COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

*PETROLEUM SEARCH SUBSIDY ACTS*

*Publication No. 10*

# D.F.S. No. 1 BETOOTA, QUEENSLAND

OF

## DELHI-FROME-SANTOS

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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

*Minister:* SENATOR THE HON. W. H. SPOONER, M.M.

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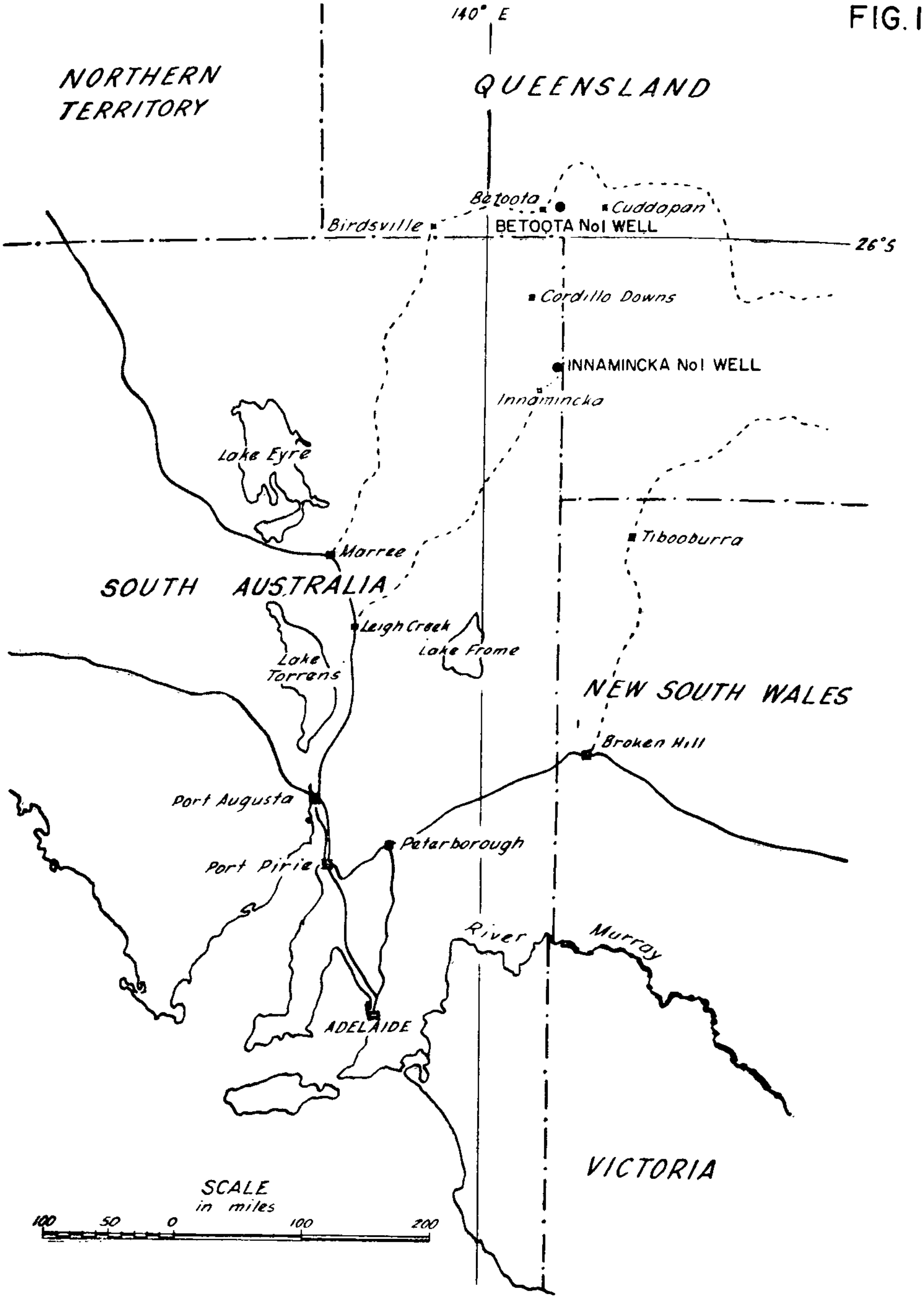


LOCALITY MAP

**BETOOTA No I WELL AND INNAMINCKA No I WELL**

# WELL COMPLETION REPORT

BY

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# SUMMARY

The Betoota No. 1 well was drilled by Delhi Australian Petroleum Ltd, Frome-Broken Hill Company Pty Ltd, and Santos Limited, in far southwest Queensland to a total depth of 9,824 feet. Drilling was commenced on 22nd December 1959 and the well was completed on 18th April 1960 as a dry hole. The rig used was a National 130 owned by Delta Drilling Company. Delhi Australian Petroleum Ltd, as the operating company, supplied the supervisory, engineering, and geological personnel. A comprehensive programme to obtain all data relative to the hydrocarbon potential of the strata penetrated by the drill bit and stratigraphic information concerning the geological history of the area was diligently carried out. The operation also provided for a complete programme of electric and mud logging, testing and coring, carried out by the operating company and their contracted service companies.

The Betoota No. 1 well established the presence of 5,757 feet of Mesozoic strata overlying 4,067 feet of sediments of probable Palaeozoic age at the site of the bore hole. Several showings of hydrocarbons were detected in sediments between 4,400 feet and 5,757 feet. After testing and examination of all evidence, they were considered to be non-commercial. From 3,450 feet to 5,757 feet some zones exhibiting very good porosity were encountered, but all were found to be water-bearing. Shales of both marine and brackish-water origin, regarded as suitable source rocks, occurred in the well between 1,350 feet and 3,245 feet and between 5,000 feet and 5,757 feet. The rest of the section penetrated was composed of sediments whose origin did not suggest conditions of accumulation likely to foster the generation of fluid hydrocarbons.


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# INTRODUCTION

The Betoota No. 1 test well was drilled to establish the capabilities of the section of sedimentary rock in this portion of the Great Artesian Basin to produce petroleum hydrocarbons from structures detected by previous surveys.

The structure at Betoota was established by surface geological mapping and seismic methods. A prominent anticlinal fold was detected well within the confines of the Great Artesian Basin, where a thick section of Mesozoic and marine Palaeozoic rocks was indicated. The test at Betoota was the second well in the deeper part of the Great Artesian Basin and was commenced after completion of the D.F.S. Innamincka No. 1 as a dry hole at 12,637 feet.*

* Petroleum Search Subsidy Acts Publication No. 9.

# WELL HISTORY

## General Data

*Well name and number.*—Delhi-Frome-Santos Betoota No. 1.

*Location.*—25° 42′ 30″ South, 140° 49′ 46″ East; *see* Plate 1.

*Name and address of tenement holder.*—Delhi Australian Petroleum Ltd, 316 Da Costa Building, Adelaide, South Australia; Santos Limited, Mutual Life Chambers, 44 Grenfell Street, Adelaide, South Australia; Frome-Broken Hill Company Proprietary Limited, 55 Flemington Road, Melbourne, Victoria.

*Details of petroleum tenement.*—Authorities to Prospect 66P and 67P, State of Queensland.

*District.*—Southwestern.

*Total depth.*—9,824 feet.

*Date drilling commenced.*—22nd December 1959.

*Date drilling completed.*—17th April 1960.

*Date well completed.*—18th April 1960.

*Date rig released.*—The rig was not released but stacked on location for an indefinite period.

*Drilling time in days to total depth.*—117 days.

*Elevation.*—Ground, 345 feet a.s.l.; Rotary table, 359 feet.

*Status.*—The well was completed as a dry hole at 9,824 feet.

## Drilling Data

*Name and address of drilling contractor.*—Delta Drilling Company, Tyler, Texas, U.S.A.

*Drilling plant—*

Make: National Ideal Type 130.
Rated capacity with 4½-in. drill pipe: 16,000 feet.
Rated capacity with 3½-in. drill pipe: 25,000 feet.
Motors (5): Superior Type PTD 6, 300 b.h.p. at 700 r.p.m.
Mast/Derrick: Lee C. Moore Type 142, 830,000 lb. rated capacity.
Pumps: two Ideal Type C-350, Size 7¾″ x 18″; one Ideal Type C-250, Size 7¼″ x 15″.

*Blow-out preventor equipment—*

Shaffer Gate: Model—Hydraulic Double, Size 13⅝ inches, Test Pressure 6,000 p.s.i.
Shaffer Gate: Model—Hydraulic Double, Size 10 inches, Test Pressure 10,000 p.s.i.
Shaffer Gate (2): Model—Single 34, Size 18 inches, Test Pressure 4,000 p.s.i.
Hydril: Model—GK12–900, Size 13⅝ inches, Test Pressure 6,000 p.s.i.
Hydril: Model—GK10–1500, Size 11 inches, Test Pressure 10,000 p.s.i.

*Hole sizes and depth—*

(i) 26-in. hole from 0 feet to 44 feet.
(ii) 17½-in. hole from 44 feet to 1,203 feet.
(iii) 12¼-in. hole from 1,203 feet to 4,028 feet.
(iv) 8½-in. hole from 4,028 feet to 9,824 feet.

*Casing and Liner details—*

(*a*) Date: 23rd December 1959.
Size: 20-in. conductor.
Weight: 94 lb./ft.
Grade: H40.
Range: 1
Setting Depth: 39 feet.

(*b*) Date: 28th December 1959.
Size: 13⅜ inches.
Weight: 54.50 lb./ft. and 48 lb./ft.
Grade: J55 and H40.
Range: 1, 2 and 3.
Setting Depth: 1,203 feet.

(*c*) Date: 16th January 1960.
Size: 9⅝ inches.
Weight: 40 lb./ft.
Grade: J55
Range: 2 and 3
Setting Depth: 4,028 feet.

*Casing and Liner Cementing details—*

(*a*) Size: 20 inches.
Setting Depth: 39 feet.
Quantity cement used: 42 sacks
Cemented to: Surface.
Method used: Circulated to surface with a Howco T-10 pumper.
Type cement: Adelaide.

(*b*) Size: 13⅜ inches.
Setting Depth: 1,203 feet.
Quantity cement used: 1,050 sacks.
Cemented to: Surface.
Method used: Cement was mixed and circulated with a Howco T-10 pumper.
Type cement: Adelaide.

(*c*) Size: 9⅝ inches.
Setting Depth: 4,028 feet.
Quantity cement used: 460 sacks.
Cemented to: 2,130 feet.
Method used: Cement was circulated with a Howco T-10 pumper. Casing centralizers were used.
Type cement: Adelaide.

The total amount of cement used in all casing jobs was 1,552 sacks.

*Drilling Fluids.*—The mud programme was designed by A. R. Gibson, Petroleum Engineer. A natural water-based mud was used to approximately 4,000 feet depth. The qualities of the mud varied as drilling approached this depth, but on the average the mud weight was 10.1 and viscosity 40.

Mud data were checked daily from 4,000 feet to total depth at 9,824 feet. Bentonite, myrtan, gel, and caustic were continually added to the mud to maintain the properties desired for the specific drilling conditions encountered. The following averages give an approximation of the mud characteristerics throughout the duration of the operation:—

| Depth | Mud Weight | Viscosity | Water Loss |
|---|---|---|---|
| Feet | (lb./gal.) | (Sec.) (Marsh) | (c.c./30 min.) |
| 4,000–7,571 .. .. .. .. | 10.4 | 49 | 11.2 |
| 7,571–7,912 .. .. .. .. | 10.5 | 47 | 9.4 |
| 7,912–9,060 .. .. .. .. | 10.5 | 48 | 10.1 |
| 9,060–9,824 .. .. .. .. | 10.5 | 48 | 10.4 |

ACCUMULATED MUD USED

| Date | Depth feet | Sabar 100-lb. sacks | Myrtan 50-lb. sacks | Caustic lb. | Ben-tonite 100-lb sacks | Clay 100-lb. sacks | CMC lb. | Mica lb. | Other as listed |
|---|---|---|---|---|---|---|---|---|---|
| 1960 | | | | | | | | | |
| January 7 .. | 4,028 | 30 | .. | .. | 30 | .. | .. | .. | 20 bbl. diesel |
| January 21 .. | 4,555 | 474 | 13 | 490 | 159 | 66 | 168 | 550 | |
| January 25 .. | 5,025 | 499 | 21 | 690 | 178 | 77 | 224 | 750 | |
| January 31 .. | 5,590 | 559 | 42 | 1,090 | 199 | 82 | 588 | 750 | |
| February 5 .. | 6,073 | 609 | 50 | 1,315 | 205 | 82 | 700 | 750 | |
| February 12 .. | 6,669 | 694 | 68 | 1,815 | 283 | 109 | 924 | 1,350 | |
| February 26 .. | 7,253 | 767 | 95 | 2,495 | 287 | 120 | 1,400 | 1,850 | |
| March 6 .. | 7,773 | 1,106 | 121 | 3,007 | 297 | 123 | 1,764 | 1,850 | 336 lb. Barium Carbonate |
| March 16 .. | 8,307 | 1,216 | 133 | 3,162 | 322 | 126 | 1,764 | 1,850 | |
| March 25 .. | 8,804 | 1,317 | 143 | 3,317 | 322 | 126 | 2,268 | 1,850 | |
| April 5 .. | 9,318 | 1,385 | 153 | 3,507 | 332 | 128 | 2,968 | 1,850 | |
| April 17 .. | 9,824 T.D. | 1,410 | 166 | 3,752 | 337 | 128 | 3,640 | 1,850 | |

*Water Supply.*—Water supply for the D.F.S. Betoota No. 1 was obtained from a well drilled 400 yards south of the drillsite. The well was drilled and completed for this purpose by Mines Administration Pty Ltd of Brisbane. It attained a total depth of 3,700 feet and flowed at a rate of 35,000 gallons per day. The aquifer producing the flow was located at 3,616 feet–3,630 feet.

Analysis revealed that the water contained 3.785 gm. of dissolved solids per litre consisting of 1.794 gm. NaCl, 1.630 gm. $Na_2CO_3$, 0.286 gm. organic matter, and the remainder magnesium and sodium carbonates and sulphates.

*Perforation and Shooting Record.*—No shooting or perforation operations were conducted on the well operation.

*Plugging Back and Squeeze Cementation Jobs.*—No squeeze jobs were performed on this well. In plugging and abandoning the well two plugs were set at depth intervals listed below and a steel plate was welded on the top of the casing.

| — | Cement Plug No. 1 | Cement Plug No. 2 |
|---|---|---|
| Date | 18th April 1960 | 18th April 1960 |
| Depth | 4,213–3,913 feet | 530–330 feet |
| Hole size | 8½–9⅝ inches | 9⅝ inches |
| Amount cement | 75 sacks | 50 sacks |
| Type | Adelaide | Adelaide |

*Fishing Operations.*—Two fishing operations were carried out in this well.

*Total depth* 4,000 *feet.* On 9th January 1960 the drill pipe became stuck at 4,000 feet. After spotting diesel oil around the drill collars, an unsuccessful attempt was made to pull the drill pipe loose. A Welex free-point indicator was run and the free point was found two drill collars off bottom. A string shot was then run and the pipe backed off one joint above the drill collars. The " fish " was then washed over to the bit and retrieved with a Bowen overshot. Normal operations resumed on 12th January 1960.

*Total depth* 9,053 *feet.* The second fishing job occurred on 30th March 1960 when the Welex electric logging sonde became lodged in the hole at 9,053 feet. Attempts to free it resulted in the logging cable breaking, leaving 136 feet of cable and the sonde in the hole. Both objects were recovered separately and normal operations resumed on 1st April 1960.

*Side-tracked Hole.*—The hole was not side-tracked.

## Logging and Testing

*Ditch Cuttings.*—Samples were taken by Core Laboratories Inc. in their logging unit from mud passed from the flowline over the shale shaker. The samples were taken every two feet and sacked in 10-foot intervals, the depths marked on the sacks being true depth, which was calculated from the lag time. The lag time was established at frequent intervals by putting a tracer (corn or calcium carbide) in the mud stream and timing the travel from derrick floor to shale shaker. This interval less 15 percent for travel down the drill pipe was taken as the lag time.

*Coring.*—The programme called for cores to be taken:

" (1) At each change of formation indicated by a change in the penetration rate or by cuttings.

(2) When oil and/or gas is detected in the returns.

(3) When an indication of porosity and/or permeability is noted.

(4) At depths selected by the Company's wellsite geologist and to provide that the interval between any two consecutive cores shall not be more than 200 feet, except in thick uniform lithology when by agreement the maximum interval may be extended to 500 feet."

Information from cores within the Mesozoic sequence was augmented by the taking of sidewall samples at selected points. The programme was followed to total depth.

Thirty-four cores of a total length of 365 feet were cut in the hole. Of this 288.85 feet were actually recovered, giving a percentage recovery of 79 percent.

Both diamond and conventional type equipment was used in coring operations. In softer formations, a " Korking " Model K500 barrel with Hughes " J " type coring head was used; Core Nos. 1 to 19 and Core No. 24 were taken with this equipment. Core Nos. 20 to 23 and 25 to 34 were cut with a Hycalog barrel and a Hycalog 8¾-in. diamond core head. Hughes " J " type core head gave a core of 2½-in. diameter, while the diamond head cut a core of 4⅜-in. diameter. Core No. 24 was cut with the " J " type head because the presence of softer material made the use of the diamond head unsatisfactory.

*Sidewall Sampling.*—Run I.

| Shot | Intervals sampled | |
|---|---|---|
| | Depth | Recovery |
| 1 | 3,251 | Nil |
| 2 | 3,250 | Nil |
| 3 | 3,250 | Nil |
| 4 | 2,998 | Wall cake |
| 5 | 2,750 | Wall cake |
| 6 | 2,750 | Nil |
| 7 | 2,750 | Nil |
| 8 | 2,500 | Nil |
| 9 | 2,500 | Nil |
| 10 | 2,499 | Nil |
| 11 | 2,252 | Nil |
| 12 | 2,251 | Nil |
| 13 | 2,250 | Nil |
| 14 | 2,250 | Nil |
| 15 | 1,851 | Nil |
| 16 | 1,850 | Nil |
| 17 | 1,850 | Nil |
| 18 | 1,849 | Nil |
| 19 | 1,701 | Nil |
| 20 | 1,700 | Nil |
| 21 | 1,700 | Nil |
| 22 | 1,699 | Nil |
| 23 | 1,376 | Nil |
| 24 | 1,375 | Nil |
| 25 | 1,375 | Nil |
| 26 | 1,374 | Wall cake |
| 27 | 1,250 | Nil |
| 28 | 1,249 | Siltstone, grey, micaceous, lignitic, with very fine laminae of shale |
| 29 | 1,248 | Sandstone (" salt and pepper "), fine-grained, angular to sub-angular, poorly sorted, quartz, chert, glauconite, lignitic, slightly calcareous, silty, very poor porosity, no odour, stain or fluorescence, streaks of shale |
| 30 | 1,248 | As for 29 |

Run II.

| Shot | Intervals sampled | |
|---|---|---|
| | Depth | Recovery |
| 1 | 5,723 | Nil |
| 2 | 5,721 | Sandstone, light grey, fine-grained, poorly sorted, angular, quartz, kaolin, soft, tight |
| 3 | 5,719 | Nil |
| 4 | 5,175 | Shale, dark grey, fissile, very micaceous, silty, very lignitic |
| 5 | 5,155 | Nil |
| 6 | 5,150 | Nil |
| 7 | 5,120 | Nil |
| 8 | 5,000 | Nil |
| 9 | 4,995 | Sandstone, light grey, fine-grained, poorly sorted, angular, quartz, chert, trace glauconite, calcareous, poorly consolidated, tight |
| 10 | 4,850 | Sandstone, dark grey, very fine-grained, very shaly, trace glauconite, tight |
| 11 | 4,732 | Nil |
| 12 | 4,730 | Nil |
| 13 | 4,727 | Nil |
| 14 | 4,725 | Nil |
| 15 | 4,520 | Sandstone, light grey, medium-grained, poorly sorted, angular, clean quartz, poorly consolidated, no porosity |
| 16 | 4,515 | Nil |
| 17 | 4,510 | Nil |
| 18 | 4,505 | Nil |
| 19 | 4,455 | Nil |
| 20 | 4,453 | Nil |
| 21 | 4,450 | Sandstone, light grey, fine-grained, poorly sorted, angular, quartz, chert, kaolin, poorly consolidated, tight, spotted yellow fluorescence, weak cut |
| 22 | 4,314 | Sandstone, light grey, fine-medium-grained, poorly sorted, angular, quartz, chert, kaolin, trace glauconite, slightly calcareous, very poorly consolidated, few lignite streaks |
| 23 | 4,312 | As for 22 |
| 24 | 4,298 | Nil |
| 25 | 4,250 | Sandstone, light grey, fine-grained, angular, poorly sorted, quartz, chert, kaolin, trace glauconite, calcareous, soft, poorly consolidated, fine lignite laminae, tight |
| 26 | 4,205 | Siltstone, dark grey, grading to very fine grained, and sandstone, soft, very argillaceous, fine lignite laminae |
| 27 | 4,200 | Nil |
| 28 | 4,198 | Nil |
| 29 | 4,195 | Nil |
| 30 | 4,150 | Nil |

*Method Used.*—Welex sidewall coring gun. Cores were sent to Bureau of Mineral Resources, Canberra, for examination and analysis.

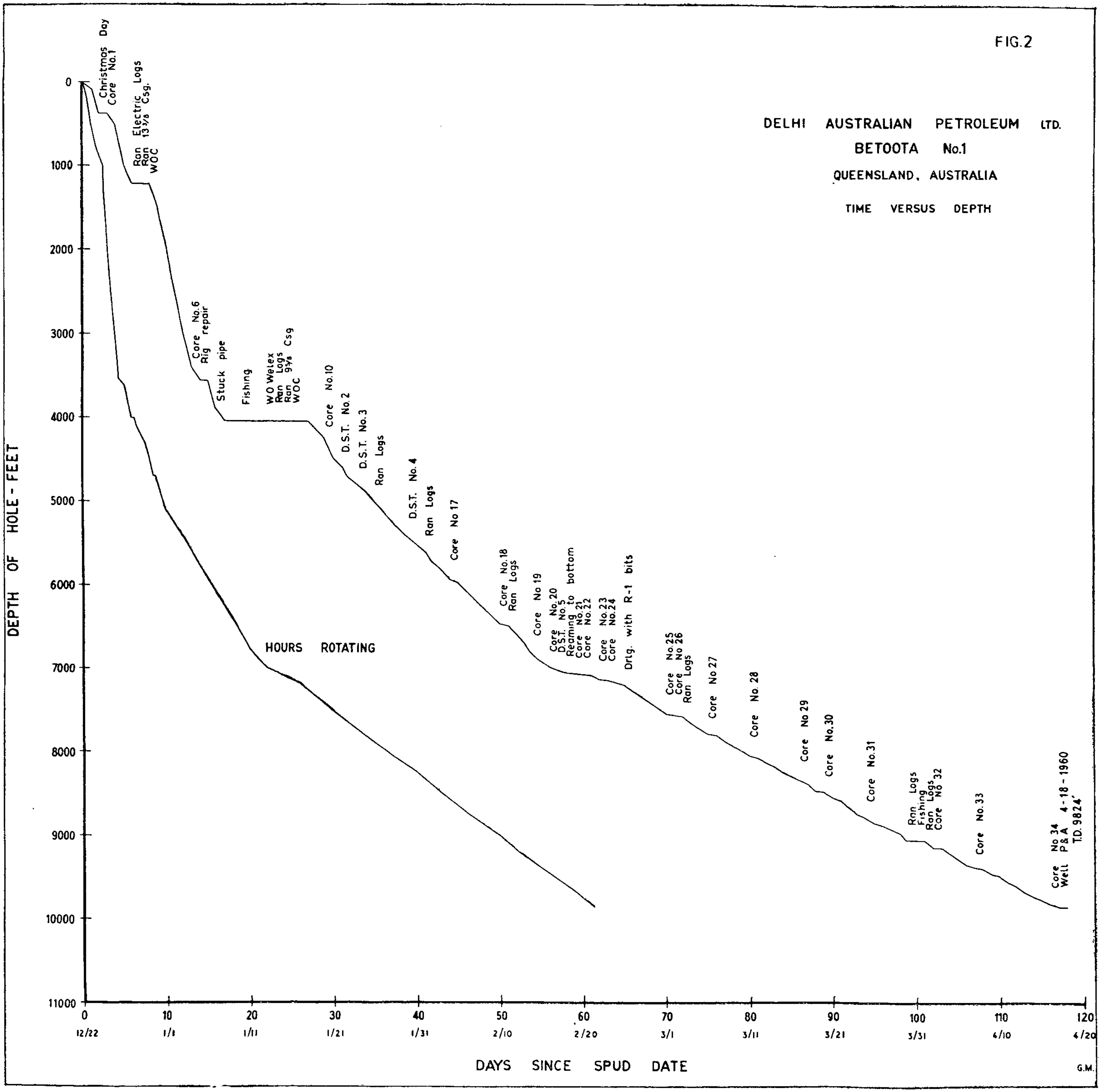
*Electrical and other Logging*—

*Electrical and other Wireline Logging.*—The following wireline logs were run by Welex Inc., the logging division of Halliburton Oil Well Cementing Company:—

1. Electrical self-potential-resistivity.
2. Guard.
3. Contact-caliper.
4. Radioactivity (gamma-ray/neutron).
5. Dipmeter survey.

Logging was carried out before setting the two strings of casing at 1,203 feet and again at 4,028 feet. Below 4,028 feet, logs were run every 500 to 1,000 feet.*

* *See* Plates 2-5. Complete logs are available for inspection at the Bureau of Mineral Resources, Canberra.




[To face page 12.]

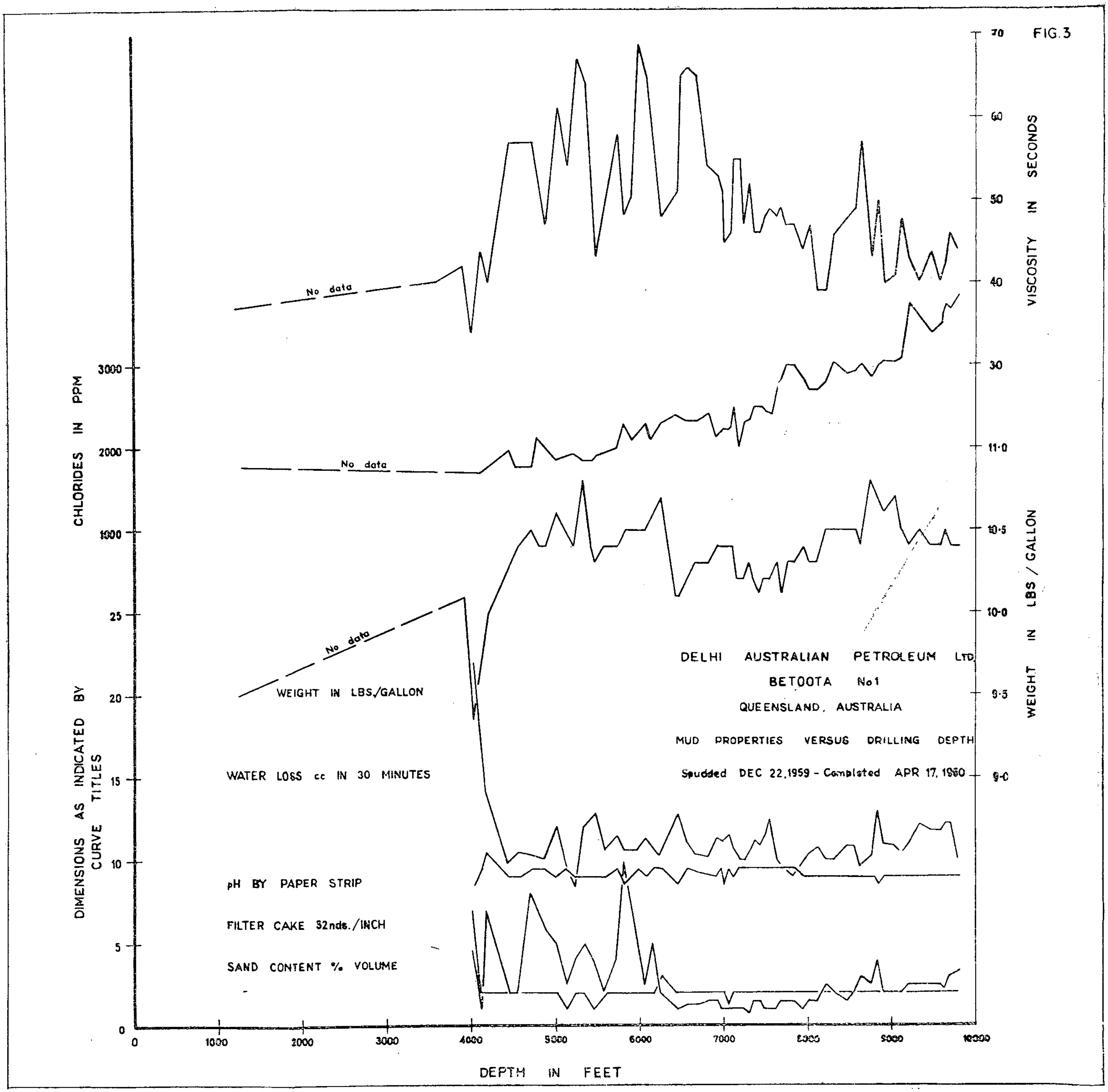
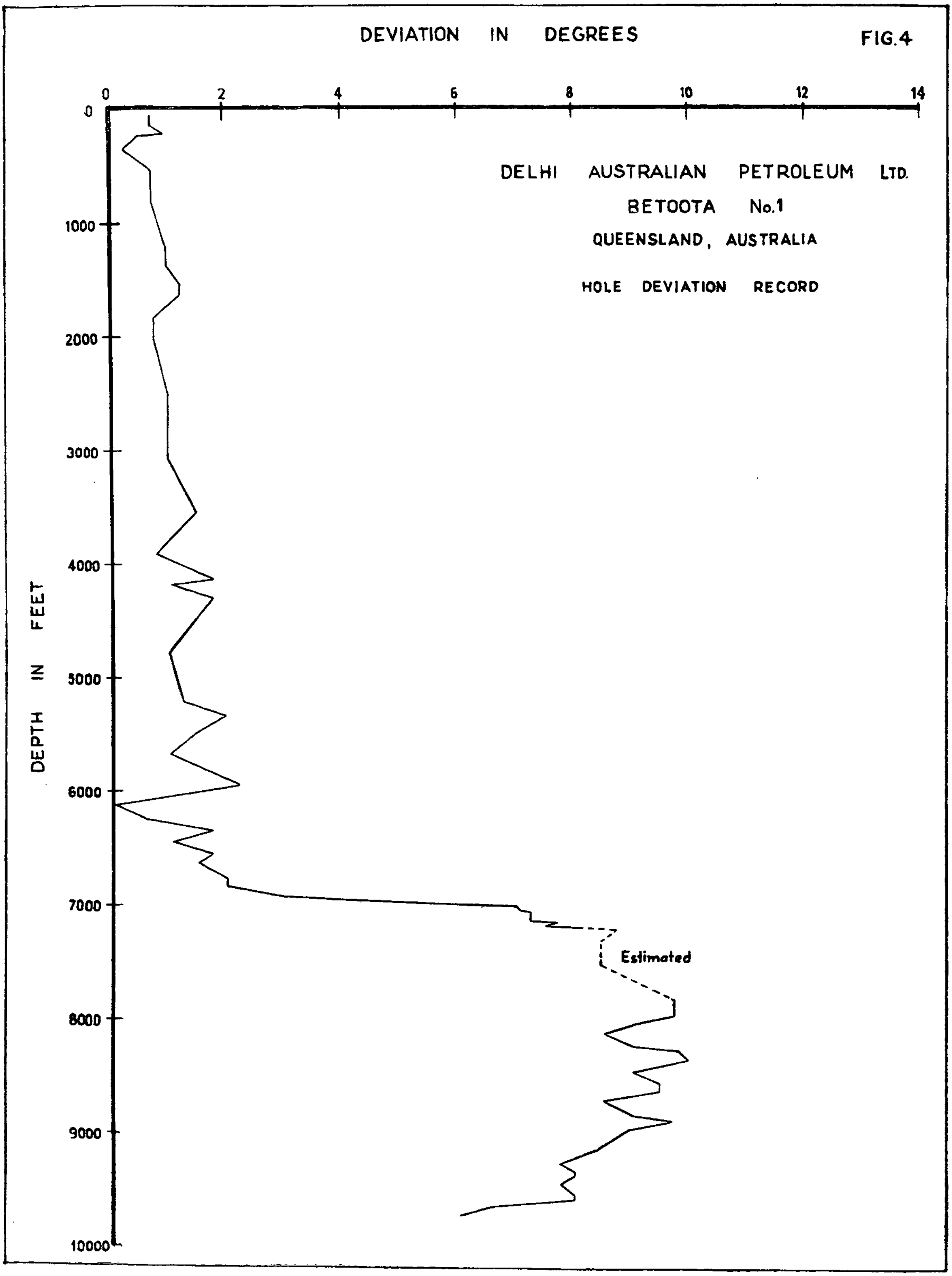
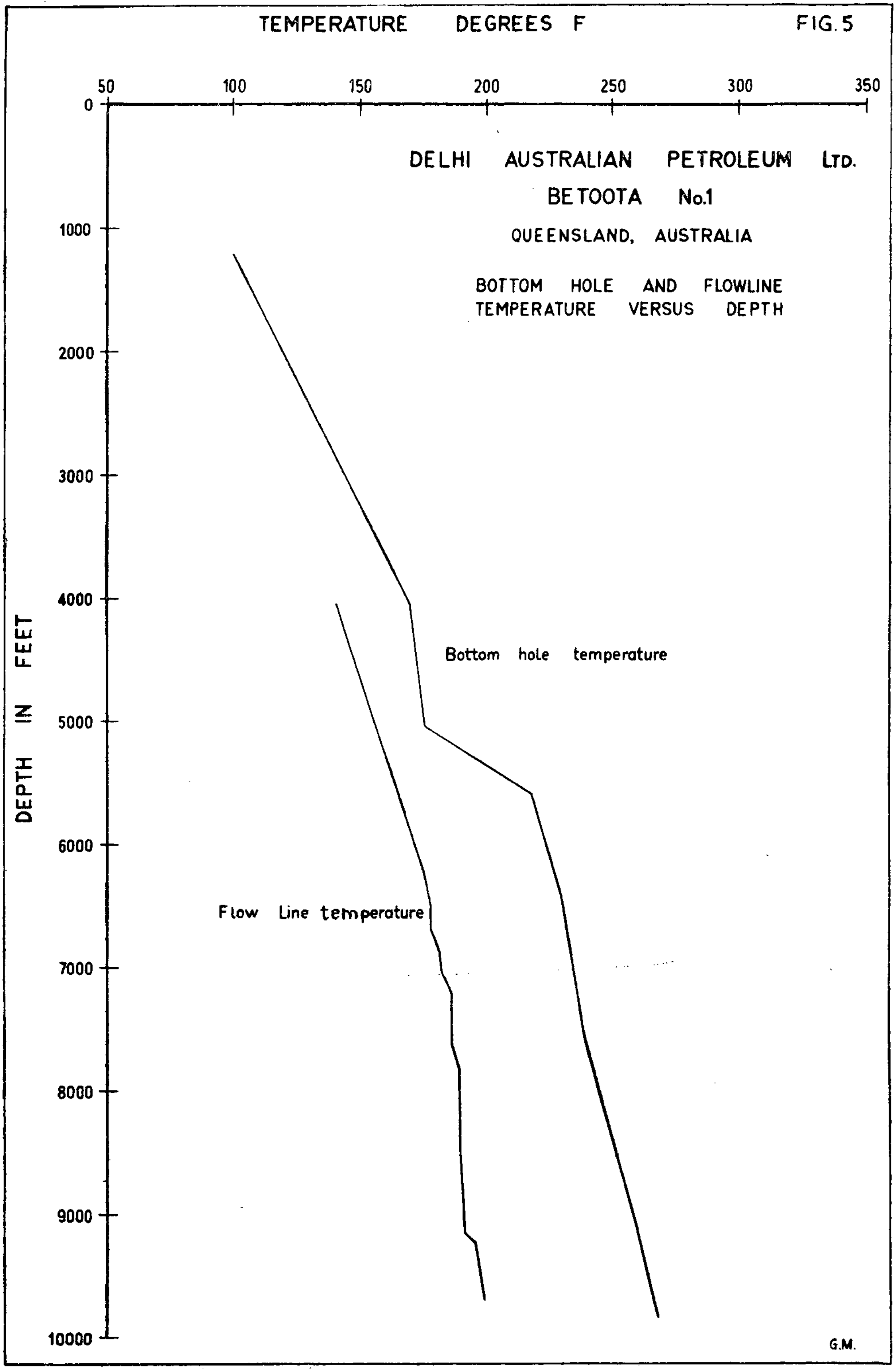


FIG. 3
DELHI AUSTRALIAN PETROLEUM LTD
BETOOTA No 1
QUEENSLAND, AUSTRALIA
MUD PROPERTIES VERSUS DRILLING DEPTH
Spudded DEC 22, 1959 - Completed APR 17, 1960
VISCOSITY IN SECONDS
WEIGHT IN LBS / GALLON
CHLORIDES IN PPM
DIMENSIONS AS INDICATED BY CURVE TITLES
WEIGHT IN LBS./GALLON
WATER LOSS cc IN 30 MINUTES
pH BY PAPER STRIP
FILTER CAKE 32nds./INCH
SAND CONTENT % VOLUME
No data
No data
No data
DEPTH IN FEET
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
70
60
50
40
30
11·0
10·5
10·0
9·5
9·0
3000
2000
1000
25
20
15
10
5
0


DEVIATION IN DEGREES
FIG.4
0
2
4
6
8
10
12
14
DELHI AUSTRALIAN PETROLEUM LTD.
BETOOTA No.1
QUEENSLAND, AUSTRALIA
HOLE DEVIATION RECORD
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
DEPTH IN FEET
Estimated


TEMPERATURE DEGREES F
FIG. 5
50
100
150
200
250
300
350
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
DEPTH IN FEET
DELHI AUSTRALIAN PETROLEUM LTD.
BETOOTA No.1
QUEENSLAND, AUSTRALIA
BOTTOM HOLE AND FLOWLINE
TEMPERATURE VERSUS DEPTH
Bottom hole temperature
Flow Line temperature
G.M.

*Mud Logging*.—A mud logging service was provided by Core Laboratories Inc. The logging unit was manned by three engineering geologists, each working an eight-hour shift. The service included catching and examination of cuttings, examination and analysis of cores, continuous recording of any hydrocarbons in the mudstream, and checks for hydrocarbons in the cuttings. Related data, such as rate of penetration, pump pressure, weight on bit, and mud pit level, were also continuously recorded. All these data were incorporated in a daily rig report and a weekly " Grapholog ".*

*Drilling Time and Gas Log*.—As mentioned above, rate-of-penetration or drilling time and continuous hydrocarbon indication log were kept by Core Laboratories, Inc., and are an integral part of their " Grapholog ".*

*Formation Testing*.—Open hole formation tests were called for by the Delhi Australian wellsite geologist and carried out by Delhi Australian supervisory drilling personnel. The testing tool assembly consisted of a Halliburton Hydraspring tester with single packer, safety joint, jars and circulating sub.

All tests were conducted in open hole and concurrent with drilling operations, and all were considered to have successfully evaluated the zone of interest in each interval.

Drill Stem Test No. 1 (3,542–3,563 feet) was run in the lower part of the aquifer from which water is produced at the Betoota artesian well. As expected, water was recovered, but the amount of water and the pressures recorded indicated low permeability for this section of the aquifer.

Drill Stem Test No. 2 (4,424–4,463 feet) was conducted to evaluate spotted yellow fluorescence and weak cut with carbon tectrachloride in the cuttings, the formation being a very poorly porous sandstone. No hydrocarbons were recovered and the pressures recorded showed a very tight formation.

Drill Stem Test No. 3 (4,779–4,801 feet) was run after examination of Core No. 12, the top part of which showed sandstone with very good porosity, having the appearance of an aquifer. This observation was substantiated when the well flowed water at 1,200 gallons per hour.

Drill Stem Test No. 4 (5,388–5,420 feet) was run because of a combination of factors, viz., the appearance of a substance resembling " dead oil " in the cuttings and giving a weak cut with carbon tetrachloride, a drilling break from 6 to 2 minutes per foot, suggesting more porosity than appeared in the cuttings, and a rise of 10 units on the gas detector. Individually these factors would not be considered very significant, but taken together made a test desirable. Only drilling mud was recovered, the pressures recorded indicating an extremely tight formation.

---

* *See* Plates 2-5. The original reports and logs may be consulted at the Bureau of Mineral Resources, Canberra.

Drill Stem Test No. 5 (6,910–7,036 feet) was carried out when a small amount of gas was detected, coupled with the appearance of a yellow fluorescing clear quartz sandstone, which gave a moderate cut with carbon tetrachloride and showed small amounts of " dead oil ". It was believed possible that the sandstone was caving from above, but to evaluate this " show " fully a test was run. Mud and watery mud with no hydrocarbons was recovered, indicating a zone of very low porosity and permeability devoid of oil and gas.

Detailed results of these tests will be found in Appendix 4.

*Deviation Surveys.*—Hole deviation surveys were conducted periodically, in general before pulling the pipe to change the bit. The Totco instrument was used, dropped down the drill pipe, and recovered during the trip. The deviation was not more than 1¼° down to 3,000 feet, and between 1° and 2° from 3,000 feet to 6,920 feet; from 6,920 feet to total depth (9,824 feet), because of high dipping beds and very hard drilling, the deviation averaged between 8° and 9°, reached 10°, the maximum, at 8,370 feet, and thereafter tended back toward verticality, being only 6° at 9,708 feet. The Totco deviation readings were:—

| Date | Depth | Deviation Degrees |
|---|---|---|
| 1959— | | |
| December 23 | 60 | ¾ |
| | 120 | ¾ |
| December 24 | 210 | 1 |
| | 250 | ½ |
| | 345 | ¼ |
| December 26 | 522 | ¾ |
| | 738 | ¾ |
| | 820 | ¾ |
| December 31 | 1,250 | 1 |
| | 1,350 | 1 |
| | 1,510 | 1¼ |
| | 1,610 | 1¼ |
| 1960— | | |
| January 1 | 1,820 | ¾ |
| | 2,020 | ¾ |
| | 2,525 | 1 |
| January 3 | 3,040 | 1 |
| January 4 | 3,545 | 1½ |
| January 7 | 3,905 | ¾ |
| January 19 | 4,130 | 1¾ |
| | 4,190 | 1 |
| January 20 | 4,300 | 1¾ |
| January 23 | 4,780 | 1 |
| January 27 | 5,210 | 1¼ |
| January 29 | 5,345 | 2 |
| January 31 | 5,497 | 1½ |
| February 2 | 5,690 | 1 |
| February 4 | 5,960 | 2¼ |
| February 6 | 6,132 | 0 |
| February 8 | 6,226 | ¾ |
| | 6,342 | 1¾ |
| February 9 | 6,435 | 1 |
| February 11 | 6,490 | 1¼ |
| | 6,565 | 1¾ |

| Date | Depth | Deviation Degrees |
|---|---|---|
| 1960—*continued* | | |
| February 12 | 6,620 | 1½ |
| February 13 | 6,770 | 2 |
| February 14 | 6,835 | 2 |
| | 6,925 | 3 |
| February 15 | 6,975 | 5 |
| February 16 | 7,010 | 7 |
| February 18 | 7,050 | 7 + |
| February 19 | 7,070 | 7¼ |
| February 21 | 7,110 | 7¼ |
| February 22 | 7,128 | 7¾ |
| February 23 | 7,156 | 7½+ |
| February 24 | 7,185 | 7½− |
| February 25 | 7,207 | Over 8 |
| February 26 | 7,312 | Over 8 |
| February 28 | 7,405 | Over 8 |
| February 29 | 7,480 | Over 8 |
| March 1 | 7,535 | Over 8 |
| March 4 | 7,647 | Over 8 |
| March 5 | 7,720 | Over 8 |
| March 6 | 7,783 | Over 8 |
| March 8 | 7,858 | 9¾ |
| March 9 | 7,910 | 9¾ |
| March 10 | 7,980 | 9¾ |
| March 11 | 8,040 | 9 |
| March 12 | 8,115 | 8½ |
| March 14 | 8,167 | 9 |
| March 15 | 8,230 | 9½ |
| March 16 | 8,290 | 9¾ |
| March 17 | 8,370 | 10 |
| March 18 | 8,440 | 9¼ |
| March 19 | 8,485 | 9 |
| March 20 | 8,485 | 9 |
| March 21 | 8,562 | 9½ |
| March 22 | 8,630 | 9½ |
| March 24 | 8,715 | 8½ |
| March 25 | 8,780 | 8¾ |
| March 26 | 8,842 | 9 |
| March 27 | 8,900 | 9¾ |
| March 29 | 8,971 | 9 |
| March 30 | 9,050 | 8¾ |
| April 2 | 9,125 | 8½ |
| April 4 | 9,205 | 8 |
| April 5 | 9,275 | 7¾ |
| April 6 | 9,335 | 8 |
| April 7 | 9,380 | 8 |
| April 9 | 9,458 | 7¾ |
| April 11 | 9,530 | 8 |
| April 12 | 9,585 | 8 |
| April 13 | 9,655 | 6½ |
| April 14 | 9,705 | 6 |

*See also* Plates 2–5.

*Temperature Surveys.*—After the 9⅝-in. casing was set at 4,028 feet, a temperature survey was run by Welex to 3,992 feet. The log of this survey may be consulted at the Bureau of Mineral Resources, Canberra.

Welex also recorded bottom hole temperatures on each run of electric logs, using a maximum reading thermometer placed in a special compartment in the electric sonde. Temperatures recorded in this manner, together with flowline temperatures and gradients, were as follows:—

FLOWLINE AND BOTTOM HOLE TEMPERATURES

(ASSUME 75° F. MEAN SURFACE TEMPERATURE.)

| Date | Depth Feet | Bottom Hole Temperature, ° F. | Gradient °/100 Feet | Flow Line Temperature, ° F. | Gradient °/000 Feet |
|---|---|---|---|---|---|
| 1959— | | | | | |
| December, 28 .. .. | 1,204 | 101 | 2.16 | .. | .. |
| 1960— | | | | | |
| January 8 .. .. | 4,028 | .. | .. | 142 | 1.61 |
| January 14 .. .. | 4,028 | 170 | 2.36 | .. | .. |
| January 26 .. .. | 5,025 | 177 | 2.03 | .. | .. |
| February 1 .. .. | 5,590 | 218 | 2.56 | .. | .. |
| February 5 .. .. | 6,073 | .. | .. | 174 | 1.63 |
| February 7 .. .. | 6,259 | .. | .. | 177 | 1.63 |
| February 10 .. .. | 6,452 | 232 | 2.43 | .. | .. |
| February 11 .. .. | 6,493 | .. | .. | 178 | 1.59 |
| February 12 .. .. | 6,588 | .. | .. | 178 | 1.57 |
| February 13 .. .. | 6,695 | .. | .. | 178 | 1.54 |
| February 14 .. .. | 6,833 | .. | .. | 182 | 1.57 |
| February 21 .. .. | 7,096 | .. | .. | 184 | 1.54 |
| February 25 .. .. | 7,200 | .. | .. | 186 | 1.54 |
| March 3.. .. .. | 7,556 | 240 | 2.18 | 187 | 1.48 |
| March 9.. .. .. | 7,900 | .. | .. | 190 | 1.46 |
| March, 20.. .. .. | 8,484 | .. | .. | 190 | 1.36 |
| March 26.. .. .. | 8,820 | .. | .. | 190 | 1.30 |
| March 27.. .. .. | 8,860 | .. | .. | 190 | 1.30 |
| March 30.. .. .. | 9,053 | 260 | 2.04 | .. | .. |
| April 2 .. .. .. | 9,125 | .. | .. | 192 | 1.28 |
| April 4 .. .. .. | 9,207 | .. | .. | 196 | 1.31 |
| April 9 .. .. .. | 9,410 | .. | .. | 198 | 1.31 |
| April 14 .. .. .. | 9,700 | .. | .. | 200 | 1.29 |
| April 17 .. .. .. | 9,824 | 268 | 1.96 | .. | .. |

*Other Well Surveys.*—No other well surveys or logs were run.

# GEOLOGY

## PREVIOUS WORK

*Geological.*—The Betoota structure was mapped during 1958 by geologists under contract to Delhi Australian Petroleum Ltd furnished by Geosurveys of Australia Limited. The geological report by Fitzpatrick and Wilson*, was made available to all interested parties. The mapping was of a reconnaissance type aided by air photos and mosaics. Fifteen east-west traverses were made across the structure to define it more closely, and scarp sections were measured on the eroded limbs, together with the dip, to provide correlation across the fold. The Betoota structure was shown to be a closed fold 36 miles long and 8 miles wide, the amount of closure being indeterminate due to lack of survey information (*see* Plate 1).

* Fitzpatrick, B. F., and Wilson, R. B.—Report on geological reconnaissance of the Betoota Structure. August, 1958.

*Geophysical.*—A seismic survey was conducted over the Betoota anticline in January 1959. It consisted of split correlation reflection seismic reconnaissance. The work was carried out by the Geophysical Department of the South Australian Department of Mines, under contract to Delhi Australian Petroleum Ltd, with supervision by both Delhi Australian exploration personnel and the Department's personnel.

Thirty holes were shot along two traverse lines, one across the wider part of the structure and the other lengthwise along it, the holes being 10,000 feet apart and covering 53.5 miles of line. Three thousand five hundred and fifty-nine feet of hole were drilled, the average depth being 118 feet.

Record interpretation and contour mapping were done separately by the Geophysical Department, Delhi-Taylor Oil Corporation, Dallas, Texas*, and the Geophysical Department, South Australian Department of Mines. Maps prepared include contour maps on the following horizons: " C2 " (near top of Cretaceous); " C3 " (near base of Cretaceous); and " P " (believed to be the unconformity near the top of the Palaeozoic). An isopach map, " C3 " to " P ", was also prepared.

*Drilling.*—No prior stratigraphic drilling was done on the Betoota structure.

## STRATIGRAPHY

120 feet–1,350 feet. (Thickness—1,230 feet +)

Winton Formation equivalent.

*Age:* Mesozoic (Cretaceous: Cenomanian).

Predominantly light grey, soft, silty, carbonaceous, micaceous shale, grading to grey, carbonaceous, slightly pyritic siltstone, minor amounts of "salt and pepper", fine to very fine grained, angular to subangular, soft, poorly consolidated to well cemented, slightly glauconitic, calcareous sandstone; scattered traces of grey to brown microcrystalline dense limestone.

*Palaeo interval:* 120 feet–1,350 feet.

1,350 feet–2,490 feet. (Thickness—1,140 feet)

Tambo Formation—probable equivalent.

*Age:* Mesozoic (Cretaceous: Albian).

Light to dark grey, soft, micaceous, carbonaceous, silty shale with some plant fragments: grey, soft, carbonaceous siltstone, grading to sandstone in places; lesser amounts of grey " salt and pepper ", fine to very fine grained, angular, poorly sorted, soft, friable sandstone, occasionally very calcareous and much harder; traces of grey to brown microcrystalline dense limestone.

*Palaeo interval:* 1,350 feet–2,530 feet.

No definite lithological break, but top of formation placed at first appearance of shell fragments.

2,490 feet–3,245 feet. (Thickness—755 feet)

Roma Formation equivalent.

*Age:* Mesozoic (Cretaceous: Aptian).

Light grey to greenish, fissile, micromicaceous, slightly pyritic, slightly calcareous monotonous shale, with shell fragments scattered throughout but extremely abundant around 2,500 feet, where shale also becomes very calcareous. *Inoceramus* prisms common throughout; scattered streaks of brown to white microcrystalline to medium crystalline dense limestone. From 2,700 to 2,800 feet prominent grey-green, very fine grained, soft, pyritic, very glauconitic sandstone.

*Palaeo interval:* 2,530 feet–3,240 feet.

No definite lithological break between Tambo and Roma Formation. Top of Roma placed where shale becomes very calcareous and shell fragments very abundant.

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* **Sanford, R. E.—Seismic reflection survey of the Betoota Dome Area, Queensland, Australia. February, 1959.**

3,425 feet–3,451 feet. (Thickness—206 feet.)

Blythesdale Group—possibly transition beds.

*Age:* Mesozoic (Lower Cretaceous—Jurassic).

Mainly dark grey, soft, shaly siltstone, carbonaceous in places, with minor light grey, very fine grained, slightly calcareous, glauconitic sandstone. Shale dark grey, hard, splintery, with few fish scales; little white, soft, clayey, bentonitic shale.

*Palaeo interval:* 3,240 feet–3,451 feet.

3,451 feet–4,196 feet. (Thickness—745 feet)

Blythesdale Group—possibly Mooga Sandstone equivalent.

*Age:* Mesozoic (Lower Cretaceous—Jurassic).

Light grey, fine to medium grained, angular, poorly sorted, mainly clear quartz sandstone to 3,570 feet, slightly calcareous, showing fair to medium porosity, but kaolin infilled in places. Dark grey, silty, splintery shale and light grey, fine grained, slightly glauconitic sandstone to 3,710 feet. Light grey, fine to coarse grained, angular to subangular, poorly sorted, poorly consolidated sandstone, with some chert pebbles and showing poor to fair porosity to 3,910 feet. Tan, soft, very silty, carbonaceous shale, with angular fragments of chert, passing into light grey, very fine grained, unconsolidated sandstone, with traces of gypsum.

*Palaeo interval:* 3,451 feet–4,200 feet.

4,196 feet–4,484 feet. (Thickness—288 feet)

Blythesdale Group—possibly Fossil Wood Beds equivalent.

*Age:* Mesozoic (Upper and Middle Jurassic).

Dark grey to brown, soft, very shaly, carbonaceous, micaceous siltstone, interbedded with light grey, fine to very fine grained, angular quartz sandstone, becoming clean, coarser and very unconsolidated toward base of formation. Two- to four-foot seams of coal at 4,202 feet and 4,310 feet.

*Palaeo interval:* 4,200 feet–4,484 feet.

4,484 feet–5,000 feet. (Thickness—516 feet)

Blythesdale Group—possibly Gubberamunda Sandstone equivalent.

*Age:* Mesozoic (Upper and Middle Jurassic).

Light grey to white, thickly and in part cross bedded, fine to coarse grained, angular to subangular, poorly sorted, clean quartz sandstone, with minor interbeds and streaks of dark grey to dark brown, micaceous, carbonaceous, silty shale. Sandstone varies from clean, very porous, to hard, tight, very calcareous.

*Palaeo interval:* 4,484 feet–5,000 feet.

5,000 feet–5,757 feet. Thickness—757 feet.

Walloon Coal Measures—possible equivalent.

*Age:* Mesozoic (Lower Jurassic).

Light grey to tan, very fine to fine grained, angular, carbonaceous, pyritic, clean quartz sandstone, with fair sorting and streaks of tarry substance or lustrous coal, interbedded with black to dark grey fissile, micromicaceous, very carbonaceous, waxy shale. Sandstone predominates at top and bottom of unit. Toward base, sandstone becomes very coarse and conglomeratic, with boulders 1½-in. across, and minor lenses of dark grey, silty, carbonaceous shale.

*Palaeo interval:* 5,000 feet to at least 5,600 feet.

Top of formation indefinite, but taken as first appearance of coalified wood.

5,757 feet–9,824 feet. (Thickness—4,067 feet +)

*Age:* Palaeozoic (pre-Jurassic).

Mottled dark to light green and brick red to maroon, fine to very coarse grained, angular to subangular, unsorted greywacke, of grains and fragments of reworked red siltstone and green, hard, shaly siltstone. Slickensiding and alignment of pebbles common.6,000–6,200 feet mainly red, soft, kaolinitic shale, red, slightly dolomitic, hard, silty shale, and green, hard silty shale. 6,200–8,700 feet red and green mottled, conglomeratic, ferruginous, chloritic greywacke, with boulders up to 4 inches long of red silty shale, green chloritic shale, and milky quartz, shear zones common, filled with quartz and calcite. From 8,700 to 9,400 feet generally red, green and tan conglomerate, boulders up to 12 inches across of red ferruginous quartzite, tan dolomitic quartzite, and green chloritic quartzite, showing much evidence of elongation and post-depositional movement. Matrix consists of mylonite with sericite, chlorite and crushed and drawn out pebbles cut by numerous calcite and dolomite veins. 9,400 to 9,824 feet red, grey and green conglomeratic greywacke, quartzitic, sericitic, chloritic, schistose and indurated, showing evidence of shearing, faulting and fracturing.

STRUCTURE

Surface geological mapping defined a long, fairly wide anticlinal structure, plunging at both ends and very slightly asymmetrical to the west. The fold is 36 miles long and 8 miles wide: the axis strikes north-north-east. Erosion has proceeded to the stage where the core of the anticline is now occupied by a broad, gently rolling plain, in part " gibber " covered, while the limbs stand up on either side as two irregular lines of cuesta scarps, strongly indented and even broken through in places. At the plunging ends, the topography is much depressed, but a few isolated mesas still remain to indicate the dip and strike of the strata. The limbs of the fold are held up by the silicified Tertiary sediments forming the hard " duricrust ". Wherever this is broken through, erosion is much more rapid, as the underlying strata consist of soft shales and siltstones, such as those in the core of the anticline, where the soft sediments of the Cretaceous Winton Formation are exposed.

Reflection seismic shooting confirmed the existence of the Betoota structure at depth and indicated that the anticline within the Mesozoic sequence generally conformed to the outline of the surface feature. Reflections from the " P " horizon indicated 2,000 feet of contourable closure in all directions, with the closing contour measuring 35 miles from north to south and 16 miles from east to west, giving a contourable area of 577 square miles. Below the " P " horizon, which on drilling the well proved to be the unconformity at the top of the " red beds ", the reflections were weaker and correspondingly more difficult to interpret.

Correlations which would lead to a greater understanding of the structure and general attitude of the beds cannot be attempted until further drilling in the Basin is undertaken. Data relevant to the actual attitude of the beds were derived from examination of the cores and from dipmeter surveys. Drilling established the exact depth to the various reflectors above, including the unconformity. This will aid in the re-evaluation of the seismic data.

Thirty-four cores were taken in the Betoota No. 1 well, and dipmeter surveys were run from 1,201 feet to 8,990 feet. Dips recorded by the dipmeter down to 5,730 feet varied from 5° to 14°, with the bulk of the readings around 8°. Two recorded dips (17° and 22°) were considered spurious. These dips suggest that the well was located slightly down the flank from the actual crest. At a depth of 5,757 feet the lithology of the strata changed suddenly and the recorded dips jumped suddenly to readings of 50° to 60°, indicating the presence of a strong unconformity, which had been suspected from results of the seismic work and correlation with Innamincka No. 1. Between 7,450 feet and total depth of 9,824 feet, the dip from dipmeter surveys and cores varied from 70° to 85°. Thus, the factual data relative to the attitude of the beds at the location of the Betoota No. 1 well are—

(1) The beds in the Mesozoic have gentle dips.

(2) There is a very pronounced angular unconformity at the base of the Mesozoic section.

(3) The pre-Mesozoic sediments dip very steeply. Although the drill penetrated 4,067 feet of these sediments, the true stratigraphic thickness is calculated to be only 1,057 feet.

Several interpretations can be placed on the known facts. Firstly, it has been established that a very considerable hiatus occurred between the deposition of the pre-Mesozoic " red beds " and the Mesozoic sediments and, further, that a strong unconformity exists between the two sequences. The following several postulations can them be made:—

(1) The axes of the Mesozoic and pre-Mesozoic structures coincide, but the structure in the older beds was eroded down to a zone of steeper dips which were accentuated during the Mesozoic diastrophism.

(2) The axes of the Mesozoic and pre-Mesozoic structures do not coincide, so that the culmination of the older structure may be offset from that of the younger. Consequently the bit drilled into the older structure well down on the steep flank.

(3) The structure in the "red beds" may bear no relation to the anticline in the Mesozoic sediments, the steep dips representing convoluted beds thrown into isoclinal folds.

(4) Renewed movement along an old fault plane in the pre-Mesozoic caused the formation of the surface anticline and the bit passed into the zone of steeply dipping dragged beds at the side of the old fault. The fault would have to be vertical or near-vertical to account for the consistently high dips over such a large interval (4,067 feet).

## Relevance to Occurrence of Petroleum

Only the strata in the immediate vicinity of Betoota No. 1 well from surface to total depth, 9,824 feet, will be dealt with under this heading, and the remarks made are limited to sediments in this vicinity.

It is generally held that petroleum is the product of the action of anaerobic bacteria on the remains of minute organisms of a low order and plant spores which accumulate on the floor of the basin of deposition. Marine conditions are a more favourable habitat for these organisms, and it follows that marine sediments, particularly shales and marls, are regarded as the most likely source rocks for oil. This does not exclude brackish-water sediments as sources for the generation of petroleum. The shales are usually dark coloured, contain organic matter, and are bituminous or carbonaceous or both. The close proximity of porous strata into which the oil, once generated, can move is also a pre-requisite for accumulation. Once in the porous beds, the oil may migrate for considerable distances from the source rocks.

With these various points in mind, the stratigraphic sequence penetrated in the Betoota No. 1 well was reviewed with regard to its relevance to the occurrence of petroleum. Several porous sandstone beds capable of acting as reservoirs were shown to exist, but no significant accumulations of oil or gas were found, all the porous zones being water-saturated. These porous zones were identified as aquifers previously known in the Great Artesian Basin. Therefore, it can be concluded that if any oil had been generated beneath the Betoota bore hole or had migrated there in times past, it has since been flushed out by water.

From the surface to 1,350 feet the well penetrated fine sandstones, siltstones, and lignitic shales of the Upper Cretaceous Winton Formation, a shallow water lacustrine deposit, with nothing to commend it as a source rock. There followed 1,895 feet (1,350 feet to 3,245 feet) of definite marine sediments. These belonged to the Tambo and Roma Formations of the Rolling Downs Group of Cretaceous age and consisted of grey, soft marine shales, minor siltstone, and traces of limestone bands. The section from 3,245 feet to 5,000 feet represented the Blythesdale Group equivalent of Cretaceous-Jurassic age and was composed of quartz sandstone with lesser amounts of carbonaceous shale and two thin coal seams. Traces of gas were picked up by the gas detector in this section and very slight " dead oil " staining was detected in the cuttings. This may have been derived from decayed plant material and from the coal seams. These beds are not regarded as source material for oil or gas. The Walloon Coal Measures equivalent from 5,000 feet to 5,757 feet was mainly an arenaceous sequence, but did contain an appreciable amount of dark grey to black, waxy, carbonaceous, and sometimes bituminous shale. A weak fluorescence and a little " dead oil " staining was noticed in the sandstone beds adjacent to bands of this shale. Although they are of brackish-water origin, it is felt that the shales in this formation are probable source beds for petroleum. Below the angular unconformity at 5,757 feet are 4,067 feet of red, green, tan and white conglomeratic greywacke, conglomerate, quartzite and indurated shale, all sheared, fractured, and dense. This lowest sequence was devoid of any organic, carbonaceous or bituminous material and, whether of marine or continental origin, can in no way be considered a petroleum source rock.

## Porosity and Permeability of Sediments Penetrated

Three methods of determining the porosity and permeability of the sediments penetrated were used during the drilling of the Betoota No. 1 well: visual examination, core analysis, and electric and radioactivity logs, the first being qualitative and the latter two quantitative. Each method is discussed briefly below.

*Visual Examination.*—The first indication of porosity in the strata penetrated (other than a possible increase in the drilling rate) can be seen in the cuttings under the microscope. The experienced wellsite geologist determines whether the rock is completely devoid of pore spaces and is dense and tight or whether voids exist. With further examination, he can grade the porosity as poor, fair, good, etc., and can also give a fair estimate of how much of the pore space is interconnected. These observations are noted with the lithological description on the stratigraphic log and thus an estimate of the porosity of the various formations is recorded as the well is drilling. This method is, of course, only qualitative and no accurate quantitative determination can be made by it.

*Core Analysis.*—Upon the recovery of a core, the wellsite geologist examines it for porosity and selects intervals on which determinations are to be made. Core Laboratories, Inc. then cuts cubes (plugs) from the core and analyses them at the wellsite. The plugs are selected so as to avoid any shaly partings which would lead to erroneous readings in an otherwise clean porous sandstone. This fact should be taken into account when comparing these porosity determinations with those from Welex logs.

*Electric and Radioactivity Logs.*—Selected intervals where porosity is found in the cuttings are chosen from the lithologic log and the porosities determined, using the radioactivity log and the figures checked against the electric log. Intervals where no porosity is observed in the cuttings are also calculated for comparison. Only the average porosity over each zone is obtained by this method. Determinations are made and averaged for 10-foot sections, and these in turn averaged out for 50-foot intervals. On the Betoota No. 1 well the Delhi wellsite geologist chose the intervals and the Welex engineer performed the analyses.

The neutron device 'sees' total porosity whether the voids are connected or not so that porosity determinations from radioactivity logs will represent total porosity rather than effective porosity, and may thus give an over-optimistic figure. The figures from logs will not necessarily agree with the core analyses figures because the latter are true effective porosity. Also, the plugs were selected to exclude all shaly material, whereas shale laminae were undoubtedly present in the intervals determined from radioactivity logs. This would have the effect of increasing the total porosity, whereas the effective porosity would have dropped.

| Depth | General Description | Radioactivity Log | | Core Analysis | |
|---|---|---|---|---|---|
| | | Interval | Porosity Average Percent | Interval | Porosity Effective Percent |
| 120–1,003 | Light grey, soft, silty, carbonaceous, micaceous shale and siltstone, with thin bands of "salt and pepper", fine to very fine grained, poorly consolidated sandstone | No calculations—tight, impervious | | | |
| 1,003–1,007 | Grey, fine grained, carbonaceous, calcareous sandstone | .. | .. | 1,003–1,004 | 36.1 |
| | | | | 1,004–1,005 | 8.8 |
| | | | | 1,005–1,006 | 8.1 |
| | | | | 1,006–1,007 | 6.3 |
| 1,007–1,510 | Light to dark grey, soft, micaceous, carbonaceous, silty shale and siltstone, with plant fragments, with "salt and pepper", very fine grained, friable sandstone and some brown, dense limestone | No calculations—tight, impervious | | | |
| 1,510–1,520 | Grey, very fine grained, glauconitic, slightly calcareous sandstone, with some calcareous shale | .. | .. | 1,510–1,511 | 26.3 |
| | | | | 1,515–1,516 | 28.4 |
| | | | | 1,519–1,520 | 34.9 |
| 1,520–3,470 | Light grey to green, fissile, micromicaceous, slightly pyritic and calcareous monotonous shale, with grey green, very glauconitic sandstone between 2,700 and 2,800 feet | No calculations—tight, impervious | | | |
| 3,470–4,196 | Light grey, fine to coarse grained, angular to subangular, clean quartz sandstone, with poor porosity and spotted yellow fluorescence. Dark grey, fissile, micaceous splintery shale | 3,470–3,490 | 26 | 3,553–3,554 | 16.7 |
| | | 3,494–3,520 | 16 | 3,555–3,556 | 16.4 |
| | | 3,520–3,560 | 26 | 3,556–3,557 | 18.3 |
| | | 3,570–3,728 | 22 | 3,557–3,558 | 12.9 |
| | | 3,745–3,830 | 16 | 3,558–3,559 | 17.7 |
| | | 3,830–3,860 | 20 | 3,559–3,560 | 15.1 |
| | | 3,875–3,894 | 23 | 3,560–3,561 | 19.1 |
| | | 3,950–3,980 | 25 | 3,561–3,562 | 18.9 |
| | | 4,000–4,050 | 12 | 3,562–3,563 | 18.3 |
| | | 4,050–4,100 | 11 | 3,907–3,908 | 12.3 |
| | | 4,100–4,150 | 11 | 3,914–3,914.5 | 14.6 |
| | | 4,150–4,196 | 5 | .. | .. |

| Depth | General Description | Radioactivity Log | | Core Analysis | |
|---|---|---|---|---|---|
| | | Interval | Porosity Average Percent | Interval | Porosity Effective Percent |
| 4,196–4,208 | Grey, very fine grained, shaly sandstone with coal | No calculations—tight, impervious | | | |
| 4,208–4,212 | Grey, fine to medium grained, angular to subangular, poorly sorted, carbonaceous, mainly clean quartz sandstone, with fine shale partings, poor porosity | .. | .. | 4,208–4,209 | 12.0 |
| | | | | 4,209–4,210 | 16.6 |
| | | | | 4,210–4,211 | 16.5 |
| | | | | 4,211–4,211.3 | 16.5 |
| 4,212–4,490 | Light grey, fine to coarse grained, angular carbonaceous sandstone, poorly consolidated, and dark grey, carbonaceous siltstone and shale | No calculations—tight, impervious | | | |
| 4,490–4,830 | Light grey to white, fine to coarse grained, angular to subangular, poorly sorted clean quartz sandstone, with, in places, very good porosity, occasionally calcareous, thin interbeds of shale and siltstone | 4,490–4,500 | 21 | 4,697–4,698 | 16.2 |
| | | 4,500–4,550 | 15 | 4,698–4,699 | 14.1 |
| | | 4,550–4,600 | 19 | 4,699–4,700 | 13.1 |
| | | 4,600–4,650 | 18 | 4,700–4,701 | 14.5 |
| | | 4,650–4,700 | 18 | 4,701–4,702 | 14.3 |
| | | 4,700–4,750 | 13 | 4,702–4,703 | 13.4 |
| | | 4,750–4,800 | 13 | 4,703–4,704 | 14.3 |
| | | 4,800–4,830 | 8 | 4,704–4,705 | 12.8 |
| | | .. | .. | 4,784–4,785 | 16.9 |
| | | .. | .. | 4,785–4,786 | 16.6 |
| | | .. | .. | 4,786–4,787 | 15.9 |
| | | .. | .. | 4,787–4,788 | 9.9 |
| | | .. | .. | 4,788–4,789 | 7.1 |
| | | .. | .. | 4,789–4,790 | 5.9 |
| | | .. | .. | 4,793–4,794 | 8.4 |
| | | .. | .. | 4,794–4,795 | 22.4 |
| | | .. | .. | 4,795–4,796 | 7.0 |
| | | .. | .. | 4,797–4,797.3 | 20.6 |
| | | .. | .. | 4,797.3–4,798 | 4.9 |
| 4,830–4,860 | Light grey, medium to coarse grained, angular, poorly sorted, shaly sandstone, thinly interbedded with dark brown, carbonaceous, silty shale | No calculations—tight, impervious | | | |
| 4,860–5,170 | Light grey to white, medium to coarse grained, angular to subangular, clean calcareous quartz sandstone, with minor interbeds of dark grey carbonaceous shale | 4,860–4,900 | 14 | .. | .. |
| | | 4,900–4,950 | 13 | .. | .. |
| | | 4,950–5,000 | 6 | .. | .. |
| | | 5,000–5,050 | 4 | .. | .. |
| | | 5,050–5,100 | 9 | .. | .. |
| | | 5,100–5,140 | 13 | .. | .. |
| | | 5,140–5,170 | 5 | .. | .. |
| 5,170–5,220 | Mainly black, fissile, micaceous, waxy, carbonaceous shale, with minor thin bands and lenses of calcareous siltstone | No calculations—tight, impervious | | | |

| Depth | General Description | Radioactivity Log | | Core Analysis | |
|---|---|---|---|---|---|
| | | Interval | Porosity Average Percent | Interval | Porosity Effective Percent |
| 5,220–5,650 | Black to dark grey, fissile, carbonaceous, waxy shale and interbedded fine grained, tan, carbonaceous, pyritic, clean quartz sandstone, becoming coarser grained downward. Occasional poor porosity | 5,220–5,230 | 20 | .. | .. |
| | | 5,230–5,270 | 9 | .. | .. |
| | | 5,270–5,300 | 17 | .. | .. |
| | | 5,300–5,350 | 9 | .. | .. |
| | | 5,350–5,400 | 11 | .. | .. |
| | | 5,400–5,450 | 12 | .. | .. |
| | | 5,450–5,490 | 8 | .. | .. |
| | | 5,490–5,500 | 12 | .. | .. |
| | | 5,500–5,600 | 5 | .. | .. |
| | | 5,600–5,650 | 7 | .. | .. |
| 5,650–5,910 | 5,650–5,757—as for previous depth; 5,757–6,910—red and grey mottled, fine to very coarse and conglomeratic, ferruginous, sericitic, indurated greywacke | No calculations—tight, impervious | | | |
| 6,910–6,940 | Red and green mottled conglomerate of sub-rounded boulders of red, silty shale and green, siliceous shale in mylonite matrix, dense, well indurated. Shear zones and fractures common | 6,910–6,940 | 11* | .. | .. |
| 6,940–9,824 | Red and green mottled conglomeratic greywacke and conglomerate, ferruginous, sericitic, chloritic, mylonite common, schistose, indurated, dense, sheared and fractured | No calculations—tight, impervious | | | |

* This reading is of doubtful value as, though the fractures in the rock would give some porosity, the large amount of shaly material in the boulders would tend to give a much higher reading. It is to be noted that a drill stem test run including this interval recovered only watery drilling mud.

## Contribution to Geological Concepts

Delhi-Frome-Santos Innamincka No. 1 well was the first deep well drilled in the south-western portion of the Great Artesian Basin, the results of which established a stratigraphic sequence for this general region.* As this well is the only source of information in the Lower Mesozoic and Palaeozoic sequence in this region, it is inevitable that the results of subsequent exploration, either drilling or seismic work, will be related to the geological picture as found in the Innamincka No. 1 well. Any discussion on the results of the Betoota No. 1 well resolves itself into a comparison with the Innamincka well. It is therefore proposed to compare and contrast the two wells and thereby reveal in a very broad sense the geological changes, both lateral and vertical, which have taken place in the regions of both wells. It must be understood that any interpretation based solely on the information from two rather widely separated wells must be of the broadest and most general nature.

The drilling of Innamincka No. 1 established the existence of a geological succession of beds which compared quite well with the stratigraphical column worked out by Whitehouse for the eastern margin of the Great Artesian Basin. The sequence found in the

* *Petroleum Search Subsidy Acts Publication No. 9.*

Betoota No. 1 well agreed closely with the Innamincka No. 1 well lithologic log down to the base of the Lower Jurassic. Probable equivalents of the Winton, Tambo and Roma Formations, the Blythesdale Group and the Walloon Coal Measures could all be identified; in fact, the Blythesdale Group in the Betoota well could be broken down into its four members as described by Whitehouse* and others, i.e., Transition Beds, Mooga Sandstone, Fossil Wood Beds, and Gubberamunda Sandstone, palaeontological evidence being relied on greatly for the determination of the unit boundaries. These latter divisions were not so apparent in the Innamincka well. Below the Jurassic, the logs of the two wells are totally different. In Innamincka No. 1, Triassic-Jurassic Marburg Formation, Triassic Bundamba Series and Moolayember Shales and Permian strata were present, but in Betoota No. 1 these were entirely lacking. In Innamincka No. 1, a thick series of " red beds " thought to be of Devonian age were present below the Permian, whereas in Betoota No. 1 these were absent, the Mesozoic sediments resting directly on a steeply dipping series of red and green conglomeratic greywacke. Petrological studies show the matrix of this conglomeratic greywacke to be partially altered; whether this alteration is regional or local is unknown and cannot be determined, and whether it is a result of both heat and pressure or whether one or the other predominated is equally obscure. This series is over 4,000 feet thick, with a sedimentary break at 8,700 feet. The boulder conglomerate below this depth is suspected from petrological studies to be the source material for the beds above. No fossils were found in these beds, so their age cannot be determined; however, they appear to be much older than the " red beds " at Innamincka.

Considering these factors, certain conclusions may be drawn as to past geological conditions in the Betoota area. It can be postulated that either (1) there existed a strong high area of pre-Innamincka " red bed " age which remained an island in the Betoota region throughout at least Middle and Upper Palaeozoic time, being finally overwhelmed in the Middle Mesozoic. Thus, while the Innamincka region was under Palaeozoic seas and receiving sediments, the Betoota area could have been a land mass undergoing erosion which could have contributed sediments to the Innamincka region to form the " red beds " there; or, (2) the Betoota region received a normal accumulation of Palaeozoic sediments, and an orogeny of pre-Middle Mesozoic age uplifted the Betoota area, which was subsequently deeply eroded prior to Middle Mesozoic deposition. When the Betoota area was again inundated, the first deposits were coarse grits and conglomerates some 70 feet thick of doubtful age, as no fossils were found in them. For the present, they have been included in the Lower Jurassic. The sedimentary history is approximately the same as Innamincka from the Lower Jurassic upwards. First, swampy conditions obtained, which resulted in the formation of the Walloon Coal Measures. Following this were several stages of sedimentation in a partly land-locked sea where the water was brackish. In Aptian and Albian times the open oceans had greater access to the region and marine shales were laid down. Cenomanian times saw a retreat of the seas, and lacustrine conditions prevailed in the Winton Lake. Deposition of freshwater sediments in shallow Tertiary lakes brought the sedimentary history of the region to a close.

The only new rock unit encountered in the Betoota No. 1 well is the conglomeratic greywacke and boulder conglomerate below the unconformity at 5,757 feet. It is not proposed to name this unit until more data are accumulated concerning its age, distribution. and relationship to the Palaeozoic and Proterozoic rocks.

* Whitehouse, F. W., 1954.—The geology of the Queensland portion of the Great Australian Artesian Basin. *Appendix G* to Artesian water supplies in Queensland. *Brisbane Gov Printer*

# APPENDIX 1

## PETROGRAPHIC EXAMINATIONS OF CORE SAMPLES

*All the following petrographic reports are by the Australian Mineral Development Laboratories (A. W. Whittle, Chief Mineralogist and Petrologist) except that of the Core at 7,164 feet, which is by B. R. Houston, Geological Survey of Queensland.*

### CORE, 4,785 FEET: SAMPLE P56/60

The rock is a quartz sandstone cemented by fine-grained, iron-stained calcite with variable amounts of pink garnet, some feldspar and sericite, and accessory apatite. Quartz comprises 80% of the rock, calcite 10%, garnet 10%, feldspar 5% and sericite 2%.

The quartz grains are commonly rounded and vary in size from 100 microns to 5 mm. A number of grains are strained, indicating possible mechanical stress.

Calcite cements and partially replaces quartz, garnet and feldspar. A few shattered grains of quartz have been invaded by calcite.

The garnet displays rounded shape and an average grain diameter of 500 microns.

Twinned plagioclase feldspar is a minor constituent and commonly shows alteration to sericite.

### CORE, 5,969 FEET; SAMPLE P68/60

This is a highly siliceous and ferruginous conglomerate consisting of well rounded pebbles of clastic rocks and a poorly sorted matrix. The rock fragments range in size from about 1 mm. to 0.5 inches in diameter and are composed of a high proportion of fine-grained quartz.

There are the following types of rocks in this sediment:—quartz-sericite and quartz-clayey siltstone, sericite-chloritic siltstone, chloritic slate, pebbles of sandstone, quartzite and particles of strained quartz. All these rocks are impregnated with iron minerals and constitute approximately 70–80% of the bulk.

The cementing medium consists principally of fine sericite and chlorite with unsorted particles of quartz scattered throughout.

### CORE, 6,447 FEET: SAMPLE P67/60

COMPOSITION

| | |
|---|---|
| Major Constitutents .. .. .. .. .. | Sericitized feldspar<br>Quartz |
| Minor Constituents .. .. .. .. .. | Quartzite<br>Siltstone<br>Slate<br>Limonite<br>Goethite<br>Leucoxene |

TEXTURE

Subangular-subrounded grains of stressed quartz and highly sericitized feldspar, 150–500 microns across, together with sparse rock fragments up to 1 mm., occur in a matrix of sericite and limonite. Locally the sericitized feldspar has been partly replaced by goethite and limonite.

CLASSIFICATION

Arkose. There are traces of replacement by iron oxide, possibly following stress and hydrothermal alteration of the feldspar.

### CORE, 7,024 FEET: SAMPLES P117/60, P118/60

This is a massive and highly siliceous conglomerate impregnated by iron oxide. The bulk of the rock consists of a mass of secondary silica, coarse grained crushed quartz and variously shaped pebbles of sedimentary rocks. The matrix is an extremely fine mass of chloritic-sericitic matter. The coarse-granular structure of the conglomerate shows in places a conspicuous deformation due to shearing stress and crushing. Evidence of metamorphism is seen in the development of sericitic-chloritic matter and in the development of " strain " extinction in the fragments of quartz. The rock pebbles are composed principally of arenaceous clastic deposits with minor chloritic and sericitic slates. Iron oxide heavily impregnates the rock and is associated with all constituents of the sediment. Secondary calcium carbonate in the form of thin veins intersects the rock in various directions.

The metamorphic status is low.

## CORE, 7,073 FEET, 7,089 FEET, 7,156 FEET, 7,166 FEET

P140/60—7,073 FEET

This is a ferruginous quartz-sericitic conglomerate consisting of quartz and a great deal of rock fragments embedded in a chloritic-sericitic matrix. The rock fragments are commonly fine textured sediments. These include—quartz-sericite or hematite-quartz siltstones, slates and fine-grained sandstone. The rock fragments are well rounded, sometimes subangular and often lenticular in form. The sediment is strongly contaminated with iron oxide (hematite) which is present in the form of finely disseminated material or thin veinlets.

P141/60—7,089 FEET

This is a coarse-textured conglomerate similar in its mineral composition to P140/60. The dominant constituents of this rock are large, well-rounded particles of quartz and fragments of clastic sediments (siltstone, sandstone and slate). The rock is intersected by veins of iron minerals and calcium carbonate. The matrix is composed of chlorite-sericite and fine granular quartz intermixed with iron minerals.

P142/60—7,156 FEET

This is a slightly ferruginous chloritic-sericitic siltstone. The groundmass of this rock has a fine and uniform-granular appearance and consists principally of quartz closely set in a chloritic-sericitic matrix. The rock is intersected by a thick vein of calcitic dolomite and thin veinlets of hematite. In places the rock also contains heavy mineral bands which are composed mainly of zircon and opaque minerals.

P143/60—7,166 FEET

This rock is similar in its mineral composition to those above but shows a notable disturbance in its structure due to shearing stress. The rock is highly siliceous and ferruginous. It consists principally of siltstone fragments and pebbles of sericitic slate embedded in a quartz-sericite matrix. Most rock fragments are flattened out in a long lenticular form and interbedded with chloritic-sericitic or fine quartzitic material. Iron minerals heavily impregnate the rock throughout.

All three rocks are of low-grade metamorphic status.

## ROCK FROM DELHI-FROME-SANTOS BETOOTA No. 1, 7,164 FEET

A very thinly-bedded, dark-red rock in which quartz grains and rock fragments can be identified. Several fragments of red, argillaceous material up to 2 cm. long, at least, occur on the surface.

MICROSLIDES GSQ 196, 197

The texture of the rock is dominated by the shape and packing of the dominant constituent—approximately 60–70% ellipsoidal fragments of argillaceous material, mostly sericite and chlorite. The fragments are well sorted, average 1 mm. x 0.25 mm. in size, are very closely packed, lie with their long axes parallel and tend to be concentrated in layers. The coarse fragments seen in hand specimen have the same orientation as this finer material. They are of quartz siltstone, consisting of about 60% quartz grains with minor feldspar, clastic mica, green chlorite and translucent material, possibly iron-stained quartz in an argillaceous matrix. The bedding is micro-graded, with a concentration of hematite at the base of the beds and at the margins of the fragments.

Along with the lithic fragments, the rock also contains 40–30% well-sorted, subrounded, quartz grains (average 0.06 mm.) together with about 2% subrounded quartz grains (average 0.5 mm.), and less than 1% subrounded fragments of quartzite, up to 0.75 mm. The quartz grains tend to be concentrated in narrow, irregular bands between the layers in which the rock fragments are concentrated. Layers of each type of phenoclast contain a small percentage of the other type.

There appears to be an argillaceous matrix present also; this is almost impossible to distinguish from the argillaceous rock fragments. There is an abundance of opaque grains and dust; much of this material is hematite.

NOTE.—The texture of the rock, especially with respect to the rock fragments, indicates that it may be slightly schistose. The sericite and chlorite may indicate embryonic metamorphism. As there is no definite evidence of recrystallization, it is assumed that the rock has undergone normal diagenetic processes only.

*Name.*—Lithic sandstone.

## CORE, 8,294–5 FEET: SAMPLE P196/60

The section of core examined consisted of a well-defined shear (at 10–20° to the core axis) which passes through red rock.

Sections were cut across the wall rocks as well as across the shear.

### The Wall Rocks

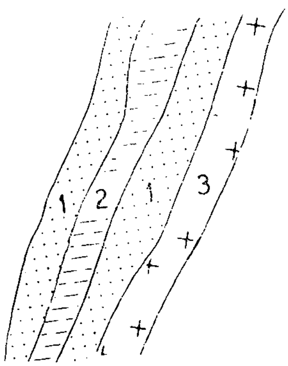
The rocks bordering the shear are of three types, viz.:—

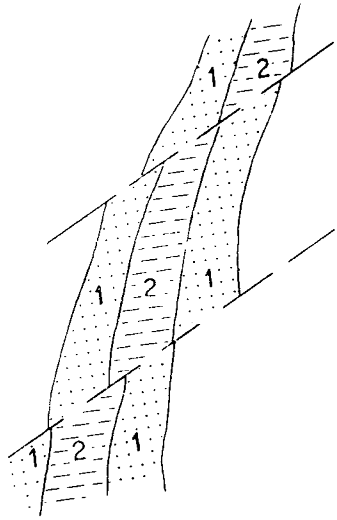
(1) Dark red fine grained highly ferruginous, silty, sericitic quartzite.

(2) Very finely mottled red-green fine-grained greywacke varying to slate within its fine laminations. This pelitic facies carries angular detrital quartz and is differentially ferruginized by limonite.

(3) Pale pink-brown greywacke which consists largely of pelitic material with very low quartz content. Its paler colour is due to a weaker ferruginous content.

All these rock types are intersected by micro-shears consisting of lineated aggregates of sericite and chlorite which are parallel to the principal shear. Furthermore, these diverse lithological types may be considered to have been a closely laminated interbedded group which, due to low angle shears crossing the bedding, has been split up into an en echelon group of affected beds thus—




### The Principal Shear

This consists of several inches of compacted strongly lineated sericite and newly formed chlorite incorporating fractured, displaced, dragged out fragments of rock types (1), (2) and (3). The whole of this mylonitized mass is impregnated by secondary calcite.

Chlorite is prominent, appearing dark green in the hand specimen, and may be regarded as having formed under severe stress by reaction of ferruginous matter and sericite.

### Conclusion

Comparison of the lithology of rock types (1), (2) and (3) with that of the pebbles of the conglomerate at, say, 7,086 feet, and with the " secondary " greywacke at 7,557 feet and at 7,785 feet, lead to the conclusion that the rock at 8,294 feet is the source bed of these pebbles and overlying fragmental greywackes.

## CORES 13, 16, 20, 26, 27, 28: SAMPLES P181/60–P187/60

### Density Values

| | | | |
|---|---|---|---|
| Core 13 | 5,217 feet .. .. .. .. | 2.55 gm./c.c. | P181/60 |
| Core 16 | 5,836 feet .. .. .. .. | 2.67 gm./c.c. | P182/60 |
| Core 20 | 7,017 feet .. .. .. .. | 2.74 gm./c.c. | P183/60 |

### Orientation Determination

The pebbles in the conglomerate are predominantly of lenticular shape. They lie in approximate parallelism and at an angle of 10–15° to the core axis. The pebbles consist of fine-grained siltstone and of sericitic slate containing limonite pseudomorphs after pyrite.

The matrix consists of sericite, silt, finer or coarser quartz detritals and fragments of slate and siltstone, irregularly impregnated by limonite. The disposition of sericite flakes and the general orientation of inequidimensional rock fragments within the matrix is similar to that of the large conglomerate pebbles. Most granular quartz in the matrix is irregular in shape, seldom lenticular or well rounded, and lies at random orientation.

There is incipient recrystallization of fine felted sericite in the matrix to form locally continuous larger flakes.

Calcite veins cross-cut the matrix and the pebbles alike. It is therefore a post dynamic metamorphic phenomenon. The limonite which impregnates the rock occurs irregularly in the matrix and commonly along the peripheries of the larger pebbles. Where limonite and cross-cutting calcite veins meet, the limonite intersects the calcite indicating that ferruginization is even more recent than carbonatization of the sediment.

CORE 26—DEPTH 7,557 FEET—P185/60

This is a rock of uniform granularity and is to be regarded as greywacke. It consists principally of slate fragments mingled with subordinate detrital quartz, or of ferruginous quartzite, the average grain size of which is 0.4 mm. There is a minor quantity of detrital tourmaline and zircon.

Thin, sheet-like veins of calcite-chlorite intersect the rock. This chlorite is visible on fractured faces of the drill core.

The rock has virtually no matrix; the detrital grains are of highly irregular size and are accumulated in tightly packed fashion. There is no evidence of shear stress.

CORE 27—DEPTH 7,785 FEET—P186/60

This rock is a greywacke which is comparable with the material at 7,557 feet but with minor distinctions. It has a small amount of finer granular quartz which forms a matrix. The pebbles of slaty material are augmented by small amounts of dark coloured highly ferruginous fine-grained quartzite or siltstone. Aggregates of chlorite occur in the rock as individuals or as chloritic quartzite grains.

There is weak bedding in the rock due to incipient parallelism amongst elongate slaty grains. This bedding is nearly parallel to the core axis.

CORE 28—DEPTH 8,043 FEET—P187/60

This is also a greywacke, but differs in that it displays quite well developed bedding which is not readily apparent in the rough drill core. The bedding is at 10–20° off the direction of the core axis.

In thin section, the laminations consist of alternations of greywacke of the type found at 7,557 feet and 7,785 feet with a much finer grained, more strongly quartzitic greywacke which contains blue tourmaline and green chlorite. These slightly green beds vary up to ¼ inch in thickness. The components of the sediment are irregular in shape and form a heterogeneous aggregate of quartz grains, slaty grains and ferruginous silty and quartzitic grains in subordinate quartz-sericite matrix.

### CORES 30, 31, 32: THIN SECTIONS 6227, 6312, 6313, 6314

CORE 30 AT 8,494–95 FEET—T.S. 6227

A coarse conglomerate, consisting of red and green pebbles in a shaly matrix.

The red pebbles consist of rounded fragments of quartz, quartzite, sericitic sandstone and siltstone. Many of them have a skin of hematite or peripheral zone of hematite impregnation. In parts this zone has been abraded, indicating that the pebbles were more or less in their present state of rounding and oxidation prior to deposition, and that only a small amount of abrasion occurred during their subsequent transport and deposition.

Similarly, the pale green pebbles, which are predominantly sericitic shale, are rounded and " bent ", indicating that they were probably soft and plastic at the time of deposition. With increasing hydrostatic pressure due to accumulating sediments, the shale fragments were squeezed out into available spaces between harder fragments. Sedimentary layering is discernible in the shale and is in most cases conformable with the general layering of the rock (i.e., parallelism of the long axes of the pebbles). Microshear, are localized around larger and harder fragments and only very minor recrystallization of the sericite has taken place. Crystalline dolomite has penetrated along the microshears and also into some of the pebbles, as veinlets. This evidently represents a comparatively late-stage phenomenon.

CORE 31 AT 8,786 FEET—T.S. 6312

The coarseness of this conglomerate makes the term boulder bed more appropriate. The original rock is similar in every detail to Core 30. However, there is evidence of fairly widespread moderate cataclasis which post-dates the dolomite veinlets, and has resulted in further squeezing out of the matrix, with limited recrystallization of sericite to larger flakes of muscovite. Some of the pebbles have been fractured along planes of weakness (e.g., dolomite veinlets), but there has been no great displacement. Peripheral granulation of some dolomitized sericitic sandstone pebbles has occurred, resulting in a marginal zone of crypto-crystalline quartz, sericite and dolomite.

CORE 32 AT 9,128 FEET—T.S. 6313 + 6314

A red and green conglomerate, basically very similar to Core 30. Effects of cataclasis are evident in hand-specimen in the same way as in Core 31. In fact, this core is essentially the same as Core 31; however, one important feature is present here. Some of the pebbles are spotted slates or phyllites of greenschist facies; they consist of weakly lineated aggregates of sericite, micro-augen of chlorite, very fine-grained black opaques, quartz and " spots " of limonite. The presence of low-grade metamorphic rocks in the core could indicate the erosion of a Proterozoic terrain.

## CORE 33: SAMPLE P344/60

At 9,386 feet 6 in.——T.S. 6325

A fine-grained sandstone to siltstone, strongly ferruginous and micaceous; tourmaline is conspicuous. Quartz fragments are angular to subangular, sericite is weakly lineated and very abundant. Narrow sericitic shear zones traverse the rock, and are associated with patches and veins of cloudy dolomite. Younger veinlets of clear dolomite cut across earlier ones and across shear zones. The effect of cataclasis in relatively incompetent rocks such as this one may not be very marked, even though it is fairly widespread.

At 9,401 feet——T.S. 6326

This core consists of large shattered fragments of quartzite and vein quartz, showing signs of stress and distortion. The fragments have been dolomitized prior to cataclasis and dynamic metamorphism. Smaller fragments of sericite shale, with very conspicuous blue and green tourmaline, sphene and zircon, have also been subjected to strong stress and have acquired strong lineation and subparallel microshears. Diagenetic dolomite patches and veins have been shattered. The whole core is cracked approximately perpendicular to its general structure (and axis).

At 9,404 feet——T.S. 6327

Large pebbles are embedded in a ferruginous, silty matrix. The pebbles consist of quartzite with pronounced medium grained mosaic texture, conspicuous green tourmaline and patches of fine-grained hematite. Extensive shear-zones surround the pebbles and extend into the matrix. They consist of contorted, lineated sericite, cloudy dolomite, fine-grained quartz and cryptocrystalline silica. The matrix is a ferruginous, sericite sandstone grading into siltstone; graded bedding is evident. Most fragments of quartz are angular, sericite is in subparallel allgnment, and heavy minerals (especially green tourmaline) are conspicuous. Fine-grained hematite is abundant throughout. Veinlets of quartz-dolomite run roughly parallel to bedding and appear to be contemporaneous with and later than the shearing.

At 9,407 feet——T.S. 6328

This rock is essentially the same as the matrix described above (9,404 feet). It shows conspicuous bedding and graded bedding, and small-scale slumping or scouring. Shearing appears to be limited to distortion of bedding, increased lineation of sericite, and slight bleaching of portions of the ferruginous rock.

## CORE 34: SAMPLE 380/60

The rock consists of bands of fine-grained sericite quartzite which alternate with bands of ferruginous siltstone. The sericite quartzite consists of subangular grains of quartz in a matrix of fine sericite and occasional patches of dolomite. Occasional tourmaline, zircon and opaques are also present. These bands of quartzite exhibit graded bedding and pass into bands of siltstone which consist of angular and subangular grains of quartz in a matrix of fine sericite and fine-grained opaques.

There is evidence of intraformational slumping within the rock.

# APPENDIX 2

## SUBSURFACE STRATIGRAPHY AND MICROPALAEONTOLOGICAL STUDY

By

N. H. LUDBROOK*

This report presents lithological and stratigraphic data based on identification of foraminifera and other microfossils. The determination of a Lower Jurassic age for the carbonaceous siltstones at 5,214 to 5,230 feet (Core 13) was made by Dr. N. J. de Jersey of the Geological Survey of Queensland. Both core and cutting samples were examined over the whole sequence; cores were taken at approximately 500-ft. intervals and cuttings at 10-ft. intervals.

The micropalaeontological log was drafted by Mrs. A. O. Wolverson of the Geological Survey of South Australia.

### STRATIGRAPHY

Stratigraphic units present in Betoota No. 1 Well are as follows:—

| | | | Depth (feet) |
|---|---|---|---|
| *Cretaceous—* | | | |
| Winton Formation | | Cenomanian | 120–1,350 |
| Tambo Formation equivalents | | Upper Albian | 1,350–1,850 |
| | | Middle Albian | 1,850–2,560 |
| Roma Formation equivalents | | Aptian | 2,560–3,240 |
| Transitional Beds | | Aptian to Neocomian | 3,240–3,451 |
| *Jurassic—* | | | |
| Blythesdale Group | Equivalents of Mooga Sandstone | Upper and (?) Middle Jurassic | 3,451–4,196 |
| | " Fossil Wood Beds " | | 4,196–4,484 |
| | Gubberamunda Sandstone | | 4,484–5,000 |
| Equivalents of Walloon Coal Measures | | Lower Jurassic | 5,000–5,500 |
| and ? Marburg Formation | | | 5,500–5,757 |
| (?) *Lower Palaeozoic or Upper Proterozoic Rocks* | | | 5,757–9,824 |

As in Innamincka No. 1 Well, only the Cretaceous sediments carried foraminifera. The Jurassic rocks and the ferruginous conglomerate and sandstone below the unconformity were of non-marine origin and completely devoid of marine fossils.

### CRETACEOUS

The Cretaceous microfaunal sequence is tabulated in Table 1. The sequence is similar to that in Innamincka No. 1 Well so far as the foraminifera are concerned except that species characterizing the basal part of the Aptian are very rare or absent. Table 2 compares the first appearance of each species in Betoota with its first appearance in Innamincka.

Megafossils are scarce. *Inoceramus* is recognized from prisms in cores and cuttings, and a few fragments of *Aucellina* are present in the Albian section. However, the sequence has been entirely determined on the foraminifera, which are less abundant than, and poorly preserved by comparison with, the Innamincka assemblages.

CENOMANIAN: WINTON FORMATION (Thickness 1,230 feet)

From 120 feet, where the first samples were taken, to 1,350 feet the well intersected green-grey arkosic calcareous sandstones and siltstones, carbonaceous calcareous mudstone with some coal, and limestone of the Winton Formation. Iridescent megaspores and characteristic megaspores of the water fern *Azolla* were present at somewhat irregular intervals. No foraminifera were observed, and the formation is considered to have been deposited in freshwater lagoons.

UPPER ALBIAN (Thickness 500 feet)

The top of the Albian is placed at 1,350 feet, where the first shell fragments and *Inoceramus* prism appeared. The well here entered grey carbonaceous mudstone, calcareous siltstone and carbonaceous siltstone with *Inoceramus* and other molluscan fragments, ostracods, and a few species of arenaceous foraminifera. None of the species are restricted, all continuing downwards into the middle Albian.

*Azolla* is also present in this interval.

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* Department of Mines, South Australia.

Middle Albian (Thickness 710 feet)

Below 1,850 feet the well entered the grey calcareous pyritic siltstone and mudstone with pyritic limestone near the base, which are dated as middle Albian. The microfauna consists largely of small calcareous species dominated by *Globigerina* sp. 4, which is restricted to this level in uncontaminated material. Near the base of the formation, *Globigerina* is almost the only fossil present.

The upper and middle Albian sediments belong to the Tambo Formation.

Aptian: Roma Formation (Thickness 680 feet)

At 2,560 feet a sharp lithological and faunal change occurs; relatively abundant arenaceous foraminifera, including *Verneuilina howchini* and *Ammobaculoides romaensis*, appear in grey mudstone and siltstone with pale green glauconite. *Haplophragmoides chapmani* and *Bigenerina loeblichae* follow within the next 50 feet. *Patellina jonesi*, *Ammobaculoides coonanaensis* and *Textularia anacooraensis* (one individual only) make their first appearance towards the base of the formation in approximately the same order as in the Innamincka and Oodnadatta wells.

Aptian-Neocomian Transitional Beds (Thickness 211 feet)

The base of the Aptian was poorly fossiliferous, and most of the foraminifera normally occurring at this level were represented by single individuals only. At 3,240 feet the first chips of buff arkosic sandstone appeared with carbonaceous micaceous siltstone. *Textularia anacooraensis* was present at 3,260–3,270 feet. The beds are believed to straddle the Aptian-Neocomian boundary.

## JURASSIC

At 3,451 feet the well passed out of the marine and paralic Cretaceous into the non-marine sandstones of the Blythesdale Group.

Upper Jurassic Equivalents of Mooga Sandstone (Thickness 745 feet)

Between 3,451 and 4,196 feet the well intersected strongly cross bedded fine to medium grey-white quartz sandstone irregularly banded with carbonaceous siltstone laminae. The quartz grains are tightly packed, usually with little cementing material. They are very little worn and commonly show crystal faces. The sandstone appears to be equivalent to the Mooga Sandstone.

? Middle to Upper Jurassic Equivalents of the " Fossil Wood Beds " (Thickness 288 feet)

Below 4,196 feet siltstone and fine calcareous arkosic sandstone occur, with coal bands at 4,190 feet and 4,310 feet. These seem to correspond to the " Fossil Wood Stage " of Reeves (1947, page 1347) and Fossil Wood Beds of Whitehouse (1954, Fig. 12).

?Middle Jurassic Equivalents of Gubberamunda Sandstone (Thickness 516 feet)

At 4,484 feet the well passed into a distinctive dirty buff to brownish grey crossbedded sandstone consisting of coarse angular quartz grains with fractured surfaces, abundant pink garnets, and some apatite, in a silty and calcareous matrix. This sandstone was not present in Innamincka Well. It is believed to be equivalent to the Gubberamunda Sandstone.

Lower Jurassic Walloon Coal Measures Equivalents (Thickness 500 feet)

Below 5,000 feet a sequence of grey white fine sandstones and highly carbonaceous siltstones was intersected. The writer is indebted to Dr. N. J. de Jersey for dating the carbonaceous material as Lower Jurassic—equivalent to the Walloon Coal Measures.

?Lower Jurassic Conglomerate (Thickness 257 feet)

Below the Walloon Coal Measures equivalents the sandstones become progressively coarser, grading into a calcareous basal conglomeratic sandstone with grains and pebbles of diverse origins. It is not certain whether the 257 feet between 5,500 feet and 5,757 feet should be considered a basal conglomerate of the Walloon equivalents or the stratigraphic equivalent of the Marburg Formation. The sediments are radioactive at 5,650–60 feet, and at 5,720–30 feet contain grains of quartz, quartzite, granite, feldspar and quartz-mica schist. The conglomeratic sandstone was represented by Cores 14 and 15, Core 15 intersecting a light chocolate fine sandstone boulder 1¼–2½ inches thick over the whole width of the core.

## (?)PALAEOZOIC OR UPPER PROTEROZOIC

A marked angular unconformity occurred at 5,757 feet, below which the sediments consisted entirely of steeply dipping conglomerate and conglomeratic or lithic sandstone. The sequence is chocolate coloured, highly ferruginous, and composed mostly of grains and pebbles of chocolate siltstone, green-grey siltstone, and milky quartz. In the upper part of the section bedding is obscured, but in the lower part the flat pebbles are elongated along bedding planes. Many of the pebbles have ferruginous skins, indicating weathering before deposition. The finer-grained sandstone interbedded with conglomerate and boulder beds consists of grains of siltstone in a ferruginous chloritic and sericitic matrix (*see* Appendix 1).

The whole sequence is sheared at a high angle with pebbles elongated along the line of shear.

The sediments are considered to be torrent gravels of non-marine origin. The constituent pebbles are all of Precambrian rocks (Upper Proterozoic). In the absence of fossil evidence, no firm opinion can be given on the age of the conglomerates, which may be Lower Palaeozoic or Upper Proterozoic.

Drilling was discontinued in this formation at 9,824 feet. The actual thickness intersected was between 700 and 1,400 feet.

## CORRELATION WITH INNAMINCKA No. 1 WELL

The Cretaceous Albian-Aptian marine and paralic sections in Innamincka and Betoota Wells are of comparable thickness, although a greater thickness (710 feet) of the Middle Albian is determined for Betoota at the expense of the Aptian. The whole sequence is, however, less fossiliferous than Innamincka and poorly fossiliferous by comparison with Oodnadatta No. 1.

Below the base of the marine Aptian comparison of the two wells emphasizes the lenticular nature of the non-marine sandstones of the Great Artesian Basin. The uppermost part of the Blythesdale Group appears to be missing in Betoota Well, but the sediments correlated with the Mooga Sandstone, " Fossil Wood Beds " and Gubberamunda Sandstone are well represented. The Gubberamunda was apparently missing from Innamincka.

Middle Jurassic micaceous siltstones in Innamincka Well were correlated doubtfully by the writer with the Walloon Coal Measures. Some revision of this correlation may be necessary if the age of determination is correct.

The Triassic and Permian were not intersected in Betoota Well and the Jurassic rested directly on what should be regarded as bedrock.

## LITHOLOGICAL DESCRIPTION

| Core | Depth | Lithology |
|---|---|---|
| | Feet. | |
| | 120– 220 | Green-grey arkosic calcareous silty sandstone, with subangular quartz grains, calcite, green clay minerals, plant remains, biotite, feldspar, chlorite. |
| | 220– 320 | Green-grey calcareous arkosic siltstone, with subangular to subrounded quartz grains, feldspar, green and grey grains, pyrite, chlorite, woody fragments, iridescent plant spores. |
| | 320– 370 | Green-grey arkosic and calcareous siltstone with abundant green and grey grains, subangular to angular quartz grains, chlorite, plant remains. |
| | 370– 430 | Grey calcareous mudstone with green and grey grains, calcite, subangular quartz, pyrite, mica, plant remains. |
| | 430– 500 | Grey calcareous mudstone with abundant green clay minerals, chlorite, calcite, gypsum, subangular quartz, pyrite, plant remains. |
| 1 | 500– 510 | Recovered 8.9 feet. |
| | | Grey mudstone and siltstone grading to fine sandstone, feldspathic, with abundant green clay minerals, plant fragments, coaly matter, biotite, chlorite. |
| | 510– 550 | Mudstone and siltstone as above. |
| | 550– 600 | Grey-green argillaceous limestone, mudstone, and siltstone, with fine angular quartz grains, green and grey grains, pyrite, biotite, carbonaceous matter. |
| | 600– 700 | Grey carbonaceous mudstone with fine angular quartz grains, abundant green and grey grains, carbonized plant remains and coal fragments. |
| | 700– 900 | Grey calcareous and carbonaceous mudstone with fine to medium angular quartz grains, chlorite, grey and green mineral grains, carbonaceous matter, calcite, biotite, coaly matter, pyrite. |
| | 900– 910 | Grey carbonaceous and calcareous mudstone as above with *Azolla* and a fish spine. |
| | 910– 950 | Mudstone as above. |
| | 950–1,000 | Grey coaly mudstone and light grey limestone with *Azolla* at 950–960 feet. |
| 2 | 1,000–1,010 | Recovered 7 feet. |
| | | 1,003–1,005 feet: Light greenish-grey laminated siltstone somewhat irregularly and finely crossbedded with carbonaceous matter on laminae. Fine angular quartz and feldspar grains, chlorite, green grains, carbonaceous matter, pyrite. |
| | | 1,005–1,010 feet: Darker grey, harder and more dense fine calcareous arkosic sandstone grading to siltstone. |
| | 1,010–1,050 | Light green-grey siltstone with angular quartz grains, feldspar, chlorite, green grains, carbonaceous matter, pyrite. |
| | 1,050–1,100 | Light greenish-grey mudstone as 1,010–1,050 feet with trilete megaspore and plant fragments. |
| | 1,100–1,150 | Light greenish-grey siltstone with fine angular quartz grains, feldspar, green and grey grains, pyrite. |
| | 1,150–1,200 | Grey carbonaceous siltstone with medium angular quartz grains, feldspar, carbonaceous matter, chlorite, green and grey grains. One shell fragment. |
| | 1,200–1,350 | Green-grey carbonaceous siltstone and calcareous mudstone, fine angular quartz and feldspar grains, grey grains and abundant carbonaceous matter. |

| Core | Depth | Lithology |
|---|---|---|
| | feet | |
| | 1,350–1,360 | Grey carbonaceous mudstone with shell fragments and *Inoceramus* prisms, fine angular quartz grains, calcite, feldspar, abundant carbonaceous matter. |
| | 1,360–1,400 | Grey carbonaceous mudstone. |
| | 1,400–1,450 | Grey calcareous and carbonaceous siltstone with medium angular quartz grains, calcite, feldspar, carbonaceous matter. |
| | 1,450–1,460 | Grey carbonaceous siltstone with medium to fine angular quartz grains, glauconite, chlorite, biotite, pyrite, carbonaceous matter. *Inoceramus* prisms. |
| | 1,460–1,500 | Grey carbonaceous siltstone. |
| | 1,500–1,510 | Grey carbonaceous siltstone with *Inoceramus.* |
| 3 | 1,510–1,520 | Recovered 11 feet. |
| | | 1,510–1,514 feet: Highly carbonaceous grey mudstone and siltstone with plant remains and thin coal bands. |
| | | 1,515–1,520 feet: Grey siltstone with mudstone patches, abundant plant remains, glauconite, fine angular quartz grains, feldspar, pyrite, coaly fragments, and abundant plant remains. |
| | | *Azolla* present at 1,513 feet. Foraminifera rare. |
| | 1,520–1,720 | Grey carbonaceous mudstone and siltstone. |
| | 1,720–1,750 | Grey calcareous and carbonaceous mudstone and siltstone with *Inoceramus.* |
| | 1,750–1,800 | Grey calcareous pyritic mudstone with fine quartz grains, feldspar, pyrite, glauconite, coaly matter, plant fragments, *Inoceramus.* |
| | 1,800–1,860 | Grey limestone and siltstone with glauconite, pyrite and carbonized plant fragments. Abundant *Inoceramus.* |
| | 1,860–1,960 | Grey calcareous pyritic siltstone with abundant *Inoceramus* and pyritized foraminifera. Pyritized mollusca at 1,940–1,950 feet. |
| | 1,960–1,970 | Siltstone as above with *Azolla, Inoceramus,* and *Aucellina.* |
| | 1,970–2,020 | Siltstone as above, *Bulimina* first appearance at 1,980–1,990 feet. |
| 4 | 2,020–2,032 | Recovered 11 feet. Dark grey fissile mudstone, carbonaceous and weakly calcareous, with clay material, calcite, pyrite and carbonaceous matter. Foraminifera abundant, both in species and individuals, *Haplophragmoides dickinsoni* dominant. |
| | 2,032–2,100 | Grey calcareous and carbonaceous mudstone with *Inoceramus* and abundant foraminifera. Pyritic. |
| | 2,100–2,130 | Grey calcareous and carbonaceous mudstone with clay matter, pyrite, plant remains. Foraminifera recalcified and pyrite infilled. First *Globigerina* sp. 4 at 2,120–2,130 feet. |
| | 2,130–2,140 | Slightly calcareous mudstone with abundant carbonized fragments. |
| | 2,140–2,150 | Grey pyritic carbonaceous and calcareous mudstone. |
| | 2,150–2,160 | Grey carbonaceous and calcareous mudstone with fine muscovite. |
| | 2,160–2,170 | Grey pyritic and calcareous mudstone with *Inoceramus.* |
| | 2,170–2,200 | Grey calcareous mudstone with *Inoceramus.* Foraminifera rare. |
| | 2,200–2,280 | Grey calcareous and carbonaceous mudstone and siltstone with pyrite and abundant carbonaceous matter. |
| | 2,280–2,300 | Grey siltstone, mudstone, and limestone with *Inoceramus.* |
| | 2,300–2,330 | Grey carbonaceous mudstone with clay material, pyrite, calcite, carbonaceous matter. Foraminifera rare. |
| | 2,330–2,340 | Grey carbonaceous siltstone and limestone with cone-in-cone structures. |
| | 2,340–2,350 | Grey carbonaceous mudstone and siltstone. |
| | 2,350–2,360 | Grey carbonaceous calcareous mudstone and siltstone with abundant carbonaceous matter, pyrite, calcite. |
| | 2,360–2,400 | Grey carbonaceous mudstone, siltstone, and limestone, with *Inoceramus, Aucellina,* first radiolarian at 2,360–2,370 feet. Mainly pyritized *Globigerina* at 2,380–2,390 feet. |
| | 2,400–2,450 | Grey mudstone and siltstone with abundant plant remains, calcite, pyrite. Rich in *Inoceramus* and *Globigerina* sp. 4. |
| | 2,450–2,490 | Dark grey mudstone with very abundant *Inoceramus.* |
| | 2,490–2,530 | Highly carbonaceous laminated siltstone rich in plant remains, coal fragments, pyrite. |
| 5 | 2,530–2,540 | Nil recovery. |
| | 2,540–2,560 | Dark grey mudstone and arkosic siltstone with glauconite, *Inoceramus, Globigerina.* |
| | 2,560–2,570 | Grey mudstone and siltstone with grains of pale green glauconite. First *Verneuilina howchini* and marked faunal change. |

| Core | Depth | Lithology |
|---|---|---|
| | feet | |
| | 2,570–2,610 | Grey glauconitic siltstone with abundant arenaceous foraminifera, bright green glauconite, muscovite. |
| | 2,610–2,650 | Light grey glauconitic siltstone with pale green glauconite, pyrite, carbonaceous material. |
| | 2,650–2,730 | Glauconitic sandstone and siltstone. Sandstone with bright green glauconite, angular quartz grains, feldspar, pyrite, siltstone partings. |
| | 2,730–2,780 | Glauconitic sandy siltstone with fine angular quartz grains, glauconite, pyrite, muscovite, carbonaceous matter. |
| | 2,780–2,790 | Green-grey glauconitic sandy siltstone and mudstone. |
| | 2,790–2,800 | Brown-green arkosic siltstone with glauconite and abundant carbonaceous matter. Calcite. |
| | 2,800–2,820 | Grey sandy siltstone and mudstone, calcareous, glauconitic, with fine angular quartz grains, plant remains, mica, pyrite. |
| | 2,820–2,830 | Glauconitic fine arkosic sandstone and siltstone. |
| | 2,830–2,840 | Grey carbonaceous mudstone, glauconitic arkosic siltstone, glauconitic and pyritic sandstone. |
| | 2,840–2,850 | Grey carbonaceous and pyritic siltstone, brown limestone. |
| | 2,850–2,920 | Fine glauconitic sandstone and siltstone with subangular quartz grains, bright pale green glauconite, pyrite, carbonaceous matter, muscovite. |
| | 2,920–2,930 | Fine sandstone, siltstone, and mudstone, with fine angular quartz grains and glauconite in feldspathic matrix. |
| | 2,930–2,960 | Grey brown limestone with glauconite, siltstone with medium to coarse subrounded quartz grains and ovoid glauconite grains. |
| | 2,960–2,980 | Grey siltstone with glauconite, pyrite and carbonaceous matter. Grey-brown limestone with glauconite. |
| | 2,980–3,040 | Grey glauconitic siltstone, pyritic mudstone, and some limestone. Foraminifera pyritized. |
| 6 | 3,040–3,046 | Recovered 3 ft. 8 in. |
| | | Dark grey dense mudstone and siltstone irregularly banded, small slump structures. Glauconite, muscovite, pyrite, abundant carbonaceous matter. Foraminifera common, not abundant. |
| | 3,046–3,170 | Mudstone and siltstone as above. Cavings of glauconitic siltstone and mudstone with *Inoceramus* from Albian above. |
| | 3,170–3,240 | Grey pyritic mudstone and pyritic and glauconitic siltstone. Calcareous. |
| | 3,240–3,330 | Medium arkosic sandstone with some glauconite, medium subrounded quartz grains, plant remains, matrix feldspathic. Cavings of siltstone and mudstone. |
| | 3,330–3,350 | Medium arkosic sandstone with siltstone partings and cavings. |
| | 3,350–3,390 | Arkosic sandstone with fine angular to coarse subrounded quartz grains, carbonaceous matter, green clay mineral, muscovite. |
| | 3,390–3,420 | Fine to coarse arkosic sandstone and siltstone. |
| | 3,420–3,450 | Grey micaceous siltstone and mudstone with carbonaceous matter. Some coarse arkosic sandstone and fine buff sandstone. |
| | 3,450–3,480 | Grey-white medium quartz sandstone with medium angular quartz grains, tightly packed with little cement. Crystal faces showing. Carbonaceous siltstone partings, coal fragments. Cavings of glauconitic siltstone and Albian mudstone. |
| | 3,480–3,550 | White quartz sandstone, porous, medium to coarse angular quartz grains with a very little feldspathic cementing material. Some muscovite, chlorite, carbonaceous matter. |
| 7 | 3,550–3,553 | Nil recovery. |
| 8 | 3,553–3,563 | Recovered 10 feet. |
| | | Grey white strongly crossbedded medium fine micaceous arkosic sandstone with carbonaceous siltstone laminae, silty partings, and pellet impressions. Green clay minerals and chlorite. Dark grey carbonaceous siltstone band at 3,561 feet–3,561 ft. 6 in. |
| | 3,563–3,730 | Sandstone and siltstone as above, cavings from Albian. |
| | 3,730–3,750 | Coarse sandstone with angular quartz grains as before. Some siltstone. |
| | 3,750–3,760 | Sandstone and siltstone as Core 8. |
| | 3,760–3,770 | Coarse sandstone as 3,730–3,750 feet, friable. |
| | 3,770–3,820 | Sandstone as Core 8. |
| | 3,820–3,880 | Medium angular quartz sandstone, somewhat more tightly packed than above, with carbonaceous matter and feldspathic cement. |
| | 3,880–3,905 | Carbonaceous siltstone and minor sandstone as above. |

| Core | Depth | Lithology |
|---|---|---|
| | feet | |
| 9 | 3,905–3,915 | Recovered 9 ft. 6 in. |
| | | Strongly crossbedded fine grey-white micaceous laminated sandstone and carbonaceous siltstone irregularly banded throughout. Medium angular quartz grains fairly tightly packed with feldspathic cementing material, muscovite, chlorite, calcite. |
| | 3,915–3,940 | Sandstone and siltstone as above. |
| | 3,940–4,020 | Siltstone and sandstone as above. Cavings from Albian. |
| | 4,020–4,190 | Siltstone and sandstone as before; heavily contaminated with cement and mica. No cuttings returns 4,130–4,180 feet. |
| | 4,190–4,200 | Siltstone and coal. |
| | 4,200–4,208 | No cuttings returns. |
| 10 | 4,208–4,218 | Recovered 3.3 feet. |
| | | Light greenish grey fine to medium arkosic sandstone, fairly compact with calcareous matrix which contains also feldspar and kaolin. Green clay minerals, mica, ferromagnesian minerals, carbonaceous matter. |
| | 4,218–4,260 | No cuttings returns. |
| | 4,260–4,270 | Calcareous arkosic sandstone and carbonaceous siltstone. |
| | 4,270–4,280 | Brown-grey carbonaceous siltstone with abundant plant remains, coaly matter, medium arkosic sandstone. |
| | 4,280–4,300 | Brown-grey fine arkosic sandstone and siltstone with fine muscovite and abundant plant remains. |
| | 4,300–4,310 | Green-grey arkosic sandstone with subangular quartz grains with pitted surfaces. feldspathic and calcareous matrix, mica, green clay minerals. |
| | 4,310–4,320 | Brown coal. |
| | 4,320–4,330 | Fine grey arkosic and somewhat calcareous sandstone and siltstone with abundant carbonaceous matter and some coal fragments. |
| | 4,330–4,350 | Brown-grey carbonaceous siltstone with some fine sandstone. |
| | 4,350–4,480 | Fine grey arkosic sandstone and brown-grey carbonaceous siltstone (micaceous). |
| | 4,480–4,510 | Buff coarse quartz sandstone with angular quartz grains. |
| | 4,510–4,550 | Buff coarse sandstone with coarse quartz grains with unworn fractured surfaces; some siltstone and carbonaceous matter (? cavings). |
| | 4,550–4,620 | Buff coarse sandstone with coarse quartz grains with fractured surfaces, tightly packed with little cementing material. Pink garnet. Some carbonaceous siltstone. |
| | 4,620–4,660 | Buff medium to coarse sandstone as above, pink garnet. Some coaly and carbonaceous matter. |
| | 4,660–4,696 | Dirty brown medium to coarse sandstone with brown carbonaceous cementing material. Some garnet. |
| 11 | 4,697–4,707 | Recovered 7 ft. 7 in. |
| | | Dirty buff to brownish grey quartz sandstone, somewhat cross-bedded. |
| | | 4,700 ft. 6 in.: Buff-grey medium to coarse quartz sandstone with angular strained and fractured irregular grains and small amount of sericitic cementing material. Some chlorite and garnet. |
| | | 4,707 feet: Buff-grey quartz sandstone with grains of varying size, irregular, strained, cementing material composed of feldspar, sericite, garnet, carbonaceous matter. |
| | 4,707–4,730 | Coarse sandstone as above. |
| | 4,730–4,750 | Brown-grey sandstone and carbonaceous siltstone. |
| | 4,750–4,760 | Brown-grey medium fine sandstone and carbonaceous siltstone, angular strained quartz grains. |
| | 4,760–4,770 | Brown-grey calcareous sandstone with garnet and carbonaceous siltstone, some apatite. |
| | 4,770–4,784 | Brown-grey coarse sandstone as Core 11, calcareous with carbonaceous cementing material. |
| 12 | 4,784–4,801 | Recovered 16 ft 3 in. |
| | | 4,784–4,788 feet: Brown-grey coarse sandstone to grit and fine grained calcareous sandstone (*see* Appendix 1, Sample P 56/60). |
| | | 4,788–4,798 feet: Dirty buff-grey medium to coarse arkosic calcareous sandstone with angular strained quartz grains, apatite, carbonaceous matter, garnet, in calcareous cement. Cross-bedding 4,789–4,790 feet, thin carbonaceous strings at 4,793 feet. Thin coaly band and carbonaceous strings at 4,796 feet. Cross-bedding at 4,797 feet. |

| Core | Depth | Lithology |
|---|---|---|
| | feet | |
| | | 4,798–4,801 feet: Grey medium fine quartz sandstone. Angular to subangular quartz grains with etched surfaces, some grains fractured and strained, apatite, garnet, carbonaceous matter, all tightly packed in calcareous matrix. |
| | 4,801–4,810 | Brown-grey calcareous medium to coarse sandstone with garnet. Carbonaceous siltstone. |
| | 4,810–4,840 | No samples recovered |
| | 4,840–4,850 | Brown-grey sandstone as above. |
| | 4,850–4,870 | Brown-grey calcareous sandstone and carbonaceous siltstone. |
| | 4,870–4,910 | Medium to coarse sandstone as above and carbonaceous siltstone, mostly non-calcareous with coarse strained and fractured quartz grains, some opaline quartz grains, little cement. |
| | 4,910–4,920 | Grey-white calcareous sandstone and coarse sandstone with little cement. Most grains strained. |
| | 4,920–4,950 | Sandstone as above with garnet and pyrite, some carbonaceous siltstone. |
| | 4,950–5,000 | Dark brown-grey sandstone and carbonaceous siltstone with coaly matter. |
| | 5,000–5,030 | Grey-white fine to coarse sandstone with carbonaceous siltstone, some garnet. |
| | 5,030–5,050 | Grey-white calcareous sandstone and carbonaceous siltstone with coaly matter. |
| | 5,050–5,090 | Carbonaceous siltstone and sandstone with pyrite and coaly matter. |
| | 5,090–5,170 | Grey-white calcareous sandstone with carbonaceous siltstone, garnet, feldspar, apatite, coaly matter. |
| | 5,170–5,180 | Sandstone and highly carbonaceous siltstone with some coaly matter. |
| | 5,180–5,190 | Highly carbonaceous siltstone with coaly matter and sandstone as above. |
| | 5,190–5,200 | Fine to medium sandstone and carbonaceous siltstone. |
| | 5.200–5,214 | Dark grey highly carbonaceous siltstone and some sandstone. |
| 13 | 5,214–5,230 | Recovered 13 ft. 3 in. |
| | | 5,214–5,215 feet: Flat lying cross-bedded highly carbonaceous dark grey micaceous siltstone. |
| | | 5,215–5,216 feet: Finely cross-bedded dark grey fissile carbonaceous shale with fine bands of coaly matter. |
| | | 5,216 ft. 3 in.: as 5,214–5,215 feet. |
| | | 5,217 feet: Finely cross-bedded carbonaceous shale. |
| | | 5,218–5,219 feet: Dark grey carbonaceous shale. |
| | | 5,220–5,221 feet: Cross-bedded shale as 5,215–5,216 feet. |
| | | 5,222 feet–5,225 ft. 9in.: Dark grey highly carbonaceous siltstone. |
| | 5,230–5,250 | Grey carbonaceous siltstone and fine to medium quartz sandstone. |
| | 5,250–5,260 | Fine to medium quartz sandstone and grey siltstone. |
| | 5,260–5,270 | Medium angular quartz sandstone, relatively even grain size, some carbonaceous siltstone. |
| | 5,270–5,290 | Carbonaceous micaceous siltstone and sandstone as before. |
| | 5,290–5,360 | Grey-white even-grained medium quartz sandstone with angular interlocking grains, little cement; carbonaceous siltstone. Non-calcareous. |
| | 5,360–5,380 | Sandstone as above, with some coarse grains and garnet, some arkosic sandstone. |
| | 5,380–5,410 | Sandstone as above and carbonaceous siltstone with coalified plant remains, grain size variable, some pyrite and some arkosic cement. |
| | 5,410–5,420 | Dark grey carbonaceous siltstone and some medium arkosic sandstone. |
| | 5,420–5,450 | Medium arkosic sandstone and carbonaceous siltstone. |
| | 5,450–5,500 | As above, with some greenish siliceous siltstone, mica, and plant remains, some pyritic siltstone. |
| | 5,500–5,580 | Coarse arkosic sandstone with angular to subrounded grains with fractured surfaces. Some coaly matter, garnet; micaceous siltstone partings, some coaly matter. |
| | 5,580–5,590 | Sandstone and micaceous siltstone as above; pyritic sandstone. |
| | 5,590–5,600 | Arkosic sandstone and micaceous siltstone with coal and coalified plant remains. |
| | 5,600–5,640 | Somewhat arkosic buff sandstone as above and carbonaceous siltstone. |
| | 5,640–5,660 | Sandstone as above with grains of varying size, some micaceous siltstone and coarse quartz grains mostly strained and interlocked. |
| | 5,660–5,670 | Fairly even grained coarse angular quartz sandstone with unworn automorphic quartz. |
| | 5,670–5,720 | Sandstone as above, and carbonaceous siltstone. |
| | 5,720–5,731 | Sandstone with grains of quartz, quartzite, granite, feldspar, quartz-mica schist. |

| Core | Depth | Lithology |
|---|---|---|
| | feet | |
| 14 | 5,731–<br>5,733 ft. 3 in. | Recovered 2 ft. 3 in.<br>2 in. Dark grey carbonaceous and micaceous arkosic gritty sandstone with angular quartz grains, milky quartz and ferromagnesian mineral in a silty groundmass. Shale pebble 0.9 in. diameter.<br>2 in. Coarse grained gritty cross-bedded sandstone.<br>2 in. Grey gritty coarse arkosic sandstone.<br>2 in. Grey arkosic polymictic conglomerate including one pebble of light chocolate fine sandstone 1 in. diameter.<br>1½ in. Conglomerate with light chocolate fine shale pebble 2-in. diameter.<br>1½ in. Arkosic conglomerate.<br>1 in. Grey arkosic gritty quartz conglomerate with angular grains. |
| 15 | 5,734–5,742 | Recovered 1 ft. 3 in.<br>4 in. Grey arkosic coarse conglomeratic sandstone with illsorted angular quartz grains held together by a small amount of kaolinitic cement; pebbles of light chocolate slightly calcareous fine sandstone 1½ in. diameter.<br>4 in. Conglomeratic sandstone. The boring passed through a flat irregular boulder 1¼ in. to 2½ in. thick, completely covering diameter of core. |
| | 5,742–5,750 | Sandstone, with grains of grey sericitic sandy and dolomitic siltstone with brown granules, quartz grains, pink quartzite, carbonaceous sandstone and siltstone. |
| | 5,750–5,760 | Ferruginous sandstone and siltstone, sericitic siltstone, cavings of carbonaceous siltstone. |
| | 5,760–5,780 | Ferruginous fine sandstone and sericitic siltstone, chocolate siltstone. Cavings of carbonaceous siltstone and buff white sandstone. |
| | 5,780–5,835 | Dark chocolate-coloured ferruginous quartz sandstone with sericitic matrix. Cavings of sandstone and carbonaceous siltstone. |
| 16 | 5,835–5,845 | Recovered 4 ft. 6 in.<br>5835 feet:<br>3 in. Dark chocolate and grey-green sheared conglomerate with pebbles of chocolate siltstone and fine sandstone in a chloritic matrix. Apparent dip 60°. Pebbles elongated along plane cutting core at about 60°.<br>4½ in. Dark chocolate and grey-green mottled sheared and brecciated conglomerate with pebbles of quartzite, red fine sandstone and chocolate siltstone. Pebbles aligned at about 60° to horizontal.<br>5836 feet: Dark chocolate and greenish grey brecciated conglomerate as above. Sheared.<br>5837 feet: Dark chocolate brecciated conglomerate sheared and veined.<br>5838–5839 feet: Dark chocolate conglomerate, finer grained from 5839 feet to 5839 ft. 5 in. Sheared and veined. Apparent dip 45°. |
| | 5,845–5,900 | Conglomerate as above with chocolate ferruginous siltstone and green siltstone in chloritic cement. |
| | 5,900–5,940 | Chocolate ferruginous sandstone and siltstone, green siltstone, chloritic and sericitic matrix. |
| | 5,940–5,962 | As above with some calcite in matrix. |
| 17 | 5,962–5,978 | Recovered 10 feet.<br>Dark chocolate-coloured indurated conglomeratic sandstone.<br>5,962–5,965 feet: Dark chocolate indurated sheared gritty sandstone. Dip 45°.<br>5,966 feet: Indurated chocolate brecciated conglomerate with quartz pebbles up to 1 inch diameter strained and sheared at high angle.<br>5,967–5,968 feet: as 5,962–5,965 feet.<br>5,969–5,970 feet: Dark chocolate indurated sheared and brecciated conglomerate with milky quartz pebbles, red siltstone pebbles.<br>*See* Appendix 1, Sample P 68/60.<br>5,971–5,972 feet: Dark chocolate indurated sandstone with angular to subrounded quartz grains in a poorly-sorted matrix. |
| | 5,980–6,010 | Chocolate and green siltstone, mottled siltstone, and quartz chips. |
| | 6,010–6,020 | Chocolate siltstone, some quartz. |
| | 6,020–6,040 | Chocolate siltstone, green siltstone, and quartz. |
| | 6,040–6,060 | Highly ferruginous sandstone and siltstone, slickensiding, with chlorite and sericite on shear planes. |
| | 6,060–6,070 | Dark chocolate medium-fine ferruginous sandstone. |
| | 6,070–6,100 | Dark chocolate medium-fine ferruginous sandstone, quartz and iron-rich sericitic siltstone. |

| Core | Depth | Lithology |
|---|---|---|
| | feet | |
| | 6,100–6,130 | Dark chocolate siltstone and green sericitic siltstone; quartz. |
| | 6,130–6,150 | Dark chocolate medium-fine ferruginous sandstone. |
| | 6,150–6,170 | Chocolate siltstone and sandstone, green siltstone and quartz. |
| | 6,170–6,190 | Ferruginous siltstone and sandstone; green siltstone. |
| | 6,190–6,200 | As above, with milky quartz chips, and cavings of carbonaceous sandstone. |
| | 6,200–6,250 | Ferruginous siltstone and quartz chips, some coarse quartz. |
| | 6,250–6,270 | Fine ferruginous sandstone. |
| | 6,270–6,310 | Ferruginous sandstone and siltstone, green siltstone and quartz chips. |
| | 6,310–6,350 | Chocolate siltstone and green siltstone. |
| | 6,350–6,360 | Highly ferruginous siltstone and sandstone. |
| | 6,360–6,380 | Same, with some green siltstone, and quartz. |
| | 6,380–6,420 | Circulation partly lost, cuttings returns negligible. |
| | 6,420–6,430 | Chocolate siltstone as above. |
| | 6,430–6,437 | Chocolate and green siltstone and quartz. |
| 18 | 6,437–6,452 | Recovered 14 feet (*see* Appendix 1, Sample P 67/60). |
| | | 6,437 feet: Chocolate conglomeratic sandstone with strained and elongated grains of red shale and green shale or siltstone in a fine red sericitic groundmass. Angular milky quartz pebbles scattered irregularly throughout. At 6,437 feet, narrow zone of shearing (less than ½ inch) with red and green clastics and elongated quartz pebbles. Shear plane cutting core at 55°. |
| | | 6,438 feet: As above, slightly dolomitic, no bedding evident. |
| | | 6,439 feet–6,445 ft. 3 in.: Iron-rich conglomerate, stained with limonite. |
| | | 6,446–6,450 feet: Conglomerate as above with irregular quartz pebbles to 1 inch diameter, sheared and fractured, fractures filled with iron oxide. |
| | | 6,451 feet: Highly ferruginous quartzose clastic rock with some calcareous patches. Shearing; vein of gypsum, patches of limonite. Stretched grains of red and green shale. |
| | 6,452–6,460 | Conglomerate with constituents as above. |
| | 6,460–6,500 | Chocolate ferruginous siltstone and quartz. |
| | 6,500–6,530 | Ferruginous siltstone and sandstone as above; cavings of carbonaceous siltstone. |
| | 6,530–6,560 | Dark chocolate and green ferruginous siltstone and quartz. |
| | 6,560–6,570 | As above with cavings of carbonaceous siltstone. |
| | 6,570–6,590 | Dark fine ferruginous sandstone and siltstone; some green siltstone. |
| | 6,590–6,620 | Ferruginous sandstone and siltstone, mottled sandstone with ferruginous margins. |
| | 6,620–6,640 | Ferruginous siltstone, some quartz. |
| | 6,640–6,650 | Ferruginous sandstone and chocolate and green siltstone, some quartz. |
| | 6,650–6,660 | Chocolate siltstone. |
| | 6,660–6,800 | Mottled siltstone and chocolate siltstone, some calcite and quartz veining. |
| | 6,800–6,880 | Chocolate siltstone, some green siltstone, and a little quartz. |
| | 6,880–6,910 | Chocolate and buff sandstone and siltstone, some quartz. |
| | 6,910–6,925 | Sandstone and siltstone as above, with quartzite and cavings of carbonaceous siltstone. |
| 19 | 6,925–6,931 | Recovered 5 feet. |
| | | 6,925–6,926 feet: Dark chocolate and grey mottled indurated ferruginous conglomerate with pebbles of red and green shale, dolomite, and quartz. Rich in iron oxide. Veined with calcite and chlorite. Sheared and elongated at high angle. Matrix sericitic and chloritic. |
| | | 6,926 feet. 6 in.: Conglomerate as above with dolomite pebble. |
| | | 6,927 feet: Heavily sheared conglomerate, with pebbles and finer grains of chocolate and green shale. Pebbles of calcite and dolomite slickensided on sheared surfaces. |
| | | 6,927 ft. 6 in.: Medium-coarse conglomerate sheared at 50° with pebbles elongated along line of shear. Pebbles of chocolate siltstone, green-grey siltstone, banded quartzite with calcite veins. |
| | | 6,928 feet: Conglomerate as 6,925 feet, pebbles up to 2½ inches strained and elongated at 50° to horizontal. Pebbles of chocolate shale, quartz, coarse to medium angular quartz grains. |
| | | 6,929 feet: Massive and indurated conglomerate as before, highly ferruginous, with red and green siltstone pebbles and quartz pebbles all elongated at same high angle. |
| | | 6,930–6,931 feet: Conglomerate as above with pebbles elongated along line of shear at 50° to horizontal. Angular milky quartz pebbles to 1½ inches length. |

| Core | Depth | Lithology |
|---|---|---|
| | feet. | |
| | 6,920–6,990 | Chocolate and green siltstone. |
| | 6,990–7,000 | Chocolate and green siltstone, vein quartz and some quartzite. |
| | 7,000–7,014 | Same. Mostly chocolate, red, and mottled siltstone. |
| 20 | 7,014–7,036 | *See* Appendix 1, Sample P117–P118/60. |
| | | 7,014–7,015 feet: Massive chocolate indurated brecciated conglomerate with ferruginous chocolate siltstone, green siltstone, and quartz, with limonite on fractures, all elongated, sheared and strained at angle of about 70°. Angular quartz and dolomitic pebbles irregularly scattered through the rock mass. Calcite along shears. |
| | | 7,015–7,017 feet: As above, chloritic and sericitic matrix. |
| | | 7,017–7,018 feet: As above, quartz grains to 2½ inches. |
| | | 7,019 feet: As above, abundant quartz pebbles strained and elongated. Chlorite and sericite on shear planes. |
| | | 7,020 feet: Conglomerate as above. Angular quartz pebbles sheared at high angle. |
| | | 7,021–7,023 feet: Massive chocolate sandstone with relatively few quartz pebbles scattered irregularly throughout the rock mass; abundant limonite, sericite. |
| | | 7,023–7,033.5 feet: Massive chocolate sandstone with angular quartz pebbles irregularly scattered throughout, mostly ½ in. to 1½ in. Some green siltstone pebbles all sheared and elongated at 50° to horizontal. |
| | 7,036–7,072 | Chocolate and green siltstone, rich in iron oxide, some quartz and quartzite; slickensiding. |
| 21 | 7,072–7,075 | Recovered 2.5 feet (*see* Appendix 1, Sample P140/60). |
| | | Indurated, massive, dark chocolate iron-rich conglomerate, pebbles elongated at high angle to horizontal, up to 2 inches long, of chocolate siltstone, some green siltstone, with sericitic and chloritic matrix wrapped around pebbles. At 7,072 feet: Quartz pebbles of varying size, some angular, some stretched and elongated. Micro veins of calcite. |
| 22 | 7,076–7,096 | Recovered 16.25 feet. |
| | | 7,077 feet: Indurated, massive, dark chocolate iron-rich conglomerate with pebbles of chocolate siltstone, green siltstone, slate, and angular milky quartz in chloritic and iron-impregnated matrix. |
| | | 7,078 feet: As above with quartz pebbles, some elongated along direction of shear. |
| | | 7,079 feet: *See* Appendix 1, Sample P141/60. |
| | | 7,080–7,082 feet: Conglomerate as above, matrix chloritic and very ferruginous. |
| | | 7,083–7,084 feet: Siltstone pebbles at high angle, but some quartz pebbles to 1½ inches diameter not elongated along shear, but cutting across rock mass at about 90° to core axis. Matrix wrapped around pebbles. |
| | | 7,085–7,086 feet: As above, with chocolate and green siltstone pebbles. |
| | | 7,087 feet: As above, with fairly numerous angular milky quartz pebbles. |
| | | 7,088 feet: As above, some quartz elongated along shear but others cutting across it and angular. |
| | | 7,089–7,090 feet: As above. Quartz pebbles mostly angular. |
| | | 7.091–7,092 feet; As above. Angular and subrounded quartz pebbles. |
| | 7,096–7,120 | Chocolate and mottled siltstone. |
| | 7,120–7,140 | Chocolate to mottled siltstone, slickensiding, chlorite on shear planes. |
| | 7,140–7,150 | Ferruginous sandstone and siltstone, some quartz. |
| | 7,150–7,156 | Chocolate and mottled siltstone. |
| 23 | 7,156–7,157 | Recovered 1 foot. (*See* Appendix 1, Sample P142/60.) |
| 24 | 7,159–7,172 | Recovered 13 feet. (*See* Appendix 1, Sample P143/60.) |
| | | 7,159 feet: Conglomeratic lithic sandstone consisting of siltstone and slate fragments in ferruginous sericitic quartzose matrix. |
| | | 7,160 feet: Conglomerate, with siltstone pebbles sheared at high angle. Chlorite and calcite in shear zones. |
| | | 7,161–7,165 feet: Conglomerate, with pebbles of green siltstone, shale, and angular to subrounded quartz in very ferruginous matrix. |
| | | 7,166 feet: As above, with chert pebble. |
| | | 7,168–7,171 feet: As above, siltstone pebbles. |
| | 7,172–7,180 | Chocolate and mottled siltstone, some quartz and micaceous siltstone. |
| | 7,180–7,200 | Chocolate and green siltstone, some quartz. |
| | 7,200–7,220 | As above, with vein quartz and quartzite. |
| | 7,220–7,230 | Chocolate and mottled siltstone and quartz. |
| | 7,230–7,250 | Chocolate ferruginous sandstone with siltstone and quartz. |

| Core | Depth | Lithology |
|---|---|---|
| | feet | |
| | 7,250–7,270 | Chocolate and mottled red and green siltstone, ferruginous sandstone, and quartz. |
| | 7,270–7,340 | Mottled siltstone, some quartz, quartzite, and sandstone. |
| | 7,340–7,350 | Mottled siltstone, micaceous siltstone and sandstone, some quartz. |
| | 7,350–7,380 | Chocolate and mottled siltstone. |
| | 7,380–7,440 | Sandstone composed of grains of siltstone; some quartz. Heavily impregnated with iron. |
| | 7,440–7,460 | Siltstone, sandstone, and some coarse ferruginous quartzite. |
| | 7,460–7,470 | Siltstone, fine sandstone, and quartz. |
| | 7,470–7,480 | Sandstone, siltstone, and quartz as above. |
| | 7,480–7,540 | Mostly ferruginous siltstone with abundant milky quartz. |
| 25 | 7,540–7,546 | Recovered 6 feet. |
| | | 7,540 feet: Massive, dense dark chocolate coarse sandstone of fairly uniform texture, heavily impregnated with iron. |
| | | 7,541–7,546 feet: Coarse subrounded quartz grains in a chlorite-sericite matrix which flows around grains; all heavily impregnated with iron. Conglomeratic at 7,545 feet. |
| 26 | 7,546–7,560 | Recovered 14 feet. |
| | | 7,548 feet: Massive dark chocolate conglomeratic sandstone with occasional elongated pebbles. |
| | | 7,549–7,552 feet: Massive tight chocolate sandstone as above with small angular milky quartz pebbles and 1-in. pebbles of chocolate and green siltstone scattered throughout. Dip 75°–80°. |
| | | 7,553–7,560 feet: Massive tight chocolate sandstone as above and highly sheared sandy siltstone with small grains of siltstone all elongated and stretched, and subrounded quartz in ferruginous chloritic matrix. |
| | 7,560–7,570 | Coarse lithic sandstone with grains of green siltstone. |
| | 7,570–7,600 | Sandstone as above, with ferruginous matrix. |
| | 7,600–7,620 | Sandstone as above, and milky quartz. |
| | 7,620–7,660 | Dark chocolate siltstone and lithic sandstone with grains of chocolate and green siltstone. |
| | 7,660–7,690 | Chocolate siltstone, green siltstone, and some quartz. |
| | 7,690–7,730 | Mottled lithic sandstone. |
| | 7,730–7,740 | Mostly quartz, with chocolate and green siltstone. |
| | 7,740–7,785 | Chocolate lithic sandstone, some quartz. |
| 27 | 7,785–7,793 | Recovered 8 feet. |
| | | Chocolate, highly ferruginous coarse sandstone with grains of siltstone; some evidence of bedding at about 80° to horizontal at 7,789 feet. Sheared at high angle, with chlorite on shear planes. Angular milky quartz pebbles at 7,787 and 7,790 feet, up to ½ inch diameter, not strained at angle of shear. |
| | 7,793–7,900 | Ferruginous lithic sandstone as above. |
| | 7,900–7,990 | Ferruginous lithic sandstone as above with quartz, ferruginous and chloritic matrix. |
| | 7,990–8,020 | Sandstone as above, quartz veining. |
| | 8,020–8,043 | Sandstone as above, quartz veining and slickensiding. |
| 28 | 8,043–8,050 | Recovered 5 ft. 4 in. |
| | | Dark chocolate ferruginous sandstone with grains of siltstone, angular milky quartz pebbles as Core 17, calcite veins. Dip 75°–80°. |
| | 8,050–8,090 | Dark chocolate ferruginous sandstone as above, with quartz. |
| | 8,090–8,130 | Ferruginous quartz sandstone, lithic sandstone and quartz. |
| | 8,130–8,180 | Chocolate lithic sandstone with quartz; some slickensiding. |
| | 8,180–8,190 | Milky quartz, feldspar, and lithic sandstone as above. |
| | 8,190–8,200 | Ferruginous lithic sandstone, some quartz and calcite. |
| | 8,200–8,240 | Highly ferruginous chocolate lithic sandstone and siltstone, with milky quartz. |
| | 8,240–8,250 | Sandstone as above with abundant quartz. |
| | 8,250–8,295 | Sandstone as above, considerable shearing. Matrix squeezed around pebbles. |
| 29 | 8,294–8,306 | Recovered 11 ft. 4 in. |
| | | Dark chocolate lithic sandstone with calcite veining; quartzite pebbles to 1 inch across at 8,300 feet cutting across angle of shear. |
| | 8,307–8,320 | Sandstone as above, shearing with chlorite on shear planes, quartz veining. |
| | 8,320–8,360 | Sandstone as above with chocolate and green siltstone grains. |
| | 8,360–8,400 | Dark chocolate lithic sandstone with mostly chocolate siltstone grains, little quartz, very ferruginous matrix, quartz veining and banding. Some coarse angular quartz grains. |

| Core | Depth | Lithology |
|---|---|---|
| | feet | |
| | 8,400–8,440 | Ferruginous sandstone, quartzite, lithic sandstone, and quartz. |
| | 8,440–8,470 | Chocolate ferruginous lithic sandstone with chocolate siltstone grains. |
| | 8,470–8,487 | Quartz sandstone and lithic sandstone as above. |
| 30 | 8,487–8,498 | Recovered 11 feet (*see* Appendix 1, Sample T.S. 6227). |
| | | Conglomerate with chocolate shale and green shale pebbles, elongated and stretched at 80° to horizontal. Milky quartz pebbles to 2 inches diameter cutting across angle of shear and not elongated along line of shear. |
| | 8,500–8,540 | Green siltstone, chocolate siltstone, sandstone and quartz. |
| | 8,540–8,550 | Lithic sandstone and quartz. |
| | 8,550–8,570 | Ferruginous quartz sandstone, lithic sandstone and quartz. |
| | 8,570–8,680 | Green siltstone, chocolate siltstone, sandstone and quartz. |
| | 8,680–8,786 | Ferruginous sandstone, green siltstone, and chocolate siltstone, with quartzite and quartz. |
| 31 | 8,786–8,791 | Recoverd 2.5 feet (*see* Appendix 1, Sample T.S. 6312). |
| | | Boulder conglomerate. |
| | 8,791–8,830 | Ferruginous sandstone, siltstone and quartz. |
| | 8,830–8,920 | Mostly green dolomitic sandstone, siltstone, calcite, and calcareous quartz sandstone. Chlorite and sericite abundant at 8,870–8,880 feet. |
| | 8,920–8,990 | Ferruginous sandstone, green dolomitic siltstone, and some calcite. |
| | 8,990–9,050 | As above, with chocolate siltstone. |
| | 9,050–9,070 | Fine greenish sandstone, fine red ferruginous calcareous sandstone, calcite, sericitic siltstone. |
| | 9,070–9,080 | Fine calcareous sandstone, fine green sandstone, and pinkish red ferruginous sandstone. |
| | 9,080–9,090 | Same, with quartzite and abundant chlorite and sericite. |
| | 9,090–9,125 | As 9,070–9,080, with abundant calcite. |
| 32 | 9,125–9,134 | Recovered 8.6 feet. (*See* Appendix 1, Samples TS6313–4.) |
| | 9,134–9,190 | Fine calcareous sandstone and ferruginous sandstone. |
| | 9,190–9,220 | Calcareous sandstone, quartzite, slate, green-grey and light red shale. |
| | 9,220–9,270 | Calcareous sandstone, ferruginous sandstone, quartzite. |
| | 9,270–9,310 | Green chloritic siltstone, ferruginous sandstone. Contacts of pebbles showing in cuttings. |
| | 9,310–9,380 | Ferruginous sandstone, mostly with angular grains, and quartzite. |
| | 9,380–9,386 | Chocolate fine sandstone. |
| 33 | 9,386–9,410 | Recovered 21.8 feet. (*See* Appendix 1, Sample P344/60.) |
| | | Reddish chocolate conglomeratic sandstone with occasional quartz pebbles; vein quartz at 9,397 feet. |
| | | Quartz vein width of core at 9,401 feet. |
| | | Dip 70°–80°. |
| | 9,410–9,420 | Ferruginous calcareous sandstone and quartzite. |
| | 9,420–9,440 | Pink-white sericitic quartzite with some pyrite and ferruginous sandstone. Some mottled sheared siltstone. |
| | 9,440–9,620 | Ferruginous sandstone and some siltstone. |
| | 9,620–9,650 | Sandstone and siltstone constituents of conglomerate; pebble contacts visible. |
| | 9,650–9,690 | Mostly quartz, some sandstone and quartzite. |
| | 9,690–9,700 | Quartz, red sandstone, and red siltstone. |
| | 9,700–9,760 | Sandstone, siltstone, and quartz. |
| | 9,760–9,790 | Sandstone and siltstone. |
| | 9,790–9,812 | Sandstone, siltstone, and quartz. |
| 34 | 9,812–9,824 | Recovered 10.6 feet. (*See* Appendix 1, Sample P380/60.) |
| | | Banded red and green-grey sericitic quartzite and ferruginous siltstone throughout. Slumping at 9,816–9,817 feet. |
| | | Dip 70°–80°. |

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TABLE 1

BETOOTA No. 1 WELL

MICROPALAEONTOLOGICAL LOG–CRETACEOUS SECTION

| | CENOMANIAN | | | | | UPPER ALBIAN | | | | | | MIDDLE ALBIAN | | | | | | | | | | | | | | | APTIAN | | | | | | | | | | | | | | | APTIAN–NEOCOMIAN | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CORE | | | | | | | 3 | | | | | | | | 4 | | | | | | | | | | | | | | | | | | | | | | 6 | | | | | | | | |
| CUTTINGS (Depth in Feet) | 220–230 | 900–910 | 950–960 | 1,050–1,060 | 1,150–1,160 | 1,350–1,360 | 1,450–1,460 | 1,510–1,520 | 1,720–1,750 | 1,750–1,800 | 1,800–1,850 | 1,850–1,900 | 1,900–1,950 | 1,950–2,000 | 2,020–2,032 | 2,032–2,050 | 2,050–2,100 | 2,100–2,150 | 2,150–2,200 | 2,200–2,250 | 2,250–2,300 | 2,300–2,350 | 2,350–2,400 | 2,400–2,450 | 2,450–2,500 | 2,500–2,560 | 2,560–2,600 | 2,600–2,650 | 2,650–2,700 | 2,700–2,750 | 2,750–2,800 | 2,800–2,850 | 2,850–2,900 | 2,900–2,950 | 2,950–3,000 | 3,000–3,040 | 3,046 | 3,050–3,100 | 3,100–3,150 | 3,150–3,200 | 3,200–3,250 | 3,250–3,300 | 3,300–3,350 | 3,350–3,400 | 3,470–3,480 |
| FORAMINIFERA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Haplophragmoides* sp. 1 .. .. | — | — | — | — | — | — | — | V | V | — | — | — | — | C | — | R | F | R | V | — | V | — | — | — | — | V | — | C | — | — | V | V | R | R | — | V | — | V | V | R | V | — | — | — | — |
| *Spiroplectammina edgelli* .. | — | — | — | — | — | — | — | V | — | — | V | R | V | V | F | — | — | V | — | — | — | — | — | — | — | — | — | F | V | V | — | V | V | — | V | — | — | — | — | — | — | — | — | — | — |
| *Gaudryinella* sp. 2 .. .. | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Trochammina minuta* .. .. | — | — | — | — | — | — | — | V | — | — | — | — | F | F | V | — | V | — | — | — | — | — | — | — | — | R | R | F | — | — | — | — | V | — | — | V | V | — | — | — | V | V | — | — | — |
| *Anomalina* sp. 1 .. .. | — | — | — | — | — | — | — | — | CF | — | — | — | V | — | R | — | R | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | V | — | — | — | — | V | V | — | — | — | — | — | — |
| *Haplophragmoides dickinsoni* | — | — | — | — | — | — | — | — | — | V | V | F | R | R | A | V | V | — | — | — | — | — | — | — | — | — | F | — | V | — | — | — | — | F | R | V | F | V | R | V | — | — | — | — | — |
| *Anomalina* sp. 2 .. .. | — | — | — | — | — | — | — | — | — | V | — | V | — | V | F | — | V | V | — | — | V | — | — | — | — | — | F | — | V | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Marginulina* sp. 6 .. .. | — | — | — | — | — | — | — | — | — | V | V | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Haplophragmoides* sp. 9 .. | — | — | — | — | — | — | — | — | — | F | R | V | F | R | R | V | — | V | — | — | — | V | — | V | — | — | — | V | V | R | — | V | V | — | V | V | — | — | V | — | V | V | — | — | — |
| *Verneuilinoides* sp. 1 .. | — | — | — | — | — | — | — | — | — | V | V | C | C | V | F | V | V | V | — | — | — | — | — | V | — | — | R | R | V | R | V | V | V | V | V | V | — | V | V | V | — | — | V | — | — |
| *Reophax* sp. 2 .. .. | — | — | — | — | — | — | — | — | — | V | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | V | V | V | — | — | V | V | — | V | — | — | — | — | — | — | — | — |
| *Trochammina* sp. 8 .. .. | — | — | — | — | — | — | — | — | — | V | V | V | — | F | — | — | — | R | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Textularia* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | V | — | R | R | C | — | R | V | V | — | — | V | — | — | — | — | — | V | — | V | — | — | — | V | V | — | R | V | — | — | — | — | — | — | — |
| *Trochammina* sp. 2 .. .. | — | — | — | — | — | — | — | — | — | — | R | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Nodosaria* sp. 5 .. .. | — | — | — | — | — | — | — | — | — | — | V | V | — | — | V | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Lenticulina gunderbookaensis* .. | — | — | — | — | — | — | — | — | — | — | V | — | V | V | R | — | V | — | — | — | — | — | — | — | — | — | V | V | — | — | — | — | V | V | — | V | V | — | R | — | V | — | — | — | — |
| *Valvulineria* sp. 2 .. .. | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | V | V | — | — | — | — |
| *Marginulina* sp. 5 .. | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Valvulineria* sp. 3 .. .. | — | — | — | — | — | — | — | — | — | — | — | V | — | V | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | V | — | — | — | — | — | — | — | — | — |
| *Marginulina* sp. 2 .. .. | — | — | — | — | — | — | — | — | — | — | — | V | V | V | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — |
| *Hyperammina* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | V | V | — | V | — | — | — | — | — | — | — | — | — | — |
| *Gaudryinella* sp. 3 .. .. | — | — | — | — | — | — | — | — | — | — | — | V | — | V | V | — | R | — | — | — | V | — | — | — | — | — | V | R | V | — | — | — | — | — | V | V | — | — | — | — | — | — | — | — | — |
| *Robulus* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | V | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — |
| *Marginulina* sp. 3 .. .. | — | — | — | — | — | — | — | — | — | — | — | R | V | — | V | — | — | — | — | — | — | — | — | V | — | V | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Dentalina* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | V | — | — | R | — | — | — | — | — | — | — | — | — | — | — | V | — | — | V | — | V | — | — | V | — | V | — | — | V | — | V | — | — | — |
| *Globulina* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | V | — | R | R | — | V | — | V | — | — | — | — | — | — | — | — | V | V | V | — | — | V | — | V | V | — | — | — | — | — | — | — | — | — |
| *Dorothia* sp. 3 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | V | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — |
| *Ammomarginulina* sp. 1 .. | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Valvulineria infracretacea* .. | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | V | — | — | V | V | — | — | V | R | V | V | R | — | V | V | — | V | — | — | — | — | V | V | — | — | — | — |
| *Bulimina* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | R | R | V | V | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Cibicides* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | V | V | — | V | V | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Haplophragmoides* sp. 5 .. | — | — | — | — | — | — | — | — | — | — | — | — | — | V | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Spiroplectammina* sp. 2 .. | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Trochamminoides* sp. 1 .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | F | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — |
| *Dorothia* sp. 2 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | R | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Bigenerina* sp. 2 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | R | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Ammobaculites fisheri* .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | V | V | — | — | — | — | — | — | — | — | R | F | R | F | V | V | — | — | V | — | — | — | — | — | — | — | — | — | — |
| *Ammobaculites minimus* .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | V | V | — | V | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — |
| *Quinqueloculina* sp. 1 .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Involutina* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | V | — | — | — | — | — | — | — | — | V | V | — | — | — | V | — | — | — | — | — | — | V | — | — | — | — | — | — |
| *Lagena* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | V | — | — | V | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V |
| *Dentalina* sp. 2 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | V | — | — | — | V | — |
| *Saracenaria* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | R | — | V | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Guttulina* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | V | — |
| *Robulus* sp. 4 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Marginulina* sp. 7 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Saracenaria* sp. 3 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — |
| *Dentalinopsis* sp. 2 .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Pyrulina* sp. 2 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Bulimina* sp. 2 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | V | V | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Textularia* sp. 3 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Lagena* sp. 5 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Lenticulina australiensis* .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | V | — | — | — | — | — | — | R | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Lenticulina* sp. 4 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | R | — | V | V | — | — | — | — | — |
| *Globigerina* sp. 4 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | V | V | R | V | A | A | V | A | — | — | — | — | — | V | V | — | — | — | — | — | V | — | — | — | — | — | — |
| *Lingulina* sp. 2 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Pyrulina* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | V | — | — |
| Cf. *Anomalina* sp. 3 .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Bulimina* sp. A .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Cf. *Marginulina* sp. 9 .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Ammobaculites* sp. 3 .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | R | R | R | R | V | — | — | V | V | V | — | V | V | — | V | V | — | — | — |
| *Ammobaculoides romaensis* .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | V | — | — | V | V | R | — | — | — | — | — | — | — | — | — | — | — | — |
| *Textularia* sp. 2 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | R | F | V | V | V | V | — | V | V | V | — | — | — | V | — | — | V | — | — |
| *Verneuilina howchini* .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | F | F | V | V | — | — | V | V | V | V | — | — | — | — | — | — | — | — | — |
| *Marginulinopsis subcretaceus* .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Gyroidina* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | V | V | V | — | — | — | — | — | — | — | — | — | — | — | — |
| *Haplophragmoides chapmani* .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Haplophragmoides* sp. 2 . | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | R | V | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Haplophragmoides* sp. 8 .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | R | V | V | — | V | V | — | V | — | — | — | — | V | V | V | — | — | — |
| *Textularia* sp. 5 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Bigenerina loeblichae* .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | V | R | R | V | V | — | — | — | — | V | V | — | — | — | — |
| *Gaudryinella* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | V | — | — | V | — | — | — | — | R | V | — | — | — | — | — | — | — |
| *Marginulina* sp. 10 .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Textularia* sp. 4 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Marginulina marreensis* .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | V | — | — | V | — | — | V | — | — | — | V | — |
| *Marginulina* sp. 1A .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — |
| *Pelosina lagenoides* .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | R | — | — | — | — | — | — | — | — |
| *Ammobaculoides pitmani* .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Gaudryina* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | V | — | — | — | — | — |
| *Lenticulina* sp. 3 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | V | — | — | — | — | V | — | — | — | — | V | — | — |
| *Ammobaculites australis* .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | V | — | — | — | — | — | — | — | — |
| *Trochammina* sp. 9.. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — |
| *Nodosaria* sp. 1 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — |
| *Patellina jonesi* .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — | — | — | — |
| *Anomalina mawsoni* .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | V | V | — | — | — | — | — | — | — | — | — |
| *Siphotextularia* sp. 1 .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | V | — | — | — | V | — | — | — | — |
| *Ammobaculoides coonanaensis* | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | V | — | — | — | — | — | — | — | — |
| *Bulimina* sp. 3 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | R | — | V | V | F | — | — | — | — | — | — |
| *Valvulineria* sp. 4 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | V | — | — | — | — | — | — | — | — | — |
| *Lingulina* sp. 3 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — | — | — | — |
| *Dentalina* sp. 4 .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — | — | — |
| *Textularia anacooraensis* .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | V | — | — | — |

*V* = Very Rare .. .. 1– 2 Specimens
*R* = Rare .. .. .. 3– 5 Specimens
*F* = Frequent .. .. .. 6–10 Specimens
*C* = Common .. .. .. 11–25 Specimens
*A* = Abundant.. .. .. > 25 Specimens

| | 220–230 | 900–910 | 950–960 | 1,050–1,060 | 1,150–1,160 | 1,350–1,360 | 1,450–1,460 | 1,510–1,520 | 1,720–1,750 | 1,750–1,800 | 1,800–1,850 | 1,850–1,900 | 1,900–1,950 | 1,950–2,000 | 2,020–2,032 | 2,032–2,050 | 2,050–2,100 | 2,100–2,150 | 2,150–2,200 | 2,200–2,250 | 2,250–2,300 | 2,300–2,350 | 2,350–2,400 | 2,400–2,450 | 2,450–2,500 | 2,500–2,560 | 2,560–2,600 | 2,600–2,650 | 2,650–2,700 | 2,700–2,750 | 2,750–2,800 | 2,800–2,850 | 2,850–2,900 | 2,900–2,950 | 2,950–3,000 | 3,000–3,040 | 3,046 | 3,050–3,100 | 3,100–3,150 | 3,150–3,200 | 3,200–3,250 | 3,250–3,300 | 3,300–3,350 | 3,350–3,400 | 3,470–3,480 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RADIOLARIA .. | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | X | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| MOLLUSCA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Inoceramus Prisms* .. .. | — | — | — | — | — | X | X | — | — | X | X | — | — | X | X | — | X | X | — | X | — | — | — | X | X | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Shell Fragments* .. .. | — | — | — | — | — | X | — | — | — | — | X | — | — | X | — | — | X | — | — | — | — | X | X | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Aucellina* .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — | X | X | X | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Trigonia*(?) .. | — | — | — | — | — | — | — | — | — | — | — | — | X | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Gastropods* .. | — | — | — | — | — | — | — | — | — | — | X | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| OSTRACODES .. | — | — | — | — | — | — | — | — | X | X | X | X | X | X | X | — | X | X | — | — | — | — | — | — | — | — | — | — | X | — | — | — | — | — | — | — | X | — | X | X | X | — | X | — | — |
| ECHINOID SPINES .. | — | — | — | — | — | — | — | — | — | — | — | X | — | — | — | — | X | X | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| PLANT MEGASPORES | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Iridescent Spores* .. .. | X | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Azolla* .. .. .. | — | X | X | — | — | — | — | X | — | — | — | — | X | X | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Other Megaspores* .. .. | — | — | — | X | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |

[To face page 46.]

# TABLE 2
## LOWER CRETACEOUS FORAMINIFERA

| Species | First Appearance Betoota | First Appearance Innamincka | Range |
|---|---|---|---|
| | feet | feet | |
| *Ammobaculites australis* (Howchin) .. | 2,900–2,910 | 2,030–2,040 | Alb.–Apt. |
| *Ammobaculites fisheri* Crespin .. .. | 2,020 | 1,980–1,990 | Alb.–Apt. |
| *Ammobaculites* sp. 3 .. .. .. | 2,560–2,570 | 2,045 ft. 6 in. | Alb.–Apt. |
| *Ammobaculites minimus* Crespin.. .. | 2,020 | 2,250–2,260 | Alb.–Apt. |
| *Ammobaculoides romaensis* Crespin .. | 2,580–2,590 | ? 2,051 ft. 9 in. | Aptian |
| *Ammobaculoides coonanaensis* Crespin .. | 2,990–3,000 | 3,160–3,170 | Aptian |
| *Ammobaculoides pitmani* Crespin .. | 2,760–2,770 | —— | Aptian |
| *Ammomarginulina* sp. 1 .. .. | 1,910–1,920 | 1,980–1,990 | Alb.–Apt. |
| *Anomalina* sp. 1 .. .. .. | (?) 1,720–1,730 | 2,530–2,540 | Alb.–Apt. |
| *Anomalina* sp. 2 .. .. .. | 1,750–1,760 | 2,045 ft. 6 in. | Alb.–Apt. |
| *Anomalina* sp. 3 .. .. .. | 2,250–2,260 | 2,840–2,850 | L. Mid. Alb.–Apt. |
| *Anomalina mawsoni* Crespin .. .. | 2,940–2,950 | —— | Aptian |
| *Bigenerina loeblichae* Crespin .. .. | 2,610–2,620 | 2,740–2,750 | L. Mid. Alb.–Apt. |
| *Bigenerina* sp. 2 .. .. .. | 2,020 | —— | M. Albian |
| *Bulimina* sp. 1 .. .. .. | 1,980–1,990 | 2,600–2,610 | M. Alb.–Apt. |
| *Bulimina* sp. 2 .. .. .. | 2,060–2,070 | 3,590–3,600 | M. Alb.–Apt. |
| *Bulimina* sp. 3 .. .. .. | 2,960–2,970 | 3,023 ft. 6 in. | Aptian |
| *Bulimina* sp. A .. .. .. | 2,400–2,410 | 2,380–2,390 | L. Upper Alb.–Apt. |
| *Cibicides* sp. 1 .. .. .. | 1,980–1,990 | 2,440–2,450 | M. Alb.–Apt. |
| *Dentalina* sp. 1 .. .. .. | 1,870–1,880 | 3,020 ft. 3 in. | M. Alb.–Apt. |
| *Dentalina* sp. 2 .. .. .. | 2,020 | 2,516 ft. 6 in. | M. Alb.–Apt. |
| *Dentalina* sp. 4 .. .. .. | 3,070–3,080 | —— | |
| *Dentalinopsis* sp. 2 .. .. .. | 2,080–2,090 | 3,220–3,230 | M. Alb.–Apt. |
| *Dorothia* sp. 2 .. .. .. | 2,020 | 2,080–2,090 | M. Alb.–Apt. |
| *Dorothia* sp. 3 .. .. .. | 1,910–1,920 | 2,420–2,430 | M. Alb.–Apt. |
| *Gaudryina* sp. 1 .. .. .. | 2,780–2,790 | 2,340–2,350 | M.–L. Alb.–? Apt. |
| *Gaudryinella* sp. 1 .. .. .. | 2,610–2,620 | 3,260–3,270 | L. Alb.–Apt. |
| *Gaudryinella* sp. 2 .. .. .. | 1,513 | —— | Alb.–Apt. |
| *Gaudryinella* sp. 3 .. .. .. | 1,870–1,880 | 2,680–2,690 | M. Alb.–Apt. |
| *Globigerina* sp. 4 .. .. .. | 2,120–2,130 | 2,490–2,500 | M.–L. Alb. |
| *Globulina* sp. 1 .. .. .. | 1,870–1,880 | 2,045 ft. 6 in. | M. Alb.–Apt. |
| *Guttulina* sp. 1 .. .. .. | 2,020 | 2,513 ft. 6 in. | M. Albian |
| *Gyroidina* sp. 1 .. .. .. | 2,590–2,600 | 2,280–2,290 | M. Alb.–Apt. |
| *Haplophragmoides* sp. 1 .. .. | 1,513 | 2,049 ft. 8 in. | U. Alb.–Apt. |
| *Haplophragmoides* sp. 2 .. .. | (?) 2,620–2,630 | 2,120–2,130 | Albian |
| *Haplophragmoides chapmani* Crespin .. | 2,610–2,620 | 2,680–2,690 | L. Alb.–Apt. |
| *Haplophragmoides* sp. 5 .. .. | 1,990–2,000 | 2,750–2,760 | M. Alb.–Apt. |
| *Haplophragmoides dickinsoni* Crespin .. | 1,750–1,760 | 2,049 ft. 8 in. | U. Alb.–Apt. |
| *Haplophragmoides* sp. 8 .. .. | 2,610–2,620 | 2,049 ft. 8 in. | U. Alb.–Apt. |
| *Haplophragmoides* sp. 9 .. .. | 1,760–1,770 | 2,051 ft. 9 in. | U. Alb.–Apt. |
| *Hyperammina* sp. 1 .. .. .. | 1,790–1,800 | 2,051 ft. 9 in. | U. Alb.–Apt. |
| *Involutina* sp. 1 .. .. .. | 2,020 | 2,058 ft. 6 in. | U. Alb.–Apt. |
| *Lagena* sp. 1 .. .. .. .. | 2,020 | 2,770–2,780 | U. Alb.–Apt. |
| *Lagena* sp. 5 .. .. .. .. | 2,100–2,110 | 2,430–2,440 | M. Alb.–Apt. |
| *Lenticulina gunderbookaensis* Crespin .. | 1,800–1,810 | 2,030–2,040 | U. Alb.–Apt. |
| *Lenticulina* sp. 3 .. .. .. | 2,820–2,830 | 3,060–3,070 | Aptian |
| *Lenticulina* sp. 4 .. .. .. | 2,120–2,130 | —— | Aptian |
| *Lenticulina australiensis* Crespin .. .. | 2,100–2,110 | 2,054 ft. 6 in. | U. Alb.–Apt. |
| *Lingulina* sp. 2 .. .. .. | 2,180–2,190 | 3,020 ft. 3 in. | M. Alb.–Apt. |
| *Lingulina* sp. 3 .. .. .. | 3,046 | —— | Aptian |
| *Marginulina* sp. 1A .. .. .. | 2,690–2,700 | 2,930–2,940 | Aptian |
| *Marginulina* sp. 2 .. .. .. | 1,860–1,870 | 2,513 ft. 8 in. | U. Alb.–Apt. |
| *Marginulina* sp. 3 .. .. .. | 1,880–1,890 | 2,054 ft. 6in. | Albian |
| *Marginulina* sp. 5 .. .. .. | 1,850–1,860 | 2,420–2,430 | M. Alb.–U. Apt. |
| *Marginulina* sp. 6 .. .. .. | 1,750–1,760 | 2,051 ft. 9 in. | U. Alb.–Apt. |
| *Marginulina* sp. 7 .. .. .. | 2,070–2,080 | 2,790–2,800 | M. Alb.–Apt. |
| *Marginulina marreensis* Crespin .. .. | 2,680–2,690 | 3,530–3,540 | Aptian |
| *Marginulina* sp. 10 .. .. .. | 2,610–2,620 | 2,730–2,740 | Aptian |
| *Marginulinopsis subcretaceous* Crespin .. | 2,590–2,600 | 3,340–3,350 | Aptian |
| *Nodosaria* sp. 1 .. .. .. | 2,900–2,910 | 2,054 ft. 6 in. | U. Alb.–Apt. |

| Species | First Appearance Betoota | First Appearance Innamincka | Range |
|---|---|---|---|
| | feet | feet | |
| *Nodosaria* sp. 5 .. .. .. | 1,800–1,810 | 2,410–2,420 | Albian |
| *Patellina jonesi* Howchin .. .. | 2,940–2,950 | 3,610–3,620 | Aptian |
| *Pelosina lagenoides* Crespin .. .. | 2,760–2,770 | 3,018 ft. 6 in. | U. Alb.–Apt. |
| *Pyrulina* sp. 1 .. .. .. .. | 2,200–2,210 | 2,450–2,460 | M. Alb.–Apt. |
| *Pyrulina* sp. 2 .. .. .. .. | 2,060–2,070 | 3,740–3,750 | M. Alb.–Apt. |
| *Quinqueloculina* sp. 1 .. .. .. | 2,020 | 2,513 ft. 8 in. | M. Alb.–Apt. |
| *Reophax* sp. 2 .. .. .. | 1,790–1,800 | 1,930–1,940 | U. Alb.–Apt. |
| *Robulus* sp. 1 .. .. .. .. | 1,870–1,880 | 2,380–2,390 | M. Alb.–Apt. |
| *Robulus* sp. 4 .. .. .. .. | 2,070–2,080 | 2,360–2,370 | M. Alb.–Apt. |
| *Saracenaria* sp. 1 .. .. .. | 2,020 | 2,516 ft. 6 in. | M. Alb.–Apt. |
| *Saracenaria* sp. 3 .. .. .. | 2,070–2,080 | 2,509 ft. 8 in. | M. Alb.–Apt. |
| *Siphotextularia* sp. 1 .. .. .. | 2,960–2,970 | 2,513 ft. 8 in. | M. Alb.–Apt. |
| *Spiroplectammina edgelli* Crespin .. | 1,513 | 2,049 ft. 8 in. | U. Alb.–Apt. |
| *Spiroplectammina* sp. 2 .. .. | 1,990–2,000 | 2,513 ft. 8 in. | M. Alb.–Apt. |
| *Textularia* sp. 1 .. .. .. | 1,800–1,810 | 2,054 ft. 6 in. | U. Alb.–Apt. |
| *Textularia* sp. 2 .. .. .. | 2,570–2,580 | 2,058 ft. 6 in. | U. Alb.–Apt. |
| *Textularia* sp. 3 .. .. .. | 2,120–2,130 | 1,910–1,920 | M. Alb.–Apt. |
| *Textularia* sp. 4 .. .. .. | 2,690–2,700 | 3,710–3,720 | Aptian |
| *Textularia* sp. 5 .. .. .. | 2,610–2,620 | 4,030–4,040 | Aptian |
| *Textularia anacooraensis* Crespin .. | 3,260–3,270 | 3,710–3,720 | Aptian |
| *Trochammina* sp. 2 .. .. .. | 1,800–1,810 | 2,010–2,020 | U. Alb.–Apt. |
| *Trochammina minuta* Crespin .. .. | 1,513 | 2,440–2,450 | U. Alb.–Apt. |
| *Trochammina* sp. 8 .. .. .. | 1,790–1,800 | 1,700–1,710 | U. Alb.–M. Alb. |
| *Trochammina* sp. 9 .. .. .. | 2,920–2,930 | —— | Aptian |
| *Trochamminoides* sp. 1 .. .. | 2,020 | —— | M. Alb.–Apt. |
| *Valvulineria infracretacea* Crespin .. | 1,920–1,930 | 2,230–2,240 | M. Alb.–Apt. |
| *Valvulineria* sp. 2 .. .. .. | 1,830–1,840 | 2,058 ft. 6 in. | U. Alb.–Apt. |
| cf. *Valvulineria* sp. 3 .. .. .. | 1,850–1.860 | 2,420–2,430 | M. Alb.–Apt. |
| *Valvulineria* sp. 4 .. .. .. | 2,960–2,970 | —— | Aptian |
| *Verneuilina howchini* Crespin .. .. | 2,590–2,600 | 2,680–2,690 | L. Alb.–Apt. |
| *Verneuilinoides* sp. 1 .. .. .. | 1,760–1,770 | 2,049 ft. 8 in. | U. Alb.–Apt. |

# APPENDIX 3

## WATER ANALYSES

| | D.S.T. No. 1* | | D.S.T. No. 3† | | D.S.T. No. 5† | |
|---|---|---|---|---|---|---|
| | P.p.m. | Me./litre | P.p.m. | Me./litre | P.p.m. | Me./litre |
| $Na^+$ .. .. .. | 1,420 | 62.0 | 1,620 | 70.4 | 2,495 | 108.5 |
| $K^+$ .. .. .. | 38 | 1.0 | — | — | — | — |
| $Ca^{++}$ .. .. .. | 15 | 0.8 | 17 | 0.8 | 5 | 0.2 |
| $Mg^{++}$ .. .. .. | 5 | 0.4 | 3 | 0.2 | 3 | 0.2 |
| $Fe^{++}$ .. .. .. | — | — | — | — | 29.2 | 1.0 |
| Total Cations .. .. | 1,478 | 64.2 | 1,640 | 71.4 | 2,532 | 110.0 |
| $Cl^-$ .. .. .. | 1,300 | 36.6 | 1,584 | 45.2 | 1,995 | 57.0 |
| $SO_4^=$ .. .. .. | 55 | 1.1 | 44 | 0.9 | 52 | 1.1 |
| $CO_3^=$ .. .. .. | — | — | 778 | 25.9 | 1,581 | 52.7 |
| $HCO_3^-$ .. .. | 1,620 | 26.5 | — | — | — | — |
| $NO_3^-$ .. .. .. | — | — | Nil | Nil | — | — |
| Total Anions .. .. | 2,975 | 64.2 | 2,406 | 72.0 | 3,628 | 110.8 |
| Total Dissolved Solids .. | 4,453 | | 4,046 | | 6,160 | |
| Total Solids (heated to constant weight at 180° C) .. .. | 4,090 | | | | | |
| Conductivity at 24° C. .. | 5,900 micromhos | | | | | |
| pH at 24° C. .. .. | 8.3 | | | | | |

| ASSUMED COMPOSITION | Salt | P.p.m. | Salt | P.p.m. | Salt | P.p.m. |
|---|---|---|---|---|---|---|
| | $Ca(HCO_3)_2$ | 64 | $CaCO_3$ | 43 | $CaCO_3$ | 12 |
| | $Mg(HCO_3)_2$ | 31 | $MgCO_3$ | 10 | $MgCO_3$ | 10 |
| | $NaHCO_3$ | 2,138 | $Na_2CO_3$ | 1,317 | $Na_2CO_3$ | 2,711 |
| | $Na_2SO_4$ | 81 | $Na_2SO_4$ | 66 | $Na_2SO_4$ | 77 |
| | NaCl | 2,221 | NaCl | 2,610 | NaCl | 3,289 |
| | KCl | 75 | | | $FeCO_3$ | 61 |

| HARDNESS (as $CaCO_3$) | P.p.m. | P.p.m. | P.p.m. |
|---|---|---|---|
| Total .. .. .. | 60 | 54 | 77 |
| Permanent .. .. | Nil | Nil | Nil |
| Temporary .. .. | 60 | 54 | 77 |
| Due to Calcium .. .. | 39 | 43 | 13 |
| Due to Magnesium .. .. | 21 | 11 | 12 |
| Due to Iron .. .. .. | — | — | 52 |

* Analysis carried out by B.M.R., Canberra. † Analysis carried out by A.M.D.L., Adelaide.

# APPENDIX 4

## FORMATION TESTS

All formation testing was done in the open hole and concurrently with drilling operations.

*Drill Stem Test No.* 1.—

Interval: 3,542–3,563 feet.

Chokes: Top—open: bottom—$\frac{3}{8}$ inch.

Valve open: 40 minutes.

Valve closed: 20 minutes.

Good initial puff, steady air blow throughout.

Recovery: 300 feet water, 90 feet mud.

| | | |
|---|---|---|
| IFP —0–80 | ISIP —not taken | IHH —1,800 p.s.i. |
| FFP—390 | FSIP—1,320 | FHH—1,790 p.s.i. |

*Drill Stem Test No.* 2.—

Interval: 4,424–4,462 feet.

Chokes: Top—open; bottom—$\frac{3}{8}$ inch.

Valve open: 1 hour.

Valve closed: 30 minutes.

Good initial puff, weak air blow throughout.

Recovery: 25 feet muddy water.

| | | |
|---|---|---|
| IFP —0 | ISIP —not taken | IHH —2,450 p.s.i. |
| FFP—0 | FSIP—1,250 | FHH—2,400 p.s.i. |

*Drill Stem Test No.* 3.—

Interval: 4,779–4,801 feet.

Chokes: Top—$\frac{1}{4}$ inch; bottom—$\frac{3}{8}$ inch.

Valve open: 35 minutes.

Valve closed: 20 minutes.

Good initial puff, strong air blow, water to surface in 26 minutes—estimated 1,200 gallons per hour.

Recovery: Full string of water.

| | | |
|---|---|---|
| IFP —1,225 | ISIP —not taken | IHH —2,700 p.s.i. |
| FFP—2,100 | FSIP—2,200 | FHH—2,600 p.s.i. |

*Drill Stem Test No.* 4.—

Interval: 5,386–5,420 feet.

Chokes: Top—$\frac{1}{4}$ inch; bottom—$\frac{3}{8}$ inch.

Valve open: 30 minutes.

Valve closed: 20 minutes.

Good initial puff, weak air blow.

Recovery: 60 feet of drilling mud.

| | | |
|---|---|---|
| IFP —0 | ISIP —0 | IHH —3,000 p.s.i. |
| FFP—80 | FSIP—1,400 | FHH—2,900 p.s.i. |

*Drill Stem Test No.* 5.—

Interval: 6,910–7,036 feet.

Chokes: Top—$\frac{1}{4}$ inch; bottom—$\frac{3}{8}$ inch.

Valve open: 30 minutes.

Valve closed: 30 minutes.

Good initial puff, steady blow throughout.

Recovery: 360 feet of drilling mud, 450 feet watery drilling mud.

| | | |
|---|---|---|
| IFP —270 | ISIP —not taken | IHH —3,825 p.s.i. |
| FFP—430 | FSIP—2,250 | FHH—3,825 p.s.i. |

# APPENDIX 5

## PALYNOLOGICAL REPORTS

### (1) COAL SAMPLE FROM 4,305–4,315 FEET*

This sample was separated from the cuttings from these depths by separation with carbon tetrachloride (S.G. 1.58). The coal was macerated and the maceration residue examined for spores and pollen grains for the purpose of age determination. The species determined are listed below, together with their known stratigraphic ranges:—

| | |
|---|---|
| *Inaperturopollenites reidi* | Lower Jurassic (Walloon) |
| *Entylissa crassimarginis* | Lower Jurassic (Walloon) |
| *Leiotriletes directus* | Permian to Lower Jurassic (Walloon) |
| *Leiotriletes magnus* | Lower Jurassic (Walloon) |
| *Granulatisporites minor* | Lower Jurassic (Walloon) |
| *Araucariacites* cf. *australis* | Lower Jurassic to Lower Cretaceous |
| *Leptolepidites verrucatus* | Lower Jurassic to Upper Cretaceous |
| *Entylissa nitidus* | Lower Jurassic to Lower Cretaceous |
| *Cyathidites australis rimalis* | Lower Jurassic to Lower Cretaceous |
| *Pityosporites* cf. *ellipticus* | Lower Jurassic to Lower Cretaceous |
| *Podosporites micropterus* | Middle Jurassic to Lower Cretaceous |
| *Microcachrydites antarcticus* | Middle Jurassic to Lower Cretaceous |
| *Zonalapollenites dampieri* | Lower Jurassic to Lower Cretaceous |
| *Ischyosporites* sp. | Upper Jurassic to Lower Cretaceous |

The above stratigraphic ranges are based on the work of Balme and Cookson on Australian Jurassic and Cretaceous microfloras and on the writer's work on the microflora of the Walloon Coal Measures in the type area (regarded as Lower Jurassic in age). From the list it is evident that the species present have been recorded elsewhere mainly from sediments of Lower Jurassic to Lower Cretaceous age. Closer age determination is difficult, as the ranges of many of these species have not yet been precisely determined; however, the mixture of Walloon species with later forms strongly suggests a Middle to Upper Jurassic age (i.e., somewhat younger than the Walloon Coal Measures in the type area).

The writer has been assisted in the investigation by Mr. R. J. Allen, Geologist, Geological Survey of Queensland, who carried out the separation of coal from the cuttings at the bore site, and also by Miss C. Nix, a Science Student of the University of Queensland, who assisted in the maceration of the sample and in the examination of the micro-slides.

### (2) COAL SAMPLE FROM 4,720 FEET*

This sample was recovered from the cuttings from this depth by separation with carbon tetrachloride (S.G. 1.58). It was subjected to maceration and the maceration residue examined for spores and pollen grains for the purpose of age determination. Spores were relatively rare in the micro-slides and only a few species could be identified. The species determined are listed below, together with their stratigraphic ranges:—

| | |
|---|---|
| *Inaperturopollenites reidi* | Lower Jurassic (Walloon) |
| *Lycopodiumsporites rosewoodensis* | Lower Jurassic (Walloon) |
| *Rugulatisporites ramosus* | Lower Jurassic (Walloon) |
| *Leiotriletes directus* | Permian to Lower Jurassic (Walloon) |
| *Leiotriletes magnus* | Lower Jurassic (Walloon) |
| *Ischyosporites* sp. nov. | |

The species identified have all, with one exception, been previously recorded from the type area of the Walloon Coal Measures (regarded as Lower Jurassic in age). The exception is a previously undescribed species of *Ischyosporites*, a genus which has been recorded elsewhere in Australia from the Upper Jurassic and Lower Cretaceous. The same species occurs in the coal sample from 4,305–4,315 feet in this bore. Although a previously undescribed form, insufficient specimens are as yet available to warrant describing it as a new species. The occurrence of a typical Walloon species such as *Lycopodiumsporites rosewoodensis*, which is absent in the sample from 4,305–4,315 feet, together with the absence of trisaccate pollen grains which occur in the latter sample, suggest a Lower Jurassic age (approximately equivalent to the Walloon Coal Measures) for this sample from 4,720 feet. However, in view of the paucity of species in the sample, this correlation should be regarded as tentative only.

* By N. J. de Jersey, Geological Survey of Queensland.

The writer has been assisted in the investigation by Mr. R. J. Allen, Geologist, Geological Survey of Queensland, who separated the coal from the cuttings at the bore site, and also by Miss C. Nix, a Science Student of the University of Queensland, who assisted in the maceration of the sample and in examination of the micro-slides.

### (3) MATERIAL FROM 5,220 FEET*

The preservation is very poor, and although spores are plentiful, they are dark in colour and the ornament usually destroyed. My impression is that this sediment has been a good deal more highly devolatilized than cores from the same depth in Innamincka Well. I do not like to commit myself very strongly on the age of this assemblage, as it is easy to mis-identify or fail to recognize critical forms when the spore walls are partly destroyed. However, on the assumption that even a slight lead may be helpful my impressions are as follows:—

(1) The assemblage is certainly not older than Permian.

(2) As I did not find any specimen that resembled a characteristic Permian form, I believe a Mesozoic age to be almost certain. Some of the Permian genera are sufficiently distinctive to enable their recognition even in the poorest state of preservation.

(3) Genera which I regard as characteristically Middle Jurassic-Lower Cretaceous were not recognized.

(4) The evidence, negative as it is, is consistent with a Triassic or Lower Jurassic age.

### (4) VARIOUS CORES†

Samples from the main cores and sidewall cores which are listed below, have been subjected to a preliminary palynological examination. Suggested ages for these samples are listed.

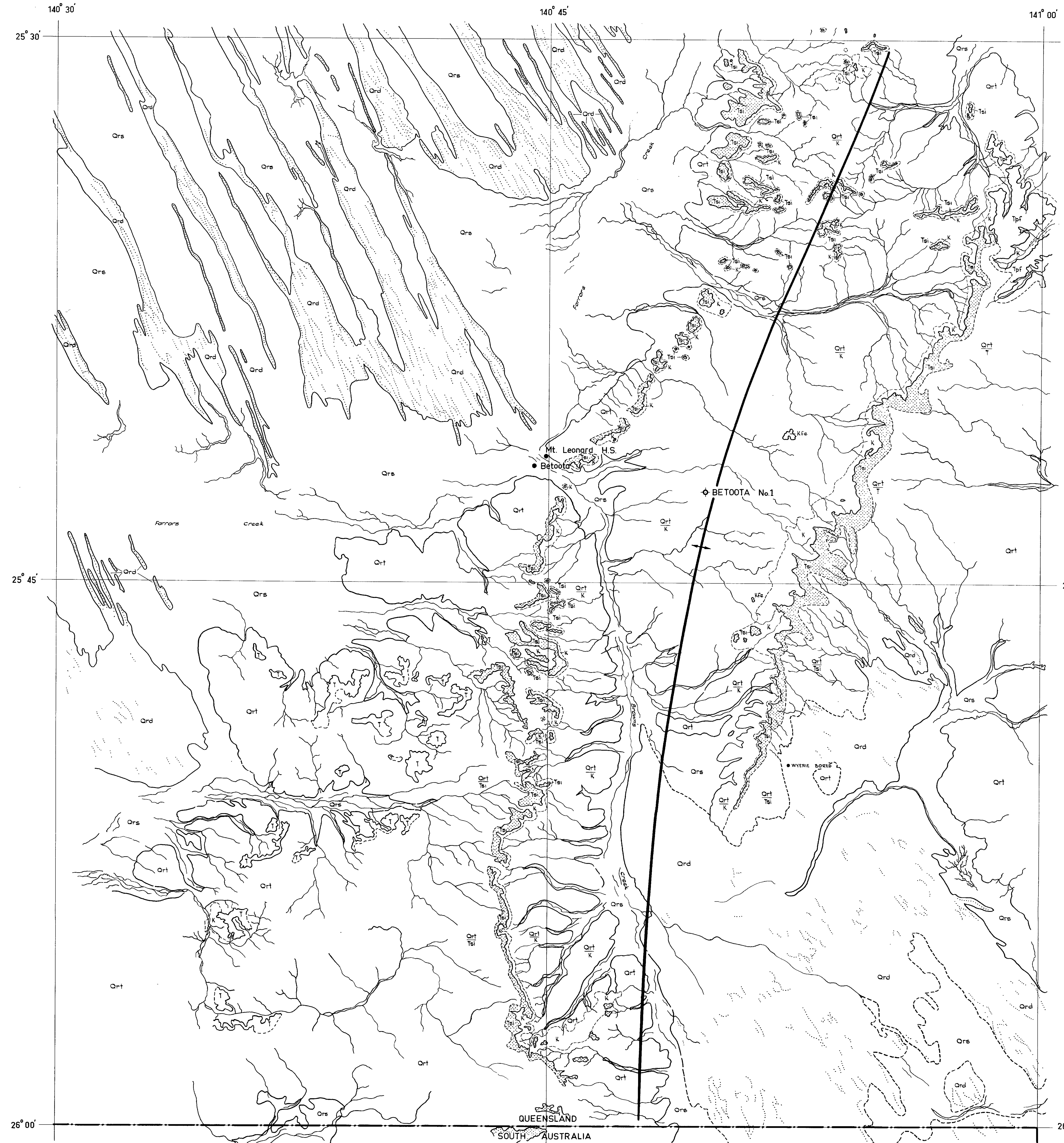
| Core | Depth | Suggested Age |
|---|---|---|
| | feet | |
| S.W.C. 28 | 1,249 | Cretaceous, non-marine |
| S.W.C. 26 | 1,374 | Cretaceous, marine |
| S.W.C. 5 | 2,758 | Cretaceous, marine |
| S.W.C. 4 | 2,998 | Cretaceous, ?marine |
| Core 10 | 4,208 | Jurassic, non-marine |
| Core 11 | 4,700 | Barren |
| Core 12 | 4,794 | Barren |
| Core 13 | 5,224–5,226 | Jurassic |

All samples but those from Cores 11 and 12 yielded abundant organisms. The state of preservation of fossils in Core 13 was poor and identification of species at that level was difficult. However, the presence of *Zonalapollenites* cf. *Z. dampieri* and *Lycopodiumsporites* sp. is indicative of a Jurassic age at that level.

This initial examination shows that close similarities exist between the sequences in the Betoota and Innamincka bores.

* By B. E. Balme, University of Western Australia. † By P. R. Evans, Bureau of Mineral Resources.

By Authority: A. J. ARTHUR, Commonwealth Government Printer, Canberra.




## LEGEND

QUARTERNARY

| | |
|---|---|
| Qrs | Alluvium outwash plains, interdunal area. |
| Qrt | Gibbers, gibber outwash, gibber terraces, talus slopes. |
| Qrd | Sand dunes. |

CRETACEOUS

| | |
|---|---|
| K | Undifferentiated Cretaceous. |
| Kfe | Laterized shales, sandstones etc. |
| Qrt/K | Gibbers over Cretaceous shales, limestones etc. |

TERTIARY

| | |
|---|---|
| T | Undifferentiated Tertiary. |
| Tsi | Siliceous duricrust. |
| Qrt/T | Gibbers over undifferentiated Tertiary. |
| Qrt/Tsi | Gibbers over duricrust. |
| Tpf | Tertiary gravels, sandstones, clays including altered sandstone below duricrust. |

Scale

2 1 0 2 4 6 miles

DELHI AUSTRALIAN PETROLEUM LIMITED

# REGIONAL GEOLOGIC MAP OF THE BETOOTA ANTICLINE

GREAT ARTESIAN BASIN

AUSTRALIA

**PLATE 1**

Drawn by: J Allen

# DELHI - FROME - SANTOS

AUTHORITY TO PROSPECT: 66P & 67P

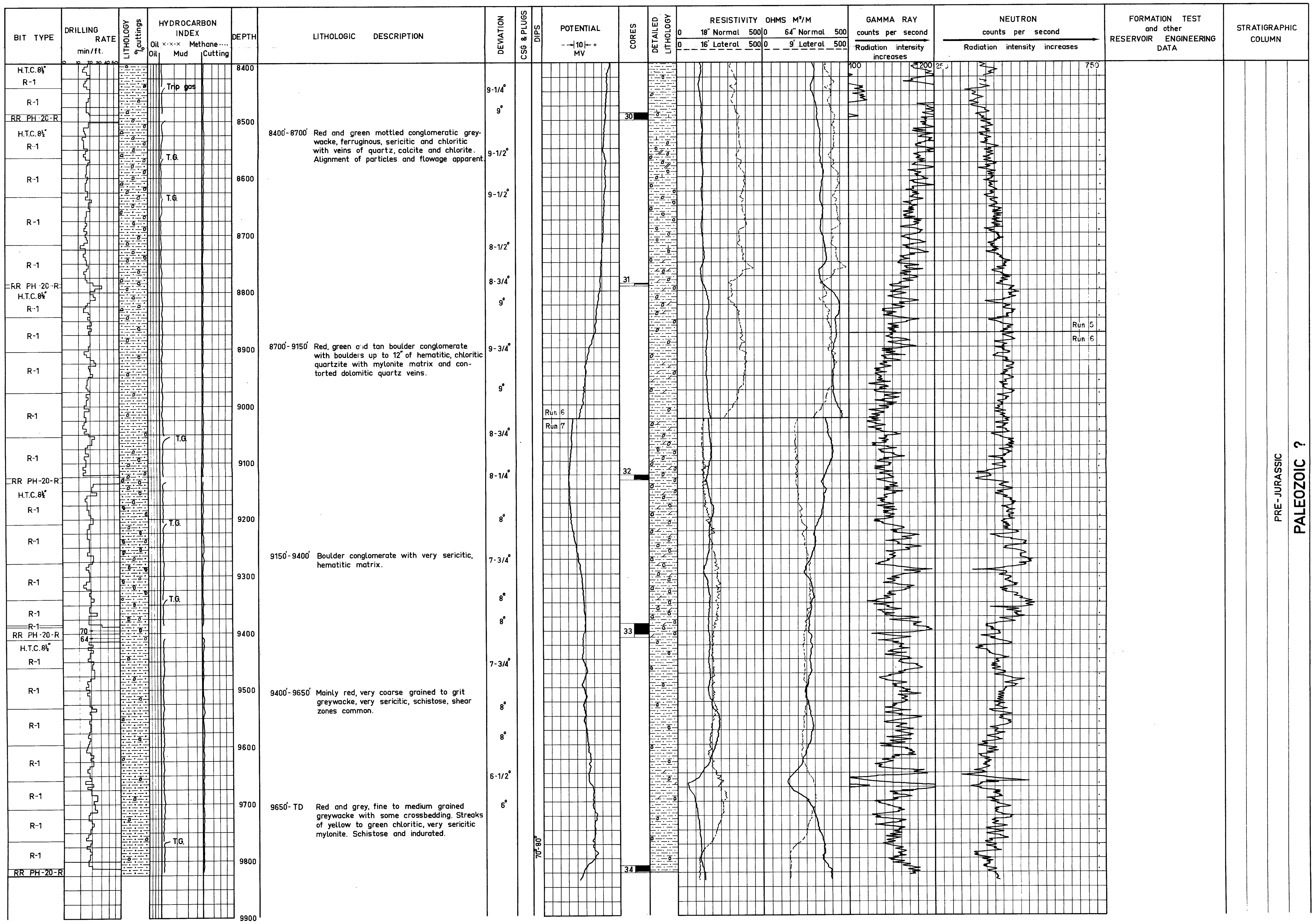
WELL NUMBER: BETOOTA No. 1

**WELL SYMBOLS**

- Core interval, number and recovery.
- Sidewall core.
- Formation test, interval and number.
- Plugged interval.
- PR Re-run bit.
- NR No recovery.

**LITHOLOGIC REFERENCE**

| | | |
|---|---|---|
| Conglomerate | Shale | Calcareous |
| Siltstone | Limestone | Unconformity |
| Greywacke | Coal | Slickenside |
| Sand | Dolomite | Calcite |




8400'-8700' Red and green mottled conglomeratic greywacke, ferruginous, sericitic and chloritic with veins of quartz, calcite and chlorite. Alignment of particles and flowage apparent.

8700'-9150' Red, green and tan boulder conglomerate with boulders up to 12" of hematitic, chloritic quartzite with mylonite matrix and contorted dolomitic quartz veins.

9150'-9400' Boulder conglomerate with very sericitic, hematitic matrix.

9400'-9650' Mainly red, very coarse grained to grit greywacke, very sericitic, schistose, shear zones common.

9650'-TD Red and grey, fine to medium grained greywacke with some crossbedding. Streaks of yellow to green chloritic, very sericitic mylonite. Schistose and indurated.

# DELHI - FROME - SANTOS

AUTHORITY TO PROSPECT: 66P & 67P

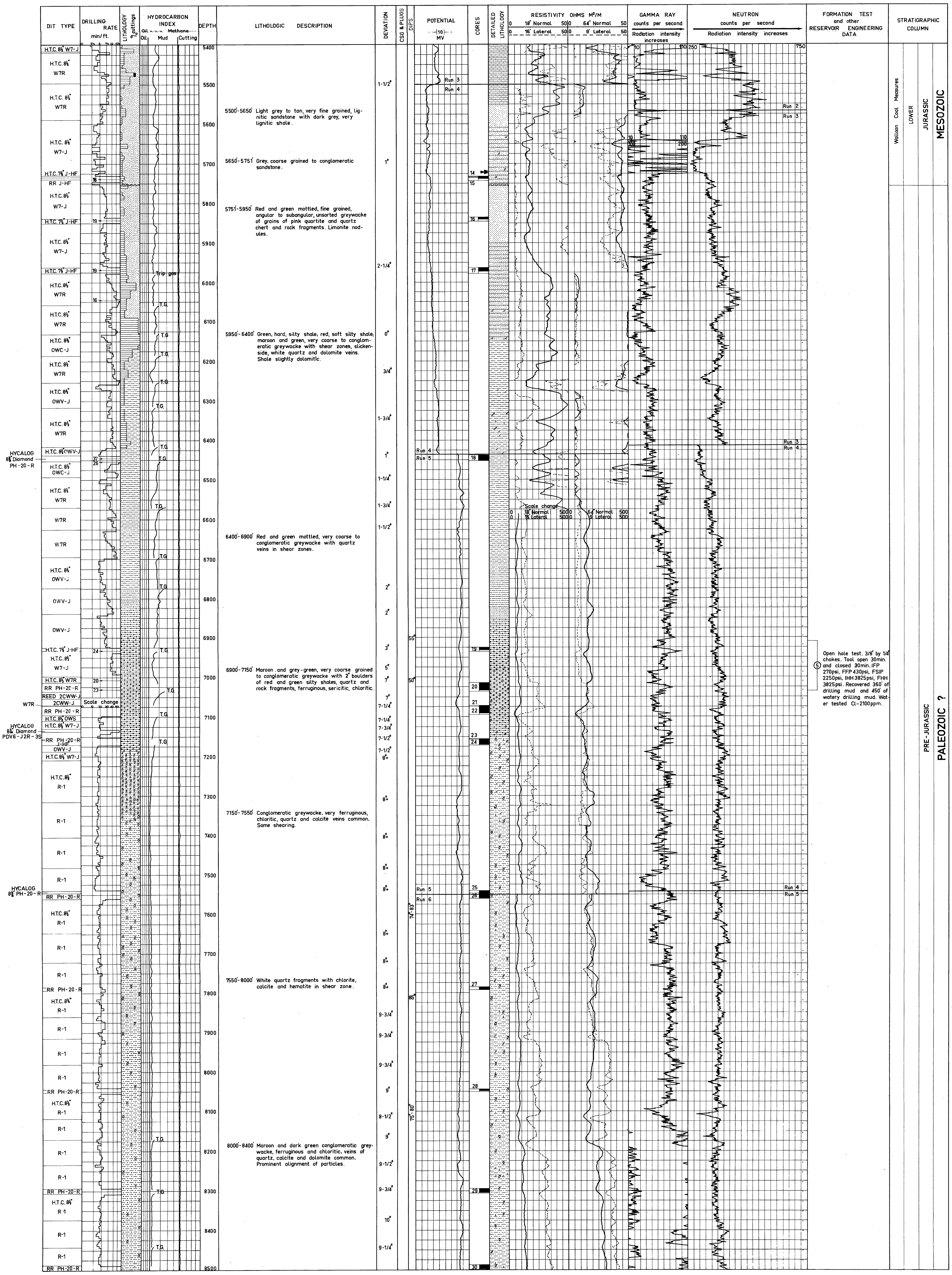
WELL NUMBER: BETOOTA No. 1

**WELL SYMBOLS**

- Core interval, number and recovery.
- Sidewall core.
- Formation test, interval and number.
- Plugged interval.
- RR Re-run bit.
- NR No recovery.

**LITHOLOGIC REFERENCE**

- Conglomerate
- Siltstone
- Greywacke
- Sand
- Shale
- Limestone
- Coal
- Dolomite
- Calcareous
- Unconformity.
- Slickenside
- Calcite



# DELHI - FROME - SANTOS

AUTHORITY TO PROSPECT: 66P & 67P

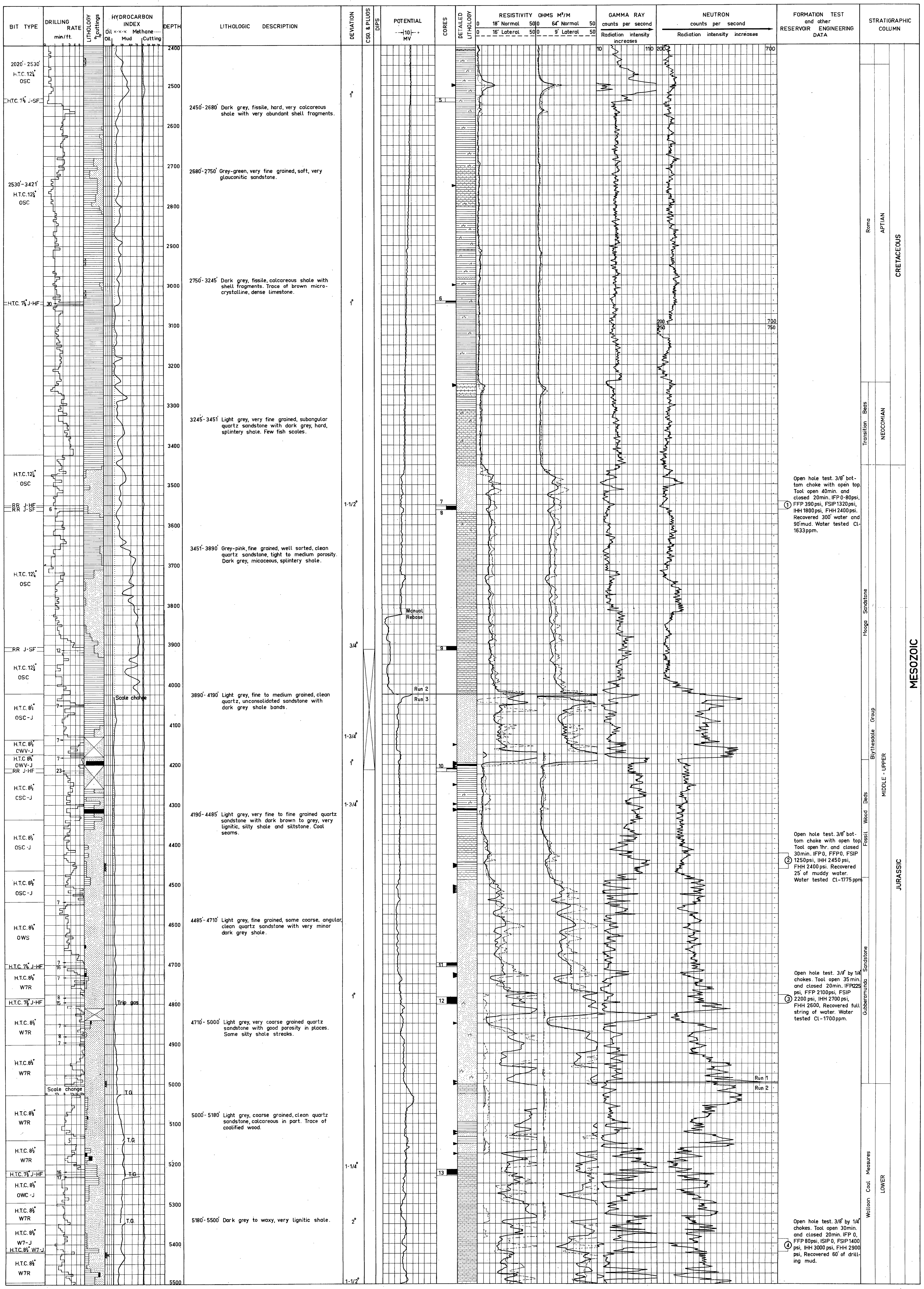
WELL NUMBER: BETOOTA No. 1

**WELL SYMBOLS**

- Core interval, number and recovery.
- Sidewall core.
- Formation test, interval and number.
- Plugged interval.
- RR Re-run bit.
- NR No recovery.

**LITHOLOGIC REFERENCE**

- Conglomerate
- Siltstone
- Greywacke
- Sand
- Shale
- Limestone
- Coal
- Dolomite
- Calcareous
- Unconformity
- Slickenside
- Calcite



# DELHI - FROME - SANTOS

AUTHORITY TO PROSPECT: 66P & 67P

WELL NUMBER: BETOOTA No. 1

STATE: QUEENSLAND

4 MILE SHEET: BETOOTA

BASIN: GREAT ARTESIAN

WELL STATUS: ABANDONED

**LOCATION:** Lat. 25° 42' 30"S Long. 140° 49' 46" E

**ELEVATION:** Reference Pt. (R.T.) 359' A.S.L.
Ground 345' A.S.L.

Date Spudded: 22nd December 1959
Date Drilling Stopped: 17th April 1960
Date Rig Off: Rig stacked at well site.
Total Depth: 9824'

Hole Size:

| In | From | To |
|---|---|---|
| 26" | 0' | 44' |
| 17" | 44' | 1203' |
| 12¼" | 1203' | 4028' |
| 8½" | 4028' | 9824' |

Casing:

| In | Wt. | Gr. | Depth | Cmt. | Cmt. To |
|---|---|---|---|---|---|
| 20" | 94 | H40 | 39' | 42 | Surface |
| 13⅜" | 54·5;48 | J55;H40 | 1203' | 1050 | " |
| 9⅝" | 40 | J55 | 4028' | 460 | 2130' |

Cement Plugs:

| From | To | Top | Sacks |
|---|---|---|---|
| 330' | 530' | 330' | 50 |
| 3913' | 4213' | 3913' | 75 |

Perforations: Nil.

Well Head Fittings: Steel plate welded over casing.
Drilled by: Delta Drilling Co.
Drilling Method: Rotary.

## ELECTRIC LOG DATA

| Run No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Date | 28/12/59 | 14/1/60 | 1/2/60 | 10/2/60 | 3/3/60 | 31/3/60 | 17/4/60 |
| Footage Logged | 1061' | 2829' | 1558' | 958' | 1132' | 1503' | 783' |
| Total Depth Electric Log | 1198' | 4031' | 5587' | 6452' | 7561' | 9054' | 9824' |
| Total Depth Driller | 1204' | 4024' | 5590' | 6452' | 7560' | 9053' | 9824' |
| Casing Shoe Elec. Log | 136' | 1201' | 4028' | | | | |
| Casing Shoe Driller | 135' | 1203' | 4028' | 4028' | 4028' | 4028' | 4028' |
| Bit Size | 17½" | 12¼" | 8½" | 8½" | 8½" | 8½" | 8½" |
| | | | | | | | |
| Mud Data - Type | Natural | Water Base | Water Base | Water Base | Water Base | Water Base | Water Base |
| | | Gel, Diesel | Gel, Caustic, | Gel, Caustic, | Gel, Carbide, | Gel, Caustic, | Gel, Myrtan. |
| | | | Tannin. | Myrtan. | Myrtan. | Myrtan. | |
| Weight | 9·5 | 10 | 10·4 | 10·1 | 10·2 | 10·7 | 10·4 |
| Viscosity | 37 | 43 | 51 | 54 | 65 | 41 | 44 |
| pH | - | 8·7 | 9 | 9 | 9·5 | 9 | 9 |
| Wtr. Loss cc/30 min. | - | 11 | 11·4 | 11 | 12·2 | 10·8 | 10 |
| Resistivity | 3·1 / 90° F | 1·6 / 95° F | ·90 / 140° F | 1·1 / 102° F | ·87 / 160° F | ·95 / 140° F | ·93 / 140° F |
| Res. / Max. Hole Temp. | | ·90 / 170° F | ·60 / 218° F | ·52 / 232° F | ·51 / 240° F | ·47 / 260° F | ·46 / 268° F |
| Electrode Spacing | 18" | 18" | 18" | 18" | 18" | 18" | 18" |
| | 64" | 64" | 64" | 64" | 64" | 64" | 64" |
| | 9' | 9' | 9' | 9' | 9' | 9' | 9' |
| | 16' | 16' | 16' | 16' | 16' | 16' | 16' |
| Recorded By | Haynes | Haynes | Haynes | Haynes | Haynes | Haynes | Haynes |

## RADIOMETRIC LOG DATA

| Type of Log | GAMMA - NEUTRON | | | | | |
|---|---|---|---|---|---|---|
| Run No. | 1 | 2 | 3 | 4 | 5 | 6 |
| Date | 26/1/60 | 1/2/60 | 10/2/60 | 3/3/60 | 2/4/60 | 17/4/60 |
| Total Depth Driller | 5024' | 5590' | 6452' | 7560' | 9053' | 9824' |
| Top Logged Interval | 100' | 4950' | 5580' | 6390' | 7500' | 8850' |
| Bottom Logged Interval | 5022' | 5585' | 6450' | 7559' | 8990' | 9822' |
| Type Fluid in Hole | Mud | Mud | Mud | Mud | Mud | Mud |
| Fluid Level | Full | Full | Full | Full | Full | Full |
| Max. Recorded Temp. | 177° F | 218° F | 232° F | 240° F | 260° F | 268° F |
| Neutron Source | Rad. Beryllium | Rad. Beryllium | Rad. Beryllium | Rad. Beryllium | Rad. Beryllium | Rad. Beryllium |
| " Strength | 400 mg | 400 mg | 400 mg | 400 mg | 400 mg | 400 mg |
| Source Spacing | 19" | 19" | 19" | 19" | 19" | 19" |
| Length Measuring Device | G 28", N 14" | G 28", N 14" | G 28", N 14" | G 28", N 14" | G 28", N 14" | G 28", N 14" |
| O.D. of Instrument | 3⅝" | 3⅝" | 3⅝" | 3⅝" | 3⅝" | 3⅝" |
| Time Constant - sec. | 2 - 2 | 2 - 2 | 2 - 2 | 2 - 2 | 2 - 2 | 2 - 2 |
| Logging Speed ft/min. | 22' | 22' | 22' | 22' | 22' | 22' |
| Sensitivity Reference | 100/500 | 100/500 | 100/500 | 100/500 | 100/500 | 100/500 |
| Recorded By | Haynes | Haynes | Haynes | Haynes | Haynes | Haynes |

### CASING RECORD

| Run | Size - In. | Wt - Lbs. | From | To |
|---|---|---|---|---|
| | 20" | 94 | 0' | 39' |
| | 13⅜" | 54·5; 48 | 0' | 1203' |
| | 9⅝" | 40 | 1203' | 4028' |

### OPEN HOLE RECORD

| Bit Size - In. | Interval |
|---|---|
| 8½" | 4028' - TD |

### OTHER ELECTRICAL LOGS

TEMPERATURE 1500' - 3992'
GUARD 136' - 7556'
CALIPER 136' - 9822'
DIP 1201' - 7559'

### WELL SYMBOLS

- Core interval, number and recovery.
- Sidewall core.
- Formation test, interval and number.
- Plugged interval.
- RR Re-run bit.
- NR No recovery.

### LITHOLOGIC REFERENCE

Conglomerate, Siltstone, Greywacke, Sand, Shale, Limestone, Coal, Dolomite, Calcareous, Unconformity, Slickenside, Calcite

LITHOLOGY BY : J. Harrison.
COMPILED BY : J.H. Allen
} DELHI AUSTRALIAN PETROLEUM LIMITED
LOGGED BY : Welex