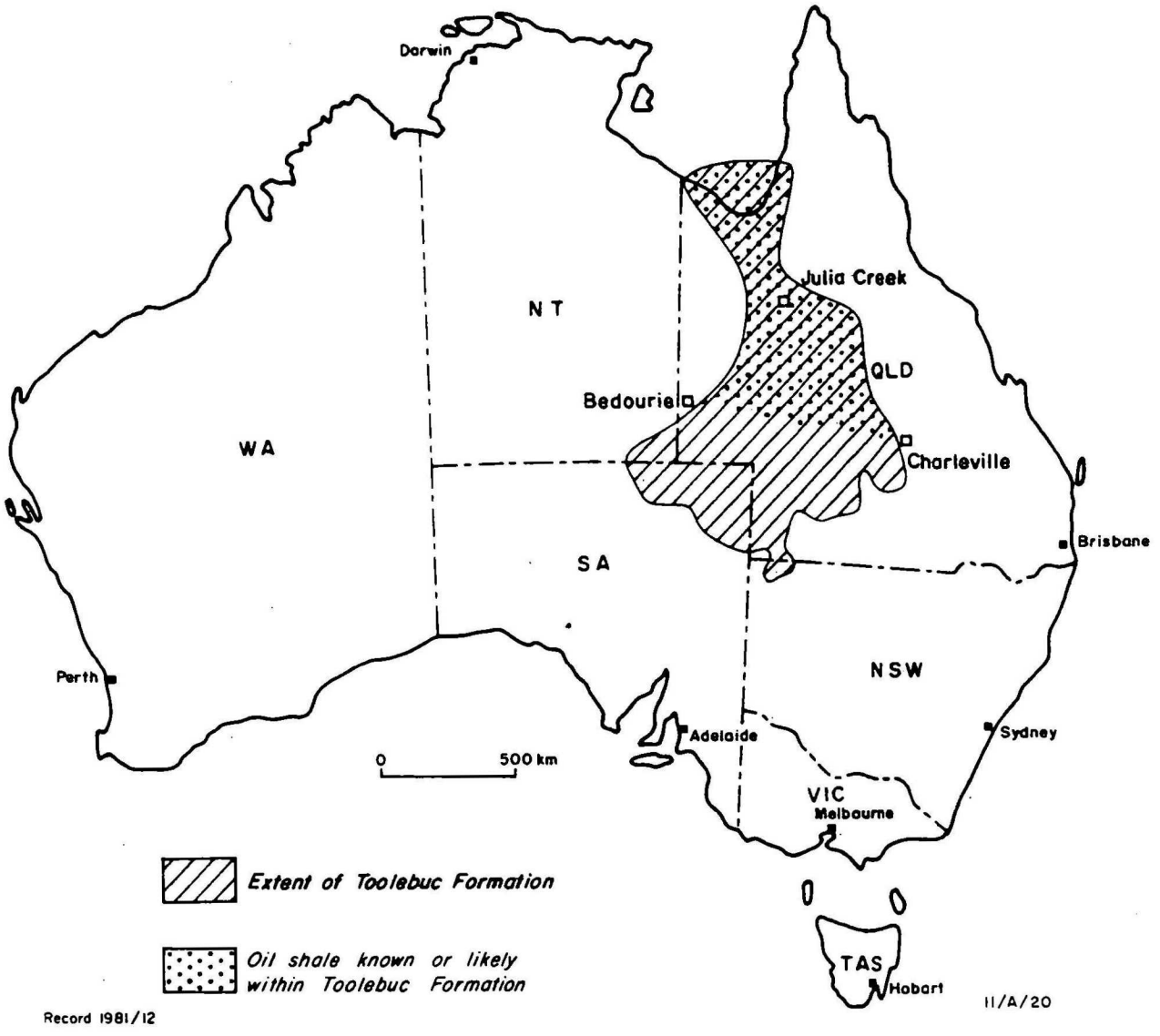

Fig. 21 Extent of known or likely oil shale within the Toolebuc Formation

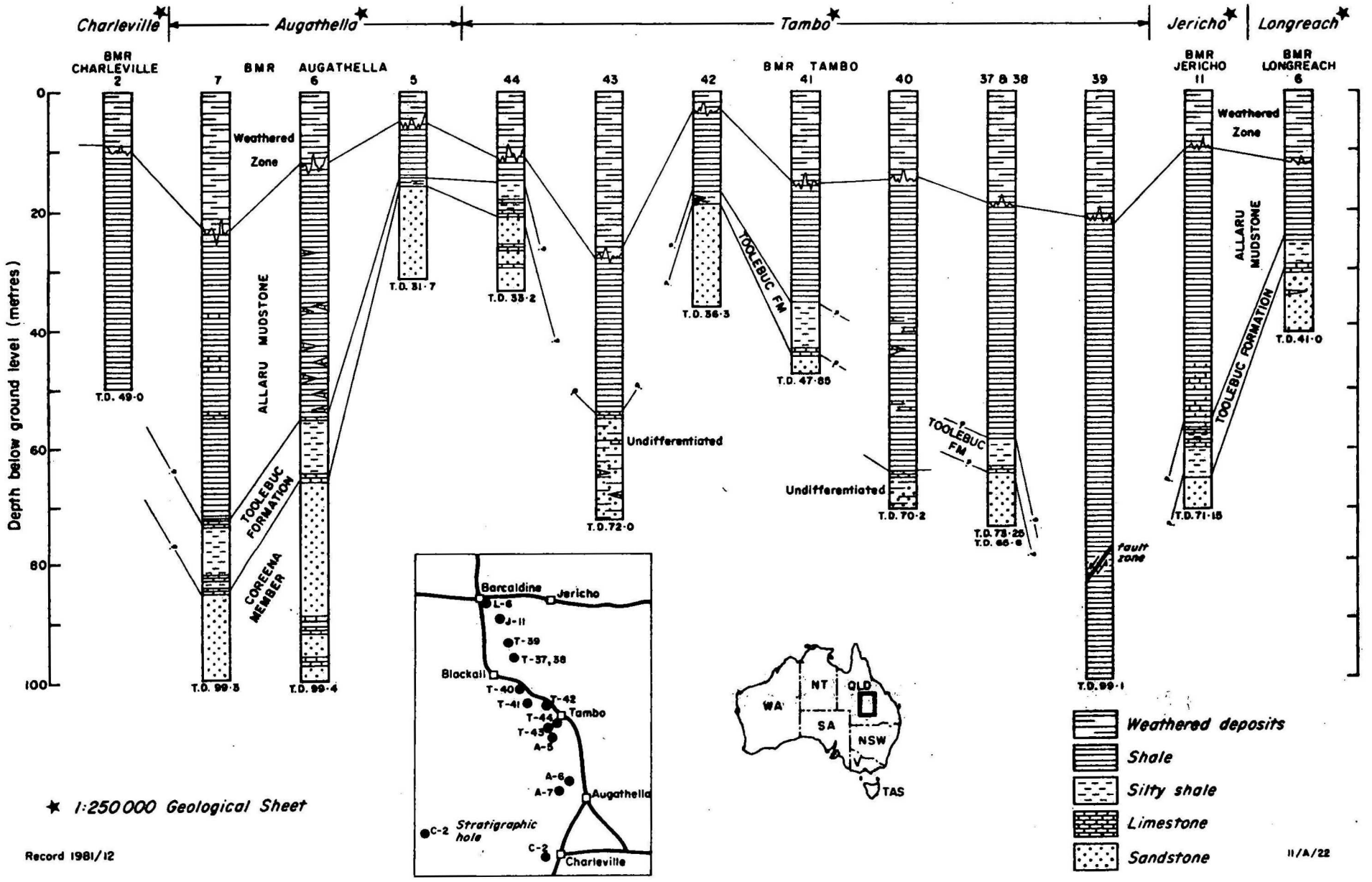

Plate 1 Correlations, Toolebuc and associated Formations