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The 1968 Bureau of Mineral Resources Drilling Programme in the Alexandria — Wonarah Area, Northern Territory

by

L.V. Bastian and R. Thieme

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SUMMARY

Six holes, which were drilled during 1968 for the Bureau of Mineral Resources in the ALROY and RANKEN 1:250,000 Sheet areas, have been studied petrologically, and tested for phosphate. They are Alroy BMR Nos 1, 2 and 3, and Ranken BMR Nos. 1, 2, and 3, located in an area between Alexandria Homestead, Soudan Homestead and Wonarah Telegraph Station on the Barkly Highway. They were drilled to depths ranging from 287 feet to 603 feet.

Basement (unit A) was encountered in two holes. Ranken BMR No. 1 bottomed in pink quartzitic sandstone resembling the Precambrian Mittiebah Sandstone, and Alroy BMR No. 2 bottomed in basalt, probably belonging to the Peaker Piker Volcanics.

A general threefold subdivision is seen in the Cambrian of these holes:

(i) lower fawn-tan dolomite unit (unit B);
(ii) grey silty limestone/dolomite unit (unit C);
(iii) upper varicoloured limestone/dolomite siltstone unit (unit D).

The lower dolomite has a low silt content, is generally crystalline, very carbonaceous in parts, and tends to be very vuggy. It contains the main aquifers in this area. The grey unit has an appreciable silt content, and includes important limestone intervals, showing two different facies- a micritic algal limestone type and a well washed coquinitic type with sparry cement. The upper, varicoloured unit also shows two facies - an orange-pink-khaki siltstone facies, and a dolomitised intraclast limestone facies. The upper varicoloured unit is probably equivalent to the Camooweal Dolomite, with the Ranken Limestone intertonguing into it.

Although the phosphate-bearing grey unit carries broadly a "Beetle Creek" fauna, it is equated with the Burton Beds but not the Wonarah Beds as in their type areas. It outcrops in the vicinity of Mount Lamb and Alexandria but is widespread at depth. The phosphate is distributed intermittently over roughly 200 feet of section, and does not seem to start at exactly the same horizon in each hole.

The bedding is subject to broad-scale low-dip folding with amplitudes of up to a few hundred feet. There may be unconformities in the sequence as well as the facies changes.

The study indicates that units in the part of the lower Middle Cambrian section encountered in these holes are widespread and may be traced laterally for some distance. This applies especially to the grey unit C, which may extend subsurface as far eastwards as Camooweal and Lake Nash areas, and southwards as far as Annitowa.

INTRODUCTION

Surface mapping in the Northern Territory portion of the Georgina Basin phosphate province tends to be inconclusive owing to the scarcity of exposed contacts and the paucity of outcrops which, furthermore, are usually deeply weathered or silicified.

Numerous shallow holes, all less than 200 feet deep, have been drilled by exploration companies (mainly IMC), but the only information on the stratigraphic sequence in depth is provided by a few scattered exploratory petroleum wells, some shallow BMR stratigraphic wells and drillers' logs from water wells; the latter, however, are very unsatisfactory.

In order to study the depositional environment of the phosphate and the relationships between the various formations known from surface exposures, a drilling programme was planned by F. de Keyser (party leader) to supplement surface mapping by the Georgina Phosphate Party in 1968. Of special importance was the lateral extent of the Camooweal Dolomite, which occupies a large area east of the drill holes. The programme consisted of six holes located north of the Barkly Highway between Soudan Homestead and Alroy Downs Homestead, on ALROY and RANKEN 1:250,000 Sheet areas, Northern Territory.

In this region the Wonarah Beds (Öpik 1957) are exposed along the Barkly Highway west of Soudan, as low hills covered by a loose scree of chert, siliceous shale and limestone. Crystalline limestone and chert in the valley of the Ranken River comprise the Ranken Limestone (Öpik op. cit.), while the Burton Beds (Smith and Roberts 1963) crop out between Buchanan Creek and the Playford River, and northwards into the Mount Drummond Sheet area. They consist mainly of limestone, chert, and siltstone, and are thought to be continuous with the Wonarah Beds. Geological work in the area is summarised in the RANKEN and ALROY explanatory notes (Randal 1966a, b), which include detailed bibliographies of the previous investigations.

A series of BMR core-holes was drilled in the region in 1962 (Milligan 1963), and of these GRG 15, 15A and 16 are very close to the present drilling locations. Petrology was carried out on some of these holes by Fehr and Nichols (1963), Nichols and Fehr (1964) and Nichols (1966a, b), but those nearest have never been petrologically investigated. Petrological work was also done on some field material from Alroy and Brunette Downs areas by Nichols (1963).

Useful descriptions of units and regional geology appear in a work on the geology of the Georgina Basin by K.G. Smith (in press).

Drilling Programme

R. Thieme

The drilling contract called for a minimum of four holes with an aggregate footage not less than 2500 feet and a maximum of seven holes with an aggregate footage not exceeding 3000 feet. It was originally expected that at least 33% of the total footage would be cored.

The actual drilling programme consisted of six holes located north of the Barkly Highway between Soudan homestead and Wonarah Telegraph Station, in the ALROY and RANKEN 1:250,000 sheet areas, Northern Territory (Fig. 1). Total footage drilled was 2984 feet 8 inches, made up as follows:-

NAME	DRILLED	CORED	TOTAL
Ranken BMR No. 1	273'8"	13'4"	287'
Ranken BMR No. 2	560'5"	42'7"	603'
Ranken BMR No. 3	499'	54'	553'
Ranken BMR No. 3A	15'	-	15'
Alroy BMR No. 1	544'8"	30'	574'8"
Alroy BMR No. 2	460'6"	110'6"	571'
Alroy BMR No. 3	355'	26'	381'
TOTAL	2708'3"	276'5"	2984'8"

Core Recovery: 236'½" or 85%

Total cored as percentage of total footage: 9¼%

WELL HISTORY

Well Name: **Ranken BMR No. 1**

Location: Latitude 19°16'00"S

Longitude 136°38'25"E

1 mile south of Alexandria No. 16 bore

Elevation: 805' (ground level)

Total Depth: 287'

Date Commenced: 24/9/68

Date Completed: 26/9/68

Time lost: Nil.

Depth	Dia. hole	Bit	Circ.	Casing
0 - 287'	5"	5" down-the-hole hammer	Air	Nil

Status: Abandoned - target reached

Aquifers: 1st at 200'

Well Name: **Ranken BMR No. 2**

Location: Latitude 19°24'40"S

Longitude 136°35'55"E

½ mile north-east of Alexandria No. 51 bore

Elevation: 775'

Total Depth: 603'

Date Commenced: 27/9/68

Date Completed: 12/10/68

Time lost: 29/9/68 to 2/10/68 = 4 days waiting on casing

4/10/68 - 10 hours rig repairs

5/10/68 - 7 hours rig repairs

9/10/68 to 12/10/68 - 4 days unsuccessful fishing for 60' of cable, 270' drill stem and a 10' core barrel lost as a result of the hoisting cable breaking. During the fishing operations an additional 280' of drill stem were lost but were recovered on 12/10/68 and the hole abandoned.

Depth	Dia. hole	Bit	Circ.	Casing
0 - 35'	6½"	5" down-the-hole hammer/reamed to 6½"	Air	6"
35'- 360'	5½"	5" down-the-hole hammer/reamed to 5½"	Air	5" from surface
360'- 577'	4¾"	4¾" down-the-hole hammer	Air	
577'- 603'	4¼"	V1 Varell bit	Mud	

Casing pulled at completion of hole.

Status: Abandoned - hole blocked by drill stem

Aquifers: 1st at 230', 2nd at 577'. Standing Water Level 230', 150' respectively.

Well name: Ranken BMR No. 3 (Ranken BMR No. 3A, spudded 10' to the south, collapsed at a depth of 15').

Location: Latitude 19°59'30"S

Longitude 136°59'30"E

5 miles north of Soudan HS, ½ mile west of the Ranken River - Loc. RK 70

Elevation: 770'

Total Depth: 553'

Date commenced: 10/11/68

Date completed: 17/11/68

Time lost: Nil

Depth	Dia. hole	Bit	Circ.	Casing
0 - 80'	6¾"	6¾" down-the-hole hammer	Air	6"
80'- 415'	5"	5" down-the-hole hammer	Air	
415' - 480'	4¼"	4¼" rock bit	Air	
480' - 553'	4¼"	4¼" rock bit	Mud/Water	

Casing not pulled at completion of hole.

Status: Abandoned - end of drilling programme.

Aquifers: 1st at 415'. Standing Water Level 200'.

Well Name:	<u>Alroy BMR No. 1</u>
Location:	Latitude 19°23'50"S Longitude 136°23'25"E 1 mile north of Alroy No. 11 bore
Elevation:	810'
Total Depth:	574'8"
Date commenced:	13/10/68
Date Completed:	25/10/68
Time lost:	20/10/68-6 hours rig repairs 21/10/68-3 hours rig repairs

Depth	Dia. hole	Bit	Circ.	Casing
0 -200'	6¾"	6¾" down-the-hole hammer	Air	6"
200'-260'	5½"	5" down-the-hole hammer/reamed to 5½"	Air	5" from surface
260'-387'	5"	5" down-the-hole hammer	Air	
387'-T.D.	4¼"	4¼" rock bit	Water	

Casing not pulled at completion of hole.

Status:	Abandoned
Aquifers:	1st at 207', 2nd at 317'. Supply at 317' minimum of 3500 GPH.

Well Name:	<u>Alroy BMR No. 2</u>
Location:	Latitude 19°30'50"S Longitude 136°17'30"E Top of Mt. Lamb
Elevation:	880'
Total Depth:	571'
Date Commenced:	26/10/68
Date Completed:	3/11/68
Time lost:	Nil

Depth	Dia. hole	Bit	Circ.	Casing
0 -200'	6¾"	6¾" down-the-hole hammer	Air	Combination of 6" and5"
200'-353'	6"	6" down-the-hole hammer	Air	
353'-571'	4¾"	4¾" down-the-hole hammer	Air	

Casing pulled at completion of hole

Status: Abandoned - target reached.

Aquifers: 1st at 269', 2nd at 303'

Well Name: Alroy BMR No. 3

Location: Latitude 19°42'30"S
Longitude 136°24'00"E
2¼ miles 060° (true) from Dalmore No. 2 bore

Elevation: 765'

Total Depth: 381'

Date Commenced: 4/11/68

Date Completed: 9/11/68

Time lost: 5/11/68 - 5 hours repairs to rig

Depth	Dia. hole	Bit	Circ.	Casing
0 - 200'	6"	6" down-the-hole hammer	Air	5"
200'- 381'	4¼"	4¼" rock bit	Air	

Casing not pulled at completion of hole

Status: Abandoned

Aquifers: 1st at 190', 2nd at 332'. Standing Water Level 160'.

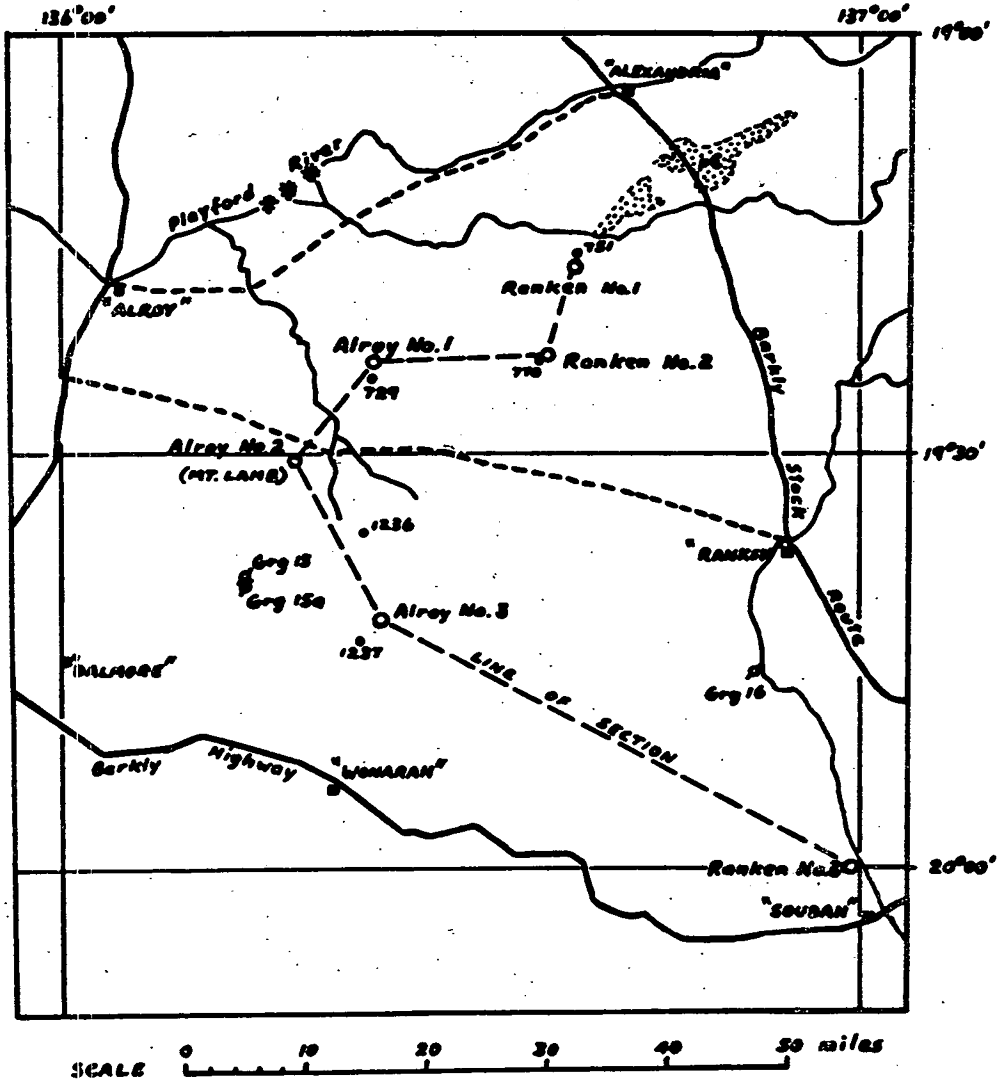

FIG. I. LOCALITY SKETCH OF GEORGINA PHOSPHATE PARTY DRILL-HOLES.

○ Georgina Phosphate Party hole

ϕ B.M.R. stratigraphic hole

● 770 Water bore & regd no.

DRILLING

The drilling was carried out by Thompson Drilling Pty Ltd, Acacia Ridge, Qld, under sub-contract to Drilling Services, Darwin.

Equipment consisted of a Mayhew 1000 rig mounted on an International SB170 4 x 6, a compressor (120 psi), and a 600 gallon water-tank mounted on a similar unit.

Drilling personnel consisted of the proprietor of Thompson Drilling, two drillers, and two offsiders, thus enabling two shifts to be run daily. The actual hours worked per day varied from 9 to 23 hours with an average of 16½ hours taken over 45 drilling days. It was found that less work was accomplished and more minor delays occurred during the night shift than during the day shift. This appears to have been due mainly to bad lighting conditions although human factors must also have contributed. (Loss of the 270' of drill stem, etc, in Ranken BMR No. 2 occurred during the early hours of 9/10/68).

The main problem encountered during the drilling was loss of circulation; however, in all except one hole this was overcome either by the use of casing, SuperCol drilling mud or bran. Mica flakes were also used in one attempt but they succeeded only in blocking up the drill stem and pump. The maximum time it took to restore circulation using SuperCol or bran was nine hours.

The exception mentioned above was Ranken BMR No. 3 where circulation was lost at 480' in cavernous dolomite. Both SuperCol and bran were unsuccessful and as it was considered impractical to case to this depth, drilling was continued "blind" to T.D. (553') with cores cut approximately every 30 feet.

Down-the-hole hammers were used as long as possible in each hole as these gave large cuttings and rapid penetration. However, below the water-table the air pressure available (120 psi) restricted these hammers to working under a head of water of less than 200 feet and consequently rock bits had to be used at depth in most of the holes which greatly reduced the cuttings size and the rate of penetration. In Alroy No. 3 rock bits were used below 200' as no 4¾" hammer bits (required to pass through the 5" casing) were available.

Diamond bits were used for coring and the only difficulties experienced were due to loose rocks jamming in the core barrel thus preventing entry of further core; cores taken in the top fifty feet (hard chert fragments in a soft, silty to sandy matrix) gave extremely poor recoveries for this reason. The diameter of the drill stem used was greater than the diameter of the core bit and hence the hole had to be reamed out after every core, a time consuming process.

Alroy BMR No. 1 and No. 3 both had to be terminated when a very hard layer of silicified coquinite(?) or dolomite(?) was encountered. Rock bits made no impression at all on this layer and the available diamond bits were polished smooth after penetrating half to three-quarters of an inch.

On all but a few days temperatures during the drilling programme were around the 100°F mark and minor delays, particularly on windless days, were caused by the compressor overheating.

Sampling, Logging and Testing

Most of the well-siting and logging was carried out by R. Theime, assisted by K.J. Armstrong. F. de Keyser participitated in the logging and testing of the first two holes: Ranken No. 1 and No. 2.

Cuttings were taken at 5 foot intervals and either represented the bottom foot of the interval when cuttings were abundant (such as in the zone from 0 to 200') or the whole interval when cuttings became less abundant (below 200').

Cores were taken whenever a change in lithology occurred, when fossiliferous strata were encountered, when rapidly changing lithology was suspected or at approximately 30 foot intervals when drilling "blind".

Cuttings were washed and sieved and examined wet under the hand-lens. To differentiate between limestone and dolomite two methods were used: (i) the intensity of effervescence of the specimen in dilute hydrochloric acid was noted - nil to weak for dolomite, medium for dolomitic limestone, strong for limestone; and (ii) the coloured precipitate produced on the specimen by a magneson solution (0.02 gm magneson - P-nitrobenzeneazo-resorcinal-dissolved in 100 ml 2N NaOH) was noted - white to pale blue on limestone, dark blue to purple on dolomite, and intermediate shades of blue on dolomitic limestone. (Under field conditions it was impractical to wash the specimen after completion of etching in dilute hydrochloric acid and consequently the magneson solution did not stain the specimen but only formed a precipitate).

Cores were also washed and examined wet under the hand-lens but as they were not split, field examination of cores was somewhat unsatisfactory.

Cores and cuttings were tested for phosphate using ammonium molybdate solution. Under the extreme heat conditions existing during the drilling the molybdate solution was not particularly stable and the intensity of the precipitate depended not only on the usual variables - type and amount of phosphate present in the sample, presence of calcareous material, etc - but also on the time of day and whether the sample was damp or dry.

All holes were Gamma logged using a Widco Porta Logger. Scales were as follows:-

Vertical scale:	1" = 10'	all holes
Sensitivity:	.020 MR/HR	all holes except Alroy No. 1 (.010)
Time constant:	5	all holes except Ranken No. 1 (1st run) and Ranken No. 2 - (T/C 2 and T/C 3 respectively)

All holes except Ranken No. 2 and Ranken No. 3 were logged to within 20 feet of the bottom. Ranken No. 2 log stopped 295 feet short owing to blockage caused by the lost drill stem, and Ranken No. 3 log was 131 feet short due to the Gamma probe repeatedly hanging up at a depth of 422 feet; the reason for this is not clear although cavernous dolomite was first encountered in this region and deviation of the hole could have occurred.

As all the holes were within a few miles of operating bores, pumping tests were generally not carried out. The only exception was Alroy BMR No. 1 where air-lifting of water from the second (317') aquifer produced a (minimum) flow of 3500 gph.

Height above mean sea level of the drill sites was determined either from spot heights given on the Ranken and Alroy 1:250,000 geological sheets or from nearby bench marks.

PETROLOGY

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Methods

Time being short, the work was restricted basically to a study of cores and cuttings under the binocular microscope. This was supplemented by the examination of thin sections from cores, and by frequent staining with Alizarin Red S to check calcite/dolomite relationships. Representative portions of the cores were polished around the outside and examined wet, to facilitate the viewing of structures and colours.

The mineralogy of the cuttings was checked under the microscope at numerous intervals by examining the powdered material. Phosphate tests were also carried out by means of the Shapiro method, based on the use of a vanadomolybdate solution. For this work, representative cuttings from each bag were selected and powdered, while for the cores small samples were drilled out at intervals of a few inches. Calcimetry and percentage-insolubles figures are likely to be the most useful parameters in any future work, and the rocks also contain plentiful fossil material for palaeontological studies. Dr J.H. Shergold examined some selected core and cuttings and provided palaeontological determinations; these are cited in the text.

The Folk (1959) classification for limestones was found useful for bringing out the more obvious differences in limestone types. Folk terms are shown in brackets on the logs. The Wentworth grade scale has been used for describing the grain-size of crystalline textures in the carbonate rocks.

In the interpretation, rocks have been divided into informal units (Fig. 2) and their suggested relationships to nearby outcrops are discussed. Formation names were not applied directly because of the prevailing uncertainty in interpretations of this region. Outcrop material from previous Georgina Basin collections was examined to aid the interpretations, and material from the BMR core-holes GRG 4, 15, 15A and 16 (Milligan 1963) was also briefly examined.

Unit A - Basement

Basement was encountered in two holes. Ranken BMR No. 1 bottomed in a pink quartzitic sandstone (Plate I) resembling the Precambrian Mittiebah Sandstone outcropping near Alexandria. Alroy BMR No. 2 entered weathered red-brown basalt at 462' (Plate V) and bottomed in fresh rock at 571'. This rock is an amygdaloidal basalt composed of phenocrysts of pyroxene and plagioclase (labradorite) in a groundmass of plagioclase, chlorite and devitrified glass, and numerous chlorite-filled amygdules. Quartz occurs in scattered pockets, possibly representing later infillings, and plagioclase laths have been largely altered to a zeolite mineral, chlorite and muscovite.

A marked weathered band at about 530' appears to form the top of a basaltic flow, and there may be a similar band, though less pronounced, at about 500'. These bands are composed of red-brown rock similar to the top of the basalt, and grade downwards into fresh rock again. In the weathered zone pockets of light blue-green chlorite are prominent, suggesting a greater number of vesicles such as might be expected to occur in the top section of a flow.

The basalt may be equated with the Peaker Piker Volcanics, which outcrop about 60 miles to the north and northeast; with the Colless Volcanics west of Lawn Hill, Queensland; and with the Helen Springs Volcanics, east of Tennant Creek. In all these volcanics the top section abounds in vesicles and amygdules.

Unit B

Unit B is basically a dolomite with characteristic fawn and tan colours, imparted to it by disseminated fine carbonaceous matter, which also occurs as discrete partings and stylolites. The silt content is low, and for the most part negligible. The unit tends to be very vuggy, and structures and fossils are usually strongly recrystallised.

Submit B1

This unit is thin, and is only found in Alroy No. 2. The main lithology is a brown calcareous dolomite with closely packed fine corrugated laminae of carbonaceous matter, and grading upwards into a maroon dolomitic claystone showing the effects of intraformational reworking, then into grey dolomitic limestone with occasional pink tints.

The distinctive finely corrugated texture was also seen in core 15 of the BMR No. 11, Cattle Creek, below 1385' (Johnson, Nichols and Bell 1964).

Submit B2

The total thickness of this subunit was only penetrated in Alroy No. 2, but several other holes bottomed in it.

The subunit consists basically of mottled fawn to tan crystalline dolomite, with intervals of carbonaceous laminae and numerous black-lined stylolites and microstylolites. There are a number of fossiliferous zones, especially near the top; these are glauconitic, and the fossils are strongly recrystallised. The silt content is generally low. White chert, which is fairly common in some intervals, shows very irregular knobbly shapes, and in thin section (e.g. in Alroy No. 2 360'5") appears to be made up of abundant recrystallised spicules. Both Alroy No. 1 and Alroy No. 3 bottomed in similar very hard white chert. Vuggy intervals are common, and this subunit provides the main aquifer in Alroy No. 2, Alroy No. 3, and perhaps Ranken No. 2.

The dolomite is mainly fine to medium crystalline, occasionally coarse, and laminations generally have lost their sharpness owing to the dolomite crystallisation. Colours are due to finely disseminated interstitial carbonaceous matter. In Ranken No. 1, at a depth of about 260', where the dolomite is very dark brown, the microscope shows abundant tiny shreds of light brown translucent vitrinite.

An unusual pale bluish grey pyritic dolomite at about 270' in Ranken No. 1 is seen also in Alroy No. 2 at about 340'; it is in both cases overlain by an interval of very carbonaceous dolomites showing fine veining and brecciation. This may suggest subunit B2 occurs in Ranken No. 1 but could point to a cyclic sedimentation sequence at two different times. A small section of dolomite at the bottom of Ranken No. 2 may belong either to B2 or B4, as it contains glauconite and fossils which may occur in either subunit (e.g. Ranken No. 3 ca. 422').

The gamma-ray logs gave pronounced peaks in the dark carbonaceous parts of this subunit, but otherwise the values were low in the typical dolomites.

Subunit B3

Although this subunit is similar to B2, it is distinguished by a well marked sequence traced between Alroy No. 1 and Alroy No. 2.

The subunit starts with cream to brown crystalline limestone, which grades upwards into a crystalline dolomite with pebbles and cobbles of white chert like that in B2, plus carbonaceous intervals and stylolites. In Alroy No. 1 at about 480', bedding compaction is visible around the chert cobbles, and at 483'9" a patch of slightly detached interlocking chert fragments is seen. These features suggest that the chert was part of the original sediment, probably a siliceous (?spicular) deposit which was transported short distances in a semi-hardened form. The top of the subunit is placed where the dolomite becomes lighter in colour and the carbonaceous laminae cut out.

In Alroy No. 3 (310' to 333') an interval of dark brown carbonaceous silty dolomite (or dolomitic shale) is difficult to relate to either B2 or B3. Laminae are sharp and smooth, and some have a distinct purple tint; in thin section (331'3") there are bands rich in recrystallised spicules, and vitrinite shreds are abundant. This lithology resembles spicular black limestone described by Newell *et al*. (1953) from the Delawere Basin, Texas. Moderate gamma-ray values were obtained from this interval (see Plate VI), but for B3 generally values were low.

Subunit B4

The highest subunit is much paler than the others, generally a light fawn to cream dolomite, and in parts almost white.

The rock is mainly a fine to coarsely crystalline mosaic of clean dolomite with only trace amounts of silt. Scattered grains of glauconite are seen in places, and in Ranken No. 3 at about 422' the dolomite is coquinitic, with strongly recrystallised fossils and fossil moulds. It is very vuggy, especially in Ranken No. 3, where a 4-foot mud-filled cavity was intersected at one point. Cores in the subunit in this hole show coarse mottlings, and around 520' there are many concentrically layered ?algal structures, generally about 1" in size. At about 550' the mottlings are smaller and coloured in shades of fawn, and some horizons have load casts. Occasional stylolites with white clay linings occur in the subunit.

Intervals where cream-white colours dominate are seen in Ranken No. 1 119'-150', Alroy No. 1 273'-308', and Ranken No. 3 450'-480'+. Dolomite crystals lining vugs in these intervals commonly have orange-brown clay coatings, suggesting some redistribution of clay occurred. This is clearly seen in Alroy No. 1 280'. In this same core also glauconite is seen to have been redistributed into undulating streaks, and in thin section (276'9") it occupies interstices between dolomite crystals.

Gamma-ray values were consistently low in the massive crystalline dolomites of this subunit.

Discussion

Unit B is only known in the subsurface in this part of the basin. The unit provides the main aquifer in the area, giving water from depths ranging from 605' a.s.l. to 198' a.s.l. in these holes. This is in accord with the general order of depths to main aquifer noted by Randal (1967). The capping of unit B by impermeable unit C poses the problem of water entry to the aquifers. Contours on the piezometric surface show a high running east from Alroy Downs through the vicinity of Alroy No. 1, then southwards towards the Barkly Highway (Randal op. cit., p.28). As unit C is virtually

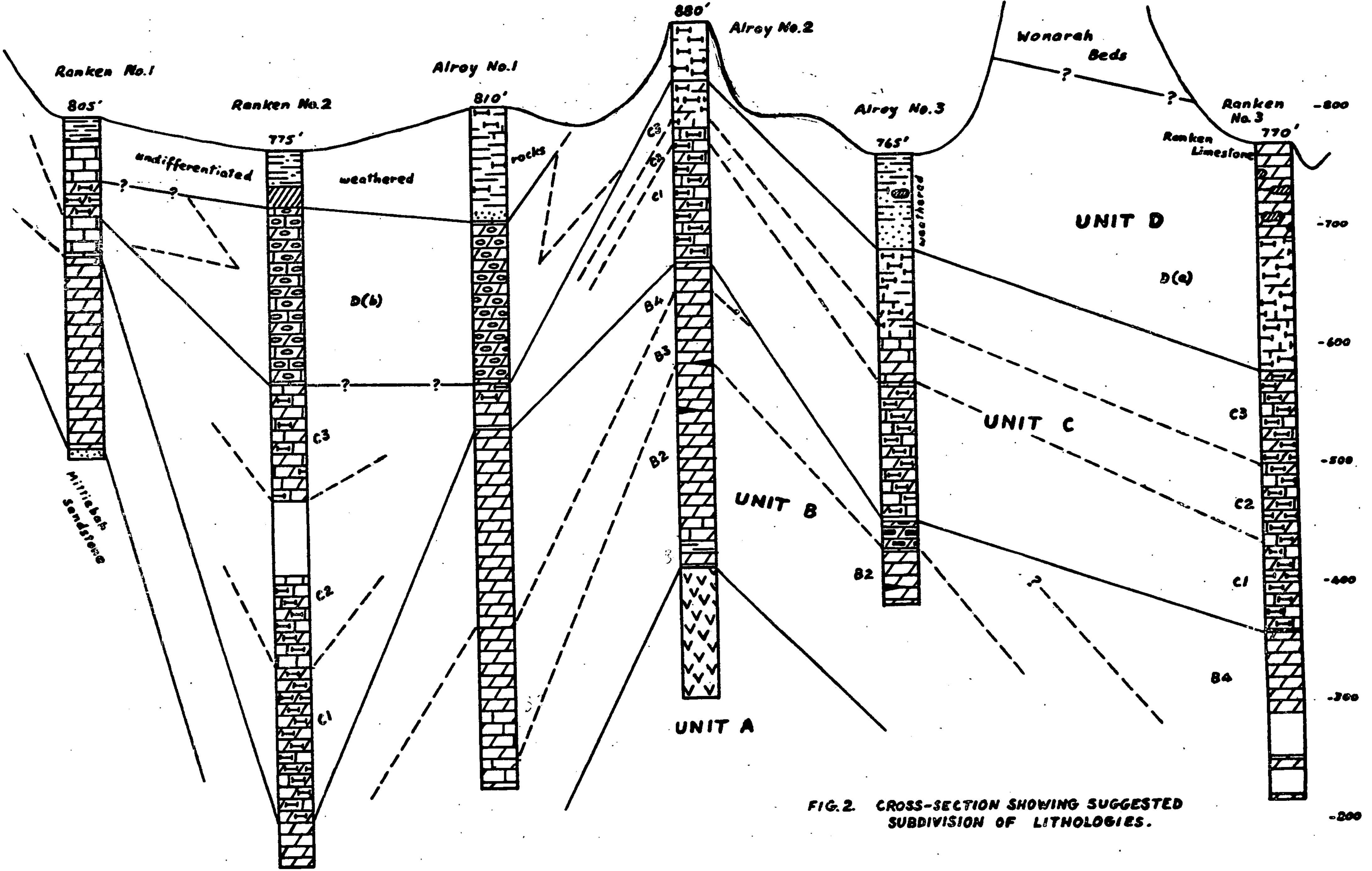

FIG. 2. CROSS-SECTION SHOWING SUGGESTED SUBDIVISION OF LITHOLOGIES.

missing from Alroy No. 1, this suggests that water entry is effected by water draining through from the permeable unit D into unit B in this locality. Water entry is also likely where units abut onto slopes of the Precambrian basement rocks; e.g. near Alexandria.

Unit B may be truncated by the overlying units, or intertongue with them. In Alroy No. 2 there is possible (doubtful) intertonguing of units C and B, between 265' and 335', and in GRG4 there appears to be intertonguing of a vuggy fawn stylolitic dolomite (?unit B) with an overlying grey laminated dolomite (?unit C) over approximately 80 feet of section between about 650' and 730' (see Appendix A). A pronounced trough is evident through Ranken No. 2 between Ranken No. 1 and Alroy No. 1; this corresponds with a dip in the piezometric surface and a rise in salinity at the locality. The phosphate percentages obtained in Alroy No. 2 at these levels may have come from cavings in the cuttings.

UNIT C

Unit C is characteristically a grey silt-rich unit, easily distinguishable from other units. It is typically very fossiliferous, especially in upper parts of the unit. Though limestone and dolomite are variable, the unit is generally more calcareous towards the top, corresponding with the increase in fossils. Phosphate is common in places. Unit C generally overlies unit B with a sharp break, apart from a doubtful possibility of intertonguing in Alroy No. 2.

Subunit C1 - Laminated subunit

A striking feature of this subunit is the presence of sharply defined grey laminae. The silt content is high, particularly in the mid-grey laminae, and lowest in the palest laminae; dark grey laminae are carbonaceous. The relationship between calcite and dolomite parallels this, with pale laminae more calcareous, and darker laminae more dolomitic. Limestone beds occur usually as thin or bulbous lenses up to 1" or 2" thick, with bedding compacted around them. Ripple marking is seen occasionally in the cores, and boudinage of thin laminae is also common, e.g. Alroy No. 3 around 200'. The subunit contains no aquifers.

Fossil bands, where present, are thin and usually glauconitic. Trilobites are common, as are brachiopods, and spicules are plentiful in many thin streaks. The fossils generally occur in a micritic lime mud matrix. Shergold (pers. comm.) states that trilobites in Core 6 of Ranken No. 2 belong to "Beetle Creek" fauna of the lower Middle Cambrian. Collophane is sporadic, occurring mainly as small pellets or occasionally as fossil moulds, and in thin section is seen to be most abundant in the vicinity of fossil bands. Fine disseminated pyrite is common.

The silt fraction is composed mainly of quartz, with some potash feldspar, muscovite, clay minerals and accessory tourmaline, and is generally well sorted.

Subunit C1 is consistent in character in each of the four holes in which it is seen, but absent from Ranken No. 1 and Alroy No. 1. In Ranken No. 3 thin cherty streaks are common; here there are more spicules generally than in the subunit elsewhere.

The gamma-ray logs generally gave moderate values for this subunit.

Subunit C2 - Limestone subunit

Subunit C2 is characterised by its limestone beds, which are generally rich in fossils.

The limestones include two basic types: firstly a coarsely coquinitic type with sparry cement (=biosparite), and secondly, a light brownish grey fossiliferous algal limestone, the algal material being developed as a lime mud (=biomicrite). The coarse sparry type is light grey, glauconitic, and commonly contains coarse intraclasts up to 5 mm or more in size; broken and abraded echinoid material is abundant as are also brachiopods and trilobite fragments. The algal limestone type generally has a fawn or brownish tint, and under the microscope is seen to consist of Girvanella filaments with enclosed fossil fragments, mainly of trilobites and brachiopods. Fossils are much less broken or abraded than in the other type. Algal coatings are commonly seen on fossiliferous limestone, and sometimes individual algal balls, though no well formed Girvanella were observed in the cores.

Laminated siltstone beds and dark grey corrugated laminae are common though subordinate to the limestones; these basically are the lithologies of subunit C1, and have essentially the same mineralogy. Streaks of small calcilutite pellets are interlaminated with either limestone type, to form pelsparite or pelmicrite. Pale grey chert nodules, often with bluish or fawn tints, are seen in the limestones, mostly in the algal type. In Ranken No. 3, at 322', pale grey chalcedony occupies interstices between silicified shell debris. Collophane is common and is associated with the fossils as in C1.

The subunit is thickest in Ranken No. 2 (Plate II); in this hole sparry cemented coquinites are dominant, whereas both the algal limestone type and the interbedded silts are considerably reduced (e.g. in Core 4, 360'+) and biomicrites are only seen in appreciable amounts at the base of the subunit. (But note that a 63' section is missing, probably due to a cave). In Ranken No. 3 sparry coquinites are common, but intervals of silty dolomite are dominant. In the other holes the algal type is dominant, and in these holes the subunit is notably thinner. Cores from Alroy No. 2 show almost continuous algal structures in zones between 83' and 104', the clastics being reduced to corrugated shaley partings.

Gamma-ray logs showed moderate to low values, lowest in the most calcareous zones.

Subunit C3

This subunit covers an interval in which colour transition occurs to the bright colours typical of unit D. It includes the top of the phosphate-bearing zone, and P_2O_5 values drop off sharply to negligible in the higher unit.

In general, the transition begins as thin red shaly laminae in grey silty dolomites, which then grade upwards to khaki, then orange with pink tints. Dolomite content in the silty beds generally decreases upwards, with a corresponding increase in silt. Interbedded sparry-cemented coquinitic limestones (biosparites) show a colour change from light grey as in C2 to light orange-brown or yellowish. Light brown fossiliferous calcilutites (?algal biomicrites) are seen towards the top, and cores at this level show zones of disturbed bedding, sometimes strongly lobate, with pockets of intraclasts. Lenses of silty calcilutite, and bands composed of fine pellets (pelmicrites) are common.

The biosparites contain abundant echinoid material, trilobite and brachiopod debris, and hyolithids; the hyolithids may be markedly directionally oriented with their long axes sub-parallel (e.g. Ranken No. 3 207'6"). Intraclasts are common and may range up to 1 cm in size. Chert occurs usually as small irregular pockets, commonly filling fossils. Collophane occurs as pellets, fossil moulds, and occasionally groups of minute lenses a few mm long.

Mineralogically the silt fraction is similar to that in lower intervals: mostly quartz with much fresh feldspar, much fine muscovite, some biotite and accessory tourmaline. Clay minerals are plentiful, carbonaceous matter subordinate. The main colour element is hydrated iron oxide, and fine spotty hematite occurs in the pink and red bands.

As in subunit C2, sparry-cemented coquinites are dominant in Ranken No. 2, whereas silty beds are subordinate and are generally reduced to thin partings or stylolites. In core 2 at ca. 200' stylolites show a marked dip, possibly due to relatively small-scale folding. A small interval in Alroy No. 1 is tentatively placed in subunit C3, but it lacks the coquinitic limestones, and its silt content is low. In Alroy No. 3 the top 30 feet of C3 is affected by weathering, with colours leached to pale orange tones.

Gamma-ray values were moderate to low in the subunit.

Discussion

Apart from Subunit C3 which outcrops on the slopes of Mt. Lamb, Unit C is perhaps only seen near Alexandria as the Burton Beds. A grey limestone interval is mentioned in some well records from the Ranken Sheet area (see Randal 1962, Plate 5), and further eastwards in BMR No. 11 Cattle Creek a grey unit was encountered at 635' (Johnson, Nichols and Bell 1964). A fossiliferous limestone interval was also seen in Lake Nash No. 1 (Brown 1965) between 586' and 790', overlying 125' of grey dolomite, the general sequence being remarkably similar to that in unit C. BMR coreholes GRG 15 and 16 probably entered this unit; GRG 16 cores show a colour transition to shades of grey near the bottom, and the last 30 feet contain numerous algal limestone structures typical of subunit C2. GRG 4 may also have passed through the unit between 452' and about 650', the top 60 feet or so being a transition zone equivalent to C3. If the apparent conformity between units C and B in that hole is correct, this would point to a sharp facies change, rather than an unconformity, between the units in the present series of holes.

The evidence suggests that this thin unit is widespread and may be more or less continuous across the northern Georgina Basin. An exception possibly is the area in the vicinity of Alroy No. 1 where the unit is thin or absent. None of the holes was drilled in the type area of the Wonarah Beds, which is located in high ground well above the line of projection of unit C. Öpik (pers. comm.) states that although Mt. Lamb rocks were mapped by extrapolation as Wonarah Beds, the fauna on Mt. Lamb is in fact somewhat older. Hence the interpretation (Fig. 2) shows unit C dipping southwards under the main Wonarah Beds, separated from them by unit D.

The two limestone types in C2 point to different facies:

(i) a low-energy environment; fossils in good condition, poorly washed, algal structures, unit thin. (e.g. Alroy No. 2)

(ii) a high-energy environment: fossils very broken, well washed (sparry cements), less shaly beds, unit thicker. (e.g. Ranken No. 2)

A pronounced trough across the area of Ranken No. 2 seems to have been filled completely by unit C sediments.

UNIT D

This is typically a light coloured dolomite-limestone-siltstone unit, characterised by a wide range of fairly bright iron oxide colours. The unit may be very silty in parts, and occasionally sandy. It can be readily divided into two distinctive subunits, which appear to be contemporaneous facies variants and hence are designated subunits D(a) and D(d).

Subunit D(a) - Varicoloured beds

This subunit is seen in reasonably fresh condition only in Ranken No. 3, with possibly portions in Alroy No. 2 (on the upper parts of Mt. Lamb), Alroy No. 3 and Ranken No. 1.

It consists mainly of calcareous and dolomitic siltstone, basically of light brown colours with orange, khaki and pink tints in varying proportions. These are interlaminated with pink silty limestone, pink and maroon calcareous claystone, occasional red shaly partings, and a few bands of weathered pale grey sandy and silty clays. The siltstones are thin bedded and fissile, and thin limestone lenses are common; bedding is undulose and shows small-scale cross-lamination in places, e.g. in Ranken No. 3 at ca. 130! The limestones are fossiliferous in Alroy No. 2 towards the base of the subunit, but in Ranken No. 2 the only fossils seen were spicular debris in a thin section from 132'7", and fossiliferous calcilutite at about 33'.

Chert is mostly a minor constituent in the fresh rocks, but much chert was encountered in weathered material near surface in possible unit D. In Ranken No. 3 chert is developed in the limestone lenses, and this kind of chert is abundant between 70' and 33', cores having the general appearance of "ribbonstone". Bedding can be traced into the nodules suggesting a post-depositional replacement origin for them.

The silt fraction is well sorted and is composed primarily of quartz with abundant potash feldspar (microcline and untwinned grains), fragments of microtextured rocks, plentiful micas (mainly muscovite with some biotite and chlorite), accessory tourmaline, and traces of other accessory minerals. The tourmaline appears in appreciable amounts, a common feature of this unit noted in previous work in the area (e.g. Nichols and Fehr 1964). Hematite and hydrated iron oxides colour the rocks. The mineralogical composition points to essentially the same provenance as for unit C, but there is notably less material of organic origin, probably due to oxidising conditions.

Weathered sands and silty or sandy clays in the top 80 feet of Alroy No. 3 may belong to this subunit; a fragment of chert from 35' is a silicified coquinitic and pelletal limestone. Fossiliferous limestone with agnostids near the top of Ranken No. 1 may belong to this unit; the limestone overlies 30 feet of dolomitic silts which are typical of D(a), and has a lower Middle Cambrian age (Shergold, pers. comm.).

In this subunit, the gamma-ray logs generally gave moderate to low values.

Subunit D(b) - Intraclast beds.

Ranken No. 2 and Alroy No. 1 are the only holes that intersected this subunit, which in Ranken No. 2 consists of a partially dolomitized coarse calcarenite, and in Alroy No. 1 of a fully dolomitized equivalent.

This rock is composed essentially of cream-yellow intraclasts in sparry cement (intrasparite); colours tend to be strongest in the middle of the subunit, where yellow and orange predominant over pink and brown colours. These intraclasts appear to be essentially the same as the composite-grains described by Nichols (1966b) from the Georgina Basin core-holes. Their colours resemble the colour range seen in subunit D(a), and suggest possible derivation by reworking from those lithologies. The intraclasts become very coarse towards the top in Ranken No. 2, where they may reach a size of 2 mm.

In approximately the middle section of the subunit, ooliths are fairly common, and there are minor intercalations of khaki dolomite. Stylolites are sporadic and have pale clay linings, in contrast to the black carbonaceous linings seen in the greater part of unit B. Well rounded echinoid fragments are plentiful and show large calcite overgrowths. Other fossil debris is abundant at the base, and decreases upwards to negligible amounts; this material is broken down considerably, which points to even stronger reworking than for the coquinites of unit C.

Intraclasts generally are elongate, mostly subangular to subrounded, and occasionally well rounded. Small angular fragments are common, and may have been torn off larger clasts near the depositional site. Internal lithologies of the intraclasts include pelletal limestone, lutites - often rather silty - and occasional fossiliferous limestones.

Gamma-ray values were minimal in this subunit, in contrast to those in D(a); although subunit D(b) is probably genetically related to D(a), the development of tight sparry cements in D(b) has produced the response typical of limestones.

Discussion

No distinct order of superposition can be seen for these subunits, which as already noted, appear to be contemporaneous facies variants. Evidence for this can be seen in Corehole GRG 16, located about 18 miles north-northwest of Ranken No. 3, where intervals containing abundant intraclasts (e.g. 98 - 103' and 142' - 151') are interbedded with mainly orange silty lithologies and some pink and khaki strata. Further evidence is afforded by the colour resemblance between the intraclasts and the lithologies of subunit D(a).

In outcrops similar relationships can be seen. Subunit D(a) bears close resemblance to the Camooweal Dolomite, especially in its colours, lack of fossils, and development of "ribbonstone". On the other hand subunit D(b) resembles outcrops of fossiliferous intraclast dolomite at the site of Ranken No. 3, which have been mapped as Ranken Limestone. Hence unit D may be regarded as equivalent to Ranken Limestone plus part of the Camooweal Dolomite.

Öpik (pers. comm.) gives the Ranken Limestone an older age than that from the type area Wonarah Beds and younger than the outcrops on Mt. Lamb, which have been mapped as silicified "Wonarah Beds". This suggests that, while Wonarah Beds of the type area are stratigraphically above unit D, rocks of this character may have commenced earlier in the Mt. Lamb area, as a facies in older units.

In GRG 4, about 90 miles south-southwest of Ranken No. 3, silty dolomites show general red-brown colours, also pink and green, between 144' and 452' (Unit V in Fehr and Nichols 1963), and intraclasts are common. These dolomites may readily be equated with unit D, whereas limestones between 568' and 628' (Unit II op. cit.) can be matched with unit C, with an intervening colour transition zone between 452' and 568'. Nichols and Fehr (1964, p. 10) added that echinodermata fragments were seen in thin sections from this hole.

The pronounced colour trend in unit D points to a widespread change in environment to strongly oxidising conditions, following upon the relatively reducing conditions that prevailed during deposition of unit C. The drop in marine fossils and the increased reworking both suggest that the main cause for the change in conditions was simple shallowing, probably due to sediments gradually filling the basin. The presence of a broad transition zone appears to support this idea.

HIGHER UNITS

Units higher than unit D are difficult to differentiate because of weathering and soil development. In Alroy No. 1, between 70 and 100 feet, pale (weathered) siltstones and sandstones gave significant phosphate values; these appear to be stratigraphically higher than phosphates in unit C, and are thought to belong to a portion of the Wonarah Beds, stratigraphically higher than unit C. Chert is common in the weathering profiles, and is associated with gritty subsoils. Chert fragments thin-sectioned from Alroy No. 1 (47'6") and Alroy No. 3 (35') both showed obvious coquinitic textures; those in Alroy No. 1 were composite, made up of fragments of silicified coquinite cemented together by partly silicified/calcareous quartz sand and silt. The evidence shows that this chert is a Cainozoic weathering product.

As mentioned, the Wonarah Beds appear to be above unit C and unit D, on the assumption that the strata trend as shown between Alroy No. 3 and Ranken No. 3. Hydrological data support this - if the outcropping Wonarah Beds were equivalent to unit C, they would necessarily dip down to the north and east and should comprise an important intake area. However, the depth to the first aquifer shown by Randal (1967) suggests strata rise to the north from the Barkly Highway. Furthermore the isosalinity contours show that, although the outcropping Wonarah Beds are fairly close to the belt of low salinity, they do not coincide with it. The main intake area in this region seems to be farther west, in the Wonarah-Dalmore area, and to the north in the Alexandria area.

CONCLUSIONS

Petrological work suggests that units in this part of the Georgina Basin can be traced laterally for some distances, and can be subdivided into traceable lithologic units. A threefold subdivision of the lower Middle Cambrian of the area is apparent:

(i) lower fawn-tan dolomite unit; (unit B)
(ii) grey limestone/dolomite unit; (unit C)
(iii) upper varicoloured unit. (unit D)

Parameters of greatest value in tracing these units are: colours, calcite/dolomite proportions, silt (and total insolubles) content, and fossil content. Of supporting value are the nature of bedding, the phosphate content, the degree of recrystallisation, the types of chert, the abundance of stylolites, the presence of glauconite, and the degree of porosity (vugs).

The lower dolomite provides the main aquifers in the area, and is not considered to be the Camooweal Dolomite, but to be separated from it by unit C at least in this area. It may be a westward extension of the Thorntonia Limestone. It is typically very vuggy and characterised by its carbonaceous content. Unit C is of particular interest. It shows two facies in its fossil beds: a micritic algal limestone facies, and a well washed coquinitic facies with sparry cement. The unit can be traced at least as far as BMR Cattle Creek No. 11, Lake Nash No. 1, and GRG 4 at Annitowa. Its fossil content drops off considerably southwards and only algal mats are present in GRG 4.

Unit C is believed to be a subsurface continuation of rocks in the type area of Burton Beds, and to outcrop only in the vicinity of Mt. Lamb. The phosphate in it is intermittent over roughly 200 feet of section, and does not start at exactly the same horizons in each hole. The phosphate is probably of biogenic origin, as postulated by de Keyser (1968, 1969) for the origin of phosphate in northwestern Queensland. It typically occurs as collophane pellets associated with fossil beds, frequently filling or replacing fossils, and occasionally concentrated along small lenses.

The sharp boundary between units B and C suggests that unit B dolomites may have been located in well-defined banks, with the silty lithologies of unit C restricted to slightly deeper waters outside. However, at some time the silts seem to have virtually blanketed the area, when unit C attained its greatest extent. Variations in water depth are still evident in unit C in the two types of fossil beds to be found.

Unit D marks a widespread change to oxidising conditions, and a further increase in the influx of silt. The area appears to have become more uniformly shallow by this time, but unit D again shows two facies: a clastic orange-pink-khaki facies, and a reworked clastic facies of dolomitized intraclast limestone. The latter was probably laid down by reworking from the other type. Nichols (1966) considered that in his "Middle Units" (p. 45) - probably identified with this unit - the whole environment was probably an extremely shallow one, possibly a mud bank area, partly exposed at low tide. Unit D is considered to be part of the Camooweal Dolomite, with the Ranken Limestone and possibly part of the Wonarah Beds intertonguing into it.

The section indicates that the strata are subject to broad-scale folding with amplitudes of up to a few hundred feet (see Fig. 2). Especially the environs of Ranken No. 2 seem to have remained a shallow trough throughout the deposition of these units.

A basement high is suggested in the vicinity of Alroy No. 2, which over a general area probably influenced the deposition of these units, remaining consistently an elevated area.

In these units, the actual mineralogy of the silt fraction does not appear to be of great potential for correlation, as no obvious variations were seen throughout the section.

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APPENDIX A

Extract from Report on well GRG 4 (Georgina Basin), by A.E. Fehr and R.A.H. Nichols (Institut Francais du Pètrole AUS/85).

	0 - 91'4"	Quaternary sands
		unconformity
VII	91'4" - 106'	Dolomite, very light grey to beige, often brecciated, silicified and replaced by coarse calcite.
VI	106' - 144'	Claystone to clayey dolomite, silty or sandy especially in lower part.
V	144' - 452'	Dolomite, with considerable ferrugination, i.e. red-brown, less greenish, sharp, clayey and micaceous beds or lenses and persistent terrigenous sand or silt admixture.
IV	452' - 462'	Limestone (and dolomite) with intercalations of sandstone and conglomerates, overlying a possible unconformity.
III	462' - 568'	Dolomite, light grey, calcareous or with limestone interbeds, $CaCO_3$ content oscillating around 25%. Sand content decreases downwards. Persistent scour-and-fill structures indicate strong (tidal?) currents and channelling, possibly comparable with recent conditions on the Bahama Banks.
II	568' - 628'	Limestone, light grey to medium grey (less brown) with dolomite intercalations. High energy structures are significant as well.
I	628' - 738'	Dolomite, light to medium grey with downwards increasing content of secondary silica in beds or patches. Sharp clay beds, often developed as stylolites are frequent.

Footnote: Under the criteria used in the present work for boundaries of the units, a transition zone (=subunit C3) would be located from 452' to approximately 510', and the bottom of the grey unit may be about 650' with interfingering down to near 730'.

APPENDIX B

INTERVALS CORED AND RECOVERED

Name	Core No.	Interval cored	Recovery	Percentage
Ranken B.M.R. No. 1	1	27'0" - 29'6"	2'1"	83
	2	65'0" - 69'4"	4'4"	100
	3	125'0" - 126'6"	1'2"	80
	4	257'0" - 262'0"	3'10"	77
Ranken B.M.R. No. 2	1	59'6" - 64'6"	5'0"	100
	2	197'0" - 202'2"	5'2"	100
	3	255'0" - 260'2"	5'2"	100
	4	358'0" - 367'0"	8'10"	98
	5	440'0" - 441'0"	9"	75
	6	510'0" - 517'3"	7'1½"	98
Ranken B.M.R. No. 3	1	27'0" - 37'0"	7'4"	73
	2	37'0" - 39'0"	1'10"	92
	3	125'0" - 134'0"	9'0"	100
	4	205'0" - 215'0"	9'9"	97
	5	320'0" - 328'0"	8'0"	100
	6	421'0" - 423'0"	1'11"	96
	7	518'0" - 528'0"	9'10"	96
	8	550'0" - 553'0"	2'6"	83

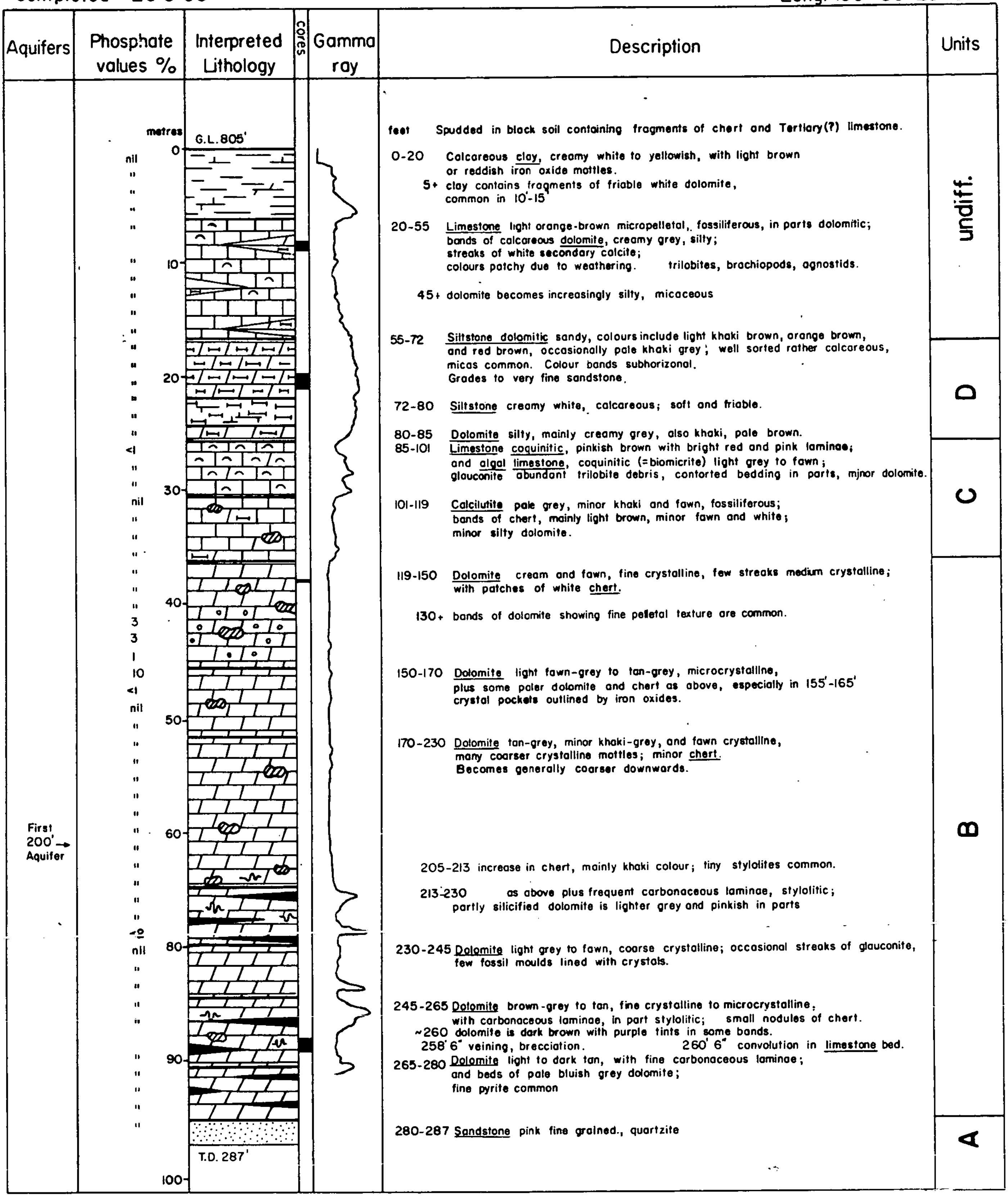
APPENDIX B (cont.)

Name	Core No.	Interval cored	Recovery	Percentage
Alroy B.M.R. No. 1	1	47'0" - 51'6"	6"	11
	2	125'0" - 135'0"	9'3"	92
	3	275'0" - 280'0"	5'0"	100
	4	475'0" - 485'0"	10'0"	100
Alroy B.M.R. No. 2	1	12'0" - 22'0"	8"	7
	2	32'6" - 40'0"	6'9"	90
	3	40'0" - 50'0"	5'6"	55
	4	50'0" - 56'0"	5'7"	93
	5	56'0" - 60'0"	3'0"	75
	6	60'0" - 66'0"	6'0"	100
	7	66'0" - 76'0"	10'0"	100
	8	76'0" - 86'0"	9'8"	97
	9	86'0" - 95'0"	9'0"	100
	10	95'0" - 105'0"	10'0"	100
	11	290'0" - 296'0"	6'0"	100
	12	353'0" - 360'6"	7'6"	100
	13	440'0" - 444'6"	4'6"	100
	14	485'0" - 495'0"	9'8"	97
Alroy B.M.R. No. 3	1	35'0" - 37'0"	6"	25
	2	125'0" - 133'0"	7'4"	92
	3	200'0" - 209'6"	9'6"	100
	4	330'0" - 333'0"	3'0"	100
	5	355'0" - 358'6"	3'6"	100

Commenced 24·9·68
Completed 26·9·68

RANKEN (B.M.R) No. I

Lat. 19° 16' 00" S
Long. 136° 38' 25" E



feet Spudded in black soil containing fragments of chert and Tertiary(?) limestone.

0-20 Calcareous clay, creamy white to yellowish, with light brown or reddish iron oxide mottles.
5+ clay contains fragments of friable white dolomite, common in 10'-15'

20-55 Limestone light orange-brown micropelletal, fossiliferous, in parts dolomitic; bands of calcareous dolomite, creamy grey, silty; streaks of white secondary calcite; colours patchy due to weathering. trilobites, brachiopods, agnostids.

45+ dolomite becomes increasingly silty, micaceous

55-72 Siltstone dolomitic sandy, colours include light khaki brown, orange brown, and red brown, occasionally pale khaki grey; well sorted rather calcareous, micas common. Colour bands subhorizonal. Grades to very fine sandstone.

72-80 Siltstone creamy white, calcareous; soft and friable.

80-85 Dolomite silty, mainly creamy grey, also khaki, pale brown.
85-101 Limestone coquinitic, pinkish brown with bright red and pink laminae; and algal limestone, coquinitic (=biomicrite) light grey to fawn; glauconite abundant trilobite debris, contorted bedding in parts, mjnor dolomite.

101-119 Calcilutite pale grey, minor khaki and fawn, fossiliferous; bands of chert, mainly light brown, minor fawn and white; minor silty dolomite.

119-150 Dolomite cream and fawn, fine crystalline, few streaks medium crystalline; with patches of white chert.

130+ bands of dolomite showing fine pelletal texture are common.

150-170 Dolomite light fawn-grey to tan-grey, microcrystalline, plus some paler dolomite and chert as above, especially in 155'-165' crystal pockets outlined by iron oxides.

170-230 Dolomite tan-grey, minor khaki-grey, and fawn crystalline, many coarser crystalline mottles; minor chert. Becomes generally coarser downwards.

205-213 increase in chert, mainly khaki colour; tiny stylolites common.

213-230 as above plus frequent carbonaceous laminae, stylolitic; partly silicified dolomite is lighter grey and pinkish in parts

230-245 Dolomite light grey to fawn, coarse crystalline; occasional streaks of glauconite, few fossil moulds lined with crystals.

245-265 Dolomite brown-grey to tan, fine crystalline to microcrystalline, with carbonaceous laminae, in part stylolitic; small nodules of chert.
~260 dolomite is dark brown with purple tints in some bands.
258' 6" veining, brecciation. 260' 6" convolution in limestone bed.
265-280 Dolomite light to dark tan, with fine carbonaceous laminae; and beds of pale bluish grey dolomite; fine pyrite common

280-287 Sandstone pink fine grained., quartzite

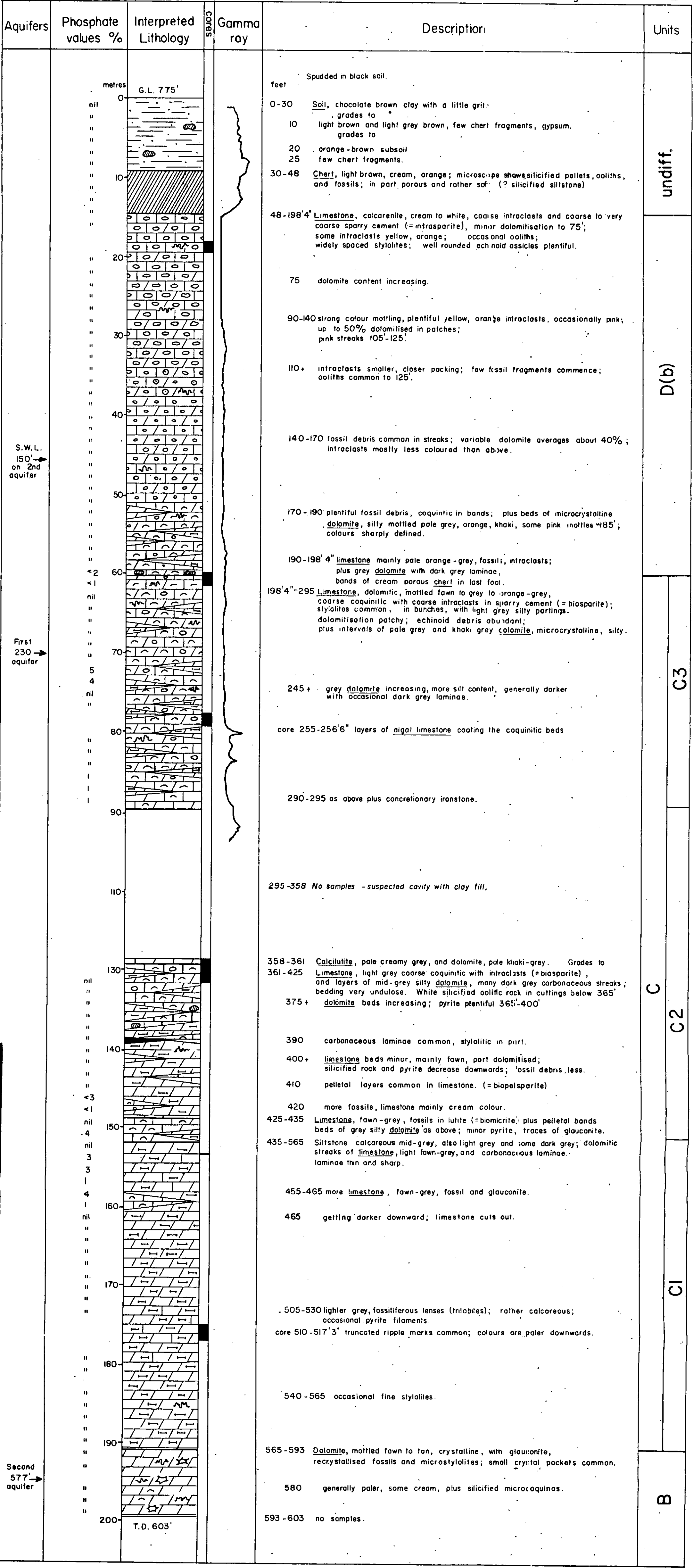
To accompany Record 1970/114

Plate II

Commenced 27·9·68
Completed 12·10·68

RANKEN (B.M.R.) No.2

Lat. 19° 24' 40" S
Long. 136° 35' 55" E



Spudded in black soil.

feet	
0-30	Soil, chocolate brown clay with a little grit. grades to
10	light brown and light grey brown, few chert fragments, gypsum. grades to
20	orange-brown subsoil
25	few chert fragments.
30-48	Chert, light brown, cream, orange; microscope shows silicified pellets, ooliths, and fossils; in part porous and rather soft (? silicified siltstone)
48-198'4"	Limestone, calcarenite, cream to white, coarse intraclasts and coarse to very coarse sparry cement (= intrasparite), minor dolomitisation to 75'; some intraclasts yellow, orange; occasional ooliths; widely spaced stylolites; well rounded echinoid ossicles plentiful.
75	dolomite content increasing.
90-140	strong colour mottling, plentiful yellow, orange intraclasts, occasionally pink; up to 50% dolomitised in patches; pink streaks 105'-125'.
110+	intraclasts smaller, closer packing; few fossil fragments commence; ooliths common to 125'.
140-170	fossil debris common in streaks; variable dolomite averages about 40%; intraclasts mostly less coloured than above.
170-190	plentiful fossil debris, coquinitic in bands; plus beds of microcrystalline dolomite, silty mottled pale grey, orange, khaki, some pink mottles ~185'; colours sharply defined.
190-198' 4"	limestone mainly pale orange-grey, fossils, intraclasts; plus grey dolomite with dark grey laminae, bands of cream porous chert in last foot.
198'4"-295	Limestone, dolomitic, mottled fawn to grey to orange-grey, coarse coquinitic with coarse intraclasts in sparry cement (= biosparite); stylolites common, in bunches, with light grey silty partings. dolomitisation patchy; echinoid debris abundant; plus intervals of pale grey and khaki grey colomite, microcrystalline, silty.
245+	grey dolomite increasing, more silt content, generally darker with occasional dark grey laminae.
core 255-256'6"	layers of algal limestone coating the coquinitic beds
290-295	as above plus concretionary ironstone.
295-358	*No samples - suspected cavity with clay fill,*
358-361	Calcilutite, pale creamy grey, and dolomite, pale khaki-grey. Grades to
361-425	Limestone, light grey coarse coquinitic with intraclasts (= biosparite), and layers of mid-grey silty dolomite, many dark grey carbonaceous streaks; bedding very undulose. White silicified oolific rock in cuttings below 365'
375+	dolomite beds increasing; pyrite plentiful 365'-400'
390	carbonaceous laminae common, stylolitic in part.
400+	limestone beds minor, mainly fawn, part dolomitised; silicified rock and pyrite decrease downwards; fossil debris less.
410	pelletal layers common in limestone. (= biopelsparite)
420	more fossils, limestone mainly cream colour.
425-435	Limestone, fawn-grey, fossils in lutite (= biomicrite) plus pelletal bands beds of grey silty dolomite as above; minor pyrite, traces of glauconite.
435-565	Siltstone calcareous mid-grey, also light grey and some dark grey; dolomitic streaks of limestone, light fawn-grey, and carbonaceous laminae. laminae thin and sharp.
455-465	more limestone, fawn-grey, fossil and glauconite.
465	getting darker downward; limestone cuts out.
505-530	lighter grey, fossiliferous lenses (trilobites); rather calcareous; occasional pyrite filaments.
core 510-517'3"	truncated ripple marks common; colours are paler downwards.
540-565	occasional fine stylolites.
565-593	Dolomite, mottled fawn to tan, crystalline, with glauconite, recrystallised fossils and microstylolites; small crystal pockets common.
580	generally paler, some cream, plus silicified microcoquinas.
593-603	no samples.

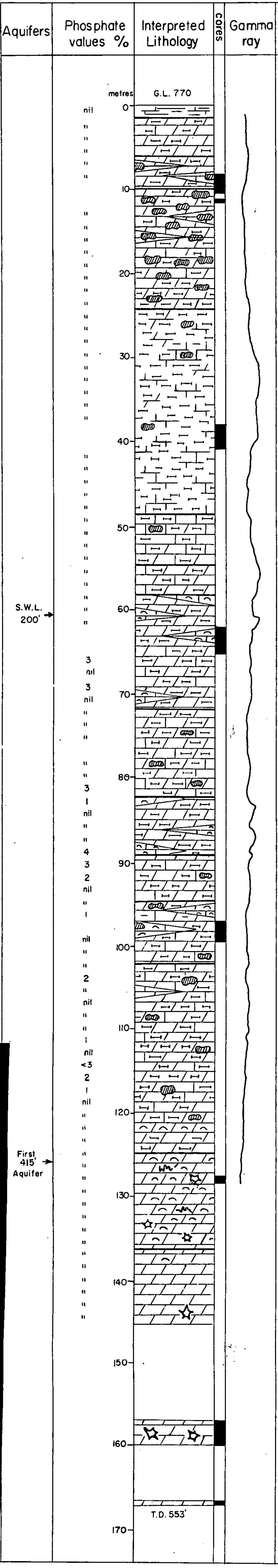
To accompany Record 1970/114

Plate III

Commenced 10·11·68
Completed 17·11·68

RANKEN (B.M.R.) No. 3

Lat. 19° 59' 30" S
Long. 136° 59' 30" E



Description

Spudded on "outcrop" of coarsely crystalline bioclastic limestone.
Mapped as Ranken Limestone. Loc. R.K. 70

feet

0-5 Soil, brown and light brown calcareous clay with cream-white secondary limestone.

5-20 Weathered silty dolomite, cream to light orange-brown, calcareous; ranging to pale grey-white limestone; limestone decreases downwards.

20-33 Silty dolomite, slightly weathered, calcareous in bands, pale tones of orange brown, khaki and pink, laminated; lenses of pale cream-grey limestone, small chert nodules in the lenses; fine fossil debris.

33-80 Silty dolomite partly calcareous, mainly orange, some pale pink; many bands of cream-grey and white chert, developed from limestone (most of the limestone has been silicified); some fine fossil debris.

50+ mainly pale brown to khaki, plus colours as above, and occasional red laminae; less silicification of limestone.
60-65 more silicification of limestone; no red laminae.
65+ silt content increasing; grades to dolomitic siltstone in parts.
70+ more pale pink laminae, lamination marked; limestone and chert minor.

80-160 Siltstone, dolomitic and calcareous grading to silty dolomite, light brown with orange, khaki and pink tints, laminate and fissile, micas plentiful with pale grey-brown microcrystalline limestone and chert in thin lenses.

95-100 drop in silt content, more limestone and chert.

105+ becomes more brownish generally, and more calcareous.
110-160 calcareous mainly, minor dolomite, colour mainly orange-brown; with silty limestone, pale pinkish brown.

core - pinkish brown, with orange, khaki and cream tints; khaki bands are finest grain; bedding undulose; 132' increase in amount of limestone, which becomes fawn to brown-grey downwards. (thin section 132'7" has fine spicular debris)

145-155 few thin red laminae.

160-180 Limestone, silty light to mid grey, dolomitic, laminated; with pale brown-grey calcilutite, silicified in parts.

175 dolomite content increasing; some dark maroon laminae.
180-192 Dolomite silty, grey at first then khaki, with maroon laminae; plus limestone, silty as above, mainly light grey, dolomitic.

192-237 Siltstone, dolomitic, khaki with orange, pink and maroon laminae; beds of coquinitic limestone, light fawn-grey to orange, glauconitic, sparry cements (=biosparite), part dolomitised; plentiful echinoid debris and biconulites; minor silicification; streaks show pelletal textures.

210+ drop in fossils, more silty dolomite; lenses of pale brown-grey ?algal limestone.

225-237 transition to light to mid grey silty dolomite, interlaminated with colours as above. coquinitic band ~230

237-271 Siltstone, dolomitic, light to mid grey, sharply laminated, in part calcareous; streaks of limestone, light brown-grey, crystalline, dolomitic; and patches of pale grey-white chert in the limestone; occasional small stylolites.

255-260 few fossil bands in the limestone.

271-294 Siltstone, dolomitic, light to mid-grey as above; with beds of coarse coquinitic limestone, mainly pale grey also fawn and cream, glauconitic, sparry cements (= biosparite) intraclasts in bands; minor cherty patches.

294-312 Siltstone, dolomitic, colours as above, sharply laminated; grading to minor dolomitic limestone, light grey, with a few cherty bands.

312-337 Siltstone, dolomitic, colours as above, with some stylolitic dark grey laminae. beds of coquinitic limestone, light grey, some fawn, glauconitic, mainly sparry cement; some light grey calcilutite; patches of creamy-grey chert in the limestones; bedding undulose.

330+ drop in coquinite beds.

337-412 Siltstone, dolomitic, mainly mid grey, some light grey, minor dark grey, sharply laminated, micaceous; lenses of fawn-grey calc lutite, fossiliferous, and pelletal in bands (= biomicrite, biopelmicrite) spicules common, scattered glauconite and pyrite; streaks of chert, mainly pale grey-white. Fossils minor below 350'

360+ limestone is dolomitic in patches.

~370 shaley dark grey lamimae common.

400 band of dolomitised coquinite, fawn-grey, traces of glauconite.
405 carbonaceous laminae common, few red laminae

412-450 Dolomite, mottled cream to fawn, medium to coarse crystalline; abundant recrystallised fossils, glauconite common; small vugs (some are shell moulds) few stylolites with white clay linings.

425-435 few streaks with plentiful glauconite.

450-480 Dolomite, mainly cream, with fawn mottles, medium to coarse crystalline, scattered glauconite; few fossils.

470-480 yellow coated crystals, and orange clays common (? from cavities)

480-T.D. no cutting samples

core 518 Dolomite, fawn, large mottles in shades of fawn (? algal balls); mainly medium crystalline; many crystal-lined vugs up to 1"; structures show concentric layering in parts.
528-550 Numerous cavities usually 6" to 12" high; between 540-544 intercepted 4' mud filled cavity.

core 550 Dolomite, fawn with light tan mottles, mainly fine crystalline, convolute bedding common. vugs up to $\frac{1}{2}$"

Units

D(a)
C
C3
C2
C1
B
B4

To accompany Record 1970/114

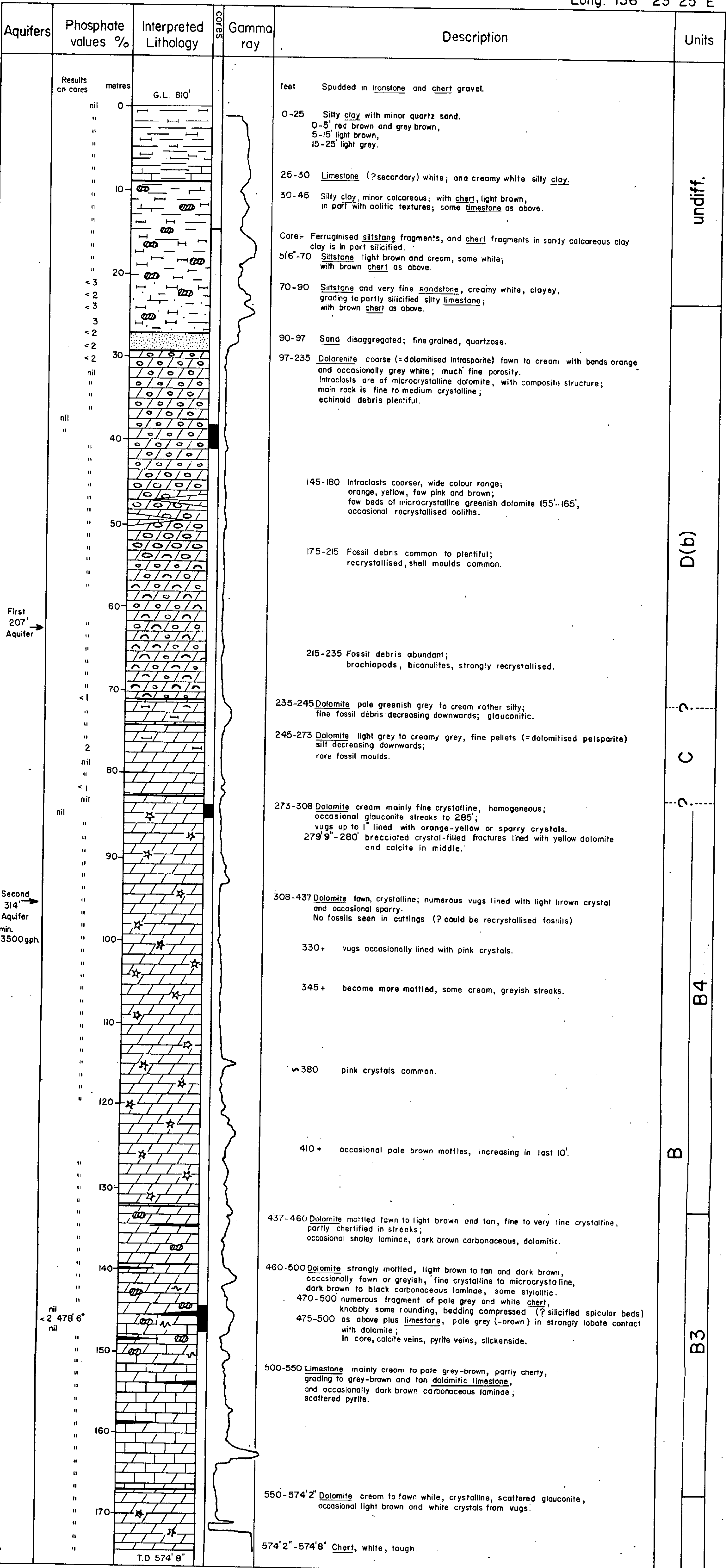
MP(Lt)15

Plate IV

Commenced 13·10·68
Completed 25·10·68

ALROY (B.M.R.) No 1

Lat. 19° 23' 50" S
Long. 136° 23' 25" E



feet Spudded in ironstone and chert gravel.

0-25 Silty clay with minor quartz sand.
0-5' red brown and grey brown,
5-15' light brown,
15-25' light grey.

25-30 Limestone (?secondary) white; and creamy white silty clay.

30-45 Silty clay, minor calcareous; with chert, light brown,
in part with oolitic textures; some limestone as above.

Core:- Ferruginised siltstone fragments, and chert fragments in sandy calcareous clay
clay is in part silicified.
51'6"-70 Siltstone light brown and cream, some white;
with brown chert as above.

70-90 Siltstone and very fine sandstone, creamy white, clayey,
grading to partly silicified silty limestone;
with brown chert as above.

90-97 Sand disaggregated; fine grained, quartzose.

97-235 Dolarenite coarse (=dolomitised intrasparite) fawn to cream with bands orange
and occasionally grey white; much fine porosity.
Intraclasts are of microcrystalline dolomite, with composite structure;
main rock is fine to medium crystalline;
echinoid debris plentiful.

145-180 Intraclasts coarser, wide colour range;
orange, yellow, few pink and brown;
few beds of microcrystalline greenish dolomite 155'-165',
occasional recrystallised ooliths.

175-215 Fossil debris common to plentiful;
recrystallised, shell moulds common.

215-235 Fossil debris abundant;
brachiopods, biconulites, strongly recrystallised.

235-245 Dolomite pale greenish grey to cream rather silty;
fine fossil débris decreasing downwards; glauconitic.

245-273 Dolomite light grey to creamy grey, fine pellets (=dolomitised pelsparite)
silt decreasing downwards;
rare fossil moulds.

273-308 Dolomite cream mainly fine crystalline, homogeneous;
occasional glauconite streaks to 285';
vugs up to 1" lined with orange-yellow or sparry crystals.
279'9"-280' brecciated crystal-filled fractures lined with yellow dolomite
and calcite in middle.

308-437 Dolomite fawn, crystalline; numerous vugs lined with light brown crystal
and occasional sparry.
No fossils seen in cuttings (? could be recrystallised fossils)

330+ vugs occasionally lined with pink crystals.

345+ become more mottled, some cream, greyish streaks.

~380 pink crystals common.

410+ occasional pale brown mottles, increasing in last 10'.

437-460 Dolomite mottled fawn to light brown and tan, fine to very fine crystalline,
partly chertified in streaks;
occasional shaley laminae, dark brown carbonaceous, dolomitic.

460-500 Dolomite strongly mottled, light brown to tan and dark brown,
occasionally fawn or greyish, fine crystalline to microcrystalline,
dark brown to black carbonaceous laminae, some stylolitic.
470-500 numerous fragment of pale grey and white chert,
knobbly some rounding, bedding compressed (? silicified spicular beds)
475-500 as above plus limestone, pale grey (-brown) in strongly lobate contact
with dolomite;
In core, calcite veins, pyrite veins, slickenside.

500-550 Limestone mainly cream to pale grey-brown, partly cherty,
grading to grey-brown and tan dolomitic limestone,
and occasionally dark brown carbonaceous laminae;
scattered pyrite.

550-574'2" Dolomite cream to fawn white, crystalline, scattered glauconite,
occasional light brown and white crystals from vugs.

574'2"-574'8" Chert, white, tough.

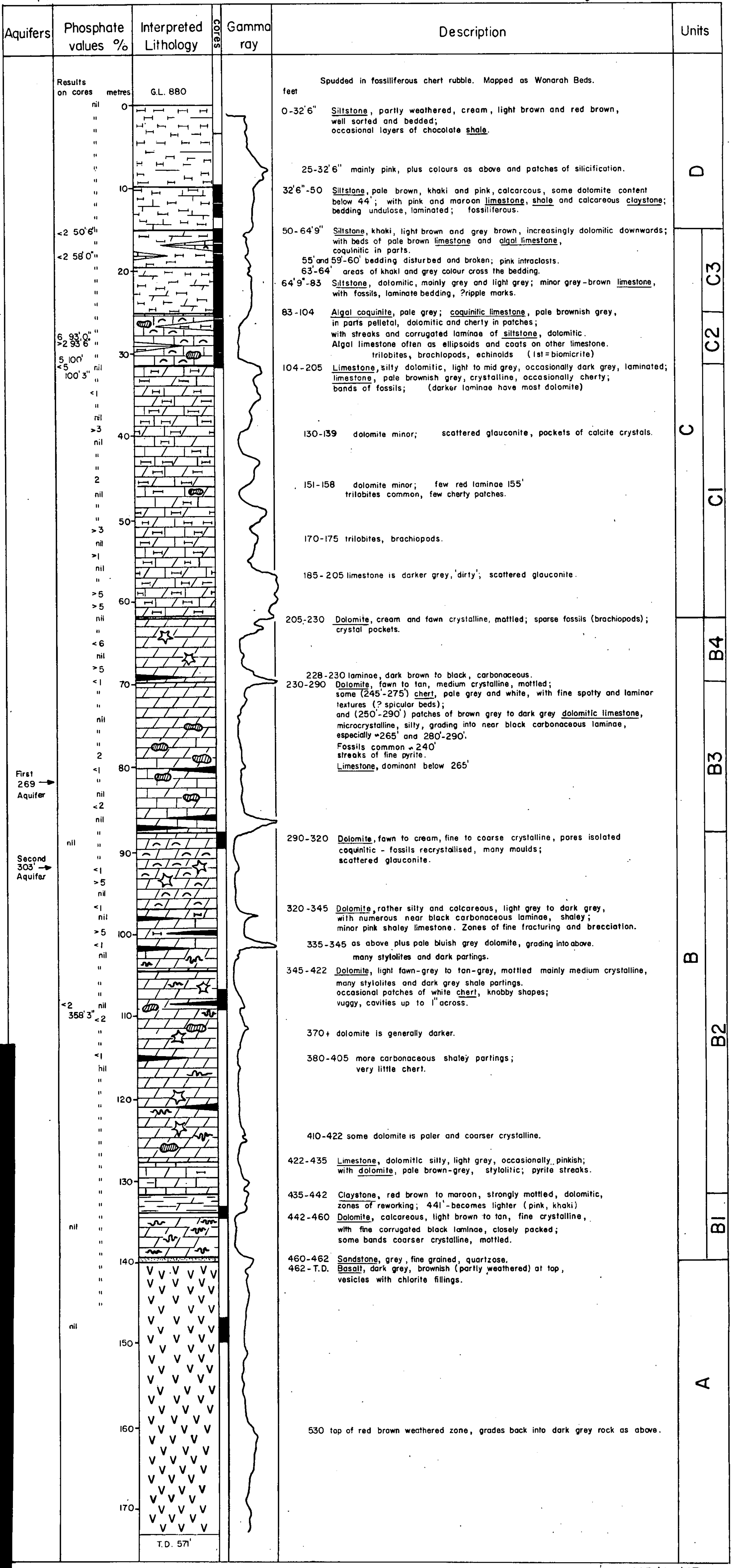
To accompany Record 1970/114

MP(Lt)16.

Commenced 26·10·68
Complet 3·11·68

ALROY (B.M.R.) No. 2

Lat. 19° 30' 50" S
Long. 136° 17' 30" E



Spudded in fossiliferous chert rubble. Mapped as Wonarah Beds.

feet

0-32'6" Siltstone, partly weathered, cream, light brown and red brown, well sorted and bedded; occasional layers of chocolate shale.

25-32'6" mainly pink, plus colours as above and patches of silicification.

32'6"-50 Siltstone, pale brown, khaki and pink, calcarcous, some dolomite content below 44'; with pink and maroon limestone, shale and calcareous claystone; bedding undulose, laminated; fossiliferous.

50-64'9" Siltstone, khaki, light brown and grey brown, increasingly dolomitic downwards; with beds of pale brown limestone and algal limestone, coquinitic in parts.

55' and 59'-60' bedding disturbed and broken; pink intraclosts.

63'-64' areas of khaki and grey colour cross the bedding.

64'9"-83 Siltstone, dolomitic, mainly grey and light grey; minor grey-brown limestone, with fossils, laminate bedding, ?ripple marks.

83-104 Algal coquinite, pale grey; coquinitic limestone, pale brownish grey, in parts pelletal, dolomitic and cherty in patches; with streaks and corrugated laminae of siltstone, dolomitic. Algal limestone often as ellipsoids and coats on other limestone. trilobites, brachiopods, echinoids (1st = biomicrite)

104-205 Limestone, silty dolomitic, light to mid grey, occasionally dark grey, laminated; limestone, pale brownish grey, crystalline, occasionally cherty; bands of fossils; (darker laminae have most dolomite)

130-139 dolomite minor; scattered glauconite, pockets of calcite crystals.

151-158 dolomite minor; few red laminae 155' trilobites common, few cherty patches.

170-175 trilobites, brachiopods.

185-205 limestone is darker grey, 'dirty'; scattered glauconite.

205-230 Dolomite, cream and fawn crystalline, mottled; sparse fossils (brachiopods); crystal pockets.

228-230 laminae, dark brown to black, carbonaceous.

230-290 Dolomite, fawn to tan, medium crystalline, mottled; some (245'-275') chert, pale grey and white, with fine spotty and laminar textures (? spicular beds); and (250'-290') patches of brown grey to dark grey dolomitic limestone, microcrystalline, silty, grading into near black carbonaceous laminae, especially ~265' and 280'-290'. Fossils common ~ 240' streaks of fine pyrite. Limestone, dominant below 265'

290-320 Dolomite, fawn to cream, fine to coarse crystalline, pores isolated coquinitic - fossils recrystallised, many moulds; scattered glauconite.

320-345 Dolomite, rather silty and calcareous, light grey to dark grey, with numerous near black carbonaceous laminae, shaley; minor pink shaley limestone. Zones of fine fracturing and brecciation.

335-345 as above plus pale bluish grey dolomite, grading into above. many stylolites and dark partings.

345-422 Dolomite, light fawn-grey to tan-grey, mottled mainly medium crystalline, many stylolites and dark grey shale partings. occasional patches of white chert, knobby shapes; vuggy, cavities up to 1" across.

370+ dolomite is generally darker.

380-405 more carbonaceous shaley partings; very little chert.

410-422 some dolomite is paler and coarser crystalline.

422-435 Limestone, dolomitic silty, light grey, occasionally pinkish; with dolomite, pale brown-grey, stylolitic; pyrite streaks.

435-442 Claystone, red brown to maroon, strongly mottled, dolomitic, zones of reworking; 441'-becomes lighter (pink, khaki)

442-460 Dolomite, calcareous, light brown to tan, fine crystalline, with fine corrugated black laminae, closely packed; some bands coarser crystalline, mottled.

460-462 Sandstone, grey, fine grained, quartzose.

462-T.D. Basalt, dark grey, brownish (partly weathered) at top, vesicles with chlorite fillings.

530 top of red brown weathered zone, grades back into dark grey rock as above.

To accompany Record 1970/114

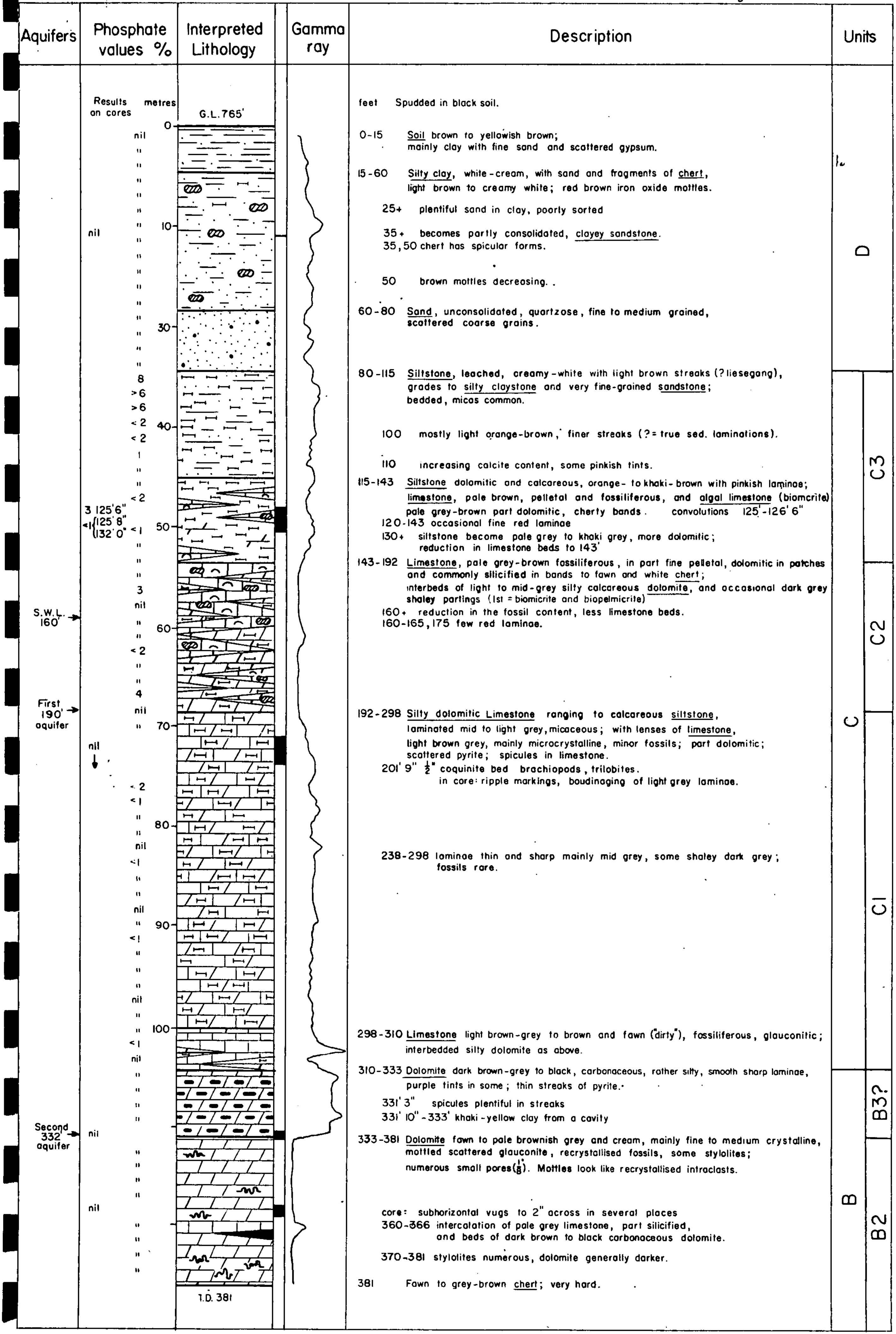
MP(Lt)17

Plate VI

Commenced 4·11·68
Completed 9·11·68

ALROY (B.M.R.) No. 3

Lat. 19° 42' 30" S
Long. 136° 24' 00" E



feet Spudded in black soil.

0-15 Soil brown to yellowish brown;
mainly clay with fine sand and scattered gypsum.

15-60 Silty clay, white-cream, with sand and fragments of chert,
light brown to creamy white; red brown iron oxide mottles.

25+ plentiful sand in clay, poorly sorted

35+ becomes partly consolidated, clayey sandstone.
35,50 chert has spicular forms.

50 brown mottles decreasing..

60-80 Sand, unconsolidated, quartzose, fine to medium grained,
scattered coarse grains.

80-115 Siltstone, leached, creamy-white with light brown streaks (? liesegang),
grades to silty claystone and very fine-grained sandstone;
bedded, micas common.

100 mostly light orange-brown, finer streaks (?= true sed. laminations).

110 increasing calcite content, some pinkish tints.

115-143 Siltstone dolomitic and calcareous, orange- to khaki-brown with pinkish laminae;
limestone, pale brown, pelletal and fossiliferous, and algal limestone (biomcrite)
pale grey-brown part dolomitic, cherty bands. convolutions 125'-126'6"
120-143 occasional fine red laminae
130+ siltstone become pale grey to khaki grey, more dolomitic;
reduction in limestone beds to 143'

143-192 Limestone, pale grey-brown fossiliferous, in part fine pelletal, dolomitic in patches
and commonly silicified in bands to fawn and white chert;
interbeds of light to mid-grey silty calcareous dolomite, and occasional dark grey
shaley partings (1st = biomicrite and biopelmicrite)
160+ reduction in the fossil content, less limestone beds.
160-165,175 few red laminae.

192-298 Silty dolomitic Limestone ranging to calcareous siltstone,
laminated mid to light grey, micaceous; with lenses of limestone,
light brown grey, mainly microcrystalline, minor fossils; part dolomitic;
scattered pyrite; spicules in limestone.
201' 9" ½" coquinite bed brachiopods, trilobites.
in core: ripple markings, boudinaging of light grey laminae.

238-298 laminae thin and sharp mainly mid grey, some shaley dark grey;
fossils rare.

298-310 Limestone light brown-grey to brown and fawn ("dirty"), fossiliferous, glauconitic;
interbedded silty dolomite as above.

310-333 Dolomite dark brown-grey to black, carbonaceous, rather silty, smooth sharp laminae,
purple tints in some; thin streaks of pyrite.

331' 3" spicules plentiful in streaks
331' 10"-333' khaki-yellow clay from a cavity

333-381 Dolomite fawn to pale brownish grey and cream, mainly fine to medium crystalline,
mottled scattered glauconite, recrystallised fossils, some stylolites;
numerous small pores(⅛"). Mottles look like recrystallised intraclasts.

core: subhorizontal vugs to 2" across in several places
360-366 intercalation of pale grey limestone, part silicified,
and beds of dark brown to black carbonaceous dolomite.

370-381 stylolites numerous, dolomite generally darker.

381 Fawn to grey-brown chert; very hard.

To accompany Record 1970/114

MP(Lt) 18