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GEOLOGICAL INVESTIGATIONS OF THE A.B.C. URANIUM RESERVATION, NEAR KATHERINE, NORTHERN TERRITORY

by

D.E. Gardner and J. Rade

DARWIN. N.T.

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C O N T E N T S   Page

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C O N T E N T S

(continued)

SUMMARY

The A.B.C. Reservation embraces the south-eastern end of an elongated basin of broadly folded Upper Proterozoic sandstones and interbedded volcanics. It is intersected by two major regional faults, which trend approximately north-east and by several lesser faults with about the same trend. The southern part of the area is divided into several displaced blocks bounded by strike faults and by transverse faults which trend east to north-east.

The Upper Proterozoic Rocks have been named the A.B.C. Group in reference to the A.B.C. Uranium Prospect which occurs within them. They consist of three sandstone members A, C, and E whose thicknesses are approximately 2900, 1500 and 1000 feet, and two basic volcanic members, the B member, 800 feet thick, and the D member, which is only about 30 feet thick in the southern part of the structural basin. The A-Member is the oldest.

Three uranium prospects have been found, all in the B-Member, and they occur within or near a bed of fine-grained siliceous tuff about 10 feet thick.

Of these, the A.B.C. Prospect, which occurs within the tuff near a regional fault, has been proved to be a small but high grade uranium deposit. Extensions of this deposit down the dip of the ore body have been uplifted in fault blocks to the north and have been largely if not entirely removed by erosion. Any search for remnants of the ore body would necessitate close drilling through alluvium 20 to 34 feet deep.

The volcanic rocks of the B-Member, in which all the known prospects occur, crop out at scattered localities near their contact with the overlying and underlying sandstones, and elsewhere are covered with alluvium. Investigation of the B-Member was restricted to radiometric testing and structural investigation of the small outcropping areas, supplemented by a little costeaning and diamond drilling of radiometric anomalies.

The areas of exposed rocks were carefully tested, and the unimpressive radiometric anomalies discovered were thoroughly examined. The results of the work give little encouragement for further testing of the Reservation. Any additional work that may be undertaken should be restricted to radiometric surveys of the surface of the B-volcanics beneath the alluvium on that side of the adjacent fault in which the laminations of the fine tuff would tend to be opened by dragging. Check radiometric testing could be made along the same faults of any relatively coarse clastic beds in the Edith River Volcanics.

INTRODUCTION

<u>General</u>. The A.B.C. Uranium Reservation was authorized in September 1953 by the Mines Branch, Northern Territory, in response to a request from the Bureau of Mineral Resources to protect the A.B.C. Prospect, which had been discovered earlier that month. The initial reservation embraced an area of 250 square miles. It was reduced on 1st April 1954 to 36 square miles, a map of which is given in Plate 1 of this report. Investigations within the Reservation proceeded concurrently with development work at the A.B.C. Prospect, which is described in a separate report by Gardner et al (1955). The preliminary investigation of the Prospect is described by Jones (1954). Geophysical investigations within the Reservation, between October 1953 and September 1954, consisted of radiometric, magnetic and self-potential surveys carried out by ground parties (Misz, 1955) and airborne radiometric surveys (Barlow, 1955). Geological investigations included the examination

of areas containing geophysical anomalies, and of localities considered favourable, geologically, for uranium mineralization. A little bulldozing and diamond drilling was done at three minor radiometric anomalies and also in the vicinity of the A.B.C. Prospect.

The area was mapped on a regional scale in 1953 by J.H. Rattigan and A.B. Clark, geologists of the Bureau of Mineral Resources. Clark discovered the A.B.C. Prospect in the course of his work. During 1954, D.E. Gardner mapped in slightly greater detail the A-Member west and north-west of the Prospect and the block-faulted region of C, D, and E members, shown in Plate 2, mainly south of the A.B.C. Regional Fault. The structural mapping on the geological maps that accompany this report was nearly all done by J. Rade. Geological prospecting in the B-Volcanic valley west and north-west of the A.B.C. Prospect was done mainly by D.E. Gardner, and the prospecting of faults by J. Rade. Prospecting of other parts of the Reservation was shared by D.E. Gardner and J. Rade. Logging of drill holes was undertaken by R.A. Britten. The work of mapping uranium prospects by means of plane table surveys was shared by D.E. Gardner, J. Rade and R.A. Britten. Most of the maps that accompany this report were drawn by J. Rade, and the text of the report was compiled by D.E. Gardner and J. Rade.

<u>Situation and Access</u>. The A.B.C. Reservation is square in plan, being bounded by sides each 6 miles in length, and directed north-south and east-west. Its south-western corner is distant 10.2 miles on a bearing of 47 degrees from the Katherine Post Office. A geological map of the Reservation and a locality map are given in Plate 1. Access to the Reservation is by means of a bull-dozed track which can be reached both from Nixons Crossing on the Katherine River opposite the Katherine Hospital, and from a turn-off from the Stuart Highway 5 miles on the Darwin side of Katherine. The road is boggy during the wet season. Within the Reservation transport by vehicles is practicable only in the valley occupied by the B-(volcanic) Member. The areas underlain by sandstone are rough and are bordered by escarpments.

GEOLOGY OF AREA SURROUNDING A.B.C. RESERVATION.

<u>Stratigraphy</u>.

The geology of the Katherine and Mt. Todd 1-Mile sheets, part of which is occupied by the broad structural unit that contains the A.B.C. Reservation, was mapped during 1953 by J.H. Rattigan and A.B. Clark, geologists of the Bureau of Mineral Resources. The regional map of Plate 1 is based on their work. The oldest rocks are strongly folded sediments, in part tuffaceous, of the Lower Proterozoic Brock's Creek Group. They are unconformably overlain by the Upper Proterozoic Edith River Group of volcanics and tuffaceous sediments. These are succeeded with slight unconformity by Upper Proterozoic sediments and interbedded basic volcanics of the A.B.C. Group. (This was originally termed the Mt. Callanan Group on the basis of a supposed correlation with similar rocks in the Coronation Hill area, mapped by Walpole and others (Walpole, 1953). The correlation is now in doubt). Between the Brock's Creek and the Edith River Groups, and unconformable with both, a thin sedimentary sequence, the Phillips Creek Group, outcrops in a narrow belt for several miles south of Edith River. It is not represented in the A.B.C. Reservation.

The Proterozoic rocks are overlain unconformably by horizontal and gently dipping Cambrian beds of the Leights Creek and Daly River Groups, and Lower Cretaceous sediments of the Mullaman Group. Seattered remnants of Tertiary laterite cover small areas.

Structure.

The A.B.C. Reservation is situated at the southern end of an elongated, Upper Proterozoic basin that forms a large part of the area shown on the Mt. Todd and Katherine 1-Mile Sheets. For convenience this structure will be named the A.B.C. Basin. Its axis is about 28 miles long and trends to the north-west. The basin is roughly pear-shaped in plan, being widest towards the north-western end. The average width is 8 miles. Near the eastern margin the Upper Proterozoic beds are folded into a narrow anticlinal ridge, and within less than half a mile farther east they sag to form another broad, shallow basin, which is capped by Lower Cretaceous sediments. Southwards, the A.B.C. Basin is fringed by a narrow belt of Lower Proterozoic beds, beyond which is a broad area of flatly dipping Cambrian beds. To the west and north the A.B.C. Basin is bounded by Lower Proterozoic rocks which extend northwards to the coast.

The south-eastern part of the basin is displaced by two major regional faults which intersect the structural axis at localities about 8 miles and 4 miles from its southern end. They cross the south-western limb of the B-Member at about 4 miles north-west and a few hundred feet south-east, respectively, of the A.B.C. Prospect. For ease of reference they will be named the Four-Mile Regional Fault and the A.B.C. Regional Fault. Two prominent faults that trend east-north-east displace the boundary between the A and B Members at points 1.8 and 1½ miles north-west, respectively, from the A.B.C. Prospect. They will be termed the Two-Mile and the One-and-a-Half-Mile Faults. A swarm of dolerite dykes and numerous major joints strike parallel to these faults. They are either vertical or dip at very high angles. The northern part of the basin is displaced by a regional fault that trends to the north-west and intersects the structural axis about 5 miles from the northern end of the basin.

In transverse section the basin is asymmetrical, the axis being situated about 2 miles closer to the north-eastern than to the south-western boundary. The dips of the beds on the south-western side of the basin range from 10 to 25 degrees, except in the vicinity of strike faults in the A sandstone north of the A.B.C. Fault, where dips are locally as steep as 80 degrees. On the eastern side of the basin dips are of the order of 50 degrees or steeper.

Intrusive Rocks.

The eastern boundary of the Cullen granite (Noakes, 1949), near the southern end of the batholith, runs southwards approximately parallel to the western edge of the A.B.C. Basin and 6 to 10 miles west of it as far as the southern extremity of the batholith, at latitude 14° 15'. This is 20 miles north-west of the A.B.C. Prospect. A small exposure of Lower Proterozoic diorite has been mapped by Rattigan and Clark (1954) in the Maude Creek Goldfield 4 miles south-east of the A.B.C. Basin (8 miles south-east of the A.B.C. Prospect). This is closer to the Prospect than any other known plutonic rock. The southern boundary of the diorite is covered by Cambrian basalt.

Minor Upper Proterozoic dacitic and toscanitic dykes and sills have been mapped near the Fergusson River (Carter, 1952) and near Edith River (Rattigan and Clark, 1954). These localities are about 16 miles north-west of the A.B.C. Basin, and 25 miles north-west of the A.B.C. Prospect. Fine-grained or aphanitic siliceous rocks, in the B-Member of the A.B.C. Group, thought by the field geologists to be rhyolites and flows have been determined by Dallwitz and Stevens (Appendix 1) as fine-grained tuffs. J. Rade, who did much of the field work, maintains that some at least of these rocks are rhyolites. In this, he is supported by petrographic descriptions furnished by Dr. W.R. Browne (private communication). Reference is made in the following paragraph (Mineral Deposits) to the possible occurrence of small acidic dykes in the Cullen Granite.

Mineral Deposits

Metalliferous mineral deposits, excluding those of uranium, have been found only in Lower Proterozoic rocks, viz. in the Brock's Creek Group, the Cullen Granite, and the Maude Creek Diorite. They include deposits of tin, gold, and a little wolfram between Mt. Todd and Emerald Creek in a belt 5 to 6 miles wide roughly parallel to the boundary of the granite, and gold and copper between Maude Creek and Dorothy Creek in or adjacent to the Maude Creek Diorite. The Cullen Granite contains minor lead and copper mineralization within faults and shears, apparently of academic interest only, and small deposits of tin and wolfram near its margin.

Uranium minerals have been deposited within fractured shear zones in the granite (Fisher, 1952; Gardner, 1953; a Jones, 1953) apparently at a late stage in the tectonic history of the area. Some of them are associated with vein-like occurrences of fine-grained or aphanitic siliceous rock, distinguished from the surrounding rocks by a comparative absence of jointing and shearing. They are possibly rhyolitic dykes (Gardner, 1953, a). No uranium prospects have been found in the Lower Proterozoic Brock's Creek beds that occupy the belt of country between the Cullen Granite and the A.B.C. Basin.

GEOLOGY OF A.B.C. RESERVATION

General

The A.B.C. Reservation, situated near the southern end of the A.B.C. Basin, was intended primarily to include the area in which the A.B.C. and Four-Mile Regional Faults intersect the south-western limb of the B-Volcanic Member. Its position is shown in Plate 1.

Structure

The middle part of the Reservation is occupied by the south-western part of the basin, where the regional dip is about 15 to 20 degrees north-east. The eastern margin of the basin runs nearly parallel to the eastern boundary of the Reservation and extends about a mile east of it. The dips, a little south of west, are much steeper than those on the western side of the structural axis. Where measured on the southern side of a gorge cut through the A sandstone by a tributary of the Seventeen Mile Creek, 2 miles east-north-east of the A.B.C. Prospect, the dip is 64 degrees.

The Reservation is crossed by numerous faults which can be grouped into four sets on the basis of their trends, viz., north-north-west, east-north-east, north-east, and west-north-west. The faults of the first set are comparatively short ones, encountered mainly in the north-western portion of the Reservation, where they are obvious in the sandstone members of the A.B.C. Group.

The faults that trend east-north-east are longer and occur throughout the area. Several of them intersect the middle portion of the Reservation e.g., the One-and-a-Half-Mile Fault and the Two-Mile Fault which cross the boundary of the A and B Members 1½ miles and 1.8 miles respectively north-west of the A.B.C. Prospect. These faults can easily be traced on air photos over lengths of several miles and they displace the complete succession in the A.B.C. Basin. Their northern sides have apparently moved to the east-north-east and the southern sides apparently to the west-south-west.

The third set of faults, viz. those that trend to the north-east include the A.B.C. and Four-Mile Regional Faults, both of which displace the south-eastern portion of the A.B.C. Basin and continue for several miles beyond it. Horizontal movement has occurred along the A.B.C. Fault, the north-western side having apparently moved north-east relative to the south-eastern side. A smaller fault of the same set, half a mile west of the A.B.C. Prospect passes from the A sandstone to the displaced axial portion of the basin, where it terminates against the One-and-a-Half-Mile Fault. Another fault belonging to the same set, a mile south of the A.B.C. Prospect, marks the south-eastern edge of a block-faulted area that is bounded on the north by the A.B.C. Fault.

A large west-north-west fault or fault zone, of the fourth set, intersects the middle and western portion of the Reservation. It runs approximately parallel to the strike of the beds for approximately 2 miles west of the A.B.C. Prospect. Some shorter faults of the fourth set occur in the eastern part of the Reservation.

Stratigraphy

General. In addition to the rocks of the A.B.C. Group, the Upper Proterozoic Edith River Volcanics are exposed towards the southern part of the Reservation and Lower Proterozoic rocks of the Brock's Creek Group in the south-west. The A.B.C. Group (formerly named the Mt. Callanan Group) comprises the following five members (Rattigan and Clark, 1954):-

(Top)	E	Sandstone
	D	Basalt (and dacites and pyroclastic rocks)
	C	Well-bedded sandstone and thin red siltstones
	B	Basalts and pyroclastic rocks
(Bottom)	A	Sandstone

The A, B, and C Members were mapped in greater detail within portions of the Reservation and are described below.

A-Member. The thickness of the A-Member of the A.B.C. Group in the vicinity of the Reservation was measured on the eastern side of the Basin. On the southern and western sides the section is complicated by faulting. At a locality 2.1 to 2.7 miles east of the A.B.C. Prospect the estimated thickness, based on a recorded dip of 50 degrees near the eastern edge of the outcrop, is 2500 feet. J. Rade estimated a thickness of 2900 feet on the southern side of a gorge a mile farther north.

On the western side of the basin north of the Two-Mile Fault, practically the entire A-Member is exposed as a broad belt of gently dipping beds. Its basal part on the west has been uplifted by strike faulting, and part of it has been eroded. Hence a section across this part of the A-Member is not entirely representative of the Group. Near the boundary of the B-Member the dips are of the order of 10 to 15 degrees. The block bounded on the north and the south by the Two-Mile and the One-and-a-Half-Mile Faults is tilted towards the east. As a result, the dips are steepened to at least 18 degrees, and the outcrop-width is reduced. At its western edge the tilted block terminates against an uplifted block, from which it is separated by a zone of strike faulting. The conglomeratic beds of the A-Member, viz., its basal beds, have been eroded from the uplifted block. Minor strike faults which may be regarded as step faults with downthrow of the eastern side intersect the tilted block at several localities, and drag along them has locally steepened the dip of the strata up to angles of 45 degrees.

South of the One-and-a-Half-Mile Fault the broad structural pattern is similar to the pattern observed south of the Two-Mile Fault, viz., the displacement on the transverse fault is comparatively small, but a zone of strike faulting some distance westward across the A member marks the edge of a strongly uplifted block, from which the A member has been almost completely removed by erosion. The strike faults terminate or displace the One-and-a-Half-Mile Fault about a mile west of the boundary between the A and B Members. They follow the strike of the beds in the uplifted western block, which is about 60 degrees east of south, in comparison with a strike of about 50 degrees east of south in the downthrown side. Hence, in a south-easterly direction, the width of the downthrown block across the strike of the beds gradually decreases, and the strike faults approach towards the boundary of the A and B Members and almost meet it at about a third of a mile west-north-west of the A.B.C. Prospect. However, the boundary has a slight eastward curvature and over this distance it has changed direction sufficiently to become parallel to the strike faults. Near the Prospect some of the upper beds of the A member have been faulted down and are concealed by the down-faulted B-volcanics which overlie them.

The A Member has been investigated in reconnaissance traverses across it between the A.B.C. Prospect and a point on the boundary of the B Member 3 miles north-west of the Prospect. J. Rade has also examined the section on the southern side of the Gorge on the eastern side of the basin. On the western side, despite an increasing absence of strata due to strike faulting as one proceeds from the Two-Mile Fault towards the A.B.C. Prospect, the sections can be related to one another by means of marker beds. A conglomerate band can readily be followed south-eastward for some distance. It gradually becomes thinner and at about half a mile from the Prospect two bands of siltstone interbedded with sandstone bands provide more satisfactory markers.

The northernmost traverse across the A Member started 3 miles north-west of the A.B.C. Prospect. There, the lower part, at least 1500 feet thick, consists of massive cross-bedded sandstone. From the base to about 1000 feet above it, it contains numerous scattered quartz-pebbles commonly about 2 inches in diameter; the upper 500 feet of the massive cross-bedded sandstone contains few pebbles. This massive basal portion of the A Member is overlain by about 300 feet of well stratified, thinly cross-bedded sandstone which contains narrow bands of laminated fine sandstone. The fine-grained beds are relatively easily eroded and tend to form flat-floored, narrow valleys a little below the general level. The succeeding 300 feet (1800 to 2100 feet above the base) consists of relatively coarse grained beds and at least one thin band of siltstone or fine-grained sandstone. It starts with pebbly and coarse granular sandstone which crops out as prominent, bare dip slopes. This is succeeded

TABLE 1

SECTIONS ACROSS A MEMBER

Strat. Height Above Base Feet		1A. Three Miles North-West of the A.B.C. Prospect (North-west of tilted block)
2500	WB	Well-bedded sandstone
	X1	Thinly cross-bedded sandstone
	F1	Flaggy sandstone
		STRIKE FAULTING
	X1	Thinly cross-bedded sandstone; silicified
	F1	(Flaggy sandstone)
	X2	(Thin cross-bedded sandstone, ferruginous)
	L1	Laminated sandstone
	X3	(Cross-bedded sandstone; silicified) (Thin cross-bedded sandstone)
	L2	(Fine sandstone)
	X4	(Thin cross-bedded sandstone, dominant)
2100		
	X5	(Cross-bedded sandstone, granule bands) (" " " pebble bands)
	P	(Pebble conglomerate, 1-foot) (Thin cross-bedded sandstone, 3 feet) (Pebble conglomerate, 3 feet)
	X6	Cross-bedded sandstone, strong outcrop
	F2	Flaggy sandstone
	L3	Laminated sandstone
	P	Pebbly & granular sandstone
1800		
	X7	(Cross-bedded sandstone, dominant)
	L4	(Laminated sandstone)
1500		
	X8	(Massive cross-bedded sandstone) (Sandstone, few quartz-pebbles)
		STRIKE FAULTING
1000		
	X9	Massive cross-bedded sandstone, many quartz-pebbles
Approx. thickness may be up to 1400'.		
0		

TABLE 1 (continued)

SECTIONS ACROSS A MEMBER

Strat. Height Above Base. Feet	1B.	Two Miles North-West of A.B.C. Prospect (In tilted block)
2500		
	WB	Sandstone, somewhat flaggy, well-bedded
	X1	? Sandstone, more massive and siliceous
	F1	Flaggy; many fragmental bands
		STRIKE FAULTING
	X3	? Cross-bedded sandstone, medium-grain
		Thin cross-bedded sandstone, silicified.
		STRIKE FAULTING
2100		
	X5	(Cross-bedded sandstone, granule bands)
		(" " " pebble bands)
	C	Pebble conglomerate
	F2	(Laminated fine sandstone)
		(Somewhat flaggy medium-grain sandstone)
	L3	Laminated sandstone and siltstone
1800	P	Coarse granular sandstone
	X7	? Massive silicified cross-bedded sandstone
		STRIKE FAULTING
1500		
	X8	Cross-bedded sandstone fractured and silicified
		STRIKE FAULTING
	X9	Massive silicified, cross-bedded sandstone with quartz-pebbles
		STRIKE FAULTING

TABLE 1 (continued)

SECTIONS ACROSS A MEMBER.

Strat. Height Above Base. Feet.	10	At 1.4 Miles West-North-West of A.B.C. Prospect (South-east of tilted block).
		STRIKE FAULTING
2500		
	F1	Flaggy sandstone
	X2	Thin cross-bedded sandstone
	L1	Fine laminated sandstone
		STRIKE FAULTING
	X3	? Thin cross-bedded sandstone, fractured and silicified
		STRIKE FAULTING
	X6	? Cross-bedded sandstone, strongly silicified
		STRIKE FAULTING
1800		
	X7	Cross-bedded, much fractured
		STRIKE FAULTING
	X9?	Cross-bedded sandstone, pebbles
		STRIKE FAULTING

by fine-grained, laminated sandstone, flaggy sandstone, and a resistant band of well-stratified, cross-bedded sandstone that forms conspicuous bare outcrops and flat dip-slopes in the sides of gullies. This resistant band is overlain by a bed of pebble-conglomerate 3 feet thick, 3 feet of thinly cross-bedded sandstone, an upper layer of pebble conglomerate 1 foot thick, and thinly cross-bedded sandstone that contains pebbly bands along the main bedding planes. The upper part of the A-Member comprises thinly cross-bedded sandstone, flaggy sandstone, and several bands of finer sediment ranging in grain size from coarse siltstone to fine sandstone. The top beds are typically well-stratified or flaggy and noticeably ferruginous. The succession exposed in this section across the A-Member is summarized in Table 1.

Within the tilted block, bounded north and south by the Two-Mile and One-and-a-Half-Mile Faults, the same section applies, except that because of faulting parallel to the strike, some beds do not occur. This is illustrated in Table 1.

In the section 1 mile north-north-west of the A.B.C. Prospect the outcrop width of the A Member is less than 1400 feet, in comparison with about 6000 feet in the tilted block. The massive, cross-bedded basal part of the Member has been almost completely removed by erosion of the uplifted block south of the strike faults. In the interval that ranges from 0.9 to 0.7 mile west-north-west of the A.B.C. Prospect the width of the A Member is little more than 700 feet. This is apparently a block that has been uplifted between two easterly-trending faults. The conglomerate band at the north-western end of this area is exposed in a deep gully, and is 18 inches wide. Its dip, and that of the adjacent beds is steepened to 80 degrees by dragging on the nearby strike faults. South-east of the deep gully the conglomerate is not well exposed but it can be followed for about half a mile towards the Prospect. It forms the second oldest unit in the sequence of beds given in Table 2.

Within about half a mile of the A.B.C. Prospect, the conglomerate band cannot be traced with certainty, but beds 1 to 4 of Table 2 can readily be followed to a locality about 1000 feet from the Prospect. Here, beds 1 and 2 (sandstone and coarse siltstone) do not occur. Apparently they are faulted down and covered by overlying rocks of the B Member.

<u>Table 2.</u> Conglomerate Band and Adjacent Beds ½ Mile to 1 Mile West of A.B.C. Prospect.

	Lithology	Outcrop Width (approx). feet
Top		
1.	Siliceous sandstone, cross-bedded, well stratified	10
2.	Coarse siltstone and thin beds of sandstone	15
3.	Siliceous sandstone, cross-bedded, well stratified	15
4.	Siltstone	10
5.	Thin cross-bedded sandstone and inter-bedded siltstone	20
6.	Massive cross-bedded sandstone	15
7.	Pebble conglomerate	Several inches
8.	Siltstone	? 10 feet

South of the A.B.C. Prospect the A Member has been uplifted and largely removed by erosion. Only the massive cross-bedded, conglomeratic sandstone remains. In a small down-faulted block 300 feet south-west of the Prospect the uppermost sandstone beds appear to be less massive and better stratified. The scree near the boundary of the B Member contains small fragments of siltstone, and probably this block contains beds 5 and 6 of Table 2.

A section measured across the A Member south of the Gorge Prospect (2 miles east-north-east of the A.B.C. Prospect is given in Table 3. At this locality the dip is 64 degrees west-south-west, and the estimated thickness is 2900 feet.

Table 3. Section Across A Member, South of Gorge Prospect.

Thickness (feet)	Lithology
Top	
120	Fine-grained quartzitic sandstone
20	Reddish violet siltstones
8	Grey flaggy fine quartzitic sandstone with siltstone intercalations
6	Grey fine stratified sandstones
11	Reddish brown siltstones
33	Brownish grey quartzitic fine sandstones; fractured
17	Reddish grey sandy siltstones
58	Grey sandstones, fine-grained, quartzitic and fractured at the top, and changing gradually to coarse, current bedded sandstone at the bottom. The current bedded sandstone contains a few quartz pebbles, ¼ inch to ½ inch.
46	Grey coarse stratified sandstone
117	Grey coarse sandstone interbedded with fine quartzitic sandstone
1	Conglomerate, consisting of rounded quartz pebbles 2" x 1"; 2" x 2½" x ¾"; 2½ x 1"; 3" x 2½" x ¾" and smaller.
40	Grey quartzitic sandstone. Coarse-grained layers are interstratified with fine-grained. At the bottom some pebbles occur, 2" x 1½" x ½".
2400 (approx)	Fine grey sandstone interbedded with coarse sandstone and possibly a few bands of reddish brown siltstone. Conglomerate layers at the bottom.

This section work in the A-Member has been incidental in the examination of drill cores at the A.B.C. Prospect.

Specimens A400 and A399 (diamond drill hole No. 2, 223' and 231' respectively) are described by Dallwitz (Appendix 1, page 26) as ferruginous sandstone and medium-grained quartzite.

B-Member. The B-Member, which is about 800 feet thick, consists mainly of basalt. A thin band of fine-grained tuff occurs about 180 feet stratigraphically above its base. The basalt weathers readily and hence the B Member occurs within a valley, surrounded by walls of the more resistant A and C (sandstone) Members. The floor of the valley is covered by alluvium, and the basalt is exposed in places along its sides, in general near creek beds or gullies leading down from the sandstone. The contact between the B Member and each of the sandstones is covered by scree, but has been investigated by diamond drilling at the A.B.C. Prospect. Appendix 1, page 26, specimen A400). From the base to at least 200 feet above it the basalt is in part amygdaloidal and aphanitic (Appendix 1, page 26, specimens A400, A8382), and in part non-amygdaloidal and fine-grained or aphanitic. (Appendix 1, page 27, specimens A8373, A8378, A8387). Specimens in which the amygdales are fairly abundant are Nos. A8377, A8380, A8390 and A8397 (Appendix 1, page 27). It probably consists of two or more flows, the boundaries of which may be indicated by an increase in the numbers and sizes of the amygdales. W.B. Dallwitz, petrologist, doubts the validity of such an assumption, and states that variation in amygdular content could be expected in different parts of a single flow. The middle portion of the B-Member, exposed near the creek that flows along the Four-Mile Regional Fault, consists of amygdaloidal basalt. It appears to be made up of broken blocks several feet in dimensions, and may represent a breccia formed at the front of an advancing flow. The cavities between the blocks are now partly or completely filled with encrusting quartz and cherty silica, deposited probably from ground water.

The upper part of the B Member consists of three or more flows of fine grained and micro-crystalline basalt, each of which is amygdaloidal near its top. The contact with the C-Member is covered by scree. Detrital fragments of banded, red-brown encrusting quartz and chalcedony a short distance down-slope from the sandstone may be derived from a flow-breccia similar to that which occurs in the vicinity of the Four Mile Regional Fault.

The following remarks were made on the basalts by W.B. Dallwitz, petrologist, after examining numbers of hand specimens:-

"Some of the basalts appear to have contained olivine, but it is not certain that those in which no suggestion of the former presence of this mineral was found in thin section did not actually contain it - alteration has generally been so severe that possible chlorite pseudomorphs of olivine could have become obscured beyond recognition.

"Some basalts are richer in felspar than are others, and they may be bordering on intermediate in composition. They also have a strong suggestion of doleritic texture, which does not necessarily indicate that they have been emplaced as a dyke or dykes, or a sill, but which could be attributed to slow cooling of a thick flow. If they represent a dyke or sill, intrusion must have taken place at very shallow depth, because amygdales are present in some of them. It was difficult to make a strict demarcation between felspar-rich types and those poorer in felspar, especially as chlorite appears to have replaced felspar in certain rocks. However, the following rocks appear to be rich in felspar, have doleritic texture, and rather few or no amygdales; hematite percentage varies over a wide range:

"Specimens A8373, A8375, A8387, A8392, A8393, A8394, A8395."

At a distance of 200 to 300 feet across the valley from the boundary of the A-Member and north-westwards from it, small, discontinuous outcrops are found of a narrow, finely laminated band of fine-grained siliceous rock which was regarded in the field as intrusive rhyolites and flows. Numerous thin sections examined by W.B. Dallwitz and R.D. Stevens, petrologists of the Bureau of Mineral Resources, were classified as fine-grained tuff. In the case of the laminated rock, this is accepted by D.E. Gardner. J. Rade, however, considers that many of the rocks are rhyolitic and is supported by thin section descriptions supplied by Dr. W. R. Browne. At the A.B.C. Prospect the laminated rock is the host rock to nearly all the uranium mineral, and its thickness, determined by drilling, is 10 feet. Petrological descriptions are given in Appendix 1, pages 28, 29, 31, specimens A8389, B7866 and A6900. In a report on the A.B.C. Prospect, written before the petrological work was completed, Gardner et al (1955) suggested that the laminated rock is rhyolite, occurring as dykes and small sills. This assumption was made to explain, firstly, a failure to find any extension of the bed at an appreciable depth in drill holes, and secondly, its occurrence in dyke-like bodies at several localities within the A.B.C. Reservation. However, at the Prospect, it occurs in a downfaulted block, and its extension down-dip has been removed by erosion of the relatively up-lifted blocks to the north. Drilling at the One-and-a-Half Mile Prospect failed to reveal any downward extension of the laminated band, presumably for the same reason, viz.: faulting. An alternative explanation is that the bed of fine tuff was removed from some localities by contemporaneous erosion. Again, in the eastern part of the A.B.C. Prospect, the fine tuff occurs as small discontinuous bodies which dip steeply, mainly to the east, and range in strike from a few degrees to about 50 degrees east of north. The regional dip of the sandstones and presumably the B Volcanics is a little over 20 degrees and the strike about 80 degrees west of north, but both strike and dip vary locally in the vicinity of faults. The dyke-like bodies either lack directional structure or have a faint banding which resembles igneous flow rather than sedimentary lamination. Petrographic work (Appendix 1, Specimens B7865, B7866, A6900, A 8391, B8216 and B8225, pages 28 to 31) shows that these dyke-like bodies are of fine tuff, and hence their strike and dip must be ascribed to dragging in the vicinity of faults. J. Rade, on the basis of the petrographic work received from Dr. W.R. Browne, adheres to the original field interpretation, viz., that they are rhyolites. Two outcrops of laminated rock 1400 and 1500 feet west of the A.B.C. Prospect were exposed by costeaning (Plate 3). The eastern body strikes north-east and dips 48 degrees north-west. The western body strikes a little north of west and dips 45 degrees northward. Drill hole No. 58 put down in the eastern costean to a depth of 40 feet encountered only amygdaloidal basalt, which appeared in the core to be dipping approximately 20 degrees.

At the Half Mile Prospect (Plate 6), 0.4 mile west of the A.B.C. Prospect, detrital fragments of laminated rock appear on the surface, and blocks of it, apparently fragmental, are exposed in a shallow costean. A specimen, No. A6900 is described by W.B. Dallwitz as acid ashstone (Appendix 1, pages 29, 31). Two drill holes near the costean failed to intersect any laminated rock, even though one of them, No. H1, was put down 154 feet to a sandstone. The other hole, No. H2, passed through a brecciated band from 14 feet to 15 feet containing fragments which appeared in hand specimen to be silicified rhyolite. Presumably they are fragments of the fine tuff in a fault zone. Drill Hole No. 60, 700 feet north-north-east of the A.B.C. Prospect was put down to sandstone, at a depth of 455 feet. No bed of fine tuff, comparable with that occurring at the A.B.C. Prospect, was found in the drill core, but from 115 to 123 feet above the sandstone the basalt appeared to be intruded by thin veins and stringers of rhyolitic rock. These have been determined in thin section by R.D. Stevens to be fine tuff (Appendix 1, Specimens B8227, B8228, page 30) and, like the occurrence 0.4 miles west of the A.B.C. Prospect, must be assumed to be brecciated fragments within a fault zone. Two specimens of the same rock are classified as rhyolite in petrological descriptions received from Dr. W.R. Browne, and J. Bade accepts this determination. He considers that the fine siliceous rock occurs not as breccia fragments but as veins and stringers.

A laminated band exposed at a point 1¼ miles north-west of the A.B.C. Prospect, about 500 feet across the valley from the A sandstone contains appreciable quantities of oxidized copper mineral. Films of malachite occur between the laminae and as coatings on joint surfaces. At this locality the laminated band overlies a dense, hard, dark-green or grey rock which has the appearance of an aphanitic acidic volcanic rock. In thin section the rock has been determined as a silicified fine-grained tuff (Appendix 1, specimens B8216, B8225, pages 29 to 31).

In addition to those already mentioned, outcrops of fine-grained or aphanitic siliceous rocks, which were considered in the field to be dykes and sills of rhyolite, occur at other localities within the B-Member, e.g., at the Two-Mile Prospect (1.8 miles north-west of the A.B.C. Prospect), 0.6 mile east-south-east of the A.B.C. Prospect, where it appears to be a stockwork in the basalt, and at several localities near the top of the B-Member on the eastern side of the basin.

Those which occur near the base of the B Member probably consist of silicified fine-grained tuff. Possibly some of the others, e.g., those near the top of the B-Member, which have not been examined in thin section, are small rhyolitic intrusives.

<u>C-Member.</u> The C-Member has a thickness of approximately 900 feet. It consists of about 800 feet of sandstone ranging from massive and cross-bedded to well-bedded and flaggy, and 100 feet of laminated siltstone interbedded with thin bands of cross-bedded sandstone. At the base of the C-member the sandstone is medium-grained, massive, cross-bedded and has a noticeable proportion of clayey material in its matrix. At about 100 feet above the base it is coarser-grained and contains many scattered quartz-pebbles. This massive conglomeratic unit has a thickness of about 50 feet. It is succeeded by flaggy, ripple-marked beds, possibly 50 to 100 feet thick, which pass upwards into thin bands of cross-bedded sandstone. Several horizons are marked by angular casts and moulds

At about 600 feet above the base, in a total thickness of about 125 feet, thinly cross-bedded sandstone alternates with (?) three bands of red siltstone. The upper part of the C-Member consists of about 150 feet of massive, cross-bedded, clayey or felspathic, pebbly sandstone. The flaggy beds and the well stratified (thinly cross-bedded) sandstone are in part silicified and ferruginous, and this appears to be associated with strike faulting. Slickensiding shows that some at least of the strike faulting is due to bedding-plane slip, in which the upper beds moved up-dip with respect to the lower.

<u>D-Member.</u> The D-Member is a narrow band of basic volcanic rock which is largely covered by sand and scree from the adjacent sandstones. It has a thickness of about 30 feet in the A.B.C. Reservation, but the regional map (Rattigan and Clark, 1954) indicates that it is much thicker farther north.

E-Member. The central part of the A.B.C. Basin is occupied by massive cross-bedded sandstone, which constitutes the E-Member. Air photographs suggest that its lithology does not change much, and it has not been examined in detail.

Intrusive Rocks. A swarm of dolerite dykes which trend east-north-east were mapped by Rattigan and Clark (1954), mainly in Edith River Volcanics and Brock's Creek sediments west of the A.B.C. Basin. During the investigation of the Reservation dolerite dykes were found in the A sandstone south of the Prospect and in the C sandstone east of it. A strong magnetic anomaly mapped at the surface within the B-Member 2000 feet north of the A.B.C. Prospect was shown by drilling to be due to a dolerite dyke.

Outcrops of siliceous, aphanitic rock which differ from the fine tuff only in absence of lamination and steepness of dip were mapped in the field as rhyolitic dykes but those which have been examined in thin section by W.B. Dallwitz and R.D. Stevens prove to be fine grained tuffs. (Appendix 1, Specimens A6900, B8216, B8225, pages 29-31). It is probable that they all have the same origin. If so, a bed of fine tuff must occur near the top of the B-Member, at least on the eastern side of the basin, where outcrops of the siliceous rock have been found.

J. Rade adheres to the original view that some of them are rhyolites.

Hydrothermal Activity. The country rock has been silicified in the vicinity of faults in both sandstones and volcanics, and specular hematite is present in tension fractures at the same localities. The sandstones are quartzose, and the addition of silica from solutions has resulted in the formation of bands which are highly resistant to weathering and form prominent outcrops. In them, it is clear that movements on the faults have been recurrent, and the rocks have been brecciated and re-cemented by silica on at least two occasions. Tension fractures along some of the faults are filled with massive and specular hematite. This must have been introduced during one of the later movements along the faults because generally speaking the hematite has not, itself, been faulted. No gossanous outcrops have been found on or near the fault zones, which indicates that no appreciable quantities of sulphides have been introduced into the area. Support is gained from the results of the drilling on and near the A.B.C. Prospect. In a total length of 2550 feet of core, one small grain of sulphide was detected, and it is pyrite. This suggests that no hydrothermal solutions have risen through the faults or associated fractures. If so, the silicia and the hematite must have been deposited from ground-water, and could have been derived from the weathering of the basic volcanic rocks of the B Member. There are objections to such a theory. Firstly, it is clear that much of the silica was precipitated before any hematite at all became available. Secondly, no silica was available at the time that the hematite was being deposited. Otherwise it too would have been deposited within the late tension fractures. Possibly the silica and hematite were transported in attenuated hydrothermal solutions at a great distance from their magmatic source, forming deposits of the telethermal class (Graton, 1933; quoted by McKinstry, 1949). No evidence of the strong faulting is seen at the surface in the basic volcanic rocks. Presumably, the silica, which must have been present in solution in about the same concentration as in the sandstone, has partly been "expended" by reaction with constituents of the basalt, e.g. the constituents of ferromagnesians could combine with silica to form chloritic or clayey minerals. Despite the absence of silicified outcrops, costeans and drill cores in the B Member provide evidence of siliceous and hematitic additions in the form of narrow veins of quartz, stringers and irregular masses of crystalline hematite, and quartzose and hematitic amygdales.

In the vicinity of faults, the fine tuff is strongly silicified and its altered fragments make up an abnormally large proportion of the detritus at the surface. A specimen picked up near the Two Mile Fault is described in Appendix 1 (Specimen B8213, page 32). It contains cavities which are partly filled with hematite and limonite, and these could represent former sulphides. However, as noted above, there is little evidence of sulphidic mineralization at the A.B.C. Prospect. Specimen B8225 from the Copper Prospect contains a few small grains of pyrite. Other detrital fragments of highly silicified rock from the same localities, and also from the upper part of the B Member on the eastern side of the basin are stained green, presumably by copper silicate. The occurrence of malachite in laminated rock near the One-and-a-Half Mile Fault has already been mentioned, and small scattered cubic cavities in similar rock 200 feet to the north-west point to sparing pyritic mineralization.

GEOLOGICAL PROSPECTING

__General__. The investigation of the A.B.C. Prospect is described by Gardner et al (1955). Other more general investigations were made within the Reservation. They included geological inspection of radioactive anomalies discovered by geophysical surveys, geological and radiometric examination of all known outcrops of the fine tuff in the B Member, and geological and radiometric investigations of rocks outcropping in the vicinity of the regional faults. In the latter work, particular attention was given to areas underlain by volcanic rocks, viz., areas underlain by rocks of the B Member and by rocks of the Edith River Group.

__The B Member: Inspection of Anomalies Reported by Geophysical Parties__

__Ground Party__. The conduct of the work done by the Geophysical Ground Party and its results are stated by Misz (1955). In the present report the localities of the anomalies are shown in Plate 5. Three small anomalies 1400 feet north of the A.B.C. Prospect were check-tested during August 1954, when they gave counts of about 30 on a C.A.E. scintillometer, which was 1½ times the local background count. A.D. Parton, geophysical assistant, who did the initial radiometric survey, reported that the radiation was slightly higher during October, 1953, when the anomalies were first discovered. The count decreased during the following wet season. At this locality, the bedrock is covered by at least 12 feet of sandy alluvium. The anomalies are probably due to traces of radioactive material carried into the alluvium by ground water.

At the three anomalies 1 mile south-south-west of the A.B.C. Prospect in the B Volcanic rock, counts up to 2½ times the local background, viz., that on the adjacent alluvium, are obtained on outcrops of amygdaloidal basalt. A small pit 1 foot deep revealed only unaltered basalt. It is concluded that the anomalies are due to the outcrops of basalt, which are more radioactive than the alluvium.

Carborne Party.

General. The Carborne radiometric survey was done by Geophysical Assistant, M.W. Stevens, who plotted the results of his work onto maps enlarged from air photos. The photo-coordinates of a centrally placed spot in each anomaly is given in Tables 3 to 8 below and the localities of the anomalies are plotted in Plate 5.

Except at the A.B.C. Prospect, where a high-order anomaly was obtained, the anomalies are weak. They constitute areas which give counts exceeding 1½ times and in some cases twice the background count of the alluvium in the valley. This background count is approximately 40 per minute on Austronic P.R.M. 200 Geiger Counter.

In the following paragraphs the anomalies are grouped into types and described in the order of their relative abundance.

1. Outcrops of Basalt.

Outcropping basalt has a background count ranging from 80 to 120, and as a result, each mass of basalt exposed in the valley yields a radiometric anomaly. Generally, the basalt appears to be massive. Although it must have been fractured, openings were not readily made within it. Tension fractures found in some localities have been filled with fine quartz stringers. These have not been found to be more radioactive than the massive basalt. The fine tuffs already described generally seem to have the same background count as the basalt, or perhaps a slightly higher count. However, they, with or without adjacent basalt, are host rocks to the uranium minerals at all known prospects within the A.B.C. reserve. The most highly radio-active basalt in the eastern part of the basin appears to be the slightly cupriferous (?) flow near the contact with the C-sandstone. The basalt containing encrusting quartz is not more highly radioactive than massive basalt.

An outcrop of basalt in the vicinity of a strong fault 4½ miles north-west of the A.B.C. Prospect gave counts of nearly 200 per minute within an area of a few square feet. A map of the locality on a scale of 40 feet to 1 inch was prepared by J. Rade. A shallow costean exposed little-altered basalt which gave no increase in the count-rate. A close radiometric contouring of the locality was started, with the intention of seeking a site for additional costeaning. No additional work is recommended on anomalies localized on outcrops of basalt. Following are photo-coordinates of central points in such anomalies, and their alphabetical designations as shown on M. Stevens maps:-

(Table overleaf)

TABLE 3. RADIOMETRIC ANOMALIES CAUSED BY OUTCROPS OF BASALT.

Run	Photo-reference: Survey 314, Katherine 1 - Mile Sheet.				
	Photo No.	Coordinates.	Diagonal.	M. Stephens.	
		Inches.	Inches.	Anomaly.	Sheet.
2	107	2.52N/1.20W	2.92	A	B
		2.88N/0.75W	3.0	B	
		2.16N/0.74W	2.32	C	
		2.34N/0.11W	2.34	D	
		1.88N/0.05W	1.98	E	
		1.94N/0.34W	1.96	F	
		1.65N/0.84W	1.85	G	
		1.44N/1.28W	1.96	H	
		1.31N/1.75W	2.20	I	
		1.01N/1.16W	1.56	J	
3	73	0.18N/2.16W		F	C2
	74	3.45 S/1.07E	3.64	L	C3
		2.80S/0.55E	2.86	N	
		3.20S/0.72W	3.30	P	C4
		2.35S/2.25W	3.27	Q	C4 & C5
		2.32S/2.97W	3.79	S	C5
		2.90S/2.66W	3.94	R	
		2.27S/3.81W	4.44	U	

2. Humus-rich soil:

At four localities in the eastern part of the reserve the valley floor contains areas a few hundred feet in length and 50 feet or so in width where the soil is exceptionally rich in humus. The ground supports a dense growth of grass and small herbaceous plants. Apparently it remains damp for considerable periods after the wet season. At least two of these localities are close to breaks in the C-sandstone caused by erosion along fault lines, and probably prolonged seepage of ground-water along these breaks is the reason for the dampness. Counts of these anomalies range from 80 to 100, and 120 at a few spot localities. At a shallow depth the dark soil gives place to white or grey quartz-sand, which gives a count of 40 or less. The slight anomalies are due to traces of radioactive material absorbed by humus from the ground-water. The localities where these anomalies were found are given in Table 4.

TABLE 4. RADIOMETRIC ANOMALIES CAUSED BY HUMUS-RICH SOIL

Run	Photo-reference: Survey 314, Katherine 1 - Mile Sheet.			
	Photo No.	Coordinates.	M. Stephens.	
		Inches.	Anomaly	Sheet.
2	110	0.60N/0.08E	A	C1
		0.30N/0.30E	B	
		0.32S/0.32E	C	
		0.64S/0.52E	D	

3. Detritus in Outwash and Detritus Covering Basalt.

At several localities counts slightly above the background, viz. counts of 60 to 80 and nearly 100 at isolated spots, are obtained in alluvium or scree which forms small accumulations of outwash a few hundred feet in dimensions near gullies in the sandstone walls of the of the valley. The area of higher count tends to be localized around the marginal part of the outwash, a short distance up-slope from its junction with the sandy valley-floor. A careful search with an Austronic P.R.M. 200 failed to locate on any of these anomalies a count higher than 100 per minute. The slight radioactivity is thought to be due to traces of radio-active material carried down the gully into the outwash by seeping ground-water. The clearest anomaly of the type is situated as follows:-

TABLE 5. RADIOMETRIC ANOMALY IN OUTWASH NEAR GULLY

	Photo-reference: Survey 314. Katherine 1 - Mile Sheet.			
Run	Photo No.	Coordinates.	M. Stephens.	
		Inches.	Anomaly	Sheet.
2	74	0.938/1.90E	1	C3

A slight increase in count is obtained at some localities where thin detritus covering basalt rises from the flat valley-floor, towards the sandstone scarp. The radio-activity, like that in the outwash accumulations, is probably due to traces of radio-active material carried in seeping ground water, and is too feeble to be significant. The source of the seeping ground-water is, in some cases, the fracture zones in the sandstones, demarked by gullies running laterally into the valley. Anomalies of this type, viz. where basalt has a thin detrital covering, were found at the following localities:-

TABLE 6. RADIOMETRIC ANOMALIES IN DETRITUS OVER BASALT.

	Photo-reference: Survey 314. Katherine 1 - Mile Sheet.			
Run	Photo No.	Coordinates.	M. Stephens.	
		Inches.	Anomaly	Sheet
3	73	2.1N/2.28W 00 N/2.06W 0.09S/1.94W	E G H	C2
	74	3.11S/0.10E	O	C4

4. Lateritic Alluvium.

One small anomaly, which gives a count of 80 per minute compared with 40 to 60 per minute in the creek and the surrounding alluvium is underlain by ferruginous "laterite", consisting of angular fragments of sandstone cemented by cellular iron oxide. Apparently the ferruginous cement, which gives a count of 80 where exposed in the creek bank, has absorbed a trace of radio-active material. The locality of the anomaly is:-

TABLE 7. RADIOMETRIC ANOMALY IN FERRUGINOUS LATERITE.

	Photo-reference: Survey 314. Katherine 1 - Mile. Sheet.				
Run	Photo No.	Coordinates.	Diagonal.	M. Stephens.	
		Inches.	Inches.	Anomaly	Sheet.
3	74	3.28S/1.27E	3.56	K	C3

5. Indefinite Anomalies in Alluvium.

The remaining anomalies, four in number, occupy small areas covered by alluvium. The counts range from 60 to 80, and the cause of the slight increase over the common count of 40 in the alluvium is not clear. The localities are listed below. At J, basalt underlies the alluvium, and at M "laterite" similar to that described in the preceding paragraph. These may be the causes of the slight anomalies. At T1 and T2 alluvium only is exposed. It may be underlain by basalt at a shallow depth, but on the other hand the slight increase in count here, and also at J and M, may be due to a variable distribution of traces of radio-active material carried in ground-water. The anomalies are too weak to warrant additional work. Their localities are:-

TABLE 8. INDEFINITE RADIOMETRIC ANOMALIES IN ALLUVIUM.

Run	Photo-reference: Survey 314. Katherine 1 - Mile Sheet.			M. Stephens	
	Photo No.	Coordinates.	Diagonal.		
		Inches.	Inches.	Anomaly	Sheet.
3	74	2.92S/1.40E	3.27	J	C3
		3.34S/0.53E	3.40	M	
		2.72S/3.60W	4.50	T1	C5
		2.74S/3.75W	4.65	T2	

Geological Investigations of the B Member

Area Adjacent to A.B.C. Prospect. Near the A.B.C. Prospect, west and north-west of it, nine diamond drill holes (Plate 3) were put down to obtain structural information and to attempt to find an extension of the A.B.C. ore body. An additional hole, No. M1, 1800 feet north-north-east of the Prospect, was put down by the geophysical party to test a magnetic anomaly mapped at the surface. It intersected a dolerite dyke. Hole No. 60, situated 700 feet north-north-east of the A.B.C. Prospect, was drilled primarily to provide a reasonably complete section of the B Member and, secondarily, to intersect the band of fine grained tuff at some depth in the vicinity of the A.B.C. Regional Faults. The geological section and log of the hole is given in Appendix 2. The tuff bed was not intersected, but a siliceous, fine-grained or aphanitic rock which appeared to consist of veins of rhyolite was found in the core at heights of 123 feet to 123 feet 6 inches and 114 feet 6 inches to 115 feet vertically above the sandstone. Stringers of the same rock were observed both above and below these depths. The strati-graphic intervals between the sandstone and the two occurrences of rhyolitic-looking rock is 116 feet and 108 feet, respectively. The bed of fine tuff is approximately 150 feet above the sandstone. A specimen (B8228) from 115 feet above the sandstone and another (B8227) from 123 feet 6 inches have been thin-sectioned and are described in Appendix 1, page 30. They are classified as fine silicified tuff, and presumably have been dragged down in a fault zone. As noted in the geological description of the B Member, J. Rade considers this rock to be intrusive rhyolite and his opinion is supported by thin-section descriptions received from W.R. Browne.

Two costeans were bulldozed at a locality where fragments of fine-grained siliceous rock were found on the surface 1400 feet and 1500 feet west of the A.B.C. Prospect (Plate 3). In the western costean the body of siliceous rock strikes a little north of west, apparently concordant with the strike of the basic volcanics, and dips 45 degrees northwards. In the eastern costean the siliceous rock strikes north-east and dips 48 degrees north-west. Drill hole No. 58 put down in the eastern costean to a depth of 40 feet encountered only amygdaloidal basalt, which appeared in the drill core to be dipping approximately 20 degrees. The bodies of siliceous rock were considered to be small rhyolitic dykes. However, the results of petrographic work done on specimens of similar rock obtained at other localities within the Reservation suggest that they are displaced portions of the bed of fine tuff. J. Rade considers that they are rhyolites.

Hole No. 65 was drilled to a depth of 30 feet, 1100 feet north-west of the Prospect, viz. 250 feet north-west of the horst-like bodies of sandstone that project north-eastwards into the B Member. It was thought that this area might be a fault block in which the structural conditions of the A.B.C. Prospect could be repeated. The drill hole passed through 8 feet of alluvium and then weathered basalt.

<u>The Fine-Grained Tuff</u>. Investigation of the bed of fine tuff was practicable in places in the south-western limb of the B Member. In the eastern part of the basin the B Member is almost completely covered by alluvium. There are virtually no outcrops near the boundary with the A Member, but several relatively small areas are exposed near the C Member. Weak radiometric anomalies were discovered at three localities 0.4 mile, 2 miles and 4½ miles west to northwest from the A.B.C. Prospect. These were named the Half Mile, Two Mile and Four Mile Prospects. The Two Mile Prospect was discovered during the geological investigations of the fine tuff bed; the Half Mile Prospect was similarly found, and was independently discovered by the Geophysical Carborne Party. The Four Mile Prospect was discovered by the Carborne Party. Each prospect is situated on or adjacent to a fault that trends approximately north-east. Traces of uranium minerals were found at the Half Mile and Two Mile Prospects. Pitting and costeaning at each locality and drilling at two of them failed to reveal any concentration of uranium minerals. At about 1¾ miles north-west of the A.B.C. Prospect the band of fine tuff contains malachite on joints and between the laminae. It has been named the Copper Prospect. No uranium minerals were found there. Further details concerning the Prospects are given below.

<u>Half Mile Prospect</u>. A geological map of the Half Mile Prospect is given in Plate 6. It is within the B Volcanic valley 0.4 mile west of the A.B.C. Prospect, and about 250 feet north-east of the boundary of the A. Member, adjacent to a fault that trends east-north-east. A detrital block of dense, siliceous rock which appeared in hand specimen to be rhyolite gave a count of 400 per minute with an Austronic P.R.M. 200 Geiger Counter. A few small flakes of yellow (?) autunite were found in a fragment of similar rock, (Specimen A6900, Appendix 1, page 29). A shallow costean was dug and four diamond drill holes put down to test the underlying rock for uranium mineralization.

The country rock is amygdaloidal basalt of the B Member. Brownish silicified rubble scattered on the surface and exposed in the costean appeared to be rhyolite but in thin section it proved to be fine grained tuff (Appendix 1, specimen A6900, pages 29, 31). J. Rade considers that this is a rhyolitic volcanic rock. Two boreholes drilled vertically close to the costean failed to intersect any of the fine tuff in situ. The northerly hole, D.D.H. No. E1 passed through basalt down to 154 feet, where it entered altered sandstone or quartzite of the A Member. Drill hole E2, on the southern margin of the costean was drilled to 50'6", entirely in basalt. A breccia zone from 14' to 15' contains silicified fragments of fine tuff. Drill hole E3, 100 feet east of the costean and 18'6" deep, penetrated alluvium from the surface to a depth of 3 feet, and siliceous fine-grained rock from 3' to 4' and from 8'9" to 9'6". The latter was described in the field as acidic volcanic rock, but presumably it is silicified fine-grained tuff. Drill hole E4, 200 feet east-north-east of the costean and 10 feet deep passed through amygdaloidal basalt.

The regional dip in the vicinity of the Prospect is 18 to 20 degrees north-east. However, the nearby sandstone has a much steeper dip, the beds having been dragged on an east-west fault. A transverse fault that trends approximately N30°E crosses the Prospect and the sandstone south-west of it. The southern side has apparently moved to the north east relative to the northern side.

No uranium minerals were found in the costean or drill holes. It is possible that the (?) autunite flakes found in the fragment of tuff at the surface may be related to hydrothermal activity associated with the transverse fault. Traces of copper are observed in detrital-silicified fine tuff, and cavities, within some of the fragments (Specimen B8213, Appendix 1, page 32), may have formed through leaching of sulphides.

<u>Copper Prospect</u>. The Copper Prospect is located about 1¾ miles west-north-west of the A.B.C. Prospect and 500 feet from the A sandstone, a short distance east-south-east of the Two Mile Fault. A geological map of it is given in Plate 7. A band of laminated fine-grained rock contains an appreciable proportion of malachite which occurs as a thin coating on joints and between the laminae. No petrographic work has been done on the laminated rock, but a dense hard band immediately beneath it proved in thin section to be silicified fine tuff (Appendix 1, page 29 to 31), specimens B8216 and B8225). It is assumed that the laminated rock also is a fine tuff. Both the laminated band and the underlying hard, structureless rock are classified by J. Rade as rhyolites. This is based on petrographic descriptions of similar rocks received from Dr. W.R. Browne. Two hundred feet north-west from the cupriferous rock, finely laminated fragments in the surface detritus contain small, scattered cubic cavities, formed presumably by leaching of pyrite. No uranium minerals were found at the Prospect and no radiometric anomaly was detected there.

Two vertical holes were intended to be drilled, one at the outcrop of copper-bearing rock and a second 50 feet to the north-east, across the strike of the beds. The drill hole at the outcrop (D.D.H. No. 67) passed through 17 feet of alluvium and then entered amygdaloidal basalt. The second hole was not started because of the onset of wet weather at the end of the dry season.

<u>Two Mile Prospect</u>. The Two Mile Prospect occurs within the B-Volcanic valley 1.8 miles north-west of the A.B.C. Prospect. A detrital fragment of fine tuff (as at the Copper Prospect, regarded by J. Rade as rhyolite) was broken and observed to contain a few flakes and small irregular masses of yellow (?)-autunite. Four shallow costeans were dug and one diamond drill hole was put down. A map of the Prospect is given in Plate 8.

The country rock consists of amygdaloidal basalt, and rubble from fine grained tuff is scattered on the surface. A diamond drill hole was put down 54 feet at an angle of 30 degrees to the horizontal, on a magnetic bearing of south 75 degrees west, with the intention of intersecting the tuff at depth. However, only amygdaloidal basalt was encountered, beneath a cover of alluvium 18 feet thick.

The dip of the sandstones 350 to 450 feet west to south-west of the Prospect is 10 to 15 degrees north-east. Several faults that trend mainly east-north-east, including the Two Mile Fault, cross the general area of the Prospect and they and the associated tension ...

fractures are clearly visible in the sandstone. Their northern sides are displaced to the north-east relative to the southern sides. The fact that the only known uranium prospects within the A.B.C. Reservation occur in the vicinity of these and other east-north-east faults suggests that the mineralization may be associated with this transverse faulting.

Four Mile Prospect. The Four Mile Prospect is situated 4 miles north-west of the A.B.C. Prospect in the B Volcanic valley, on the northern side of the Four Mile Regional Fault. A geological map of the Prospect is given in Plate 9. At the surface a count of 200 per minute is obtained over an area of a few square feet with an Austronic P.R.M. 200 Geiger Counter. The counyry rock is amygdaloidal basalt, and loose fragments of fine-grained siliceous rock are sparsely scattered on the surface, mainly in a small area about 200 feet north of the radiometric anomaly.

Many shears as well as tension fractures occur in the zone of regional faulting just south of the Prospect and shearing is observed on the Prospect.

The rather feeble radiometric anomaly is possibly due to slight uranium mineralization associated with the faulting, but more probably it results from the relatively high inherent radioactivity of the exposed basalt. Misz (1955) arrived at this conclusion. No uranium minerals were detected at the Four Mile Prospect.

Geological Prospecting of the Sandstone Members.

General. The A and C Members and a very small portion of the E Member were tested radiometrically in the vicinity of strike faults and east to north-east regional faults. The count rate obtained was consistently low except at one locality, the Gorge Prospect, on the eastern side of the Basin. On the western side of the Reservation the A sandstone was tested in the vicinity of the Two Mile Fault, and gave counts up to 80 per minute on an Austronic P.R.M. 200 Geiger counter. The same instrument gave counts up to 180 per minute on the Edith River Volcanics farther west. The E Member was tested radiometrically for short distances along and near the A.B.C. and Two Mile Regional Faults. At both localities the count was 60 to 80.

Gorge Prospect. The Gorge Prospect is situated 2 miles east-north-east of the A.B.C. Prospect in a steep, narrow valley cut through the A Member along the line of the east-west Gorge Fault by a tributary of the Seventeen Mile Creek. It is accessible by a track which enters the valley of the B Member approximately 1 mile south-west of the A.B.C. Prospect. Slickensides on the southern side of the fault indicate relative westward movement of that side. This is borne out by tension fractures which can be easily seen in the sandstone, on air photos as well as on the ground. The creek flows through the gorge during and for some time after the wet season, deriving its water from surface drainage in the valley of the B Member, and probably in part by seepage from the enclosing sandstone. The floor of the gorge is formed of damp, humus-rich, black soil.

Counts up to 800 per minute, which is 16 times the local background, were obtained over areas of a few square feet with an Austronic P.R.M. 200 Geiger counter. Counts up to at least 400 per minute were obtained over a length of about 100 feet and a width that ranges from 3 to 12 feet. No pitting or drilling was done, and the cause of the radioactivity was not demonstrated.

Probably it is due to traces of uranium minerals absorbed by humus from the groundwater draining from the B valley.

D Member

The D Member has been tested in rapid radiometric traverses with an Austronic P.R.M. 200 Geiger counter, mainly in the fault blocks shown in Plate 2. The narrow member is largely covered by detritus from overhanging sandstone and exposures of it are small. The count rate ranged from about 80 to 120 and in places to 140.

Edith River Volcanics.

A search was made for coarse pyroclastic beds in the vicinity of faults, with the idea that they could have provided suitable openings for any uranium mineralization that might have accompanied the faulting. Coarse clastic beds have been observed at the top of the Edith River Group elsewhere in the Katherine-Darwin Area, e.g. at the Edith River Falls, and in the Sleisbeck and Coronation Hill areas. At the Edith Falls, the basal part of the A Member of the A.B.C. Group, overlying the Edith River Volcanics, is a thick bed of coarse conglomerate which appears to have a tuffaceous matrix. At Sleisbeck the conglomerate contains large angular fragments of volcanic rock, which are probably pyroclastic. Near Coronation Hill the upper bed of the Edith River Volcanics is a coarse agglomerate. It is overlain by a thick bed of conglomerate which contains a large proportion of coarse, angular, pyroclastic fragments.

Within the A.B.C. Reservation the contact beds vary lithologically from place to place, but no thick beds of coarse agglomerate or conglomerate were seen. At a point 2½ miles south-west of the A.B.C. Prospect the top beds of the Edith River Group comprise andesite-(?) flows and tuffs. The A Member is formed of current-bedded sandstone, at the base of which is a 6 inch band of pebble conglomerate. A few hundred feet east of this locality, medium-grained cross-bedded sandstone rests on coarse tuff. At a locality 1 mile south-south-east of the Prospect the basal part of the A Member consists of medium-grained tuffaceous sandstone.

At approximately ¾ mile west of the A.B.C. Prospect medium-grained sandstone rests directly on a few feet of agglomerate in which the fragments range up to cobble size. A mass of sandstone nearby, but not in situ, contains scattered rounded pebbles but no volcanic fragments. About 1½ miles west-south-west of the Prospect the base of the sandstone is a pebble conglomerate 6 inches thick, resting on andesitic tuff. In a gully 50 feet south of it a 5-foot bed of agglomerate is exposed at a depth of about 20 feet below the pebble conglomerate. It contains fragments, up to boulder size, of sub-rounded Edith River volcanic rocks, angular fragments of quartzite and rounded pebbles. The agglomerate is overlain by coarse tuff in which the fragments are of pebble size.

The Edith River volcanics were tested radiometrically at the following places:-

A. East and south of the A.B.C. Basin near their contact with the A Member, in the vicinity of faults. Strong outcrops 4½ miles south-south-west from the A.B.C. Prospect were examined.

B. Along the A.B.C. Fault ½ to 1½ miles and 2½ to 3½ miles south-west of the Prospect.

C. West of the Prospect, in the vicinity of east-west faults and east-north-east to north-east faults.

In general, the Edith River volcanics gave a count of 80 to 120 per minute on an Austronic P.R.M. 200 Geiger counter. Some beds yielded counts of 140 to 160 and, exceptionally, 180 per minute but these are due to the relatively high inherent radioactivity of the rocks, and do not indicate concentrations of uranium minerals. In the vicinity of the A.B.C. fault and the east-west faults west of the Prospect, the Edith Volcanics are silicified and veined with white and grey quartz. No indications of metallic minerals, such as gossanous or vuggy outcrops, were seen. Following are brief notes concerning the several localities tested:-

A. On the eastern side of the basin near the faults, the volcanics are sheared or closely jointed. They are slightly silicified in narrow zones and contain stringers of specular hematite. The narrow, non-persistent band of conglomerate at the base of the A Member was not observed on any fault, since the fault lines are marked by gullies in which the contact is covered by detritus. Counts ranged from 80 to 140. The prominent outcrops of Edith Volcanic rock a few hundred feet east of the A Member are jointed but little altered. Possibly they have been slightly silicified. Counts recorded are about the same as near the contact with the A sandstone, viz., 80 to 140.

B. Along the line of the A.B.C. Fault, on its western side, from half a mile to 1 mile south-west of the A.B.C. Prospect the Edith Volcanics form a rugged, dissected area. They are well exposed and not deeply weathered. Directional structures clearly exposed by differential weathering include flow-banding, jointing, and shearing. In places the rocks are silicified and veined with quartz and with thin stringers of specular hematite. The exposures are nearly all of flow rock, and thin bands of tuff. No coarse clastics were observed. Counts indicated on an Austronic Ratemeter ranged from 80 to about 140.

On the eastern side of the fault 2 miles south-west of the A.B.C. Prospect, fractured and silicified dacitic (?) tuff forms a prominent outcrop about 20 feet high and 200 feet long. Joint surfaces in it are covered with fine coatings of quartz and of hematite. Counts up to 160 per minute, about 3 times the local background, obtained at several localities along the outcrop, are thought to be due simply to high inherent radioactivity of the tuff.

A similar outcrop of dacitic (?) tuff at least ½ mile long occurs on the western side of the A.B.C. Fault 1½ miles south-west of the Prospect. Cross faults that trend roughly north-north-east cut it in several places and result in relative southward displacement of the western side. The tuff band is silicified in the vicinity of these faults and veined with white quartz. Nowhere does it appear vuggy or gossanous. Counts ranged from 80 to 120 and 140 in places. Prospecting of the Edith Volcanics 2½ to 3 miles south-west of the A.B.C. Prospect disclosed no anomalies, although the high inherent radioactivity of the rocks yielded counts up to 180 per minute.

C. West and west-south-west of the A.B.C. Prospect the Edith River Volcanics are strongly jointed in the vicinity of east-west faults. Agglomerate bands in the area were considered possible host rocks for uranium deposits. However, the counts obtained were not in excess of the usual high background count. In the vicinity of the Two Mile and One-and-a-Half Mile Faults near the western edge of the Reservation similar results were obtained. The counts ranged up to 180 per minute.

Brock's Creek Group.

The rocks of the Brock's Creek Group are in general poorly exposed. Large areas are covered by alluvium and other parts are deeply weathered. They were prospected sporadically near the A.B.C. Regional Fault and in creek gullies farther west. Counts up to 100 per minute were recorded on exposed beds but no radiometric "highs" were found.

CONCLUSIONS.

Within the A.B.C. Reservation uranium minerals have been found only within the B Member. The A, C, and E Members, predominantly arenaceous, have relatively low background counts and no indications were found of any concentrations of radioactive material except in the A sandstone at the Gorge Prospect. This is probably due to traces of uranium minerals adsorbed by humus. These members are essentially quartz-sandstones and apparently are unfavourable chemically and physically for the deposition of uranium minerals. The thin D Member, of basic igneous rock, has a higher background count than the sandstones, but no concentration of radioactivity was found in it. It is not unlikely that fractures in this rock would tend to close rapidly because of hydration of the constituent minerals. The Edith River Group contains clastic beds which are probably susceptible to intense fracturing near faults and probably are suitable, chemically, as host rocks for deposition of uranium minerals. However, in the A.B.C. Reservation, no indications of deposits within them were found. The Brock's Creek beds are not well exposed. Farther north in the Mt. Todd area where they have been prospected carefully (Gardner, 1953b; Jones, 1953), they have low background counts, and no radiometric highs were detected in them.

The B Member is mainly covered by alluvium and was prospected effectively only in the relatively small exposed areas. Within these the band of laminated, fine-grained tuff contains one deposit of commercial grade and size and traces of uranium minerals at two other localities. Each is in the vicinity of a fault that trends north-east or east-north-east.

The A.B.C. deposit occurs within a small down-faulted block in which dragging would tend to slightly open the laminae. The source of the uranium is not known. It could have been leached from the comparatively highly radioactive volcanics, carried in ground water along faults, and concentrated in favourable beds, presumably in the fine-grained tuff. Alternatively, the uranium minerals may be hydrothermal in origin, belonging to the low temperature telethermal class, deposited far from their magmatic source. Some signs of hydrothermal activity are detected in the vicinity of faults viz., silicification, hematization, and the introduction of very small quantities of sulphide minerals.

RECOMMENDATIONS.

Extensive investigations have already been made at the A.B.C. Prospect and within the Reservation as a whole. Further work would necessitate drilling to obtain information from ground covered by alluvium. Because of the negative results of the work already done this is not recommended. However, since an unfavourable report may be disregarded, following are comments on past work and suggestions for any future work that may be started.

Extension of the A.B.C. deposit are thought to have occurred formerly in the uplifted blocks north of the present outcrop, but if so they have been greatly reduced by erosion, or even completely removed (Gardner et al, 1955). At a point 200 feet north of the Prospect 3 feet deep in a costean, a detrital fragment in the alluvium gave a count of 7000 per minute. This was underlain by at least 6 feet of alluvium. It probably came from the A.B.C. Prospect, but could have drifted downslope from a former outcrop, now covered, near the projecting horst-like masses of sandstone 400 feet to the north-west. Drill hole No. 54, 200 feet from the sandstone, intersected a large block of fine tuff, from 8'6" to 14'. It is not mineralized and is underlain by 20 feet of sand and clay. The drill encountered fine tuff again from 34'6" to 35' and then basalt down to 137 feet, where it entered quartzite. Considering the depth of alluvium, and the comparatively thin section from the bedrock of basalt down to the sandstone, viz. 102 feet, it is clear that there is little chance of finding any appreciable remnant of the fine tuff in the vicinity of the A.B.C. Prospect. The deep drill hole, No. 60, 700 feet north-north-east of the Prospect shows no sign of uranium concentrations, and the tuff bed occurs only as fragments in a fault zone. Any additional hole drilled near the A.B.C. Prospect could only be regarded as highly speculative or "wildcat". Such a hole could be put down about 200 feet east of hole No. 54, but its only justification would be that no direct information is available on the strongly faulted alluvium-covered ground between here and hole No. 60.

Any additional exploration within the A.B.C. Reservation should be restricted mainly to investigation of the bed of fine tuff near its intersection with the faults that trend north-east and east-north-east, particularly those along which radiometric anomalies have been found. Exploration should comprise the drilling of holes through the alluvium in order to make a radiometric survey of the surface of the bedrock. This work should ~~naturally,~~ be done on the side of the fault where dragging would tend to form openings between the laminae viz., on the downthrow side of a fault on which the displacement is mainly vertical, and, in a fault with mainly horizontal displacement, on the side in which the direction of the relative displacement is opposite or approximately opposite to the direction of dip.

The agglomerate beds in the Edith River Volcanics west and south-west of the A.B.C. Prospect could be check-tested for radioactivity along the faults that trend north-east to east-north-east.

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APPENDIX 1.

ROCK DESCRIPTIONS AND THIN SECTION PETROGRAPHY.

This work was done at the Petrological Laboratory, Bureau of Mineral Resources, Canberra.

Arenaceous Rocks.

Specimen A399: Described by W.B. Dallwitz.
Locality: D.D.H. No. 2, 231'.
Description: Medium-grained quartzite.

Specimen A400: Described by W.B. Dallwitz.
Locality: D.D.H. No. 2, 223'
Description: This core consists of two different kinds of rock. The top portion appears to be altered purplish red to purplish grey amygdaloidal basalt with a smooth to soapy feel, and the lower part is purplish red to pink sandstone containing veins of quartz and greenish grey bands.

In thin section it is seen that the basalt has been entirely altered to hematite and a clay mineral, probably a member of the illite group. Clear traces of basaltic texture remain, particularly in those parts of the rock which are altered mainly to hematite. Vesicle fillings are largely illite, but in most of them dusty to granular hematite is scattered through the illite; many of them have a concentration of dusty hematite in the core.

The sandstone of the bottom part of the core consists of rounded to subangular grains of quartz (with very minor amounts of chert) set in a matrix of hematite, two unknown green minerals with a radiating structure, and limonite. The grains of quartz range in size from 0.04 mm. to 0.5 mm., the average being about 0.25 mm. Quartz makes up about 70 per cent of the rock.

Part of the slide represents one of the greenish-grey bands noted in hand-specimen. These bands are approximately parallel to the bedding, and are due to partial replacement of the hematite and limonite cement by green minerals. The more abundant of these appears to be a micaceous mineral, and the other has a columnar habit; both have, as noted above, a radiating structure. Further work will be necessary to establish the identity of these minerals.

A pleochroic golden-yellow mineral and zircon are rare accessories.

The rock is a medium-fine ferruginous sandstone.

Basalt Containing Abundant Amygdales.

Specimen A400: Described by W.B. Dallwitz.
(See above under "Arenaceous Rocks").

Specimen A8382: Described by W.B. Dallwitz.
Locality: D.D.H. No. 2, 164'
Description: Chloritised and silicified amygdaloidal basalt. Rock consists of at least 60 per cent. chlorite, in which are set abundant spherules of chalcedony measuring about 0.04 mm. across, numerous amygdales, and pockets of granular quartz. The amygdales consist of chlorite which may or may not be bordered by quartz, or of quartz and/or quartz and chalcedony bordered by

interbanded quartz and chlorite. Hematite is much less abundant in this rock than in most of the A.B.C. basalts, and amygdales are unusually plentiful.

Basalt in which Amygdales are Fairly Common.

Specimen A8377: Described by W.B. Dallwitz.
Locality: D.D.H. 2, 100'.
Description: Amygdaloidal basalt, strongly chloritised. Probable plagioclase phenocrysts replaced by granular, hematite-stained quartz, and plagioclase microlites replaced by sericite. Pseudomorphs of probable olivine in chlorite and hematite. Veinlets and pockets consisting of quartz and chlorite. Vesicles filled with quartz, chalcedony and sericite, bordered by a shell of chlorite.

Specimen A8380: Described by W.B. Dallwitz.
Locality: D.D.H. 2, 130'.
Description: Chloritised amygdaloidal basalt with hematite and hydrated iron oxide. Amygdales consist of quartz and chlorite, which may be intermingled or show the following layered succession: quartz, chlorite, quartz (core). Veins consisting of quartz, carbonate, chlorite, and a limonite-stained uniaxial negative mineral resembling orthoclase.

Specimen A8390: Described by W.B. Dallwitz.
Locality: D.D.H. 3, 7'3"-9'0"
Description: Chloritised and hematitic amygdaloidal basalt with numerous flakes of probable autunite along cracks, and around and within vesicle-fillings. Vesicles consist of core of quartz bordered by a shell of chlorite. One contains coarsely-crystalline autunite in quartz, and another fine-grained autunite, chlorite, and hematite mingled with the quartz.

Specimen A8397: Described by W.B. Dallwitz.
Locality: D.D.H. 1, 9'6" to 10'.
Description: Chloritised amygdaloidal basalt. Amygdales fairly plentiful; filled with chlorite. Felspar abundant. Suggestion of doleritic texture. A few specks of probable autunite.

Basalt in which Amygdales are Scarce or Absent.

Specimen A8373: Described by W.B. Dallwitz.
Locality: D.D.H.2, 43'-43'6".
Description: Chloritised amygdaloidal basalt with subordinate hematite; quartz-hematite veins. Doleritic texture. Felspar sericitised. Few amygdales only filled with chlorite.

Specimen A8375: Described by W.B. Dallwitz.
Locality: D.D.H. 2, 85'.
Description: Chloritised basalt; subordinate hematite, but slightly more than in A8373. Suggestion of doleritic texture in chlorite pseudomorphs of pyroxene.

Specimen A8378: Described by W.B. Dallwitz.
Locality: D.D.H. 2, 107'.
Description: Chloritised basalt, closely similar to A8375. Plagioclase partly altered, and stained by dusty hematite. Suggestion of doleritic texture in places, but this could be due to slow cooling in an extrusive rock.

Specimen A8387: Described by W.B. Dallwitz.
Locality: D.D.H. 3, 50'
Description: Altered and weathered basalt, similar to A8375, but with fewer clots of chlorite. Hematite plentiful. A few possible amygdales filled with chlorite. Chlorite-hematite pseudomorphs possibly after olivine. Felspar coarser-grained than usual; texture fine-grained doleritic.

<u>Basalt which Appears to be Rich in Felspar.</u>

<u>Specimens A8373, A8375 and A8392</u> described above.

Also! -

<u>Specimen A8393</u>: Described by W.B. Dallwitz.
Locality: D.D.H. 1, 44'6"-44'9".
Description: Grey Chloritised basalt, resembling A8375. Doleritic texture. Leucoxene present. No hematite. A few patches of iron-stained quartz.

<u>Specimen A8394</u>: Described by W.B. Dallwitz.
Locality: D.D.H. 1, 38'9" - 39'
Description: Grey chloritised basalt with few amygdales. Leuxocene and a little hematite. Doleritic texture. Amygdales filled with quartz and chlorite or with chlorite alone. Almost identical with A8373, except for containing less hematite.

<u>Specimen A8395</u>: Described by W.B. Dallwitz
Locality: D.D.H. 1, 30'6" - 31'6".
Description: Chloritised hematite-stained basalt, with few amygdales, largely filled with chlorite. Similar to A8375. Doleritic texture. Carbonate (insoluble in dilute HCl) abundant.

<u>Laminated Fine-Grained Tuff;</u>

<u>Specimen A8389</u>: Described by W.B. Dallwitz.

Locality: D.D.H. 1, 4'6"-5'.
Description: This is a fine-grained, red-brown rock, part of which shows well-developed, though irregular, flow banding or bedding, lying at an angle of about 45° to the length of the core.

In thin section the banding, although visible, is much less clearly marked than in the hand-specimen. The rock is an acid ashstone, and therefore the banding represents bedding.

Set in a devitrified, almost isotropic base are grains of quartz (average size about0.02 mm), minute flakes of sericite, and small grains of hematite and limonite. A few scattered quartz grains measure up to 0.4 mm. The hematite has probably been introduced, either by mineralizing fluids or during weathering, as it is more abundant than would normally be expected in an acid igneous rock. Possibly the sericite has been derived from felspar by mineralizing fluids.

Banding shows up in thin sections as thin, discontinuous layers containing very few or no quartz grains.

Veinlets of quartz traverse the rock in various directions, and pockets of quartz and silicified clots, with or without sericite and brown chalcedony, are irregularly scattered through the slide.

<u>Specimen B7866</u>: Described by W.B. Dallwitz.
Locality: D.D.H. 20, 6'
Description: Specimen B7866 is also an acid ashstone through which ramifies a complex system of closely-spaced quartz veinlets. Mottling noted in the hand-specimen is again due to uneven distribution of hematite.

No undoubted and persistent bedding is visible in thin section. A few pockets of brown chalcedony are present.

<u>Specimen A6900:</u> Described by W.B. Dallwitz.
Locality: Half Mile Prospect, surface fragment, not in situ.
Description: Specimen A6900 from the Half Mile Prospect has been sectioned, and has been found to be an acid ashstone essentially similar to those described above. The red and cream mottling is due to strongly varying concentrations of hematite. Veinlets of quartz and of brown chalcedony traverse the rock; the quartz veinlets are of later origin than those of chalcedony, which they commonly intersect.

Cavities containing a small quantity of a secondary uranium mineral occur in the less hematitic portions of the rock. This mineral has not yet been identified.

<u>Fine-Grained Tuff</u>
(Including specimens not laminated or banded).

Following are additional remarks by W.B. Dallwitz:-

"There remains for brief consideration that group of rocks I regard, from microscopic examination, as being, either acid ashstones or, more probably, siliceous fine-grained sedimentary tuffs. The following of these rocks have been examined:

	B7865, D.D.H. No. 20, 5'6"	
	B7866, D.D.H. No. 20, 6'	(described)
	A6900 (A.B.C. Extended)	(described)
(b)	A8389, D.D.H. No. 1, 4'6"-5'	(described)
	A8391, D.D.H. No. 3, 6'0"-7'3"	
(b)	A8399, D.D.H. No. 1, 4'6"-5'10"	
(b)	A8400, D.D.H. No. 1, 2'9"-3'3"	
	A8398, D.D.H. No. 1, 8'6"-9" (not sectioned, similar to A8400 in handspecimen).	

The prefix (b) before a number indicates that the corresponding rock is banded; banding is faint in specimen A8400.

These rocks are generally very closely similar to one another, and, as three of them have already been described, it will not be necessary to give many further details.

Two of them (B7866, A8391) contain numerous quartz veinlets, and have been strongly silicified. One (B7865) contains what appear to be either glass shards or fragments of very fine-grained sedimentary rock. (Some of these fragments are scimitar-like in outline). In my opinion they are fragmentary rocks of volcanic origin. As there is some difficulty in postulating acid igneous activity contemporaneous with outpouring of basalt it is suggested that they owe their origin to the pulverising of sediments near a basaltic volcano by steam explosions. The sediments in question were probably not the sandstone represented by specimen A400 because the proportion of non quartzose (i.e. sericitic or argillaceous) material in the fine tuff is too great. However, even if the sandstone had been involved, it is possible that the individual grains would have been reduced in size by shattering."

Additional descriptions by R.D. Stevens, petrologist are:-

<u>Specimen B8216:</u> Described by R.D. Stevens.
Locality: underlying laminated band at Copper Prospect.
Description: "<u>B.8216 - Fine, silicified tuff</u>.

In hand-specimen this rock is dark grey (sometimes with a faint brownish tinge), very hard and fine-grained, and has a distinct sub-conchoidal fracture. Large (2 to 3 mm.) grains and narrow lenses of dark, lustrous quartz stand out in the hand-specimen and may easily be mistaken for ferromagnesian phenocrysts. The rock is massive, having no directional structures of any kind.

In thin-section the rock consists largely (90%) of very fine-grained quartz from 0.1 mm. in diameter down to microcrystalline and crypotocrystalline dimensions. Most of the quartz grains down to a diameter of 0.1 mm. are distinctly angular and obviously of detrital origin. These individually discernible quartz grains are set in an extremely fine cryptocrystalline siliceous matrix, almost isotropic in the thicker parts of the section, but identifiable as a delicate mosaic on the thin edges. In places recrystallisation has resulted in coarser patches and lenses with individual grains up to 0.2 mm. across. The matrix commonly has a pale greenish colour, probably due to included chlorite.

Small bodies of green chlorite and red-brown hematite may represent decomposed ferromagnesian minerals. They are few in number and seldom exceed 0.05 mm. in diameter. Finely granular masses of white or hematite-stained leucoxene are of fairly common occurrence but their origin is not apparent.

The only other identifiable component is sericite mica in flakes up to 0.1 mm. long and in completely random orientation. The sericite is commonly slightly greenish owing to a general chloritic stain. A small amount of colourless and almost isotropic chlorite is also developed interstitially in the coarser grained secondary quartz lenses.

One small, angular fragment of foreign rock was detected in the thin-section. It may represent a piece of completely silicified basalt."

Specimen B8225: Described by R.D. Stevens.
Locality: Underlies laminated band at Copper Prospect.
Description: "B8225 - Fine tuff.

The hand-specimen is essentially similar to B8216, but the colour is lighter and brown shades are more apparent.

In thin-section sericite and determinable quartz are less abundant, and the matrix seems to be of a more chloritic and clay-like nature. Small, elongated leucoxene bodies are common and may represent pseudomorphed ferromagnesian minerals.

The coarser-grained secondary quartz lenses commonly have a core of green, weakly birefringent to almost isotropic chlorite (? penninite). Finely granular to lath-shaped epidote is also present. It is commonly pale greenish, and usually very cloudy. In form it is very similar to the leucoxene pseudomorphs and may in some way be related to the latter. Fine grains of pyrite are few in number, but fairly generally present.

The obviously angular, fragmental nature of the quartz grains (varying from 0.05 to 0.3 mm. across) precludes the possibility of this having been an igneous rock in the usual sense. The presence of mafic minerals (epidote and chlorite) in considerable quantity (20%), however, suggests that the rock is possibly of pyroclastic origin. Many of the larger quartz grains are somewhat rounded in outline.

Specimens B8227 and B8228: Described by R.D. Stevens.
Locality: D.D.H. No. 60, 332'6" and 340'.
Description: Both are essentially similar to those described in an earlier report (xxxxxxxxxxxxxxxx, consisting of angular to sub-angular grains of detrital quartz about 0.05 mm. across and minute flakes of sericite embedded in an exceedingly fine siliceous matrix. Clear patches of recrystallised chalcedonic silica are common. A sub-parallel alignment of the sericite flakes and of the longer axes of the detrital quartz grains indicate the layering of the rock. Patches and veins of pale green weakly birefrigent chlorite are abundant.

In the specimen from 332 ft. 6" (B8227) cross-cutting veins of coarsely crystalline quartz are of frequent occurrence and narrow veins of carbonate intersect and pass through the quartz grains approximately at right-angles. The specimen from 340 ft.,(B8228) however, contains no carbonate veins even though veins of quartz are abundant. It also carries small pseudomorphs of hematite, after an original tabular mineral.

Both rocks are classified as very fine, silicified tuff."

Other remarks given by R.D. Stevens are:-

"The following brief notes record the results of further examination of the group of rocks described by Dallwitz as acid ashstones or siliceous sedimentary tuffs. These are all essentially similar in that they consist of very fine detrital (angular) quartz, fine flaky sericite, and much hematite set in a more or less indeterminate matrix, largely siliceous in character.

Features worthy of special note in some of these are:-

<u>A.8389</u>. Distinct, small-scale <u>graded bedding</u> in parts of the section; quartz angular and obviously detrital; hematite in flakes roughly parallel with the bedding; numerous quartz veins.

<u>A.8400</u>. Indistinct bedding (not graded); vague quartzose lenses parallel to bedding; numerous quartz veins.

<u>A.8399</u>. Parallel fabric in sericitic and clay-like material representing bedding; much cryptocrystalline and spherulitic silica; more extensive silicification with silicification extending parallel to the bedding.

<u>A.8391</u>. Similar, but with considerably more chlorite (possibly derived from the decomposition of ferromagnesian minerals). No bedding.

<u>A.6900</u>. Similar; apparently brecciated, but structure due to patchy distribution of hematite enrichment; veins of quartz and brown spherulitic chalcedony. No bedding.

<u>B.7865</u>. Similar; clear quartz veins and much flaky hematite. No bedding. Quantity of detrital quartz lower. Scimitar-shaped fragments.

<u>B.8225</u>. Much detrital quartz; very little hematite; numerous quartz/chlorite patches; no bedding. (described above).

<u>B.8216</u>. Same as 8225; less chlorite (described above).

<u>B.7866</u>. Heavily impregnated by hematite; very strongly veined-almost a replacement breccia; obvious detrital quartz; veins of clear crystalline quartz and brown cryptocrystalline chalcedony.

<u>CONCLUSIONS</u>.

It has been decided to classify all of these rocks as fine sedimentary tuffs arising more from the accumulation of ejected macerated sedimentary (country rock) material rather than strictly igneous products. Thus, it is not necessary to postulate coexistent acid and basic volcanic activity. It is further suggested that the chlorite abundant in some specimens has been derived from the decomposition of basaltic material originally present in these particular phases of the tuff. One specimen does, in fact, contain a fragment of what is probably highly silicified basalt (B.8216).

Evidence in favour of the classification of these rocks as tuffs lies in the following observations:

1. Included fragments of angular outline in B.8216 and B.7865.

2. Marked angularity of the detrital quartz grains.

3. Graded bedding in A.8389 and less obvious bedding in others.

In support of their origin from the accumulation of ejected sedimentary material the following observations are cited:

1. The very high content of angular quartz fragments in most specimens.

2. The presence of much flaky sericite.

3. The general lack of obviously igneous material, except as indicated above.

4. Their present similarity to fine pelitic sediments.

The origin of the hematite which characterises so many of these rocks is problematical, but it is thought that it is probably secondary (i.e. post-depositional). It may be connected with the wide-spread silicification of these rocks which has resulted in the formation of quartz veins discordant to the bedding and quartzose lenses parallel to the bedding.

Hydrothermally-(?) Altered, Fine-Grained Tuff.

Specimen B8213: Described by R.D. Stevens.
Locality: Detrital fragment from Copper Prospect.
Description: B.8213 - Secondary quartzite veined or replaced by jasper.

In hand-specimen this is a very hard red to red-brown rock of extremely fine grain-size and has a distinct sub-conchoidal fracture. Hematite and limonite-filled cavities are common in the relatively coarser grained parts of the specimen. The larger of these cavities reach up to 1 cm. across. It is also apparent from the hand-specimen that this rock would have one particularly well-marked direction of jointing in outcrop.

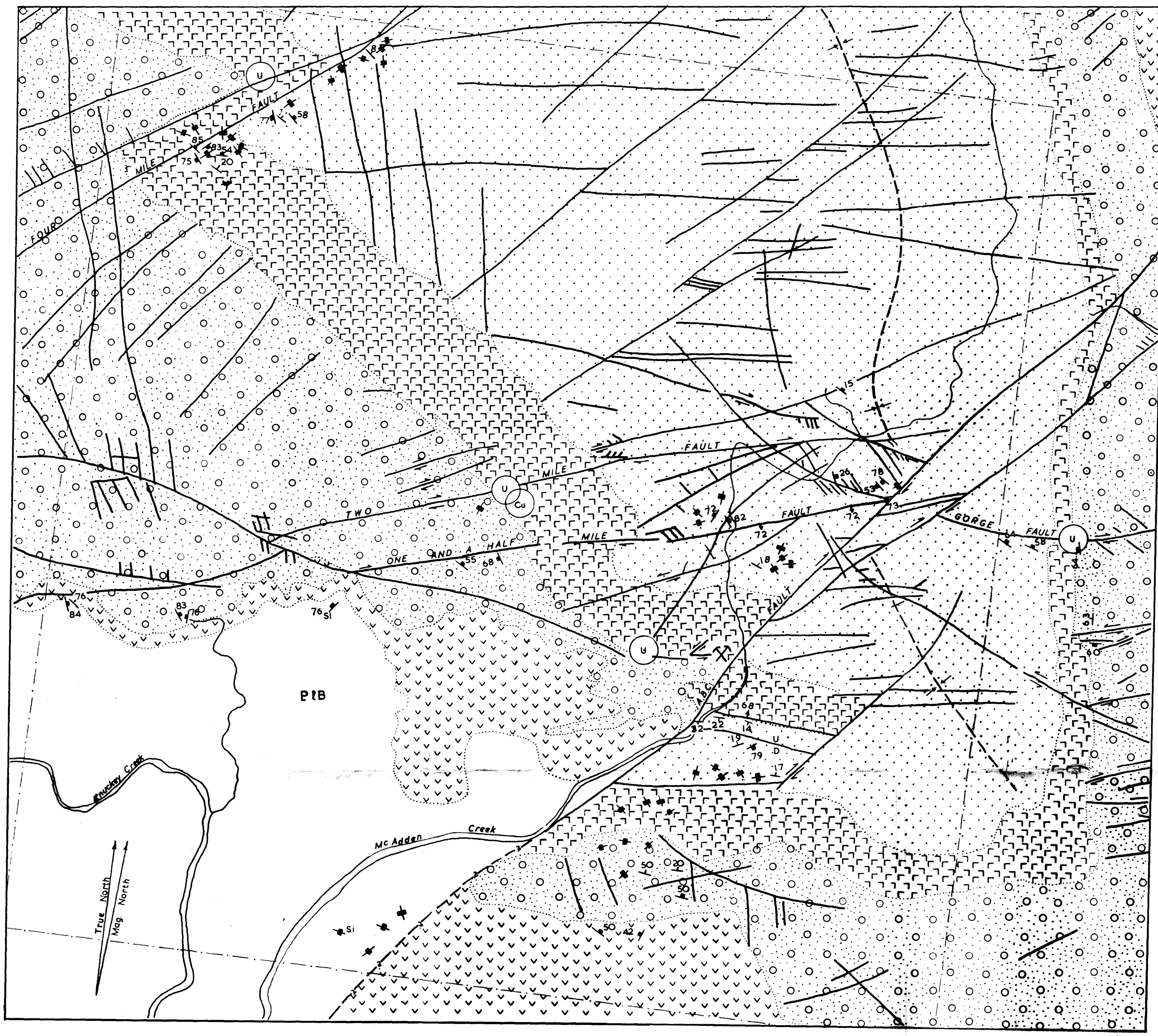
Thin-section (A), cut from the jasper-like part of the specimen, shows that the rock consists almost entirely (98%) of very fine-grained (0.05 mm. max.) secondary, granular and spherulitic chalcedony. The remaining 2% of the rock is made up of very finely granular hematite forming narrow stringers and semi-dendritic masses through the rock. These hematite bodies are included within the chalcedony and often pass through several grains without deflection.

Under very low magnifications the thin-section exhibits a vague banding due to layers of differing hematite concentration. These bands are planar in form and not curved or contorted and are, therefore, more reminiscent of sedimentary lamination than of igneous flow-structure.

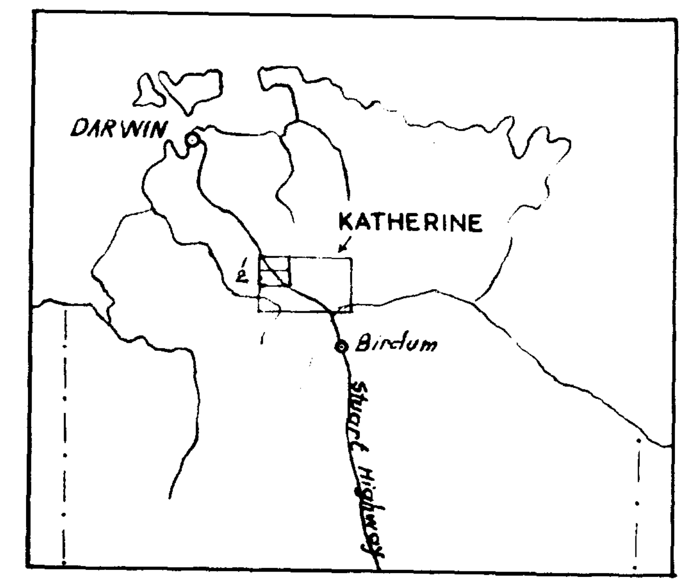
Thin-section (B), from a darker and coarser-grained part of the specimen (the part with abundant cavities), contains similar hematite aggregates but banding is not easy to detect. Again, hematite constitutes about 2% of the rock, the remaining 98% being an aggregate of secondary quartz grains with a distinct mosaic texture, and irregular veins and patches of spherulitic chalcedony veining or replacing the coarser material. The average grain-size is greater than in section (A), being about 0.1mm. Many of the quart grains have a curious core (about 0.01 mm. in diameter) very rich in dusty inclusions. These cores form a remarkably constant feature of the section and they are all of roughly the same dimensions, irrespective of the size of the grain in which they occur. That they are relict features is distinctly possible, but no evidence of their ultimate origin can be found in the section. They could also indicate a simple tendency towards concentration of impurities at the centers of the grains during (re)crystallisation. The (improbable) suggestion could also be made that they may represent the oolites of a completely silicified oolitic limestone!

The rock, in its present state, certainly represents the product of intense silicification, but we can offer no definite suggestion as to the nature of the original rock, so that field evidence will be the determining factor in establishing its origin and the cause of the silicification."

PLATE I

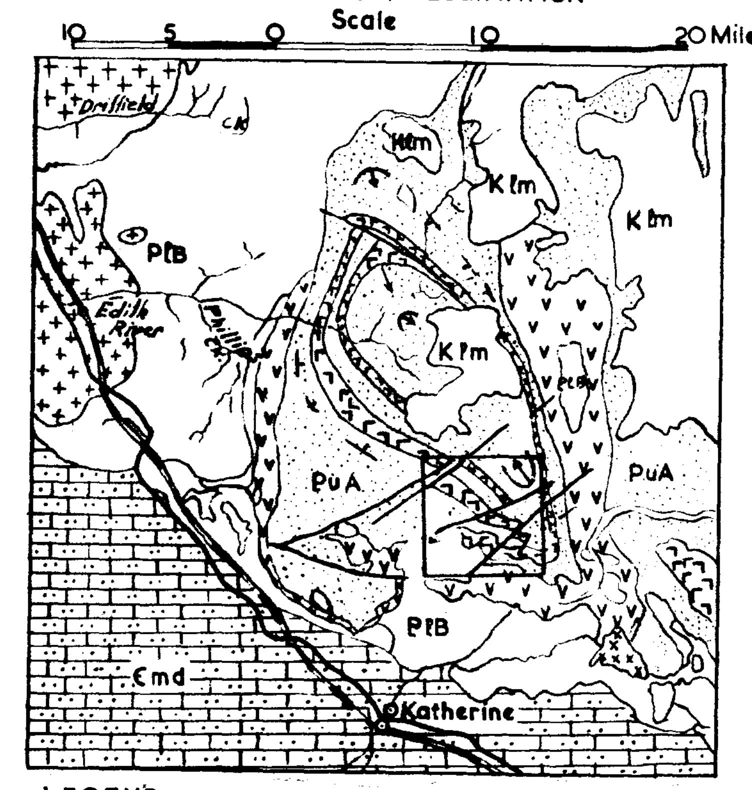


POSITION OF AREA DEALT WITH IN REPORT AND REFERENCE TO AUSTRALIAN FOUR-MILE AND ONE-MILE SERIES



Four-Mile Sheet: KATHERINE
One-Mile Sheet: 1 *Mt. Todd*, 2 *Katherine*

MAP OF AREA COVERED BY MT. TODD AND KATHERINE ONE-MILE SHEETS SHOWING GEOLOGY AND POSITION OF A.B.C. RESERVATION



LEGEND
(Additional to legend of large scale map)

CRETACEOUS	Klm	*Mullaman Group*
CAMBRIAN		*Daly River Group*
UPPER PROTEROZOIC	PuA	*A.B.C. Group (undifferentiated)*
LOWER PROTEROZOIC	+ +	*Cullen Granite*
		Maude Creek Diorite

LEGEND

UPPER PROTEROZOIC	A.B.C. Group	PuA_{C-E}		*Well bedded sandstone and thin basic volcanic member*
		PuA_B		*Basic volcanic rock*
		PuA_A		*Massive conglomeratic sandstone and medium grained sandstone*
	Edith River Volcanics	Pue		*Andesites, dacites, pyroclastics*
LOWER PROTEROZOIC Brock's Creek Group			PlB	*Tuffaceous sandstone, slates phyllites & hornfels*
				Syncline
				Fault and large fault fracture
				Inferred fault
				Apparent movement along faults

→	*Dip of fault*
32	*Dip and strike of strata*
35	*Strike and dip of fractures*
	Vertical fracture
Si	*Vertical fracture with SiO_2*
	Geological boundary
U	*Uranium prospect*
Cu	*Copper prospect*
	A.B.C. uranium prospect
	Boundary of A.B.C. Reservation

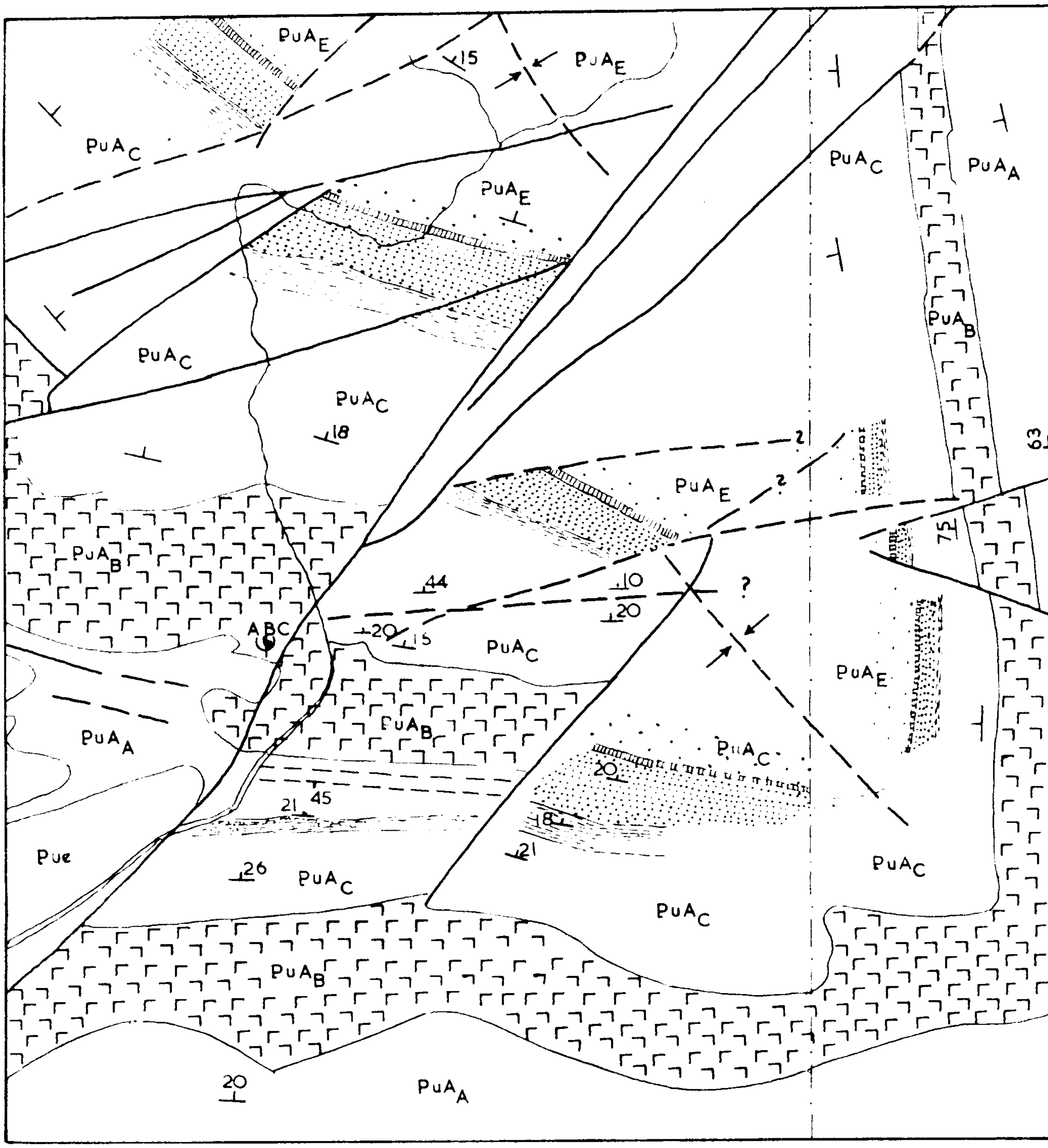
BUREAU OF MINERAL RESOURCES
Darwin Uranium Group
GEOLOGICAL MAP
OF
A.B.C. RESERVATION Near KATHERINE, N.T.

Approximate Scale: 1 inch = 2400 feet
(Traced from air photos)

General geology after Rattigan and Clark, 1954
Structural geology by J. Rade

April, 1955

PLATE 2



LEGEND

PuAE	Massive cross-bedded sandstone; PuAE	PuAB	Basic flows
PuAD	Basic volcanic rock	PuAA	Sandstone
PuAC	Massive cross-bedded pebbly sandstone; Siltstone and thin bands of sandstone; PuAC	Pue	Edith River Group
		Ψ	A.B.C. Uranium Prospect
		——	Boundary of A.B.C. Reservation

N

BUREAU OF MINERAL RESOURCES
Darwin Uranium Group

GEOLOGICAL SKETCH MAP
Of
SOUTH EASTERN PART
Of
A.B.C. RESERVATION Near KATHERINE, N. T.
Showing Position of D Member and Adjacent Beds where Mapped

Scale 1 inch = 2400 feet

D. E. Gardner May, 1955

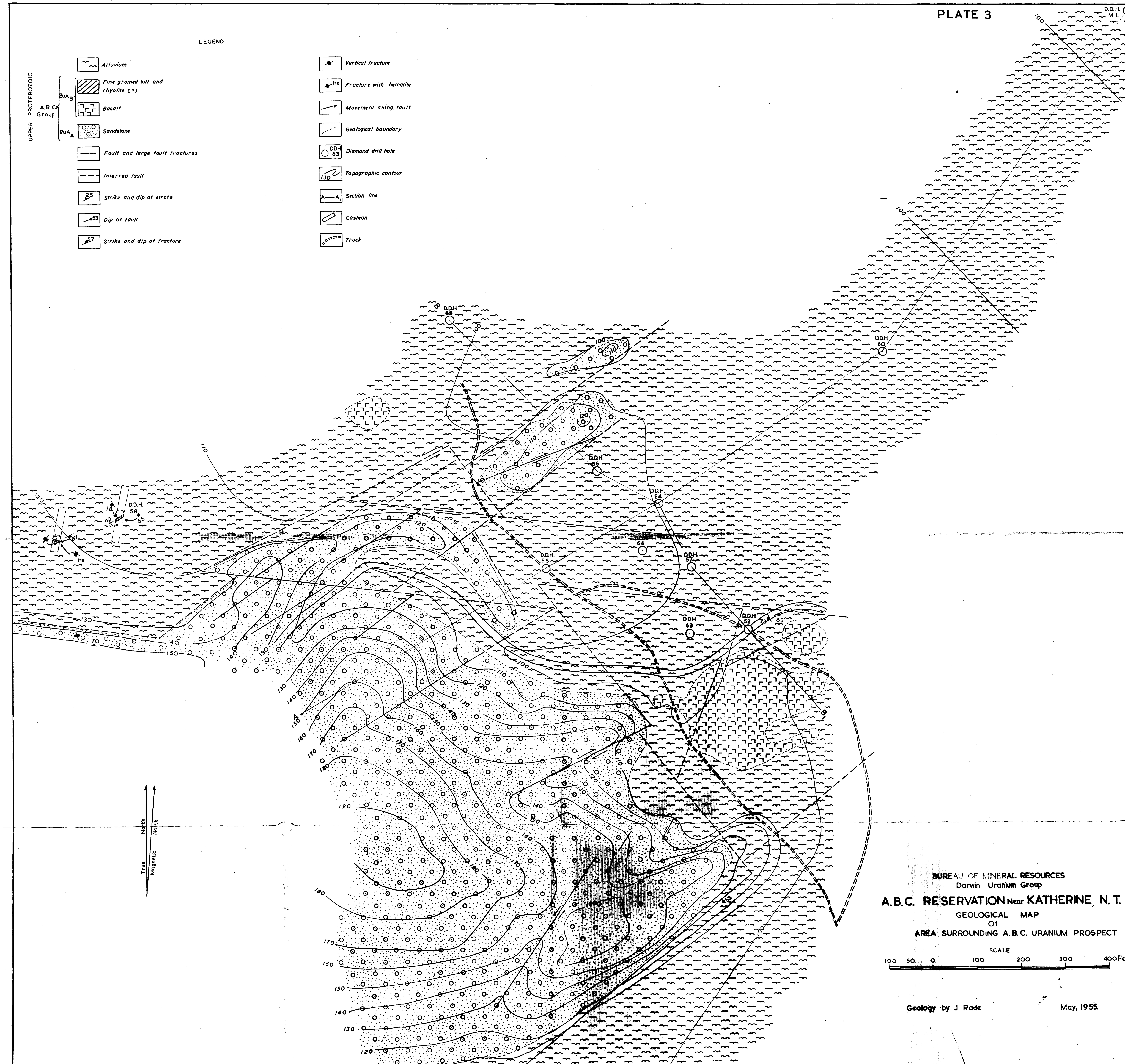
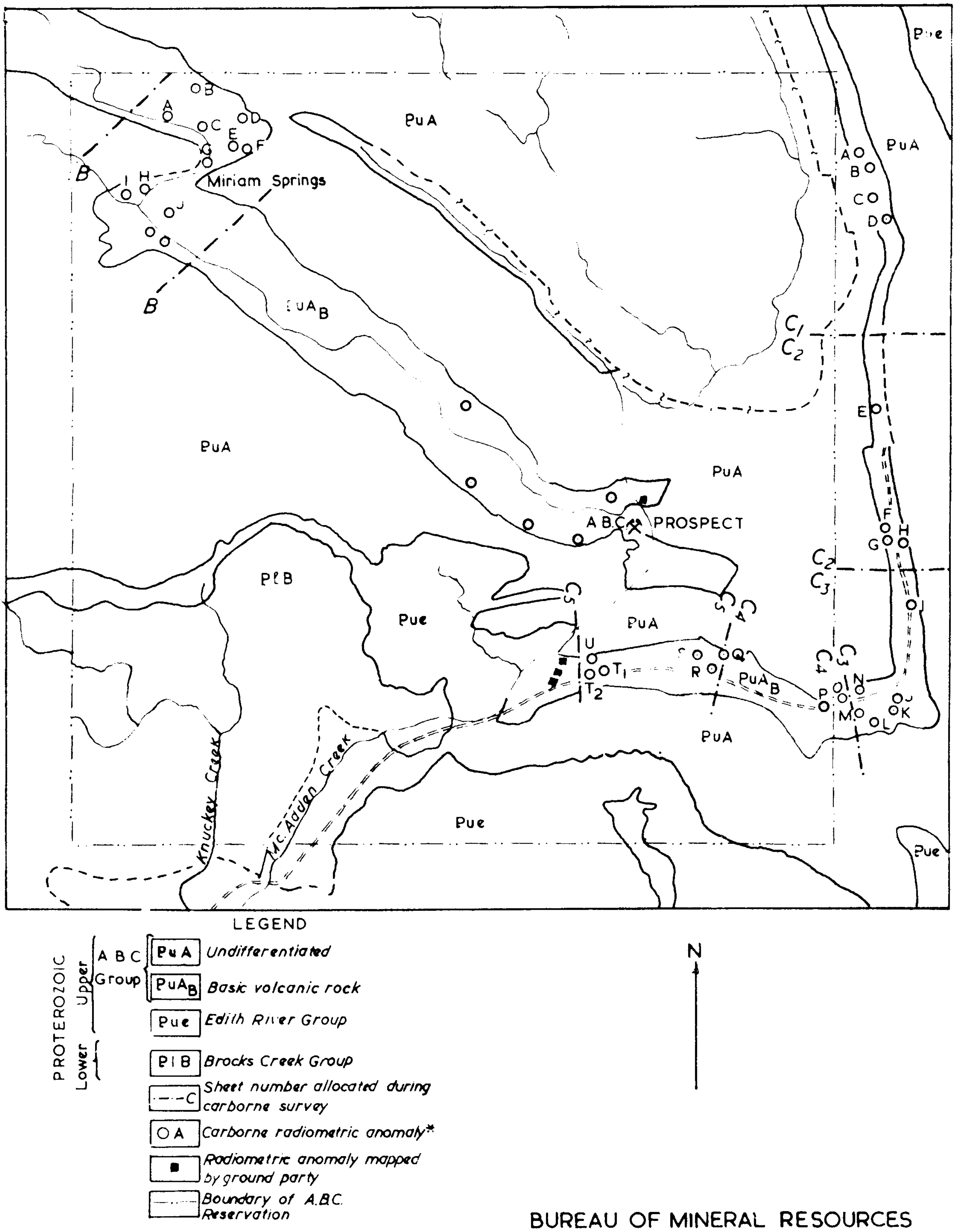


PLATE 3
LEGEND
Alluvium
UPPER PROTEROZOIC
A.B.C. Group
ꝐuA_B
Fine grained tuff and rhyolite (?)
Basalt
ꝐuA_A
Sandstone
Fault and large fault fractures
Inferred fault
Strike and dip of strata
Dip of fault
Strike and dip of fracture
Vertical fracture
Fracture with hematite
Movement along fault
Geological boundary
Diamond drill hole
Topographic contour
Section line
Costean
Track
True North
Magnetic North
D.D.H. 65
D.D.H. 60
D.D.H. 56
D.D.H. 54
D.D.H. 58
D.D.H. 55
D.D.H. 64
D.D.H. 57
D.D.H. 63
D.D.H. 52
D.D.H. M.L.
BUREAU OF MINERAL RESOURCES
Darwin Uranium Group
A.B.C. RESERVATION Near KATHERINE, N.T.
GEOLOGICAL MAP
Of
AREA SURROUNDING A.B.C. URANIUM PROSPECT
SCALE
100 50 0 100 200 300 400 Feet
Geology by J. Rade
May, 1955


SECTION AA1
PLATE 4
S.W.
N.E.
Section
BB1
D.D.H.
No. 54
D.D.H.
No.55
D.D.H.
No.60
D.D.H.
No.M1
CREEK
100′
100′
SECTION B B1
N.W.
S.E.
D.D.H.
No.65
D.D.H.
No.56
Section
AA1
D.D.H.
No.54
D.D.H.
No.57
D.D.H.
No.52
100′
100′
LEGEND
Pleistocene to recent
Alluvium
UPPER PROTEROZOIC ABC GROUP
PuA_B
Dolerite
Basalt
PuA_A
Sandstone
Fault definite
Fault probable
Geological boundary
57
Bore hole
BUREAU OF MINERAL RESOURCES
Darwin Uranium Group
A.B.C. RESERVATION NEAR KATHERINE N.T.
Geological Sections AA1 & BB1
SCALE 40 0 40 80 FEET
Geology by J. Rade.
May, 1955.

PLATE 5



* Several carborne anomalies plotted near the central (5) and north western part (3) of the Reservation have no distinguishing designations

BUREAU OF MINERAL RESOURCES
Darwin Uranium Group

MAP OF A.B.C. RESERVATION

Near KATHERINE, N. T.

Showing Localities of Radiometric Anomalies Mapped by Geophysical Parties

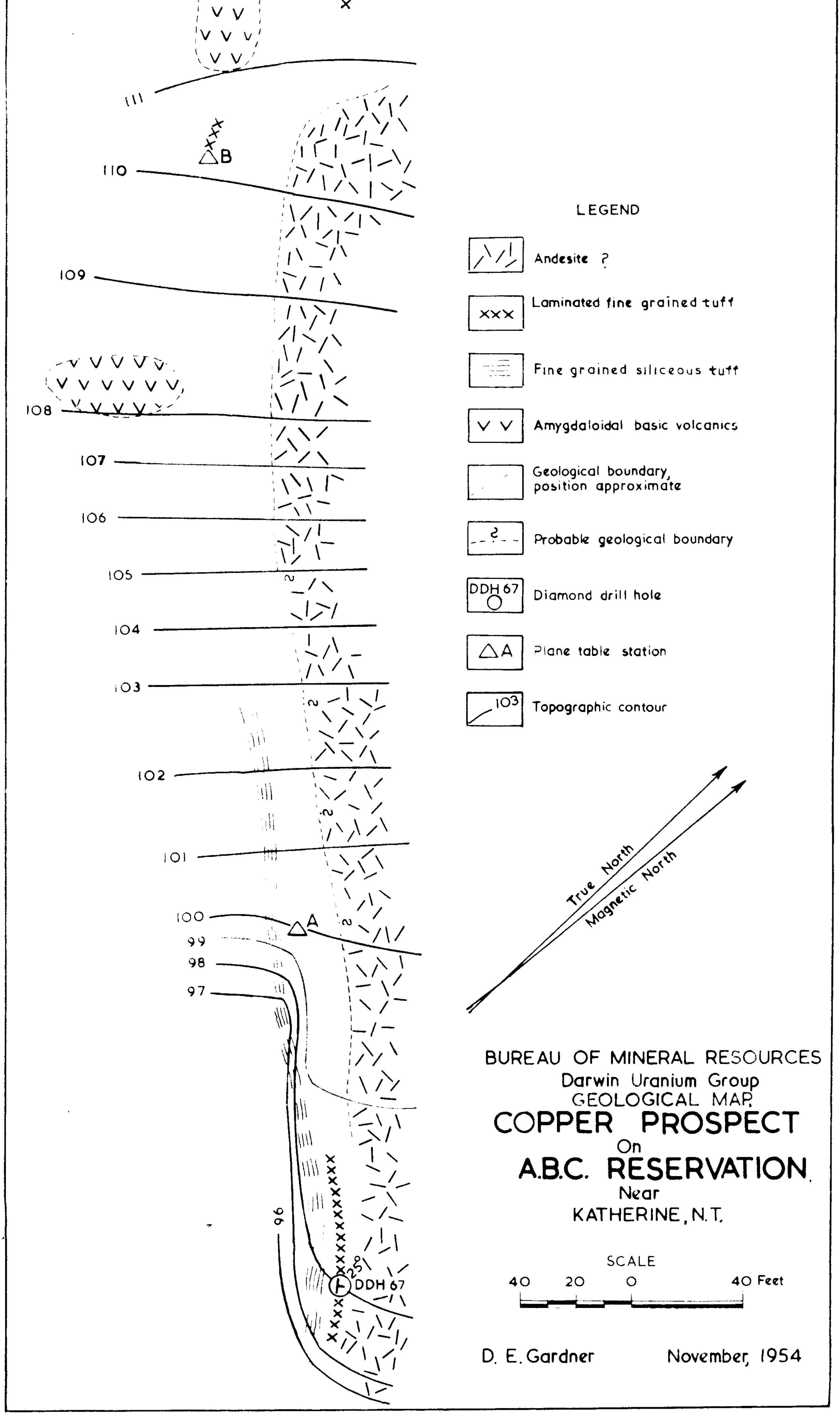
Compiled by D. E. Gardner

SCALE

1 ½ 0 1 2 MILE

PLATE 6
LEGEND
PLEISTOCENE to RECENT
Sand and rubble
Sandstone rubble
UPPER PROTEROZOIC A. B. C. Group*
Siliceous rubble**
Brown jasperoid volcanic rock
Basic amygdaloidal volcanic rock
Sandstone
Strike and dip of strata
Strike and dip of fractures and joints
Vertical fractures and joints
Fault (definite)
Fault (inferred)
Prominent fracture faces
Movement along fault
Topographic contour
Geological boundary of rock outcrops
Plane table station
Costean
Diamond drill hole
* Originally called Mt. Callanan Group
** Fine grained tuff and rhyolite
True North
Magnetic North
Stream
E1
E2
E3
E4
D
U
BUREAU OF MINERAL RESOURCES
Darwin Uranium Group
A. B. C. RESERVATION Near KATHERINE, N. T.
GEOLOGICAL MAP Of HALF MILE PROSPECT
SCALE
40 20 0 40 80 Feet
Geology by J. Rade
May, 1955

PLATE 7



LEGEND
Andesite ?
Laminated fine grained tuff
Fine grained siliceous tuff
Amygdaloidal basic volcanics
Geological boundary, position approximate
Probable geological boundary
DDH 67
Diamond drill hole
A
Plane table station
103
Topographic contour
True North
Magnetic North
B
A
111
110
109
108
107
106
105
104
103
102
101
100
99
98
97
96
25°
DDH 67
BUREAU OF MINERAL RESOURCES
Darwin Uranium Group
GEOLOGICAL MAP
COPPER PROSPECT
On
A.B.C. RESERVATION
Near
KATHERINE, N.T.
SCALE
40 20 0 40 Feet
D. E. Gardner
November, 1954

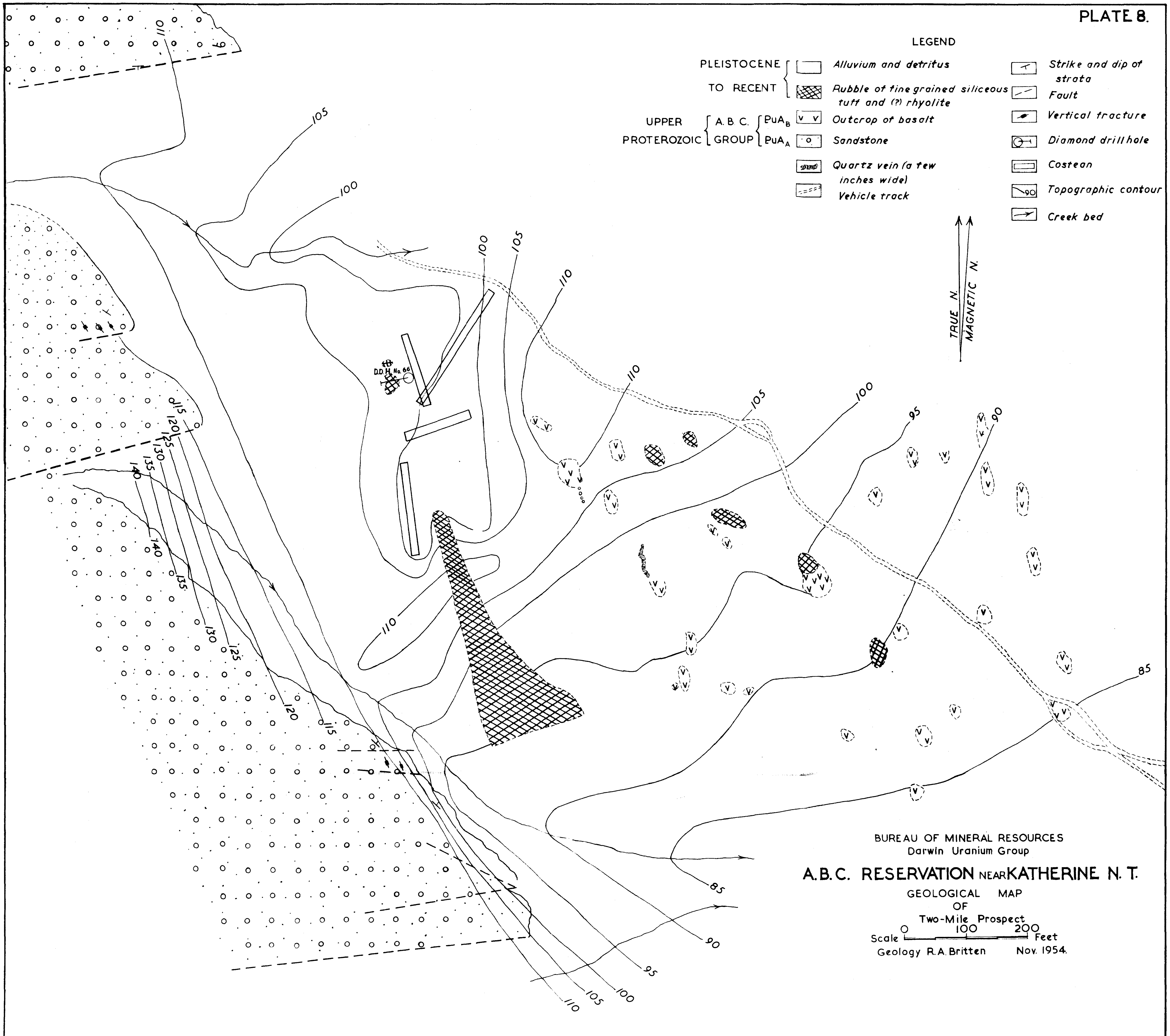
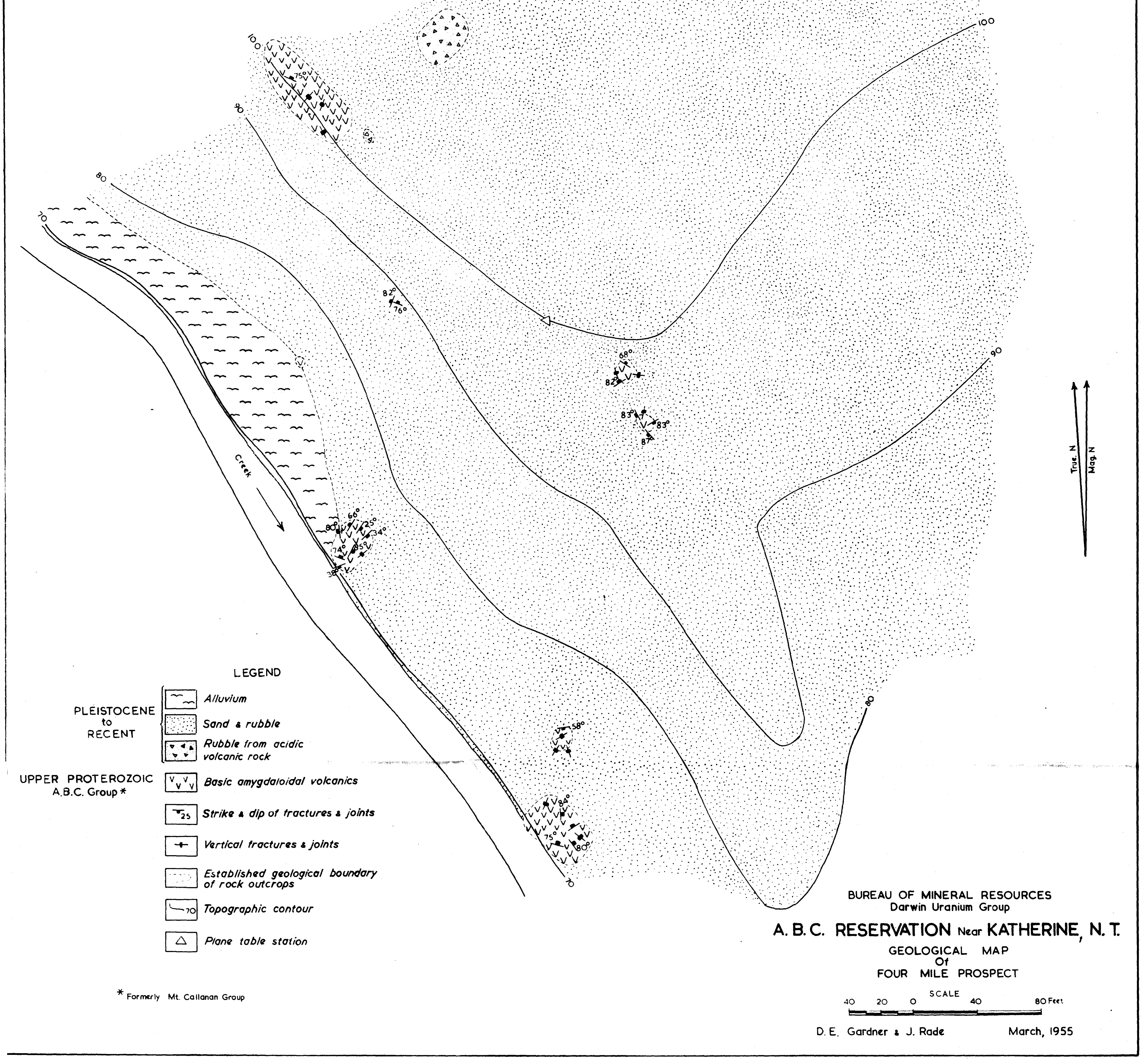

LEGEND
PLEISTOCENE TO RECENT
Alluvium and detritus
Rubble of fine grained siliceous tuff and (?) rhyolite
UPPER PROTEROZOIC
A. B. C. GROUP
PuA$_B$
Outcrop of basalt
PuA$_A$
Sandstone
Quartz vein (a few inches wide)
Vehicle track
Strike and dip of strata
Fault
Vertical fracture
Diamond drill hole
Costean
Topographic contour
Creek bed
TRUE N.
MAGNETIC N.
D.D.H. No. 66
BUREAU OF MINERAL RESOURCES
Darwin Uranium Group
A.B.C. RESERVATION NEAR KATHERINE N.T.
GEOLOGICAL MAP OF Two-Mile Prospect
Scale 0 100 200 Feet
Geology R.A. Britten Nov. 1954.

PLATE 9


LEGEND
PLEISTOCENE to RECENT
Alluvium
Sand & rubble
Rubble from acidic volcanic rock
UPPER PROTEROZOIC A.B.C. Group *
Basic amygdaloidal volcanics
Strike & dip of fractures & joints
Vertical fractures & joints
Established geological boundary of rock outcrops
Topographic contour
Plane table station
* Formerly Mt. Callanan Group
Creek
True N
Mag N
100
90
80
70
BUREAU OF MINERAL RESOURCES
Darwin Uranium Group
A. B. C. RESERVATION Near KATHERINE, N. T.
GEOLOGICAL MAP Of FOUR MILE PROSPECT
SCALE
40 20 0 40 80 Feet
D. E. Gardner & J. Rade
March, 1955