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The Antrim Plateau Volcanics, Victoria River District, Northern Territory

by

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CONTENTS

APPENDICES

TABLES

FIGURES

SUMMARY

The Antrim Plateau Volcanics consist predominantly of a succession of parallel or sub-parallel lava flows. The formation underlies extensive areas in the Victoria River District of the Northern Territory but is poorly exposed. A total of nine stratigraphic holes were drilled in the formation during the 1969 and 1970 field seasons to provide core and chip samples for a detailed laboratory investigation of the volcanics. Forty five flows and one band of agglomerate were penetrated during the course of the drilling. Flow thicknesses range from a minimum of 4 m to a maximum of 114.3 m. The average flow thickness is 35.6 m.

The lavas are dominantly basalts. Labradorite, clinopyroxene, opaque oxide, and devitrified glass or a quartzo-feldspathic residuum account for a high proportion of the total volume of the rocks. Accessory components include olivine (replaced by chlorite or "iddingsite"), quartz, hornblende and mica. The majority of the flows show a central, compact or nearly non-vesicular, medium-grained interior grading into a fine-grained vesicular zone in the upper, and generally also the basal, portions. Basalt from the more massive portions of virtually every flow contains phenocrysts of plagioclase. However, the feldspar phenocrysts are nowhere abundant.

Despite the overall similarity of hand specimens from the different lava flows, many possess, on a microscopic scale, distinctive characteristics that enable individual flows to be delineated. There are generally slight differences from flow to flow such as the presence or absence of pigeonite or olivine. There are also differences marked by the character of the opaque oxide - as interstitial granules or as microphenocrysts. Clinopyroxene may occur as small interstitial grains, as subhedral phenocrysts or as large anhedral phenocrysts containing very fine exsolution lamellae and commonly ophitically and sub-ophitically enclosing feldspar laths.

Based on a modal mineralogical classification, the basalts (senso lato)of the Antrim Plateau Volcanics range from olivine tholeiites, through tholeiites to quartz tholeiites. The occurrence of minor amounts of interstitial primary quartz in the lavas is a characteristic of the formation. Some of the more quartz-rich variants are possibly best described as basaltic andesites. Often several rock types are represented in single flows suggesting that some fractionation occurred in the lavas during consolidation.

Vesicles are frequently filled with a variety of secondary minerals, the most common being chlorite, quartz, calcite, chalcedony, agate, prehnite and pumpellyite. The basalts have undergone a certain amount of alteration - the alteration generally being most severe in the upper and basal vesicular portions of flows. These zones normally grade into massive, comparatively slightly altered or virtually fresh basalt in the central and lower portions of the flows.

Sandstone, siltstone, limestone and chert beds are commonly intercalated with the lava flows. The sedimentary interbeds are characteristically very thin, the average thickness being 2.8 m.

INTRODUCTION

In 1969 a drilling project was initiated by the Bureau of Mineral Resources in the Victoria River District of the Northern Territory, encompassing the Delamere, Victoria River Downs, Wave Hill, Limbunya and Waterloo 1:250,000 Sheet areas (see figure 1). A total of nine stratigraphic holes have been drilled - two during the 1969 field season and the remainder during the 1970 season. The holes were drilled by contract with Ingersoll-Rand Trucm 3 and Trucm 4 rotary percussion rigs (rated maximum capacity 305 m and 457 m respectively) equipped to drill with both air and mud.

The aim of the project was to provide samples of Antrim Plateau Volcanics for a detailed mineragraphic, petrographic and petrological study. The Antrim Plateau Volcanics comprise a large and little known expanse of flood basalts exposed mainly in the East Kimberley District of Western Australia and the adjoining Victoria River District of the Northern Territory.

Four hundred thin sections of cores and cuttings collected from the straigraphic holes were examined by the writer.

Previous Work

Hardman (1885) named the hilly, dissected country east of the Elvire River in the East Kimberley District, the Great Antrim Plateau. The region is occupied by a succession of basic lava flows with minor interbedded pyroclastics and sediments. David (1932) used the name Antrim Plateau Basalts. Traves (1955) recognised pyroclastic horizons within the succession and consequently modified the name of the formation to Antrim Plateau Volcanics. He also extended usage of the name to include the large belt of volcanic rocks which crop out in the Northern Territory from Hooker Creek through Wave Hill to north of Willeroo. The name, Antrim Plateau Volcanics, is now applied to the almost continuous outcrop of volcanics in the East Kimberley, Victoria River and Daly River Basin regions. Extension of the volcanics below the Cambrian sediments of the Northern Wiso and Daly River Basins has been indicated by intersections of the formation in water bores.

A comprehensive study of the volcanics has not been undertaken previously. Edwards and Clarke (1940) described some specimens from the East Kimberley District and brief notes have been made on other localities in various unpublished records of the Bureau of Mineral Resources (Dow et al., 1964; Roberts et al., 1965; Randal and Brown, 1967; Morgan et al., 1970; Sweet et al., 1971).

Dunn and Brown (1969) correlated the Antrim Plateau Volcanics with volcanics mapped in other parts of the Northern Territory and Western Queensland: the Nutwood Downs Volcanics (Dunn, 1963), the Helen Springs Volcanics (Ivanac, 1954), the Peaker Piker Volcanics (Smith and Roberts, 1963) and the Colless Volcanics (Carter et al., 1961). No proof exists of the continuity of the volcanics beneath the younger Cambrian and Cretaceous sediments of the Georgina Basin as very few bores put down in the northern part of the basin have

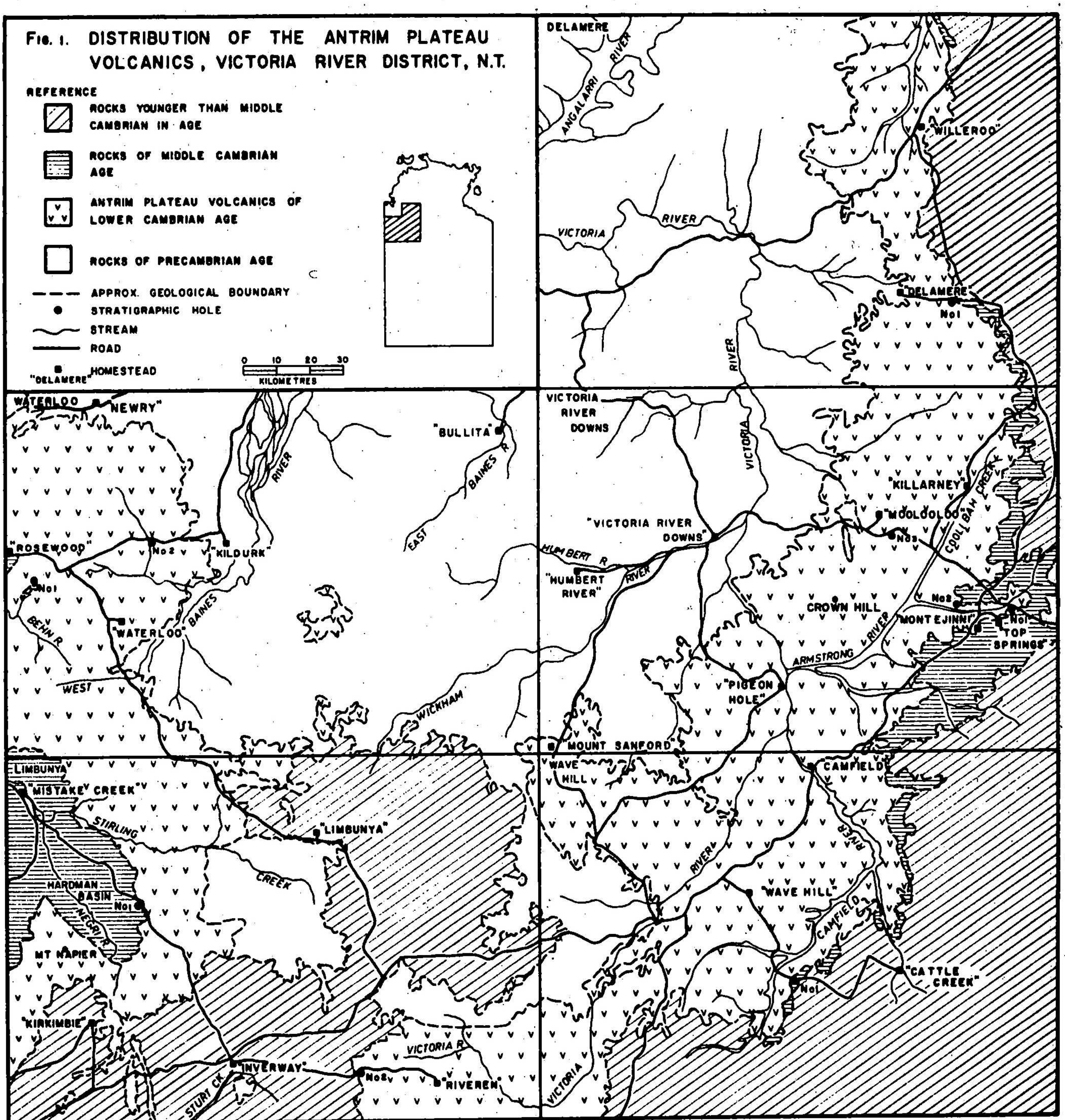

FIG. 1. DISTRIBUTION OF THE ANTRIM PLATEAU VOLCANICS, VICTORIA RIVER DISTRICT, N.T.

To accompany Record 1971/69

penetrated the Middle Cambrian carbonate sequence. The stratigraphic hole B.M.R. Alroy No. 2 penetrated volcanics tentatively correlated with the Peaker Piker Volcanics (Bastion and Thieme, 1970).

Regional Geology

The age of the Antrim Plateau Volcanics must be inferred from stratigraphic evidence. Diagnostic fossils have not been found in the interbedded sediments and the volcanics have not been dated by isotopic means. The volcanics overlie the Precambrian sediments of the Victoria River and East Kimberley Districts with an angular unconformity. The most definitive age limits for the formation are set in the East Kimberley region where the volcanics unconformably overlie shales - the Timperley Shale in the Albert Edward Group (Dow and Gemuts, 1969) - dated at 666 $\pm$ 43 million years (Bofinger, 1967). The volcanics were eroded and faulted before the deposition of the Blatchford Formation in the late Lower Cambrian (Kaulback and Veevers, 1969). The data suggest an age for the volcanics of early Lower Cambrian or very latest Precambrian. Supporting evidence for the younger age is seen elswwhere. The volcanics are overlain disconformably or with only a slight angular unconformity by the Headleys and Montejinni Limestones. The Headleys Limestone is the basal formation in the Negri Group. Faunal assemblages indicate a lower Middle Cambrian age for the group (Öpik, in Traves, 1955). A lower Middle Cambrian age has also been assigned to the fossiliferous Montejinni Limestone (Gatehouse, in Randal and Brown, 1967).

The volcanics constitute a very widespread unit in the five sheet areas mapped. However, in general, the volcanics are poorly exposed. The formation in the five sheet areas consists of a succession of flat-lying or gently dipping, parallel or sub-parallel lava flows with subordinate agglomerate and interbedded sandstone, chert, limestone and siltstone. In the Wave Hill and Victoria River Downs Sheet areas the volcanics underlie extensive black soil plains with few trees and low, rounded, well-grassed hills (representing remnants of overlying flows) strewn with basalt cobbles. In the Waterloo and Limbunya Sheet areas the country underlain by the volcanics tends to be more hilly and highly dissected. Terracing is common in the sides of hills.

Traves (1955) divided the formation into two belts - an eastern and a western. The former extends from Hooker Creek (Winnecke Creek 1:250,000 Sheet area) through Wave Hill to Willeroo and further north while the latter extends from the Antrim Plateau in Western Australia northwards through Mistake Creek and Rosewood to Argyle Downs and beyond. Continuity of outcrop between the two belts cannot be completely traced because of superficial cover in the central portions of the Limbunya Sheet area. The distribution of outcropping volcanics in the five sheet areas is shown in figure 1. The formation is exposed over a total area of approximately 26,000 sq km in the sheet areas (3,500 sq km in the Delamere Sheet area, 7,700 sq km in the Victoria River Downs Sheet area, 6,500 sq km in the Wave Hill Sheet area, 3,900 sq km in the Limbunya Sheet area and 4,600 sq km in the Waterloo Sheet area).

In three separate areas along the western belt of volcanics Cambrian sediments have been downfolded into the Antrim Plateau Volcanics. These markedly asymmetrical basins were called by Matheson and Teichert (1948) the Hardman (covering portions of the Limbunya, Waterloo and Dixon Range Sheet areas), Rosewood (covering portions of the Waterloo and Lissadell Sheet areas) and Argyle (covering portions of the Lissadell Sheet area) Basins. The largest parts of the basins are in the East Kimberley region of Western Australia, the Hardman and Rosewood Basins extending into the adjoining Limbunya and Waterloo Sheet areas. The sediments within the basins are mostly easily eroded, marl and shale belonging to the Negri Group.

The Headleys Limestone forms the basal unit of the Negri Group and is very resistant to weathering. In many places the formation occurs as cappings on the volcanics. Where the formation has been steeply tilted around the edges of the basins the limestone protrudes above the surrounding country in characteristic "walls". One well known occurrence - the Rosewood Wall can be traced from Rosewood homestead along the northern side of the Rosewood Basin. A similar feature has also been observed along the southern margin of the Hardman Basin (north of Mt Napier, Limbunya Sheet area). East and southeast of Mistake Creek homestead the Headleys Limestone occurs as sub-horizontal to gently dipping beds.

The Headleys Limestone disconformably overlies the Antrim Plateau Volcanics. In places the basalt immediately beneath the limestone is highly altered and ferruginised to depths up to 3 m.. A similar feature was observed by Dow et al. (1964) along the western margin of the Hardman Basin. Thus, although the contact between the two formations appears to be conformable, the presence of a ferruginised layer is indicative of a period of weathering and possible erosion before the deposition of the Headleys Limestone.

The volcanics of the eastern belt are overlain with a very slight angular unconformity by the Middle Cambrian Montejinni Limestone in the eastern portions of the Delamere, Victoria River Downs and Wave Hill Sheet areas (Randal and Brown, 1967). The Montejinni Limestone forms the basal unit of the Wiso Basin in this region. In places the volcanics are unconformably overlain by sediments assigned to the Lower Cretaceous Mullaman Beds (Randal and Brown, 1967). The sediments occur as isolated mesas capping the volcanics.

Agglomerate horizons have been observed within the formation at several localities. By far the most extensive exposures occur in the region bordering the eastern portion of the Hardman Basin. Two sub-horizontal agglomerate horizons separated by a moderately thick (24.4 m) basalt flow occur practically at the top of the basalt sequence in the region east and southeast of Mistake Creek homestead. The horizons form very prominent bands in the steep-sided hills bordering Stirling Creek. Only one comparatively thick agglomerate horizon is present around the southern margins of the Hardman Basin. The agglomerate horizon northwest of Mt Napier is approximately 39.6 m thick;

to the northeast, the stratigraphic hole B.M.R. Limbunya No. 1 penetrated 72 ft* (21.9 m) of this agglomerate layer. A much thinner layer (approximately 9 m thick) of agglomerate was observed in a similar stratigraphic position within the formation in several localities along the western margin of the Hardman Basin.

Around Spring Creek (Lissadell Sheet area) the hills west of the Duncan Highway are capped by agglomerate. Approximately 6.1 m of agglomerate (base not exposed) is exposed in the bank of the Ord River near Lincoln Yard (Lissadell Sheet area). There, the agglomerate is overlain by a thin, lenticular horizon of friable, red-brown sandstone varying in thickness from 0.6 m to 2.4 m. The sandstone is overlain by the Headleys Limestone forming the basal unit of the Rosewood Basin in that area. Small outcrops of agglomerate are also exposed approximately 50 km east of Inverway homestead (Limbunya Sheet area) and in the Crown Hill area (Victoria River Downs Sheet area).

The agglomerate horizons are composed of angular to rounded fragments of vesicular and massive basalt up to 15 cm in diameter set in a matrix consisting predominantly of fine-grained, aphanitic, volcanic detritus often with minor sandstone and sandy siltstone. The basaltic material has been very extensively altered and ferruginised.

Thin, irregular lenses of sandstone and siltstone are prevalent within the agglomerate units and are taken to indicate that the bulk of the pyroclastic material was deposited under subaqueous conditions. The poorly sorted nature of the intermixed sedimentary material precludes an aeolian origin. Some of the volcanic detritus appears to be reworked. However, it is obvious, from the relatively large size, and often angular outlines, of the basalt clasts, that the fragmental material has not suffered extensive reworking nor transportation over long distances.

To date dykes have only been found in the southwestern portion of the Limbunya Sheet area. A small dyke swarm occurs west of Kirkimbie homestead. A number of dykes were also observed northeast of the homestead. The dykes are mainly small, discontinuous, vertical bodies, generally only around 1.5 m in width. Because of their comparative resistance to weathering they protrude 0.3-9 m above the surface. One relatively large dyke northeast of Kirkimbie homestead is approximately 4.6 m width and projects 6-9 m above the surrounding country.

The dykes consist of angular fragments (up to 15 cm in diameter) of extensively altered, highly vesicular basalt in a very fine-grained, heavily altered basaltic matrix that ranges from massive to moderately vesicular. Quartz and calcite veining is common. These two minerals also occur filling vesicles. Hand specimens often closely resemble specimens from the agglomerate horizons occurring near the top of the formation. Slickensides are fairly common. The dominant trend is northwest.

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* All measurements taken by the writer and the operators of the drilling rigs were recorded in inches and feet. Standard sized drilling bits were also used - the sizes being given in inches. Consequently, all measurements pertaining to the stratigraphic holes are given in feet and inches as originally recorded. The metric conversions are given alongside in brackets. Elsewhere the metric system of measurement is used exclusively. Figures for converting to the British system of measurement are given in Appendix VII.

The lavas and interbedded sediments in the five sheet areas are mainly flat-lying or very gently dipping and have been little disturbed since their formation. Randal and Brown (1967) drew up structure contours showing the regional dip of the eastern belt of volcanics to be $\frac{1}{2}^{o}$ or less (in an easterly direction). Regional dips in the western belt are also very slight (less than 5^{o} in a westerly or northwesterly direction) within the five sheet areas. The volcanics dip at much higher angles (20-30^{o}E) along the western margin of the Hardman Basin in the Dixon Range Sheet area.

DETAILS OF DRILLING

To investigate the Antrim Plateau Volcanics at depth and to obtain fresh specimens of rock a programme of stratigraphic drilling was planned. The contract called for the drilling of a minimum of six vertical holes and a maximum of eight, with an aggregate depth of not less than 3,500 ft (1067 m). The average total depth of the holes was to be 500 ft (152.4 m), and the final depth of any one hole was not to exceed 1000 ft (304.8 m).

A truck-mounted Ingersoll-Rand Trucm 3 rig (figure 2) was used for the 1969 drilling and an Ingersoll-Rand Trucm 4 Drillmaster rig for the 1970 drilling. Both rigs were owned and operated by Gorey and Cole, Drillers Ltd., Alice Springs.

Nine sites were drilled, the aggregate depth totalling 5800 ft (1767.8 m). The bulk of the drilling was carried out using down-the-hole-air-hammer and rotary percussion techniques. Consequently, most of the material collected is in the form of small cuttings averaging 0.5-1 cm in length. Because of excessive influx of water, the driller had to revert to the use of tricone roller bits in some of the deeper holes; these bits caused a marked decrease in the size of the individual cuttings. The first 3-25 ft (1-8 m) of each drill hole was cased to prevent caving. All of the holes were drilled using air to circulate the cuttings. Deviation surveys were not carried out as they were judged to be unnecessary. A brief account of drilling details for each hole is given in Appendix III.

For economic reasons coring had to be kept to a minimum and was restricted to obtaining specimens from the massive parts of flows. A total of seventeen cores were taken, ranging in length from 18 in (0.5 m) to 15 ft (4.6 m). The diameter of core recovered from B.M.R. Waterloo No. 1 is 2 in (5.1 cm) from the other holes $2\frac{3}{4}$ in (7 cm). Core recoveries were excellent. Recovery rates of 100% were obtained for fourteen of the intervals cored and greater than 90% for the remainder, except for Core No. 5 from B.M.R. Waterloo No. 1 (nil recovery). The intervals cored in each hole and the respective recovery rates are given in Appendix IV.

Cuttings were collected normally at 5 ft (1.5 m) intervals. Representative samples were collected in a plastic sieve placed below the top of the casing. Dry cuttings were bagged without further treatment at the bore site. Wet cuttings were washed and bagged. The bags

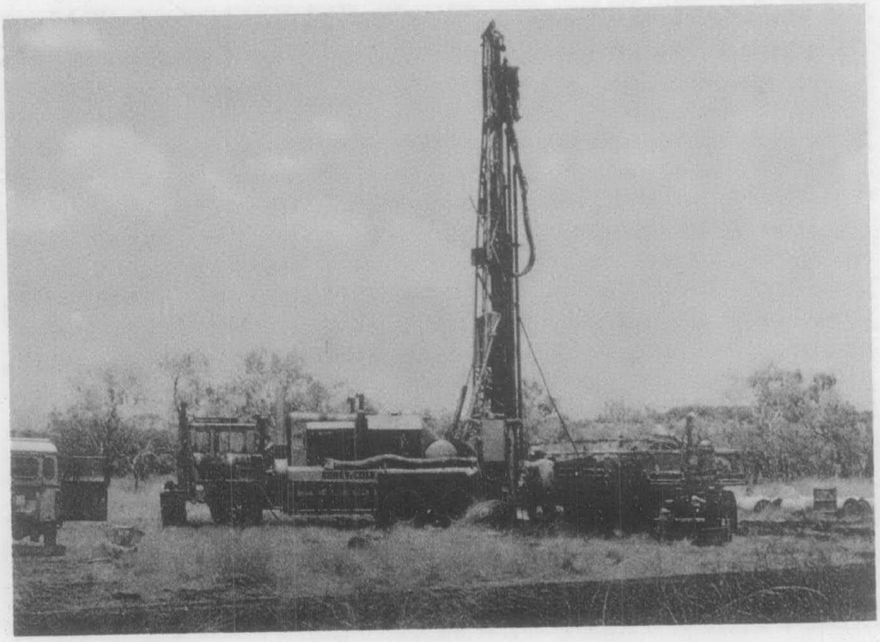


Fig. 2. Truck-mounted Ingersoll-Rand Trucm 3 drilling rig (Neg. No. GA/5068).

were left open for as long as possible and most samples were completely dry by the time they were packed. The cuttings and cores were examined and described at the bore site and again in the laboratory. The descriptions are given in Appendices V and VI and the lithological logs in figure 3. Thin sections have been cut at fairly closely spaced intervals. An average of three chips from each cuttings interval were thin sectioned and examined as a check for contamination.

Resistivity, gamma radiation and self potential logs were run for each hole using a Widco 1000 Portalogger operated by B.M.R. geophysicists.

Location of Drilling Sites

Most of the holes were sited on, or adjacent to, limestone overlying the volcanics and are situated in an arc extending from Rosewood through Mistake Creek and Inverway in the west and Wave Hill and Top Springs to Delamere in the east. Their positions are shown on figure 1 and the five map sheets and are also given in Appendix II. Brief details of the surface geology around each stratigraphic hole and general bore-hole data are also given in Appendix II. The thickness of the volcanic succession was confirmed to be more than 500 ft (152.4 m) in every hole except B.M.R. Delamere No. 1 and possibly B.M.R. Wave Hill No. 1. The contractor agreed to deepen the holes as required.

Contamination of Samples

Possible contamination of samples by cuttings originating from higher up the hole is a problem in this type of drilling and particular attention was paid to this possibility when examining the cuttings. As a further check thin sections of samples from intervals were made up from a minimum of three chips. Each thin section was examined for variations in grainsize, texture and modal and mineralogical composition between individual chips. These criteria are, of course, inadequate for the determination of possible contamination in a stratigraphic sequence of several flows that are alike in microscopic make-up. Fortunately, however, the majority of flows intersected in each of the stratigraphic holes possess microscopic characteristics that differ at least slightly, and often markedly, from the other flows penetrated in the same hole.

In most cases, where it has been detected, only slight contamination of the samples has occurred. The most common contaminant is relatively soft, highly vesicular, decomposed basalt from the upper portions of flows. Heavily jointed sections occurring mainly in the basal portions of flows are another source of contamination - as are water-bearing zones in the rocks.

Time Lag

Corrections were not made for time lag - i.e., the time taken for the cuttings to travel from the drilling zone at the bottom of the stratigraphic hole to the surface. The time lag would progressively increase with depth, but is influenced by other factors such as water in the hole which could slow the ascent of the cuttings to the surface.

The rate of penetration also influences the time lag. It was observed that the drilling rate increased significantly whenever the soft, highly vesicular portions of flows were encountered. Depending upon depth, the drilling rods would descent a distance of up to 1 metre before the vesicular material reached the surface. The overall effect is that cuttings collected from say the 500 (152.4 m) - 505 ft (153.9 m) interval as measured on the drilling rods have actually come from slightly higher levels in the hole. However, as a continuous set of samples was.collected from top to bottom of each hole, the intra- and inter-flow variations can still be recorded. It is thought that the maximum error in flow thicknesses introduced by time lag is in the order of 1.5 m and that in the majority of cases the error is considerably less.

GEOLOGY

Separation of the Flows

The separation of the cuttings and core samples into individual flows is based on evidence derived from three principal sources: viz. -

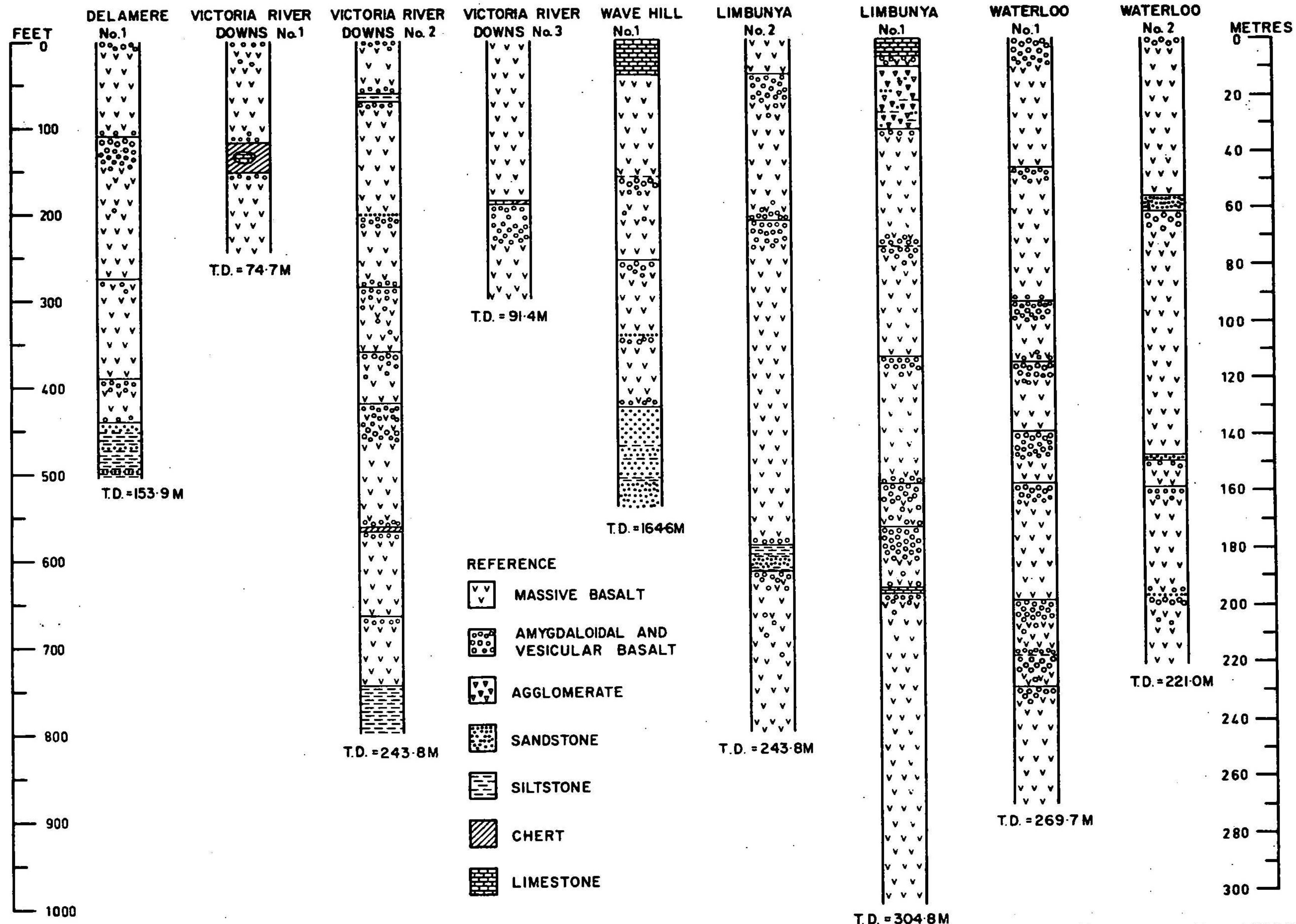
a) hand specimen examination of the cores and cuttings.
b) thin section examination of the cores and cuttings.
c) geophysical data.

Normally each flow has a highly vesicular upper portion accounting for up to 30% of the flow and a slightly to moderately vesicular basal portion generally accounting for less than 5% of the flow. The border zones grade downwards and upwards respectively into a central zone composed of massive basalt. Even in the thickest flows, occasional amygdales may be found anywhere in the interior. Several flows are slightly to moderately amygdaloidal, on at least a microscopic scale, throughout.

The upper portion of a flow may be only slightly to moderately vesicular. On the other hand comparatively thick flows consisting predominantly of highly vesicular basalt were recorded; approximately 37 m of soft, highly vesicular, decomposed basalt with only very minor massive material (as thin bands) was penetrated in B.M.R. Limbunya No. 1. It is highly likely that a number of relatively thin, highly vesicular flows are represented in this interval. However, they could not be delineated with any confidence and the sequence has been tentatively divided into two moderately thick flows.

Almost invariably the vesicular portions of flows are more extensively altered than the massive portions. Most flows are characterised by moderately to heavily decomposed upper contacts and, to a lesser extent, basal contacts with fresh to moderately altered massive centres. Typically, the thicker the flow the fresher the basalt from the central and lower parts. Locally, former glass and ferromagnesian minerals in basalt from the uppermost parts of flows are very extensively chloritised or replaced by pumpellyite. Chlorite and pumpellyite also occur filling amygdales. This type of alteration imparts a pale green to greyish green colour to the rocks.

Fig. 3 LITHOLOGICAL LOGS OF STRATIGRAPHIC HOLES DRILLED IN THE ANTRIM PLATEAU VOLCANICS, VICTORIA RIVER DISTRICT, N. T.



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Many thin sections show distinctive detail characteristics not apparent in hand specimen. Normally chips from the central portion to within 3 m or so of the base of a flow are characterised by relatively coarse grainsize, the grainsize becoming noticeably finer towards the top and the base of the flow. Devitrified glass decreases in abundance from the chilled, upper and basal, vesicular portions towards the massive, highly crystalline interior. Devitrified glass may account for an estimated 80-90% of the total volume of basalt from a chilled contact, whereas in the centre of a flow, intersertal "glass" generally only accounts for 5-10% of the rock.

The massive central-basal zone constitutes the least altered part of a flow. A series of thin sections from individual flows typically exhibit a gradual increase in the proportions of late-stage, secondary minerals towards the top and base of each flow: sericite replacing feldspar and chlorite and pumpellyite filling amygdales and replacing clinopyroxene and former glass.

The positions of flow junctions have been fairly accurately determined in most cases. If a succession of petrographically similar flows had been extruded in rapid succession, the lack of clearly defined interflow contacts may make recognition of individual flows difficult. West (1958) also observed that layers of vesicular basalt may be distributed in an haphazard manner in some of the Deccan Trap lavas and similar observations have been made by the writer in surface exposures of the Antrim Plateau Volcanics. However, in the Antrim Plateau Volcanics, irregular distribution of vesicular zones in individual flows occurs very rarely.

Even where flow junctions are identifiable, their contacts cannot always be accurately fixed. Two factors contribute to this difficulty of determining the exact positions of flow junctions: the common occurrence of the decomposed, vesicular base of one flow immediately superimposed on the decomposed, vesicular top of the next lower. Sometimes there are different weathering characteristics between the two successive flows that make their separation relatively easy. The second factor is the inaccuracy of determining the exact depth from which the cuttings were collected.

To conclude, by utilising all available evidence there proved to be few cases where serious doubt arose regarding the approximate limits of a flow. From the writer's experience individual lava flows can be more easily and accurately delineated from examination of cores and cuttings than by examination of surface exposures in the field.

Thickness of Flows

The approximate thicknesses of individual flows and sedimentary interbeds penetrated in each of the nine stratigraphic holes are listed im Table 1. Where the junction of a flow is indefinite it is indicated in the table. A total of 45 flows and one band of agglomerate were intersected. The thickness of individual flows varies, from a minimum of 4.0 m (flow No. 1, B.M.R. Limbunya No. 1) to a maximum of 114.3 m (flow No. 3, B.M.R. Limbunya No. 2). The average flow thickness, excluding those flows whose total thicknesses are not known (i.e., flows from the tops and bottoms of holes), is 35.6 m. Fermor (1925) identified 27 complete flows with an average thickness of 12.2 m in cores of the Deccan Traps from Bhusawal, India, in which individual flows range from 1.5 to 29.6 m in thickness. Waters (1961) determined the average thickness of flows in the Columbia River Basalt as 23.5 m.

TABLE 1. APPROXIMATE THICKNESSES OF LAVA FLOWS AND SEDIMENTARY INTERBEDS PENETRATED IN THE STRATIGRAPHIC HOLES.

B.M.R. Delamere No. 1

Interval (feet)	Thickness (metres)	Unit
0-110 (0-33.5 m)	33.5 + (1.5)*	Flow No. 1
110-275 (33.5 - 83.8 m)	50.3	" " 2
275-390 (83.8 - 118.9 m)	35.1	" " 3
390-440 (118.9 - 134.1 m)	15.2	" " 4
440-505 (134.1 - 153.9 m)	19.8+	pale green, dark brown and purple siltstone (Stubb Formation)

Average thickness of flows: 33.9 metres

B.M.R. Victoria River Downs No. 1

Interval (feet)	Thickness (metres)	Unit
0-118 (0-36.0 m)	36.0+ (3.0)*	Flow No. 1
118-152 (36.0 - 46.3 m)	10.3	chert; minor limestone and sandstone
152-245 (46.3 - 74.7 m)	28.44	Flow No. 2

B.M.R. Victoria River Downs No. 2

Interval (feet)	Thickness (metres)	Unit
0-62 (0 - 18.9 m)	18.9+ (3.0)*	Flow No. 1
62-70 (18.9 - 21.3 m)	2.4	coarse-grained, quartz siltstone; minor limestone
70-200 (21.3 - 61.0 m)	39.7	Flow No. 2
200-285 (61.0 - 86.9 m)	25.9	" " 3
285-360 (86.9 - 109.7 m)	22.8	" " 4
360-420 (109.7 - 128.0 m)	18.3	" " 5

B.M.R. Victoria River Downs No. 2 (cont.)

Interval (feet)	Thickness (metres)	Unit
420-536 (128.0 - 171.6 m)	43.6	Flow No. 6
563-566 (171.6 - 172.5 m)	0.9	red and white chert; impure chert (replacement) containing detrital quartz and feldspar grains, muscovite flakes and clay minerals
566-665 (172.5 - 202.7 m)	30.2	Flow No. 7
665-745 (202.7 - 227.1 m)	24.4	" " 8
745-800 (227.1 - 243.8 m)	16.7+	siltstone; minor sandstone (Stubb Formation)

Average thickness of flows: 28.4 metres

B.M.R. Victoria River Downs No. 3

Interval (feet)	Thickness (metres)	Unit
0-188 (0 - 57.3 m)	57.3+	Flow No. 1
188-190 (57.3 - 57.9 m)	0.6	dark grey and brown limestone, partly replaced by chert
190-300 (57.9 - 91.4 m)	33.5+	Flow No. 2

B.M.R. Wave Hill No. 1

Interval (feet)	Thickness (metres)	Unit
0-40 (0 - 12.2 m)	12.2+	Montejinni Limestone
40-158 (12.2 - 48.2 m)	36.0	Flow No. 1
158-159 (48.2 - 48.5 m)	0.3	sandy siltstone, partially recrystallised
159-255 (48.5 - 77.7 m)	29.2	Flow No. 2
255-340 (77.7 - 103.63 m)	26.9	" " 3
340-340.2 (103.63 - 103.68 m)	0.05	quartz sandstone, partially recrystallised
340.2-425 (103.68 - 129.5 m)	25.9	Flow No. 4
425-545 (129.5 - 166.1 m)	36.6+	silty sandstone; micaceous sandy siltstone; minor quartz sandstone

Average thickness of flows: 29.3 metres

B.M.R. Limbunya No. 1

Interval (feet)	Thickness (metres)	Unit
0-20 (0 - 6.1 m)	6.1+	limestone; minor chert (Headleys Limestone)
20-33 (6.1 - 10.1 m***)	4.0	Flow No. 1
33-105 (10.1 - 32.0 m***)	21.9	agglomerate; minor intercalated sandstone
105-240 (32.0 - 73.2 m)	41.2	Flow No. 2
240-242 (73.2 - 73.8 m)	0.6	pale brown, medium-grained siltstone-partially recrystallised
242-368 (73.8 - 112.2 m)	38.4	Flow No. 3
368-515 (112.2 - 157.0 m)	44.8	" " 4
515-565 (157.0 - 172.2 m)	15.2	" " 5
565-637 (172.2.- 194.2 m)	22.0	" " 6
637-641 (194.2 - 195.4 m)	1.2	white and pink limestone - partly replaced by chert
641-1000 (195.4 - 304.8 m)	109.4+	Flow No. 7

Average thickness of flows (excluding flow No. 7): 27.6 metres

B.M.R. Limbunya No. 1

Interval (feet)	Thickness (metres)	Unit
0-40 (0 - 12.2 m**)	12.2	Flow No. 1
40-210 (12.2 - 64.0 m)	51.8	" " 2
210-585 (64.0 - 178.3 m)	114.3	" " 3
585-625 (178.3 - 190.3 m)	12.2	white and palg brown calcareous siltstone; minor medium-grained, quartz sandstone
625-800 (190.5 - 243.8 m)	53.3+	Flow No. 4

Average thickness of flows (excluding flow No. 4):
59.4 metres

B.M.R. Waterloo No. 1

Interval (feet)	Thickness (metres)	Unit
0-150 (0 - 45.7 m)	45.7+	Flow No. 1
150-305 (45.7 - 93.0 m)	47.3	" " 2
305-375 (93.0 - 114.3 m)	21.3	" ". 3
375-455 (114.3 - 138.7 m)	24.4	" " 4
455-515 (138.7 - 157.0 m)	18.3	" " 5
515-650 (157.0 - 198.1 m)	41.1	" " 6
650-714 (198.1 - 217.6 m)	19.5	" " 7

B.M.R. Waterloo No. 1 (cont.)

Interval (feet)	Thickness (metres)	Unit
714-715 (217.6 - 217.9 m)	0.3	white to creamy, fine-grained, friable, tuffaceous(?), siltstone - chalcedony and mica common; minor calcite and pumpellyite
715-750 (217.9 - 228.6 m)	10.7	Flow No. 8
750-885 (228.6 - 269.7 m)	41.1+	Flow No. 9

Average thickness of flows (excluding flows Nos. 1 and 9): 26.1 metres

B.M.R. Waterloo No. 2

Interval (feet)	Thickness (metres)	Unit
0-184 (0 - 56.1 m)	56.1+	Flow No. 1
184-202 (56.1 - 61.6 m)	5.5	cream and red-brown, friable, quartz sandstone
202-484 (61.6 - 147.5 m)	85.9	Flow No. 2
484-489 (147.5 - 149.0 m)	1.5	pale grey to brown, medium-grained sandstone containing basalt clasts
489-522 (149.0 - 159.1 m)	10.1	Flow No. 3
522-644 (159.1 -196.3 m)	37.2	" " 4
644-645 (196.3 - 196.6 m)	0.3	pale brown, medium-grained, quartz sandstone
645-725 (196.6 - 221.0 m)	24.4	Flow No. 5

Average thickness of flows (excluding flow No's. 1 and 5): 44.4 metres

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* approximate thickness of surface outcrop above level of drill hole

** not certain of presence of flow junction

*** position of boundary between units very approximate - could not be accurately delineated

Table 1 illustrates the comparatively great thicknesses of many of the flows. The lowermost flow penetrated in B.M.R. Limbunya No. 1, for example, appears to be at least 115 m thick (base of flow not reached). Detailed examination of thin sections from closely spaced intervals in the flow did not reveal any features such as decrease in grainsize, increase in degree of alteration, presence of vesicular zones etc. that would justify dividing the flow into a number of smaller units. Instead the central portions of the flow show coarse grainsize comparable to that observed in some dolerites and consistent with slow cooling in a thick lava pile. A decrease in grainsize was observed only in the upper portions of the flow. The variations in modal mineralogy (e.g., concentration of quartz in the central portions of the flow, accompanied by the appearance of accessory amounts of primary amphibole and mica) are compatible with slow cooling, possibly accompanied by some differentiation, in a thick lava flow.

The volcanics are either flat-lying or very gently dipping with regional dips of less than 5° in areas around the drill sites. Consequently no corrections have been applied to depths of holes, or thicknesses of flows and all readings remain the same as recorded on the drill sites.

Correlation of Flows

Correlation of individual flows from one bore hole to another has not been attempted. From available information, however, the writer tentatively correlates flow No. 7 (109.4 m in thickness - base of flow not reached) from B.M.R. Limbunya No. 1 and flow No. 3 (114.3 m in thickness) from B.M.R. Limbunya No. 2. These two thick flows bear a close resemblance to each other, both on a macro- and a micro-scopic scale. Both are characterised by the presence of large pigeonite phenocrysts, relatively abundant intersertal quartzo-feldspathic residuum and traces of primary amphibole and mica in their central and lower parts.

Even where field, laboratory and stratigraphic data are in agreement correlation of lava flows presents a problem, especially where exposures are poor or where the flows have been intersected in drill holes but not mapped at the surface. The flows being correlated may represent either parts of a single lava sheet or separate tongues of lava that issued from either the same or different effusive centres.

PETROGRAPHY

Hand Specimen

Massive basalts from the Antrim Plateau Volcanics are fine to medium-grained and dark red-brown, reddish to purplish grey or dark to light grey. Colours tend to be darker in rocks with high "glass" contents and lighter in the more highly crystalline types. Large phenocrysts are rare but a few flows contain phenocrysts of plagioclase and clinopyroxene clearly visible to the naked eye. Weathering colours are various shades of reddish brown and, less commonly, pale grey.

The basalts are often weathered. The altered rocks are stained a dark red by secondary hematite(?). They also often contain irregular patches and streaks rich in chlorite. Secondary ferruginisation as indicated by the occurrence of irregular red-brown patches and lenticular streaks rich in hematite(?) has affected portions of practically every flow.

The massive basalt from the central and lower portions of the flows grades upwards into fine-grained, reddish brown or purplish grey, oxidised flow tops. The flow tops are normally vesicular and are usually comparatively soft and highly decomposed. Vesicles are often filled with a variety of minerals, the most common being chlorite, quartz, agate, calcite and prehnite.

Texture

Microtextures vary with "glass" content and range from hyalopilitic through intersertal to intergranular. Intersertal textures are the most common. The groundmass in basalts from the massive portions of the flows is typically composed of plagioclase-clinopyroxene-opaque oxide-devitrified glass or quartz-alkali feldspar fabrics which can be divided into four main textural types, gradational into one another.

The four textural types are as follows:-

1. Intersertal Type. The small plagioclase, pyroxene and opaque oxide grains which form the bulk of the rock are not noticeably moulded onto one another. The pyroxene and opaque oxide occur in interstices between feldspar laths. The devitrified glass is red-brown in colour, often densely charged with tiny granules and rods of opaque oxide, and may constitute up to an estimated 30-40% of the total volume. Irregular patches (up to 1 mm in diameter) of devitrified glass commonly occur filling voids between feldspar laths.

2. Intergranular Type. The plagioclase, pyroxene and opaque oxide grains are more densely packed than in (1), the pyroxene and opaque minerals still occurring mainly in interstices between feldspar grains. Devitrified glass usually accounts for less than an estimated 10% by volume. It is pale red-brown and occurs interstitially. In the thicker flows, the late-stage, intersertal material from the central and lower portions is colourless or practically so and is usually composed of a crystalline quartzo-feldspathic residuum. In the upper and, to a lesser extent, basal portions of the flows the proportion of coloured devitrified glass increases and the groundmass fabric becomes intersertal.

3. Porphyritic Type. This type is fairly uncommon and is characterised by a comparatively coarse-grained groundmass with subhedral prisms of clinopyroxene up to 0.5 mm in length. Red-brown devitrified glass generally accounts for less than an estimated 15% of the total volume.

4. <u>Subophitic and Ophitic Types</u>. Plagioclase laths in this type are often partially or entirely enclosed by anhedral pyroxene grains which are seen in thin section as prisms 0.5-1.5 mm in length. The late-stage interstitial residuum consists mainly of fine quartz-alkali feldspar intergrowths and is generally scarce (less than 10% by volume). This type is also fairly uncommon and is generally restricted to the comparatively coarse-grained central and lower portions of the thicker flows.

Each of these textural types commonly bear small amounts of plagioclase (1-4 mm) and more rarely clinopyroxene (0.5-2 mm) phenocrysts. Smaller microphenocrysts of opaque oxide (0.5 mm across) occur in some flows.

The chilled upper and basal portions of flows are characterised by an abundance (up to an estimated 80-90% of the total volume) of dark red-brown to almost black, semi-opaque devitrified glass often containing slender plagioclase microlites (0.05-0.2 mm x 0.01 mm) and very scarce pyroxene granules. Rarely, the plagioclase microlites display a well developed "birdsfoot" texture - sheaves of long, slender (0.2 mm x 0.1 mm) radiating laths set in a base of devitrified glass.

Chips containing only very scarce, euhedral laths of feldspar (0.5 mm x 0.15 mm) and rare rectangular prisms of clinopyroxene (0.2 mm x 0.1 mm) set in an originally glassy base have been observed but are uncommon. These chips presumably originated from the rapidly chilled surfaces of the flows.

Grainsize normally varies inversely with the content of devitrified glass. In most massive rocks the groundmass laths and granules range from 0.1 mm to 0.3 mm in length. Groundmass grains are invariably less than 1 mm in length.

The uncommon plagioclase and rare clinopyroxene phenocrysts are sometimes flow aligned, whereas the groundmass grains generally show no alignment whatever. The upper, fine-grained, devitrified glass-rich portion of flow No. 1 from B.M.R. Waterloo No. 2 [0-10 ft (0-3 m) interval] is characterised by a poorly developed trachytic texture, and is one of the very few examples in which flow banding was observed. Apparently most of the crystallisation took place in the lavas after the fluid extrusives had come to rest in large lava lakes. Thus the flows were above or only slightly below their liquidus temperatures during movement, a conclusion borne out by the scarcity of phenocrysts. The general scarcity of phenocrysts could also indicate that the parent magma had not undergone a long and complex crystallisation history prior to extrusion.

<u>Classification</u>

The basalts are essentially tholeiitic in character, the principal modal minerals being plagioclase, clinopyroxene and opaque oxide. Accessory constituents include devitrified glass, quartz, amphibole, mica, alkali feldspar and apatite. Chlorite and "iddingsite" replacements after olivine occur in some flows. There is a gradation in rock types from relatively undersaturated olivine tholeiites (modal quarz absent or very rare) through tholeiites (olivine absent; quartz absent or very scarce), quartz tholeiites (quartz 5%) to quartz-rich tholeiites (5% quartz 15%). In most cases, however, instead of having a series of flows each representing a specific rock type, the whole, or part, of the variation spectrum occurs within individual flows. The variations in modal mineralogy suggest that some differentiation occurred within many of the individual lava flows as they consolidated after extrusion. Schmincke (1967), however, found that the vertical and lateral variations in modal compositions in the upper flows of the Yakima Basalt (Columbia River Plateau) could be explained solely by difference in degrees of crystallinity. Whatever vertical or lateral differentiation that may have occurred was effectively masked by the differing degrees of crystallinity. A similar explanation could possibly account for all, or at least some, of the modal variations observed in individual flows from the Antrim Plateau Volcanics. Until detailed mineralogical and chemical studies are carried out on these flows it will not be possible to define the role played by fractionation processes during crystallisation of the lava flows.

MINERALOGY

<u>Plagioclase</u> is the most abundant mineral in nearly every basalt examined and occurs in two distinct forms - as small elongate groundmass laths up to 0.5 mm in length and as larger phenocrysts up to 4 mm in length. The lath-shaped groundmass grains are the more abundant of the two varieties and may account for up to an estimated 45-50% of the total volume of a sample. In the highly crystalline rocks the feldspar laths occur as small, euhedral, tabular grains with an average grainsize of 0.1-0.2 mm x 0.03 mm and exhibit moderate zoning. Smaller microlites occur in the fine-grained basalts from the chilled, upper and basal portions of flows, while coarser grainsizes occur in the centres of some flows. The laths are invariably twinned. Albite twinning predominants, although carlsbad twinning is quite common.

In addition, the rocks usually contain up to 5% (estimated) euhedral to subhedral plagioclase phenocrysts of coarse grainsize (1.0-4.0 mm x 0.05-1.0 mm). They appear mainly as isolated lath-like grains, rarely as glomeroporphyritic groups. The phenocrysts are zoned and twinned. Rare cruciform intergrowths resulting from the interpenetration of two individual laths occur in section 70770594 from B.M.R. Waterloo No. 1 [340-345 ft (103.6-105.2 m) interval].

Sericitisation of the plagioclase grains is common and sometimes very extensive, the phenocrysts being particularly susceptible to replacement. Many of the phenocrysts consist of a narrow outer rim of fresh, unaltered feldspar enclosing a heavily altered core. In some specimens the plagioclase is replaced by chlorite which is generally associated with sericite (but not always) - very rarely by calcite and epidote. Quartz, opaque oxide and devitrified glass occur as apparent replacements of large plagioclase phenocrysts from the 300-305 ft (91.4-93.0 m) interval in B.M.R. Delamere No. 1.

Clinopyroxene is usually slightly less abundant than plagioclase in the basalts and generally accounts for around 35% of the total volume in the highly crystalline basalts. However, in the finer grained variants there is a marked decrease in the porportion of clinopyroxene granules relative to feldspar laths and in devitrified glass - rich types clinopyroxene may be difficult to distinguish at all. In their relationship to the feldspars the clinopyroxenes are commonly intersertal or intergranular, occasionally subophitic and ophitic.

The clinopyroxenes vary from idiomorphic in the more "glassy" basalts to sub-idiomorphic and granular in the more crystalline varieties. Groundmass grains often occur as clusters of small granules. Average length in the majority of flows is between 0.05 mm and 0.1 mm. A small minority of basalt flows with medium to coarse grainsize contain comparatively large subhedral to anhedral prisms of clinopyroxene (0.3-0.5 mm). Subhedral to anhedral phenocrysts ranging in length from 0.5 mm to 2.0 mm with well developed ophitic and subophitic textures are a striking feature of a few flows. Simple twinning is common in the larger grains; multiple twinning has only been observed in two small phenocrysts, both occurring in the same section.

Augite and/or sub-calcic augite ($2V > 30^{o}$) is the most common pyroxene. However, pigeonite ($2V = 0-15^{o}$)has been tentatively identified from a number of flows and appears to be common constituent of the volcanic succession as a whole. It is generally associated with a more calcic clinopyroxene ($2V > 15^{o}$) but as yet no attempt has been made to accurately determine the relative proportions of each pyroxene present in individual flows. The pigeonite occurs most commonly (and apparently abundantly) in the more quartz-rich tholeiites as small groundmass grains. Numerous pseudo-uniaxial figures indicative of pigeonite have also been obtained on large clinopyroxene phenocrysts in sections of coarse-grained basalt from flow No. 7, B.M.R. Limbunya No. 1 and flow No. 3, B.M.R. Limbunya No. 2. According to Deer, Howie and Zussman (1963) pigeonite is not particularly common as phenocrysts in volcanic rocks.

Most clinopyroxene phenocrysts are characterised by finely striated appearances due to the presence of extremely fine exsolution lamellae. Characteristically, exsolution has not affected entire phenocrysts - rather, small patches of massive, non-striated material occur in marginal areas and as small "inclusions" within striated portions. Herringbone structure due to a combination of simple twinning and exsolution is common.

Phenocryst of pigeonite and augite presumably crystallised under deep-seated conditions. With slow cooling in thick lava flows the pigeonite phenocrysts exsolved a Ca-rich pyroxene as very fine sub-microscopic lamellae parallel to (001) and the augite phenocrysts exsolved pigeonite(?), also as very fine lamellae. There is no indication of inversion of the pigeonite to orthopyroxene.

Occasionally, the pyroxene phenocrysts contain small euhedral to anhedral inclusions of another clinopyroxene. Pyroxene grains are sometimes rimmed by clinopyroxene of a different orientation. The junctions between the different pyroxene grains are sharp. Most grains display a certain amount of compositional zoning as indicated by variations in birefringence colours within individual grains.

Fresh, unaltered clinopyroxene is colourless. Minor replacement by green or yellow-green chlorite is common. More rarely clinopyroxene has been replaced by blue-green amphibole. Replacement occurred preferentially along exsolution and cleavage planes. Heavily altered grains are generally rimmed by narrow, irregular borders of opaque oxide while stringers and granules of similar material occur along cleavage and exsolution planes and cracks in the grains. Red-brown "iron" (secondary hematite?) staining is common. Typically, however, clinopyroxene is the least altered mineral present in most of the basalts and appears to be fairly resistant to alteration.

In the majority of the highly crystalline, massive basalts opaque minerals occur in accessory amounts (less than 5% by volume) as small, subhedral to anhedral, interstitial, equidimensional grains (0.01-0.1 mm) and scarce, elongate rods (0.1 mm x 0.01 mm) evenly disseminated through the rocks. In some flows euhedral microphenocrysts (0.4 mm x 0.2 mm) of opaque oxide occur, generally containing small inclusions of plagioclase and rare clinopyroxene. Some of the finer grained specimens from towards the tops of flows are characterized by an abundance (up to an estimated 30% by volume) of opaque oxide as numerous small granules. However, in the chilled edges of flows often only plagioclase and clinopyroxene are evident and opaque oxide is either obscured by, or has not crystallised from, the dense, dark red-brown to brownish black devitrified glass.

Opaque oxide in chips from the uppermost portions of flow No. 1 from B.M.R. Waterloo No. 2 displays a marked change in habit and a notable increase in abundance compared with opaque oxide occurring in specimens from deeper in the flow. The opaque minerals occur as numerous tiny granules in the fine-grained chips from the 5-30 ft (7.6-9.1 m) interval and account for more than an estimated 20% by volume of the rock, whereas chips from the coarser grained, more highly crystalline 45-50 ft (13.7-15.2 m) interval, for example, contain only very minor opaque oxide (less than an estimated 5% by volume) as scarce microphenocrysts.

The frequently observed tendency for opaque oxide to occur as equidimensional grains with square cross-sections is taken by many to be indicative of magnetite or titanomagnetite, while its occurrence as elongate rods is regarded as being a characteristic of ilmenite. If such is the case, then the bulk of the opaque oxide present in the Antrim Plateau lavas consists of magnetite or titanomagnetite with only very minor ilmenite. The magnetic properties of the opaques have not been determined. The opaque oxide grains are commonly fringed with irregular streaks and patches of red-brown to orange-red, translucent, secondary hematite. Secondary iron oxide also occurs as a stain surrounding plagioclase and clinopyroxene grains. The dark red-brown colour of massive basalts in the central and lower parts of some flows indicates that the primary opaque oxide has been altered, at least partially, to hematite.

Irregular streaks and patches of dark brownish red, heavily ferruginised basalt are commonly observed in hand specimens of both massive and vesicular basalt. The vesicular upper and basal portions of flows were evidently more susceptible to this type of alteration than the massive central and lower portions. In the latter, the ferruginised areas tend to be concentrated in zones adjacent to joint planes and fractures in the rocks.

In thin section the ferruginised basalt consists of networks of irregular stringers of opaque oxide emanating from anhedral blebs up to 2 mm in diameter of black, opaque material, and penetrating plagioclase laths and pyroxene grains along cleavage planes and fratures. Clinopyroxene is very scarce in the ferruginised patches, having been extensively replaced by secondary hematite. Much of the black opaque material has a dark red, semi-opaque appearance under intense, transmitted light and is thought to consist largely of hematite. Extensive red-brown to orange-red, translucent, "iron" staining occurs within, and in areas adjacent to, the heavily ferruginised portions.

Devitrified <u>glass</u> occurs in practically every section and ranges from scarce (less than 5%) to very abundant (greater than 80%). It varies from dark red-brown, ore-studded, or practically opaque material in the more quickly chilled basalts from the upper and basal margins of flows to red-brown, pale red-brown, pale pink or practically colourless, crypto-crystalline, feebly birefringent material in highly crystalline rocks from the centres. The red-brown colour is presumably due to the alteration of iron oxide crystallites and "dust" contained in the glass to hematite and limonite.

Devitrified glass is generally most abundant in the chilled upper and basal surfaces of the flows. It is also most deeply coloured in these parts and often contains feldspar microlites and numerous tiny granules and elongate rods of opaque oxide. In the coarser grained, highly crystalline central and lower parts of the flows the percentage of modal "glass" decreases, and the "glass" is paler coloured. With increasing degrees of crystallisation the iron content of the former glass decreased. Prolonged crystallisation and cooling of the basalt allowed time for the opaque crystallites and "dust" in the glass to aggregate into larger microlites and granules, thereby clearing the glass.

In some lavas the uppermost 50 cm or so form slightly to moderately vesicular or amygdaloidal zones comprising 80-90% dark red-brown to black, semi-opaque to opaque, devitrified glass. The "glass" is often characterised by a reddish translucency under strong illumination and contains small quantities of crystalline material - relatively large euhedral laths (0.1 mm) of plagioclase and crystals of clinopyroxene (0.08 mm). These chilled margins grade into zones of more highly amygdaloidal basalt containing microlites and larger crystals of feldspar and clinopyroxene.

The devitrified glass occurs as interstitial patches up to 1 mm in diameter (but generally less than 0.5 mm) in the massive basalts and commonly contains tiny feldspar microlites, granules and rods of opaque oxide and needles of apatite.

In many of the coarser grained rocks from the central and lower portions of thick flows the bulk of the interstitial, late-stage residuum has crystallised to fine-grained intergrowths of quartz and alkali-feldspar. However, holocrystalline rocks are very rare for in most cases a careful search will lead to the discovery of at least traces of interstitial, devitrified glass. Commonly, even the coarsest grained of rocks show a comparative abundance (5-20%) of devitrified glass.

Only one fresh grain of olivine has been detected in this series of thin sections. However, in several of the sections "iddingsite"* and fibrous aggregates of chlorite are believed to be replacements of olivine.

The original olivine occurred as euhedral-subhedral grains (0.1 mm x 0.05 mm) and small microphenocrysts (0.4 mm x 0.3 mm), and was present in only a small proportion of the flows examined. Even when present, there are usually only a few grains (completely replaced) in any one section. Flow No. 2 from B.M.R. Waterloo No. 2 is a notable exception as chlorite replacements of olivine account for 20% of the total volume in the basal portion of the flow. Such a concentration could be due, at least in part, to the gravitational settling of early-formed olivine crystals during crystallisation of the magma.

In most cases the olivine was confined to the more quickly chilled, upper and basal portions of flows. Very rarely, grains are distributed throughout the central portions. Rarely clinopyroxene phenocrysts contain small rounded inclusions of olivine(?) completely replaced by chlorite.

Pale yellow or yellow-green chlorite is the most common replacement of olivine. Dark red, markedly pleochroic (to pale reddish yellow), "iddingsite" pseudomorphs after olivine occur in some flows, e.g., in the uppermost flow (flow No. 1) from B.M.R. Delamere No. 1. The altered grains are rimmed with, and sometimes partially replaced by, opaque oxide (hematite?). Narrow stringers of opaque oxide also occur along cracks in the grains and red-brown "iron" staining is common.

The "iddingsite" lacks a fibrous habit and possesses a prominent parting. Extinction is parallel to the parting which coincides with the slow direction of the pseudomorph. Colour is often unevenly distributed throughout individual grains. Birefringence colours are usually masked. However, high second and third order colours were observed in some grains.

Baker and Haggerty (1967) regarded "iddingsite" as an orientated assemblage of goethite and interstratified phyllosilicates containing a smectite. They claimed that the formation of "iddingsite" resulted from the alteration of olivine under oxidising conditions at low temperatures (probably less than 140°C) by deuteric or weathering processes and stated that post-deuteric alteration produced strongly pleochroic, highly ordered varieties.

* "a sheet mineral of the chlorite - serpentine group that is intimately mixed with iron oxides in various stages of oxidation and hydration" (Fawcett, 1965).

Coronas of clinopyroxene, indicating the existence of a reaction relationship between olivine and pyroxene - a common characteristic of tholeiitic magmas - are not developed on the completely replaced olivine crystals, nor are there any other indications, such as embayed outlines, of the original olivine grains having undergone any marked resorption.

Primary quartz occurs in many of the basalts and in exceptional specimens accounts for a maximum of 10-15% of the total composition. It is a late-stage crystallisation product and usually occurs as small, anhedral, interstitial grains. In the quartz-rich portions of flows, the quartz grains tend to occur concentrated in small patches and pools, often associated with small grains of primary amphibole and mica. The grains show sharp extinction and may contain inclusions of acicular apatite. The abundance of quartz-bearing rocks is a characteristic of the formation as a whole.

In most flows, quartz is either very scarce or absent in the upper portions and becomes more abundant with depth. Maximum concentrations occur in the central and lower portions. Usually there is also a noticeable decline in the abundance of quartz in the chilled basal 1.5 - 3.0 m of a flow. This decrease is accompanied by an increase in the amount of devitrified glass, a diminution in grainsize and sometimes, the appearance of chlorite or "iddingsite" after original olivine.

Large, anhedral grains of secondary quartz commonly occur in amygdales. Smaller grains fill small patches in massive basalt. These grains are usually characterised by undulose extinction and sometimes contain numerous, very fine, opaque or semi-opaque inclusions ("dust").

Fine-grained, interstitial intergrowths of quartz and alkali feldspar occur instead of devitrified glass in coarser grained, highly crystalline basalts from the central portions of some flows. These intergrowths are often so fine that the presence of alkali feldspar cannot be definitely established by optical means. However, the tiny patches of low relief mineral associated with the quartz grains are considered to be alkali feldspar. Occasionally, narrow overgrowths of alkali feldspar occur mantling groundmass plagioclase grains. The alkali feldspar has a colourless, homogeneous appearance with low relief and refractive indices less than those of quartz. A nearly uniaxial figure (negative) was obtained on feldspar mantling plagioclase laths in basalt from the 380-385 ft (115.8-117.3 m) interval, B.M.R. Limbunya No. 2, indicating that the alkali feldspar is sanidine.

Accessory amounts of primary amphibole and mica also occur in massive, relatively quartz-rich basalts from the central and lower portions of some flows.

Amphibole occurs as comparatively large, somewhat poikilitic, euhedral to subhedral, prismatic grains (0.2 mm x 0.1 mm) with maximum extinction angles around 15° and as smaller interstitial grains often associated with patches of relatively coarse-grained quartz. The hornblende prisms occur between the quartz grains and around the margins of the quartz aggregates. They are also commonly moulded on clinopyroxene grains and, rarely, the coarser grained of the opaque oxide crystals.

Rarely the amphibole has partly replaced clinopyroxene. The amphibole is distinctly pleochroic from greenish yellow to pale pink.

A second type of amphibole was observed in some of the basalts from B.M.R. Delamere No. 1. The amphibole in flows Nos. 1 and 2 differs very markedly in appearance from the more common variety of amphibole. The less common variety is green or greenish brown in colour and moderately pleochroic to yellowish green or pale brown and occurs mainly as a replacement of clinopyroxene. Rare small, discrete grains occur around the margins of pyroxene grains.

Mica occurs as small tabular flakes (average grainsize 0.2 mm x 0.1 mm), generally associated with small aggregates of quartz grains. Less frequently primary mica occurs, rimming and partially replacing clinopyroxene, rimming amphibole and, very rarely, with quartz and chlorite in amygdales. Pleochroism is very strong - from dark brownish red to practically colourless.

Traces of apatite, as long slender needles, were detected in practically every section. The apatite is mainly confined to the interstitial devitrified glass and quarto-feldspathic residuum and presumably crystallised very late.

The basalts contain a number of late-stage minerals. Only brief mention will be made of the more common and significant varieties in this record.

Chlorite, generally in minor amounts (5-15%), occurs in practically every basalt examined. Its mode of occurrence varies considerably from that of an alteration product after olivine or clinopyroxene to small, irregular patches and fibrous masses in amygdales. Interstitial patches of chlorite occur in many of the rocks examined. Much of this chlorite does not appear to be replacing any pre-existing mineral.

In the majority of the rocks, chlorite occurs as pale yellow or pale yellow-green aggregates of extremely fine-grained plates. Pleochroism in varying shades of pale green is very slight and interference colours are low first order greys.

A second variety of chlorite(?) occurs in some basalts. In marked contrast to the more common type, it is characterised by, a deep blue-green colour, strong pleochroism (blue-green to pale yellowish green) and low second order birefringence. Individual grains are relatively coarse (0.03 mm in length). This variety is confined mainly to amygdales, where a pronounced concentric zonation often exists with pale yellow-green chlorite in the outer portions and the blue-green variety in the inner portions.

Pumpellyite has been identified in the altered, vesicular, upper and basal portions of a number of flows. Only minor amounts (less than 15%) are usually present. Rarely, pumpellyite accounts for more than 50% of the total volume of a specimen. Crystals have a fine fibrous habit and occur in clusters with a stellate arrangement or as dense mats of randomly oriented fibres in interstices and amygdales - also sometimes replacing feldspar phenocrysts and groundmass constituents. The fibres are distinctly pleochroic from pale blue-green to colourless. Birefringence colours are commonly masked by anomalous interference colours. Calcite, prehnite and quartz are often associated with the pumpellyite. Chips collected from the 385-390 ft (117.3-118.9 m) interval, B.M.R. Waterloo No. 1 are a pale grey-green colour and have a heavily altered appearance. The chips have an overall massive habit in hand specimens although they contain numerous fine vesicles. Under the microscope the chips are seen to consist predominantly of a felted mass of small fibres of pumpellyite. The plagioclase phenocrysts have been extensively replaced by sericite and pumpellyite while the groundmass constituents have been completely replaced. Quartz occurs lining small amygdales. X-ray diffraction traces confirmed the presence of pumpellyite, feldspar and quartz.

Minor amounts of secondary calcite, hematite and very rare epidote occur in many basalts - mainly occupying interstices, replacing groundmass constituents and filling amygdales in vesicular parts of flows.

Portions of segregation veins or small pegmatitic patches occur in some chips from the massive portions of flows. Though the constituent minerals are the same as in the host rocks the segregations are characterised by high contents of red-brown devitrified glass charged with opaque oxide grains and granules. Large, euhedral plagioclase laths (0.5 mm x 0.1 mm), rare clinopyroxene as smaller, euhedral grains (0.3 mm x 0.2 mm), apatite needles and opaque oxide occur set in a red-brown, cryptocrystalline groundmass of devitrified glass. The opaque oxide ranges in size from large subhedral prisms (0.3 mm x 0.2 mm) to tiny granules and elongate rods. The "glassy" groundmass generally accounts for at least 50% of the vein or patch. Junctions between the coarse-grained segregated material and the basaltic host rocks are generally slightly diffused. Devitrified glass from the segregation veins invades the enclosing basalt for short distances along grain boundaries. Contacts are unchilled.

Small irregular, elliptical and spherical amygdales and vesicles are very common in the Antrim Plateau lavas and are concentrated mainly in the upper portions of flows. They range in size from less than 0.5 mm to greater than 5 mm in diameter. There is generally a decrease in vesicle size and abundance away from the top of a flow. Fine-grained, chilled, only slightly vesicular, "glassy" basalt (approximately 50 cm thick) grading into highly vesicular basalt, occurs as the very top of flow No. 4, B.M.R. Limbunya No. 2. The basal 1.5-3.0 m of many flows are also vesicular or amygdaloidal. However, the extent of the vesicular zone is always less than that observed in the upper portion of the same flow.

The vesicles are often filled with a variety of minerals, the most common being, in approximate order of abundance, chlorite, quartz, chalcedony, calcite, opaque oxide, prehnite, pumpellyite, epidote, alkali feldspar(?) and very rarely basaltic material rich in devitrified glass.

The mineralogy of the amygdales has not been studied in detail and other minerals may well be present. Concentric zoning involving both similar and different mineral species is common within the amygdales.

The question arises whether the late-stage minerals were deposited from deuteric solutions, or from extraneous hydrothermal solutions of meteoric, or later igneous, origin. No post-basalt igneous intrusions are known in the area. The very widespread distribution of the vesicle infillings and the apparent lack of any mineralogical zonation point to a deuteric origin. However, chlorite, quartz and calcite are found not only within vesicles but also commonly infilling joints and cracks that were formed long after consolidation of the flows. Under the microscope, prehnite, chlorite, calcite, quartz and chalcedony have been observed filling small cross-cutting veinlets in altered basalts from the upper portions of flows. It would appear, therefore, that the solutions depositing the bulk of the late-stage minerals were not deuteric but extraneous in origin - most likely percolating meteoric waters. The constituents in the solutions were probably derived during processes of weathering of the basalts. Nasher and Davies (1960) pointed out that vesicles in recently erupted lavas from Hawaii, New Guinea and New Zealand are generally completely void of minerals. They suggested that the data pointed to the fact that when lavas are first consolidated, and for some considerable time thereafter, their vesicles remained unfilled.

INTERBEDDED SEDIMENTS

Surface Exposures

Thin interbeds of sandstone, chert and limestone commonly occur in the Antrim Plateau Volcanics. The more extensive outcrops are shown on the five map sheets. Sediments in the Wave Hill and Victoria River Downs Sheet areas have already been described in some detail by Randal and Brown (1967) and Barclay and Hays (1965). Morgan et al. (1970) have also described similar occurrences in the Delamere Sheet area.

A number of parallel, elongate, sandstone ridges trending in a northwesterly direction crop out west of Pigeon Hole outstation (Victoria River Downs Sheet area), north and northwest of Delamere homestead and northwest of Willeroo homestead (both in the Delamere Sheet area). The largest in the area west of Pigeon Hole is approximately 15 km in length with a maximum thickness of approximately 30 m. The sandstone is medium-grained and very friable. An aeolian origin is inferred from the large scale of the cross-bedding, the very good sorting of the sand grains and the occurrence of the sandstones as depositional mounds and ridges resembling dunes.

A second, and the most common, type of sandstone is fine to medium-grained and is either flat-laminated with current lineations on bedding surfaces or ripple-bedded. The sandstone occurs as thin (0.5-15 m), rather extensive horizons interbedded with the volcanics. It commonly contains siltstone and chert intercalations.

A third variety of sandstone occurs as small, scattered outcrops, often associated with chert, in the Mucka Waterhole-Buchanan Springs region in the southwestern portion of the Limbunya Sheet area. It is a massive, thickly bedded, fine-grained, pale to dark grey, indurated sandstone. Angular chert fragments up to 3 cm in length occur in places while elsewhere fragments of extensively altered vesicular basalt are prominent. The unit has a maximum thickness of 9 m (top eroded); most exposures being less than 4 m thick.

Thin chert horizons are common intercalations in the lava flows. The chert occurs largely as a replacement of former carbonate units (limestone and calcareous siltstone). Randal and Brown (1967) disucssed close associations of chert and limestone beds with laminations in limestone grading laterally into chert. Silicified stromatolites (Conophyton sp.) occur in chert 23 km southwest of Inverway homestead in the Limbunya Sheet area, 1.5 km north of Catfish Waterhole (on the Victoria River) in the southwestern corner of the Wave Hill Sheet area and at Top Springs (Victoria River Downs Sheet area). At Top Springs a silicified algal "bioherm" is exposed for a length of many hundred metres. The thickness of the chert horizons ranges from a maximum of around 8 m down to a minimum of 25 cm.

Conglomerate in the basalt has been found in two areas (Morgan et al., 1970): approximately 29 km southwest of Willeroo homestead, and east of Delamere homestead. The conglomerate consists of large lumps, up to 1 m in diameter, of heavily altered vesicular basalt in a sandstone matrix. Sandstone also forms lenses from 5 to 70 cm thick in the conglomerate and also overlies the conglomerate.

Sedimentary Horizons Intersected in the Stratigraphic Holes

The interbedded sediments intersected in the stratigraphic holes are described in Table 2. The sedimentary horizons are characteristically very thin (see Table 1), their average thickness being 2.8 m. No systematic attempt at correlating the sedimentary horizons intersected in the stratigraphic holes has been made. However, brief observations indicate that many of the interbeds are of restricted distribution and apparently were not deposited over widespread areas. This conclusion is supported by the data obtained from drilling in the region around Top Springs.

Randal and Brown (1967) observed three beds of chert, separated by basalt flows, forming benches in the hills south of Moolooloo homestead- the middle bed being the most persistent. The stratigraphic hole, B.M.R. Victoria River Downs No. 2, approximately 23 km to the southeast penetrated the complete volcanic succession (with the exception of approximately 9 m of highly weathered, vesicular basalt overlain by Montejinni Limestone exposed adjacent to the drill site) and only one very thin bed of chert (0.9 m thick) was intersected [563-566 ft (171.6-172.5 m) interval]. A sedimentary horizon, 2.4 m thick and comprising coarse-grained sandy siltstone with minor limestone, was penetrated at a depth of between 62 and 70 ft (18.9 and 21.3 m). Approximately 25 km further to the east a relatively thick chert horizon with minor limestone and sandstone was intersected between 118 and 152 ft (36.0 and 46.3 m) in B.M.R. Victoria River Downs No. 1.

TABLE 2. DESCRIPTION OF INTERBEDDED SEDIMENTS PENETRATED IN THE STRATIGRAPHIC HOLES

Stratigraphic Hole	Interval (feet)	Description
B.M.R. Victoria River Downs No. 1	118-152 (36.0-46.3 m)	White grey brown and red finely banded chert; numerous small cavities (<3 cm in diameter) lined with tiny quartz crystals. Minor pale brown fine-grained crystalline limestone; extensively replaced by chert.
B.M.R Victoria River Downs No. 2	62-70 (18.9-21.3 m)	Coarse-grained pale brown siltstone; medium (0.05-0.1 mm) subangular to subrounded detrital grains of quartz, minor feldspar (mainly plagioclase) and rare tourmaline in a micaceous, limonite (?) - stained matrix (>50%) consisting largely of very fine-grained silt and clay together with somewhat coarser angular to subrounded grains of quartz and rare feldspar and flakes of muscovite; minor chalcedony and calcite replacing matrix constituents; portions of some chips appear to have recrystallised. Minor white cream and buff medium-grained (0.05-0.1 mm) crystalline limestone, often extensively replaced by chalcedony; very minor detrital quartz and rare muscovite; the chalcedony has partially recrystallised.
" " " " "	563-566 (171.6-172.5 m)	Red and white chert, composed of a fine mosaic of limonite(?) - stained chalcedony. Impure chert (silicified calcareous? siltstone?) containing detrital quartz (0.1 mm), feldspar and muscovite; a number of relatively large patches of kaolin.
B.M.R. Victoria River Downs No. 3	188-190 (57.3-57.9 m)	Dark grey and brown limestone, partly replaced by chert.
B.M.R. Wave Hill No. 1	158-159 (48.2-48.5 m)	Pale grey siltstone containing rounded clasts of heavily altered basalt, minor detrital quartz (0.05-0.15 mm) and rare plagioclase (0.05 mm) as subrounded to rounded grains; fine-grained pale brown silty matrix forms bulk of rock with small opaque oxide granules common; recrystallised patches and veins consisting of coarse interlocking quartz grains common; rare calcite. Some chips contain large patches (5 mm) of coarse quartz grains; characterised by radiating extinction and containing numerous tiny inclusions.
" " " "	340-340.2 (103.63-103.68 m)	Pale grey sandstone forming a thin layer on surface of flow and filling vesicles; consists of subangular to subrounded and rounded quartz grains (0.1 mm) with low sphericity; grains often surrounded by relatively thick (0.05 mm) quartz overgrowths; minor muscovite and chlorite and rare grains of plagioclase and microcline. Open framework; matrix composed of fine quartz grains and very fine limonite (?) - stained indeterminate material with minor opaque oxide as small granules. A few small patches consisting of anhedral interlocking quartz grains with highly undulose extinction.
B.M.R. Limbunya No. 1	33-105 (10.1-32.0 m)	Sandstone and siltstone occurring as thin intercalations within agglomerate band. Well sorted brown often friable quartz sandstone consisting mainly of subrounded to rounded quartz grains (0.15 mm) with minor plagioclase and microcline and rare heavily altered lithic fragments; grain margins commonly limonite? - stained. Grains are of moderate sphericity. Fairly closed to moderately open framework; cement consists mainly of carbonate, sometimes quartz (towards base of agglomerate). Grades into sandy siltstone with decreasing amounts of quartz and feldspar as relatively large clasts in a finer grained brownish matrix composed of small angular to subrounded fragments (0.03 mm) of quartz and feldspar, flakes of muscovite and chlorite and granules of opaque oxide all set in a very fine-grained silty groundmass.
" " "	240-242	Pale brown medium-grained micaceous siltstone containing minor quantities of angular to subrounded (0.03-0.1 mm) quartz and scarce feldspar clasts in a fine-grained silty matrix; contains numerous tiny flakes of muscovite and chlorite. A number of small recrystallised patches consisting of relatively coarse (0.05-0.1 mm) anhedral interlocking quartz grains with highly undulose extinction.

TABLE 2 (continued)

Stratigraphic Hole	Interval (feet)	Description
B.M.R. Limbunya No. 2	637-641 (194.2-195.4 m)	White and pink crystalline limestone; partly replaced by chert.
" " "	585-625 (178.3-190.5 m)	White and pale brown coarse calcareous siltstone; minor pale grey medium-grained quartz sandstone. The sandstone consists mainly of subrounded to rounded quartz clasts (0.15 mm) with minor plagioclase and microcline and rare heavily altered lithic fragments. Closed to moderately open framework. Fine-grained matrix has been extensively replaced by chalcedony and carbonate.
B.M.R. Waterloo No. 1	714-715 (217.6-217.9 m)	White to creamy fine-grained friable tuffaceous(?) siltstone; has a different appearance to the other interbedded siltstones described. The siltstone consists mainly of very fine-grained indeterminate material with abundant tiny flakes of mica; has been extensively replaced by chalcedony (as comparatively coarse grains, 0.3-1.0 mm), less commonly by calcite (as large anhedral grains, 0.5-1.0 mm) and pumpellyite (as radiating fibres, 0.1 mm in length). The pumpellyite is generally associated with calcite. Subrounded to rounded clasts (0.1-0.2 mm) of detrital quartz and feldspar occur in minor quantities.
B.M.R. Waterloo No. 2	184-202 (56.1-61.6 m)	Cream brown and dark red-brown well sorted friable medium-grained quartz sandstone; closed framework; composed mainly of subrounded to rounded quartz grains (0.2-0.3 mm) with very minor plagioclase and microcline and a few small heavily altered lithic fragments; medium sphericity; quartz overgrowths on a few grains. Very fine-grained clay matrix containing minor sericite.
" " "	484-489 (147.5-159.0 m)	Pale grey and pale brown medium-grained quartz sandstone containing mainly subangular to subrounded quartz grains (0.05-0.2 mm); minor black opaque oxide as small subrounded grains (0.05-0.1 mm); rare feldspar (mainly microcline); low to medium sphericity; poorly developed bimodal quartz distribution. Contains a number of relatively large angular clasts (1 mm) of heavily altered basalt. Matrix of very fine-grained brownish silty material containing chlorite and numerous tiny blebs and granules of opaque oxide; extensively replaced by carbonate.
" " "	644-645 (196.3-196.6 m)	Cream to light brown poorly sorted medium-grained silty sandstone; partly recrystallised; clasts consist mainly of subrounded to rounded quartz grains with minor plagioclase and microcline and rare tourmaline and show a range in grainsize (0.03-0.2 mm); open framework; poorly developed bimodal distribution; matrix of fine-grained pale brown (limonite? - stained) indeterminate silty material containing flakes of muscovite and chlorite and tiny opaque blebs and granules; often extensively replaced by carbonate. Two chips display a well developed bimodal distribution defined by very large (0.4-0.8 mm) rounded quartz grains (with rare lithic fragments and feldspar grains) and smaller subrounded to rounded quartz and feldspar grains (0.1-0.2 mm) set in a carbonate cement. Alternatively the coarse grains are set in a matrix of smaller closely packed quartz and feldspar grains with minor chalcedony. Another chip comprises completely recrystallised sandstone and consists of a mosaic of a coarse (0.2 mm) interlocking angular quartz grains; the finer grains are characterised by highly undulose extinction, the larger grains forming the bulk of the chip by fairly sharp extinction; pumpellyite relatively common as small patches scattered throughout chip; often occurs in the central portions of small quartz grains with highly undulose radiating extinction. Small euhedral cubes (0.05 mm) of opaque oxide are present in very minor amounts.

To the north, B.M.R. Delamere No. 1 also penetrated virtually the complete volcanic succession and no interbedded sediment was observed in the cuttings. Morgan et al., (1970), however, described the occurrence of a conglomerate with an exposed thickness of approximately 18 m about 13 km east of Delamere homestead and only a comparatively short distance (7 km) west of B.M.R. Delamere No. 1.

Thin sections of the sandstones show that the grainsize is variable. The sandstones consist mainly of quartz with minor feldspar and heavily altered lithic fragments and accessory tourmaline. The feldspar includes microcline and plagioclase. Grains are mainly fresh. The thin sections have yet to be tested with potassium cobaltinitrite to identify orthoclase. The grains are subrounded to rounded and are often coated with brownish iron oxide (limonite?). The basalt fragments are generally angular and notably larger than the other clasts. They obviously had not been subjected to the same amount of abrasian and attrition as the other clasts. Quartz and calcite cements are fairly common.

The sandstones often contain variable amounts of fine-grained, largely indeterminate, pale brown, silty material forming the matrix between the clasts. With increasing silt content they grade into sandy siltstones and siltstones.

The siltstones contain variable sized clasts of quartz and feldspar and flakes of mica set in a fine-grained matrix consisting largely of clay, sericite and fine quartz grains. In some specimens the fine-grained matrix consists largely of cryptocrystalline silica.

The limestones were identified from examination of thin sections and by the occurrence of a vigorous effervescence when treated with a solution of 10% hydrochloric acid. They are microcrystalline and often contain some sand, silt and clay impurities. Chert is almost invariably associated with the limestone. The carbonate crystals are variable sized and irregular shaped. Randal and Brown (1967) suggested that most of the limestones interbedded within the volcanics were deposited as carbonate muds and subsequently recrystallised. The carbonate grains have commonly been replaced, or partly replaced, by chalcedony and it appears as though most of the interbedded chert has resulted from the replacement of original limestone or calcareous siltstone by cryptocrystalline silica.

A feature of the sedimentary horizons is the general scarcity of included volcanic detritus. The bulk of the detritus was derived from Precambrian sedimentary and igneous plutonic rocks. It appears, therefore, that the surfaces of the lavas in most places were not subjected to pronounced erosion and denudation during the deposition of the sediments.

The poorly sorted nature of many of the sandstones and the common occurrence of siltstone indicate that the sediments were either deposited close to the source of the detritus or alternatively, the sediments were deposited from low-energy transporting media such as those typically found in lacustrine or lagoonal environments.

Metamorphic effects caused by the inundation of the sediments under later lava flows are very slight. Occasionally, small recrystallised patches consisting of interlocking, angular, relatively coarse-grained quartz grains were observed in thin sections of chips from towards the tops of some horizons. Randal and Brown (1967) described a thin section of an indurated sandstone at the base of a basalt flow. The quartz cement in the sandstone contains abundant needles and short prismatic grains of an orthorhombic mineral tentatively identified as mullite.

A thin section of sandstone from the 644-645 ft (196.3-196.6 m) interval B.M.R. Waterloo No. 2 contains one chip that appears to have been completely recrystallised - the other chips show no signs of recrystallisation at all. Interstices between the angular, relatively coarse quartz grains in the recrystallised sandstone are filled with thin needles and small fibrous aggregates of pumpellyite. The fibres are distinctly pleochroic from blue-green to colourless and are often characterised by anomalous birefringence. Minor carbonate (calcite?) occurs associated with the pumpellyite. Calcite(?) also forms the kernels of small quartz grains characterised by highly undulose radiating extinction. Some quartz grains appear to contain needles of pumpellyite.

The sediments have been deposited in an aqueous environment. Judging from the poor sorting of constituent grains the sandstones are unlikely to be of aeolian origin. Randal and Brown (1967) concluded from evidence obtained from surface exposures that the bulk of the interbedded sediments were deposited under shallow-water marine (intertidal zone) or lacustrine conditions. The apparent lenticular nature and restricted occurrence of many of the individual sedimentary units suggest that the basalt surface was somewhat uneven and that at any one time portions of the area covered by the basalts were above water level. The very widespread distribution of the sedimentary types indicates that most of the lava field was under water at one time or other.

The data suggest, therefore, that much of the water-laid sedimentary detritus was deposited in lakes formed either by upwarping of the surface of the lava field or by blockage of drainage systems by lava flows. The general scarcity of basaltic detritus in the sediments indicates that those portions of the lava field above water level were not eroded to any extent. Deposition of the conglomerate containing basalt clasts east of Delamere homestead could be due to a mixing of littoral sand with fragments of a basalt derived from wave erosion.

ECONOMIC GEOLOGY

No occurrences of significant mineralisation were observed in the cores and cuttings taken from the drill holes. Sparse disseminations of native copper were detected in massive basalt from the 405-415 ft (123.4-126.5 m) interval in B.M.R. Waterloo No. 2. Minor pyrite is rarely found in amygdales and along joint planes.

Water

Water supplies encountered in the boreholes are listed in Table 3. The figures tabulated are derived from calculations based on the time taken for the supply from each hole to fill a 9.1 litre (2 gallon) bucket and consequently are approximate only. The normal procedure was to dig a system of small trenches around each drill hole so that the water from the hole was channelled into one main trench. This was dammed and the overflow allowed to pass, without hinderance, through a section of bore casing into a bucket.

Excellent supplies of good quality water were obtained in B.M.R. Victoria River Downs No. 1, B.M.R. Victoria River Downs No. 2, B.M.R. Limbunya No. 1 and B.M.R. Waterloo No. 1. The supply from B.M.R. Victoria River Downs No. 1 was estimated to be well in excess of 800 litres/min (10,560 gal/hr) and was responsible for the failure to reach target depth.

The groundwater is contained in joints, fractures, porous zones in the vesicular portions of flows and in interbedded sediments.

TABLE 3. DETAILS OF GROUNDWATER SUPPLIES IN THE STRATIGRAPHIC HOLES

B.M.R. Stratigraphic Hole	Standing Water Level (metres)	Supply (litres/min)	Principal Aquifers	Depth of Principal Aquifers (metres)
B.M.R. Delamere No. 1	4.6	7	vesicular basalt	35
" Victoria River Downs No. 1	29.9	8	heavily altered, slightly vesicular basalt	9
		800	chert (replacement) - limestone interbed	40
" Victoria River Downs No. 2	10.4	227	vesicular basalt + thin sandstone interbed	62
" Victoria River Downs No. 3		Dry hole		
" Wave Hill No. 1	13.7	7.6	jointed basalt	23
" Limbunya No. 1	12.8	15	" "	40
" Limbunya No. 2	8.5	227	vesicular basalt	13
" Waterloo No. 1	19.2	227	" "	45
" Waterloo No. 2	15.2	7.6	thin sandstone interbed	60

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APPENDIX I

Nomenclature used in Indexing the Stratigraphic Holes

The stratigraphic holes were originally named either after the station property on which they were sited, or after a nearby settlement. However, it has since been decided to store the specimens collected in the B.M.R. Core and Cuttings Laboratory. In order to conform to the Laboratory's policy of indexing B.M.R. stratigraphic holes after the 1:250,000 sheet areas in which they are situated, most of the original names given to the holes have had to be changed. The revised nomenclature has been used exclusively throughout this record. However, the original nomenclature was used for many of the specimens selected for thin sectioning and chemical analysis.

TABLE 4. NAMES OF THE STRATIGRAPHIC HOLES

Original Name	Revised Name
B.M.R. Delamere No. 1	B.M.R. Delamere No. 1
" Top Springs No. 2	" Victoria River Downs No. 1
" Top Springs No. 1	" Victoria River Downs No. 2
" Victoria River Downs No.1	" Victoria River Downs No. 3
" Wave Hill No. 1	" Wave Hill No. 1
" Mistake Creek No. 1	" Limbunya No. 1
" Inverway No. 1	" Limbunya No. 2
" Rosewood No. 1	" Waterloo No. 1
" Rosewood No. 2	" Waterloo No. 2

APPENDIX II

Positions of the Stratigraphic Holes and Drilling Details

B.M.R. Delamere No. 1

Location: Latitude 15°44'S; longitude 131°42'E - situated in the Delamere 1:250,000 Sheet area, approximately 2.5 km southwest of the Katherine-Top Springs road along the track to Delamere homestead.

Surface Geology: The hole is sited in highly weathered basalt, almost at the top of the volcanic succession. Soft, pale grey, heavily decomposed, vesicular basalt is exposed in a creek bed approximately 15 metres south of the bore site and at about the same level. The basalt is overlain by 20 metres of soft, dark red sandstone (interbedded within the Montejinni Limestone, Morgan et al., 1970), very poorly exposed in a small escarpment and capped with white and dark brown, coarse-grained sandstone of the Mullaman Beds.

General Data

Total Depth: 505 ft (153.9 m)

Date spudded: 9/10/69

Date completed: 12/10/69

Status: Plugged and abandoned

Drilling Data

Drilling Plant	Ingersoll - Rand, Trucm 3
Hole Sizes	Surface - 5 ft (1.5 m) : 8 in (20.3 cm)
	5 ft (1.5 m) - 505 ft (153.9 m): 7½ in (19.1 cm)
Bits Used	Surface - 505 ft (153.9 m): 7½ in (19.1 cm)
	Carset hammer
	Surface - 5 ft (1.5 m): 9 in (22.9 cm) wing (reamer)
Casing Used	5 ft (1.5 m) [8 in (20.3 cm) in diameter]

B.M.R. Victoria Downs No. 1

Location: Latitude 16°35'S; longitude 131°52'E - situated in the Victoria River Downs 1:250,000 Sheet area, approximately 1 km east of Illawarra Creek and 15 metres west of the Buchanan Highway.

Surface Geology: Area of poor outcrop. Approximately 3-5 metres of heavily weathered, soft, vesicular basalt exposed in a creek bed southwest of bore site. The basalt is overlain by a thin layer (0.3 metres thick) of dark brown sandstone. The sandstone is ripple marked and occurs as small angular blocks on the surface. The sandstone is overlain by limestone and chert rubble belonging to the Montejinni Limestone.

General Data

Total Depth: 245 ft (74.7 m)

Date spudded: 13/10/69

Date abandoned: 16/10/69

Status: Plugged and abandoned
- excellent water bore.
At present cased to 150 ft
(45.7 metres)

Drilling Data

Drilling Plant	Ingersoll-Rand, Trucm 3
Hole Sizes	Surface - 150 ft (45.7 m) : 9 5/8 in (24.4 cm)
	150 ft (45.7 m) - 245 ft (74.7 m) : 7½ in (19.1 cm)
Bits Used	Surface - 245 ft (74.7 m) : 7½ in (19.1 cm)
	Carset hammer
	Surface - 150 ft (45.7 m) : 9 5/8 in (24.4 cm)
	Varel tricone roller
Casing Used	150 ft (45.7 m) /8 in (20.3 cm) in diameter - still in hole7

B.M.R. Victoria River Downs No. 2

Location: Latitude 16°37'S; longitude 131°43'E - situated in the Victoria River Downs 1:250,000 Sheet area, approximately 3 km north of the Armstrong River along the old Top Springs-Victoria River Downs road.

Surface Geology: Bore site situated approximately 10 metres west of limestone-capped escarpment approximately 12 metres high. Approx- 9 metres of very soft, decomposed, vesicular basalt exposed in escarpment. The heavily altered basalt is overlain by a thin layer of dark brown sandstone (0.15 metres thick). The sandstone is overlain by a layer (0.3 to 0.6 metres in thickness) of soft, heavily weathered, thinly bedded, fine-grained, calcareous siltstone (?). The escarpment is capped by massive, grey, crystalline limestone (Montejinni Limestone) approximately 3 metres thick with small nodules and lenses of grey and white banded chert.

Abundant small agates occur on the basalt surface in areas adjacent to the escarpment. They have presumably weathered out of the amygdaloidal portion of the uppermost basalt flow.

General Data

Total Depth: 800 ft (243.8 m)

Date spudded: 23/7/70

Date completed: 8/8/70

Status: Cased to 50 ft (15.2 m) and abandoned
- excellent water bore

Drilling Data

Drilling Plant	Ingersoll-Rand, Trucm 4 Drillmaster
Hole Sizes	Surface - 15 ft (4.6 m) : 9 5/8 in (24.4 cm)
	15 ft (4.6 m) - 725 ft (221.0 m) : 6¾ in (17.1 cm)
	725 ft (221.0 m) - 800 ft (243.8 m) : 5½ in (14.0 cm)
Bits Used	Surface 440 ft (134.1 m) : 6½ in (16.5 cm)
	Carset hammer
	Surface - 15 ft (4.6 m) : 9 5/8 in (24.4 cm)
	Varel tricone roller
	15 ft (4.6 m) - 725 ft (221.0 m) : 6¾ in (17.1 cm)
	Williams tricone roller - reamed from 15-440 ft (4.6 - 134.1 m)
	725 ft (221.0 m) - 800 ft (243.8 m) : 5½ in (14.0 cm)
	Varel tricone roller
	Coring: 2 7/8 in (7.3 cm) Mindrill diamond
Casing Used	15 ft (4.6 m) (20.3 cm) in diameter

B.M.R. Victoria River Downs No. 3

Location: Latitude 16°23'S; longitude 131°32'E - situated in the Victoria River Downs 1:250,000 Sheet area, approximately 5 km south-southeast of Moolooloo outstation and 30 metres south of the Victoria River Downs-Katherine road.

Surface Geology: Bore sited in the lower portion of the basalt succession. To the south and north of Moolooloo homestead interbedded chert occurs higher in the sequence. Differential erosion has produced prominent ledges and plateau surfaces.

General Data

Total Depth: 300 ft (91.4 m)

Date spudded: 9/8/70

Date completed: 10/8/70

Status: Plugged and abandoned

Drilling Data

Drilling Plant	Ingersoll-Rand, Trucm 4 Drillmaster
Hole Sizes	Surface - 15 ft (4.6 m) : 9 in (22.9 cm)
	15 ft (4.6 m) - 300 ft (91.4 m) : 6½ in (16.5 cm)
Bits Used	Surface - 300 ft (91.4 m) : 6½ in (16.4 cm)
	Carset hammer
	Surface - 15 ft (4.6 m) : 9 in (22.9 cm)
	wing (reamer)
Casing Used	15 ft (4.6 m) /8 in (20.3 cm) in diameter7

B.M.R. Wave Hill No. 1

Location: Latitude 17°37'S; longitude 131°15'E - situated in the Wave Hill 1:250,000 Sheet area, approximately 6 km southeast of Chungamidgee Waterhole and 15 m north of the track to Cattle Creek homestead.

Surface Geology: Bore sited in flat-lying Montejinni Limestone, overlying the Antrim Plateau Volcanics.

General Data

Total Depth: 540 ft (164.6 m)

Date spudded: 19/7/70

Date completed: 22/7/70

Status: Plugged and abandoned

Drilling Data

Drilling Plant	Ingersoll-Rand, Trucm 4 Drillmaster
Hole Sizes	Surface - 14 ft (4.3 m) : 9 5/7 in (24.4 cm)
	14 ft (4.3 m) - 540 ft (164.6 m) : 6½ in (16.5 cm)
Bits Used	Surface - 540 ft (164.6 m) : 6½ (16.5 cm)
	Carset hammer
	Surface - 14 ft (4.3 m) : 9 5/8 in (24.4 cm)
	Varel tricone roller
Casing Used	(4.3 m) /8 in (20.3 cm) in diameter7

B.M.R. Limbunya No. 1

Location: Latitude 17°25'S; longitude 129°23'E - situated in the Limbunya 1:250,000 Sheet area, approximately 50 km southeast of Mistake Creek homestead and 200 metres west of the Mistake Creek-Inverway road.

Surface Geology: Gently dipping (less than 5°W) Headleys Limestone overlying Antrim Plateau Volcanics.

General Data

Total Depth: 1000 ft (304.8 m)

Date commenced: 30/6/70

Date completed: 8/7/70

Status: Plugged and abandoned

Drilling Data

Drilling Plant	Ingersoll-Rand, Trucm 4 Drillmaster
Hole Sizes	Surface - 5 ft (1.5 m) : 9 5/8 in (24.4 cm)
	5 ft (1.5 m) - 100 ft (304.8 m) : 6½ in (16.5 cm)
Bits Used	Surface - 1000 ft (304.8 m) : 6 in (24.4 cm)
	Varel tricone roller
	Coring: 2 7/8 (7.3 cm) Mindrill diamond
Casing Used	5 ft (1.5 m) [8 in (20.3 cm) in diameter]

B.M.R. Limbunya No. 2

Location: Latitude 17°52'S; longitude 130°00'E - situated in the Limbunya 1:250,000 Sheet area, 39 km east of Inverway homestead and 10 metres south of the Inverway-Riveren track.

Surface Geology: Bore site situated at base of laterite-capped escarpment approximately 22 metres high. Approximately 3 metres of soft, very heavily weathered, crumbly, vesicular basalt exposed in creek bank 50 metres south of the bore site and at about the same level. Overlying the vesicular basalt is a thin flow, 12 metres thick, of poorly outcropping, fine-grained, altered, red-brown, massive basalt. This is in turn overlain by a thin band (6-11 metres thick) of agglomerate. The agglomerate has been very heavily weathered and lateritized.

General Data

Total Depth: 800 ft (243.8 m)

Date commenced: 9/7/70

Date completed: 18/7/70

Status: Cased to 50 ft (15.2 m) and abandoned - excellent water bore

Drilling Data

Drilling Plant	Ingersoll-Rand, Trucm 4 Drillmaster
Hole Sizes	Surface - 14 ft (4.3 m) : 9 in (22.9 cm)
	14 ft (4.3 m) - 420 ft (128.0 m) : 7½ in (19.1 cm)
	420 ft (128.0 m) - 710 ft (216.4 m) : 6½ in (16.5 cm)
	710 ft (216.4 m) - 800 ft (243.8 m) : 5½ in (14.0 cm)
Bits Used	Surface - 70 ft (21.3 m) : 6½ in (16.5 cm)
	Carset hammer
	Surface - 14 ft (4.3 m) : 9 in (22.9 cm)
	wing (reamer)
	14 ft (4.3 m) - 70 ft (21.3 m) : 7½ in (19.1 cm)
	Williams tricone roller
	70 ft (21.3 m) - 355 ft (108.2 m) : 7½ in (19.1 cm)
	Carset hammer
	355 ft (108.2 m) - 710 ft (216.4 m) : 6½ in (16.5 cm)
	Carset hammer
	710 ft (216.4 m) - 800 ft (243.8 m) : 5½ in (14.0 cm)
	Williams tricone roller
	Coring: 2 7/8 in (7.3 cm) Mindrill diamond
Casing Used	14 ft (4.3 m) /8 in (20.3 cm) in diameter7

B.M.R. Waterloo No. 1

Location: Latitude 16°32'S; longitude 129°6'E - situated in the Waterloo 1:250,000 Sheet area, approximately 13 km southeast of Rosewood homestead and 10 metres west of track.

Surface Geology: Bore sited in Antrim Plateau Volcanics - near top of formation. Approximately 300 metres south of the bore site a prominent escarpment rises 68.6 metres (determined from barometric readings) above the level of the hole. The escarpment is capped by 4.6 metres of Headleys Limestone.

General Data

Total Depth: 885 ft (269.7 m)

Date spudded: 10/6/70

Date completed: 22/6/70

Status: Cased to 10 ft (3.0 m) and abandoned
- excellent water bore

Drilling Data

Drilling Plant	Ingersoll-Rand, Trucm 4 Drillmaster
Hole Sizes	Surface - 5 ft (1.5 m) : 9 5/8 in (24.4 cm)
	5 ft (1.5 m) - 626 ft (190.8 m) : 7½ in (19.1 cm)
	626 ft (190.8 m) - 855 ft (260.6 m) : 6¾ in (17.1 cm)
	855 ft (260.6 m) - 885 ft (269.7 m) : 5½ in (14.0 cm)
Bits Used	Surface - 626 ft (190.8 m) : 7½ in (19.1 cm)
	Carset hammer
	626 ft (190.8 m) - 855 ft (260.6 m) : 6¾ in (17.1 cm)
	Varel tricone roller
	855 ft (260.6 m) - 885 ft (269.7 m) : 5½ in (14.0 cm)
	Williams tricone roller
	Coring: 2 in (5.1 cm) Mindrill diamond
Casing Used	5 ft (1.5 m) /8 in (20.3 cm) in diameter7

B.M.R. Waterloo No. 2

Location: Latitude 16°25'S; longitude 129°25'E - situated in the Waterloo 1:250,000 Sheet area, approximately 50 km east-northeast of Rosewood homestead and 10 metres south of the Rosewood-Kildurk track.

Surface Geology: The stratigraphic hole is sited in basalt from the lower part of the formation.

General Data

Total Depth: 725 ft (221.0 m)

Date spudded: 24/6/70

Date completed: 28/6/70

Status: Plugged and abandoned

Drilling Data

Drilling Plant	Ingersoll-Rand, Trucm 4 Drillmaster
Hole Sizes	Surface - 24 ft (7.3 m) : 9 5/8 in (24.4 cm)
	24 ft (7.3 m) - 725 ft (221.0 m) : 6½ in (16.5 cm)
Bits Used	Surface - 725 ft (221.0 m) : 6½ in (16.5 cm)
	Carset hammer
	Surface - 24 ft (7.3 m) : 9 5/8 in (24.4 cm)
	Varel tricone roller
Casing Used	24 ft (7.3 m) /8 in (20.3 cm) in diameter7

APPENDIX III

Summary of Drilling Progress

B.M.R. Delamere No. 1

10/10/69	: Hammer drilled 320 ft (87.5 m) in basalt
11/10/69	: Hammer drilled 105 ft (32.0 m) in basalt
12/10/69	: Hammer drilled 100 ft (30.5 m) in basalt and siltstone (3 hours); packed up and moved to B.M.R. Victoria River Downs No. 1 site (4 hours)

B.M.R. Victoria River Downs No. 1

12/10/69-14/10/69	: Hammer drilled 195 ft (59.4 m) in basalt; a large supply of water encountered around the 141 ft (43 m) mark
14/10/69	: Hole reamed to 128 ft (39 m) and 8 in (20.8 cm) casing run to reduce the supply of water
15/10/69	: Hammer drilled from 195-245 ft (59.4-74.7 m) - still excessive amounts of water. Pulled up casing and reamed to 150 ft (45.7 m) using 9 5/8 in (24.4 cm) Varel tricone roller bit
16/10/69	: Ran casing - jammed at 145 ft (44.2 m). Very little, if any, decrease in water supply
16/10/69	: Hole abandoned

B.M.R. Victoria River Downs No. 2

23/7/70	: Drove to drill site and set up camp (1½ hours); hammer drilled 50 ft (15.2 m) (3½ hours)
24/7/70	: Hammer drilled 96 ft (29.3 m) (7 hours); cored 4 ft (1.2 m) (4 hours)
25/7/70	: Repaired rig (8 hours)
26/7/70	: Replaced rotation motor on power head (3 hours); cored 10 ft (3.0 m) (5 hours); hammer drilled 65 ft (19.8 m) (3 hours)
27/7/70	: Hammer drilled 30 ft (9.1 m) (4½ hours); cored 15 ft (4.6 m) (7½ hours)
28/7/70	: Hammer drilled 55 ft (16.8 m) (6 hours); cored 15 ft (4.6 m) (4½ hours)
29/7/70	: Hammer drilled 60 ft (18.3 m) (11 hours)

30/7/70	: Hammer drilled 25 ft (7.6 m) (5 hours); cored 10 ft (3.0 m) (4 hours)
31/7/70	: Hammer drilled 15 ft (4.6 m) (4 hours); reamed 0-440 ft (0-134.1 m) (4 hours); drilled 55 ft (16.8 m) using roller bit (3 hours)
1/8/70 - 2/8/70	: Repaired rig - replaced power head
3/8/70	: Drilled 30 ft (9.1 m) (2 hours); cored 10 ft (3.0 m) (4 hours); retrieved 12 drill rods lost down hole (3 hours)
4/8/70	: Drilled 90 ft (27.4 m) (11 hours) using roller bit
5/8/70	: Cored 10 ft (3.0 m) (4 hours); repaired rig (1 hour)
6/8/70	: Drilled 90 ft (27.4 m) (10½ hours)
7/8/70	: Tried to obtain core (1½ hours) - head of water too great; trips (6½ hours); maintenance and repair to rig (2½ hours)
8/8/70	: Drilled 75 ft (22.9 m) (3 hours); trips (3½ hours); packed up camp (4 hours)

B.M.R. Victoria River Downs No. 3

9/8/70	: Packed up camp and travelled 50 km to next drill site (6 hours); drilled 175 ft (53.3 m)(4 hours)
10/8/70	: Hammer drilled 125 ft (38.1 m) (5 hours)

B.M.R. Wave Hill No. 1

19/7/70	: Loaded fuel, travelled 80 km to drill site and set up camp (6½ hours); hammer drilled 100 ft (30.5 m) (4 hours); reamed 25 ft (7.6 m) (1 hour)
20/7/70	: Hammer drilled 150 ft (45.7 m) (12 hours)
21/7/70	: Hammer drilled 175 ft (53.3 m) (11½ hours)
22/7/70	: Hammer drilled 115 ft (35.1 m) (5 hours); packed up and drove to Top Springs (7 hours)

B.M.R. Limbunya No. 1

30/6/70	: Travelled to drill site and set up camp (2½ hours); hammer drilled 225 ft (68.6 m) (10 hours)
31/6/70	: Cored 10 ft (3 m) (4½ hours); hammer drilled 90 ft (27.4 m) (3 hours)

2/7/70	: Hammer drilled 116 ft (35.4 m) (6 hours); cored 4 ft (1.2 m) (3 hours)
3/7/70	: Hammer drilled 205 ft (62.5 m) (12 hours); repaired rig (½ hour)
4/7/70	: Hammer drilled 125 ft (38.1 m) (12 hours)
5/7/70	: Cored 5 ft (1.5 m) (3 hours); maintenance on rig (2½ hours); trips (4½ hours)
6/7/70	: Hammer drilled 115 ft (35.1 m) (11½ hours)
7/7/70	: Hammer drilled 85 ft (25.9 m) (12 hours)
8/7/70	: Repaired rig (2 hours); hammer drilled 20 ft (6.1 m) (3 hours); pulled rods, packed up camp and travelled 30 km towards next site (4½ hours)

<u>B.M.R. Limbunya No. 2</u>

9/7/70	: Travelled approximately 70 km to site; hammer drilled 70 ft (21.3 m) (3 hours) using 6½ in (16.5 cm) diameter bit. Broke control rod in the down-the-hole-hammer mechanism (no spare)
10/7/70	: Reamed 70 ft (21.3 m) (1 hour); assembled the 7½ in (19.1 cm) down-the-hole-hammer (½ hour); drilled 200 ft (61 m) (11 hours)
11/7/70	: Hammer drilled 75 ft (22.9 m) (8 hours); cored 5 ft (1.5 m) (3 hours)
12/7/70	: Hammer drilled 5 ft (1.5 m) (1 hour) - hammer mechanism not functioning. Rest of day (10 hours) spent trying to make hammer mechanism function correctly.
13/7/70	: Replacement 6½ in (16.5 cm) down-the-hole-hammer flown in from Alice Springs. Hammer drilled 65 ft (19.8 m) (10½ hours)
14/7/70	: Hammer drilled 35 ft (10.7 m) (5 hours); cored 10 ft (3 m) (4 hours)
15/7/70	: Hammer drilled 115 ft (32 m) (13 hours)
16/7/70	: Hammer drilled 125 ft (38.1 m) (13½ hours); routine maintenance (½ hour)
17/7/70	: Hammer drilled 15 ft (4.6 m) (5½ hours); replaced hammer bit with roller bit (2 hours); drilled 90 ft (27.4 m) (5 hours)
18/7/70	: Ran 2 lengths of 6 in (15.2 cm) casing (½ hour); packed up and travelled approximately 210 km to Wave Hill Police Station (11 hours)

B.M.R. Waterloo No. 1

10/6/70	: Hammer drilled 170 ft (51.8 m) (11 hours) in basalt; cored 5 ft (1.5 m) (3 hours)
11/6/70	: Hammer drilled 110 ft (33.5 m) (9 hours); cored 5 ft (1.5 m) (1½ hours)
12/6/70	: Hammer drilled 10 ft (3 m) (¾ hour); trouble with starter motor - had to wait for replacement to be flown in from Alice Springs
13/6/70	: Replaced starter motor (1 hour); cored 5 ft (1.5 m) (2½ hours); hammer drilled 85 ft (25.9 m) (6 hours)
14/6/70	: Hammer drilled 83 ft (25.3 m) (8½ hours); cored 1 ft 8 in (50 cm) (1 hour)
15/6/70	: Hammer drilled 125 ft (38.1 m) (13½ hours)
16/6/70	: Hammer drilled 25 ft (7.6 m) (6 hours); cored 1 ft 8 in (50 cm) (2 hours). Core barrel left down hole
17/6/70 - 19/6/70	: Constructing fishing apparatus and fishing for core barrel and connecting sub
20/6/70	: Drilled 184 ft (56.1 m) (using roller bit - 13 hours)
21/6/70	: Drilled 45 ft (13.7 m) (9½ hours)
22/6/70	: Drilled 30 ft (9.1 m) (10 hours)
23/6/70	: Pulled rods, packed up camp and moved to next site (8½ hours)

B.M.R. Waterloo No. 2

24/6/70	: Hammer drilled 40 ft (12.2 m) (2 hours); reamed 24 ft (7.3 m) (1 hour); trip to nearby station for casing (2½ hours); ran casing (3 hours)
25/6/70	: Hammer drilled 260 ft (79.2 m) (14½ hours)
26/6/70	: Hammer drilled 115 ft (35.1 m) (12 hours)
27/6/70	: Hammer drilled 180 ft (54.9 m) (13½ hours)
28/6/70	: Hammer drilled 130 ft (39.6 m) (10 hours)
29/6/70	: Packed up and moved towards next site

APPENDIX IV

Core Recoveries

B.M.R. Victoria River Downs No. 2

Core Number	Interval Cored (feet)	Recovery (%)
1	100-104 (30.5 - 31.7 m)	92
2	150-160 (45.7 - 48.8 m)	100
3	250-265 (76.2 - 80.8 m)	100
4	325-340 (99.1 - 103.6 m)	100
5	400-410 (121.9 - 125.0 m)	100
6	525-535 (160.0 - 163.1 m)	100
7	625-635 (190.5 - 193.5 m)	100

B.M.R. Limbunya No. 1

Core Number	Interval Cored (feet)	Recovery (%)
1	225-235 (68.6 - 71.6 m)	100
2	350-354 (106.7 - 107.9 m)	100
3	775-780 (236.2 - 237.7 m)	100

B.M.R. Limbunya No. 2

Core Number	Interval Cored (feet)	Recovery (%)
1	305-310 (93.0 - 94.5 m)	100
2	450-460 (137.2 - 140.2 m)	98

B.M.R. Waterloo No. 1

Core Number	Interval Cored (feet)	Recovery (%)
1	100-105 (30.5 - 32.0 m)	100
2	225-230 (68.6 - 70.1 m)	100
3	300-305 (91.4 - 93.0 m)	100
4	450-451½ (137.2 - 137.7 m)	100
5	625-626½ (190.5 - 191.0 m)	Nil

Cores were not taken from B.M.R. Delamere No. 1, B.M.R. Victoria River Downs No. 1, B.M.R. Victoria River Downs No. 3, B.M.R. Wave Hill No. 1 or B.M.R. Waterloo No. 2.

APPENDIX V

Description of Drill Cores - Hand Specimen

B.M.R. Victoria River Downs No. 2

Core No. 1. 100-104 ft (30.5 - 31.7 m). Recovered 3 ft 6 in (1.1 m)

Dark red-brown, fine to medium-grained, mainly massive, heavily altered basalt - slightly amygdaloidal; amygdales up to 2.5 cm in diameter (but generally less than 5 mm) and filled with chlorite, calcite and quartz. Thin veins (less than 5 mm in width) of calcite occur along joint planes - often with coating of dark green chlorite. Tiny patches and streaks of dark green alteration (chlorite) common.

Core No. 2. 150-160 ft (45.7 - 48.8 m). Recovered 10 ft (3.1 m)

Predominantly dark grey to dark red-brown, massive, medium-grained, relatively fresh basalt with numerous irregularly distributed red-brown more heavily altered (ferruginised) patches and streaks. Appear to have two sets of joints - one set almost horizontal and the other steeply inclined. Joint planes are lined with a thin film of dark green chlorite and rare calcite.

Core No. 3. 250-265 ft (76.2 - 80.8 m). Recovered 15 ft (4.6 m)

Massive, medium-grained, dark grey, brown basalt with tiny irregular streaks of brighter reddish brown, more heavily altered basalt; contains irregular patches of dark grey, relatively fresh basalt. Numerous small spots of dark green chlorite in places. Minor calcite in thin veins (5 mm thick) occurs lining joint planes. Jointing well developed - joint planes are closely spaced and lined with a thin film of dark green chlorite.

Core No. 4. 325-340 ft (99.1 - 103.6 m). Recovered 15 ft (4.5 m)

Dark red-brown, extensively altered, porphyritic basalt - slightly to moderately amygdaloidal - amygdales filled mainly with dark green chlorite, together with minor calcite, quartz, chalcedony, white zeolite(?) and pyrite - amygdales circular and elliptical in shape and generally less than 1 cm in diameter. Small patches and streaks of dark green alteration (chlorite) common. The basalt has an overall competent, massive appearance and is not sufficiently vesicular to enable it to be easily broken.

Core No. 5. 400-410 ft (112.9 - 125.0 m). Recovered 10 ft (3.1 m)

Dark grey to dark red-brown, massive, medium-grained, porphyritic basalt with bright red-brown heavily ferruginised patches. Tiny patches of dark green chlorite common. Glomeroporphyritic aggregates of small plagioclase phenocrysts give a white, mottled appearance to the basalt. Joint planes lined with a thin film of dark green chlorite.

Core No. 6. 525-535 ft (160.0 - 163.1 m). Recovered 10 ft (3.1 m)

Fresh, dark grey, massive, medium-grained, porphyritic basalt. Patches and streaks of dark red-brown to red-brown, heavily ferruginised basalt irregularly distributed throughout - generally minor and tend to be concentrated in areas adjacent to joint planes. Joint planes lined with thin film of dark green chlorite - occasional thin veins of calcite.

Core No. 7. 625-635 ft (190.5 - 193.5 m). Recovered 10 ft (3.0 m)

Dark grey, fine to medium-grained, massive basalt - very fresh appearance. A few rare vesicles (less than 1 cm in diameter), filled with quartz and chalcedony - rare pyrite was observed in one vesicle. Small dark red-brown to red-brown heavily ferruginised patches and streaks are irregularly distributed throughout the interval - very minor - concentrated in areas adjacent to joints. Joint planes are lined with thin films of dark green chlorite and rare chalcedony.

B.M.R. Limbunya No. 1

Core No. 1. 225-235 ft (68.6 - 71.6 m). Recovered 10 ft (3 m)

225-232 ft (68.6 - 70.7 m) - massive, fine to medium-grained, dark grey basalt with overall fresh appearance. Minor dark red-brown, more highly altered basalt as tiny streaks and small patches - becoming more abundant towards the 232 ft (70.7 m) mark. A few small amygdales (approximately 5 mm in diameter) - increasing in number towards the 232 ft (70.7 m) mark - filled with quartz and chalcedony. Joint planes lined with thin films of dark green chlorite.

232-234 ft (70.7 - 71.3 m) - massive, medium to fine-grained, dark grey to dark red-brown basalt - red-brown ferruginised basalt more abundant than in 225-232 ft interval. Slightly amygdaloidal - amygdales generally less than 5 mm in diameter and filled with chlorite, calcite, quartz and chalcedony(?). Chlorite common - mainly lining joint planes.

234-235 (71.3 - 71.6 m) - dark red-brown, fine-grained, heavily altered basalt - moderately amygdaloidal. Irregularly shaped amygdales up to 5 cm in length - filled with chlorite, calcite, quartz and chalcedony(?) - chlorite common.

Core No. 2. 350-354 ft (106.7 - 107.9 m). Recovered 4 ft (1.2 m)

Massive, medium-grained, dark red-brown, moderately heavily altered (ferruginised) basalt -small patches of dark grey, fresher basalt [353-354 ft (107.6 - 107.9 m)]. Heavily jointed - joint planes lined with dark green chlorite.

Core No. 3. 775-780 ft (236.2 - 237.7 m). Recovered 5 ft (1.5 m)

Massive, medium-grained, altered basalt - an overall dark red-brown colour with numerous streaks and patches of brighter red-brown (more intensely ferruginised) basalt. Minor amounts of dark grey, massive, much fresher basalt occur around 778 ft (237.1 m). Minor jointing.

B.M.R. Limbunya No. 2

Core No. 1. 305-310 ft (93.0 - 94.5 m). Recovered 5 ft (1.5 m)

Massive, dark red-brown, medium-grained, porphyritic basalt. Tiny patches of dark green chlorite common. Minor jointing - joint planes lined with dark green chlorite.

Core No. 2. 450-460 ft (137.2 - 140.2 m). Recovered 10 ft (3 m).

Predominantly massive, medium-grained, dark grey basalt - fresh appearance. Minor red-brown "iron" stained basalt - mainly as thin, irregular streaks concentrated in areas adjacent to joints. Dark green chlorite common along joint planes. Thin layers (less than 5 mm thick) of calcite also occur along many of the joints.

B.M.R. Waterloo No. 1

Core No. 1. 100-105 ft (30.5 - 32.0 m). Recovered 5 ft (1.5 m)

Massive, medium-grained, porphyritic (small plagioclase laths), dark grey basalt - fresh appearance.

Core No. 2. 225-230 ft (68.6 - 70.1 m). Recovered 5 ft (1.5 m)

Medium-grained, dark grey to dark red-brown, massive basalt.

Core No. 3. 300-305 ft (91.4 - 93.0 m). Recovered 5 ft (1.6 m)

Dark red-brown, massive, medium-grained basalt - moderately altered appearance. Joint planes lined with dark green chlorite and thin veins of calcite.

Core No. 4. 450-451½ ft (137.2 - 137.7 m). Recovered 1½ ft (0.5 m)

Massive, fine to medium-grained, dark grey basalt with numerous red-brown patches of more heavily altered (ferruginised) basalt. Tiny patches of dark green chlorite common. Joint planes lined with dark green chlorite together with thin veins of calcite in places.

Core No. 5. 625-626½ ft (190.5 - 191.0 m). No core recovered.

APPENDIX VI

Description of Drill Cuttings - Hand Specimen

B.M.R. Delamere No. 1

Interval (feet)		Description of Cuttings
0-15 (0-4.6 m)		soil + extensively altered, massive, medium-grained, basalt - grey to pale brown in colour.
15-25 (4.6-7.6 m)	100%	basalt; extensively altered, grey, red-brown, massive, medium-grained.
25-40 (7.6-12.2 m)	100%	basalt; dark grey, medium-grained, porphyritic plagioclase phenocrysts); minor red-brown "iron" (hematite) staining in places - still fairly heavily altered.
40-45 (12.2-13.7m)	100%	basalt; dark grey, massive medium-grained, porphyritic basalt (approx. 10%). Predominantly (approx. 90%) dark brown, heavily altered, medium-grained basalt - represents a more extensively altered version of the dark grey basalt.
45-90 (13.7-27.4 m)	100%	basalt; dark grey, medium-grained, massive, porphyritic (small plagioclase phenocrysts). Ferruginised patches irregularly distributed throughout. Rare quartz lining joint planes.
90-110 (27.4-33.5 m)	100%	basalt; massive, medium-grained, pale grey, porphyritic (small plagioclase laths). Extensively altered; dark-red, "iron" staining common; tiny irregular patches of dark green chlorite fairly abundant. Minor quartz filling small cracks, joins etc. Slightly vesicular towards 110 ft (33.5 m) mark.
110-160 (33.5-48.8 m)	100%	basalt; extensively altered with abundant hematite and chlorite. Amygdaloidal - amygdales filled with quartz, prehnite and chlorite; generally <1 mm in diameter. Small supply of water between 100 ft (33.5 m) and 120 ft (36.6 m) - estimated 7 litres/min (92.4 gal/hr).

160-200 (48.8-61.0 m)	100%	basalt; pale grey-brown, extensively altered, porphyritic (small plagioclase phenocrysts); red-brown "iron" (hematite) staining common - also tiny patches of dark green chlorite. A few tiny amygdales - filled with quartz and and unidentified, soft, white mineral (zeolite?).
201-270 (61.0-82.3 m)	100%	basalt; dark grey, medium-grained, massive, porphyritic (small plagioclase laths), relatively fresh appearance; small ferruginised patches in places. Slightly contaminated by heavily altered vesicular basalt.
270-275 (82.3-83.8 m)	100%	basalt; predominantly dark grey, medium-grained, massive, porphyritic, relatively fresh. Minor finer grained, extensively altered, pale grey-brown basalt.
275-310 (83.8-94.5 m)	100%	basalt; pale grey, brown, heavily altered, mainly massive - some small amygdales filled with chlorite and, rarely, calcite. Abundant chlorite; minor quartz and prehnite. Slight increase in water supply between 275 ft (83.8 m) and 280 ft (85.3 m) - estimated <35 litres/min (462 ga/hr).
310-365 (94.5-111.3m)	100%	basalt; grey, brown, medium-grained, extensively altered with numerous patches of dark green chlorite and dark red, ferruginised basalt - porphyritic (small plagioclase phenocrysts). A few amygdaloidal chips from 310 ft (94.5 m) - 315 ft (96.0 m) (together with minor quartz), 335 ft (102.1 m) - 340 ft (103.6 m) and 360 ft (109.7 m) - 365 ft (11.3 m) intervals.
365-390 (111.3-118.9 m)	100%	basalt; relatively fresh, grey-green, massive, medium-grained, porphyritic; reddish brown "iron" staining common; minor amygdaloidal basalt between 365 ft (111.3 m) and 370 ft (112.8 m) (contamination?).

390-395 (119.9-120.4 m)	100%	basalt; extensively altered, dark reddish brown; amygdaloidal with minor chlorite and quartz. Minor massive, dark grey, porphyritic basalt.
396-420 (120.4-128.0 m)	100%	basalt; altered, mainly massive - some chips finely amygdaloidal. Minor, very extensively altered, brown, highly vesicular basalt between 400 ft (121.9 m) and 405 ft (123.4 m) with quartz and chlorite common in vesicles. Traces of fine-grained sandstone - subrounded, medium, quartz grains set in a fine-grained, white, silty matrix.
420-435 (128.0-132.6 m)	100%	basalt; brown, fine to medium-grained, massive, porphyritic - a few tiny amygdales (1 mm in diameter)-filled with chlorite. Small patches of dark green chlorite and red-brown hematite common.
435-440 (132.6-134.1 m)	98%	basalt; extensively altered, fine to medium-grained, massive, slightly porphyritic. Minor (5%) heavily altered, pale grey, slightly amygdaloidal basalt; amygdales filled with quartz and chlorite - forms a thin zone at base of flow.
	2%	sandstone; slightly hornfelsed appearance.
440-505		Mainly medium-grained, pale green, dark brown and purple siltstone containing medium to coarse, rounded quartz grains. Minor, white and dark red-brown, medium, quartz sandstone with a silty matrix - occurs as thin lenses or bars.

B.M.R. Victoria River Downs No. 1

Interval (feet)		Description of Cuttings
0-5 (0-1.5 m)	50%	soil.
	30%	basalt; dark brown, massive, heavily weathered.
	20%	limestone and chert; as loose pebbles and cobbles in soil layer; derived from overlying Montejinni Limestone.

5-10 (1.5-3.0 m)	50%	basalt; as above.
	40%	limestone; as above.
	10%	chert; as above.
10-15 (3.0-4.6m)	80%	basalt; as above.
	20%	limestone; as above.
15-20 (4.6-6.1 m)		as above; sample moist.
20-25 (5.1-7.6 m)	100%	basalt; dark brown, heavily altered, rare vesicles.
25-35 (7.6-10.7 m)	100%	basalt; dark brown, pale grey; a few small amygdales filled with dark green chlorite, quartz and chalcedony - basalt still extensively altered. Small supply of water - estimated < 7.6 litres/min (100.3 gal/hr).
35-90 (10.7-27.4 m)	100%	basalt; dark brown to grey, massive, medium-grained, extensively altered. Dark green chlorite common - as thin films along joint planes and in numerous tiny irregular patches (altered clinopyroxene?) distributed throughout the basalt.
90-115 (27.4-35.1 m)	100%	basalt; dark grey, fine-grained, slightly amygdaloidal amygdales < 3 mm/in diameter and filled with dark green chlorite; still characterised by relatively large chip size.
115-120 (35.1-36.6 m)	90%	basalt; dark grey, massive, fine-grained.
	10%	chert; white, brown and red. Water supply increased - bucket test indicated supply > 76 litres/min (1003.2 gal/hr).
120-125 (36.6-38.1 m)	60%	chert; white, grey, brown and red; finely banded.
	20%	limestone; pale brown, fine-grained, crystalline - effervesces vigorously in 10% HCl; largely replaced by chert.
	15%	basalt; dark grey, massive, fine-grained - a few dark brown chips.
	5%	calcite; colourless

125-145 (38.1-44.2 m)	98%	chert; red, grey and white, banded, numerous small, irregular cavities (<3 cm in diameter) lined with tiny quartz crystals.
	2%	limestone; occurs as thin, irregular lenses in the chert, effervesces vigorously in 10% HCl.
145-150	70%	chert; as above
(44.2-45.7 m)	30%	basalt; dark brown, massive, medium-grained, heavily altered. Large supply of water - estimated >800 litres/min (10,560 gal/hr).
150-155	30%	chert; as above.
(45.7-47.2 m)	trace	sandstone; red-brown, medium-grained, quartzose
	70%	basalt; brownish grey, massive, medium-grained, heavily altered.
155-245 (47.2-74.7 m)	100%	basalt; dark grey, massive, medium-grained; numerous tiny red streaks and dark green patches (altered ferromagnesian and opaque minerals?); relatively large chips (up to 2 cm in length); very minor, slightly amygdaloidal basalt between 180 ft (54.9 m) and 195 ft (56.4 m), 215 ft (65.5 m) and 225 ft (68.6 m).

B.M.R. Victoria River Downs No. 2

Interval (feet)		Description of Cuttings
0-20 (0-6.1 m)		Soft, heavily weathered, brown basalt gradually grading down into harder, medium-grained basalt - still heavily altered. Minor soil between 0 and 5 ft (1.5 m).
20-60 (6.1-18.3 m)		Dark red-brown, heavily altered, massive, medium-grained basalt.
60-65 (18.3-19.8 m)	70%	basalt; grey, fine-grained, massive with numerous red-brown, more heavily altered patches - passes into a thin zone of grey, extensively altered, moderately amygdaloidal basalt - amygdales <5 mm in diameter and filled mainly with dark green chlorite.
	25%	sandy siltstone; pale brown to buff, medium-grained, quartzose, compact.
	5%	limestone; white, cream and buff, crystalline, effervesces vigorously in 10% HCl.

65-70 (19.8-21.3 m)		White, cream and buff, crystalline <u>limestone</u>. Rare red <u>chert</u>.
70-75 (21.3-22.9 m)	10%	<u>limestone</u>; as above - rare red and grey <u>chert</u>.
	90%	<u>basalt</u>; grey to dark red-brown, very extensively altered, moderately vesicular.
75-80 (22.9-24.4 m)	100%	<u>basalt</u>; as above.
80-100 (24.4-30.5 m)		Dark grey and dark red-brown <u>basalt</u> - heavily altered, fine to medium-grained. A few tiny vesicles between 80 ft (24.4 m) and 85 ft (25.9 m).
100-195 (30.5-59.4 m)		Massive, medium-grained, dark red-brown, altered basalt - rare quartz along joint planes, cracks etc. Relatively fresh appearance from 150 ft (45.7 m) downwards.
195-200 (59.4-61.0 m)		Similar to above for the first 3 ft (1 m) or so - then changes to red-brown, heavily altered <u>basalt</u> heavily jointed (chips relatively large and blocky). Marked increase in the rate of drilling.
200-205 (61.0-62.5 m)	95%	<u>basalt</u>; heavily altered, moderately to highly amygdaloidal with relatively abundant chlorite and quartz (chiefly lining small geodes and filling amygdales). A few large chips (up to. 2.5 cm in length) of only slightly amygdaloidal, heavily alter, red-brown basalt.
	5%	<u>sandstone</u>; pale brown, fine-grained. Good supply of water between 200 ft (61.0 m) and 205 ft (62.5 m) - bucket test indicated supply 226.2 litres/min (3000 gal/hr).
205-220 (62.5-67.1 m)		Pale grey, heavily altered, amygdaloidal <u>basalt</u> - amygdales 5 mm in diameter and often filled with chlorite; rarely quartz. Basalt becoming increasingly massive with depth.
220-230 (67.1-70.1 m)		Heavily altered, red-brown, massive <u>basalt</u> with numerous small, dark grey patches - still some slightly amygdaloidal chips.

230-280 (70.1-85.3 m)	Massive, medium-grained, red-brown <u>basalt</u> - heavily altered appearance - tiny patches and streaks of dark green chlorite relatively common. Minor bright red-brown ferruginised basalt. Basalt becoming fresher with depth.
280-285 (85.3-86.9 m)	Similar to above - grades into moderately amygdaloidal basalt over 1 ft (30 cm) or so - amygdales generally <5 mm in diameter and filled with chlorite, calcite and quartz (rare).
285-350 (86.9-106.7 m)	Grey, heavily altered, moderately amygdaloidal <u>basalt</u> - amygdales filled with chlorite, calcite and quartz. Patches of red-brown, more highly altered (ferruginised) basalt. Dark green chlorite also common.
350-360 (106.7-109.7 m)	Dark red-brown, medium-grained, massive, porphyritic basalt; tiny patches of chlorite common; minor calcite.
360-390 (109.7-118.9 m)	Mainly grey to dark red-brown, fine to medium-grained, heavily altered, moderately amygdaloidal basalt - amygdales generally <5 mm in diameter and filled with chlorite and minor calcite and quartz?; very minor fine-grained, pale grey, massive, porphyritic basalt between 360 ft (109.7 m) and 365 ft (11.3 m).
390-415 (118.9-126.5 m)	Dark red-brown, massive, medium-grained basalt with dark grey, less altered patches.
415-420 (126.5-128.0 m)	Similar to above - somewhat finer grained, porphyritic - a few slightly vesicular fragments.
420-495 (128.0-150.9 m)	Dark red-brown, heavily altered, fine-grained <u>basalt</u> - moderately amygdaloidal - amygdales approx. 5 mm in diameter and filled with chlorite, quartz and minor amethyst, smoky quartz and pyrite. Passed through a number of geodes the walls of which are lined with a very thin inner film of chlorite, followed by an outer lining of tiny quartz crystals with minor pyrite. Numerous large fragments up to 3 cm across. Basalt becoming increasingly massive from 480 ft(146.3 m) downwards.

495-560 (150.9-170.7 m)		Dark red-brown, massive, medium-grained, heavily altered basalt; patches of dark grey, less altered basalt. Grades into slightly amygdaloidal basalt between 550 ft (167.6 m) and 560 ft (170.7 m).
560-565 (170.7-172.2 m)	70%	basalt; heavily altered, slightly to moderately amygdaloidal - amygdales filled mainly with chlorite.
	25%	chert; red and white.
	5%	sandstone; pale grey-green, fine-grained.
565-575 (172.2-175.3m)	10%	chert; as above.
	90%	basalt; grey to dark red-brown, heavily altered, moderately amygdaloidal.
575-666 (175.3-203.0 m)		Mainly massive, dark grey to dark red-brown, medium-grained, altered basalt. Tiny specks of pyrite(?) in some of the chips between 580 ft (176.8 m) and 585 ft (178.3 m). Minor contamination. Minor heavily altered, pale grey basalt from 595 ft (181.4 m) to 600 ft (182.9 m) interval. Mainly relative fresh, dark grey basalt from 635 ft (193.5 m) to 666 ft (203.0 m) interval.
666-745 (203.0-227.1 m)		Mixture of dark grey, massive, medium-grained basalt and dark red-brown, more highly altered (ferruginised) basalt. Minor finely amygdaloidal, red-brown basalt. Pale grey basalt between 720 ft (219.5 m) and 745 ft (227.1 m). Slight contamination.
745-750 (227.1-228.6 m)	30%	basalt; mainly massive, medium-grained, dark grey. Minor dark red-brown, slightly amygdaloidal basalt.
	70%	siltstone; purple-brown, micaceous; minor white and pale green siltstone.
750-800 (228.6-243.8 m)		Purple-brown and pale olive-green, micaceous siltstone.

B.M.R. Victoria River Downs No. 3

Interval (feet)		Description of Cuttings
0-20 (0-6.1 m)		Heavily weathered, dark brown basalt - minor soil between 0 and 5 ft (1.5 m).
20-40 (6.1-12.2 m)		Massive, fine to medium-grained, pale grey basalt - extensively altered. Minor contamination.
40-90 (12.2-27.4 m)	100%	basalt; dark grey, massive, medium-grained - streaks and patches of red-brown, ferruginised basalt common.
90-105 (27.4-32.0 m)	100%	basalt; mixture of dark grey or red brown basalt and more extensively altered, red-brown basalt as relatively large, rounded fragments (up to 2.5 cm across).
105-185 (32.0-56.4 m)	100%	basalt; dark grey massive, medium-grained - patches and streaks of red-brown altered basalt. Grainsize slightly finer from 175 ft (53.5 m) downwards.
185-190 (56.4-57.9 m)	60%	basalt; dark red-brown, massive, fine to medium-grained.
	40%	limestone; dark grey and brown, partly replaced by chert.
190-240 (57.9-73.2 m)	100%	basalt; grey and dark red-brown, heavily altered, fine-grained, amygdaloidal - amygdales filled with soft, white, chalky mineral and minor calcite. Basalt becoming more massive with depth - only slightly amygdaloidal between 190 ft (57.9 m) and 200 ft (61.0 m).
240-300 (73.2-91.4 m)	100%	basalt; dark grey to dark red-brown, massive, fine to medium-grained, altered. Ferruginised patches common in places.

B.M.R. Wave Hill No. 1

Interval (feet)		Description of Cuttings
0-10 (0-3.0 m)	40%	soil.
	40%	chert; white and grey, large angular fragments.
	20%	limestone; white, cream and buff, crystalline.
10-15 (3.0-4.6 m)	75%	limestone; white to cream fine-grained, crystalline.
	20%	chert; grey, massive, relatively large angular fragments (2 cm in length).
	5%	siltstone; red-brown, calcareous.
15-35 (4.6-10.7 m)	80%	limestone; white to cream, fine-grained, crystalline.
	20%	chert; grey, massive.
35-40 (10.7-12.2 m)	50%	limestone; as above.
	20%	chert; grey, massive.
	30%	basalt; dark red-brown, very soft, heavily weathered.
40-55 (12.2-16.8 m)	80%	basalt; brown, soft, massive, heavily weathered.
	20%	limestone and chert; as above (contamination).
55-65 (16.8-19.8 m)	100%	basalt; dark red-brown, massive, medium-grained.
65-80 (19.8-24.4 m)	100%	basalt; dark grey, massive, fine to medium-grained. Small supply of water between 75 ft (22.9 m) and 80 ft (24.4 m) - supply estimated <7.6 litres/min (100 gal/hr).
80-110 (24.4-33.5 m)	95%	basalt; dark grey, massive, medium-grained; tiny patches of dark green chlorite fairly common.
	5%	limestone and chert; as above - contamination.
110-158 (33.5-48.2 m)	95%	basalt; dark grey, dark brown, red-brown, massive, medium-grained.
	5%	limestone and chert; as above - contamination.

158-175 (48.2-53.3 m)	85%	basalt; dark grey, moderately amygdaloidal - amygdales generally 5 mm in diameter and filled mainly with dark green chlorite; deep red-brown ferruginised patches fairly common.
	10%	sandstone; pale grey, fine-grained, quartzose - occurs intermixed with the amygdaloidal basalt.
	5%	limestone and chert; as above -contamination.
175-185 (53.3-56.5 m)	100%	basalt; mixture of moderately amygdaloidal basalt and massive basalt.
	trace	limestone and chert; as above - contamination.
185-249 (56.5-75.9 m)	95%	basalt; massive, dark grey with dark red-brown patches of ferruginised basalt. A few tiny amygdales between 195 ft (59.4 m) and 200 ft (61.0 m).
	5%	limestone and chert; as above - contamination.
249-265 (75.9-80.8 m)	100%	basalt; dark grey, purplish brown, fine-grained, altered, moderately amygdaloidal - amygdales generally 5 mm in diamater and filled with chlorite, quartz and calcite.
	trace	limestone and chert; as above - contamination.
265-270 (80.8-82.3 m)	100%	basalt; mixture of amygdaloidal basalt and massive, medium-grained, dark grey, slightly ferruginised basalt.
270-310 (82.3-94.5 m)	95%	basalt; dark grey with minor red-brown "iron" staining, massive, medium-grained. A few small amygdales and minor quartz from the 275 ft (83.8 m) to 285 ft (86.9 m) and 290 ft (88.4 m) to 310 ft (94.5 m) intervals; joint planes often lined with thin film of dark green chlorite.
	5%	limestone and chert; as above - contamination.
310-340 (94.5-103.6 m)	95%	basalt; predominantly dark grey, massive, medium-grained basalt containing numerous tiny dark green patches of chlorite (altered ferromagnesian minerals?); minor dark red-brown ferruginised basalt; joint planes lined with thin coating of dark green chlorite.
	5%	limestone and chert; as above - contamination.

340-350 (103.6-106.7 m)	95%	basalt; dark grey, fine-grained, extensively altered, amygdaloidal; abundant dark green chlorite and minor quartz. Contaminated with massive, medium-grained basalt from overlying flow.
	3%	sandstone; pale grey, fine-grained, quartzose; occurs filling vesicles.
	2%	limestone and chert; as above - contamination.
350-365 (106.7-111.3 m)	100%	basalt; dark grey, medium-grained, mainly massive - a few small amygdales; scarce quartz, chalcedony and agate.
	trace	limestone and chert; as above - contamination.
365-420 (111.3-128.0 m)	98%	basalt; dark grey, massive, medium-grained, relatively fresh appearance, patches of red-brown to dark purplish brown, ferruginised basalt common. Scarce quartz (contamination).
	2%	limestone and chert; contamination.
420-425 (128.0-129.5 m)	100%	basalt; grey, fine-grained, altered basalt, slightly to moderately amygdaloidal - amygdales generally 1 cm in diameter. Minor quartz, chalcedony, calcite and chlorite (vesicle fillings). Minor dark grey to brownish red, massive basalt similar to that from 415 ft (126.5 m) to 420 ft (128.0 m) interval.
425-430 (129.5-131.1 m)	60%	Dark grey, red-brown, altered, amygdaloidal basalt with minor quartz, chalcedony, chlorite and calcite.
	40%	sandstone; dark red-brown, fine-grained, quartzose; characterized by a bimodal quartz distribution; silty matrix.
430-470 (131.1-143.3 m)		sandstone; as above; minor pale grey, white and brown fine-grained sandstone. Minor contamination (limestone, chert and basalt).
470-490 (143.3-149.4m)		sandstone; similar to above, very friable. Minor contamination (principally basalt).

490-540 (149.4-164.6 m)		Fine, brown sand; heavy mineral fraction present. A few chips of white, grey and brown, fine-grained, silicified sandstone. Minor blue-green silty sandstone with a bimodal quartz distribution.

B.M.R. Limbunya No. 1

Interval (feet)		Description of Cuttings
0-20 (0-6.1 m)	100%	limestone; cream to buff, fine-grained, crystalline.
20-33 (6.1-10.6 m)	100%	basalt; very heavily weathered, red-brown, soft, amygdaloidal.
33-105 (10.1-32.0 m)	80%	agglomerate; mixture of dark-red, brown, heavily altered, relatively soft volcanic detritus - mainly massive but often slightly to moderately amygdaloidal and pale grey, extensively altered, massive, fine-grained basalt. Minor chlorite, quartz and calcite in small veins and filling amygdales.
	15%	sandstone; brown, medium-grained, friable, quartzose; minor feldspar; silty matrix - occurs as thin lenses, scattered throughout the sequence. Small supply of water between 40 ft (12.2 m) and 45 ft (13.7 m) (not continuous). Bit dropped approx. 18 in ($\frac{1}{2}$ m) between 40 ft (12.2 m) and 45 ft (13.7 m) accompanied by temporary loss of circulation. Some quite large fragments (up to 5 cm across) from around this interval displaying what is possibly crude bedding. The fragments are mainly fine-grained, very heavily altered, relatively soft, basalt. One relatively large specimen consists of a subrounded, heavily altered fragment of vesicular basalt set in a sandstone matrix.
	5%	limestone; contamination. Chips moist from 80 ft (24.4 m) downwards.
105-150 (32.0-45.7 m)	100%	basalt; dark brown, medium-grained, massive, altered - thin films of dark green chlorite often occur along joint planes, also rare pyrite. Small supply of water between 130 ft (39.6 m) and 135 ft (41.1 m) - estimated to be $<$15 litres/min (200 gal/hr)

150-225 (45.7-68.6 m)	100%	basalt; fresh, dark grey, massive, medium-grained - minor ferruginisation. Minor chlorite as thin coating along joint planes. Relatively large chips.
	trace	agglomerate; contamination
235-240 (71.6-73.2 m)	100%	basalt; extensively altered, dark grey to red-brown, amygdaloidal - amygdales range from 2 mm to 1.5 cm in diameter - filled mainly with quartz.
240-250 (73.2-76.2 m)	90%	basalt; dark grey to red-brown, extensively altered, highly amygdaloidal-amygdales filled with quartz and chlorite.
	10%	siltstone; pale brown, fine-grained.
250-260 (76.2-79.2 m)	100%	basalt; heavily altered, dark red-brown, slightly to moderately amygdaloidal - chlorite relatively common, rare quartz.
260-290 (79.2-88.4 m)	100%	basalt; dark grey, medium-grained, massive; ferruginised patches common. A few small amygdales, mainly filled with chlorite. Minor chlorite and rare calcite - often occur as thin catings along joint planes.
290-365 (88.4-111.3 m)	100%	basalt; fresh, dark grey, medium-grained, massive - ferruginised patches.
	trace	agglomerate; contamination.
365-380 (111.3-115.8 m)	100%	basalt; dark to light grey, fine to medium-grained, ferruginised patches common, slightly to moderately amygdaloidal - amygdales filled with dark green chlorite and calcite.
380-500 (115.8-152.4 m)	100%	basalt; fresh, dark grey, fine to medium-grained, massive, slightly ferruginised. Minor chlorite and calcite. Several chips from the 380 ft (115.8 m) to 395 ft (120.4 m) interval contain small patches (5 mm in diameter) of coarse-grained, dark purplish red, pegmatitic basalt. Minor dark green chlorite and calcite lining joint planes. Moderately amygdaloidal basalt from the 390-415 ft (118.9-126.5 m) and 430-535 ft (131.1-132.6 m) intervals. Slight contamination.

500-513 (152.4-156.4 m)	100%	basalt; dark brown and grey, massive, tiny patches of dark green chlorite common (altered ferromagnesian minerals?) - a few small amygdales filled with pink chalcedony and chlorite. Ferruginised patches common.
513-545 (156.4-166.1 m)	100%	basalt; soft, heavily altered, dark brown to red-brown, vesicular basalt - vesicles generally <5 mm in diameter - often lined and filled with chlorite and chalcedony. The basalt becomes more massive and harder with depth.
545-560 (166.1-170.7 m)	100%	basalt; pale greyish brown, extensively altered, slightly amygdaloidal; chlorite common - filling small vesicles and replacing ferromagnesian minerals.
560-565 (170.7-172.2 m)	100%	basalt; grey, massive, fine-grained - commonly ferruginised.
565-570 (172.2-173.7 m)	100%	basalt; mixture of massive basalt similar to above and soft, pale grey-brown, moderately vesicular basalt.
570-600 (173.7-182.9 m)	100%	basalt; pale grey to dark red-brown, extensively altered, moderately to highly vesicular, basalt - vesicles often lined and filled with pale green chlorite and rare chalcedony. Slightly contaminated with massive basalt from higher up hole.
600-635 (182.9-193.5 m)	100%	basalt; mixture of dark red-brown, highly vesicular basalt and pale grey, more massive (only slightly - moderately vesicular) basalt - both types extensively altered with chlorite relatively common. Rare quartz. Slight amount of contamination (limestone).
635-650 (193.5-198.1 m)	60%	basalt; pale grey, massive to moderately vesicular basalt together with dark red-brown highly vesicular basalt - chlorite very common.
	40%	limestone(?); white and pink, effervesces vigorously in 10% HCl, partly replaced by chert.

650-655 (198.1-199.6 m)	100%	basalt; dark red-brown, heavily altered, fine-grained, only slightly vesicular. Minor calcite and chlorite filling vesicles and lining joint planes.
655-660 (199.6-201.2 m)	100%	basalt; dark red-brown, mainly massive, fine to medium-grained - still a few vesicles (up to 1 cm in diameter); minor chlorite and rare calcite.
660-790 (201.2-240.8 m)	100%	basalt; massive, dark red-brown, medium-grained; minor chlorite - mainly lining joint planes. A few rare amygdales, filled with chlorite and calcite. Patches of dark grey, fresh basalt.
790-1000 (240.8-304.8 m)		Mainly dark grey, fresh basalt - patches of dark red-brown ferruginised basalt.

B.M.R. Limbunya No. 2

Interval (feet)		Description of Cuttings
0-30 (0-9.1 m)		Mainly soil and very heavily weathered, soft, pale brown to dark red-brown basalt.
30-35 (9.1-10.7 m)		Massive, fine to medium-grained, light grey basalt - heavily altered.
35-40 (10.7-12.2 m)	100%	basalt; soft, light grey to brown, massive, very heavily altered.
40-45 (12.2-13.7 m)	100%	basalt; red-brown, very heavily altered, vesicular. Minor quartz and prehnite(?). Good supply of water - bucket test indicated supply 227 litres/min (3000 gal/hr).
45-65 (13.7-19.8 m)	100%	basalt; soft, red-brown, very heavily altered - mainly massive.
65-75 (19.8-22.9m)	100%	basalt; dark red-brown, massive, heavily altered, fine to medium-grained - numerous tiny, irregular patches and streaks of dark green chlorite. Minor, soft, brown, heavily altered, finely vesicular basalt (contamination?).

75-90 (22.9-27.4 m)	100%	basalt; heavily altered, red-brown, moderately vesicular - vesicles (up to 1.5 cm in diameter) generally lined and often filled with dark green chlorite - more rarely prehnite. Chips contain numerous tiny patches and streaks of dark green chlorite. Mainly massive basalt from 85 ft (25.9 m) to 90 ft (27.4 m).
90-150 (27.4-45.7 m)	100%	basalt; red-brown, massive, medium-grained, extensively altered (ferruginised) with numerous tiny patches of dark green chlorite. Chlorite also occurs along joint planes. Slight vesicular in places.
150-180 (45.7-54.9 m)	100%	basalt; dark red-brown, massive, medium-grained basalt - commonly ferruginised.
180-185 (54.9-56.4 m)	100%	basalt; red-brown, massive, medium to fine-grained - grades down into red-brown, fine-grained, heavily altered, moderately amygdaloidal basalt - amygdales filled with chlorite, prehnite, calcite and quartz with chlorite predominant.
185-200 (56.4-62.5 m)	100%	basalt; heavily altered, amygdaloidal basalt - amygdales filled with chlorite, calcite, prehnite, quartz, chalcedony and rare zeolite(?). Basalt fairly massive from 200 ft (61.0 m) to 205 ft (62.5 m).
200-210 (62.5-64.0 m)	100%	basalt; dark red-brown, medium-grained, massive; chlorite common - mainly lining cracks and joint planes. A few slightly vesicular chips.
210-245 (64.0-74.7 m)		Moderately amygdaloidal basalt - red-brown, fine-grained contains numerous small vesicles (generally <5 mm in diameter) filled with dark green chlorite and quartz. Basalt gradually becoming more massive from 230 ft (70.1 m) downwards. Thin films of chlorite often occur along joint planes.

245-340 (74.7-105.2 m)	100%	basalt; dark red-brown, massive, medium-grained. Minor chlorite and rare calcite as thin coatings along joint planes. Patches of grey, less altered (ferruginised) basalt.
340-550 (105.2-167.6 m)		Predominantly fresh, dark grey, medium-grained, massive basalt - streaks and patches of dark red-brown and relatively bright brownish red (ferruginised) material irregularly distributed. A few chips of coarse-grained pegmatitic basalt from 370-375 ft (112.8-114.3 m) interval. Rare, small amygdales (filled with chlorite and calcite) between 410 ft (125.0 m) and 420 ft (128.0 m) and 520 ft (158.5 m) and 525 ft (160.0 m).
550-580 (167.6-176.8 m)	100%	basalt; grey, massive, fine to medium-grained, very fresh appearance.
580-585 (176.8-178.3 m)		Predominantly fine-grained, pale grey, fresh basalt with rare amygdales (filled with quartz). Minor dark reddish brown, fine to medium-grained, massive basalt.
585-590 (178.3-179.8 m)	40%	basalt; pale grey to dark grey, massive, fine-grained, porphyritic.
	5%	basalt; bleached - pale greyish brown, very fine-grained (base of flow?).
	55%	siltstone; white, coarse-grained.
590-595 (179.8-181.4 m)	85%	siltstone; as above - some of the chips possess a faint blue colouration - chrysocolla?
	15%	basalt; contamination.
595-600 (181.4-182.9m)	90%	siltstone; as above.
	10%	basalt; contamination
600-610 (182.9-185.9 m)	90%	siltstone; white and pale red-brown, calcareous (vigorous effervescence in 10% HCl).
	5%	sandstone; fine-grained, pale grey, silty matrix.
	5%	basalt; contamination.
610-625 (185.9-190.5 m)	80%	basalt; pale grey, relatively soft, heavily altered, amygdaloidal. Minor clear calcite and pink chalcedony.
	20%	siltstone; as above.

625-630 (190.5-192.0 m)	80%	basalt; grey, massive, fine-grained, slightly amygdaloidal.
	20%	sandstone; pale grey to pale brown, medium-grained, calcareous.
630-645	90%	basalt; as above.
(192.0-196.6m)	10%	sandstone; contamination? Slight increase in water supply between 630 ft (192.0 m) and 635 ft (193.6 m).
645-655 (196.6-199.6 m)	100%	basalt; grey, to dark red-brown, massive, medium-grained.
655-680 (199.6-207.3 m)	100%	basalt; pale grey, reddish brown, pale brown, fine-grained, moderately amygdaloidal with minor calcite and chlorite. Slight contamination.
680-740 (207.3-225.6 m)		Grey - dark red-brown, mainly massive, medium-grained basalt containing relatively large pink phenocrysts of plagioclase. Small patches of dark green chlorite common. Several chips are slightly amygdaloidal - amygdales filled with calcite and chlorite.
740-800		Fresh, dark grey, medium-grained, massive basalt - minor ferruginisation. Some contamination.

B.M.R. Waterloo No. 1

Interval (feet)	Description of Cuttings
0-30 (0-9.1 m)	Red-brown, heavily altered, fine-grained, moderately vesicular basalt - rare calcite (in vesicles). Minor soil from 0-1 ft (0-0.3 m).
30-60 (9.1-18.3 m)	Red-brown, fine-grained, heavily altered, basalt - a few small amygdales (often filled with chlorite).
60-150 (18.3-45.7 m)	Massive, red-brown, medium-grained, heavily altered basalt - tiny patches rich in dark green chlorite and dark red hematite 145 ft and 150 ft (44.2-45.7 m) - supply estimated to be 227 litres/min (3000 gal/hr).

150-155 (45.7-47.2 m)		Mixture of massive, fine-grained, extensively altered, red-brown basalt and relatively soft, red-brown, extensively altered, amygdaloidal basalt - amygdales filled with chlorite, calcite and quartz.
155-165 (47.2-50.3 m)		Similar to above - massive basalt characterized by relatively large chip size. Some contamination.
165-180 (50.3-54.9 m)		Dark red-brown, heavily altered, slightly amygdaloidal basalt - amygdales filled with chlorite and quartz. Tiny patches of dark green chlorite common in the massive basalt.
180-305 (54.9-93.0 m)	100%	basalt; dark red-brown, massive, extensively altered, medium-grained. Scarce chlorite and quartz lining cracks and joint planes. Minor amounts of dark grey, fresher material.
305-310 (93.0-94.5 m)		Mixture of massive, dark-brown, fine to medium-grained, slightly vesicular and heavily altered, red-brown, amygdaloidal basalt with minor calcite and chlorite.
310-330 (94.5-100.6 m)		Dark red-brown, heavily altered, amygdaloidal basalt; chlorite, calcite and quartz occur filling amygdales and as thin films lining joint planes, cracks etc.
330-370 (100.6-112.8 m)	100%	basalt; dark red-brown, massive, medium-grained, ferruginised. Tiny patches of dark green chlorite common; rare quartz.
370-375 (112.8-114.3 m)		Mixture of extensively altered, massive dark red-brown, medium-grained basalt and minor moderately amygdaloidal basalt - amygdales filled with chlorite and quartz.
375-390 (114.3-118.9 m)		Extensively altered, red-brown, amygdaloidal basalt. Chlorite relatively common, minor calcite and quartz - mainly filling amygdales.

390-400 (118.9-121.9 m)		Basalt becoming more massive - pale grey, heavily altered, slightly to moderately amygdaloidal - amygdales filled with chlorite and more rarely quartz, agate and chalcedony. Thin films of quartz and chlorite occur along joint planes, cracks etc.
400-415 (121.9-126.5 m)	100%	basalt; pale grey, massive, fine to medium-grained, fairly heavily altered. A few slightly vesicular chips. Very minor quartz lining cracks etc.
415-430 (126.5-131.1 m)		Dark red-brown basalt.
430-455 (131.1-138.7 m)		Mixture of dark grey, relatively fresh and more altered dark red-brown, ferruginised basalt. The ferruginised basalt occurs as irregularly distributed patches, streaks throughout the interval.
455-460 (138.7-140.2 m)		Mixture of massive, mainly dark grey basalt and softer, heavily altered, red-brown vesicular basalt with minor quartz filling vesicles.
460-490 (140.2-149.4 m)		Soft, pale grey and dark red-brown, heavily altered, highly amygdaloidal basalt. Quartz and blue-green chlorite very common; very minor calcite. In some intervals quartz makes up approx. 50% of the sample (presumably filling small geodes).
490-510 (149.4-155.4 m)		Massive, grey basalt - heavily altered appearance - some chips slightly vesicular from 490-495 ft (149.4-150.9 m) interval. Minor quartz (contamination).
510-515 (155.4-157.0 m)		Mixture of basalt similar to that from 490-510 ft interval and dark red-brown, extensively altered, highly amygdaloidal basalt - quartz and chlorite common in amygdales.
515-525 (157.0-160.0 m)		Heavily altered, dark red-brown amygdaloidal basalt - quartz and calcite common. Contaminated with more massive, grey basalt.

525-530 (160.0-161.5 m)	Heavily altered, grey to dark red-brown basalt - slightly amygdaloidal.
530-535 (161.5-163.1 m)	Extensively altered, dark red-brown, highly amygdaloidal basalt - amygdales filled with mainly chlorite - minor calcite.
535-550 (163.1-167.6 m)	Mainly grey, fine to medium-grained, slightly amygdaloidal basalt. Minor amounts of red-brown, more heavily altered, ferruginised basalt.
550-560 (167.6-170.7 m)	Heavily altered, massive, grey basalt - tiny patches of dark green chlorite common - chlorite also occurs as thin films along joint planes etc. Minor amount of red-brown, more altered basalt.
560-620 (170.7-189.0 m)	Red-brown, heavily altered, fine to medium-grained basalt - a few small quartz-filled amygdales between 560 and 570 ft (170.7-173.7 m). Minor quartz and chlorite along jointplanes.
620-650 (189.0-198.1 m)	Dark grey, massive, medium-grained basalt with dark red-brown, ferruginised patches. Decrease in grainsize between 640-650 ft (195.1-189.1 m).
650-666 (198.1-203.0 m)	Relatively soft, red-brown, extensively altered, highly amygdaloidal basalt - chlorite relatively common; minor quartz.
666-680 (203.0-207.3 m)	Basalt becoming more massive- mixture of pale grey, heavily altered, fairly massive basalt containing numerous tiny spots and streaks of dark green chlorite and red-brown, amygdaloidal basalt.
680-705 (207.3-214.9 m)	Heavily altered, medium-grained, grey to red-brown basalt; slightly-moderately amygdaloidal, blue-green chlorite and quartz relatively common.
705-710 (214.9-216.4 m)	Dark red-brown, very extensively altered, fine-grained, highly amygdaloidal basalt - amygdales generally 5 mm in diameter - appear to be filled with mainly blue-green chlorite(?) and rare calcite.

710-715 (216.4-217.9 m)	80%	basalt; dark brown, heavily altered, moderately amygdaloidal - amygdales generally 5 mm in diameter and filled mainly with chlorite - also rare calcite.
	20%	siltstone; white to creamy, fine-grained, friable, quartzose.
715-720 (217.9-219.5m)	90%	basalt; as above.
	10%	siltstone; as above.
720-725 (219.5-221.0 m)		Heavily altered, fine to medium-grained, dark red-brown basalt - slightly amygdaloidal.
725-745 (221.0-227.1 m)		Pale grey, fine to medium-grained basalt - heavily altered - a few chips still slightly amygdaloidal but mainly massive.
745-770 (227.1-234.7 m)		Dark red-brown, heavily altered basalt - moderately to highly amygdaloidal. Minor chlorite and and rare calcite.
(234.7-242.3 m)		Dark red-brown, heavily altered basalt - fine-grained, mainly massive - a few small amygdales.
(242.3-269.7 m)		Small patches of fresher, dark grey basalt. Fine to medium-grained, fresh, dark grey, massive basalt containing small, irregular, ferruginised streaks, patches etc. - generally very minor. Specks of native copper in massive basalt in 800-805 ft (243.8-245.4 m) interval.

B.M.R. Waterloo No. 2

Interval (feet)		Description of Cuttings
0-20 (0-6.1 m)		Massive, fine-grained basalt - reddish brown colour, fairly heavily altered; some slightly vesicular chips. Minor soil between 0 and 5 ft (0-1.5 m).
20-180 (6.1-54.9 m)	100%	basalt; dark grey, massive, fine to medium-grained; very minor ferruginised basalt.
180-185 (54.9-56.4 m)	95%	basalt; bulk of sample similar to above - a few slightly vesicular heavily altered chips.
	5%	sandstone; brown, medium-grained, quartzose.

185-195 (56.4-59.4 m)		Predominantly cream brown, dark red-brown, medium-grained, quartzose sandstone - friable (bulk of sample consists of loose sand). Contaminated with basalt chips.
195-200 (59.4-61.0 m)	100%	sandstone; as above. Small supply of water - 7.6 litres/min (100 gal/hr).
200-205 (61.0-62.5 m)	50%	sandstone; light brown, dark reddish brown, medium-grained.
	50%	basalt; dark grey to red-brown, extensively altered, mainly massive - some chips slightly vesicular.
205-235 (62.5-71.6 m)	100%	basalt; dark red-brown, extensively altered, moderately amygdaloidal - amygdales filled with dark green chlorite, prehnite and calcite.
235-250 (71.6-76.2 m)	100%	basalt; dark grey, dark red-brown, fine to medium-grained, a few small amygdales.
250-480 (76.2-146.3 m)	100%	basalt; dark grey massive, medium-grained; minor calcite and chlorite lining cracks and joint planes. Minor ferruginisation. Small specks of native copper in chips from 405-415 ft (123.4-126.5 m) interval.
480-485 (146.3-147.8 m)	90%	basalt; mainly fresh, dark grey, massive fine to medium-grained basalt - a few slightly amygdaloidal chips. Minor, extensively ferruginised basalt - dark grey - dark brown.
	10%	sandstone; pale grey, pale brown, fine to medium-grained, indurated.
485-490 (147.8-149.4m)	50%	sandstone; as above.
	50%	basalt; dark grey, dark red-brown, heavily altered, amygdaloidal (fine amygdales) - chlorite common.
490-495 (149.4-150.9m)	70%	basalt; dark grey - similar to above.
	30%	sandstone; as above.
495-510 (150.9-155.4 m)		Grey - dark red-brown basalt; altered, fine amygdales in some chips but mainly massive. Rare sandstone between 495 and 500 ft (150.9 and 152.4 m) - contamination.

510-520 (155.4-158.5 m)	100%	basalt; mainly grey, fine-grained, massive, minor dark red-brown, more heavily altered basalt as small irregular, ferruginised patches and streaks.
520-540 (158.5-164.6 m)		Mixture of dark grey, fine to medium-grained, massive basalt and heavily altered, red-brown, vesicular basalt - vesicles generally 5 mm in diameter and lined with pale green chlorite and calcite.
540-640 (164.6-195.1 m)	100%	basalt; fresh, dark grey, fine to medium-grained, massive, ferruginisation. Minor rare red-brown, vesicular basalt between 540 ft (164.6 m) and 545 ft (166.1 m) - contamination.
640-645 (195.1-196.6 m)	80%	basalt; mixture of fresh, dark grey, fine-grained, massive basalt and pale grey, heavily altered, slightly amygdaloidal basalt - amygdales filled with dark green chlorite.
	20%	sandstone; cream, light brown, fine-grained, quartzose.
645-675 (196.6-205.7 m)		Pale grey, heavily altered basalt - a number of slightly vesicular chips. Scarce sandstone (probably contamination).
675-680 (205.7-207.3 m)	90%	basalt; mixture of pale grey, massive, heavily altered basalt and dark grey, massive, relatively fresh basalt (contamination?) - very similar to basalt from the overlying flow.
	10%	sandstone; brown, medium-grained, quartzose, friable.
680-685 (207.3-208.8 m)	95%	basalt; grey - dark reddish brown, heavily altered, slightly vesicular.
	5%	sandstone; as above.
685-690 (208.8-210.3 m)	100%	basalt; similar to above, moderately amygdaloidal - amygdales filled with quartz and chlorite.
690-700 (210.3-213.4 m)		Mainly dark grey, massive, medium-grained basalt, a few amygdales - filled with chlorite, quartz and agate.
700-725 (213.4-221.0 m)		Massive, medium-grained, dark grey basalt - ferruginised patches.

APPENDIX VII

List of Measurements in the British System of Weights and Measures and their Equivalents in the Metric System

1 inch (in)	=	2.54 centimetres (cm)
1 foot (ft)	=	0.3048 (m)
3.2808 feet	=	1 metre
100 feet	=	30.4800 metres
500 feet	=	152.400 metres
1000 feet	=	304.800 metres
2 gallons/hour (gal/hr)	=	0.07572 litres/minute (litres/min)
13.2 gal/hr	=	1 litre/min.