DEPARTMENT OF MINERALS AND ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT 167

The Geology of the Southern Victoria River Region, Northern Territory

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SUMMARY

This Report presents results of geological mapping carried out by BMR field parties in the southern Victoria River district during 1969 and 1970. The Waterloo and Limbunya 1:250 000 Sheet areas were completely mapped, as were all except the eastern parts of the Victoria River Downs and Wave Hill Sheet areas.

Precambrian rocks occupy most of the central part of the area; the remainder includes Lower Cambrian volcanics and Middle Cambrian sedimentary rocks.

The Inverway Metamorphics, which form the Archaean or Lower Proterozoic basement of the area, crop out over only 1.5 km^2, and are overlain nonconformably by the Limbunya Group, an extensive sequence of at least 1300 m of dolomite, siltstone, and sandstone. The dolomite contains abundant stromatolites. Also younger than the Inverway Metamorphics, but not in contact with them, is the Bunda Grit, which is overlain with angular unconformity by the Limbunya Group.

The Limbunya Group is overlain unconformably by the Wattie Group, which is a sandstone-siltstone sequence with minor dolomite, chert, and claystone; it is about 400 m thick.

A sequence of about 600 m of dolomite, siltstone, and minor sandstone, known as the Bullita Group, conformably overlies the Wattie Group, and is overlain with slight angular unconformity by up to 260 m of mudstone, siltstone, and glauconitic sandstone (Wondoan Hill and Stubb Formations). The Bullita Group is predominantly a shallow-water marine and lagoonal sequence, and the dolomite contains stromatolites. The rocks were mildly folded before deposition of the Auvergne Group.

Only five of the seven Auvergne Group formations crop out in the southern Victoria River district. The basal unit, the Jasper Gorge Sandstone, consists of shallow marine or fluvial sands, and is overlain by deeper-water siltstone and shale (Angalarri Siltstone). Epeirogenic movements affecting the Auvergne Group were very mild; it is flat-lying over much of the area, and is gently tilted and folded in the extreme northwest.

The Duerdin Group, the youngest Precambrian group mapped, is a non-marine glacial sequence up to 220 m thick. Tillite and sandstone were laid down in valleys carved into a basement of Auvergne Group, mostly Angalarri Siltstone.

A thin sandstone body, the Kinevans Sandstone, is Late Proterozoic or Early Cambrian. It is overlain, probably conformably, by the Antrim Plateau Volcanics, which consist of a sequence of basalt flows with thin interbeds of sandstone, chert, limestone, and siltstone. The unit crops out in a broad arc around the eastern, southern, and western margins of the area mapped; its thickness exceeds 350 m in some western localities, but as little as 150 m is preserved in the east. A prominent porphyritic basalt flow and a series of agglomerates were delineated as members. Most of the basalt flows have slightly vesicular bases and highly vesicular tops.

The Middle Cambrian Negri Group overlies the volcanics in the west, as does the Montejinni Limestone in the east. Limestone, which forms the basal part of the sequence in the west, is overlain by shale, fossiliferous limestone, siltstone, and sandstone. The sequence is capped disconformably by the ?Devonian Elder Sandstone.

Cretaceous rocks are preserved in the east, but were not examined during this survey. The whole area was lateritized during the Late Cretaceous or Early Tertiary. Miocene non-marine limestone deposited in valleys eroded into the laterite contains a rich vertebrate fauna.

The whole map area has been uplifted since the time of laterite formation and present erosion is exhuming the Palaeozoic and Precambrian rocks from below the laterite.

Regional gravity and magnetic surveys have aided interpretation of the geology, but the results contain some unexplained features.

Structurally, the area is simple. The younger Proterozoic rock groups are much less folded than the older ones; they are gently warped and affected by faults which probably represent zones of weakness in the basement.

A number of barite veins have been located in the west; most are in Antrim Plateau Volcanics and one is being worked. Two veins have been located in Adelaidean rocks in the north. The Antrim Plateau Volcanics contain many minor occurrences of copper, but the only deposits of any magnitude are at the contact with the overlying Headleys Limestone; none have proved to be economic.

Groundwater is an important resource, and adequate supplies can be obtained in most areas underlain by Antrim Plateau Volcanics. Drilling in the Bullita Group and Angalarri Siltstone has been largely unsuccessful.

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INTRODUCTION

This report describes the geology of the Waterloo, Victoria River Downs, Limbunya, and Wave Hill 1:250 000 Sheet areas in the Northern Territory and updates a preliminary unpublished report by the same authors (Sweet et al., 1971). The major part of the survey was carried out by four geologists in May-October 1969, and by two geologists in July-September 1970. This completed a project, begun in 1967, to map all 1:250 000 Sheet areas of the Victoria River district.

The area is underlain mainly by Precambrian sedimentary rocks and Lower Cambrian volcanics. A small area of Cambrian sedimentary rocks on the western side of the Limbunya Sheet area was mapped; rocks of similar age along the eastern side of Victoria River Downs and Wave Hill Sheet areas have been described previously.

Location and access. Figures 1 and 2 show the location of the four Sheet areas, which are bounded by latitudes 16° and 18°S, and longitudes 129° and 132°E.

The main access is provided by the Duncan, Buchanan, and Victoria Highways, which link with the port of Wyndham in the west. The Victoria and Buchanan Highways join the Stuart Highway in the east, and provide a link with the major port of Darwin. The Victoria Highway is sealed from Timber Creek to Katherine (290 km). A sealed road from the Victoria Highway at Willeroo joins the Buchanan Highway at Top Springs. The Buchanan Highway crosses the eastern and southern portions of the area and provides a link by way of Top Springs between the Stuart Highway (north of Dunmarra) in the Northern Territory and the Duncan Highway (at Nicholson station) in Western Australia. Two major unsealed roads extend from Victoria River Downs homestead to the highways, but most other stations are reached by minor roads. Access via station tracks is good in the east, but poor in most of the central and southwestern parts of the area. A helicopter was used to enter areas not easily or quickly accessible by vehicle.

Habitation and industry. There are no towns in the area. The nearest towns are Katherine (population 2500), Kununurra (about 1500), and Halls Creek (about 600). The total population of the mapped area is about 1000, most of whom, until recently, were employed in the pastoral industry. The 15 pastoral properties in the area range in size from Bullita (1270 km^2) to Victoria River Downs (12 220 km^2) and Wave Hill (15 630 km^2). Cattle raised for beef production are shipped live by road transport to abattoirs at Wyndham and Katherine. Road construction and maintenance gangs constitute the only other permanent population group. The Northern Territory Administration has a permanent research station at Kidman Springs, in the Victoria River Downs Sheet area, and S.A. Barytes Ltd owns a barite quarry northeast of Kirkimbie. Several hundred Aboriginals, previously employed in the pastoral industry, are now living in and near the Wave Hill Native Settlement.

Climate. The climate is monsoonal: dry southeasterly winds prevail for several months (May until October), and northeasterly, northwesterly, and westerly winds during the remaining months. Thunderstorm activity occurs from October until about April; occasional true monsoonal rain may fall between January and March, but is more frequent and persistent farther north. Rainfall decreases from about

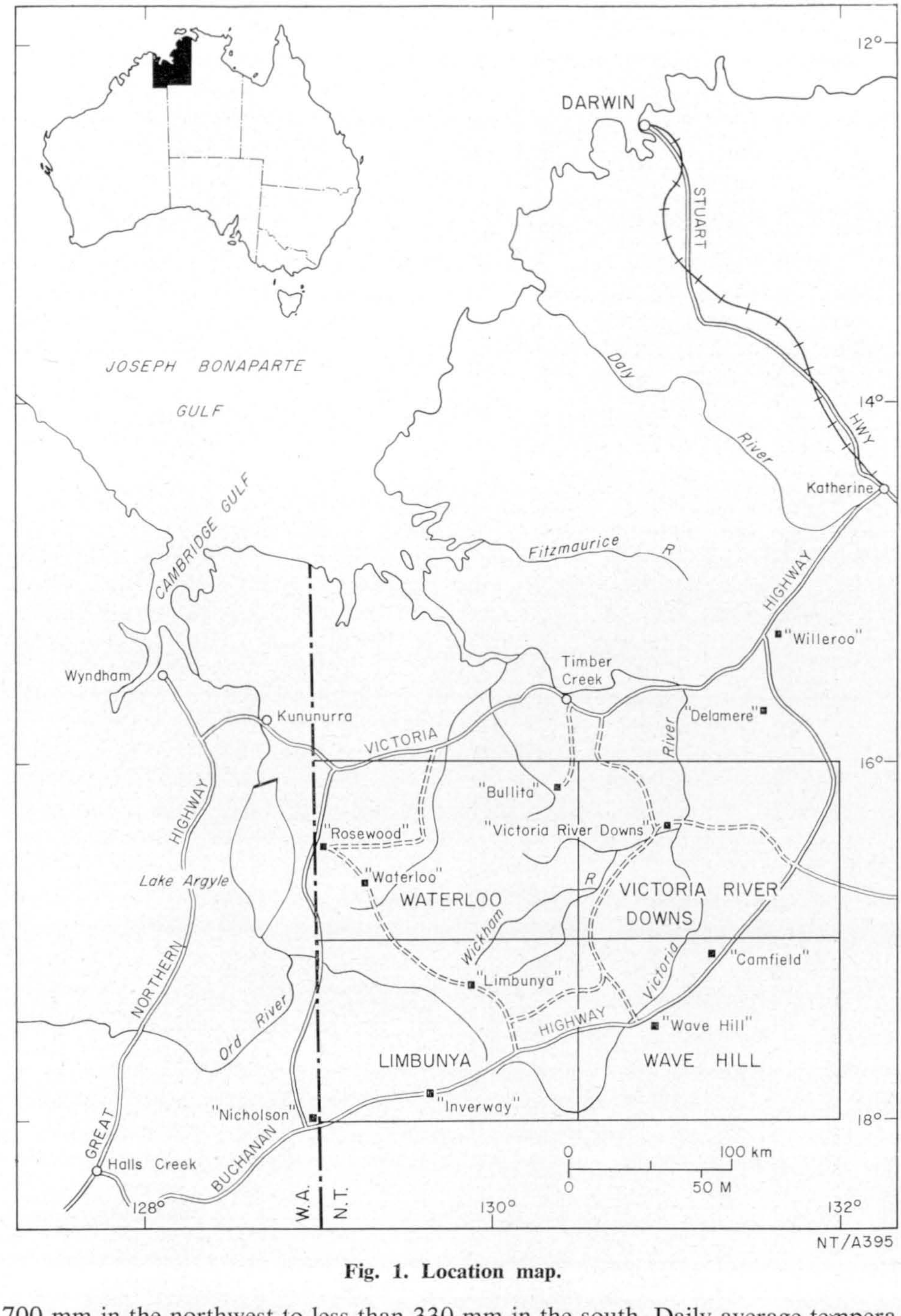


Fig. 1. Location map.

700 mm in the northwest to less than 330 mm in the south. Daily average temperatures range from about 10°C (min.) to 27°C (max.) during July, the coolest month, up to 27°C (min.) to over 40°C (max.) for November to February, the warmest months. Diurnal temperature extremes are greater in the south than in

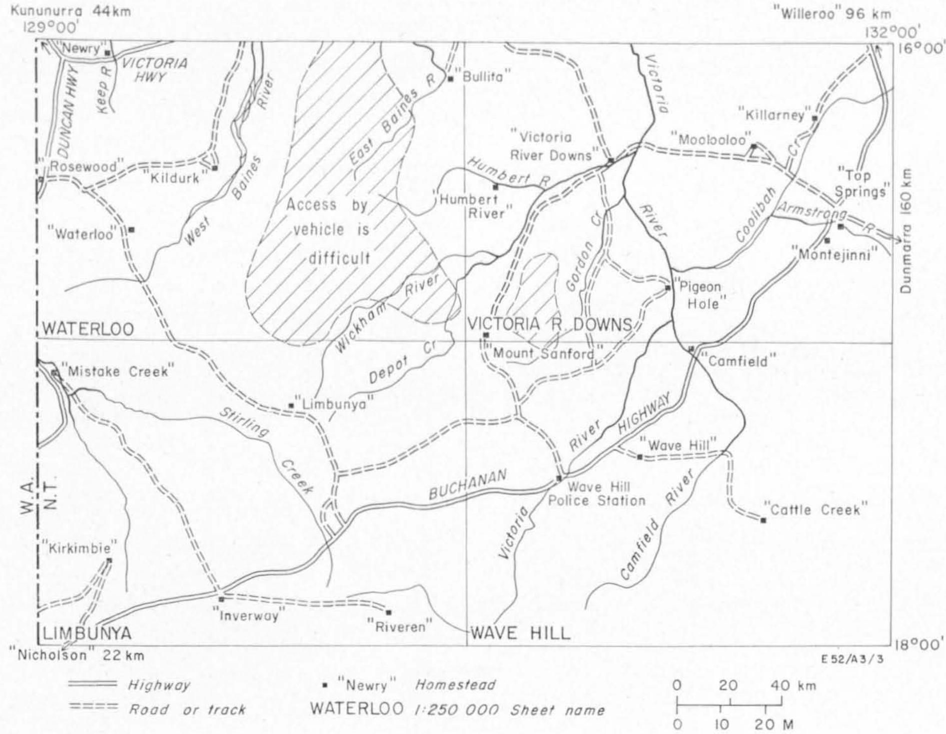


Fig. 2. Access map.

the north, owing to the greater influence of anticyclones passing across the continent in the temperate latitudes. Victoria River Downs station records average maximum temperatures of over 38°C for five months of the year (October to February). Table 1 contains temperature and rainfall figures for some stations. Slatyer (1970) described the climate of the whole Ord-Victoria region.

Vegetation. The vegetation of the area is characterized by woodlands with grassy understoreys (Perry, 1970); the most common trees are bloodwood (*Eucalyptus terminalis*) and southern box (*E. argillacea*). Black-soil areas developed on Antrim Plateau Volcanics have a sparse tree cover of nutwood (*Terminalia arostrata*) and rosewood (*T. volucris*), with Mitchell and other grasses. The skeletal soils on much of the rugged sandstone country, and the laterite areas in the south have a cover of Spinifex with trees predominantly of the snappy gum species (*E. brevifolia*). Dolomite, especially west of Humbert River homestead, supports dense stands of 'turpentine' shrub.

Watercourses are lined with several species, including paperbarks (*Melaleuca* spp.) and gums (especially *Eucalyptus camaldulensis*). A more detailed description of the vegetation types was given by Perry (1970).

Survey methods. Fieldwork was planned from 1:250 000 photogeological sheets prepared at BMR. These included reports on the Wave Hill and Victoria River Downs Sheet areas (Perry, 1966; 1967), and on the Limbunya and Waterloo Sheet areas (Maffi, 1968; 1969).

TABLE 1: CLIMATIC DATA* — SOUTHERN VICTORIA RIVER DISTRICT

RAINFALL (mm)		*Jan.*	*Feb.*	*March*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Annual*
Victoria River Downs	-	144.1	132.1	96	19.3	5.6	2.3	2.8	1.0	3.3	15.7	56.9	117.4	596.5
Wave Hill -	-	110.2	112	67.1	19.8	10.7	0.5	6.9	0.3	4.6	11.7	34.0	68.3	446.0
Rosewood -	-	158	135	83.3	20.4									
Waterloo -	-	158	149	94.0	13.7	8.1	2.8	5.6	1.0	2.0	16.0	55.1	101.9	608.2
Limbunya -	-	148.5	148	79.3	16.0	7.9	4.6	5.8	2.0	2.0	18.6	38.1	90.9	561.7
Newry -	-	198	170	117	25.6	8.1	3.6	3.6	0.8	2.0	20.8	65.3	143	757.8
Temperature (°C)						8.4	4.3	4.8	0.8	4.3	22.4	63.5	111.8	617.0
Victoria River Downs	Max. -	39.5	40.8	34.2	34.8	33.6	29.8	27.3	33.1	36.6	38.7	39.5+**	38.2	35.5
	Min. -	24.6	26.0	23.8	17.2	16.9	15.1	8.8	15.0	18.7	24.4	26.5	26.0	20.2
	Mean -	32.0	33.3	28.9	25.9	25.2	22.4	18.1	24.0	27.6	31.5	33.0+	31.8	27.0
Wave Hill (Police Station)	Max. -	37.6	37.9	35.4	34.9	30.8	27.7	27.9	30.6	34.6	37.9	39.0	38.9	34.3
	Min. -	24.0	23.8	22.6	18.6	15.4	12.8	11.1	13.7	17.3	22.0	23.9	24.2	19.1
	Mean -	30.6	30.6	29.0	26.2	23.1	20.2	19.5	22.1	25.9	30.0	31.5	31.6	26.7
Cattle Creek	Max. -	37.9	37.8	35.8	34.0	31.0	27.5	27.8	30.4	34.4	37.7	39.0	38.4	34.3
	Min. -	24.2	23.8	22.6	18.9	15.7	12.3	11.2	13.5	17.1	22.0	23.9	24.0	19.1
	Mean -	31.0	30.8	29.2	26.5	25.4	19.9	19.5	22.0	25.8	29.8	31.5	31.2	26.7

*Source—Bureau of Meteorology, Darwin.

**Insufficient records—estimated only.

Initial fieldwork was done by ground traverses using four-wheel-drive vehicles, and observations were recorded on overlays on 1:50 000 and 1:85 000 aerial photographs. A helicopter was used for six weeks at the end of the season to enter inaccessible areas and to recheck other areas.

Geological data were transferred from overlays on aerial photographs to 1:50 000 planimetric sheets compiled by the Division of National Mapping. The resulting compilations were photographically reduced to 1:250 000 scale and redrawn to give the preliminary and final editions.

Previous investigations. The first European to enter the area was Gregory, who in 1856 explored the headwaters of the Wickham and Victoria Rivers. He referred to the rugged sandstone country, and to the flat and undulating basalt areas (Gregory, 1857). Brown, the first geologist to report on the area, divided the rock sequence into four series—limestone, shale, sandstone, and basalt (Brown, 1895; 1909). Jensen (1915) traversed the country en route to the Tanami Goldfield.

Wade (1924) examined the Hardman Basin near the Northern Territory/Western Australia border during a survey to evaluate petroleum prospects in the area. He examined Precambrian rocks in both Western Australia and the Northern Territory, and noted boulders of gneiss, probably derived from Moonlight Valley Tillite, in the Keep River near Newry homestead. Matheson & Teichert (1948) studied the East Kimberley region and examined the Cambrian rocks of the Hardman Basin which extends into the Northern Territory.

Little geological work was done in the Victoria River region until the 1950s, when Traves (1955) produced a reconnaissance map of the Ord-Victoria region. He did not attempt to subdivide the Precambrian rocks into formations, but included them all in his Victoria River Group, a name which has been discarded. We have adopted, with minor modifications, the rock units described by Laing & Allen (1956) in the Victoria River Downs Sheet area (Sweet et al., in press, a; Sweet et al., in press, b). The last two references are the first reports arising from the present investigation by BMR.

Recent BMR work on the Precambrian rocks of the Katherine-Darwin region has been reported by Walpole, Dunn, & Randal (1968), and of the adjacent East Kimberley district by Dow & Gemuts (1969). Explanatory notes have been issued for the Waterloo (Sweet, 1973a), Victoria River Downs (Sweet, 1973b), Limbunya (Mendum, 1972) and Wave Hill Sheet areas (Bultitude, 1972).

Geophysical investigations are referred to in the text.

PHYSIOGRAPHY

The mapped area can be divided into three physiographic regions: high-level plains, intermediate partly dissected hilly areas, and low-level plains. In his geomorphological study of the Ord-Victoria region, Paterson (1970) used four major divisions, which are used in this Report. Paterson's Sturt Plateau and Ord-Victoria region are designated geomorphic regions; the Ord-Victoria region is divided into 3 subregions: Victoria River Plateau, Victoria River Plains and Benches, and Ord River Basin. We have further subdivided these subregions and the final classification and divisions used are shown in Figure 3.

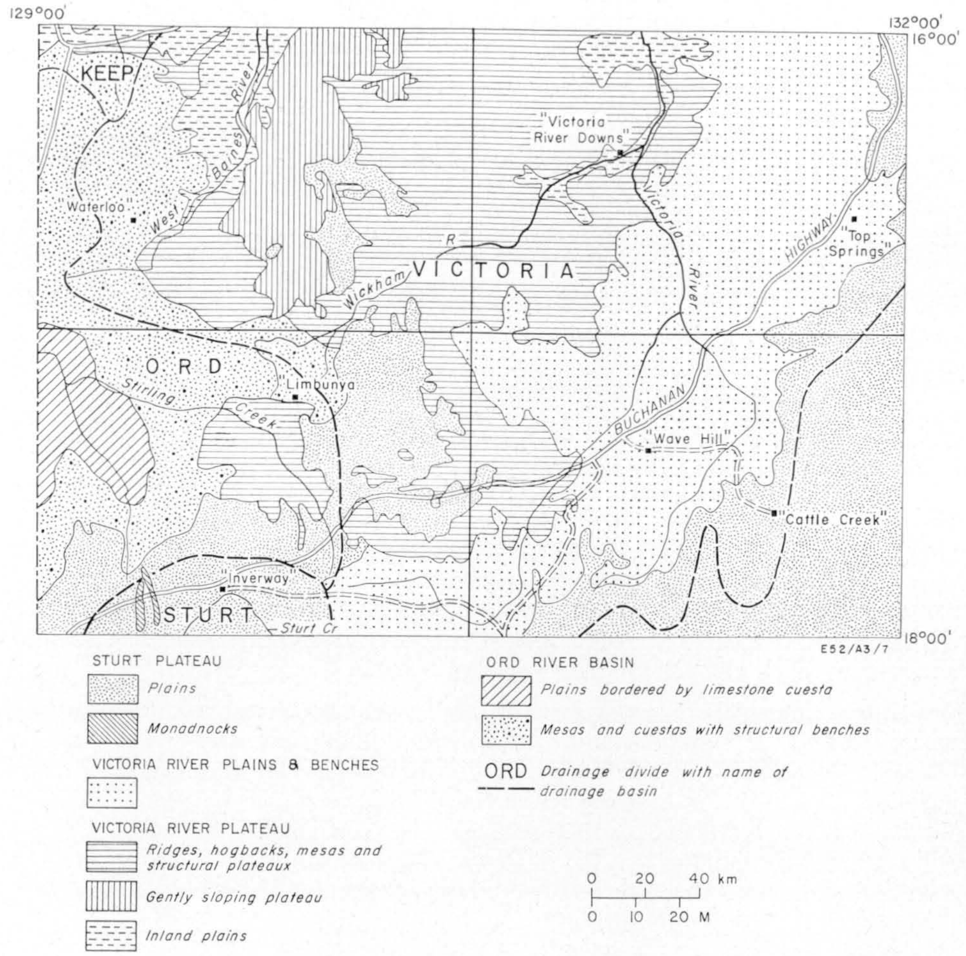


Fig. 3. Physiographic sketch map.

Sturt Plateau

This is a large region which extends south and east of the mapped area, and consists for the most part of *plains* with isolated *monadnocks* standing above them. The plains reach an elevation of 470 m above sea level near the plateau margin 20 km north of Inverway, and are 360 to 430 m above sea level throughout much of the Limbunya Sheet area. Monadnocks south and west of Inverway homestead stand about 30 m above plain level. The plains slope gently to the east and south, and in the Wave Hill and Victoria River Downs Sheet areas their altitude is 180 to 210 m.

Victoria River Plains and Benches

'These are associated with Lower Cambrian volcanics and Middle Cambrian limestones of the upper Victoria River catchment. The southern section is mainly an undulating plain with scattered mesas and buttes, and in the north the plains are less extensive. Towards the Sturt Plateau in the east is a series of volcanic structural benches topped by a limestone bench. In the south the plains rise gradually almost to plateau level. The altitude of the plains ranges from 350 ft in the north to 1200 ft in the southwest; the mesas, buttes and benches range from 500 to 1300 ft' (Paterson, 1970, p. 86). An isolated area with similar characteristics, north of Limbunya homestead, has been included in this subregion.

Victoria River Plateau

The Victoria River Plateau has been divided into three units. The *ridges, hogbacks, mesas, and structural plateaux* is the most extensive and cannot conveniently be subdivided. It includes a variety of landforms, the shape of which closely reflect the lithology and structure of the underlying rocks. Most of the rocks are Proterozoic sandstone, siltstone, and dolomite. The sandstone forms ridges and hogbacks where it is steeply dipping, and mesas and rugged dissected plateaux where it is gently dipping or flat-lying. The softer siltstone and dolomite form smooth or terraced slopes where dipping and low, rounded, terraced hills or plains where flat-lying.

The *gently sloping plateau* is a continuation of the Newcastle Range in the Auvergne Sheet area (Sweet et al., in press, b), and is underlain by gently dipping Jasper Gorge Sandstone. It is considerably more rugged and dissected in the central Waterloo Sheet area than elsewhere.

The *inland plains* include both erosional and depositional plains related to the present cycle of erosion. The most extensive is the valley of the West Baines River, which is erosional throughout the western half, but mainly floored by alluvial sediments adjacent to the river. The plains are underlain by the easily eroded Angalarri Siltstone.

Ord River Basin

The Ord River Basin includes both *plains* and hilly areas (*mesas and cuestas with structural benches*). The plains are restricted to the area occupied by the Hardman Basin, which contains easily eroded sedimentary rocks of Cambrian age. The basal formation in the basin is the Headleys Limestone, which crops out as a cuesta around most of the basin, and as a steep wall on the southwestern margin, in the Limbunya Sheet area.

The *mesas and cuestas with structural benches* are, like the Victoria River Plains and Benches, underlain by Lower Cambrian volcanic rocks. In the Ord River drainage basin, this area has been dissected more deeply and rapidly than those in the east, and consequently the relief is greater. The mesas are up to 360 m in altitude, and occur where the volcanics dip gently basinwards. Structural benches, which occur throughout, are the result of differential erosion of hard and soft layers (generally massive non-vesicular basalt and vesicular basalt, respectively).

Drainage

Most of the area falls within two major drainage basins, the Ord and the Victoria (Fig. 3). The edge of the Sturt Plateau is the inland limit of erosion of the headwaters of these rivers and their tributaries. The Sturt Plateau has virtually no surface drainage in the east, but in the south Sturt Creek rises southeast of Inverway and runs southwest and eventually spreads out in semi-arid country and disappears. A small area around Newry homestead is drained by the Keep River, which flows into the Bonaparte Gulf between the Ord and Victoria Rivers.

Age of Land Surfaces

Hays (1967) named and described four distinct land surfaces of different ages in the Northern Territory. Recognition of them is aided by surface laterites whose ages are known only within broad limits.

The oldest surface, the Ashburton Surface, is represented only by the monadnocks in the Limbunya Sheet area. Farther south similar monadnocks are laterite-capped; this surface may be contemporaneous with deposition of Mesozoic sediments to the north and east (Paterson, 1970).

The most extensive surface is the Sturt Plateau, which has a well developed lateritic profile; it is the *Tennant Creek Surface* of Hays (1967). The laterite is post-Lower Cretaceous as it has formed on rocks of that age in the north, but it has not been dated accurately. It is probably older than the Miocene limestone in the Wave Hill area (Camfield Beds), and is generally considered to be of lower Tertiary age.

In the Wave Hill area Hays (1967) recognized an erosional plain below the level of the Sturt Plateau and called it the *Wave Hill Surface.* Randal & Brown (1967) noted that numerous lithologically controlled plateaux and ledges away from the type area of the Wave Hill Surface make recognition of it virtually impossible. The surface was considered by Hays to be very extensive; he recognized it by the presence of detrital laterites below the level of the Tennant Creek Surface. No such surface has been observed away from the Wave Hill area in the area mapped.

The most recent land surface, the *Koolpinyah Surface,* is a modern erosion surface, and has reached base level only in coastal areas. The inland plains are the nearest in altitude and maturity to this surface, although the plains around Victoria River Downs contain one main terrace which is now being dissected. This terrace presumably indicates minor uplift in the Recent. The remainder of the Koolpinyah Surface is immature, with variable relief; it includes all of the Victoria River Plateau described above.

STRATIGRAPHY

The Precambrian stratigraphy of the four Sheet areas mapped is summarized in Table 2 and Figure 4. The time-stratigraphic terms are used in the sense of Dunn, Plumb, & Roberts (1966). Terminology used in describing rock outcrops and hand specimens appears at the beginning of Appendix I.

Twenty-eight new stratigraphic units are defined and described in this Report, and their distribution is shown on the accompanying map Sheets.

Basement rocks of probable Lower Proterozoic or Archaean age (*Inverway Metamorphics*) are overlain with marked unconformity by rocks of Adelaidean or Carpentarian age (Limbunya Group). The Bunda Grit is also overlain unconformably by Limbunya Group, and although it is not seen in contact with the Inverway Metamorphics, it is assumed to be younger than them.

The *Limbunya, Wattie, Bullita,* and *Auvergne Groups* crop out over a large area in the Victoria River region. The sequence is very gently folded in the upper part, and slightly more folded at deeper levels; it contains four regional uncon-

TABLE 2: SUMMARY OF PRECAMBRIAN STRATIGRAPHY — SOUTHERN VICTORIA RIVER REGION

Age	*Unit*	*Map Symbol*	*Lithology*	*Maximum Thickness (m)*
Adelaidean or Cambrian	Kinevans Sandstone	ⱣCk	Sandstone	45
Proterozoic		Unconformity		
Adelaidean	Duerdin Group			
	Ranford Formation	Ᵽos	Ferruginous siltstone and claystone, sandstone	60+
	Jarrad Sandstone Member	Ᵽoj	Quartz sandstone	10+
	Moonlight Valley Tillite	Ᵽom	Tillite, laminated dolomite at top	70
	Blackfellow Creek Sandstone	Ᵽol	Quartz sandstone	30
	Fargoo Tillite	Ᵽof	Tillite, dolomitic conglomerate	50
	Skinner Sandstone	Ᵽoi	Quartz sandstone, conglomerate	115
		Unconformity		
	Auvergne Group			
	Pinkerton Sandstone	Ᵽap	Quartz sandstone	50?
	Saddle Creek Formation	Ᵽad	Oolitic dolomite overlying quartz sandstone	50?
	Angalarri Siltstone	Ᵽaa	Siltstone, sandstone, minor shale and limestone	230+
	Jasper Gorge Sandstone	Ᵽaj	Quartz sandstone	80
		Unconformity		
	Stubb Formation	Ᵽat	Shale, siltstone, sandstone	115
	Wondoan Hill Formation	Ᵽwo	Sandstone, claystone, siltstone	145+
Adelaidean (?)		Unconformity		
	Bullita Group			
	Nero Siltstone	Ᵽbe	Siltstone and shale	80
	Mount Gordon Sandstone	Ᵽbo	Sandstone	10
	Battle Creek Formation	Ᵽba	Siltstone, dolomite, sandstone	150+
	Weaner Sandstone	Ᵽbw	Sandstone, grit	15
	Bynoe Formation	Ᵽby	Siltstone, dolomitic sandstone	200
	Skull Creek Formation	Ᵽbs	Dolomite, dolomitic siltstone	165
	Bardia Chert Member	Ᵽbm	Laminated and brecciated chert	60
	Supplejack Dolomite Member	Ᵽbu	Dolomite, dolarenite	10
	Timber Creek Formation	Ᵽbt	Dolomitic siltstone and sandstone, dolomite	200+
	Wattie Group			
	Seale Sandstone	Ᵽim	Quartz sandstone	100
	Gibbie Formation	Ᵽig	Siltstone, sandstone	75
	Neave Sandstone	Ᵽin	Quartz sandstone	20
	Mount Sanford Formation	Ᵽio	Siltstone, dolomite, claystone	250
	Hughie Sandstone	Ᵽih	Quartz sandstone	130
	Burtawurta Formation	Ᵽib	Siltstone, sandstone	40
	Wickham Formation	Ᵽiw	Quartz sandstone, chert	315
Carpentarian or Adelaidean		Unconformity		
	Limbunya Group	Ᵽhu		
	Killaloc Formation	Ᵽhk	Siltstone, minor dolomite and sandstone	60
	Fraynes Formation	Ᵽhf	Dolomite, chert, siltstone	130
	Campbell Springs Dolomite	Ᵽhb	Dolomite	380
	Blue Hole Formation	Ᵽhl	Siltstone, dolomite	320

TABLE 2—Continued

	Farquharson Sandstone	Pha	Quartz sandstone	115
	Kunja Siltstone	Phj	Siltstone, minor dolomite	65
	Mallabah Dolomite	Phm	Dolomite	100
	Amos Knob Formation	Pho	Dolomite, siltstone, sandstone, shale	50
	Pear Tree Dolomite	Php	Dolomite and chert	75
	Margery Formation	Phr	Chert, claystone, dolomite	125
	Stirling Sandstone	Phs	Sandstone, conglomerate	120
Carpentarian (?)		Unconformity		
	Bunda Grit	Pbg	Sandstone, grit	1200+
Archaean or Lower Proterozoic		Unconformity		
	Inverway Metamorphics	Pi	Schist	

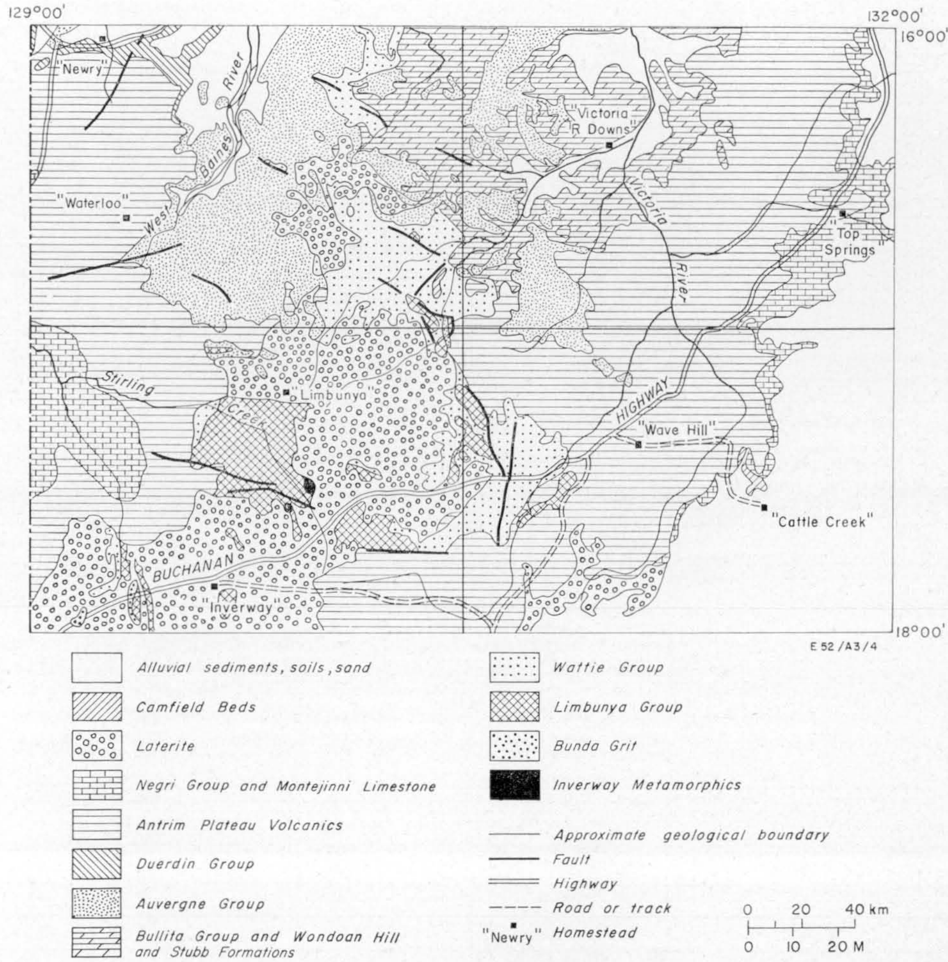


Fig. 4. Geological sketch map.

formities. Although the depositional area has been called the Victoria River Basin, it is in reality a broad platform area which received shallow-water marine sediment for a long period. Some of the units are continuous with rocks in the East Kimberley area of Western Australia. Isotopic age determinations have been carried out on glauconites of the Wondoan Hill Formation (between the Bullita and Auvergne Groups), and on the basis of these ages (1120 m.y.—R. W. Page, pers. comm.) the Wattie and younger groups are placed in the Adelaidean.

The Antrim Plateau Volcanics covered most or all of the mapped area in early Cambrian time. They are best preserved around the margins of the Hardman and Rosewood structural basins in the west, and the Wiso Basin in the east. In all three basins, lower Middle Cambrian sedimentary rocks overlie the volcanics. Only part of the Hardman basin was mapped during this survey; the portion in Western Australia was reported by Dow et al. (1964), and the Wiso Basin by Randal & Brown (1967).

The youngest consolidated sediments in the area are Cretaceous sandstone and siltstone (Skwarko, 1966), and the Miocene Camfield Beds (Randal & Brown, 1967). The Cretaceous rocks are lateritized in the east; they are absent in central and western areas. Laterite has also formed directly on Antrim Plateau Volcanics and, more rarely, on Precambrian rocks.

Archaean or Lower Proterozoic

Inverway Metamorphics (new name)

Derivation of name: From the Inverway pastoral lease in the Limbunya Sheet area.

Distribution: The only known metamorphics crop out in two localities in the Limbunya Sheet area: the larger outcrop, of 2 km^2, is 3 km northeast of No. 19 Bore (grid ref. 602058), and the other, of 0.5 km^2, is about 8 km west-southwest of the bore.

Stratigraphic relations: The metamorphics are unconformably overlain by sediments of the Limbunya Group. In the northeastern outcrop they occupy the core of a northeasterly-trending anticline of Limbunya Group. In the southwestern area they occur as an inlier in gently dipping Stirling Sandstone.

Type area: The outcrop 3 km northeast of No. 19 Bore, Limbunya Sheet area. The unit cannot be regarded as a single stratigraphic unit, hence the name 'Metamorphics' and the lack of a type section.

Lithology: The metamorphics in both areas are deeply weathered, and exposures consist of low, reddish brown rubbly mounds.

Northeast of No. 19 Bore reddish brown schist and grey to reddish grey sheared ?volcanics crop out. The volcanics are schistose in appearance, and consist of a groundmass of quartz (0.1-0.3 mm), sericite, and iron oxide, containing flakes of muscovite, subhedral and anhedral grains of quartz, and yellowish green feldspar up to 5 mm across; the quartz grains have rounded and embayed edges and some retain the B-quartz crystal shape; the feldspar is completely altered to sericite. Both schist and volcanics are cut by massive white quartz veins up to 2 m across.

About 8 km southwest of No. 19 Bore, schist similar to that northeast of the bore consists of angular quartz grains from fine-grained to 2 mm across, and flakes of muscovite up to 2 mm across, set in a fine-grained groundmass of sericite and iron oxide, with minor tourmaline and zircon. The rocks appear to have been strongly sheared, and lenses and veins of quartz are abundant.

CARPENTARIAN(?)

Bunda Grit (new name)

Derivation of name: From Bunda Creek, 16 km west of Inverway homestead, Limbunya Sheet area.

Distribution: The unit crops out in a north-trending anticline near the southern margin of the Limbunya Sheet area, 28 km west of Inverway homestead.

Lithology: Grit predominates (grainsize 2-4 mm), with coarse sandstone and subordinate fine-grained sandstone.

Type section locality: Measured in a creek which cuts through the western limb of the anticline. The base of the section is at 17°54′30″S, 129°21′E; the section extends west-southwest for almost 2 km to 17°55′S, 129°20′E. Generalized section is 600+ m of massive and cross-bedded grits; these are the oldest beds exposed in the core of the anticline and are overlain by 600 m of coarse sandstone and grit with medium and fine beds near the top.

Thickness: 1200+ m in the type section.

Age: Proterozoic, probably Carpentarian.

Stratigraphic relations: The base was not seen, but Bunda Grit probably unconformably overlies Inverway Metamorphics; it is unconformably overlain by Stirling Sandstone (well exposed angular unconformity).

Description: The oldest beds exposed are cross-bedded poorly sorted grit with abundant scattered quartz pebbles and pebble beds. The pebble beds become less abundant upwards and are scarce near the top of the formation. The sandstone becomes fine-grained westwards and the upper parts of the formation consist of orange and white, blocky and massive, medium-grained quartz sandstone. Cross-bedded units are 5 to 50 cm thick, and preserved foresets are 15 cm to 2 m long. Bedding-plane slickensiding is abundant in the upper part of the unit.

The youngest beds exposed are thin-bedded and laminated, banded purple cherts which crop out in two places adjacent to major north-trending faults west of Bunda Creek. These contain minor folds and are commonly brecciated.

The unit was deposited in a fluvial or very shallow marine environment which became progressively lower in energy. The unsorted nature of the grits suggest that the sediments in the lower parts of the unit were laid down quickly with little reworking.

CARPENTARIAN OR ADELAIDEAN

LIMBUNYA GROUP (new name)

Names of constituent formations:

Killaloc Formation (youngest)
Fraynes Formation
Campbell Springs Dolomite
Blue Hole Formation
Farquharson Sandstone
Kunja Siltstone
Mallabah Dolomite
Amos Knob Formation

Pear Tree Dolomite
Margery Formation
Stirling Sandstone (oldest)

Derivation of name: From Limbunya pastoral lease, Limbunya Sheet area.

Distribution: In the southwestern, central and eastern Limbunya Sheet area, and in isolated outliers in the Auvergne, Wave Hill, and Waterloo Sheet areas.

Lithologic affinities of constituent formations: The sequence is essentially a carbonate-fine clastic group, with minor intercalations of coarser clastics. All units were deposited in marine and paralic environments.

Thickness: About 1300 m in the central Limbunya Sheet area; there is at least 900 m above the Kunja Siltstone near Kirkimbie, and probably more than 1300 m for the whole group.

Stratigraphic relations: A complete conformable sequence of all eleven units of the Limbunya Group occurs in the central part of the Limbunya Sheet area. The Wickham Formation overlies Killaloc Formation in this area, and older units (including Campbell Springs Dolomite and Blue Hole Formation) in the east. The unconformity is obvious, and the Wickham Formation in places rests on an erosion surface in which sinkholes existed in the underlying dolomites. Near the northern margin of the Limbunya Sheet area Campbell Springs Dolomite is overlain, with angular unconformity, by Jasper Gorge Sandstone (basal Auvergne Group).

Fossils: Stromatolites occur at several stratigraphic levels, but further studies are needed before their usefulness in biostratigraphy can be established.

Age and correlations: The age of the group cannot be deduced with any degree of accuracy. The stratigraphic sequence between the Limbunya Group and the late Adelaidean glacial rocks (Duerdin Group) consists of more than 2400 m of stable shelf strata and, perhaps more importantly, includes regional unconformities. Some of this 2400 m — the Angalarri Siltstone and Jasper Gorge Sandstone — is correlated with the Helicopter Siltstone and Mount Wade Sandstone, which have yielded a date of 1128 ± 100 m.y. (Dow & Gemuts, 1969); because the time interval between the Limbunya Group and the Jasper Gorge Sandstone (represented by 1200 m of rocks and three regional unconformities) cannot be estimated, the Limbunya Group is designated 'probably early Adelaidean, but could be as old as late Carpentarian'. The Limbunya Group is equated with the Bungle Bungle Dolomite in the East Kimberley, about which Dow & Gemuts (1969) were unsure in regard to age.

Discussion: The Limbunya Group was previously included in the Victoria River Group of Traves (1955). Present mapping has shown that it is the oldest group of unmetamorphosed sedimentary strata in the southern Victoria River area. The 'Undivided Limbunya Group' shown on the accompanying Limbunya Sheet was originally named Kirkimbie Beds (Morgan et al., 1971). This name was discarded when it became apparent that the sequence comprised Kunja Siltstone and all younger units of the Limbunya Group (Table 3 and Fig. 6).

Stirling Sandstone (new name)

Derivation of name: From Stirling Creek, which drains the northwestern quarter of the Limbunya Sheet area.

Distribution: In several outcrops near Swan yard, near the centre of the Limbunya Sheet area, and in outcrops 10 to 20 km south-southeast of Inverway homestead.

TABLE 3: SUMMARY OF LIMBUNYA GROUP STRATIGRAPHY

Unit	*Map Symbol*	*Lithology*	*Thickness range (m)*	*Stratigraphic relations*	*Physiographic expression*	*Remarks*
Killaloc Formation	Ᵽhk	Siltstone above dolomite	60	Overlain unconformably by Wickham Formation. Conformable on Ᵽhf	Low relief in type area	Youngest preserved formation of Limbunya Group
Fraynes Formation	Ᵽhf	Silty dolomite, with siltstone, dolomite, and chert	110-130	Conformable on Ᵽhb	Chert band at top forms low ridge, remainder is fairly low relief	Chert at top is of replacement origin
Campbell Springs Dolomite	Ᵽhb	Dolomite, dolarenite, and dolrudite	340-380	Conformable on Ᵽhl	Lapies, rocky low hills	Stromatolites well developed
Blue Hole Formation	Ᵽhl	Siltstone, silty dolomite, and shale	160-320	Conformable on Ᵽha	Valleys, low relief areas	Contains some stromatolites
Farquharson Sandstone	Ᵽha	Sandstone, siltstone	40-110	Conformable on Ᵽhj	Hogbacks, cuestas	
Kunja Siltstone	Ᵽhj	Siltstone, shale, and silty dolomite	60-65	Conformable on Ᵽhm	Forms valleys	
Mallabah Dolomite	Ᵽhm	Dolomite	10-100	Conformable on Ᵽho	Low relief, rocky pavements	
Amos Knob Formation	Ᵽho	Dolomite, green siltstone	40-50	Conformable on Ᵽhp	Low relief areas	
Pear Tree Dolomite	Ᵽhp	Dolomite and dolarenite, chert at top	75	Conformable on Ᵽhr	Low terrace hills, chert forms small rocky ridges	Chert has replaced dolomite at top of unit; contains stromatolites
Margery Formation	Ᵽhr	Claystone, chert (shale, dolomite)	125	Conformable on Ᵽhs	Valleys, some low hills	Rock types usually seen are altered from shale and dolomite
Stirling Sandstone	Ᵽhs	Sandstone	120	Unconformable on Inverway Metamorphics	Cuestas, rocky pavements, plateaux	

Lithology: A fairly uniform sequence of thin to medium-bedded, medium to coarse, white blocky sandstone; some pebbly beds near the base.

Type section locality: 3 km north of No. 19 Bore, in a small creek in which the whole unit is well exposed, at 17°32′S, 129°58′E.

Thickness: 120 m at the type section, comprising 3 m of basal gritty and pebbly sandstone overlain by 117 m of sandstone described above.

Age: Proterozoic, probably early Adelaidean, but could be as old as late Carpentarian.

Stratigraphic relations: The Stirling Sandstone unconformably overlies metamorphic basement (Inverway Metamorphics) at the type section, and Bunda Grit farther southwest, and is overlain conformably by the Margery Formation.

Description: The formation is composed entirely of sandstone. At the type section locality the sandstone generally is poorly sorted and well indurated. The thickness estimated from aerial photographs and measured dips is 105 to 120 m. The basal part of the formation consists of purple or fawn sandstone which is massive, thin-bedded, medium-grained, poorly sorted, and friable owing to a clayey matrix; grit and pebble conglomerate are also present in the basal 3 m of the formation. The sandstone contains subrounded grains of quartz, and minor tourmaline and chert 0.1 to 1.5 mm in diameter. The matrix is mainly silica in the form of syntaxial rims, and minor interstitial sericite and fine-grained opaque material.

In outcrops 10 to 20 km south and southeast of Swan yard the sandstone is fawn, massive, thin-bedded, medium-grained, poorly sorted, and contains interference ripple marks.

Three kilometres south of Mount Rose (grid ref. 573061), the sandstone is white, blocky, thin-bedded, medium-grained, but poorly sorted, with some sub-angular grains up to 3 mm across. White clay grains form about 1 percent of the rock. Cross-bed units about 15 cm thick are common. Oscillation ripples and interference ripple marks are less common.

West of Inverway homestead the Limbunya Group has not been subdivided into formations. The basal beds which overlie the Bunda Grit differ somewhat from the Stirling Sandstone and consist of ferruginous quartz grit and conglomerate bands. The conglomerate contains abundant rounded quartzite cobbles, and shale, chert, and rare actinolite-quartz pebbles. The matrix is poorly sorted ferruginous grit and coarse-grained sandstone. The conglomerate is overlain by abundantly cross-bedded, gritty, poorly sorted sandstone which is irregularly indurated. This is overlain by coarse-grained massive sandstone with minor grit and pebble bands and is in turn overlain by flaggy medium-bedded quartzitic sandstone with skip casts and poorly preserved ripple marks. Parts of this section of the unit contain small hematite inclusions. Higher in the sequence the sandstone is well sorted, mud flakes are present, partings are blocky, and grit bands are absent. Abundant current lineations in the upper beds indicate an easterly or westerly current direction; an easterly provenance is most likely because the basal beds in the west are medium and fine flaggy sandstone.

In the low hills 9 km south-southeast of Inverway homestead quartzitic sandstone and chert are common. The oldest beds crop out on the limbs of a syncline, and are composed of pink quartzitic sandstone containing a breccia bed 8 m thick which consists of angular quartzite and sandstone fragments in a ferruginous clay matrix. Flaggy to fissile micaceous sandstone crops out above the breccia and forms small-scale similar folds. Shale inclusions and quartz pebbles are common in the flaggy beds. Above this zone is a brecciated chert band with possible stromatolites. The overlying red-brown blocky quartz sandstone is cross-bedded and is the youngest bed seen in the syncline. This sequence includes Stirling Sandstone and possibly some Margery Formation, but the latter has not been delineated on the accompanying map Sheet.

Similar stratigraphic levels exposed 13 km southeast of Kirkimbie homestead comprise blocky to flaggy, pink to white, indurated medium-grained sandstone with some thin feldspathic beds. Cream and maroon claystone, siltstone, shale, and minor interbedded finely banded quartzitic sandstone crop out below the sandstone. The thin (5 cm) sandstone bands exhibit purple and white, regularly banded iron-staining which in places defines small kink folds. Within the shale a 1-cm band of pink chert is tentatively regarded as tuff. These rocks are shown as undivided Limbunya Group; they almost certainly include Margery Formation in addition to Stirling Sandstone.

Margery Formation (new name)

Derivation of name: From Margery Creek, which cuts through the formation south of Blue Hole yard (grid ref. 577075) in the Limbunya Sheet area.

Distribution: Fairly extensive outcrops in the headwaters of Swan Creek and tributaries in the central Limbunya Sheet area. The unit probably occurs farther south near Inverway and Kirkimbie homesteads, but poor exposures have prevented positive identification.

Lithology: Most outcrops are either chert or claystone. The rare better exposures retain sedimentary structures and show that the chert was originally carbonate rock, probably dolomite, and the claystone was siltstone, shale, or possibly ash-stone.

Type section locality: 3.5 km northwest of No. 19 Bore. The section was measured in a southwesterly direction on the northern side of a small gully at 17°32′S, 129°47′E (Section 1, Appendix 1).

Thickness: 125 m in the type section, the only complete section measured.

Age: Proterozoic, probably early Adelaidean, but could be as old as late Carpentarian.

Fossils: Silicified stromatolites are common.

Stratigraphic relations: The upper and lower boundaries are conformable with other Limbunya Group formations (Pear Tree Dolomite and Stirling Sandstone, respectively).

Description: The formation consists of a central claystone bed between upper and lower chert beds. It has not been divided into three separate units mainly because of the difficulty in distinguishing between the upper and lower cherts.

About 3 km northeast of No. 19 Bore the basal chert member is green, massive, and thin-bedded, with abundant silicified stromatolites. Near Swan yard numerous outcrops of the upper chert member are composed of green, yellow, and white, flaggy to massive stromatolitic thin-bedded chert. The zone of silicification passes down through semi-silicified claystone into white, flaggy soft claystone.

East of No. 19 Bore siltstone and semi-silicified siltstone are interpreted as the middle member of the Margery Formation. They are blocky and flaggy, reddish brown and pink with small black stains (possibly manganese), and consist of fine quartz grains and sericite flakes in a very fine-grained groundmass apparently consisting of quartz and sericite.

Between Swan yard and Mount Rose, chert belonging to the Margery Formation crops out along the major east-trending fault system between these two points. It is white or brown, ferruginous, and massive; both bedded chert and chert breccia crop out. Large stromatolites up to 0.6 m across are common; they are similar to specimens seen in the overlying Pear Tree Dolomite.

Most outcrops of the Margery Formation have been subjected to the effects of lateritization, and both the chert and claystone are almost certainly within the pallid zone of the laterite profile. The chert is silicified dolomite, as shown by the stromatolites, and the claystone could be altered shale, siltstone, or even ashstone.

Pear Tree Dolomite (new name)

Derivation of name: From Pear Tree Creek in the north-central Limbunya Sheet area.

Distribution: Two main areas — one in the central Limbunya Sheet area, the other near the western margin of the Wave Hill Sheet area at Farquharson Gap.

Lithology: Interbedded micrite, dolarenite, dolrudite, and sandy and oolitic dolomite. Chert is common in the upper part.

Type section locality: 2 km south-southeast of Swan yard. The section was measured northeastwards on the southeastern side of a small gully at 17°32′30″S, 129°50′30″E.

Thickness: About 75 m in type section, comprising about 45 m of fawn and red-brown, massive thin-bedded dolarenite overlain by 30 m of silicified dolomite (mostly laminated micrite containing stromatolites).

Age: Proterozoic, probably early Adelaidean, but could be as old as late Carpentarian.

Fossils: Well preserved diamond-shaped stromatolites (in horizontal section) occur in the silicified upper part of the formation.

Stratigraphic relations: The upper and lower boundaries are conformable with other Limbunya Group formations (Amos Knob and Margery Formations, respectively).

Description: The Pear Tree Dolomite consists of dolomite, dolarenite, dolrudite, sandy dolomite, and oolitic dolomite. The top 30 m of the formation has been almost completely silicified; the resulting chert still contains many stromatolites with cores of dolomite, indicating the original rock type.

The high percentage of dolarenite, oolite, sandy dolomite, and intraformational conglomerate is quite distinctive. The formation forms low terraced hills and generally shows up as a medium-toned unit on aerial photographs, although near Swan yard it is light-toned and banded. The silicified upper parts show up as dark-toned areas on aerial photographs.

About 1.5 km southeast of Swan yard the lower part of the formation consists of fawn and red-brown, massive and thin-bedded dolarenite. The dolomite fragments are vaguely defined, probably owing to recrystallization and to the fine-grained nature of both fragments and matrix. Subangular quartz grains up to

0.1 mm diameter form less than 1 percent of the rock. Minor contortion of the bedding may have been due to movement (possibly slumping) soon after deposition. The upper part of the formation consists of yellow-brown blocky fine-grained dolomite with interbeds of intraformational conglomerate and oolitic and sandy dolomite. The oolites are 0.3 to 0.5 mm in diameter, and have centres occupied either by dolmicrite or, more rarely, by grains of quartz or quartzite. The matrix is dolmicrite or silty dolomite and also contains fine grains of opaque iron oxide. The sandy dolomite is yellowish brown and blocky, with numerous fragments of dolomite up to 5 cm long. It consists of about 30 percent of subangular grains of quartz and minor tourmaline and chert with diameters of about 0.5 mm, set in a matrix of dolmicrite. The dolmicrite fragments are subrounded or angular, and up to 4 mm long. Some fragments of silty dolomite and some oolites are also included.

A minimum thickness of 75 m was measured northeast of Swan yard; the formation is faulted against the underlying Margery Formation.

About 10 km east of Swan yard the lower part of the formation is obscured by chert thought to be of Cambrian age. The lowest exposed rock in the formation is dolomite which is red, blocky, thin-bedded, and coarse-grained. Above this is dolarenite, and dolrudite with a matrix of dolarenite. Hemispherical stromatolites are quite common in both rock types. The rocks contain small lenses of oolitic or sandy dolomite, and undulating bedding which may have been formed by algal mats. The dolarenite consists of angular and rounded fragments of dolomite and dolomitic siltstone, separated by sparry dolomite. The fragments vary from 0.2 mm to several centimetres in diameter. The dolrudite contains dolomite fragments up to 15 cm long.

In two localities, one 6 km west of Swan yard and the other 3 km northwest of No. 19 Bore, the silicified dolomite at the top of the Pear Tree Dolomite contains distinctive stromatolites which are diamond-shaped in horizontal section (Fig. 5). The fossils are up to 0.5 m high and 0.3 m across and in many cases still contain a core of unreplaced dolomite.

At Farquharson Gap in the Wave Hill Sheet area the formation consists of interbedded sandstone, dolomite, and dolarenite, the dolarenite being the dominant rock type. The sandstone is white or dark brown, flaggy, thin-bedded, and fine to medium-grained. It contains varying amounts of dolomite fragments and grades into the dolarenite. The dolomite is pink, flaggy, thin-bedded, and fine-grained.

The dolarenite is pink, massive, and thin-bedded, with cross-bedded units up to 10 cm thick. It contains up to 90 percent dolomite fragments which are of medium to coarse sand-sizes. The rock also contains small quantities of quartz grains and of quartz lining cavities. The dolomite fragments are subangular to rounded, very fine-grained, and up to 2 mm in diameter. The matrix consists of coarse dolomite with silt-size quartz grains distributed unevenly through it; the quartz accounts for 5 to 10 percent of the rock.

Amos Knob Formation (new name)

Derivation of name: From Amos Knob in the central Limbunya Sheet area.

Distribution: Two main areas — in the central Limbunya Sheet area (east and west of Swan yard), and along the western margin of the Wave Hill Sheet area, extending northwards into the Waterloo Sheet area.

Fig. 5. Stromatolite in a silicified bed at the top of the Pear Tree Dolomite, 3 km northwest of No. 19 Bore, Limbunya Sheet area.

Lithology: Interbedded dolomite and green fissile siltstone and shale.

Type section locality: 1.5 km southeast of Swan yard, and immediately northeast of the type section for Pear Tree Dolomite. The section is across flat ground at 17°32′20″S, 129°50′20″E, and comprises at least seven dolomite beds 1 to 3 m thick, alternating with beds of green siltstone and shale 1 to 10 m thick.

Thickness: 50 m at the type locality; 40 m at Farquharson Gap.

Age: Proterozoic, probably early Adelaidean, but could be as old as late Carpentarian.

Fossils: None known.

Stratigraphic relations: The upper and lower boundaries are conformable with other Limbunya Group formations (Mallabah and Pear Tree Dolomites, respectively). Boundaries are drawn at the first and last occurrences of green siltstone.

Description: The Amos Knob Formation consists of poorly outcropping dolomite and siltstone and forms valleys between outcrops of Pear Tree Dolomite and Mallabah Dolomite. It shows a faint tonal banding on aerial photographs.

Two sections were measured through the Amos Knob Formation. At one, 1.6 km southeast of Swan yard, the unit is about 50 m thick (Section 2, Appendix I), and at the other (near Farquharson Gap, Wave Hill Sheet area) about 40 m (Section 3, Appendix I).

As the sections show, the unit consists of dolomite interbedded with a softer rock type, probably green fissile siltstone. In the Limbunya Sheet area 5 km southwest of Mount Rose (grid ref. 573061), outcrops of fissile green shale and siltstone and red-brown ferruginous flaggy dolomite are tentatively mapped as Amos Knob Formation.

Mallabah Dolomite (new name)

Derivation of name: From Mallabah Creek, a tributary of Stirling Creek, in the central Limbunya Sheet area.

Distribution: Scattered outcrops lie between No. 19 Bore and Mount Rose in the central Limbunya Sheet area; near Farquharson Gap in the Wave Hill Sheet area; and in the southeastern corner of the Waterloo Sheet area.

Lithology: Flaggy, thin-bedded and laminated, grey and pink dolmicrite.

Type section locality: A continuation of the sections through the Pear Tree Dolomite and Amos Knob Formation, 1.6 km east of Swan yard, at 17°32′S, 129°51′E, measured northeastwards across rocky pavements for 1 km.

Thickness: 100 m at the type section, where there is a fairly uniform sequence of dolomite (Section 5, Appendix I); it is only 13.5 m at Farquharson Gap (Section 4, Appendix I).

Age: Proterozoic, probably early Adelaidean, but could be as old as late Carpentarian.

Fossils: Small stromatolites are known from one locality.

Stratigraphic relations: The upper and lower boundaries are conformable with other Limbunya Group units (Kunja Siltstone and Amos Knob Formation, respectively).

Description: The formation is composed of predominantly ferruginous, thin-bedded and laminated, finely crystalline dolomite which grades into the siltstone units above and below it through dolomitic siltstone. It crops out as rocky pavements, and appears on aerial photographs as a very light-toned unit. However, the lower blocky part of the unit gives a rather darker tone in the area around Swan yard.

In the Limbunya Sheet area 8 km south of G.B. Rockhole, a red-brown, flaggy and blocky, thin-bedded dolomite has been tentatively mapped as Mallabah Dolomite. Flaggy and fissile, red silty dolomite with cream reduction spots also crops out in the area.

Several outcrops between 1 and 2 km south and southwest of Mount Rose are included in the formation. They include red-brown flaggy laminated dolomite and silty dolomite which contain small stromatolites.

Kunja Siltstone (new name)

Derivation of name: From Kunja Creek, a tributary of Stirling Creek, which drains the northern central Limbunya Sheet area.

Distribution: Between No. 19 Bore and Mount Rose in the central Limbunya Sheet area; at Farquharson Gap in the Wave Hill Sheet area; and in the southeastern corner of Waterloo Sheet area.

Lithology: Predominantly green fissile laminated siltstone with interbeds of shale and silty dolomite.

Type section locality: A continuation of the section through the Limbunya Group 2 km east-northeast of Swan yard at 17°31′30″S, 129°51′30″E, measured for 0.5 km in a northeasterly direction.

Thickness: 61 m at the type section, consisting of siltstone with a few interbeds of dolomite; 64 m at Farquharson Gap.

Age: Proterozoic, probably early Adelaidean, but could be as old as late Carpentarian.

Fossils: None known.

Stratigraphic relations: The upper and lower boundaries are conformable with other Limbunya Group units (Farquharson Sandstone and Mallabah Dolomite, respectively).

Description: The formation comprises siltstone, shale, and silty dolomite which generally crop out very poorly.

At Farquharson Gap 64 m of interbedded green fissile laminated fine siltstone and silty dolomite was measured. The silty dolomite is grey, pink-grey, and pink-brown, flaggy or fissile, and contains medium crystals (0.1 mm) of dolomite, 10 to 15 percent of subangular quartz, and minor feldspar grains with an average diameter of 0.05 mm. Cross-laminations can be seen in some beds, and vague ridges on weathered surfaces indicate that the rock is an intramicrite.

At the type section (Section 6, Appendix I) is 61 m of poorly outcropping rocks, mainly siltstone and minor flaggy dolomite. West and northwest of Swan yard outcrops comprise purple and green, fissile laminated siltstone.

In the area 7 km east of Kirkimbie homestead Kunja Siltstone is the oldest outcropping unit of the Limbunya Group and is exposed in the core of an anticline; all younger units of the group are present (Fig. 6). The Kunja Siltstone consists of at least 12 m of purple fissile laminated shale overlain by flaggy siltstone (Section 7, Appendix I).

Farquharson Sandstone (new name)

Derivation of name: From Farquharson Gap in the western Wave Hill Sheet area.

Distribution: At Farquharson Gap in the Wave Hill Sheet area; minor outcrops in the central and southwestern Limbunya and southeastern Waterloo Sheet areas.

Lithology: Blocky and massive, medium and thick-bedded, massive fine-grained sandstone.

Type section locality: At Farquharson Gap in the Wave Hill Sheet area at 17°17′15″S, 130°33′E.

Thickness: 112 m at the type locality, comprising 5 m of moderately sorted fine-grained sandstone overlain by 107 m of poorly sorted sandstone with a clayey matrix and numerous mud flakes (Section 8, Appendix I); the formation is 42 m thick 3 km east-northeast of Swan yard.

Age: Proterozoic, probably early Adelaidean, but could be as old as late Carpentarian.

Fossils: None known.

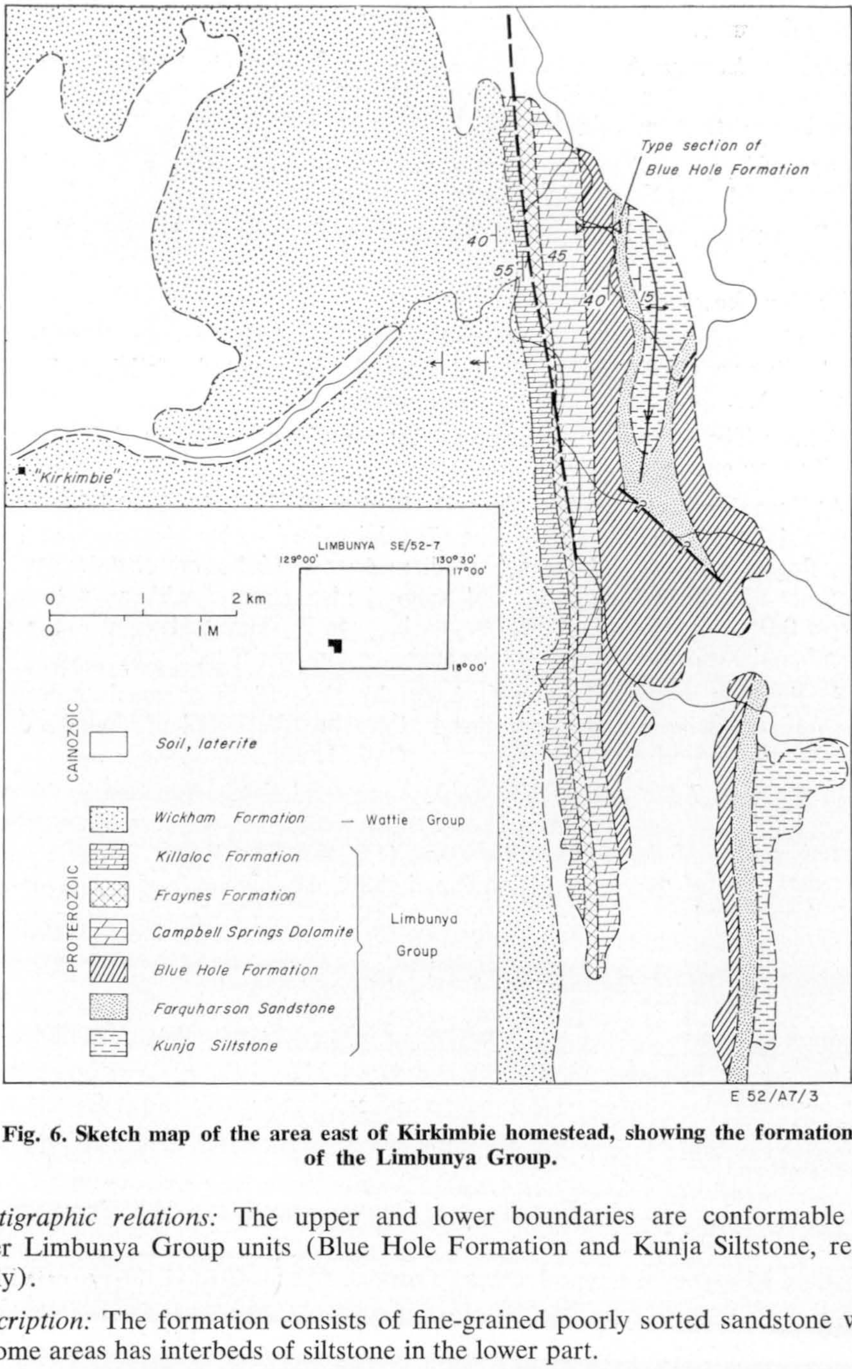


Fig. 6. Sketch map of the area east of Kirkimbie homestead, showing the formations of the Limbunya Group.

Stratigraphic relations: The upper and lower boundaries are conformable with other Limbunya Group units (Blue Hole Formation and Kunja Siltstone, respectively).

Description: The formation consists of fine-grained poorly sorted sandstone which in some areas has interbeds of siltstone in the lower part.

The formation is much thinner where it crops out in the central and southwestern Limbunya Sheet area, and 2 km east-northeast of Swan yard it is 42 m thick (Section 9, Appendix I). It is fine-grained and of similar lithology to the Farquharson Gap outcrops. Only the basal 20 m is exposed at Mount Rose, where

5 m of grey, blocky to massive, thick-bedded fine-grained sandstone (with 3% clay and feldspar grains) is overlain by 15 m of flaggy thin-bedded sandstone with abundant mud flakes. Near the top is a 1-m interbed of purple blocky thin-bedded dolomite.

East of Kirkimbie homestead (Section 7, Appendix I) the thickness of quartz sandstone is probably less than elsewhere, but if the sandy siltstone is included the unit totals 79 m. A bed of stromatolitic silty dolomite is present. Mud flakes, ripple marks, and mud cracks are common; the mud cracks are curved where they have formed in mud laminae which overlie ripple-marked sandstone.

Blue Hole Formation (new name)

Derivation of name: From Blue Hole yard, 26.5 km southwest of Limbunya homestead in the Limbunya Sheet area.

Distribution: Central and southwestern Limbunya, western Wave Hill, and southeastern Waterloo Sheet areas.

Lithology: Interbedded purple siltstone and shale, pink and grey dolmicrite, and dolarenite.

Type section locality: In the bed of a west-flowing tributary of Moonbool Creek at 17°42'30"S, 129°18'30"E, 8 km east-northeast of Kirkimbie homestead in the Limbunya Sheet area.

Thickness: 303 m at the type locality; 160 m in the central Limbunya Sheet area; 320 m at Farquharson Gap.

Age: Proterozoic, probably early Adelaidean, but could be as old as upper Carpentarian.

Fossils: Stromatolites are common in the upper dolomite beds.

Stratigraphic relations: The upper and lower boundaries are conformable with other Limbunya Group units (Campbell Springs Dolomite and Farquharson Sandstone, respectively).

Description: The Blue Hole Formation consists predominantly of siltstone, silty dolomite, dolomite, and dolarenite. The unit forms valleys, and outcrop is generally poor. It has a light-toned pattern on aerial photographs, with darker bands where the dolomitic rocks crop out.

The unit is almost completely exposed at its type section (Fig. 6), where it comprises interbedded dolomite, siltstone, and shale (Section 7, Appendix I). Shale does not crop out at any other locality but is probably present. The upper boundary has been placed at the top of a reddish stromatolitic dolomite-shale 30 m thick. Above this, as in other areas, is grey medium-crystalline dolomite of the Campbell Springs Dolomite. The Blue Hole Formation consists of a basal siltstone-shale sequence, a middle dolomite sequence, and an upper shale-dolomite sequence. The basal and upper beds are soft-weathering, a characteristic which aids air-photo interpretation of boundaries. This feature is less well developed in the Swan yard area, where the relief is more subdued and beds are not outlined by differential erosion.

Figure 7 is a bedding-plane view of peculiar structures in the middle dolomite unit. They are aligned along slight ridges on bedding planes, and are conical in plan. To the northeast near Blue Hole yard, the structures are scattered in random

Fig. 7. Conical structures aligned along ridges in bedding surfaces of the Blue Hole Formation, 8 km east-northeast of Kirkimbie homestead.

fashion through the rock. The laminae pass right through the structures and are domed upwards, but some are disrupted. The carbonate in the structure is white, and is presumably purer than the surrounding rock. The structures are probably inorganic, perhaps small carbonate-mud volcanoes. The linear arrangement in the type area is thought to be due to epeirogenic movement which kinked the unconsolidated sediment and triggered the formation of the structures. Alternatively, they might be concretions; the presence of white carbonate (recrystallized?) may support this.

Near Swan yard the contact with the overlying Campbell Springs Dolomite is taken as being above the uppermost siltstone which overlies a bed of dolomite crowded with small columnar stromatolites. In other areas where the top of the unit is exposed, the stromatolitic dolomite passes directly up into the Campbell Springs Dolomite and the contact is taken as being above the stromatolitic dolomite. This occurs 3 km southeast of Blue Hole yard, where blocky brown stromatolitic dolomite overlies green fissile siltstone and is overlain by light grey laminated dolomite (Figs.8, 9).

At the section measured 3 km northeast of Swan yard (Section 10, Appendix I), the siltstone in the unit is very poorly exposed. However, there appear to be approximately equal proportions of siltstone and dolomite in the sequence. The upper part of the formation is exposed in the floor and sides of the valley in which Blue Hole yard is situated and consists of interbedded dolomite, silty dolomite,

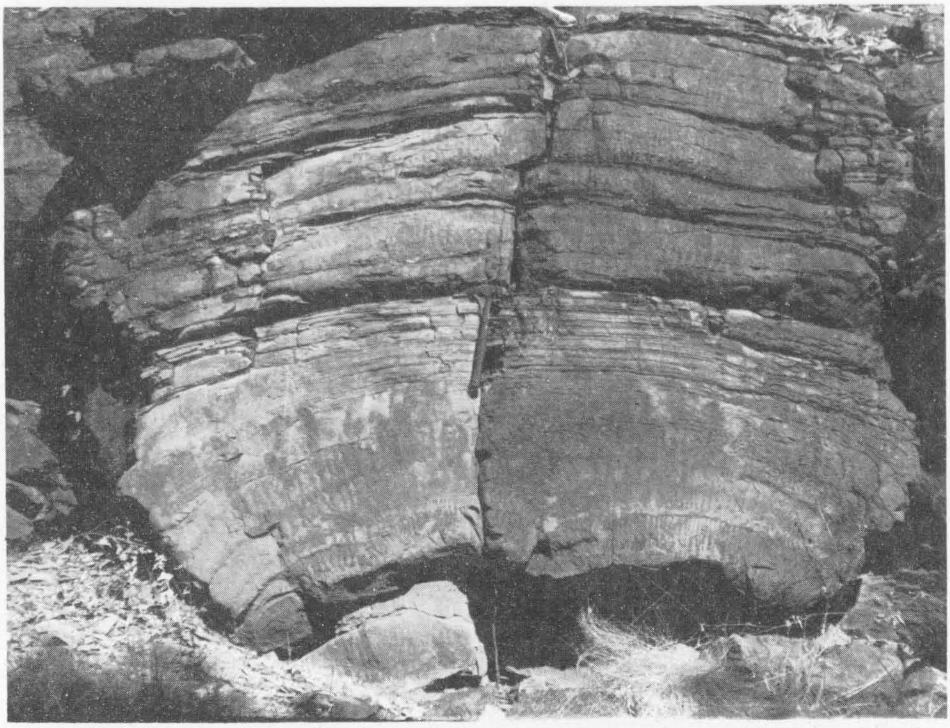


Fig. 8. Domed bioherm of columnar stromatolites at the top of the Blue Hole Formation, 3 km southeast of Blue Hole yard, Limbunya Sheet area.

and siltstone, overlain by about 15 m of dolomite crowded with small stromatolites similar to those found near Swan yard. The upper dolomite is overlain by grey crystalline dolomite mapped as Campbell Springs Dolomite.

The siltstones are well exposed 10 km northwest of Swan yard; in the upper part they are purple and flaggy, and in the lower part fawn, dark red, and green, fissile or flaggy, and laminated. The lower part of the formation contains a few interbeds of fine flaggy brown and grey sandstone.

At the easternmost outcrop at Farquharson Gap (Section 11, Appendix I), the proportion of siltstone is much higher, and a 70-m sequence of dolrudite occurs near the top of the unit.

Campbell Springs Dolomite (new name)

Derivation of name: From Campbell Springs in Campbell Creek, at 17°25′S, 129°34′E, in the Limbunya Sheet area.

Distribution: It is the most extensively outcropping unit of the Limbunya Group and crops out in southwestern, central, southeastern, and northeastern Limbunya, western Wave Hill, and southeastern and northern Waterloo Sheet areas.

Lithology: Massive, blocky and minor flaggy, grey and purplish grey dolmicrite, dolarenite, and dolrudite; stromatolites abundant.

Type section locality: Between 1 and 3 km due north of Limestone yard in the central Limbunya Sheet area. The section begins at 17°26′45″S, 129°35′30″E and extends due north over low rugged hills.

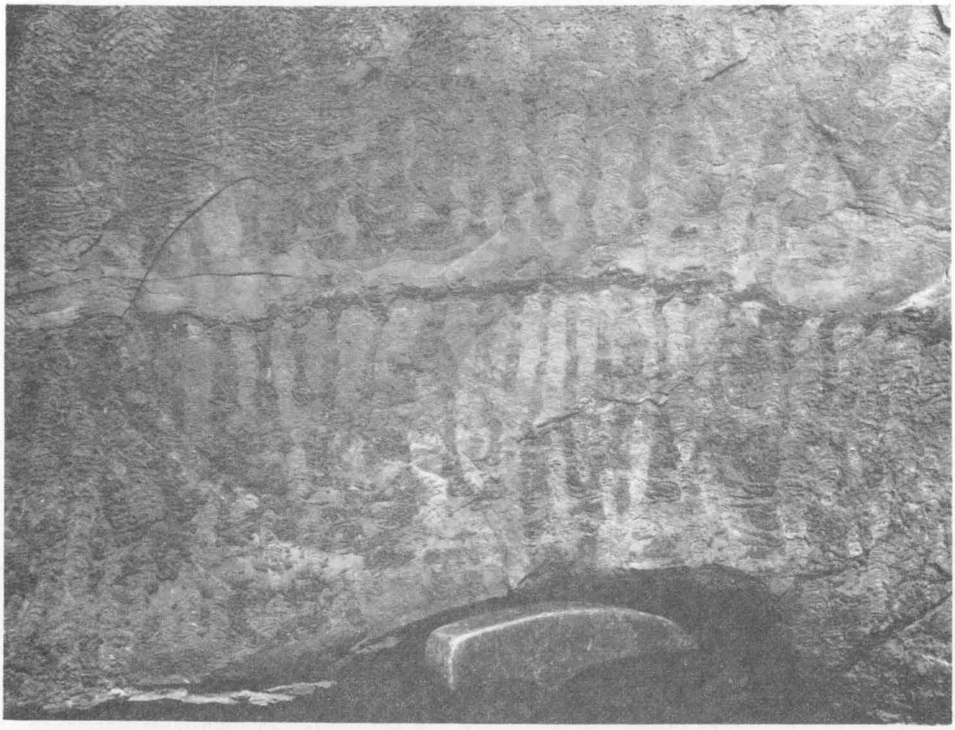


Fig. 9. Columnar stromatolites (same locality as Fig. 8). Note termination of all growths at the silt lamina in the centre of the photograph.

Thickness: 340 m of uniformly massive dolomite at the type section. The top 30 m consists almost entirely of stromatolite biostromal dolomite; the unit is nearly 380 m thick 8 km east of Kirkimbie homestead.

Age: Proterozoic, probably early Adelaidean, but could be as old as late Carpentarian.

Fossils: Stromatolites are common throughout, particularly in the uppermost beds.

Stratigraphic relations: The upper and lower boundaries are conformable with other Limbunya Group units (Fraynes and Blue Hole Formations, respectively).

Description: The Campbell Springs Dolomite consists of dolomite, dolarenite, and dolrudite. Stromatolites are common and are particularly abundant at the top of the formation in the Limbunya Sheet area.

At the type section the thickness was estimated from aerial photographs and measured dips (grid ref. 563070). The formation consists entirely of dolomite which is purple-grey, massive to blocky with minor flaggy beds, and thin-bedded. At the base it passes down into the stromatolite bed of the Blue Hole Formation. At the top it contains numerous stromatolite biostromes.

At Black Springs the formation is well exposed in Stirling Creek gorge, where the dolomite is grey or purplish grey, massive to flaggy, and thin-bedded. In the centre of the formation, biostromal stromatolites about 5 cm to 1 m across are quite common.

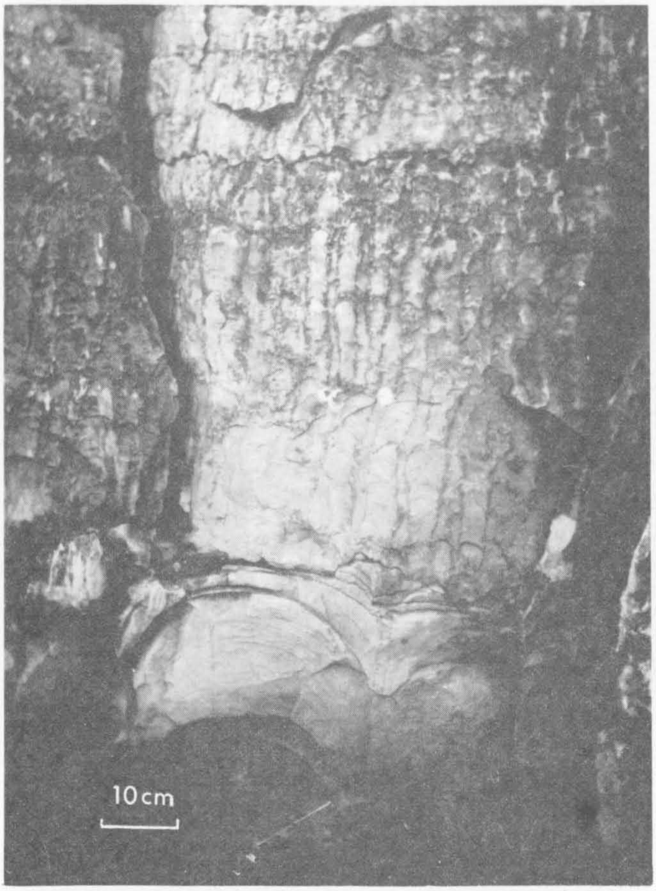


Fig. 10. Stromatolites at the top of the Campbell Springs Dolomite at Black Springs, Limbunya Sheet area.

At the top of the formation, a band about 30 m thick composed almost entirely of stromatolites is well exposed in a cliff on the southern bank of Stirling Creek where the track from Campbell Springs to Old Limbunya crosses the creek (Figs 10-13). This band of stromatolitic dolomite presumably extends uninterrupted to the outcrops 3 km northeast of Limestone yard. In the lower 3 m the stromatolites consist of very broad columns (nomenclature of stromatolite morphology is taken from Glaessner, Preiss, & Walter, 1969) with a diameter of up to 30 cm and with steeply convex laminae (Fig. 10). Above these are narrower columnar stromatolites which have sides varying from straight to bumpy. Branching is common and is of the parallel type. Laminae vary from steeply convex to moderately convex. The diameters of the columnar stromatolites decrease progressively from about 30 cm at the base to about 3 cm at the top of the cliff. Individual columns are up to at least 1 m high and are commonly truncated by beds of dolomite or silty dolomite which form the base for later growths. Some of the shorter stromatolites have a roughly conical shape. Separation between columns is 1 to 3 cm.

Similar stromatolites to those at Campbell Springs were found 10 km northeast of Swan yard, where elongate, columnar forms also occur. The columnar stroma-

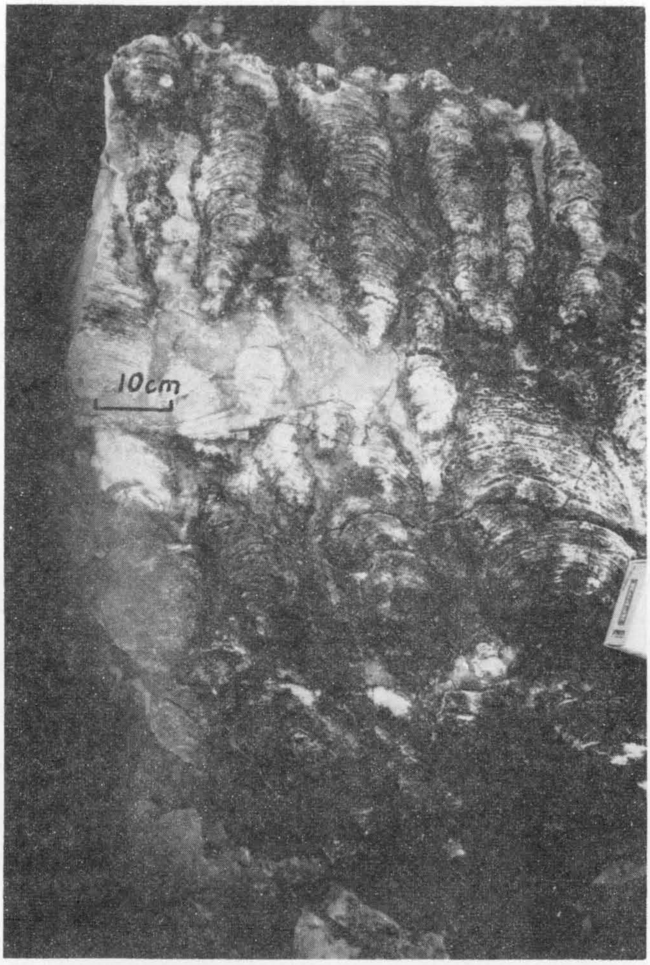


Fig. 11. Stromatolites at the top of the Campbell Springs Dolomite at Black Springs, Limbunya Sheet area.

tolites are about 3 cm wide, up to at least 0.5 m long, and about 10 cm high. A vertical section across the plane of the stromatolite shows hemispherical convex laminae similar to sections previously described and figured, but here longitudinal sections show horizontal undulating laminae. The shape of the structures is attributed to control of algal growth by currents.

Northeast of Swan yard the basal part of the Campbell Springs Dolomite consists of dolarenite which is light pink to grey, massive to flaggy, thin to medium-bedded, and cross-bedded. Rounded carbonate fragments 1 to 3 mm in diameter, and angular and curved dolomite fragments up to 3 cm long are set in a fine matrix. The rock contains about 5 percent of rounded or subangular quartz grains up to 0.5 mm in diameter, rounded clasts of fine-grained dolomite, silty dolomite, and fine dolarenite in a matrix of sparry dolomite with a grainsize of about 0.5 mm. A few vaguely defined oolites are also included.

The dolomite is thin-bedded and contains numerous stromatolites 13 km south of Farquharson Gap; in the upper part of the formation they are columnar,

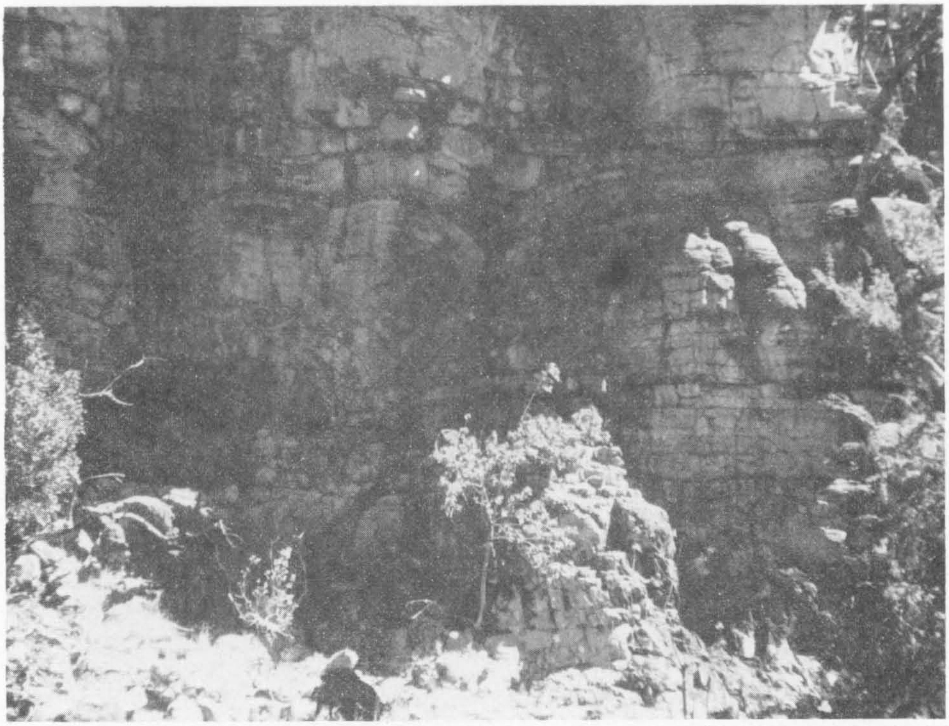


Fig. 12. Stromatolite bioherm in the Campbell Springs Dolomite at Black Springs, Limbunya Sheet area.

up to 10 cm in diameter, and up to 0.6 m high. They are generally silicified and thus stand out on weathered surfaces. Lower in the formation the stromatolites are wide hemispherical types and some have very irregular shapes.

The dolomite is pink, grey, and fawn, blocky, and thin-bedded 23 km south-southeast of Farquharson Gap. Stromatolites are abundant, and some are columnar and pencil-thin; others are up to 20 cm in diameter and are of the continuous hemispherical type with no definite wall structure.

At Depot Pile dolomite cropping out in the centre of a structural dome is pink and light grey, massive to flaggy, laminated, and contains vaguely defined columnar stromatolites. Towards the top of the succession the dolomite becomes more silty and flaggy.

The formation in the Gum Creek area is grey, blocky, thin to medium-bedded, and coarsely crystalline; it was not examined in detail.

In the Kirkimbie area (Fig. 6), a well exposed complete section of the formation is 376 m thick (Section 7, Appendix I). Near the top of the formation are numerous stromatolite beds (Fig. 13) and several beds of flaggy red limestone containing dark grey limestone concretions. Most of the concretions are sub-spherical, but a few are ellipsoidal and some are linked with others to form dumb-bell-shaped bodies. They are generally 5 to 15 cm in diameter and up to 20 cm long (Figs 14 and 15).

The abundance of stromatolites in the Campbell Springs Dolomite indicates that the unit was laid down in shallow water, probably in the intertidal zone. Their

Fig. 13. Stromatolites on a bedding surface of massive dolomite in the Campbell Springs Dolomite, 8 km east-northeast of Kirkimbie homestead, Limbunya Sheet area.

association with dolarenite shows that the environment was one in which currents were active.

Fraynes Formation (new name)

Derivation of name: From Fraynes Camp Springs in the central Limbunya Sheet area.

Distribution: Mainly in the central and southwestern Limbunya Sheet area; minor outcrops near the western margin of the Wave Hill Sheet area.

Lithology: Predominantly flaggy silty dolomite with interbeds of pure dolomite and fissile green siltstone; a prominent chert bed occurs at the top.

Type section locality: On the southern bank of Stirling Creek at Black Springs; it extends west-northwest for about 1 km to the top of the first mesa west of the springs. The section ends on the hilltop at 17°18′S, 129°41′E.

Thickness: About 107 m at the type section — basal siltstone and minor dolomite grade upwards into pure dolomite. The top 15 m in most areas is chert which has replaced dolomite; the thickness is about 130 m about 15 km south of the type section, and 40+ m in the Wave Hill Sheet area.

Age: Proterozoic, probably early Adelaidean, but could be as old as late Carpentarian.

Fossils: None known.

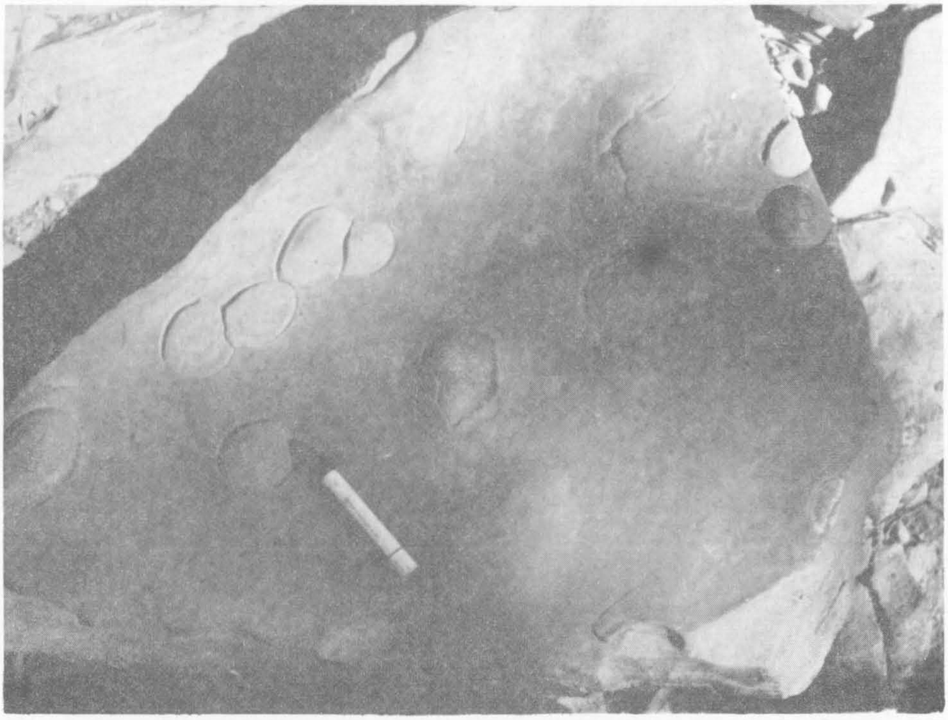


Fig. 14. Dolomite concretions protruding from a bedding plane in the Campbell Springs Dolomite, 8 km east-northeast of Kirkimbie homestead, Limbunya Sheet area.

Stratigraphic relations: The upper and lower boundaries are conformable with other Limbunya Group units (Killaloc Formation and Campbell Springs Dolomite, respectively).

Description: In the type section west of Campbell Springs, the Fraynes Formation consists of silty dolomite and siltstone, overlain by interbedded dolomite and silty dolomite, which in turn are overlain by dolomite; the thickness was estimated from aerial photographs. The silty dolomite is yellowish brown, white, grey, and reddish brown, flaggy and fissile, and laminated. In thin section it consists of fine dolomite with up to 30 percent of quartz grains and a few percent of fine sericite flakes. In some sections specks of red-brown semi-opaque iron oxide are disseminated throughout the dolomite. The dolomite is greyish purple and white, flaggy (but appears massive in fresh exposures) with very clearly defined laminae, and smells strongly of hydrocarbons. The siltstone is green and fissile.

Near Campbell Springs the formation consists of basal silty dolomite, interbedded silty and pure dolomite, and chert at the top. The chert-dolomite boundary is gradational, the chert resulting from silicification of the dolomite.

Near Burtawurta Creek interbedded silty and pure dolomite crops out. A minimum thickness of 40 m of the formation is exposed below the Wickham Formation which unconformably overlies it. The dolomite is grey, red-brown with white spots, flaggy, and blocky; it contains a few columnar stromatolites. The silty dolomite is grey and brown, fissile and flaggy (the two types are interbedded), and laminated.

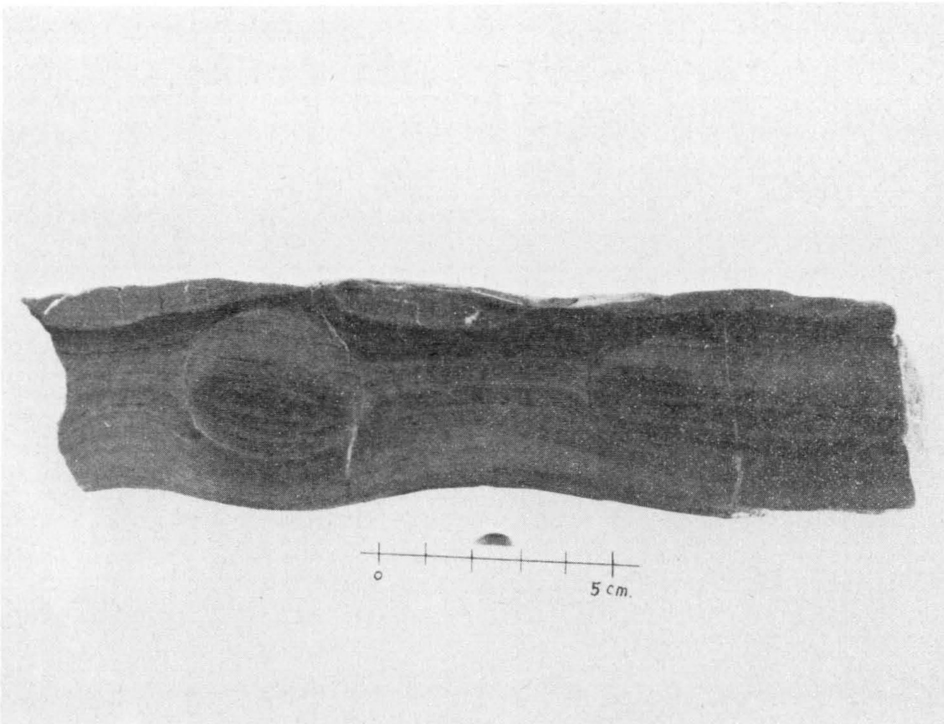


Fig. 15. Vertical section through the concretions in Figure 14. They are dark grey coarsely crystalline limestone set in brick-red limestone.

Chert in Fraynes Formation: Chert occurs at the top of the formation in several localities in the central Limbunya Sheet area. Its thickness varies, but averages about 15 m. The chert is well exposed in two gorges, one near Campbell Springs, the other between Horse Creek Junction yard and Black Springs.

The contact with the underlying dolomite is gradational 3 km north of Campbell Springs. The chert content of the rocks ranges from about 5 percent in the dolomite to 100 percent in the areas mapped as chert. The gradation occurs over about 6 m and the boundary is taken where the chert constitutes 50 percent of the rock.

The uppermost dolomite in the Fraynes Formation is greyish purple and laminated. Small nodules and lenses of chert up to 2 cm thick and 1 to 2 m long form up to 5 percent of the rock and become more abundant towards the upper part of the formation. Laminae in the dolomite pass uninterrupted through the chert bodies and the chert is thus a replacement product. Bedding within the thicker chert beds tends to be disrupted and contoured with much small-scale folding and faulting. Many thin chert bands have undergone brittle deformation, with the interbedded dolomite acting as incompetent beds (Fig. 16).

Where the chert forms 100 percent of the rock, some of it is bedded and relatively undisturbed. However, this rock type is interbedded with, and passes laterally into, finely folded bedded chert and brecciated chert (Fig. 17). The breccia consists of angular lumps and flags up to 0.3 m long in a matrix of white

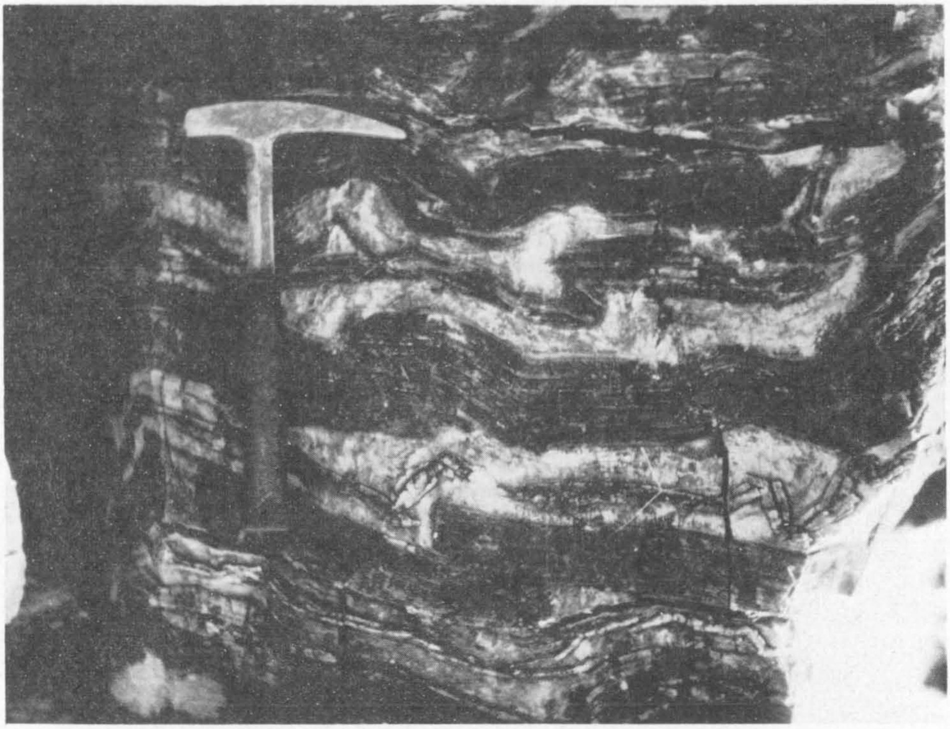


Fig. 16. Faulted and folded chert (dark-coloured) and dolomite in the Fraynes Formation, 3 km north of Campbell Springs, Limbunya Sheet area.

clay or chert. In one place a vertical 'dyke' of chert breccia at least 3 m high and nearly 1 m wide cuts the chert bed.

The upper boundary of the chert is not well exposed, but it appears to pass quite abruptly back into grey and purple, blocky to massive, laminated dolomite of the Killaloc Formation which also contains a large proportion of chert. The abrupt change has been used in defining the Fraynes Formation/Killaloc Formation boundary.

An exposure similar to that at Campbell Springs occurs in a gorge 5 km west of Black Springs. To the east of the main gorge dolomite and silty dolomite pass up abruptly into undisturbed bedded chert. Above this is chert breccia with flags of chert up to 0.3 m long in a soft white matrix which in places is silicified. Near the base of the breccia is a 1-m lens of sandstone which is moderately sorted, has well rounded grains, and a soft clay matrix containing angular lumps of siltstone. The base of the chert breccia transgresses the bedding planes in the bedded chert which in turn transgresses bedding in the underlying dolomite. The chert passes upwards abruptly into dolomite and silty dolomite of the Killaloc Formation which contains numerous chert nodules. Immediately above the contact, angular chert fragments in the dolomite indicate that some reworking took place.

Killaloc Formation (new name)

Derivation of name: From Killaloc Creek, a southwest-flowing tributary of Stirling Creek in the northwestern Limbunya Sheet area.

Fig. 17. Chert breccia at the top of the Fraynes Formation, 1.5 km southeast of Horse Creek Junction yard, Limbunya Sheet area.

Distribution: The Killaloc Formation is known only in the central Limbunya Sheet area.

Lithology: Basal dolomite with many chert nodules, passing upwards into silty dolomite and, finally, siltstone.

Type section locality: The base of the section is at 17°17′30″S, 129°39′30″E, 4 km downstream from Campbell Springs in the southern bank of Stirling Creek. The section extends for 3 km along the southern side of the creek in a westerly direction.

Thickness: About 60 m in the type section.

Age: Proterozoic, probably early Adelaidean, but could be as old as late Carpentarian.

Fossils: None known.

Stratigraphic relations: It is the youngest known formation of the Limbunya Group and conformably overlies the Fraynes Formation. It is overlain disconformably by the Wickham Formation (basal Wattie Group).

Description: The Killaloc Formation consists predominantly of an upper siltstone overlying interbedded dolomite and silty dolomite.

At Horse Creek Junction yard (grid ref. 570090) the upper siltstone is poorly exposed. In the central part of the formation the dolomite is greyish brown, blocky, thin-bedded, and contains abundant nodules of chert which has replaced the carbonate. The silty dolomite is grey with cream spots, flaggy, and thin-bedded. Dolomite at the base of the formation, immediately overlying the Fraynes Formation, is crammed with spheroidal chert nodules and other angular chert fragments up to 3 cm long. The angular fragments may have been derived from the underlying chert, but the nodules have formed by replacement of the carbonate. The thickness in this area appears to be about 60 m, but faulting, variations in dip, and low dip angles make thickness estimation difficult.

The top 7 m of the Killaloc Formation 3 km north of Campbell Springs consists predominantly of siltstone with minor interbedded dolomite and sandstone. The siltstone is green and reddish brown with white spots, ranges from fissile to flaggy (breaks into rounded lumps up to 10 cm in diameter), and is vaguely laminated. Small flakes of muscovite are quite common on bedding planes. In thin section it consists of angular quartz grains and minor chert grains 0.1 to 0.2 mm in diameter in a matrix of fine quartz and sericite. The rock also contains a few grains of chert up to 2 mm in diameter and a few grains of tourmaline. The red coloration is produced by iron oxide in the matrix. The dolomite is pink, blocky, and thin-bedded. The sandstone is coarse and contains angular fragments of chert.

The lower part of the formation consists predominantly of dolomite with some interbedded silty dolomite and a little sandstone. The dolomite is grey, massive to flaggy, and contains numerous nodules and lenses of chert, particularly at the base of the formation.

Limbunya Group palaeogeography

Figure 18 shows the thickness and lithology of the Limbunya Group in its three main areas of outcrop. Although the thickness of the lower formation is not known in the Kirkimbie area, the upper part of the group is considerably thicker than elsewhere. The Blue Hole Formation and Farquharson Sandstone are thicker at Farquharson Gap than in the central Limbunya Sheet area, but trends for the whole group are not known.

A BMR gravity survey (Whitworth, 1970) delineated the Inverway Gravity Ridge, which corresponds to the area of thinner Limbunya Group and also to the only basement outcrops known in the region. The gravity ridge is interpreted as a zone of shallower basement with a thin sediment cover; it was a ridge during deposition of the Limbunya Group and subsided at a slower rate than surrounding areas.

Nothing is known of the shape of the basin of deposition. The Limbunya Group extends into the Birrindudu Sheet area to the south, to the Auvergne Sheet area in the north, and into the Dixon Range Sheet area to the west (the Bungle Bungle Dolomite of Dow & Gemuts, 1969). At the latter two localities the rock types are essentially similar to those shown in Figure 18.

Several depositional environments are represented in the Limbunya Group, but the dominant one is undoubtedly that in which stromatolites grew. They are generally believed to be indicators of a marine intertidal environment because of present-day occurrences (Logan, 1961).

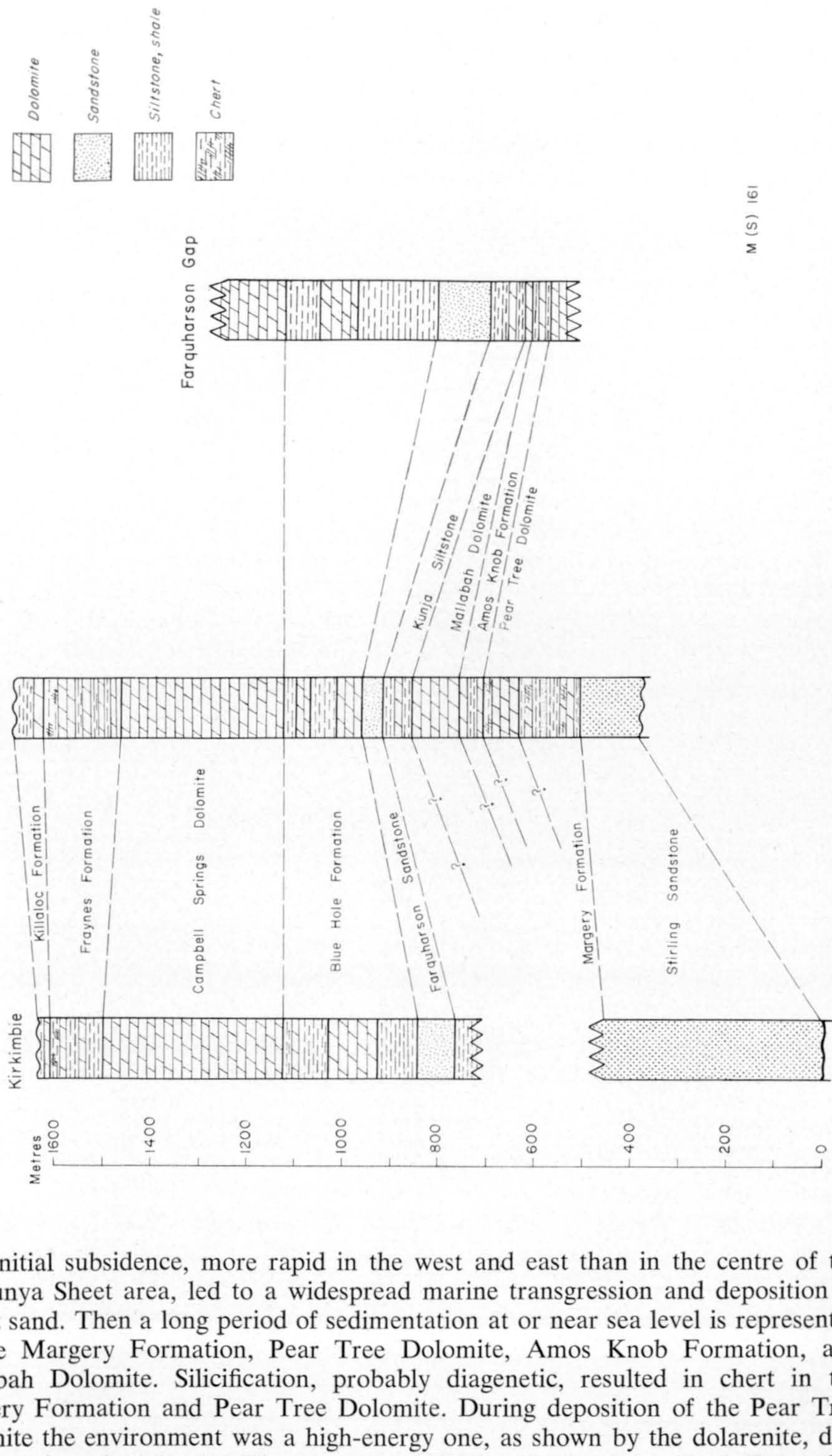


Fig. 18. Comparison of Limbunya Group formations in the three main areas of outcrop.

Initial subsidence, more rapid in the west and east than in the centre of the Limbunya Sheet area, led to a widespread marine transgression and deposition of quartz sand. Then a long period of sedimentation at or near sea level is represented by the Margery Formation, Pear Tree Dolomite, Amos Knob Formation, and Mallabah Dolomite. Silicification, probably diagenetic, resulted in chert in the Margery Formation and Pear Tree Dolomite. During deposition of the Pear Tree Dolomite the environment was a high-energy one, as shown by the dolarenite, dolrudite, and sandy dolomite. The presence of siltstone in the Amos Knob Formation and laminated dolomite in the Mallabah Dolomite indicate a lower-energy environment, perhaps owing to deeper-water conditions and to algal mats, respectively.

Siltstone and shale (Kunja Siltstone) indicate a marked increase in water depth; little or no carbonate was deposited. Either uplift or infilling of the basin caused a return to shallow-water conditions, when sand was laid down (Farquharson Sandstone). The environment may have been fluvial or shallow-water marine; mud cracks indicate some subaerial exposure.

A minor transgression caused a return to shallow-water marine conditions (dolarenite and stromatolites of the Blue Hole Formation), with some periods of deeper-water deposition (laminated silty dolomite, limestone, siltstone, and shale of the same formation). The formation is thicker and has a greater silt content in the east. In the west it thickens, has a fairly high carbonate content, and a prominent shale bed is present. The environment is therefore envisaged as a shelf, shallow in the west, and with deeper water in the east. Subsidence was rapid in the west and east and slower in the centre, but relative water depths were maintained for much of the time. The water depth increased over the whole area for short periods, resulting in deposition of laminated mud and silt.

The Campbell Springs Dolomite, the thickest formation in the group, is of very uniform lithology. The thick stromatolite biostromes indicate a shallow-water intertidal environment; dolarenite and dolrudite show that high-energy conditions existed.

The water depth again increased, and the lower part of the Fraynes Formation was laid down. A general shallowing of the basin led to more dolomite and culminated in emergence of the land; a period of silicification ensued, and the dolomite was partly replaced by chert. The presence of chert breccia suggests that cavities may have formed and were later filled by material collapsing into them.

A return to marine or lagoonal conditions resulted in deposition of carbonate and silt of the Killaloc Formation.

The palaeogeographic interpretation given is proposed on the basis that the shale and siltstone are deeper or quieter-water sediments than the dolomite. The alternative is that they were laid down in very shallow water, perhaps as lagoonal muds or flood-plain sediments. The reduced state of the iron and the lack of shallow-water or subaerial structures indicate that the alternative interpretation is unlikely.

The dolomite beds were probably all deposited in shallow, in many cases intertidal, water. This is supported by the presence of dolarenite, dolrudite, and stromatolites. The only limestone known is in the Blue Hole Formation in the beds with conical bedding-plane structures (Fig. 7). This could be a deeper-water facies and is consistent with the occurrence of finely laminated shale overlying the limestone.

ADELAIDEAN

WATTIE GROUP (new name)

Names of constituent formations:

Seale Sandstone (youngest)
Gibbie Formation
Neave Sandstone

Mount Sanford Formation
Hughie Sandstone
Burtawurta Formation
Wickham Formation (oldest)

Derivation of name: From Wattie Creek, a tributary of the Victoria River draining the central western Wave Hill Sheet area.

Distribution: Outcrops are most extensive in the eastern third of the Waterloo Sheet area and less extensive in several adjacent Sheet areas (Auvergne, Victoria River Downs, Wave Hill, and Limbunya).

Lithologic affinities of constituent formations: The formations are all clastic units, mostly siltstone and sandstone, and all were probably deposited under shallow marine or paralic conditions (Table 4).

Thickness: The group is about 400 m thick in the southeastern Waterloo Sheet area (Fig. 19).

Age: Proterozoic, probably Adelaidean.

Fossils: None known.

Stratigraphic relations: The Wattie Group overlies the Limbunya Group with pronounced angular unconformity, and is overlain conformably by the Timber Creek Formation (basal Bullita Group).

Discussion: The Wattie Group was previously included in the Victoria River Group of Traves (1955). Perry (1966) interpreted several photogeological units in the southwestern corner of the Victoria River Downs Sheet area, and present mapping has led to formal definition of these units as the Wattie Group.

The age of the Wattie Group is known only within wide limits, and the group cannot be confidently correlated with any strata of known age. It is designated 'probable Adelaidean' mainly on the basis of its conformable relation with the overlying Bullita Group, which is overlain unconformably by the Wondoan Hill Formation from which glauconites have yielded an age of about 1120 m.y. (R. Page, pers. comm.).

Wickham Formation (new name)

Derivation of name: From Wickham River, a major tributary of the Victoria River.

Distribution: Forms extensive outcrops in southeastern Waterloo, central and southwestern Limbunya, and western Wave Hill Sheet areas.

Lithology: Sandstone and conglomerate; subordinate siltstone and chert.

Type section locality: Along the southern bank of Wattie Creek in the Wave Hill Sheet area (Section 12, Appendix I). The base of the section is at 17°24′40″S, 130°10′E; the top is at the bottom of a low escarpment 1 km east of the base.

Thickness: 176 m (minimum) at the type section; 315 m in the southwestern Limbunya Sheet area.

Age: Proterozoic, probably Adelaidean.

Fossils: None known.

Stratigraphic relations: It is the basal formation of the Wattie Group and is unconformable on Limbunya Group formations. It is overlain conformably by the Burtawurta Formation.

TABLE 4: SUMMARY OF WATTIE GROUP STRATIGRAPHY

Unit	*Map Symbol*	*Lithology*	*Thickness range (m)*	*Stratigraphic relations*	*Physiographic expression*	*Remarks*
Seale Sandstone	P̱im	Sandstone	56-100	Upper and lower contacts both conformable	Cuestas, hogbacks, and rugged plateaux	Overlain conformably by basal formation of the Bullita Group
Gibbie Formation	P̱ig	Micaceous siltstone, sandstone	25-75	Conformably overlies P̱in	Valleys and smooth scarp-slopes	
Neave Sandstone	P̱in	Sandstone, minor conglomerate	3-20	Evidence of minor reworking of P̱io	Cuestas and hogbacks	May be locally unconformable on P̱io
Mount Sanford Formation	P̱io	Siltstone, dolomite, minor sandstone	25-200+	Conformably overlies P̱ih	Valleys, terraced slopes	Thickens northwards
Hughie Sandstone	P̱ih	Sandstone	50-130	Conformably overlies P̱ib	Cuestas, hogbacks	
Burtawurta Formation	P̱ib	Siltstone	20-40	Conformably overlies P̱iw	Valleys, smooth scarp-slopes	Absent in northern Waterloo Sheet area
Wickham Formation	P̱iw	Sandstone, chert	175-315	Unconformable on Limbunya Group	Low rocky hills	Overlies various Limbunya Group formations

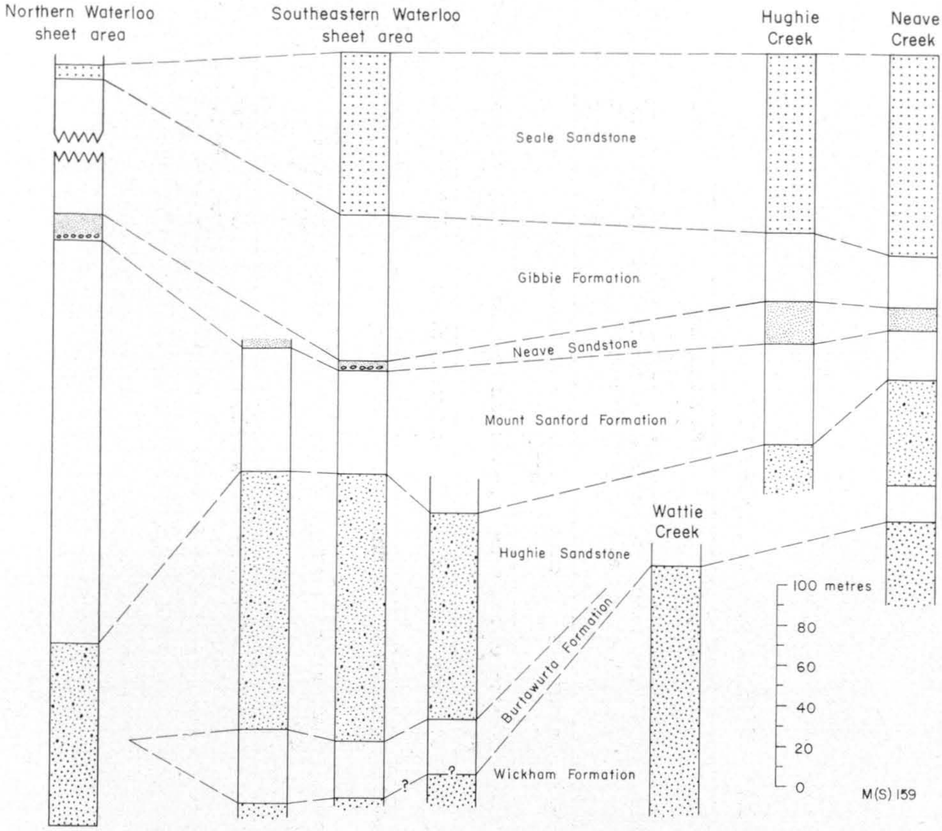


Fig. 19. Thickness variations in the Wattie Group formations.

Description: Massive sandstone in No. 8 Creek (Fig. 20) near Kirkimbie homestead was formerly named Moonbool Sandstone (Morgan et al., 1971). This name has been discarded and the outcrops assigned to the Wickham Formation on the basis of similarity of lithology and stratigraphic relations. The sandstone throughout the formation, in common with other Wattie Group sandstones, is fine to medium and moderately well sorted, with white grains of claystone, feldspar, and chert which are visible in hand specimens, as is a small percentage of clay matrix. Most sandstone beds are strongly cross-bedded in units up to 1.5 m thick, with foreset bedding 1 to 20 cm thick. The tops of some beds display current ripple marks (Fig. 21). Mud flakes are ubiquitous and mud cracks occur in a few localities.

The basal part of the formation consists of conglomerate in which the clasts are nearly all chert set in a ferruginous matrix; in some areas the matrix is ferruginous sandstone rather similar to that overlying the conglomerate, but in several localities in the western Wave Hill Sheet area the matrix is fine, weathered limonitic material with little sand. The chert clasts are angular, subangular, or subrounded.

Also included in the basal part of the Wickham Formation is chert breccia which probably is not a sedimentary breccia or conglomerate, but a chert bed brecciated by *in situ* processes; the chert is the silicified upper layers of Limbunya

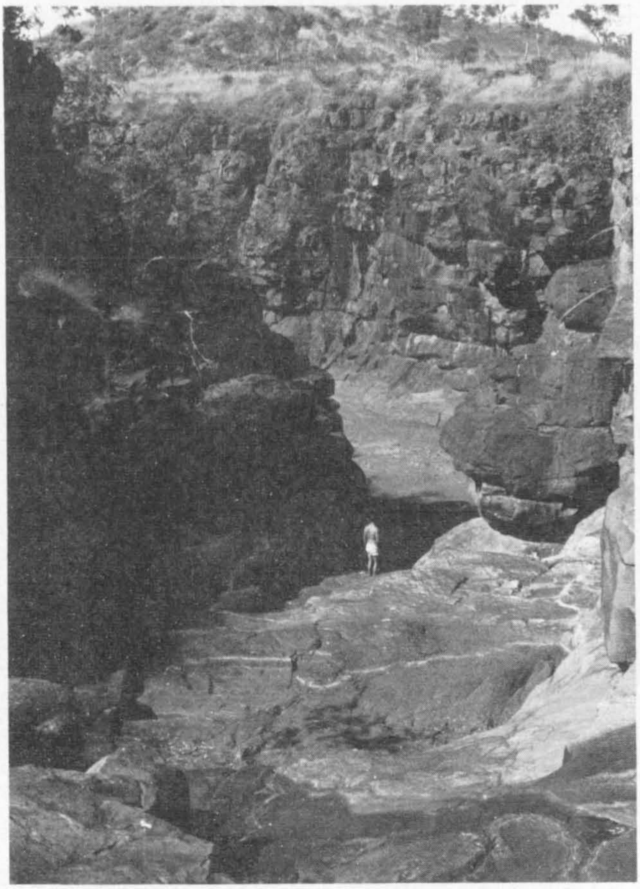


Fig. 20. Blocky and massive sandstone of the Wickham Formation in No. 8 Creek (Grid ref. 528046), Limbunya Sheet area.

Group sediments. The age of silicification is not known, but must be intermediate between the Limbunya Group and the sandstone of the Wickham Formation; it is included in the latter for convenience. The chert conglomerate is derived largely from the silicified bed.

Several beds of silty and micaceous sandstone, and thin chert occur in the Wickham Formation. One chert layer crops out in the northern bank of the Wickham River 70 km upstream from its confluence with Depot Creek. It is 1 to 2 m thick, laminated, and thin-bedded. Some layers are continuous and undisturbed; others are composed of angular fragments and seem to be the product of *in situ* brecciation.

Burtawurta Formation (new name)

Derivation of name: From Burtawurta Creek in the eastern Limbunya Sheet area.

Distribution: In the southern quarter of Waterloo, western Wave Hill, and adjacent parts of Limbunya and Victoria River Downs Sheet areas.

Lithology: Coarse quartz siltstone; sandstone, mudstone, and dolomite.

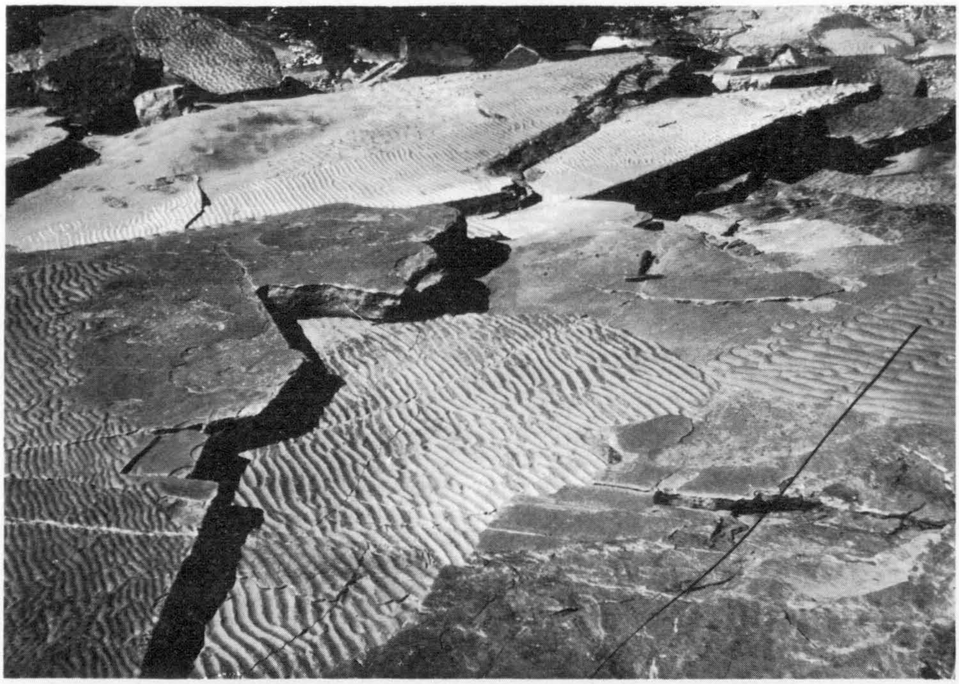


Fig. 21. Current ripple marks in the Wickham Formation in the bed of the Wickham River 26 km north-northeast of Limbunya homestead.

Type section locality: Measured along the southern side of Neave Creek 6 km upstream from its confluence with the Victoria River.

Thickness: 18 m at type section; up to 37.5 m in the eastern Waterloo Sheet area.

Age: Proterozoic, probably Adelaidean.

Fossils: None known.

Stratigraphic relations: It is a constituent formation of the Wattie Group, and both contacts are conformable.

Description: Good outcrops of Burtawurta Formation are rare; usually the only indication of its lithology is found in the weathered rubble on steep slopes underlain by the formation.

The best outcrop known is on the northern bank of the Wickham River in the Waterloo Sheet area at grid ref. 635139. This is an excellent exposure (Fig. 22) of siltstone and sandstone. Coarse-grained siltstone predominates, and is red-brown or chocolate with some purple and violet beds. As in other Wattie Group siltstones (notably in the Gibbie and Mount Sanford Formations), light greyish green beds also occur, and in many cases the colour boundaries cut across bedding planes.

Less common rock types include thin beds of mudstone and very fine-grained quartz sandstone. The sandstone is quite distinctive as it contains small (1-2 mm) crystals of carbonate scattered throughout the rock. These dissolve out on weathering, leaving a pitted surface. Other sedimentary structures include mud flakes, mud cracks, halite casts, small-scale cross-bedding, and ripple marks.

Fig. 22. Flaggy siltstone and sandstone of the Burtawurta Formation at grid ref. 635139, Waterloo Sheet area.

Thin dolomite beds are interbedded with the siltstone in the southeastern limb of an anticline 8 km northwest of Mount Sanford outstation.

The Burtawurta Formation thickens from 18 m in the south at Neave Creek to 27 m in the southeast corner of the Waterloo Sheet area and to 37.5 m (estimated) 50 km farther north. However, it is absent still farther north near the margin of the Auvergne Sheet area.

Hughie Sandstone (new name)

Derivation of name: From Hughie Creek, a tributary of the Victoria River near the western margin of the Wave Hill Sheet area.

Distribution: In the central-western Wave Hill, central-eastern Limbunya, and southeastern Waterloo Sheet areas.

Lithology: Fine and medium quartz sandstone with flaggy to massive partings; cross-bedding is common.

Type section locality: At 16°58′S, 130°29′E, in the extreme southeastern corner of the Waterloo Sheet area. The section was measured along the only creek cutting across the southeastern limb of a small anticline. The sequence is 132 m of uniformly massive quartz sandstone.

Thickness: A minimum of 50 m in the south to a maximum of 132 m at the type section; the thickness was estimated.

Age: Proterozoic, probably Adelaidean.

Fossils: None known.

Stratigraphic relations: It is a constituent formation of Wattie Group and its upper and lower contacts are conformable. Near the northern margin of the Waterloo Sheet area the Burtawurta Formation is absent, and Hughie Sandstone is assumed to overlie Wickham Formation; no boundary was recognized in the field, and outcrops have been designated Hughie Sandstone.

Description: The lithology of the Hughie Sandstone is fairly uniform throughout its area of outcrop. It is a fine to medium quartz sandstone, forms good outcrops, and has a flaggy, blocky or massive parting. The parting reflects major bedding planes between cross-bedded sets 10 to 100 cm thick. Cross-bedding and ripple marks are ubiquitous, and clay galls are common in some beds.

As in the other Wattie Group sandstones, white grains are visible in hand specimens of Hughie Sandstone. They are chert, clay, feldspar, and igneous rock fragments and constitute 10 to 15 percent of all grains. These grains and the quartz grains are moderately rounded and sorted. A small amount of clay matrix occurs in some beds.

The base of the formation at the type locality comprises cross-bedded sandstone with scattered angular and subangular chert pebbles. White sand-sized grains are probably smaller fragments of the same chert. The upper half of the formation is a lighter-coloured, better sorted sandstone than the lower half. Some mud cracks occur near the top of the section.

About 13 km east-northeast of the type section the thickness is estimated to be about 100 m; 50 km northwest of the type section it is an estimated 128 m. Near the northern margin of the Waterloo Sheet area the sandstone is thinner, probably less than 90 m; here the Burtawurta Formation is absent, and the 90 m of sandstone is Hughie Sandstone plus Wickham Formation. They overlie massive, silicified, stromatolitic dolomite assigned to the Limbunya Group.

Mount Sanford Formation (new name)

Derivation of name: From Mount Sanford, a prominent butte at 16°58′30″S, 130°32′E, in the southwestern corner of the Victoria River Downs Sheet area.

Distribution: In the western quarter of Wave Hill and the eastern third of Waterloo Sheet areas; minor outcrops in the Victoria River Downs and Limbunya Sheet areas.

Lithology: Dolomitic siltstone and dolomite; minor sandstone, claystone, and chert.

Type section locality: In the southeast corner of the Waterloo Sheet area. The section was measured on a hillslope adjacent to the west bank of Depot Creek at 16°58′S, 130°25′E.

Thickness: From a minimum of 24 m in the south to over 200 m in the north.

Age: Proterozoic, probably Adelaidean.

Fossils: None known.

Stratigraphic relations: It is a constituent formation of the Wattie Group; the lower contact is conformable, but the upper contact with the Neave Sandstone may be locally unconformable.

Description: The thickness of the Mount Sanford Formation increases markedly from south to north. At Neave Creek in the Wave Hill Sheet area it is only 23.5 m thick and consists of interbedded siltstone and dolomite (Section 13, Appendix I).

At the type section the Mount Sanford Formation comprises 52.5 m of siltstone with dolomite and sandstone interbeds (Section 14, Appendix I). Two particularly prominent, massive, finely crystalline dolomite beds near the top of the unit distinguish it from the Gibbie and Burtawurta Formations, which are otherwise very similar.

A section 35 km northwest of the type section is 61 m thick. The basal 10 m is mainly reddish brown, purple, and greyish green siltstone and fine sandstone. Small ripple marks, halite casts, micaceous partings, and green spots (owing to reduction of iron minerals) are common. The upper part of the formation is largely scree-covered; the scree is of chert and claystone, and partly obscures several thin dolomite beds. Brecciated and bedded chert caps the formation.

In the far north of the Waterloo Sheet area, Mount Sanford Formation crops out in a north-northeast-trending monocline. Its thickness, estimated from aerial photographs, is at least 200 m and is possibly more than 250 m. At this locality the base of the formation is marked by about 2 m of massive white claystone. Much of the formation does not crop out, but near the top are flaggy dolomite, siltstone, and several beds of pink claystone or siltstone 10 to 25 cm thick.

In thin section the white claystone (Reg. specimen 70770486) consists of an unidentifiable clay-size mosaic of low-birefringence grains. Most of this is probably chert, but no clay minerals were identified. X-ray diffraction methods revealed quartz and adularia as the main constituents.

The pink claystone (Reg. specimen 7077487) higher in the sequence is slightly coarser-grained (mainly very fine silt of 4-20 micrometres). X-ray diffraction shows that adularia predominates, with lesser quartz and minor illite (Berryman & Smith, 1971). The illite is visible in thin section as elongate flakes of higher birefringence than the other constituents. Because of the high feldspar content and the massive nature of these beds, they are interpreted as ashstone. The prominent claystone at the top of the formation may also be an ashstone, but no samples were available for examination.

About 3 km north-northeast of Mount Sanford outstation, dolomite beds near the top of the formation contain numerous nodules and lenses of chert. Pale green staining on chert nodules and in the dolomite gives a mica X-ray diffraction pattern (Berryman & Smith, 1971) and is probably a glauconite. Above the dolomite here and in nearby areas, white chert is the uppermost bed of the formation. It could be either a silicified dolomite or ashstone, but the latter is favoured because of its similarity to the silicified claystone lower in the formation.

Neave Sandstone (new name)

Derivation of name: From Neave Creek, a tributary of the Victoria River draining part of the southwestern Wave Hill Sheet area.

Distribution: In the western quarter of Wave Hill and the eastern third of Waterloo Sheet areas.

Lithology: Purple-grey, fine and medium sandstone.

Type section locality: In the hillslope at 17°40′S, 130°38′30″E, on the south bank of Neave Creek in the Wave Hill Sheet area. It comprises 12 m of cross-bedded, flaggy and blocky, fine and medium sandstone.

Thickness: Between 3 and 20 m.

Age: Proterozoic, probably Adelaidean.

Fossils: None known.

Stratigraphic relations: It is a constituent formation of the Wattie Group; the lower contact may be locally unconformable; the upper contact is conformable.

Description: At its type section the Neave Sandstone is about 12 m thick; 13 km north at Hughie Creek it has increased to 20 m, the greatest thickness measured. Farther north in the southeastern Waterloo Sheet area it may be as little as 3 m thick, but near the northern margin of the Sheet area it measures 10 to 15 m.

In most localities it consists of flaggy, blocky, and massive sandstone. It is generally fawn, grey, or dull purple-grey, weathering to red-brown, and of fine to medium grainsize. About 2 km northwest of Mount Sanford the base of the formation is marked by a thin bed of conglomeratic sandstone containing subangular clasts of chert up to 5 cm across. Chert of identical appearance forms the top of the Mount Sanford Formation, from which it was probably eroded. This is the only evidence of an unconformity within the Wattie Group; the two units in question are concordant throughout the area and any break in deposition was probably of restricted extent.

The sandstone in most areas is cross-bedded and ripple-marked, and commonly contains mud flakes; some primary current lineations occur. A notable feature of the sandstone is the ubiquitous occurrence of 10 to 20 percent of white grains quite distinct from the quartz grains which constitute the bulk of the rock. In thin section the quartz grains appear subrounded to subangular, and are 0.02 to 0.4 mm in grainsize. Grains which appear white or cloudy in hand specimen make up about 15 percent of the total, and include feldspar (microcline and plagioclase), chert, and clay grains, and rock fragments which consist of an extremely fine-grained mosaic of low birefringence grains and are probably fragments of an igneous rock.

The Neave Sandstone, although thin, was laid down over a large area and probably represents a shallow marine littoral unit formed during a transgressive or regressive phase of sedimentation.

Gibbie Formation (new name)

Derivation of name: From Gibbie Creek, a tributary of the Wickham River draining the southwestern Victoria River Downs Sheet area.

Distribution: It crops out near Neave Creek in the Wave Hill Sheet area and in several places in the western Victoria River Downs and eastern Waterloo Sheet areas.

Lithology: Thinly interbedded fine sandstone and coarse siltstone.

Type section locality: On the southern bank of Neave Creek at 17°40′S, 130°39′E.

Thickness: 25 m at the type section; up to 75 m in parts of the Waterloo Sheet area.

Age: Proterozoic, probably Adelaidean.

Fossils: None known.

Stratigraphic relations: It is a constituent formation of Wattie Group with conformable upper and lower contacts.

Description: The Gibbie Formation consists of interbedded fine-grained sandstone and siltstone. The type section at Neave Creek consists of flaggy sandstone and micaceous siltstone (Section 15, Appendix I).

A section measured at Hughie Creek 12 km north of the type section contains 34 m of Gibbie Formation. It comprises grey thin-bedded fine-grained quartz sandstone with many flaggy and fissile bands of strongly rippled, green and purple, micaceous siltstone in which mud flakes are extremely common.

Excellent exposures of Gibbie Formation occur at both Wattie Creek in the Wave Hill Sheet area and in a scarp bordering the Wickham River 8 km west of the eastern margin of the Waterloo Sheet area. The formation is estimated to be 75 m thick near the Wickham River, and consists mostly of siltstone. It is mostly flaggy, thin-bedded, and either reddish brown and purple, or greyish green and micaceous. The different-coloured rocks are interbedded, and in some places the colour changes laterally within the bed. Circular greenish spots within predominantly red beds are a feature of the formation. Green mud flakes, halite casts, ripple marks, cross-bedding, and flute and load casts are abundant.

Another notable feature of the fine-grained quartz sandstone beds in the Gibbie Formation is the occurrence of segregations of a white mineral similar to those in the Burtawurta Formation. Some is calcite, but one thin section contained barite and minor calcite. The crystals are generally elongate in the plane of the bedding; they are 0.5 to 2 mm long and have been leached from many weathered surfaces, leaving the surface pitted.

In the northern part of the Waterloo Sheet area an otherwise similar sequence of siltstone contains a bed of grey, blocky, cherty dolomite containing stromatolites; microscopic examination has revealed that a reddish quartz siltstone from the formation contains at least 20 percent carbonate; it is likely that much of the formation is calcareous.

The silty and fine sandy nature of the sediments, their colour, and the presence of mud flakes, ripple marks, and halite casts indicate a very shallow-water depositional environment, probably lagoonal.

Seale Sandstone

Derivation of name: From Mount Seale at 17°38′S, 130°38′30″E, in the Wave Hill Sheet area.

Distribution: In the southeastern Waterloo and western Wave Hill Sheet areas.

Lithology: Massive and blocky, light-coloured medium quartz sandstone.

Type section locality: On the southern bank of Neave Creek at 17°40′S, 130° 39′E. The formation forms a low scarp which has been dissected by Neave Creek.

Thickness: Maximum 100 m, thinning to the north; it is only 6 m in the northern Waterloo Sheet area.

Age: Proterozoic, probably Adelaidean.

Fossils: None known.

Stratigraphic relations: It is the uppermost unit of the Wattie Group; both the upper and lower boundaries are considered conformable as they are sharp and well defined, and there is no evidence of unconformity.

Description: The Seale Sandstone forms cuestas and hogbacks where it is dipping, and plateaux where it is flat-lying. The dip-slopes and plateaux generally have an even, sandy surface with minor sandstone outcrops. Where the surface has been partly eroded by streams, an irregular surface is formed because erosion takes place preferentially along joint planes in the sandstone. The scarp slopes of the cuestas and hogbacks are generally capped by a cliff of the sandstone, below which is a comparatively smooth talus slope with minor outcrop of the softer underlying Gibbie Formation.

The Seale Sandstone is 101 m thick at the type section locality, where it consists entirely of light-coloured massive sandstone (Section 16, Appendix I). At Hughie Creek 13 km to the north, the unit is 80 to 100 m thick; the lower part is composed of grey and purple brown, fine-grained sandstone which is massive, cross-bedded (in units 10-30 cm thick), fairly well sorted, and contains minor interstitial clay.

Cliffs up to 80 m high have been formed by the resistant Seale Sandstone where it has been dissected by the Wickham River and Depot Creek in the south-east corner of the Waterloo Sheet area. The thickness of the formation is similar to that farther south. The base crops out in a cliff adjacent to the Wickham River and consists of massive to blocky, strongly cross-bedded, medium-grained sandstone. Foreset laminae and thin beds contain many clay galls and, in some places, some interstitial white clay.

A number of minor outcrops of Seale Sandstone occur near the Humbert River in the Waterloo Sheet area. The quartz sandstone is generally blocky, white, fine to medium, well sorted, and contains 10 to 15 percent of white opaque grains; the grains include weathered feldspar or clay, and chert. The thickness of the formation is considerably less in the north, and is only 6 m in the anticline 30 km west of Bullita homestead (grid ref. 653215).

The Seale Sandstone is less than 5 m thick about 25 km northwest of Bullita in a monocline which extends into the Auvergne Sheet area. It consists of a bed of coarse-grained sandstone and grit in which pebbles of chert and quartz are set in a dolomitic sandstone matrix; this is overlain by brown fine-grained sandstone that is reddish when weathered.

Bullita Group

Names of constituent formations:

Battle Creek Formation (youngest)

Weaner Sandstone — Mount Gordon Sandstone } probable equivalents
Bynoe Formation — Nero Siltstone

Skull Creek Formation
- Bardia Chert Member
- Supplejack Dolomite Member

Timber Creek Formation (oldest)

Derivation of name: From Bullita pastoral lease in the northeast corner of the Waterloo Sheet area.

Distribution: In the central part of the Victoria River region it covers parts of the following Sheet areas: Auvergne, Delamere, Waterloo, Limbunya, Wave Hill, Victoria River Downs, and Fergusson River.

Lithologic affinities of constituent formations: The group is characterized by the occurrence of dolomite beds throughout, except in the Weaner and Mount Gordon Sandstones and the Nero Siltstone (Table 5).

Thickness: Up to 500 m in the Auvergne and Delamere Sheet areas. It totals 700 m in the Victoria River Downs Sheet area.

Age: Proterozoic, probably Adelaidean.

Fossils: Stromatolites occur in the Skull Creek, Battle Creek, and Banyan Formations.

Stratigraphic relations: It conformably overlies the Seale Sandstone (uppermost formation of the Wattie Group), and is unconformably overlain by the Wondoan Hill Formation and basal formations of the Auvergne Group. The Nero Siltstone and Mount Gordon Sandstone are probably lateral equivalents of the Bynoe Formation and Weaner Sandstone, respectively.

Synonymy or modification of previous nomenclature: The group was previously included in the undifferentiated Victoria River Group (Traves, 1955); some of the group was described by Laing & Allen (1956); Randal (1962) included the Banyan Formation in his Palm Creek Beds.

Discussion: The stratigraphy of the group is summarized in Table 5. The three oldest formations were originally named and partly mapped by Laing & Allen (1956). Their definitions and nomenclature were modified and the Bullita Group was established after further mapping by Pontifex et al. (1968) and Morgan et al. (1970). The major result was recognition of the fact that the Skull Creek Formation overlies the Timber Creek Formation, and that they are not lateral equivalents.

The four formations younger than the Bynoe Formation were included in the group after the 1969 fieldwork; the Battle Creek Formation is the youngest formation recognized below the unconformably overlying Wondoan Hill Formation.

The Bullita Group is characterized by the occurrence of dolomite; carbonate sedimentation was more or less continuous throughout the depositional history of the group. Maximum detrital sedimentation occurred during the deposition of the Weaner Sandstone and upper Battle Creek Formation. Detrital sedimentation was at its minimum during deposition of the Skull Creek Formation and lower Battle Creek Formation.

The Nero Siltstone and Mount Gordon Sandstone cannot be definitely correlated with other formations in the Bullita Group as they are isolated from them, but they are included in the group because they are overlain by probable Wondoan Hill Formation. Structurally and lithologically it is likely that they are lateral equivalents of the Bynoe Formation and the Weaner Sandstone respectively.

Timber Creek Formation

The Timber Creek Formation was defined and mapped in the Auvergne Sheet area (Pontifex et al., 1968; Sweet, Pontifex, & Morgan, in press, b). However, it crops out more extensively in the eastern Waterloo Sheet area and in the adjacent parts of the Victoria River Downs Sheet area. An area of 300 km^2

TABLE 5: SUMMARY OF BULLITA GROUP STRATIGRAPHY

Unit	*Map Symbol*	*Lithology*	*Thickness range (m)*	*Stratigraphic relations*	*Physiographic expression*	*Remarks*
Mount Gordon Sandstone	Ꝑbo	Sandstone	10+	Unconformably overlain by Wondoan Hill Formation; conformable on Ꝑbe	Gently dipping plateau surface	May be equivalents of Ꝑbw & Ꝑby, but lack of outcrop necessitates separate names
Nero Siltstone	Ꝑbe	Siltstone and shale	80	Lower contact not observed	Smooth scarp slopes below capping of Ꝑbo	
Battle Creek Formation	Ꝑba	Dolomite, siltstone, and sandstone, minor shale	180+	Overlain unconformably in S by Wondoan Hill Formation	Low hills, some hogbacks	Youngest unit of Bullita Group
Weaner Sandstone	Ꝑbw	Sandstone, pebbly sandstone	0-15	Conformable on Ꝑby	Prominent cuestas	
Bynoe Formation	Ꝑby	Siltstone, minor dolomite and sandstone	120-200(?)	Lower contact may be unconformable locally	Round hills with prominently terraced slopes	
Skull Creek Formation	Ꝑbs	Dolomite, minor siltstone, and sandy dolomite	165	Both contacts conformable	Rounded, terraced hills; some low relief areas with rocky pavements	
Bardia Chert Member	Ꝑbm	Laminated chert	0-60	Lower contact transgressive across bedding		Secondary chert—replaces dolomite
Supplejack Dolomite Member	Ꝑbu	Dolomite, dolarenite, and dolrudite	10-20	Upper and lower boundaries conformable	Prominent terrace; rocky pavements with lapies in flat areas	Very prominent photogeological unit
Timber Creek Formation	Ꝑbt	Sandstone, siltstone, dolomite	200-260(?)	Upper and lower boundaries conformable	Rounded terraced hills	Upper boundary gradational; thickness estimated only

around Wave Hill Police Station is underlain by Timber Creek Formation.

Stratigraphic relations: The base of the Timber Creek Formation is defined as the stratigraphic level at which siltstone and dolomite predominate over sandstone (Seale Sandstone). This is easily traced on aerial photographs because of the change in topography and soil colour. The contact with the underlying Seale Sandstone, although sharp, is regarded as conformable.

The upper boundary of the Timber Creek Formation is gradational; it has been arbitrarily placed at the base of a 2-m dark grey dolomite bed which is easily identified and coincides approximately with an increase in the carbonate content of the sequence.

Lithology and thickness: The maximum exposed thickness in the Auvergne and Delamere Sheet areas is probably about 150 m. Although the complete formation is exposed in areas farther south, it is difficult to measure because of low dips. A composite section in the southwest Victoria River Downs Sheet area and the adjacent Waterloo Sheet area contains at least 174 m of Timber Creek Formation (Section 17, Appendix I). Up to 50 m may have been missed; thus it is probably 200 to 220 m thick.

In the Wave Hill Sheet area a bore drilled at the Wave Hill Police Station penetrated 659 ft (200 m) of 'interbedded limestone and shale' (Barclay & Hays, 1965) before passing into sandstone. Barclay & Hays called these rocks the 'Wave Hill Beds'; we have mapped the limestone and shale as Timber Creek Formation and the sandstone as Seale Sandstone. The bore was started probably within 60 m of the top of the Timber Creek Formation; this indicates a maximum thickness of 260 m in the area.

Another bore, drilled on top of the scarp 3 km east of the police station, penetrated 1000 ft (305 m) of 'limestone and shale'. Lithological logs are not available, but the bore probably started in Skull Creek Formation and passed right through the Timber Creek Formation.

The Timber Creek Formation is of fairly uniform lithology and consists of thinly interbedded siltstone (some dolomitic), fine-grained sandstone, and dolomite. It is difficult to judge the relative proportion of carbonate and clastics as the carbonate crops out more strongly. On most hill-slopes the siltstone and sandstone are seen only as scree, and travertine derived from the dolomite interbeds gives a false impression of a predominantly dolomitic sequence. There may be a slight increase in dolomite content southwards, but this has not been proved. A few highly indurated sandstone beds stand out as hard bands in hill-slopes.

An excellent exposure of Timber Creek Formation in Gibbie Creek 9 km south of its confluence with the Wickham River comprises blocky and flaggy, grey, green, reddish brown, and purple siltstone and fine-grained very hard sandstone interbeds. Small-scale ripple marks and halite casts are common, especially in the sandstone.

Between 1 and 3 km farther south along Gibbie Creek, a massive dolomite bed is 6 to 7 m thick. The basal 2 to 3 m comprises flaggy, fine to medium crystalline dolomite, brownish grey where weathered; it contains thin interbeds of intraformational conglomerate, mostly dolarenite with a few clasts exceeding 2 cm diameter. The upper 4 m weathers to dark grey and is a coarsely crystalline wavy-bedded dolomite; it may all be recrystallized dolarenite. The uppermost 0.5 m contains stringers and nodules of chert, and the carbonates contain many small

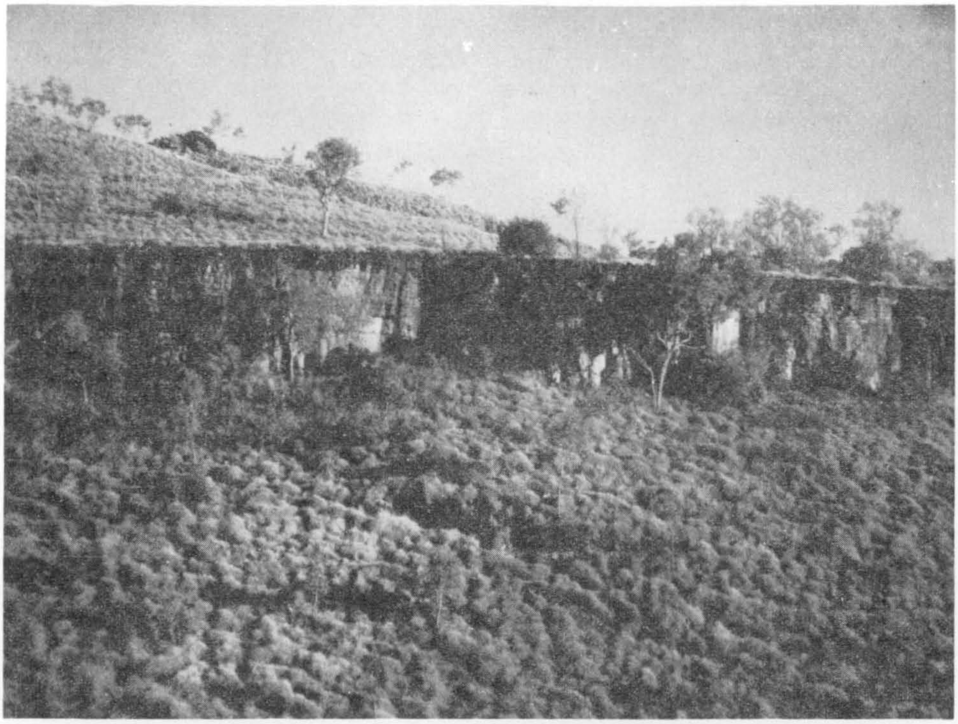


Fig. 23. Massive dolomite beds within the Timber Creek Formation on the western side of Gibbie Creek 10 km south of its confluence with the Wickham River.

holes 1 to 5 mm across which may indicate volume changes caused by dolomitization. The rock has a slightly fetid odour when split, and contains rare flecks of galena (0.5 mm diameter). The mode of outcrop of the beds is shown in Figure 23. The same dolomite bed was mapped in the composite section (Section 17, Appendix I, 9 m of dolomite). The same bed crops out farther north in the Humbert River area.

Dolomitization features have not been observed in other carbonate beds in the formation. Most beds are of finely crystalline dolomite which is believed to be primary.

An incomplete section of Timber Creek Formation measured 19 km southwest of Humbert River station is at least 200 m thick and contains at least ten flaggy or blocky dolomite beds up to 1 m thick interbedded with dolomitic siltstone and fine-grained sandstone.

Palaeogeographic significance: Small-scale ripple marks and halite casts are common throughout the Timber Creek Formation. The dolomite is mostly fine-grained, and contains chert nodules but no stromatolites. All these factors point to deposition under evaporitic conditions. The presence of silt and fine sand shows that there was a regular supply of clastic material into the area. Somewhat similar environments to that envisaged can be observed at present in the Coorong and associated hypersaline lagoons in the southeast of South Australia (von der Borch, 1965), and in parts of the Persian Gulf (Illing, Wells, & Taylor, 1965).

Skull Creek Formation

The major outcrops of Skull Creek Formation are in the area north of Victoria River Downs homestead in the Victoria River Downs Sheet area, and in the adjacent northeastern Waterloo Sheet area.

The name, derived from Skull Creek in the Delamere Sheet area, was first used by Laing & Allen (1956) as Skull Creek Limestone. This was modified by Pontifex et al. (1968), and Morgan et al. (1970) to Skull Creek Formation and formerly defined as such by Sweet, Pontifex, & Morgan (in press, b). A small area now assigned to this formation was called 'Wave Hill Beds' by Barclay & Hays (1965).

The unit comprises dolomite and siltstone and minor sandy and silty dolomite and dolomitic sandstone. Its lower contact is gradational and conformable with the Timber Creek Formation. The boundary is placed at the stratigraphic level at which the dolomite content of the rock exceeds 50 percent; in most places this level coincides approximately with a distinctive dolomite bed that has facilitated mapping of the boundary.

The upper boundary with the Bynoe Formation is sharp in most areas. The exception is in a scarp directly south of Humbert River homestead, where the boundary is gradational and could be placed above any one of three dolomite beds. In most areas the boundary is easily photo-interpreted because a change in topography reflects the change from dolomite with minor siltstone interbeds to siltstone with minor dolomite interbeds. In the Burt and Fitzgerald Ranges the top of the Skull Creek Formation is marked by about 30 m of chert.

Lithology and thickness: No single section has been measured right through the Skull Creek Formation, but two sections near the western margin of the Victoria River Downs Sheet area give a good indication of total thickness (Sections 18 and 19, Appendix I). They indicate 33.5 m above the Supplejack Dolomite Member, 12 m for the member itself, and about 118 m below the member, giving a total of nearly 165 m. There is no Bardia Chert Member in the sections.

Several distinctive beds have been recognized in the Skull Creek Formation. A basal dark grey dolomite bed 1 to 2 m thick has been recognized throughout the area. It contains vague rod-like structures 0.5 to 2 cm in diameter (Fig. 24) and the top 0.5 m of the bed is generally silicified. The structures begin in dolomite, and continue into the chert layers (which are therefore of replacement origin), where they are much more distinct and show very fine laminations. They are believed to be a type of columnar stromatolite. The dolomite has a fetid odour when split.

About 40 m above the base of the Skull Creek Formation several finely crystalline light grey to pinkish grey dolomite beds contain small spherical bodies 1 to 10 mm across and large halite casts up to 15 cm across. These beds were first observed by Laing & Allen (1956), who designated them the 'lower marker'. They have been observed in every locality where the lower part of the Skull Creek Formation crops out, but have not been separated as a formal member. At Section 19 the beds are 28 m thick, and separated from the Supplejack Dolomite Member by 35 m of dolomite and siltstone (Section 19, Appendix I).

The southernmost outcrop at which the 'lower marker' was seen is 2 km north of the Wickham River at the western margin of the Victoria River Downs Sheet area. It is at least 3 m thick and includes three beds, each about 0.5 m thick,

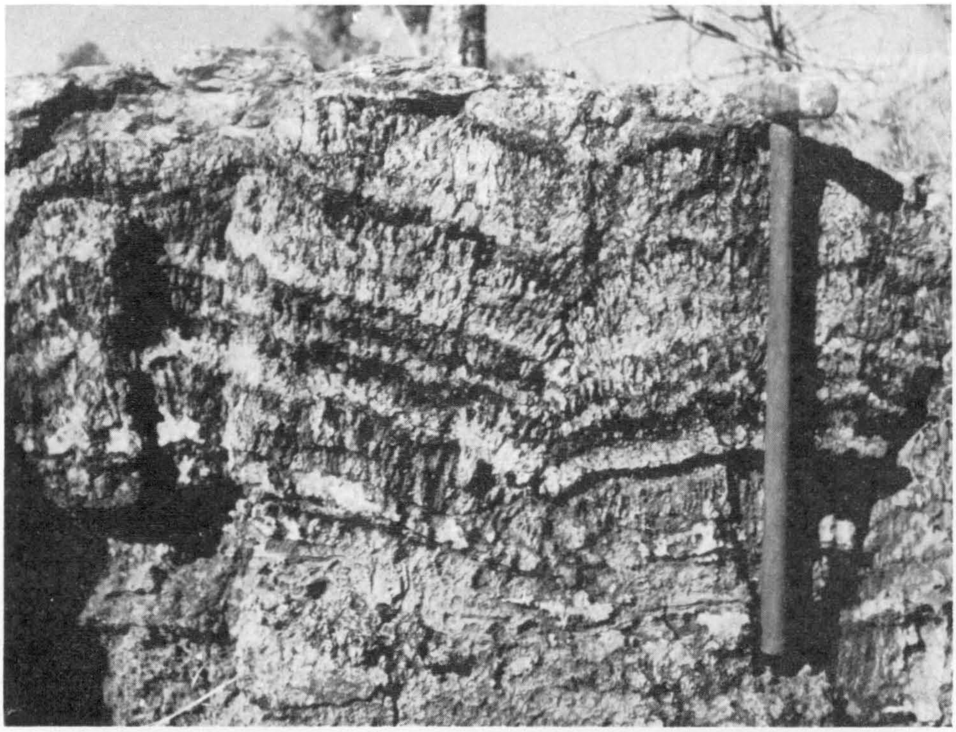


Fig. 24. Silicified stromatolitic top of the basal bed of the Skull Creek Formation in the east bank of Gibbie Creek 3.5 km north of Figure 23 locality.

which contain small spherical bodies and some halite casts. As in other localities, the beds also contain numerous thin lenses and nodules of chert; the irregular shape of the nodules shows that they are secondary. The same bed is well exposed 8 km due north of Victoria River Downs homestead at the southern end of the Fitzgerald Range.

A number of beds below the 'lower marker' contain a significant proportion of clastic material; they are silty and sandy dolomite with interbedded poorly outcropping dolomitic siltstone.

The Supplejack Dolomite Member is the most outstanding stratigraphic horizon within the formation, and because it stands out so prominently on aerial photographs it is easily mapped. The Skull Creek Formation above the Supplejack Dolomite Member is nearly all massive dolomite beds with 1 to 3 m between bedding partings. This gives a prominent banded pattern on aerial photographs and results in the development of distinctive topography on hill-slopes (Fig. 25). The soft beds constituting the partings are probably flaggy dolomite and dolomitic siltstone and are nearly always scree-covered. Section 18 (Appendix I), 4 km southwest of Humbert River station, contains two massive dolomite beds immediately above the Supplejack Dolomite Member, but they were not observed in the section measured at the southern end of the Fitzgerald Range (Section 20, Appendix I) where flaggy dolomite and siltstone are interbedded. The dolomite above the Supplejack Dolomite Member is generally more coarsely crystalline than that below the member. The crystals are mostly medium and coarse carbonate (0.06-1.0 mm: classification of Folk, 1962); fine-sized crystals are rare.

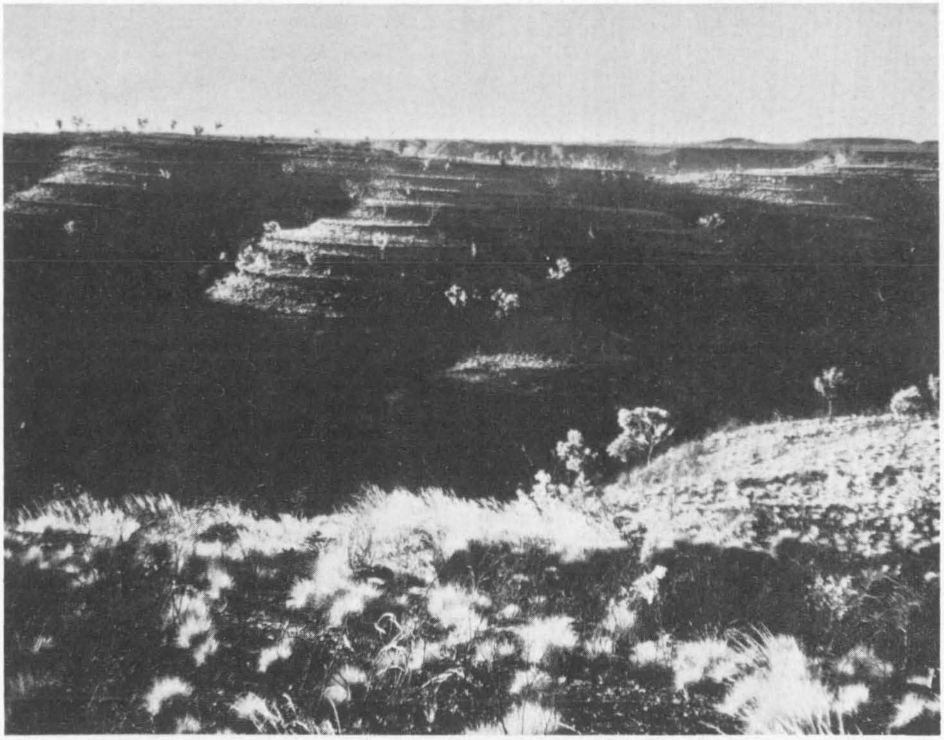


Fig. 25. Distinctive terraced hill-slopes characteristic of the upper part of the Skull Creek Formation, 4 km southwest of Humbert River homestead.

Stromatolites are found in, and above, the Supplejack Dolomite Member. Those above the member generally occur as isolated hemispherical growths (Fig. 28).

The top of the Skull Creek Formation is drawn at a prominent photogeological boundary (Perry, 1966) which on the ground corresponds to a change from dolomite to siltstone. The uppermost bed of the formation is an intramicrite 1 m thick which contains clasts of fine-grained dolomite up to 2 cm across, although most are less than 1 cm across. Interbeds of siltstone are common in the top 10 to 20 m of the formation, especially south of Humbert River homestead and in Wickham Gorge (between Victoria River Downs and Mount Sanford outstation). In these areas the boundary is gradational over at least 10 m.

The Bynoe Formation has not been observed in contact with the Bardia Chert Member in the Victoria River Downs Sheet area, although the contact has been seen to the north in the Delamere Sheet area (Morgan et al., 1970). However, the boundary has been penetrated by at least one bore at the Kidman Springs Research Station 31 km north of Victoria River Downs homestead.

Geochemical sampling of the Skull Creek Formation has not revealed any major base-metal anomalies (Appendix II, tables I and II).

Supplejack Dolomite Member

The Supplejack Dolomite Member crops out extensively in the northeastern Waterloo and northwestern Victoria River Downs Sheet areas. It has been

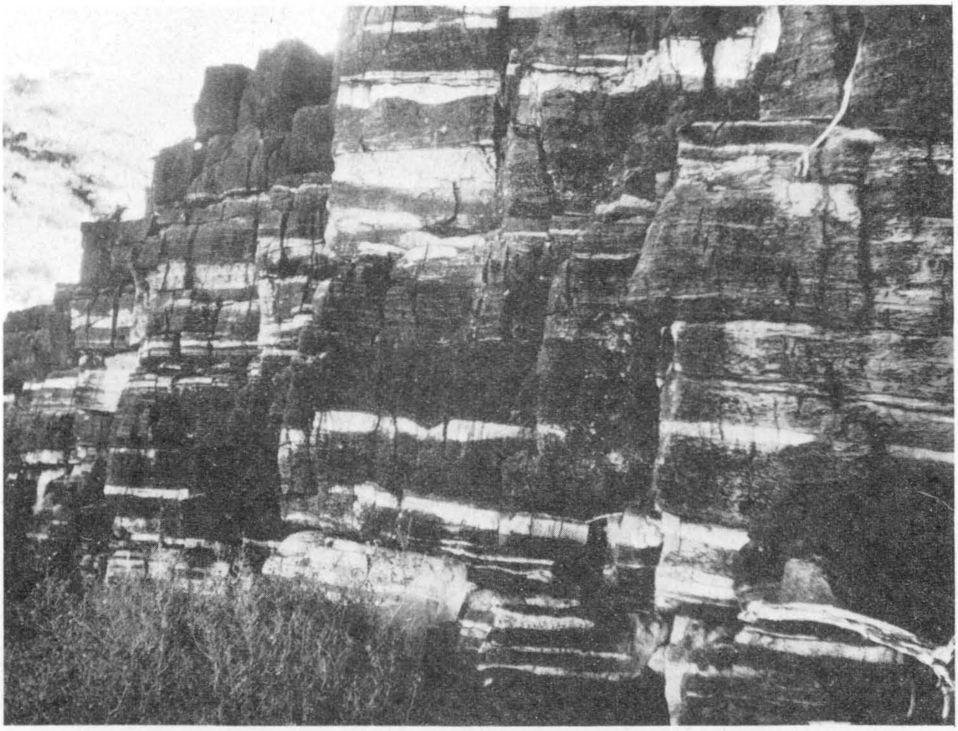


Fig. 26. Dolomite interbedded with cross-bedded dolarenite and dolrudite in the Supplejack Dolomite Member in an anticline 30 km west-southwest of Victoria River Downs homestead.

reported and defined by Sweet et al. (in press, a) in the Delamere Sheet area; it may also crop out as far north as the Fergusson River Sheet area. The name is derived from Supplejack yard (grid ref. 642228) on the south bank of the East Baines River in the Waterloo Sheet area. The type section is between Bullita homestead and Supplejack yard where the track linking them passes over the member (grid ref. 644219).

Lithology and thickness: The thickness of the Supplejack Dolomite Member at the southern end of the Fitzgerald Range is about 10 m (Section 20, Appendix I); 58 km to the west, near the Humbert River, it is estimated to be about 12 m, and is similar in other areas where the member crops out.

The member has been named and delineated on maps because of a distinctive appearance which results from the weathering of its massive beds to a dark colour. Because of the purity of the carbonate in the beds, solution effects are prominent, and karst topography has developed where outcrop of flat-lying or gently dipping sediments crop out on flat ground.

Most beds are thick; laminations between partings are rare, and partings are 1 to 3 m apart. An excellent outcrop of the lower beds occurs in the core of an anticline 30 km west-southwest of Victoria River Downs homestead. About 9 m of dolrudite and dolarenite contain numerous lenses and thin beds of finely crystalline dolomite (Figs. 26 and 27) which stand out because of their light colour and smooth surface. The coarse-grained rocks show vague cross-bedding

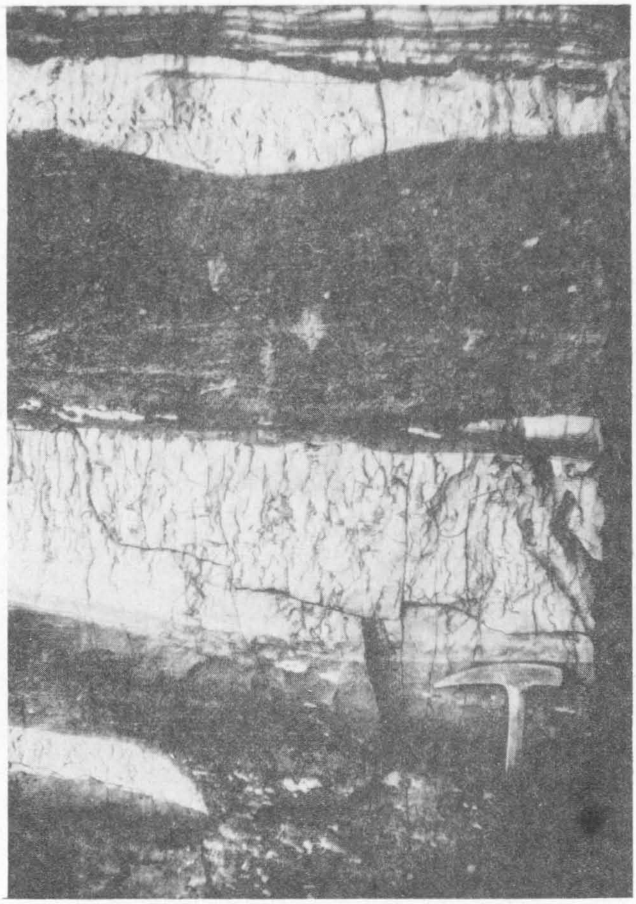


Fig. 27. Light-coloured dolomite beds with possible syneresis cracks, and dark-coloured cross-bedded dolarenite and dolrudite in the Supplejack Dolomite Member, same locality as Figure 26.

with foreset laminae up to 10 cm thick within beds 1 to 2 m thick. Most of the rocks have recrystallized and have the dark-coloured uniform appearance of the whole member in most areas. Overlying the dolarenite are two beds of laminated stromatolitic dolomite which is dark-coloured when weathered. Domed and conical stromatolites occur, some being at least 2.5 m high. The structures are not always clearly defined owing to the uniformity of the lithology and the recrystallization effects. They usually comprise laminae which become increasingly convex upwards from the base, eventually becoming conical, with apex upwards (Fig. 28). In some cases the laminae flatten out again at the top of the beds. The zone between stromatolites is usually coarse to very coarse crystalline carbonate with no well defined structures. The stromatolitic dolomite bed at the top of the Supplejack Dolomite Member has been recognized at every outcrop.

Bardia Chert Member

The Bardia Chert Member crops out in the Burt and Fitzgerald Ranges in the northwestern Victoria River Downs Sheet area (Fig. 29). The name is

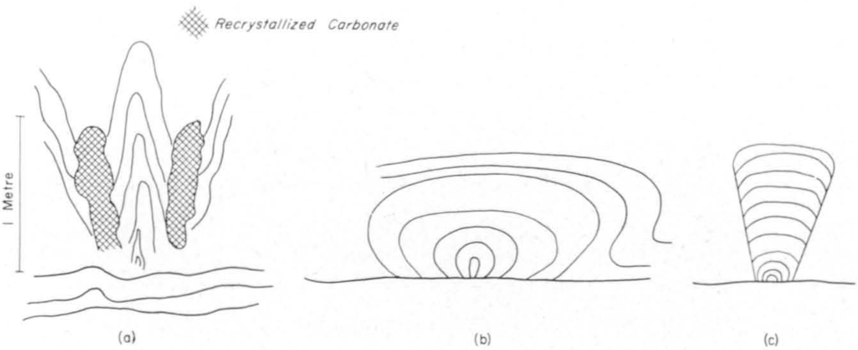


Fig. 28. Stromatolites from the Skull Creek Formation: (a) is typical of those from the Supplejack Dolomite Member; (b) and (c) are typical of those in beds above the Member.

derived from Bardia yard in the Delamere Sheet area, and the member was defined by Sweet et al. (in press, a).

The Bardia Chert Member forms the top part of the Skull Creek Formation in the Burt and Fitzgerald Ranges. Its lower boundary with the remainder of the Skull Creek Formation is somewhat irregular, and its upper boundary with the Bynoe Formation was not observed.

The evidence given below indicates that the Bardia Chert Member formed by silicification of dolomite. The lower boundary transgresses bedding planes, and the upper boundary may have an unconformable relation with the Bynoe Formation. Because there is no obvious hiatus in areas where the chert does not occur, it is assumed that any break at the top of the chert was local and not of long duration.

Lithology and thickness: Figure 29 shows areas where Bardia Chert Member is present at the top of the Skull Creek Formation, and areas where it is absent. It is thickest and most prominent in the Burt Hill and Fitzgerald Range areas, where it probably averages more than 30 m thick. Near Lounger Hill it is about 60 m thick. However, about 10 km to the southeast it is only 1 m thick, and about 25 km southwest of Lounger Hill it is absent. The base of the member is about 15 m above the top of the Supplejack Dolomite Member in the Burt Range, and 45 m at the southern end of the Fitzgerald Range. This indicates that a greater thickness of dolomite has been replaced in the Burt Range.

The chert constituting the member is pink or pinkish brown, generally laminated, and contains stromatolite-like structures. In most localities some of the chert is brecciated, and angular fragments of laminated chert have been recemented by silica of similar appearance. Such chert usually contains numerous voids lined with minute quartz crystals and, rarely, chalcedony or agate.

Age of the chert: The chert is not a Tertiary layer of silicification associated with duricrusting or lateritization. It occurs within a sequence of Precambrian rocks and must have formed before deposition of the Bynoe Formation because the latter overlies it in undisturbed attitude. It has been folded with the Bullita Group, a feature which is well displayed along the eastern margin of the Burt Range where the chert dips steeply to the east. It is therefore of similar age to the remainder of the Bullita Group.

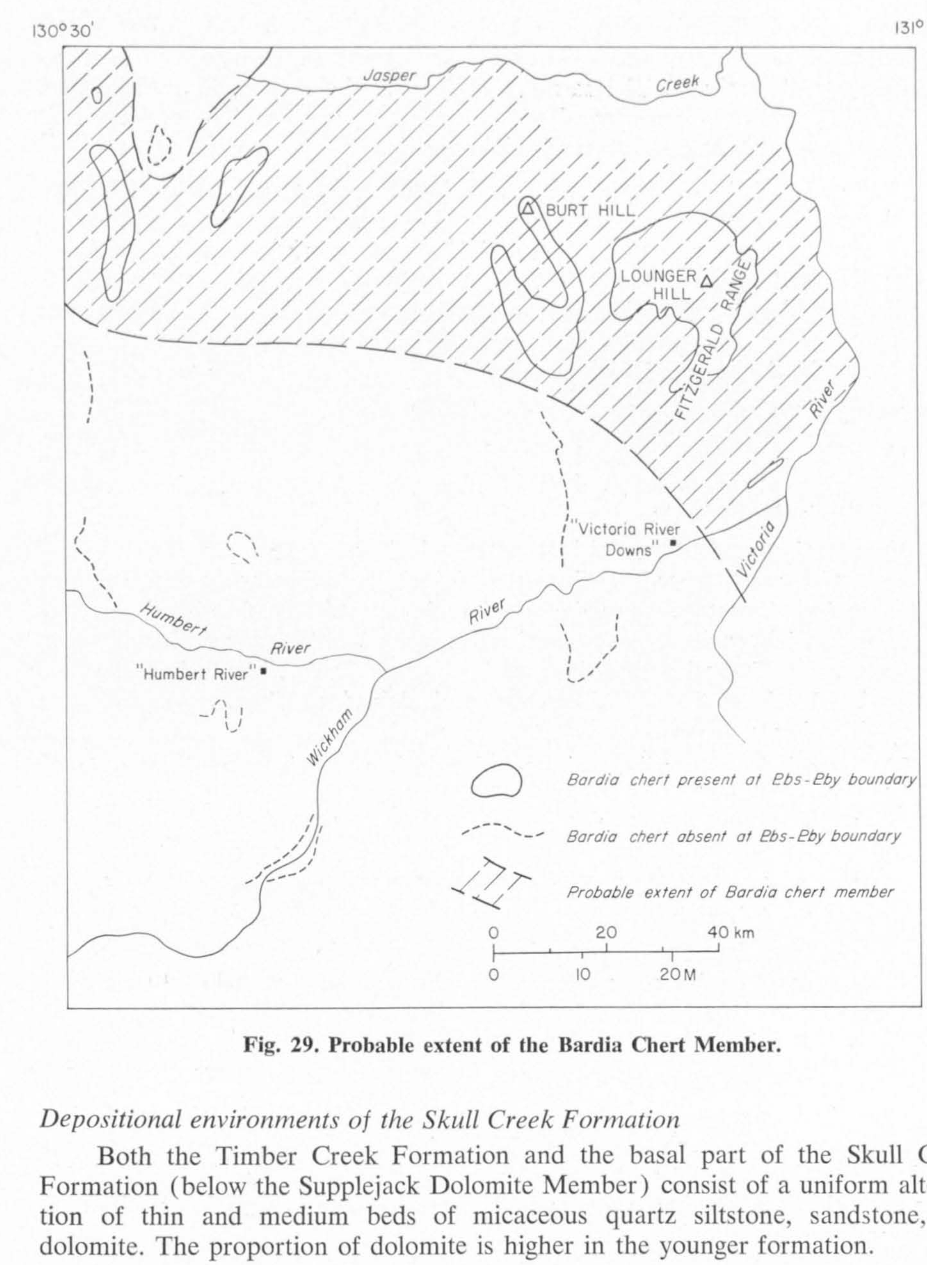


Fig. 29. Probable extent of the Bardia Chert Member.

Depositional environments of the Skull Creek Formation

Both the Timber Creek Formation and the basal part of the Skull Creek Formation (below the Supplejack Dolomite Member) consist of a uniform alternation of thin and medium beds of micaceous quartz siltstone, sandstone, and dolomite. The proportion of dolomite is higher in the younger formation.

The halite clasts in the 'lower marker' of the Skull Creek Formation indicate evaporitic conditions, but the significance of the small spherical bodies is not known. The siltstone and fine sandstone could also have been laid down in a similar environment as they also contain halite casts; in addition, they contain mud cracks.

The outcrops of Supplejack Dolomite Member 30 km southwest of Victoria River Downs homestead (Figs 26 and 27) are critical to the interpretation of environments for the whole formation. Elsewhere, the member consists of dark grey recrystallized dolomite, but at this locality micrites are interbedded with strongly cross-bedded dolarenite and dolrudite in which the clasts are of identical composition to the micrite. The member appears to be the result of deposition and reworking in an environment of strong current or wave action, perhaps as a product of a marine transgression across dolomite.

The Supplejack Dolomite Member heralds the onset of predominantly dolomite sedimentation, with only minor siltstone between dolomite beds 5 to 10 m thick. Stromatolites are also present in and above the marker, and the dolomites are generally medium to coarsely crystalline. Although the grainsize is generally coarse because of recrystallization, it is in some places an indicator of the presence of dolarenite rather than micrite. The interbedded siltstone is similar in appearance to that below the Supplejack Dolomite Member.

The following sequence of events is envisaged:

(1) a long period of lagoonal and tidal mudflat conditions during which silt and dolomite were deposited (Timber Creek Formation and lower Skull Creek Formation);

(2) a widespread transgression, after which a more open marine-shelf environment prevailed. Because of lack of sediment supply dolomite and/or limestone were deposited and stromatolites flourished in some intertidal environments, particularly where salinity was higher than normal. Extensive reworking of finely crystalline dolomite beds resulted in the formation of dolarenite and dolrudite (Supplejack Dolomite Member);

(3) a period of cyclic sedimentation when marine conditions (with carbonates and stromatolites) alternated with paralic and lagoonal conditions (with silt and sand deposition). A model for this type of process exists in the late Mississippian Pope Megagroup of the United States, described by D. H. Swann (1964). The process envisaged by Swann was one in which

> 'the shoreline fluctuated several hundred miles landward (northeast) and seaward, with 70 or more minor reversals in direction superimposed on about 15 major cycles of advance and retreat. Sea level is inferred to have been relatively static and variation in rainfall was the primary factor controlling sedimentary cycles'.

Figure 25 shows terraced hill-slopes in which each hard dolomite bed is taken to represent one cycle. At least 20 such beds are visible above the Supplejack Dolomite Member and several more occur in the basal Bynoe Formation. The ultimate mechanism causing the proposed shore-line fluctuations in the Victoria River area is not known.

Bynoe Formation

The Bynoe Formation was originally called Coolibah Formation by Laing & Allen (1956); it was modified to its present form and defined by Sweet et al. (in press, a). It crops out over a large area, including parts of western Victoria River Downs and northeastern Waterloo Sheet areas. It is possible that the Nero Siltstone in the Wave Hill Sheet area is its equivalent.

The base is conformable in most areas, but may be locally unconformable with the Bardia Chert Member. The upper contact with the Weaner Sandstone is believed to be conformable.

Lithology and thickness: A section measured through the Bynoe Formation at Station Hill, 14 km northwest of Victoria River Downs homestead, revealed at least 120 m of the formation (Section 21, Appendix I); as it is overlain unconformably by the Jasper Gorge Sandstone, this is a minimum thickness. The Bynoe Formation is overlain conformably by the Weaner Sandstone in a large arc north, east, and south of Victoria River Downs homestead. Its outcrop width is between 6 and 7 km, and as the rocks dip at a very low angle (probably less than 2°) the complete formation is probably less than 200 m thick.

The lithology of the Bynoe Formation is similar to that in the Delamere Sheet area (Sweet et al., in press, a). Chocolate and purple siltstone, usually slightly dolomitic and in most areas micaceous, forms massive structureless beds 0.5 to 2 m thick. Light greyish green siltstone is either interbedded with, or occurs as irregular patches and spots within, the purple beds. The green colour probably results from clay minerals; mica is common and forms thin partings.

Dolomite sandstone interbeds seem more common than in the Delamere Sheet area. Some crop out at Station Hill (Section 21, Appendix I) and farther south. For instance, 15 km northeast of Humbert River homestead light grey marl and blocky dolomitic sandstone with ripple marks, mud cracks, and load casts are interbedded with chocolate micaceous siltstone. About 5 km southwest of the homestead a fine-grained well indurated sandstone with halite casts is interbedded with siltstone near the base of the Bynoe Formation.

In the mesas around Bullita homestead fine-grained dolomitic sandstone contains widely disseminated chalcopyrite grains, but geochemical sampling has shown that copper values are very low (131 ppm maximum over 15 m, see Appendix II, Table III).

Environment of deposition: The greyish green siltstone and fine-grained sandstone interbeds give the main clues to the depositional environment of the Bynoe Formation. They contain ripple marks, primary current lineations, mud cracks, and halite casts, which indicate a current-swept shallow-water environment exposed to periodic subaerial conditions.

The chocolate and greyish green massive siltstones could also be products of the same environment, or they could represent periods of deposition in slightly deeper water, probably in a delta. Minor fluctuations in sea level could have resulted in periodic shallowing of the basin and in deposition of the sandy interbeds (see section on environment of Skull Creek Formation).

Weaner Sandstone (new name)

Derivation of name: From Weaner Crossing, a fording point on the Victoria River at 16°13′S, 131°8′E, in the Victoria River Downs Sheet area.

Distribution: The unit forms a crescentic belt of outcrop in the northern and central Victoria River Downs Sheet area.

Lithology: Massive cross-bedded coarse sandstone, grit, and pebble conglomerate.

Type section locality: In a low scarp 5 km east of Weaner Crossing. The unit was measured adjacent to the track passing over the scarp at 16°12′S, 131°13′E.

Thickness: The type section comprises 10 m of white, purple, and brown, medium and coarse quartz sandstone. The unit is 3 m thick in the north, and as much as 15 m in the south.

Age: Proterozoic, probably Adelaidean.

Fossils: None known.

Stratigraphic relations: It conformably overlies the Bynoe Formation and is conformably overlain by the Battle Creek Formation. Contacts with the Bynoe and Battle Creek Formations are sharp. The Weaner Sandstone is probably the lateral equivalent of the Mount Gordon Sandstone.

Description: The Weaner Sandstone varies in thickness from 3 m in the north to over 15 m in the south and consists of a blocky to massive, coarse-grained cross-bedded quartz sandstone with grit bands. Texturally the sandstone is moderately mature and quartz grains in the unit are subangular to rounded, becoming more rounded southward; feldspar content increases in this direction.

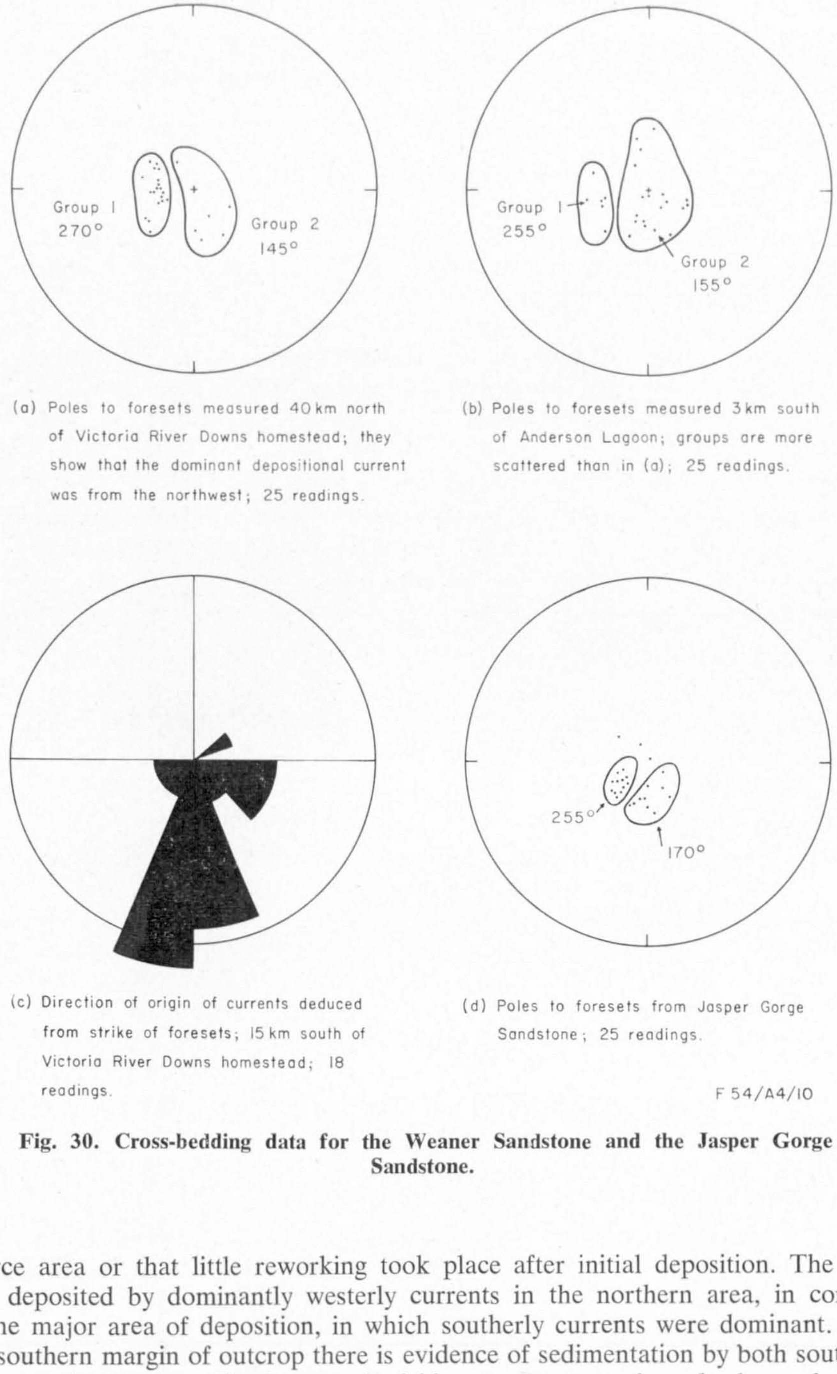
The type section consists of 10 m of white to purple and brown, medium to coarse quartz sandstone containing small shale clasts and grit bands. The sandstone is moderately sorted and contains about 2 percent of feldspar grains.

At its most northwesterly outcrop the Weaner Sandstone is 3 m thick and consists of massive, gritty, very coarse sandstone composed of poorly sorted subrounded to subangular quartz sand in cross-beds up to 0.5 m thick. About 2 km to the east (at grid ref. 715226), a blocky to massive, coarse-grained sandstone with pebbly lenses and bands crops out. Figure 30a shows 25 cross-bedding measurements taken at this locality, plotted as poles of foresets. They may be divided into two groups: Group 1 shows a consistent direction of origin from 270°; Group 2 shows a scatter in the southeast quarter of the stereogram with an average of about 145°. One of the latter group shows current reversal.

On the east bank of the Victoria River (grid ref. 729126), 5 m of brown to purple, massive coarse-grained medium-sorted quartz sandstone crops out in a cliff. Cross-bedding is abundant and 25 measurements of foresets were taken and plotted (Fig. 30b). The poles may again be divided into two groups: Group 1 shows an origin from 255° and Group 2 a more scattered southeasterly origin with an average of about 155°.

In the south and east the provenance of the unit is southerly, not westerly. This is supported by 18 readings of provenance direction taken 15 km south of Victoria River Downs homestead (grid ref. 711174). These are represented as the rose diagram in Fig. 30c, which shows a marked southerly provenance for the unit at this locality. There is also a minor easterly component in the measurements. Farther south, about 1 km west of Gordon Creek (grid ref. 711159), foresets dip consistently towards 350°. Here 15 m of sandstone is exposed and the base of the unit is not seen. The rock is white to brown, thick-bedded medium to coarse feldspathic sandstone which contains about 5 percent feldspar grains and has massive to blocky partings. Bands of rounded vein-quartz and quartzite pebbles are common, particularly within the lower part of the unit.

Palaeogeographic significance: The Weaner Sandstone was laid down in shallow-water marine conditions by near-shore currents. The poor sorting and relative immaturity of the sandstone (as compared to the Jasper Gorge Sandstone for example) indicate either that the deposited material travelled only a short distance from its



(a) Poles to foresets measured 40 km north of Victoria River Downs homestead; they show that the dominant depositional current was from the northwest; 25 readings.

(b) Poles to foresets measured 3 km south of Anderson Lagoon; groups are more scattered than in (a); 25 readings.

(c) Direction of origin of currents deduced from strike of foresets; 15 km south of Victoria River Downs homestead; 18 readings.

(d) Poles to foresets from Jasper Gorge Sandstone; 25 readings.

Fig. 30. Cross-bedding data for the Weaner Sandstone and the Jasper Gorge Sandstone.

source area or that little reworking took place after initial deposition. The sand was deposited by dominantly westerly currents in the northern area, in contrast to the major area of deposition, in which southerly currents were dominant. Near the southern margin of outcrop there is evidence of sedimentation by both southerly and easterly currents. The increase in feldspar content southwards shows that this was derived from a source situated to the south of the present area of outcrop. The unit represents a local high-energy marine phase between two calmer shallow-water marine phases.

Battle Creek Formation (new name)

Derivation of name: From Battle Creek, a westerly-flowing tributary of the Victoria River draining the central-northern Victoria River Downs Sheet area.

Distribution: In the northern and central Victoria River Downs Sheet area.

Lithology: Reddish brown and grey dolomite interbedded with greyish green and purple siltstone; some blocky fine and medium quartz sandstone near the top.

Type section locality: A composite of two sections measured southwest of Moolooloo outstation near the centre of the Victoria River Downs Sheet area. The base of the section is on the west limb of an anticline on the western bank of Waterbag Creek at 16°27′S, 131°23′20″E, and was measured due west for 1 km. The upper part of the section was measured 10 km to the north-northeast on the east limb of the anticline. The section begins at 16°21′30″S, 131°24′15″E, and extends 2 km northeast to the bank of Waterbag Creek at 16°21′15″S, 131°25′E.

Thickness: The composite type section, which is the most complete section available, is at least 187 m thick and consists of 150 m of interbedded dolomite and siltstone, overlain by 27 m of blocky fine and medium quartz sandstone, capped by 10+ m of ferruginous dolomite and siltstone.

Age: Proterozoic, probably Adelaidean.

Fossils: Abundant stromatolites in some dolomite beds.

Stratigraphic relations: The lower contact with the Weaner Sandstone is conformable. No conformable beds are exposed above the Battle Creek Formation, which is the youngest-known formation in the Bullita Group. It is overlain unconformably by the Wondoan Hill Formation south of the type section localities.

Description: Northeast of Mount Fisher the basal 10 to 20 m of the Battle Creek Formation is well exposed and consists of red-brown dolomite, greyish green siltstone, and minor shale. Stromatolites and glauconite are common in the dolomite, as are mud flakes in the siltstone. Several white and pink, blocky to flaggy, medium-grained sandstone beds containing climbing ripples and current lineations are interbedded with the dolomite and siltstone.

The lower part of the type section, which crops out best in the north-trending anticline southwest of Moolooloo outstation, was not measured accurately and was estimated to be at least 150 m thick. The dolomite is pink to red-brown, grey, and buff, massive to flaggy, and contains some chert; the siltstone is greyish green to purple, flaggy to fissile, and laminated. A blocky purple medium to fine orthoquartzite at the top of the section is probably the same sandstone as that cropping out farther north in the other part of the type section.

In the upper part of the type section (Section 22, Appendix I), 27 m of sandstone overlies siltstone similar to that seen lower in the formation. The same sequence crops out on the other side of an anticline 7 km to the northwest, where 35 m of sandstone is exposed (Section 23, Appendix I). Overlying the sandstone is an unknown thickness of dark red-brown to red blocky dolomite and greyish green to purple fissile shale and siltstone. These are the youngest beds preserved below the unconformity separating the Battle Creek and Wondoan Hill Formations. Hematite is common in fissures in the dolomite, and a thin bed of shale and siltstone breccia crops out in the same area.

The middle part of the formation is well exposed 1.5 km northwest of O.D. Bore (grid ref. 744195), where Section 24 was measured (Appendix I). About 0.5 km nearer the bore, sparsely outcropping laminated hematitic siltstone is overlain by flaggy thin-bedded maroon, grey, and red dolomite containing widely separated large hemispherical stromatolites. Glauconite is common in the fissile and blocky beds near the base of the dolomite, and groups of columnar stromatolites are present. Hematite occurs in joints in the dolomite.

About 4 km south of O.D. Bore 6 m of white to brown, massive sandstone underlies the rocks described above. The sandstone is medium-grained and contains mud flakes and limonite spots. Slump structures are common in an underlying bed of white to grey, fissile laminated very fine-grained sandstone.

At Rose Crossing (grid ref. 725226) blocky to flaggy, medium to fine sandstone in the bed of the Victoria River is near the base of the Battle Creek Formation. About 5 km southwest of Rose Crossing grey and, rarely, red flaggy crystalline dolomite is interbedded with minor greyish green siltstone. Red-brown crystalline dolomite generally overlies the grey dolomite.

In the Battle Creek/Waterbag Creek area (grid ref. 748208), 14 m of dark red glauconitic crystalline dolomite and fissile shale crop out (Section 25, Appendix I). Pyrolusite is abundant in fissures and joints at the top of the outcrop and also permeates much of the lower dolomite.

Chip samples of dolomite from various outcrops were analysed for various metal concentrations (Appendix II, Table IV). They show concentrations of manganese up to 8.9 percent.

In the Gordon Creek area greyish green fissile coarse-grained micaceous glauconitic siltstone is interbedded with flaggy to blocky, thin-bedded grey dolomite. Stromatolites are common and range from 0.15 to 0.5 m in diameter. The dolomite generally becomes red-brown higher in the sequence and is overlain by 20 m of purple to white flaggy thin-bedded silty sandstone and sandy siltstone. It is cross-bedded and contains mud flakes and halite casts. The unit crops out sparsely in this area.

Nero Siltstone (new name)

Derivation of name: From Nero Creek, a stream which drains into the Victoria River at 17°38′S, 130°44′E, in the Wave Hill Sheet area.

Distribution: Outcrop is restricted to a small area adjacent to the Victoria River in the central-western Wave Hill Sheet area.

Lithology: Olive green laminated siltstone and shale; minor sandstone.

Type section locality: The base of the section is on the southern side of Edgar Creek at 17°37′S, 130°42′E. The section was examined to the southeast; the top is at 17°39′S, 130°44′E, on the eastern side of the Victoria River.

Thickness: About 80 m at the type section (only measured section).

Age: Proterozoic, probably Adelaidean.

Fossils: None known.

Stratigraphic relations: The lower contact is not exposed but is inferred to overlie Skull Creek Formation conformably. It is overlain conformably by Mount Gordon Sandstone. The Nero Siltstone is probably the lateral equivalent of the Bynoe Formation.

Synonymy or modification of previous nomenclature: It was included in the Victoria River Group of Traves (1955).

Mount Gordon Sandstone (new name)

Derivation of Name: From Mount Gordon, a butte at 17°38′S, 130°32′E, in the Wave Hill Sheet area.

Distribution: Outcrops are within a small area between the Victoria River and Mount Gordon in the Wave Hill Sheet area.

Lithology: White blocky fine to medium quartz sandstone.

Type section locality: In a cliff face at the head of an erosion gully 3 km southwest of Mount Gordon at 17°38′30″S, 130°45′E.

Thickness: Maximum of 11 m, measured at the type section.

Age: Proterozoic, probably Adelaidean.

Fossils: None known.

Stratigraphic relations: It conformably overlies the Nero Siltstone; because the Nero Siltstone is overlain with angular unconformity by the Wondoan Hill Formation, the same relation must hold for the Mount Gordon Sandstone. The Mount Gordon Sandstone is probably the lateral equivalent of the Weaner Sandstone.

Synonymy or modification of previous nomenclature: The unit was previously included in the Victoria River Group of Traves (1955).

Description of Nero Siltstone and Mount Gordon Sandstone: These two units crop out over about 100 km^2 south of Wave Hill police station. Rocks mapped as Timber Creek and Skull Creek Formations crop out nearer the police station, but are separated from both Nero Siltstone and Mount Gordon Sandstone by a cover of Antrim Plateau Volcanics. However, all formations dip eastwards at 5 to 10°, and thus the rocks believed to be younger than the known Bullita Group have been included in it; the fact that they are overlain unconformably by rocks similar in aspect to known Wondoan Hill Formation supports their inclusion in the group.

The *Nero Siltstone* consists typically of olive green fissile laminated siltstone and shale. Thin-bedded fine-grained siltstone occurs near the top of the sequence. The upper part of the type section measured in the scarp 5 km southwest of Mount Gordon consists of 59 m of such rocks (Section 26, Appendix I). Cross-bedding is rarely seen in the sequence, but mud flakes are common in thin beds near the top of the unit. Isolated calcareous siltstone beds are known in some areas. The lower part of the type section, of similar lithology, was not measured, but is estimated to be more than 20 m thick.

The *Mount Gordon Sandstone* is 11 m thick in the southern part of its area of outcrop. Farther north it merely forms a veneer 1 to 2 m thick over the soft underlying siltstone.

White to yellow, blocky medium-bedded fine to medium orthoquartzite is typical of the unit. The orthoquartzite is commonly friable, but some areas of surface silicification are evident. There is less than 1 percent of dark grains within the rock, which is composed of well sorted subrounded clear quartz grains.

The units probably represent a quiet marine environment; shallow-water conditions prevailed during the deposition of the Mount Gordon Sandstone, in which the quartz grains were probably derived from a pre-existing sandstone as they show a very high degree of maturity.

Wondoan Hill Formation

The Wondoan Hill Formation, described and defined by Sweet et al. (in press, b), is not included in the Bullita Group. The type section, at the eastern end of the Fitzroy Range in the Delamere Sheet area, consists of interbedded glauconitic sandstone and shale.

Although widespread in the Victoria River Downs Sheet area, the composition of the Wondoan Hill Formation ranges considerably, and for this reason the outcrops near Pigeon Hole outstation (grid ref. 736141) and to the south in the Wave Hill Sheet area are only tentatively included in the unit. The exposed rocks are mostly characteristic of the Wondoan Hill Formation and appear to be a continuation of the outcrops to the north, but cannot be confirmed as definite Wondoan Hill Formation.

The formation can be broadly divided into a lower glauconitic sandstone-siltstone sequence, a middle claystone, and an upper sandstone. The complete sequence is present in the Jasper Gorge area, but is considerably condensed or partly missing in other areas.

The Wondoan Hill Formation overlies with slight angular unconformity the Bynoe Formation, the Weaner Sandstone, and the Battle Creek Formation. In the Wave Hill Sheet area it unconformably overlies both the Nero Siltstone and the Mount Gordon Sandstone with slight angular discordance. It is conformably overlain by the Stubb Formation and, with angular discordance, by Jasper Gorge Sandstone.

The angular relation of the unit to the underlying and overlying formations is not always readily apparent in one outcrop. However, when a specific bed is followed along strike it can be seen to truncate older formations.

Description: The Wondoan Hill Formation is over 90 m thick near Jasper Gorge, but thins rapidly to the east and south. A composite section in the Jasper Gorge area totals over 145 m, but farther south in the Gordon Creek/Victoria River area the unit is commonly only 30 m thick.

In the western part of Jasper Gorge it is represented by 53 m of white blocky medium to fine quartz sandstone, commonly with a brown indurated weathered surface. It is very friable and composed entirely of well sorted, well rounded quartz grains. The sandstone becomes more massive upward with bands of small nodules and mud flakes appearing and is separated from the topmost white to red-brown massive friable fine-grained sandstone by a flaggy zone.

South of Jasper Gorge, progressively lower beds of the Wondoan Hill Formation are truncated by Jasper Gorge Sandstone, and at grid ref. 677217 (about 12 km south of the gorge) the basal glauconitic sandstone and siltstone crop out. Below the upper sandstone reddish brown, partly fissile, poorly bedded siltstone is exposed. This is interbedded with flaggy to blocky, medium-grained white quartz sandstone which exhibits ripple marking, cross-bedding, and slump structures. The sandstone shows medium to good sorting and well rounded grains. These beds are underlain by flaggy to fissile, finely banded, cream to fawn siltstone, claystone, and shale. Reddish brown fissile laminated hematitic shale is present near the base of these beds. A blocky medium-grained sandstone with slump folds, skip casts, and cross-beds lies below this shale-siltstone sequence. The distinctive massive green sandstone and siltstone sequence which typifies the Wondoan Hill Formation crops out below the sandstone. It consists of friable well sorted medium to coarse green-sand with colourless rounded quartz and small glauconite grains. Some interstitial glauconite is also present. The basal unit in the formation is a white to brown, blocky to massive, friable quartz sandstone.

East of Jasper Gorge at Sundown Hill (grid ref. 698224) is an outcrop of fawn to cream, compact fine-grained siltstone, shale, and claystone; the rocks become red in the upper part of the section. Similar beds crop out at the eastern end of Jasper Gorge (grid ref. 692225). The unit thins southwards, and at grid ref. 686211 it is represented by only 8 m of white and green (glauconitic), blocky coarse-grained gritty sandstone.

The plateau-forming sandstone in the lower Gordon Creek/Mount Fisher area is white to brown, flaggy to blocky, and fine to medium-grained, with abundant mud flakes, ripple markings, and cross-bedding. Below this resistant sandstone, at grid ref. 712171, is a sequence of chocolate shale and siltstone underlain by 5 m of green friable blocky cross-bedded glauconitic siltstone and sandstone with grit bands. The sandstone is typically medium-grained, consisting of subrounded to highly spherical, pink to colourless quartz and rounded glauconite grains; there is little matrix. About 8 km to the southeast, greyish green to buff, fissile to flaggy, laminated and rarely thin-bedded siltstone and fine-grained sandstone crop out. They are overlain by greyish green to green, massive glauconitic siltstone. Slump structures are abundant in this sequence. The beds are capped by a brown to white and purple, flaggy to blocky, thin to medium-grained sandstone containing mud flakes.

About 8 km northeast of Pigeon Hole outstation the unit crops out in a northwesterly-plunging anticline at grid ref. 738148. The oldest bed is a brown flaggy coarse-grained siltstone which underlies 10 m of resistant massive thick-bedded quartz grit. Cross-bedding is widespread in the grit, which is composed mainly of moderately sorted subrounded quartz. Overlying the grit is a flaggy to blocky fine-grained sandstone and a thick fine-grained siltstone-mudstone sequence. This is overlain by a prominent brown blocky fine-grained sandstone and further flaggy sandstone. The sequence totals about 130 m.

Farther south at Rara Springs (grid ref. 742130), a thick sandstone sequence crops out in an anticlinal inlier in the Antrim Plateau Volcanics. The white to buff and purple, medium to fine sandstone is flaggy to blocky, medium-bedded, and contains abundant mud flakes; interference ripples are common.

White to grey, blocky medium-bedded fine-grained quartz sandstone crops out at the eastern margin of the outcrops in the Wave Hill Sheet area, and is underlain by 30 m of grey to purple, flaggy to fissile, fine-grained siltstone which is glauconitic in part. A fault divides this sequence from a younger one which crops out to the west. The younger sequence consists of purple to grey and buff, fissile to flaggy, laminated to thin-bedded claystone and fine-grained siltstone overlain by white to purple, flaggy to blocky, indurated quartz sandstone. The siltstone becomes coarse-grained and micaceous towards the top.

The Wondoan Hill Formation was deposited in a marine environment, as indicated by the presence of abundant authigenic glauconite grains in the basal sandstone. The whole unit may represent a single cycle of transgression and regression, in which near-shore glauconitic sands were overlain by deeper-water siltstone and claystone, which were in turn overlain by more sand as regression of the sea took place.

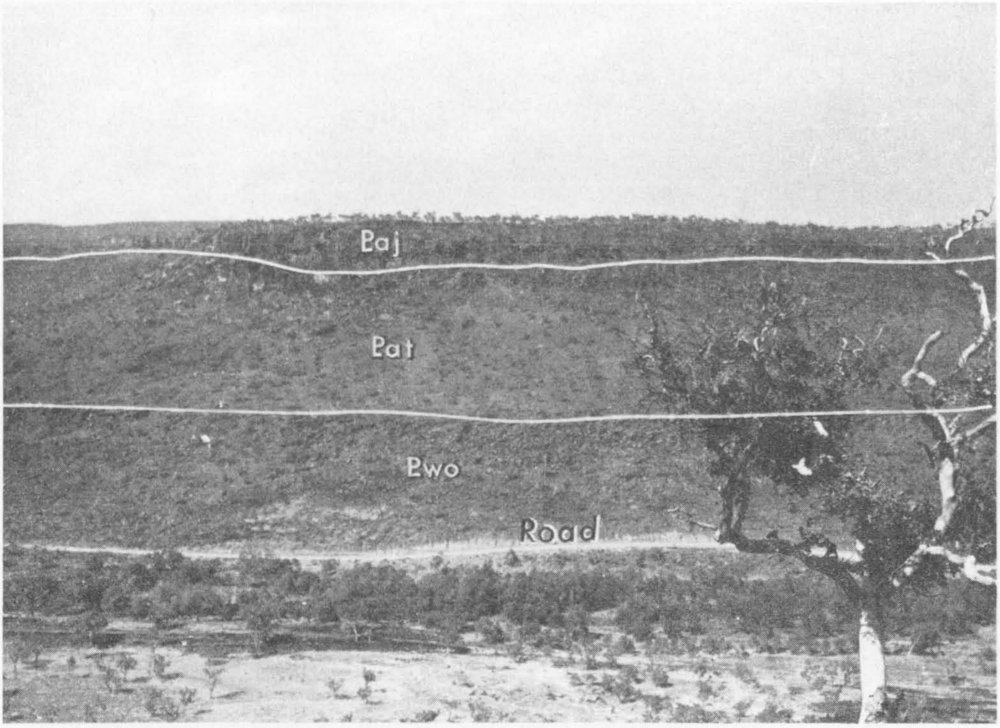


Fig. 31. Jasper Gorge Sandstone (Paj) unconformably overlying the softer Stubb Formation (Pat) which conformably overlies the upper sandstone of the Wondoan Hill Formation (Pwo). Western end of Jasper Gorge (grid ref. 681227), Victoria River Downs Sheet area.

Stubb Formation

The Stubb Formation crops out over a total area of about 80 km^2 in the northern Victoria River Downs Sheet area. It forms scarp slopes below cliffs of resistant plateau-forming Jasper Gorge Sandstone and consists of micaceous shale and siltstone grading upwards into sandstone.

The unit conformably overlies the Wondoan Hill Formation and is unconformably overlain by the Jasper Gorge Sandstone west of the Victoria River.

Description: The Stubb Formation attains a maximum thickness of 115 m in the Victoria River Downs Sheet area; in some parts it is absent. It consists of fissile laminated dark grey to red-brown micaceous shale and coarse siltstone which are coarser higher in the sequence. The shales are exposed only in Jasper Gorge (Fig. 31), where the sequence is well exposed in steep gullies beneath sandstone. At grid ref. 680228 green and dark grey shale crops out above Wondoan Hill Formation sandstone which weathers into nodules. The shale is overlain by 2.5 m of massive sandstone which displays well developed interference ripples and is succeeded by about 20 m of fissile laminated grey to light purple siltstone. The siltstone is micaceous in part and contains shaly beds and lenticular fine-grained sandstone bands. They are overlain by flaggy sandstone and the total thickness is about 73 m. The siltstone is typical of much of the outcrop of the unit and contains scattered sand grains up to 0.8 mm diameter. Unlike much of the outcrop of this unit, the Stubb Formation is well bedded at this locality.

East of Jasper Gorge (grid ref. 698231), hematite-sandstone breccia about 0.6 to 1 m thick is interbedded with flaggy coarse-grained micaceous siltstone and sandstone of the upper part of the unit. Two smaller bands 15 to 30 cm thick crop out above the major band. The breccia is composed of unsorted angular sandstone blocks in a hematitic sandstone and siltstone matrix. The hematitic band is absent in the Jasper Gorge area, but a similar zone is present to the north in the Delamere and Fergusson River Sheet areas.

East of the Victoria River are limited outcrops of fissile laminated pale green to purple micaceous friable fine to coarse siltstone. A 1.3-m ferruginous band in this area probably corresponds to the hematite-breccia noted west of the Victoria River. The siltstone is overlain by flaggy thin-bedded medium-grained sandstone containing slumped beds, current lineations, sole markings, and abundant cross-bedding.

Farther east adjacent to George Creek (grid ref. 758225), the Stubb Formation is folded into a small anticline and consists of flaggy to massive, white to brown, friable sandstone with some indurated layers. In the lower sandstone layers, thin hematite bands are common and mud flakes and ripple marks abundant. In the higher part of the sequence fissile laminated micaceous fine-grained dark red siltstone underlies 3 m of massive thick-bedded medium-grained very friable sandstone (grid ref. 763225).

Palaeogeographic significance. The unit represents a gradually shallowing marine environment, with shale being laid down in the initial deeper-water phase, and sandstone by the later shallow-water currents.

AUVERGNE GROUP

The Auvergne Group was originally defined and described by Sweet et al. (in press, b). Mapping to the north and east of the Auvergne pastoral lease, after which the group was named, has confirmed that the group is of widespread occurrence and that seven formations can be traced through much of the area (Sweet et al., in press, a).

During the present mapping the Auvergne Group was traced to the south and southeast of its type area. Because of the regional tectonic setting, only the lower part of the group has been preserved in this southern area, namely the Jasper Gorge Sandstone and Angalarri Siltstone (Table 6). Two younger formations, the Saddle Creek Formation and Pinkerton Sandstone, crop out only in the extreme northwest of the Waterloo Sheet area. The three youngest formations are not preserved at all.

Jasper Gorge Sandstone

The name was first used by Laing & Allen (1956) who, in mapping the unit, included sandstones of the Wattie Group, Wondoan Hill Formation, and Stubb Formation. The unit has been remapped and formally defined by Sweet et al. (in press, a) and Sweet et al. (in press, b).

The unit was named from Jasper Gorge (130°47′E, 16°02′S) in the northwestern corner of the Victoria River Downs Sheet area. The type section was

TABLE 6: SUMMARY OF STRATIGRAPHY OF AUVERGNE GROUP AND STUBB AND WONDOAN HILL FORMATIONS

	Unit	*Map Symbol*	*Lithology*	*Thickness range (m)*	*Stratigraphic relations*	*Physiographic expression*	*Remarks*
AUVERGNE GROUP	Pinkerton Sandstone	Ꝑap	Massive quartz sandstone	50?	Overlain conformably by Lloyd Creek Formation; conformable on Ꝑad	Prominent cuesta	Top not seen in area mapped
AUVERGNE GROUP	Saddle Creek Formation	Ꝑad	Oolitic dolomite, minor sandstone and siltstone	50?	Conformable on Ꝑaa	Low hogback (lower sandstone) and adjacent valleys (upper dolomite)	
AUVERGNE GROUP	Angalarri Siltstone	Ꝑaa	Siltstone and shale, minor sandstone and limestone	230+	Conformable on Ꝑaj	Extensive plains in N; rugged, vaguely terraced mesas in S	
AUVERGNE GROUP	Jasper Gorge Sandstone	Ꝑaj	Massive quartz sandstone, minor siltstone	50-80	Unconformable on Ꝑat	Mesa-cappings, cliffs at edge; extensive rugged plateaux	
	Stubb Formation	Ꝑat	Micaceous dark grey shale and siltstone; sandstone	0-115	Conformable on Ꝑwo	Smooth and vaguely terraced slopes; some cliffs capping mesas	
	Wondoan Hill Formation	Ꝑwo	Glauconitic and quartz sandstone; siltstone and claystone	30-145+	Lower boundary unconformable	Vaguely terraced slopes in mesas, some low hills	Glauconitic sandstone collected for Rb-Sr age determinations

measured at grid ref. 684234, about 1 km north of Jasper Gorge in the southernmost Delamere Sheet area.

The Jasper Gorge Sandstone covers much of the western third of the Victoria River Downs Sheet area and forms a large plateau in the central Waterloo Sheet area. It is patchily exposed in the Wave Hill and Limbunya Sheet areas, the outcrops amounting to about 130 km^2 and 80 km^2, respectively.

The unit forms plateaux with steep joint-controlled gorges incised into the almost level surface. Numerous mesas are capped by cliffs of Jasper Gorge Sandstone.

Description: The Jasper Gorge Sandstone is unconformably underlain in the northwestern Victoria River Downs Sheet area by the Stubb Formation, and in the remainder of the region it lies unconformably on the Limbunya, Wattie, and Bullita Groups, and is thus the basal member of the Auvergne Group. It is conformably overlain by the Angalarri Siltstone.

In the Waterloo Sheet area at grid ref. 604140, the Jasper Gorge Sandstone, dipping 12°E, unconformably overlies Mount Sanford Formation and Hughie Sandstone of the Wattie Group, which dip 25°E. Below the unconformity is a thin band of ferruginous claystone and grey to white chert boulders. This is overlain by white to brown, flaggy to blocky, fine to medium sandstone containing chert fragments 1 to 5 mm in diameter.

Farther north in the Waterloo Sheet area at grid ref. 612207, flat-bedded medium-grained white to brown sandstone with angular chert fragments overlies tightly folded sandstone and siltstone of the Neave Sandstone (Wattie Group).

The unit is of uniform thickness and lithology over a large area. It is commonly about 50 m thick but near its type locality it attains 80 m. It consists of white to brown, flaggy to massive, fine to medium quartz sandstone. Chert pebbles and sand-sized grains derived locally from the underlying units occur in the basal 10 m of the unit.

The type section, measured 1 km north of Jasper Gorge (grid ref. 684234), is 82 m thick and consists of blocky and flaggy, well sorted massive orthoquartzite (Section 27, Appendix I). In the Jasper Gorge area the basal unit is an indurated red-brown medium-grained sandstone 2 to 5 m thick. It is overlain by more blocky and flaggy beds which are commonly friable.

The chert grains and pebbles in the basal beds in the Waterloo Sheet area are absent in the Victoria River Downs Sheet area. In some parts of the Waterloo Sheet area there is a concentration of chert nodules at the base of the unit, e.g. at grid refs 604140 and 605190.

At grid ref. 626186 in the Waterloo Sheet area, the Jasper Gorge sandstone contains abundant mud flakes in some layers and exhibits longitudinal ripples; cross-beds are common.

Figure 30d shows an equal-area stereogram of 25 cross-bedding measurements taken at grid ref. 598151 in the headwaters of Leichhardt Creek in the Waterloo Sheet area. The measurements show an overall south to southwest current origin. However, they can be separated into two groups showing currents from 225° and 170°. The readings in the 170° group are scattered and show some reversals. At the same locality, massive thick-bedded sandstone higher in the sequence is interbedded with laminated to thin-bedded, light purple and cream, fissile siltstone; they are coarse-grained and micaceous. The upper sandstone is strongly cross-bedded with foresets dipping dominantly northeast (i.e. southwest provenance).

The Jasper Gorge Sandstone extends laterally for about 300 km virtually unchanged. It probably represents a marine transgression gradually advancing from the north and northeast, the unit being deposited by near-shore currents and the sediment being derived from the south and southwest.

Local siltstone intercalations are not common and occur in the northwestern area of outcrop of the unit, indicating that deeper-water conditions prevailed locally.

Angalarri Siltstone

The Angalarri Siltstone was named by Randal (1962) and defined formally by Sweet et al. (in press, b). Its northernmost outcrop is in the Fergusson River Sheet area (Sweet et al., in press, a), and in the south it crops out as a broad belt through the centre of the Waterloo Sheet area and extends into the Limbunya Sheet area. South of Kildurk homestead (grid ref. 565183), it forms rugged mesas up to 250 m high, in contrast to the usually subdued topography of the formation in most other areas.

The upper and lower boundaries of the Angalarri Siltstone are conformable in the Auvergne Sheet area (Pontifex et al., 1968), and the same relations are assumed for the Waterloo Sheet area.

Description: Two sections measured 44 km south-southeast of Kildurk homestead provide an almost complete composite section through the Angalarri Siltstone. Section 28 (Appendix I) is the basal part of the formation. The 4.5 m of sandstone at the top of Section 28 is probably the same bed measured 15 m above the base of Section 29. Combining the two sections gives a total measured thickness of at least 233 m. Although the top of Section 29 includes sandstone, it is similar in composition to sandstone lower in the Angalarri Siltstone and is not considered to be the base of the overlying Saddle Creek Formation. Near the margin of the Limbunya Sheet area, 38.5 km farther south, the southernmost known outcrop of Angalarri Siltstone consists of white fine-grained sandstone with red-brown spots, overlying fissile siltstone or shale.

A water-bore drilled at Kildurk homestead penetrated 160 m of siltstone before passing into sandstone, but the bore logs are not reliable enough to determine whether this is Jasper Gorge Sandstone or still Angalarri Siltstone. The total thickness of the formation may be over 300 m in the Auvergne Sheet area (Sweet et al., in press, b). Numerous other bores have penetrated the siltstone under the West Baines plains (Sweet, 1973a).

Between Kildurk homestead and the northern margin of the Waterloo Sheet area, the Angalarri Siltstone crops out relatively poorly. Low hills contain weathered greenish brown thin-bedded fissile siltstone and fine-grained sandstone interbeds. The sandstone is light-coloured and generally has brown spots of limonite 1 to 3 mm across; in thin section the spots are seen to be weathered glauconite pellets. Such spotted sandstone occurs throughout the formation south of Kildurk.

Siltstone and shale crop out in the basalt-capped scarp forming the western border of the West Baines valley, and limestone crops out near the northern margin of the Waterloo Sheet area. At the base of a scarp 42 km due north of Kildurk homestead, 10 m of fissile siltstone contains thin laminae and interbeds (up to 10 cm thick) of dolomite or limestone that turns brown when weathered. At the top of the outcrop is 30 cm of coarsely crystalline grey dolomite, of which the top 5 cm contains numerous limonite pseudomorphs after pyrite, in clusters of cubes, which are most common on the top surface of the bed. Above this is a 10-cm bed of very finely crystalline light greyish brown limestone. About 50 m to the south an extensive outcrop above the pyritic dolomite consists of greyish purple siltstone and shale and thin white siltstone and light grey limestone interbeds. Two other outcrops of brown dolomite or limestone were observed near the northern margin of the Waterloo Sheet area. A 1-m bed of medium and coarsely crystalline carbonate is oolitic.

The major rock type in the north is fissile siltstone, with some sandy interbeds and numerous micaceous and chloritic partings; the sandstone is probably glauconitic. Shale predominates in outcrops near Skinner Point in the Auvergne Sheet area.

Micaceous bedding-plane partings occur throughout the formation. Muscovite is the predominant mica in the south, chlorite in the north. The chlorite forms dark green bedding-plane partings, and is also finely disseminated through some beds.

A fairly well defined facies change is seen in the Angalarri Siltstone in the Waterloo and Auvergne Sheet areas. In the southern part it consists of micaceous quartz siltstone and fine-grained quartz sandstone with prominent cross-bedding (Fig. 32). In the north are finer-grained siltstone, shale, some sandstone, and slightly pyritic limestone and dolomite.

Glauconite occurs throughout the Angalarri Siltstone, indicating a marine environment. The pyritic carbonate and shale indicate deposition in deeper or quieter water than for the sandstone and siltstone. The environment in which the sediments were deposited is believed to be one of a basin deeper and farther from shore in the north. The sediments appear to have been derived from a source to the south.

Saddle Creek Formation and Pinkerton Sandstone

These formations crop out extensively in the Auvergne Sheet area (Sweet et al., in press, b) and in the Port Keats and Fergusson River Sheet areas (Sweet et al., in press, a). However, they are exposed in the southern Victoria River district only in the northwest corner of the Waterloo Sheet area near Dingo Creek, where the outcrops are continuous from the Auvergne Sheet area.

On the southern limb of an anticline near Dingo Creek (south of Victoria Highway), Auvergne Group is truncated by Duerdin Group. Basal white quartz sandstone of the Saddle Creek Formation is overlain by an upper part of at least 7 m of oolitic dolomite, siltstone, and fine-grained dolomite that is yellow-brown when weathered.

A small outcrop of sandstone 10 km east of Newry is probably basal Saddle Creek Formation. It is composed of blocky to massive, pink indurated cross-bedded sandstone; the laminations of the sandstone are commonly contorted, a characteristic feature of this unit in the Auvergne Sheet area (Sweet et al., in press, b).

The Pinkerton Sandstone consists of fine-grained flaggy quartz sandstone containing mud flakes.

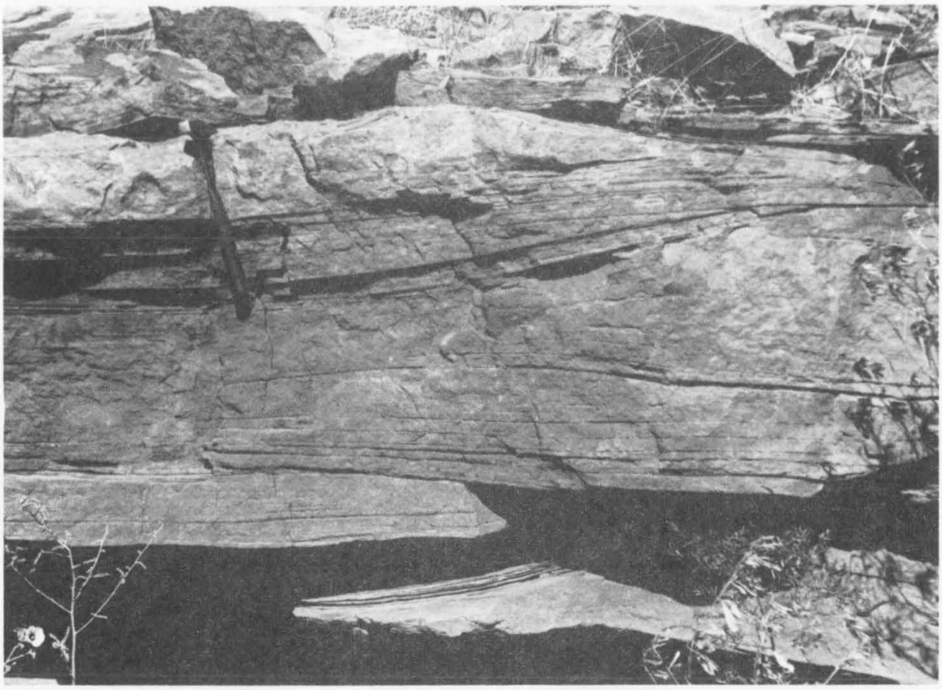


Fig. 32. Cross-bedded fine-grained sandstone in the Angalarri Siltstone, 44 km south-southeast of Kildurk homestead, Waterloo Sheet area (same locality as Section 29, Appendix 1).

DUERDIN GROUP

The Duerdin Group was originally defined and described by Dow & Gemuts (1969), and rocks belonging to the group extend into the Auvergne Sheet area (Sweet et al., in press, b). The group is now recognized in the Waterloo Sheet area, where the following formations crop out:

Ranford Formation (including Jarrad Sandstone Member)
Moonlight Valley Tillite
Blackfellow Creek Sandstone
Fargoo Tillite
Skinner Sandstone

The group comprises tillite, fluvio-glacial conglomerate and sandstone, and other glacigene rocks (Table 7).

Skinner Sandstone

The name is derived from Skinner Point (grid ref. 562236) in the Auvergne Sheet area. The name used originally was Skinner Glacials (Pontifex et al., 1968), which included both the present Skinner Sandstone and rocks now known to be Fargoo Tillite. The name Skinner Sandstone is now applied only to sandstone and conglomerate near Saddle Creek, Skinner Point, and Desmonds Passage near the southern margin of the Auvergne Sheet area, and to similar rocks in adjacent areas of the Waterloo Sheet area extending southwards about 45 km to the vicinity of Kinevans yard (grid ref. 551196).

TABLE 7: SUMMARY OF STRATIGRAPHY OF DUERDIN GROUP AND KINEVANS SANDSTONE

Unit		*Map Symbol*	*Lithology*	*Thickness range (m)*	*Stratigraphic relations*	*Physiographic expression*	*Remarks*
Kinevans Sandstone		Pck	Quartz sandstone	0-45	Unconformable on Ꝑom and Ꝑos; overlain conformably by Cla	Small cliffs and ledges in mesas and scarps	Probably aeolian and fluvial sands
Ranford Formation	DUERDIN GROUP	Ꝑos	Ferruginous siltstone and claystone, sandstone	60+	Conformable on Ꝑom	Smooth hill-slopes	Poorly exposed in most areas
Jarrad Sandstone Member	DUERDIN GROUP	Ꝑoj	Quartz sandstone	0-10+	Conformable on Ꝑom	Low cuesta in NW	Known only from NW Waterloo Sheet area
Moonlight Valley Tillite	DUERDIN GROUP	Ꝑom	Tillite, laminated dolomite at top	20-70	Conformable on Ꝑol. Unconformable on Auvergne Group	Low, rounded boulder-strewn hills	Probably all true tillite
Blackfellow Creek Sandstone	DUERDIN GROUP	Ꝑol	Massive quartz sandstone; minor shale and pebble bands	30	Unconformable on Ꝑof	Mesa and range capping; rugged slopes and cliffs	
Fargoo Tillite	DUERDIN GROUP	Ꝑof	Tillite and massive dolomite conglomerate	0-50	Conformable on Ꝑoi (probably intertongues with it)	Low, rounded boulder-strewn hills	Includes several thick lenses of boulder conglomerate
Skinner Sandstone	DUERDIN GROUP	Ꝑoi	Massive quartz sandstone and dolomitic conglomerate; minor mudstone and tillite	0-115	Unconformable on Auvergne Group		

The Skinner Sandstone truncates both Angalarri Siltstone and Saddle Creek Formation 8 km northwest of Skinner Point in the Auvergne Sheet area. It overlies only Angalarri Siltstone in the Waterloo Sheet area, but few actual contacts have been seen. However, Sweet et al. (in press, b) have shown that it unconformably overlies the Auvergne Group.

The Skinner Sandstone is overlain conformably by Fargoo Tillite near Skinner Point. Farther south in the Waterloo Sheet area it is regarded as being unconformable, but can alternatively be attributed to lensing out of the Fargoo Tillite, or to a combination of both.

Description: The Skinner Sandstone is exposed in two main groups of outcrops in the Waterloo Sheet area. The more westerly outcrops at Skinner Point and farther southwest are part of the Skinner Sandstone originally mapped by Pontifex et al. (1968) as Skinner Glacials. The main outcrop is a low ridge about 2 km wide extending 20 km southwest from Skinner Point. It is thickest in the northeast, in the Auvergne Sheet area, where it is composed of up to 60 m of sandstone and cross-bedded conglomeratic sandstone. Its thickness decreases to the southwest, and 18 km from Skinner Point the sandstone forms a single massive cliff of about 12 m of medium-grained pale yellow quartz sandstone. At the base is 3 m of pebbly and gritty sandstone. The contact with the underlying Angalarri Siltstone is not exposed. Farther southwest the sandstone does not crop out as its surface dips below plain level.

The other series of outcrops has its northeastern extremity in the Auvergne Sheet area, 10 km east of Skinner Point. The main area of outcrop extends southwest into the Waterloo Sheet area to the vicinity of Blackfellow Bore (grid ref. 555219), where the mesa broadens out to form a plateau. A section measured 15 km northeast of Blackfellow Bore at the highest point in the range contained several formations as shown in Table 8.

TABLE 8: SECTION MEASURED THROUGH DUERDIN GROUP AT GRID REF. 567228

Formation	*Thickness (m)*	*Lithology*
Ranford Formation	38	Violet, purple, and white claystone
Moonlight Valley Tillite	61	No outcrop — abundant scree of quartzite boulders
Blackfellow Creek Sandstone	27	Blocky and massive, medium-grained white and pink quartz sandstone
Skinner Sandstone	113	Massive cross-bedded grey medium to coarse and conglomeratic sandstone
	Unconformity	
Angalarri Siltstone (Auvergne Group)	50+	Greyish green siltstone

Figure 33 shows the massive nature of the Skinner Sandstone in this area. The beds appear far more lenticular in cross-section in a southeast direction and cross-bedding is well developed. This provides additional evidence that the Skinner Sandstone is a fluvial unit in which the southwesterly trend of the outcrops represents original stream channels (Sweet et al., in press, b).

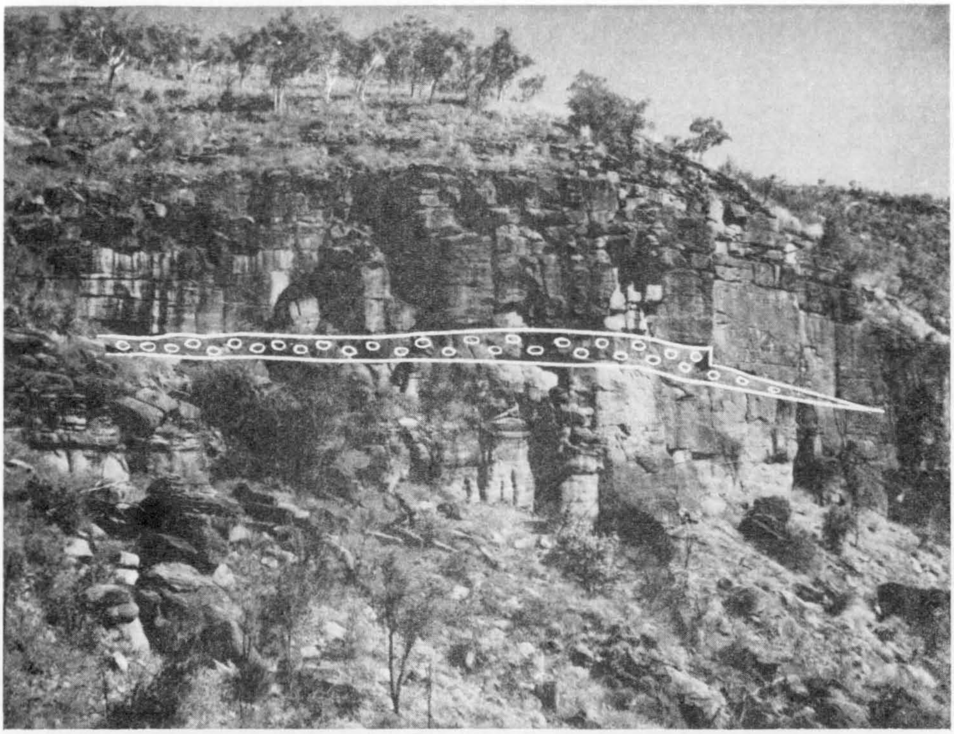


Fig. 33. Massive sandstone conglomerate of the Skinner Sandstone at grid ref. 567228 Waterloo Sheet area. The inked-in bed is a lens of cobble conglomerate up to 3 m thick, containing dolomite and quartzite clasts up to 20 cm across.

Near Blackfellow Bore the formation includes a basal 2 m of diamictite which directly overlies Angalarri Siltstone. This could be tillite or an unsorted fluvial bed. Overlying it is about 30 m of grey pebble conglomerate and pebbly sandstone.

The formation is characterized by the occurrence of dolomite clasts of sand, grit (2-4 mm), pebble, and cobble sizes. The dolomite is mostly light to medium grey micrite and some clasts contain stromatolite structures. The matrix of the conglomeratic rocks is medium-grained quartz sand. Rounding of all particles varies from poor to moderate. Although dolomite is the predominant clast-type, some clasts are quartzite and chert.

Fargoo Tillite

The Fargoo Tillite was named from Fargoo Creek in the Osmond Range, East Kimberley, Western Australia, by Dow & Gemuts (1969). It crops out north and south of the type area in several localities east of the Halls Creek Fault. Outcrops in the Auvergne Sheet area (Sweet et al., in press, b) are restricted to the southern margin and are continuous with several outcrops in the northwestern corner of the Waterloo Sheet area.

The Fargoo Tillite conformably overlies, and intertongues with, the Skinner Sandstone. It is overlain unconformably by the Blackfellow Creek Sandstone in the Skinner Point mesa, in the Auvergne Sheet area, and this relation is assumed for the Waterloo Sheet area.

Description: The areas designated as Fargoo Tillite in the Waterloo Sheet area are generally gentle hill-slopes covered with a rubble of pebbles, cobbles, and boulders of a large variety of rock types. The rubble gives the only indication of the nature of the underlying rock because no outcrops of the tillite were observed in the Waterloo Sheet area. Excellent outcrops occur in the Skinner Point mesa immediately to the north in the Auvergne Sheet area (Pontifex & Sweet, 1972; Sweet et al., in press, b).

Most of the Fargoo Tillite is confined to a triangular area between the Emu Springs, Turn-off Lagoon, and Blackfellow Bores. The surface of a low hill 2 km west of Blackfellow Bore is scattered with tillite-derived dolomite and quartzite cobbles, and angular chert and oolitic dolomite pebbles. At least two beds, each 0.2 to 0.5 m thick, of grey dolomite-rich conglomerate, crop out. Overlying the conglomerate and tillite is a light-coloured flaggy rectangularly-jointed sandstone mapped as Blackfellow Creek Sandstone.

At the northern end of a low mesa 8 km northwest of Blackfellow Bore, the only outcrop consists of a conglomeratic sandstone bed containing boulders, 15 to 20 cm across, of medium crystalline dolomite that is grey when weathered, quartzite, sandstone, chert, quartz, and red-brown oolitic dolomite.

Rubble on a hill-slope 6.5 km east-northeast of Newry homestead is noticeably richer in grey dolomite boulders and cobbles than is Moonlight Valley Tillite 2.5 km to the south. The dolomite constitutes 30 to 40 percent of the total rubble, granite clasts are common, and all clasts are of small boulder size or less (i.e. most are less than 20 cm across).

The Fargoo Tillite is known to represent the first major phase of the Moonlight Valley glaciation (Dow & Gemuts, 1969), and outcrops in the Auvergne and Waterloo Sheet areas show that the effect was widespread (it was previously known only to affect the Kimberley region). The Fargoo Tillite does not form a continuous blanket unit; this is shown by the fact that Moonlight Valley Tillite overlies bedrock from immediately east of Newry homestead westwards to the Western Australian border and probably beyond. The Fargoo Tillite is also absent in the range of hills in which the section shown in Table 8 was measured; here Skinner Sandstone is overlain directly by Blackfellow Creek Sandstone with what is regarded as a local disconformity.

The high proportion of dolomite clasts in the tillite and conglomerate indicates that the source area contained a considerable volume of sedimentary rock, although some erosion of igneous terrain took place.

Blackfellow Creek Sandstone

The Blackfellow Creek Sandstone was not recognized during the 1967 mapping of the Auvergne Sheet area. After further mapping, the unit was named and described (Sweet et al., in press, b; Pontifex & Sweet, 1972).

In its type area (the Skinner Point mesa in the Auvergne Sheet area), the formation overlies Fargoo Tillite. However, at the southern end of the mesa Skinner Sandstone is overlain directly by Blackfellow Creek Sandstone with no intervening tillite. The absence of tillite is considered to be due to a local erosional break rather than intertonguing of Fargoo Tillite and Blackfellow Creek Sandstone.

The Blackfellow Creek Sandstone is overlain by Moonlight Valley Tillite. The contact has not been observed, but is assumed to be conformable because of concordance between the sandstone and the overlying tillite.

Distinguishing the formations of the Duerdin Group is difficult in an area between 6 and 12 km east of Newry homestead. Although one of the sandstones in the area has been designated Blackfellow Creek Sandstone, its lithology is similar to that of the Frank River Sandstone of the Osmond Range area in Western Australia (Dow & Gemuts, 1969).

Description: In the western side of a range near the northern margin of the Waterloo Sheet area (see section in Table 8), the Blackfellow Creek Sandstone comprises 27 m of blocky and massive, medium-grained quartz sandstone. On the other side of the same range (2 km to the southeast), the Blackfellow Creek Sandstone consists of at least 30 m of blocky medium-grained porous quartz sandstone with some interstitial clay or limonite. It is thin-bedded and commonly has sole-markings (both flute and load casts) and ripple marks. Above this is fine-grained quartz sandstone containing pits 1 to 2 cm across; bedding surfaces have prominent primary current lineations.

Farther south, in the Waterloo Sheet area, grey conglomeratic sandstone is assumed to be Skinner Sandstone, and blocky medium-grained quartz sandstone above it is mapped as Blackfellow Creek Sandstone. Similar quartz sandstone crops out at the localities 2 km west and 8 km northwest of Blackfellow Bore. At the locality 8 km northwest of the bore, the sandstone is very porous and contains pits which are up to 3 cm across and appear to have been more ferruginous patches where the clay cement was oxidized and subsequently eroded out. On the hilltop are two beds of whiter more indurated orthoquartzite.

The westernmost locality at which Blackfellow Creek Sandstone has been mapped is between 8 and 12 km east of Newry homestead. Blocky quartz sandstone has been recognized, but greenish siltstone with ripple-marks, rill-marks, and flute casts is interbedded with fine flaggy silty sandstone. These rocks are very similar to the Frank River Sandstone in the East Kimberley region of Western Australia.

The Blackfellow Creek Sandstone is believed to be a fluvial unit laid down in the interglacial period between the two main glacial phases.

Moonlight Valley Tillite

The formation was named and described (Dow & Gemuts, 1969) from the Moonlight Valley area in the East Kimberley region, Western Australia. It crops out in a zone immediately east of the Halls Creek Fault in Western Australia, and in the southwestern quarter of the Auvergne Sheet area in the Northern Territory (Pontifex & Sweet, 1972; Sweet et al., in press, b). A number of outcrops in the Waterloo Sheet area are all within the northwestern quarter.

The Moonlight Valley Tillite overlies rocks of the Auvergne Group with pronounced unconformity in the Auvergne Sheet area (Sweet et al., in press, b). In the Waterloo Sheet area this same relation is obvious near Dingo Creek, where a cuesta on the eastern side of the highway is composed of Auvergne Group rocks, and one of the same height to the west of the highway contains Moonlight Valley Tillite and Ranford Formation capped by Antrim Plateau Volcanics. The tillite overlies Angalarri Siltstone and must have been deposited in a valley at least

40 m deep. About 1.5 km south of the cuestas the tillite overlies Saddle Creek Formation.

In its southernmost outcrops in the Waterloo Sheet area the tillite also overlies the Angalarri Siltstone, but the contact has not been observed. To the north the tillite overlies the Blackfellow Creek Sandstone and, at grid ref. 559211, what is tentatively identified as Skinner Sandstone. The Moonlight Valley Tillite is therefore more continuous than any of the lower Duerdin Group formations.

The tillite is overlain conformably by Ranford Formation, and unconformably in several areas by Kinevans Sandstone and Antrim Plateau Volcanics.

Description: In nearly all the area mapped as Moonlight Valley Tillite the only indication of the underlying rock type is the surface rubble of cobbles and boulders. Most megaclasts are quartzite or silicified sandstone, which make up more than 90 percent of the total. Dolomite cobbles and rare boulders account for the remaining 10 percent. A few boulders of granite, porphyry, and other metamorphic and sedimentary rocks have been noted. The presence of such clasts and the paucity of outcrop indicate that almost all the formation is tillite, and not conglomerate (where other rocks such as conglomerate or sandstone do occur, they are resistant to weathering and form upstanding outcrops).

Tillite is exposed in the road cutting immediately east of the Keep River Crossing, 0.5 km southeast of Newry homestead. The outcrop is more likely to be Moonlight Valley Tillite than Fargoo Tillite as the former occurs west of Newry homestead. At the Keep River the tillite consists of greyish purple friable diamictite. There is no apparent size sorting or bedding, and the matrix consists of an assemblage of grains of clay, silt, and sand. Much of the finer-grained matrix is of indeterminate mineralogy, but the silt and coarser fractions contain a very high percentage of quartz. Cobbles and a few boulders in the tillite are mostly quartzite; one granite boulder was seen. The purple colour of the tillite, the occurrence of hematite on cobbles and in joints, and the presence of small vugs all indicate that the rock was subjected to the baking effects of basalt, some of which is preserved 100 m to the east.

The tillite is also exposed 5 km farther east in a low scarp 3 km south of the main highway, where it is purple with irregular green patches. Numerous erratic cobbles protrude from the unsorted matrix, and some are vaguely striated. Weathered-out cobbles and boulders in the area include quartzite, dolomite, granite, and quartz-feldspar porphyry.

Although no actual outcrop of tillite occurs west of the highway at Dingo Creek, a large number of different clasts seen in the rubble include a pink-feldspar granite boulder 1.2 m x 1.5 m; a similar-sized block of grey stromatolitic dolomite; several boulders at least 1 m across including one of well bedded, oolitic, partly silicified dolomite; many cobbles and small boulders of grey dolomite and a wide variety of quartzite and silicified sandstone; a quartzite boulder 1.5 m across with prominent striations on one face; other granite, mica schist, conglomerate, and quartz-feldspar porphyry cobbles and boulders. About 25 m of tillite is capped by 5 m of dark pink and grey, laminated to thin-bedded dolomite which breaks into large thin sheets 1 to 10 cm thick. This is the marker dolomite used in the East Kimberley (Dow & Gemuts, 1969) to define the top of the formation. It has also been observed in the anticline 3 km west of Glenarra Bore, where it is partly recrystallized to massive grey dolomite.

A thickness of about 60 m for the Moonlight Valley Tillite is inferred in the the section given in Table 8; a few rounded quartzite boulders littering the slopes could be from either conglomerate or tillite. About 20 km to the south-southwest at grid ref. 559211, cross-bedded conglomeratic sandstone (Skinner Sandstone) is overlain by about 70 m of conglomerate and probable tillite. The tillite does not crop out, but is inferred from the presence of striated cobbles on the hill-slope. The conglomerate beds are 0.3 to 1.0 m thick and contain subangular clasts of dolomite and quartzite 1 to 10 cm across. About 23 m below the top of the section an outcrop about 4 m high of extremely friable reddish spotted sandstone shows vertical bedding; the beds above and below are horizontal, and the sandstone is thought to be either a block which has been rotated by slumping caused by sinking of part of a bed into soft sediment, or a large boulder dumped by ice. The first explanation is more likely as a block of such friable sandstone is unlikely to survive transport by ice. Beds of similar sandstone crop out lower in the sequence and are interbedded with conglomerate.

About 7 m of purple and green, fissile weathered shaly rock crops out 13 km farther south, and is underlain by 2 m of extremely friable red-brown silty sandstone. This was thought to be Angalarri Siltstone until scattered pebbles and cobbles were found. Most of the clasts are tabular, quite smooth, and nearly all striated on both flat surfaces. They are nearly all fine-grained white silty sandstone containing small spots (1-5 mm across) of red and purple iron oxide stains; one boulder is about 30 cm across. The underlying silty sandstone contains green spots and is almost identical with the sandstone block described in the previous paragraph. The rocks are interpreted as Moonlight Valley Tillite, in which the clasts and matrix have been derived almost entirely from Angalarri Siltstone and probably represent the basal few metres of tillite which immediately overlies the siltstone.

The Moonlight Valley Tillite forms a thin sheet over a large area and is considered to be a non-marine glacial-drift unit.

Ranford Formation

The Ranford Formation crops out extensively in the East Kimberley region of Western Australia (Dow & Gemuts, 1969) and in the Auvergne Sheet area in the Northern Territory (Sweet et al., in press, b). Mapping during 1969 showed that it also crops out near the northern margin of the Waterloo Sheet area from the Western Australian border eastwards for about 40 km.

The Ranford Formation conformably overlies the Moonlight Valley Tillite in Western Australia (Dow & Gemuts, 1969). The contact is not exposed in the Waterloo Sheet area, but is assumed to be conformable. The base of the Ranford Formation was defined as the top of a marker dolomite of the Moonlight Valley Tillite (Dow & Gemuts, op. cit.); this dolomite has also been observed in several localities in the Waterloo Sheet area. The top of the Ranford Formation has been eroded, and unconformably overlying the unit are the Kinevans Sandstone and the Antrim Plateau Volcanics.

Description: In Western Australia, Jarrad Sandstone and Johnny Cake Shale Members of the Ranford Formation (Dow & Gemuts, 1969) overlie the Adelaidean tillites. In the Auvergne Sheet area, Pontifex & Sweet (1972) recognized the Ranford Formation and divided it into three members, the Bucket Spring,

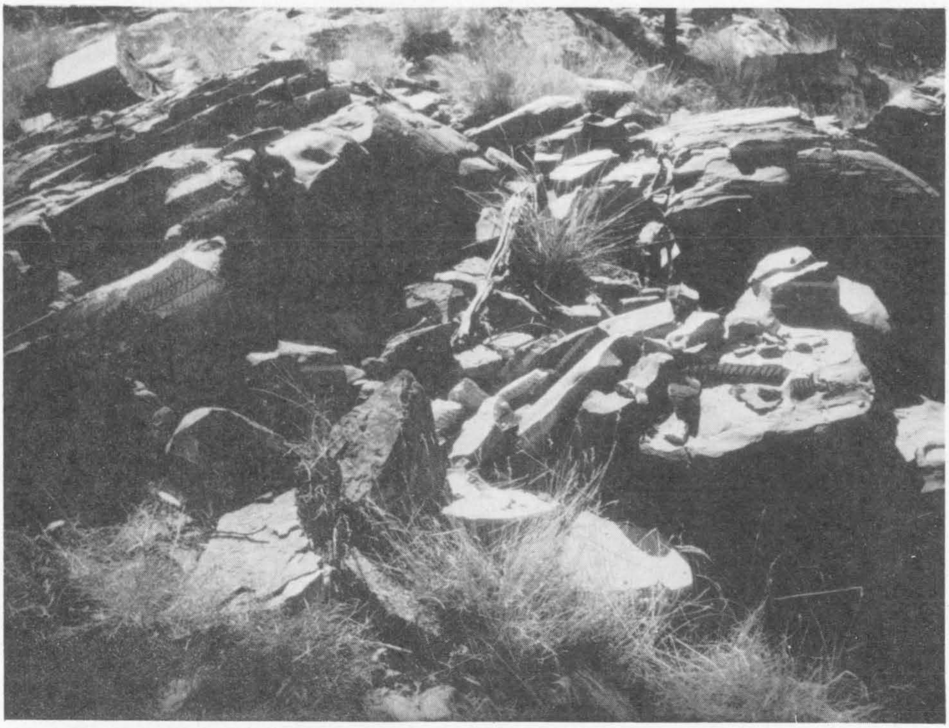


Fig. 34. Outcrop of 'zebra-stone' in the Ranford Formation on top of the range at grid ref. 567228, Waterloo Sheet area.

Beasly Knob, and Ernie Lagoon Members in ascending stratigraphic order. These consist of greyish green siltstone and micaceous sandstone; sandstone, conglomerate, and siltstone; and sandstone, respectively. The members cannot be correlated directly with the members named in Western Australia. In the northwest corner of the Waterloo Sheet area a sequence similar to that in Western Australia can be recognized.

The westernmost section measured in the Waterloo Sheet area is on the limb of an anticline at grid ref. 507220, where the dolomite at the top of the Moonlight Valley Tillite is overlain by 60 m of fissile and massive, white and light and dark purple siltstone and kaolinitic siltstone. As in two other sections measured in the northwest Waterloo area, there is no sandstone at the base of the formation. The Jarrad Sandstone Member, which is 107 m thick at Mount Brooking in Western Australia, has thus lensed out over a distance of less than 15 km.

Rocks overlying Moonlight Valley Tillite in a low hill 8 km due west of Newry homestead are mostly blocky and flaggy sandstone, and are mapped as Ranford Formation.

The easternmost outcrop of Ranford Formation tops the range at grid ref. 567228 (see Table 8), and is composed of white and purple kaolinitic shale and siltstone. Excellent specimens were collected of a rock similar to the 'Zebra-stone' of the Argyle area in the East Kimberley (Fig. 34). This rock appears to form only in one particular stratum of the Ranford Formation and the reasons for its formation, beyond the knowledge that it is probably an iron-leaching phenomenon, are unknown. The surface of a fissile bed of highly ferruginous siltstone at the same locality is packed with limonite pseudomorphs after pyrite and indicates a reducing environment.

Although some beds of the Ranford Formation are of restricted extent (e.g. the Jarrad Sandstone Member), the kaolinitic siltstone containing the 'zebra-stone' is quite widespread. The formation is probably a late-glacial lacustrine or marine unit.

Kinevans Sandstone (new name)

Derivation of name: From Kinevans yard 19 km northwest of Kildurk homestead at 16°17′S, 129°14′E, Waterloo Sheet area.

Distribution: It is confined to the Waterloo Sheet area, mainly in a scarp bordering the western side of West Baines valley, and in isolated mesas near Kildurk homestead.

Lithology: Massive reddish brown fine and medium quartz sandstone which is strongly cross-bedded in some localities; minor calcareous sandstone.

Type section: In the scarp 1 km northeast of Kinevans yard.

Thickness: From 6 m in most places up to 45 m southwest of Kildurk homestead.

Age: Uppermost Proterozoic or lowermost Cambrian.

Fossils: None known, although there is some evidence of bioturbation east of Kildurk homestead.

Stratigraphic relations: It is unconformable on the Auvergne and Duerdin Groups, and is probably conformably overlain by the Antrim Plateau Volcanics.

Description: The Kinevans Sandstone is almost flat-lying 8 km east of Kildurk homestead, where it overlies Angalarri Siltstone. A similar relation exists 10 km south of the homestead, where the contact is well exposed. There is no obvious evidence of unconformity as the beds are quite concordant. However, farther northwards the sandstone overlies Duerdin Group rocks which are much younger than the Angalarri Siltstone. The unconformity is very gently angular, and was discovered by field mapping over a large area.

In all areas the sandstone appears conformable with the overlying Antrim Plateau Volcanics; near Kinevans yard both formations dip gently west. Apart from the concordance of the formations, there is nothing else to indicate that the volcanics are actually conformable on the sandstone. No fossils have been found in the sandstone, which is thought to be either uppermost Proterozoic (younger than the Proterozoic glacial rocks) or lowermost Cambrian (older than the Antrim Plateau Volcanics).

The Kinevans Sandstone forms a thin blanket masking a number of Proterozoic rock units. It is always overlain by Antrim Plateau Volcanics and generally forms a distinctive red-brown cliff around basalt-capped scarps. It is less than 6 m thick over much of the area examined, but is up to 45 m thick between Boxer Spring and Captain Spring Creek. Farther north and east it thins rapidly, and near Kinevans yard it is 12 to 15 m thick. A marked local thickening of the formation can be seen (Fig. 35) 5 km northeast of Kinevans yard, where the shape of the upper surface of the formation suggests a dune structure.

The formation consists almost entirely of sandstone. In the type area it is strongly cross-bedded in units up to 2 m thick. It is cross-bedded in a number of

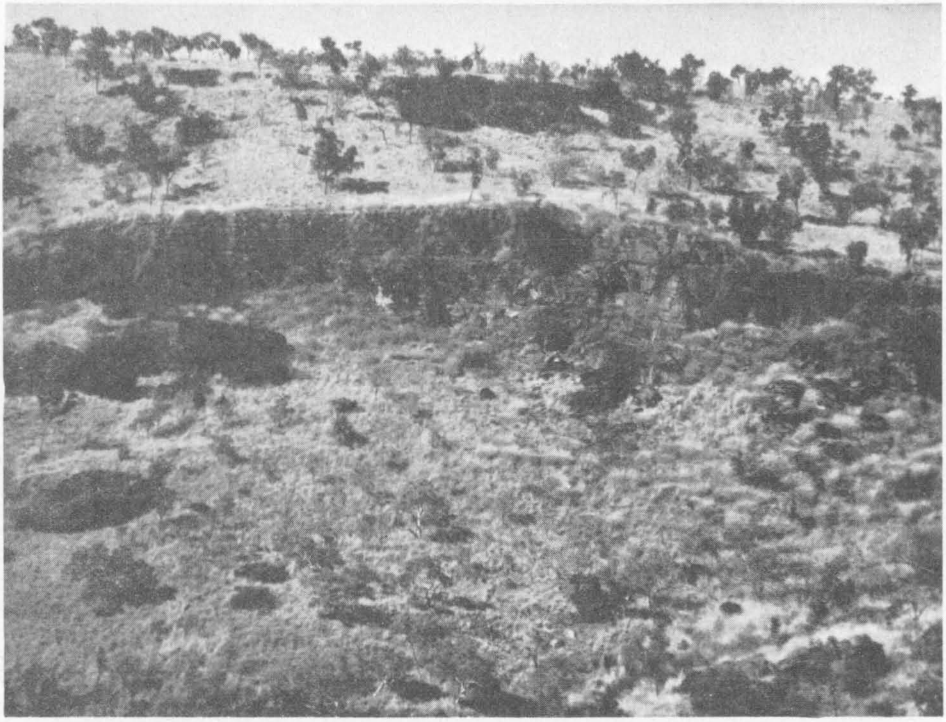


Fig. 35. Kinevans Sandstone in a scarp 5 km northeast of Kinevans yard. The upper surface of the formation is approximately dune-shaped. The dark outcrop at the top of the hill is basalt of the Antrim Plateau Volcanics, Waterloo Sheet area.

other localities, notably near Boxer Spring (13 km southwest of Kildurk homestead) and 1 km west of Donkey Gap Bore in the northwest corner of the Waterloo Sheet area. The formation is usually massive, with some flaggy and blocky partings. Where large cross-beds are absent, it is thin to medium-bedded; bedding is accentuated in some cases by thin stringers of sand grains.

The sandstone is extremely massive in a number of basalt-capped mesas east and northeast of Kildurk and there are few or no partings in the whole 5 to 8 m of the formation. Bedding in this area is poorly defined, and no continuous bedding planes or structures were observed. The only semblance of bedding is the thin stringers of medium to coarse, well rounded and sorted, quartz sand grains. The sandstone is fine to medium-grained, with a white to pale green clay matrix. The weathered surface has an uneven 'knobbly' pattern which, together with the lack of bedding, suggests that the beds may have been bioturbated.

Massive sandstone 9 km south of Kildurk homestead contains prominent bedding in layers 1 to 3 cm thick. Its upper contact with basalt of the Antrim Plateau Volcanics is baked and the sandstone is silicified.

About 5 km west and southwest of Kildurk the Kinevans Sandstone does not form a prominent cliff and ledge as it does in most other localities. Although its thickness here is quite small, the main reason for lack of outcrop is that the sandstone has a calcareous or dolomitic matrix and is more easily weathered. The carbonate is in the form of spar (Folk, 1959) which fills the voids between grains and acts as a cement.

Examination of thin sections of Kinevans Sandstone reveals that it is quite feldspathic, some samples containing more than 10 percent feldspar. The feldspar is rarely fresh; it is generally cloudy and altered and consists almost entirely of orthoclase and microcline. Some perthite, but no plagioclase, was seen.

Quartz accounts for 60 to 80 percent of the bulk of the rocks examined. Subangular grains of 0.1 to 0.4 mm diameter are common (fine sand), and most specimens have a component of 20 to 30 percent of rounded medium-grained quartz fragments.

Rock fragments account for 5 to 15 percent of the sand grains. Most grains fall within the medium sand-size range, and include siltstone, mudstone, or shale (could be completely altered feldspar) and possibly a few igneous or metamorphic rock fragments; the latter include grains containing an interlocking mosaic of quartz and feldspar.

The large cross-bedding structures, the structure shown in Figure 35, and the well rounded limonite-coated grains in some areas indicate that some of the beds are of aeolian origin. However, the general lack of well defined bedding, the poorer sorting, the occurrence of some larger rounded grains, and the carbonate-rich sandstone show that considerable areas represent deposition in a subaqueous environment. Wind-blown sand could be incorporated in such a sediment.

The formation may represent a number of environments, including near-shore marine, shore-line (dune), and fluvial environments. Alternatively, it may be predominantly fluvial with some minor lacustrine (to give carbonates) and aeolian influences.

LOWER CAMBRIAN (Table 9)

ANTRIM PLATEAU VOLCANICS

The Antrim Plateau Volcanics cover extensive areas in the Victoria River and Ord River districts of northern Australia. Hardman (1885) named the hilly dissected country occupied by a succession of basic lava flows and interbedded sediments, east of the Elvire River in the East Kimberley district of Western Australia, the Great Antrim Plateau, and, by inference, named the volcanics. David (1932) was the first to use the name Antrim Plateau Basalts. Traves (1955) found agglomerate and tuff within the succession and modified the name to Antrim Plateau Volcanics. He included in the formation the large belt of volcanics extending from Hooker Creek via Wave Hill to north of Willeroo. The name Antrim Plateau Volcanics is now applied to the almost continuous outcrop of volcanics in the East Kimberley, Victoria River, The Granites-Tanami, and Daly River Basin regions (Figs 36 and 37). A detailed account of the geology and petrology of the Antrim Plateau Volcanics is in preparation (Bultitude, in prep.).

Distribution: The volcanics form two north-trending belts and crop out extensively in the four Sheet areas (Figs 3 and 4). The eastern belt of volcanics extends from Hooker Creek via Wave Hill to north of Willeroo and the western belt extends from the Great Antrim Plateau (about 55 km east of Halls Creek) in Western Australia northwards via Mistake Creek and Rosewood to Kununurra. Continuity of outcrop between the two belts cannot be completely traced because of a veneer of laterite and surficial cover in the central Limbunya Sheet area. Water-bore data indi-

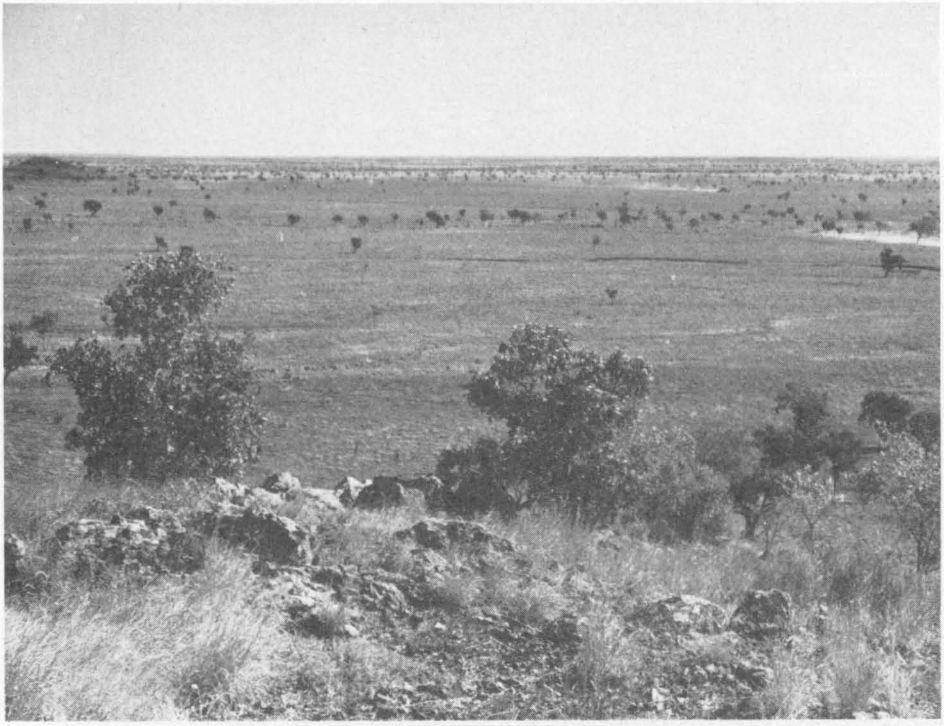


Fig. 36. Extensive black-soil plain underlain by Antrim Plateau Volcanics, Wave Hill Sheet area.

cate that the volcanics also underlie most of the eastern Victoria River Downs and Wave Hill Sheet areas.

Stratigraphic relations: The Antrim Plateau Volcanics overlie the Precambrian sedimentary rocks of the region (except the ?Adelaidean Kinevans Sandstone) with an angular unconformity. Traves (1955) observed lava flows filling old valleys up to 60 m deep along the Victoria River between Coolibah and Willeroo homesteads. A similar feature was observed near George Creek in the Victoria River Downs Sheet area. Randal & Brown (1967) interpreted the Precambrian inliers such as the one near No. 47 (Wyalong) Bore on the Wave Hill stock route, as representing small hills on the pre-volcanic land surface.

Around Mistake Creek and Rosewood homesteads the volcanics are disconformably overlain by the lower Middle Cambrian Headleys Limestone, the basal unit of the Negri Group. In places the basalt immediately beneath the limestone is highly altered and ferruginized to a depth of up to 3 m. A similar feature was observed by Dow et al. (1964) on the western side of the Hardman Basin. Thus, although the contact between the two units is concordant, the presence of a ferruginized layer is indicative of a period of weathering and probably of erosion before the deposition of the Headleys Limestone.

In the eastern portions of the Victoria River Downs and Wave Hill Sheet areas the formation is overlain with a slight angular unconformity by the Montejinni Limestone (Randal & Brown, 1967). Between Top Springs and Camfield, and west of the Top Springs/Wave Hill road, the volcanics are unconformably

Fig. 37. Terraced topography developed on the Antrim Plateau Volcanics north of Kirkimbie homestead, Limbunya Sheet area.

overlain by sediments assigned to the Mullaman Beds (Randal & Brown, op. cit.).

Stratigraphic drilling: Nine stratigraphic holes have been drilled in the Antrim Plateau Volcanics to provide samples for detailed mineragraphic and petrological work and to assess the nature of the flows. Eight of the sites were within the four Sheet areas covered by this Report; the ninth was in the adjoining Delamere Sheet area. The locations of the holes are given in Table 10 and are plotted on the accompanying 1:250 000 map Sheets.

General characteristics: The Antrim Plateau Volcanics consist predominantly of light to dark grey, dark red-brown, and purple basaltic lava flows with minor interbedded sedimentary and pyroclastic material. The tops of flows are commonly vesicular or amygdaloidal (Fig. 38). Amygdales are commonly filled with quartz, prehnite, carbonate minerals, chalcedony, agate, and green chlorite. Malachite staining and small inclusions (0.5-5 mm) of native copper were observed in several specimens. Vugs up to 1 m across in the upper portions of flows are lined, and often filled, with quartz, amethyst, smoky quartz, prehnite, agate, and carbonate. Most flows possess highly vesicular oxidized upper layers (Fig. 38), accounting for up to 30 percent of each flow, and slightly to moderately vesicular basal parts, generally amounting to less than 5 percent of each flow. The vesicular margins grade into massive basalt in the centres of the flows. The vesicular basalt is more altered than the massive; generally the greater the number of vesicles the more extensive is the alteration. The highly vesicular basalt is dark red-brown, light brown, and grey, and is commonly very soft and crumbly. Some of the highly

TABLE 9: SUMMARY OF PALAEOZOIC STRATIGRAPHY

Group	*Unit*	*Map Symbol*	*Lithology*	*Maximum Thickness range (m)*	*Stratigraphic relations*	*Physiographic expression*	*Remarks*
	DEVONIAN Elder Sandstone	Db	White to red-brown feldspathic sandstone	200	Paraconformable on Hudson Formation	Rugged plateau bounded by steep cliffs	Unconformity with Cme inferred from known relations in Western Australia
	CAMBRIAN Hudson Formation	Cme	Red-brown feldspathic sandstone, minor siltstone	75	Conformable on Cmp	Undulating low relief areas	
NEGRI GROUP	Panton Formation	Cmp	Siltstone, minor shale, gypsum, and fossiliferous limestone	300	Conformable on Cml	Plains, rare terraced hills	
NEGRI GROUP	Linnekar Limestone	Cml	Fossiliferous limestone, minor siltstone	25	Conformable on Cmo	Small cuestas, plateaux	
NEGRI GROUP	Nelson Shale	Cmo	Gypsiferous shale and mudstone, minor limestone	180	Conformable on Cmy	Plains	
NEGRI GROUP	Headleys Limestone	Cmy	Massive limestone	40	Disconformable on Cla	Rocky cuestas, lapies, steep-sided hogbacks	
	Antrim Plateau Volcanics	Cla	Massive, porphyritic, and vesicular tholeiitic basalt	300+	Unconformable on Precambrian units	Terraced rounded hills and mesas, cuestas, undulating stony country, black soil plains	
	Blackfella Rockhole Member	Cla_1	Agglomerate and basalt; minor sandstone and siltstone	75	Conformable on basalt flows of remainder of Cla	Mesas, plateaux, cuestas, rugged hills	Uppermost part of volcanics, recognized only around the Hardman Basin
		Cla_2	Quartz sandstone	30	Contacts conformable		Interbeds at various stratigraphic horizons, particularly near base

TABLE 9—Continued

Unit	*Map Symbol*	*Lithology*	*Maximum Thickness (m)*	*Stratigraphic relations*	*Physiographic expression*	*Remarks*
	Cla_3	Grey and white laminated chert	15			Interbeds at various stratigraphic horizons
	Cla_4	Chert and sandstone	5			Limited outcrops
	Cla_5	Tuffaceous sandstone with chert fragments and interbeds	10	Contacts assumed conformable	Mesas, plateaux, rugged hills, small terraces	In SE Limbunya Sheet area
Bingy Bingy Basalt Member	Cla_6	Medium-grained porphyritic basalt	40			
	Cla_7	Agglomerate, highly weathered and lateritized	9			Uppermost bed of Cla in SE Limbunya Sheet area
	Cla_8	Agglomerate, minor quartzose sandstone	9		Plateau	Uppermost unit of Cla in SE Victoria River Downs Sheet area

TABLE 10: LOCATIONS AND DEPTHS OF STRATIGRAPHIC HOLES DRILLED IN THE ANTRIM PLATEAU VOLCANICS

BMR Stratigraphic hole	*Latitude S*	*Longitude E*	*Total depth (m)*
Delamere No. 1 - - - - -	15°44′	131°42′	153.9
Victoria River Downs No. 1 - -	16°35′	131°52′	74.7
Victoria River Downs No. 2 - -	16°35′	131°43′	243.8
Victoria River Downs No. 3 - -	16°23′	131°32′	91.4
Wave Hill No. 1 - - - - -	17°37′	131°15′	164.6
Limbunya No. 1 - - - - -	17°25′	129°22′	304.8
Limbunya No. 2 - - - - -	17°52′	130°00′	243.8
Waterloo No. 1 - - - - -	16°32′	129°10′	269.7
Waterloo No. 2 - - - - -	16°25′	129°24′	221.00

Results of the drilling are detailed by Bultitude (1971).

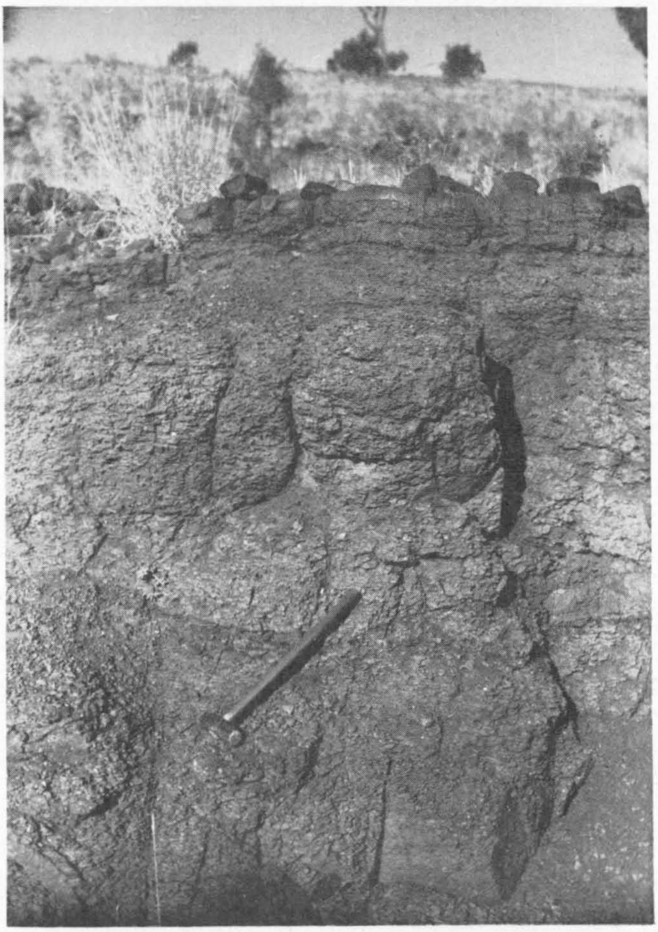


Fig. 38. Highly vesicular, extensively altered basalt from the upper portion of a flow. Note the sheeted appearance.

vesicular flow tops (Fig. 38) are fissile, the partings paralleling flow margins. The vesicular flow tops form benches and steep-sided terraces in hill-sides and plateau escarpments (Fig. 37); massive basalt from the central parts of flows forms rubble-strewn slopes between ledges of vesicular basalt.

A comparatively thick sequence (about 37 m) of soft crumbly extensively altered highly vesicular basalt with only a few thin bands of massive basalt underlies the Bingy Bingy Basalt Member (new name) and is exposed for about 5 km in the escarpment at the edge of the plateau surface north of Kirkimbie homestead in the Limbunya Sheet area. It seems very likely that a number of relatively thin highly vesicular flows are represented in this interval. However, they could not be delineated in the field.

Flow junctions are rarely observed in the field owing to poor exposures. Another factor that frequently makes it difficult to detect their exact position is the occurrence of the vesicular base of one flow adjacent to the vesicular top of the underlying flow. Pipe amygdales and spiracles are rarely found. Well developed columnar jointing (Fig. 39) has only been observed in one flow; poorly developed columnar jointing occurs in some of the thicker flows.

Petrography of the Antrim Plateau Volcanics: The basalts are fine to coarse. Large phenocrysts are rare, but the massive basalts commonly contain phenocrysts of plagioclase and rare clinopyroxene visible to the naked eye. The Bingy Bingy Basalt Member and a medium-grained basalt (Specimen No. 70770377) about 9 km north-northeast of Pigeon Hole outstation (Victoria River Downs Sheet area) are distinguished by a spotted appearance. The small white clots consist of glomeroporphyritic aggregates of large plagioclase phenocrysts.

Rocks with a high glass content tend to be darker than those displaying a high degree of crystallinity. Weathering colours are various shades of reddish brown and, less commonly, pale grey.

The basalts are commonly altered. The altered rocks are characterized by irregular dark red and green streaks which correspond to patches rich in hematite and chlorite, respectively. A feature of the rocks is the common occurrence of irregular streaks, patches, and occasional large areas of red-brown ferruginized basalt. Ferruginization tends to be most intensive against joints.

Textures in the massive basalts range from hyalopilitic through intersertal to intergranular. Intersertal textures are the most common. Rare phenocrysts of plagioclase occur in practically every basalt examined and large clinopyroxene crystals enclose plagioclase subophitically and, less commonly, ophitically in a few flows. Microphenocrysts of opaque oxide occur in several flows.

The basalts consist essentially of euhedral-subhedral laths of *plagioclase* (0.1-0.5 mm), subhedral-anhedral prisms of *clinopyroxene* (0.1-0.5 mm) and small euhedral to anhedral grains and granules of *opaque oxide* (0.01-0.5 mm). Small tabular phenocrysts of plagioclase (2 mm) occur in most sections, but are never abundant. Small subhedral (0.5-1 mm) phenocrysts of clinopyroxene are more rare. Minor amounts of pale green to yellowish green *chlorite* are very common. The chlorite occurs in interstices and small amygdales and also as fine grained, fibrous aggregate replacing clinopyroxene. In the amygdales the chlorite is associated with minor *quartz, chalcedony, carbonate,* rare *zeolites*(?), *prehnite, pumpellyite,* and rarely small aggregates of deep blue-green fibrous chlorite(?). Even in many of the massive-looking basalts small amygdales can be detected in thin section.

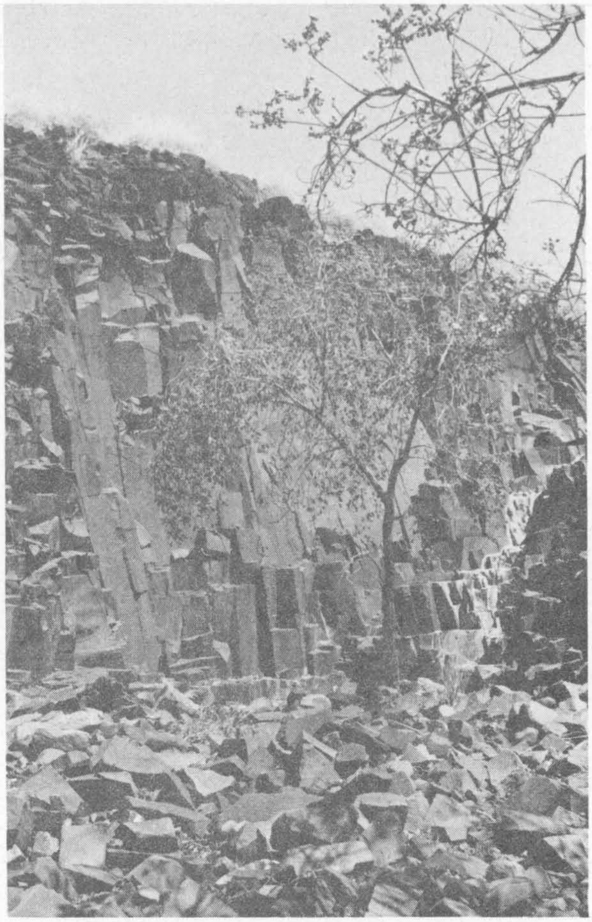


Fig. 39. Columnar jointing in the Bingy Bingy Basalt Member, 1 km north of Mount Napier, Limbunya Sheet area.

Clinopyroxene generally accounts for 30 to 40 percent of the total volume in the massive basalts and appears to be mainly *augite*. In a number of sections pseudo-uniaxial or nearly uniaxial figures (2V=0—15°) were obtained on some of the clinopyroxenes. It is assumed that these clinopyroxenes are *pigeonitic* in composition. Clinopyroxene is generally the least altered mineral present and is colourless when fresh. Many grains are pale green owing to incipient alteration. Minor replacement by fibrous green *chlorite* is widespread; rarely the clinopyroxene has been replaced by green amphibole. Simple twinning is common in the larger grains. Very fine exsolution lamellae also occur in some of the larger grains.

Plagioclase accounts for an estimated 40 to 50 percent of the total volume of the massive basalts and in the least altered specimens is *labradorite* (An_{55-60}). Compositions were obtained by measuring maximum extinction angles of albite twins in sections cut normal to (010). Replacement by *sericite* is very common.

Olivine was not detected in any of the thin sections examined. In a few, however, pseudomorphs of highly pleochroic (dark red to orange) *'iddingsite'* occur. Opaque oxide occurs as narrow rims around grain boundaries and as thin stringers along fractures. In other cases pale yellowish green chlorite has completely replaced grains of former olivine which occurred as small subrounded to rounded grains (0.1-0.5 mm).

Opaque oxide occurs as relatively large (0.1-0.5 mm) euhedral crystals (microphenocrysts) and more commonly as small irregular grains and granules scattered sparsely throughout the rocks. The grains are often fringed with bright orange-red iron oxide (hematite?) stains.

Several different rock types ranging from olivine tholeiite to quartz tholeiite and perhaps tholeiitic andesite are represented within the volcanic succession. All conform to the general characteristics of the tholeiitic suite. Randal & Brown (1967) examined a number of flows in the eastern portions of the Wave Hill and Victoria River Downs Sheet areas and concluded that they were also tholeiitic; one specimen had a rather unusual chemical composition, the most notable feature being a very high K_2O content (10.4%); it has been described as a sanidine trachyte.

Most of the basalts contain minor amounts (0-10%) of primary *quartz*. The quartz is a late-stage crystallization product and fills interstices and small patches between earlier-formed crystals.

Devitrified *glass* occurs in practically every section examined and ranges from scarce (less than 5% by volume) to very abundant (greater than 80% by volume). It varies from abundant dark red-brown practically opaque material in the more quickly chilled basalts from the upper and basal parts of flows to minor red-brown, pale red-brown, pale pink, or practically colourless interstitial cryptocrystalline low-birefringent material in highly crystalline rocks from the central portions of flows. The devitrified glass often contains microlites of plagioclase and opaque oxide.

Fine-grained interstitial intergrowths of *quartz* and *alkali feldspar* take the place of devitrified glass in coarser-grained highly crystalline basalt from the thicker flows. These intergrowths are usually so fine that the presence of alkali feldspar cannot be definitely established by optical means. Rarely, narrow overgrowths of alkali feldspar mantle groundmass plagioclase grains. Some of the massive quartz-rich basalts contain traces of primary *amphibole* and *mica*.

Long slender needles of *apatite* have been detected in practically every section. The apatite is confined mainly to the interstitial areas of devitrified glass and quartzo-feldspathic residuum and is a late-stage crystallization product.

Interbedded pyroclastics: Several agglomerate layers occur within the Antrim Plateau Volcanics. The most extensive exposures are in the region bordering the Hardman Basin in the Limbunya and Waterloo Sheet areas. Agglomerate also crops out about 50 km east of Inverway homestead (Limbunya Sheet area) and in the Crown Hill area (Victoria River Downs Sheet area). In most localities the agglomerate layers are composed of angular to rounded fragments of vesicular and massive basalt up to 15 cm across, set in a fine-grained aphanitic basaltic matrix with minor intermixed sandy siltstone, fine-grained sandstone, and silty sandstone. The basaltic detritus has been very extensively altered and ferruginized. Randal & Brown (1967) reported tuff and agglomerate in the volcanics near Wave Hill No. 3 Bore, but this locality was not re-examined.

Agglomerate caps the low escarpment bordering the headwaters of the Victoria River 50 km east of Inverway homestead. The unit is 9 m thick and has been extensively lateritized. In the Crown Hill/Mount Mervin area the agglomerate layer is about 9 m thick and contains minor amounts of white quartzose sandstone in interstices between basalt fragments.

The thin irregular lenses of sandstone and siltstone within the agglomerates were deposited under subaqueous conditions. The poorly sorted nature of the sediment precludes an aeolian origin. It is quite likely that some of the volcanic detritus represents reworked material. However, the relatively large size and often angular outlines of the basalt clasts indicate that the fragmental material has undergone neither extensive reworking nor transportation over long distances.

Dykes: Remarkably few dykes related to the Antrim Plateau Volcanics have been found. To date, dykes have only been found in the southwestern Limbunya Sheet area. A small dyke swarm occurs west of Kirkimbie homestead; a number of dykes were also observed northeast of the homestead. The dykes, whose dominant trend is to the northwest, are small discontinuous vertical bodies generally only about 1.5 m wide and protruding 0.3 to 1.2 m above the surface. Some dykes can be traced for more than 5 km. One relatively large dyke northeast of Kirkimbie is about 4.5 m wide and projects 6 to 9 m above the surrounding country. Only the larger, more conspicuous dykes are shown on the map Sheet.

The dykes consist of angular fragments (up to 14 cm across) of extensively altered highly vesicular basalt in a very fine-grained heavily altered basaltic matrix that ranges from massive to moderately vesicular. Quartz and calcite veining is common, and these two minerals also form vesicle infillings. The rocks closely resemble the basalt in the agglomerate bands near the top of the formation.

Also west of Kirkimbie is a quartz-barite vein which is about 1.5 m thick at the northern end. It trends towards 310° and is composed mainly of quartz with minor barite. The vein projects up to 1.5 m above the surrounding basalt surface and can be traced on aerial photographs for about 8 km. The vein appears to occupy a fracture in the volcanics and parallels the major regional lineament which forms the southwestern margin of the Hardman Basin in the Limbunya Sheet area.

Thickness: Owing to the gentle dips and the lack of topographic expression, the thickness of the volcanics is difficult to estimate from outcrop data. An estimate of minimum thickness can be obtained from water-bores drilled in the Antrim Plateau Volcanics, especially in the Wave Hill and Victoria River Downs Sheet areas. However, none penetrated the complete section from the overlying limestone to the underlying Precambrian strata. Stratigraphic hole BMR Victoria River Downs No. 2 (sited 14 km northwest of Top Springs) penetrated 228 m of volcanics before intersecting siltstone of the underlying Stubb Formation. The total thickness of the volcanics in this area is 237 m (Bultitude, 1971).

The succession is more than 140 m thick at W.Q. Bore in the Wave Hill Sheet area, while at W. Bore it is at least 180 m thick. In the southwest corner of the Wave Hill Sheet area, water-bores have penetrated 120 m of volcanics without intersecting the underlying formations. Farther west, in the Limbunya Sheet area, BMR Limbunya No. 2 Bore penetrated 243.8 m of volcanics (Bultitude, 1971) before being abandoned still in volcanics. Around Limbunya homestead there is at least 90 m of volcanics; northwest of Bigley Springs in BMR Limbunya No. 1, the formation thickness exceeds 298.7 m. At Byrnes Hill northeast of

Rosewood homestead, a water-bore penetrated 212 m of volcanics before reaching the underlying sediments. Farther to the east around Brolga Creek, there is at least 235 m of volcanics. The thickness of the formation exceeds 221 m (BMR Waterloo No. 2) in the Gum Creek area and 269.7 m southeast of Rosewood homestead (BMR Waterloo No. 1).

Age: The age of the Antrim Plateau Volcanics must be inferred from stratigraphic evidence. Diagnostic fossils have not been found in the sedimentary interbeds. The most definitive age limits may be deduced from the East Kimberley region, where the volcanics unconformably overlie the Timperley Shale of the Albert Edward Group, dated at 666 ± 43 m.y. (Bofinger, 1967). The volcanics were eroded and possibly faulted before the deposition of the Blatchford Formation in the early Middle Cambrian (Öpik, 1966; Kaulback & Veevers, 1969). The data suggest an age for the volcanics of early Lower Cambrian or very late Precambrian.

Supporting evidence for the younger age is seen elsewhere. The volcanics are overlain disconformably or with only slight angular unconformity by the Headleys Limestone (the basal unit of the Negri Group) and the Montejinni Limestone. Its stratigraphical position, therefore, strongly suggests an Early Cambrian age. Faunal assemblages in a higher unit of the Negri Group, the Linnekar Limestone, indicate an early Middle Cambrian age (Öpik, *in* Traves, 1955). An early Middle Cambrian age has been assigned to the fossiliferous Montejinni Limestone (Gatehouse, *in* Randal & Brown, 1967).

Ten specimens of Antrim Plateau Volcanics submitted to the Australian Mineral Development Laboratories, Adelaide, for K-Ar (whole-rock) age determination yielded ages ranging from 395 ± 10 m.y. to 506 ± 10 m.y. (from Late Silurian to Late Cambrian), the majority being grouped between 468 and 500 m.y. (Early Ordovician). The most likely explanation for the discrepancy between the ages determined by the K-Ar whole-rock method and the age inferred from the stratigraphic evidence is that the lavas have lost varying amounts of radiogenic argon since their emplacement in the Early Cambrian or late Precambrian. The reason for this loss is obscure, because the degree of alteration in most samples does not seem sufficient to account for a loss of 15 to 20 percent of radiogenic argon.

Subdivision of the Antrim Plateau Volcanics: The formation is difficult to subdivide because of the general similarity in the appearances of individual lava flows, the poor and patchy exposures over much of the country, and the scale of the mapping. Consequently, only two members have been delineated. The lower member, the Bingy Bingy Basalt Member, a thick flow characterized by glomeroporphyritic clots of plagioclase phenocrysts, crops out in the region west and north of Kirkimbie homestead. The Blackfella Rockhole Member consists dominantly of agglomerate, although a number of basalt lava flows of varying thicknesses overlie, and are interstratified with, the agglomerate layers and are included within the unit. The member forms the upper part of the formation in the area bordering the Hardman Basin.

Several prominent interbeds of sedimentary rocks have been delineated on the accompanying maps, but they have not been given formal member status. This would be impracticable because most of the interbeds are lenses of limited extent and occur at many different stratigraphic horizons; this would necessitate a large number of members.

Blackfella Rockhole Member (new name)

Derivation of name: From Blackfella Rockhole at 17°23′S, 129°06′E, about 12 km southwest of Mount Parton in the Limbunya Sheet area.

Distribution: The member forms the upper part of the Antrim Plateau Volcanics in the Limbunya and Waterloo Sheet areas and is exposed in regions bordering the Hardman Basin.

Host formation: Antrim Plateau Volcanics.

Lithology: Agglomerate, minor basic lavas, and thin lenses of sandstone and siltstone. The agglomerate consists of extensively altered angular to rounded fragments of vesicular and amygdaloidal basalt set in an aphanitic heavily altered basaltic matrix.

Type section locality: Measured at Blackfella Rockhole in the hillside bordering an unnamed tributary of Headleys Creek at 17°23′S, 129°06′E.

Thickness: 71 m at the type section. A thickness of 31 m was measured in the hillside bordering the Negri River at 17°33′S, 129°17′E, 15 km southwest of Bigley Springs, while in the hillside bordering Stirling Creek 16 km southeast of Mistake Creek homestead at 17°10′S, 129°11′E the member is 58 m thick. The sections were not taped, the thicknesses being estimated from measurements made by uncorrected barometric readings.

Age: Early Cambrian.

Stratigraphic relations: The member is disconformably overlain by the Headleys Limestone; its lower contact is conformable on the remainder of the Antrim Plateau Volcanics.

Description: The agglomerate consists of extensively altered angular to rounded fragments of vesicular basalt ranging from less than 1 cm to 60 cm across, set in an aphanitic heavily altered basaltic matrix. Chlorite commonly infills vesicles and lines joint-planes and cracks. Small calcite and quartz veins also occur. The agglomerate has weathered to a dark brownish red and is difficult to distinguish from laterite on aerial photographs.

Thin irregular lenses of fine-grained sandstone, silty sandstone, and sandy siltstone are interbedded with agglomerate layers. In most outcrops the lenses are randomly distributed. However, in some localities sandstone and siltstone are more abundant in the upper parts of the agglomerate.

The type section at Blackfella Rockhole (Section 30, Appendix I) is composed of 71 m of highly vesicular basalt and agglomerate. It overlies spheroidally weathered massive basalt. The boundary between the agglomerate and underlying basalt is not sharply defined. There is no vesicular zone in the underlying basalt.

Southwest of Bigley Springs the member is 30.5 m thick (Section 31, Appendix I), and near Stirling Creek 58 m thick (Section 32, Appendix I). Two agglomerate bands near Stirling Creek are separated by a moderately thick (24 m) flow of basalt (Fig. 40). Farther north, around Mistake Creek, Headleys Limestone immediately overlies agglomerate.

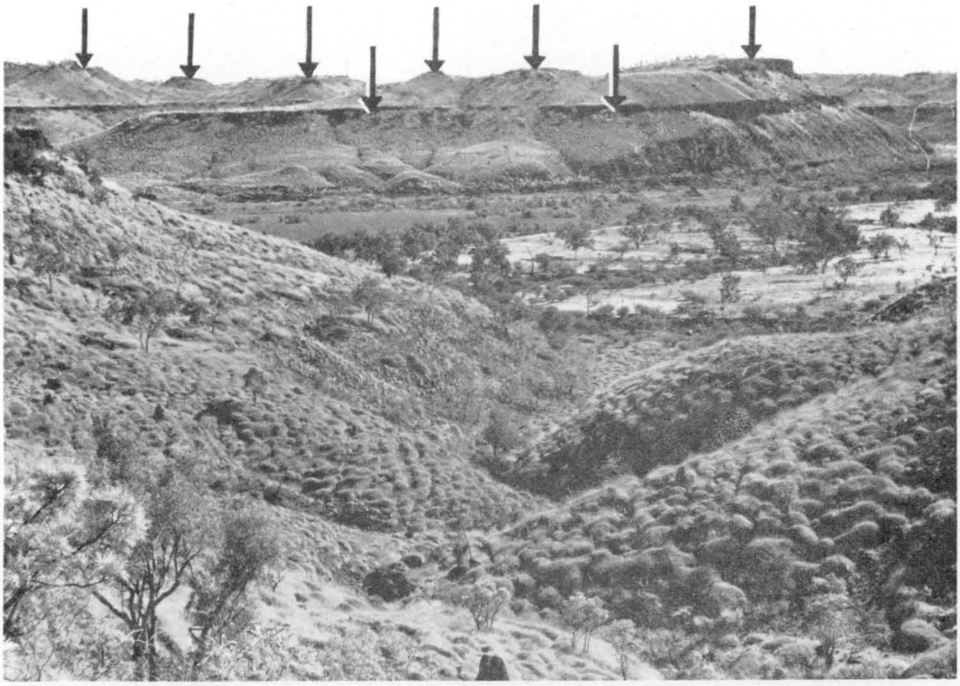


Fig. 40. Flat-lying basalt flows with a prominent lower agglomerate band (lower arrows) in a hillside bordering Stirling Creek. The upper agglomerate bed (upper line of arrows) occurs as small discontinuous cappings in the background.

The agglomerate forms very distinctive dark red-brown bands in the volcanic sequence. It crops out as flat-lying or gently dipping steep-sided terraces and cappings in the Limbunya and Waterloo Sheet areas. Southeast of Mistake Creek homestead the lower agglomerate band forms a prominent ledge that can be traced for about 15 km in the hills bordering Stirling Creek.

Palaeogeographic significance: The volcanic detritus in the agglomerate bands resulted from highly explosive volcanic activity. The prevalence of thin irregular lenses of sandstone and siltstone within the bands is taken to indicate that the bulk of the pyroclastic material was deposited under subaqueous conditions. The poorly sorted nature of the intermixed sedimentary material precludes an aeolian origin. Some of the volcanic detritus appears to be reworked. However, the relatively large size and commonly angular outlines of the basalt clasts indicate that the fragmental material has undergone neither extensive reworking nor transportation over long distances.

Bingy Bingy Basalt Member (new name)

Derivation of name: From Bingy Bingy Springs at 17°36′S, 129°09′E, about 7 km south of Mount Napier in the Limbunya Sheet area.

Distribution: The member is exposed in the southwestern Limbunya Sheet area and adjacent to and southwest of Mount Napier, north of Mount Maiyo, and around Kirkimbie yard in the central-western Limbunya Sheet area.

Host formation: Antrim Plateau Volcanics.

Lithology: Medium to coarse massive basalt from the central and lower parts of the flow contain relatively large phenocrysts (5 mm) of plagioclase. The feldspar phenocrysts typically occur as glomeroporphyritic aggregates and form small clots up to 1 cm in diameter. The white phenocrysts protrude slightly on weathered surfaces and impart a mottled appearance to the rocks. Grainsize decreases and phenocrysts become rare towards both the base and the top of the flow. The upper parts are highly vesicular with numerous small quartz-filled geodes. Vesicles are commonly filled with quartz, agate, and calcite. Spheroidal weathering occurs in the slightly vesicular to fairly massive basalt near the top of the flow.

Type section locality: Measured in the hillside at 17°32′S, 129°15′E, 7 km northeast of Bingy Bingy Springs. The section was not taped, the thickness being estimated from uncorrected barometric readings.

Thickness: 40 m at the type section.

Age: Early Cambrian.

Stratigraphic relations: The member appears to be conformable with the overlying and underlying lava flows.

Description: The phenocrysts of the member are colourless on fresh surfaces but are commonly outlined by a dark red staining of secondary hematite(?) around grain boundaries; rarely, the actual grains have been extensively stained. In the upper and lower parts of the member the basalt is more vesicular, finer-grained, and less porphyritic. Vesicles are often filled with quartz, agate, and minor calcite, and fragments of these minerals cover weathered surfaces Spheroidal weathering (Fig. 41) occurs in the slightly vesicular to fairly massive basalt near the top of the flow.

Columnar jointing is well developed in the massive portions of the flow about 1 km north of Mount Napier (Fig. 39).

Two composite sections, which include 39.5 m of Bingy Bingy Basalt Member, were measured 7 km northeast of Bingy Bingy Springs, and 26 km southwest of Mount Napier (Appendix I, Sections 33 and 34, respectively).

One flow exposed in the Pigeon Hole/Crown Hill region of the Victoria River Downs Sheet area contains large plagioclase phenocrysts and closely resembles the Bingy Bingy Basalt.

Sediments associated with the Antrim Plateau Volcanics

Sandstone, siltstone, chert, and limestone are interbedded with the volcanics. The more extensive outcrops are shown on the map Sheets. Sediments in the Wave Hill and Victoria River Downs Sheet areas have already been discussed in some detail by Randal & Brown (1967) and Barclay & Hays (1965). Sweet et al. (in press, a) have also described similar rocks from the Delamere Sheet area.

Sandstone and minor siltstone and conglomerate underlie basalt in several localities. Exposures are mainly confined to the southeast corner of the Waterloo Sheet area and along Gordon Creek in the Victoria River Downs Sheet area. As far as can be determined, contacts with the overlying basalt are conformable and hence the rocks have been mapped as part of the Antrim Plateau Volcanics. Outcrops in the Depot Creek area (grid ref. 654122) consist predominantly of red-brown flaggy thin to medium-bedded medium-grained moderately well sorted sand-

Fig. 41. Spheroidal weathering in moderately vesicular, heavily altered Bingy Bingy Basalt Member.

stone displaying large-scale cross-bedding. Thin bands of coarser-grained sandstone and massive conglomerate form a layer about 1 m thick at the base of the unit. The small (2 cm) subrounded clasts in the conglomerate consist mainly of fine to medium-grained sandstone (commonly indurated) with minor chert. The unit has a maximum exposed thickness of 15 m and unconformably overlies the Mount Sanford Formation.

White, brown, and pale purple, massive to flaggy, fine to medium friable sandstone displaying cross-bedding and slump structures and containing mud flakes is exposed in areas bordering Gordon Creek. The grains are moderately well sorted and are composed predominantly of quartz with minor feldspar. The lower parts of some outcrops consist of light purple sandy siltstone and silty sandstone; some basal portions are conglomeratic. Gregorys Remarkable Pillar (grid ref. 705147, Victoria River Downs Sheet area) is composed predominantly of flaggy to massive, medium-bedded friable sandstone (29 m) with purple siltstone (1 m) at the base.

The sediments form a layer immediately beneath the volcanics and unconformably overlie the Wondoan Hill Formation. The unit has a maximum exposed thickness of 30 m, and in other localities along Gordon Creek unconformably overlies the Battle Creek Formation and Jasper Gorge Sandstone.

A number of parallel elongate sandstone ridges trending in a northwesterly direction crop out west of Pigeon Hole outstation. The largest is about 15 km in length with a maximum exposed thickness of about 30 m. The sandstone is medium-grained and very friable. The large-scale cross-bedding, the very good sorting of the sand grains, the fineness of the sand particles, and their occurrence in depositional mounds and ridges resembling dunes indicate wind transport.

A second and more common type of sandstone is fine to medium and either laminated with current lineations on bedding surfaces or ripple-bedded. The sandstone generally occurs as thin (0.5-15 m) rather extensive bands interbedded with the volcanics. Minor siltstone and chert commonly occur within the sandstone bands. The most extensive exposures occur near the base of the volcanics in the region around Waterloo homestead(Waterloo Sheet area) and in the Mount Sanford/Pigeon Hole region (Victoria River Downs Sheet area).

The sandstone is composed mainly of quartz grains with minor feldspar (microcline and plagioclase) and heavily altered rock fragments and accessory tourmaline. The grains are often coated with a thin film of brownish iron oxide. Quartz is the most common cement but calcite cement is present in some samples. In the sandstone with large-scale cross-beds, the grains are well sorted and the rock fragments and feldspars are well rounded. In the sandstone with current lineations, the grainsize is more variable and some of the basalt fragments are angular and notably larger than the other clasts. The sandstone commonly contains variable amounts of fine-grained pale brown silty matrix and in places grades into sandy siltstone and siltstone.

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

A third variety of sandstone containing chert fragments is exposed as small scattered outcrops in the Mucka Waterhole/Buchanan Springs area in the southwestern Limbunya Sheet area. It is pale to dark grey, massive, thick-bedded, fine-grained and indurated; it contains angular fragments of chert up to 3 cm in length, and angular to subrounded fragments of extensively altered vesicular basalt up to 5 cm across. The unit has a maximum exposed thickness of 9 m; most exposures are less than 5 m thick. The sandstone is characterized by an open framework and poor sorting of angular to subrounded quartz grains (average grainsize 0.3 mm), together with minor chalcedony and rare plagioclase as angular, generally clouded grains. Opaque oxide is relatively common as angular to subrounded grains (0.1-0.3 mm) and numerous tiny blebs (0.01 mm). The matrix consists of fine-grained aggregates of chalcedony and very fine-grained colourless to murky brown indeterminate silty(?) material with low birefringence. Tiny patches of pale yellow chlorite(?) are common.

The partial replacement of laminated limestone by chert was described by Randal & Brown (1967). Silicified stromatolites (*Conophyton* sp.) occur in chert interbeds 23 km southwest of Inverway homestead in the Limbunya Sheet area,

Fig. 42. Silicified stromatolites in a chert bed within the Antrim Plateau Volcanics, 1.5 km north of Catfish Waterhole, Wave Hill Sheet area.

and 1.5 km north of Catfish Waterhole (Figs 42 and 43) in the southwestern corner of the Wave Hill Sheet area. At both localities the interbeds are about 9 m thick. At Top Springs a silicified algal biostrome is exposed near the crossing over the Armstrong River.

Randal & Brown (1967) described an extensive chert bed in the Armstrong River and Illawarra Creek areas (both near Top Springs in the Victoria River Downs Sheet area). Other chert interbeds associated with rare limestone occur west of Top Springs, northwest of Mount Crawford (Victoria River Downs Sheet area), south and west of Camfield homestead (Wave Hill Sheet area), south and east of Wave Hill homestead (old site) and in the Mucka Waterhole/Buchanan Springs region (Limbunya Sheet area). Two separate chert beds separated by basalt flows form benches in the hills south of Moolooloo homestead (Victoria River Downs Sheet area). The larger of the known outcrops are shown on the map Sheets. The limestone is laminated micrite with some sand, silt, and clay impurities. It was probably deposited as laminated carbonate mud and subsequently recrystallized (Randal & Brown, 1967). Randal & Brown considered that some of the chert may be silicified tuff or silicified tuffaceous sandstone; fragments of basaltic glass with typical outlines of glass shards are common in some thin sections. Some of the chert, especially near Camfield homestead, is vuggy and brecciated, and contains geodes lined with crystals of quartz, smoky quartz, and amethyst. The thickness of the chert beds ranges from 8 m down to about 25 cm.

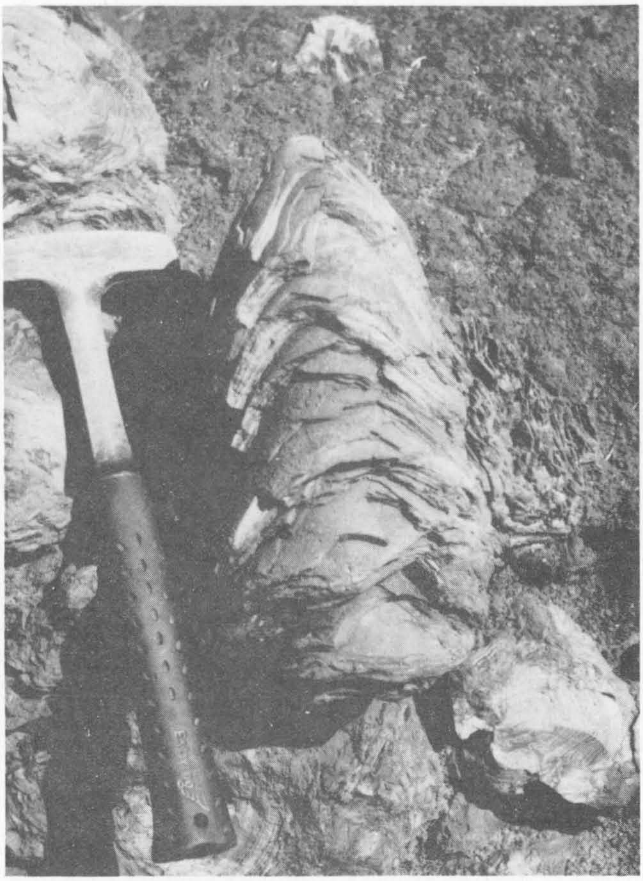


Fig. 43. Close-up view of an individual conical stromatolite from the same outcrop as Figure 42. The stromatolite has been completely silicified.

Structure of the Antrim Plateau Volcanics

The lavas and interbedded sediments exposed in the four Sheet areas are flat-lying or very gently dipping and have undergone little deformation since their effusion or deposition. Randal & Brown (1967) drew structure contours and showed that the regional dip of the eastern belt of volcanics is 0.5° or less in an easterly direction. Regional dips in the western belt are generally of a similar magnitude and in a westerly or northwesterly direction. In a number of small localized areas the volcanics dip up to 35°. Some of the steeper dips occur along minor faults near Mount Wallaston at grid ref. 759119 in the Wave Hill Sheet area.

The Antrim Plateau Volcanics and overlying Montejinni Limestone are faulted near Mount Wallaston. A graben with a maximum downthrow of about 30 m is bounded by parallel faults about 1.5 km apart. Minor faults with unknown displacements have been detected in a number of places. The fault traces are often marked by linear depressions flanked by flat-lying basalt flows.

The headwaters of the West Baines River flow along a prominent linear depression in the Waterloo Sheet area. Uplift of the northern block and/or downthrowing of the southern block has brought an agglomerate band down to approxi-

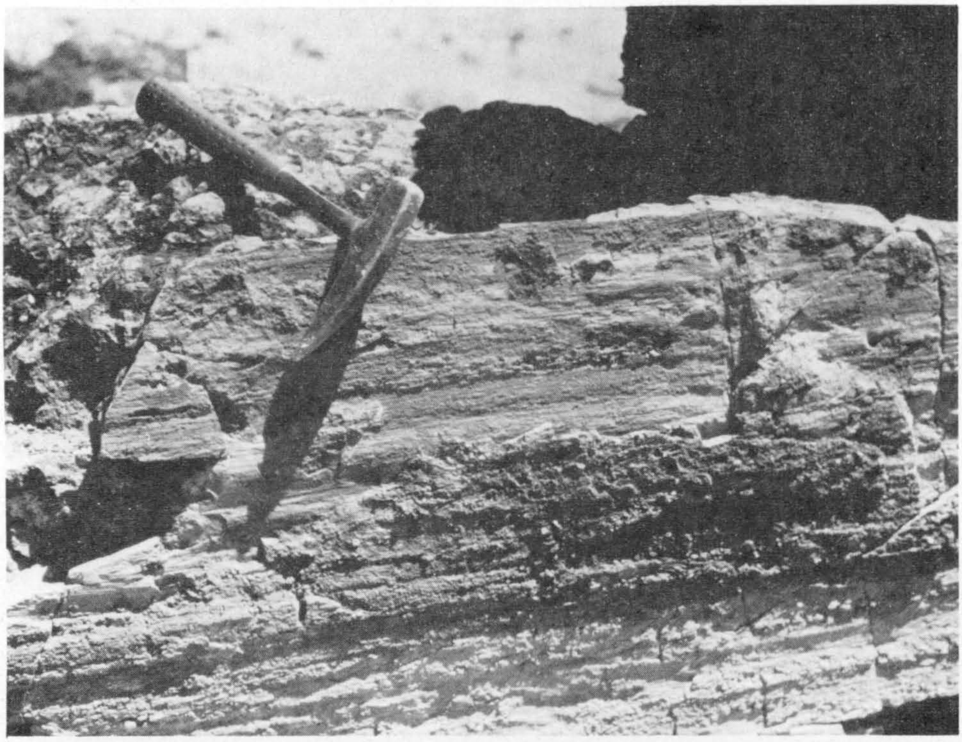


Fig. 44. Slickensided surface on barite and brecciated basalt lining the outer face of the vein, 2 km east of the Duncan Highway, Dixon Range Sheet area, Western Australia.

mately the same level as a massive lava flow from lower in the succession. The agglomerate occurs as small residual outcrops capping portions of the southern block, and the massive lava flow occurs at the top of the volcanic succession immediately north of the West Baines River. A large block of Headleys Limestone in the fault depression is probably the remnant of a fault breccia. The block comprises large angular fragments of limestone (up to 1 m across) in a matrix of recrystallized calcite.

Blackfellow Creek, northeast of Rosewood homestead, follows another prominent linear depression. The basalt dykes and barite veins in the southwestern Limbunya Sheet area presumably occupy fracture zones in the volcanics. Slickensides have been observed along the outer surfaces of some of the dykes and veins (Fig. 44).

The Negri Group has been folded into a monocline along the southern margin of the Hardman Basin and the northern margin of the Rosewood Basin. The downfolded limbs of Headleys Limestone protrude above the surrounding country as steeply dipping or vertical 'walls'. No indications of monoclinal folding have been observed in the underlying volcanics in these areas. As far as can be ascertained, the volcanics have responded to the pressures responsible for the downfolding of the more flexible Headleys Limestone by fracturing or by movement along pre-existing fault planes. Vertical displacement is about 75 m in the volcanics near the southeastern end of the Hardman Basin. West of the fault the Bingy Bingy

Basalt Member caps the plateau surface, but to the east it is at ground level. Calcite veins and rare fragments of chert breccia occur along the fault zone.

Middle Cambrian

Negri Group

The Negri Group occupies the Hardman Basin and crops out extensively in the Dixon Range Sheet area and in the adjacent part of the northwestern Limbunya Sheet area. Matheson & Teichert (1948) described the Western Australian outcrops as Negri Series, and this was modified to Negri Group by Traves (1955) who described eight formations within the group in the northwestern Limbunya outcrops.

Dow et al. (1964) discarded Traves' nomenclature when remapping the Dixon Range Sheet area (Dow & Gemuts, 1967). Most of the Dow et al. 1964 nomenclature and units have been used in this Report.

Headleys Limestone

The Headleys Limestone, the basal unit of the Negri Group, crops out extensively in the Hardman and Rosewood Basins. It was named by Traves (1955) after Headley Knob (grid ref. 501068) near the western margin of the Limbunya Sheet area. The unit is assumed to be Middle Cambrian as there are no apparent stratigraphic breaks between it and the Linnekar Limestone which has been dated as Middle Cambrian. It can be correlated with the Montejinni and Tindall Limestones in the Daly River and Wiso Basins to the east.

The Headleys Limestone crops out over an area of about 420 km^2 in the northwest Limbunya Sheet area and the southwestern corner of the Waterloo Sheet area. Several small outliers totalling 16 km^2 occur in the Waterloo Sheet area around Rosewood homestead.

The unit weathers to a barren karst topography and in many places makes access difficult. It is commonly folded into monoclines and the short vertical limb remains as a vertical wall, the upper flat limb being removed by erosion.

The Headleys Limestone may be recognized on aerial photographs by its light smooth tone and lack of vegetation. It is the only massive grey unfossiliferous limestone in the Negri Group, and invariably lies directly above the upper parts of the Antrim Plateau Volcanics.

The unit is conformably overlain by the Nelson Shale; the contact is commonly gradational. The Antrim Plateau Volcanics underlie the unit and up to 6 m of red-brown friable highly weathered basalt or agglomerate is present immediately below the contact. This presumably represents a period of erosion, with development of a weathering profile.

Description: The Headleys Limestone has a total thickness of 30 to 40 m. A drill log of the Okes-Durack Bore (Dixon Range Sheet area, Western Australia) shows that the unit is 40 m thick, but the dip of the beds is not recorded.

The basal 15 m of massive limestone contains nodular and tuberous chert inclusions which are less abundant in the upper part of the unit; they are rarely present above the basal 15-m zone. Stromatolites 10 to 15 cm in diameter were noted in the basal part of the unit near the northern margin of the Limbunya Sheet area.

A brown sideritic limestone about 3 m thick which crops out near The Caves (grid ref. 526062) forms the base of the Headleys Limestone in that area. At grid refs 519098 (Limbunya Sheet area) and 506169 (Waterloo Sheet area), the limestone has a limonitic base which contains a 0.5-cm band of chalcocite and malachite. In the Kangaroo Creek area (grid ref. 506169, Waterloo Sheet area), azurite and malachite are present throughout the 4-m thick limestone sequence.

The upper 25 m of the Headleys Limestone is blocky to flaggy, cream to grey, medium-bedded crystalline limestone. Outcrops of stromatolitic limestone are common near the top of the Headleys Limestone 10 km north-northeast of Mistake Creek homestead. The structures are a series of interlocking ellipsoidal domes, individual structures being 2 to 15 cm in diameter; the average is about 5 cm. Under the microscope the rock consists of fine-grained aggregates between the algal lamellae. The rock contains 95 percent carbonate and is probably a chemical precipitate.

At grid ref. 525097 a small upstanding outcrop of Headleys Limestone occurs between two faults. The rock types are northerly-dipping blocky limestone which is apparently bedded with a limestone breccia (Fig. 45) consisting of disoriented bedded limestone blocks in a limestone matrix. It is possible that it was formed along a fault scarp.

Nelson Shale

The Nelson Shale was named by Traves (1955) from Nelson Creek (grid ref. 524083) in the Limbunya Sheet area. It has a gradational contact with the conformably underlying Headleys Limestone; its upper contact with the Linnekar Limestone is sharp.

The unit is patchily exposed in the northwestern corner of the Limbunya Sheet area and follows the bedding trends of the Hardman Basin. The outcrop is 2 to 5 km wide on the north side of the basin, but only 300 m wide on the southern margin.

Lithology: The Nelson Shale consists of about 165 m of grey and red, calcareous and gypsiferous shale and mudstone. The lower part is well exposed along the Inverway/Mistake Creek road (grid ref. 535077), where it consists of flaggy to fissile, fawn silty limestone and calcareous siltstone with some thin coarsely crystalline limestone bands.

At grid ref. 512077, 5 km northwest of Blackfella Rockhole, grey to cream poorly bedded soft fissile calcareous shale grades downwards into flaggy limestone.

The Okes-Durack Bore in the Dixon Range Sheet area passed through 180 m of Nelson Shale, which consisted of greyish blue shale and brown mudstone with some sandy mudstone bands. Gypsum veins and crystals are common throughout the sequence and small pyrite crystals were noted in the middle one-third of the section. These rock types are consistent throughout the Hardman Basin. North of Mount Panton a section of the upper part of the formation consists of 13.5 m of red-brown siltstone with minor calcarenite and mudstone (Section 35, Appendix I).

The Nelson Shale exhibits a smooth light to medium grey-toned appearance on aerial photographs. Recent contour ploughing by conservation authorities to prevent soil erosion has produced a pattern visible on recent aerial photographs. The unit forms low rounded thornbush-covered rolling hills and valleys. Lithologi-

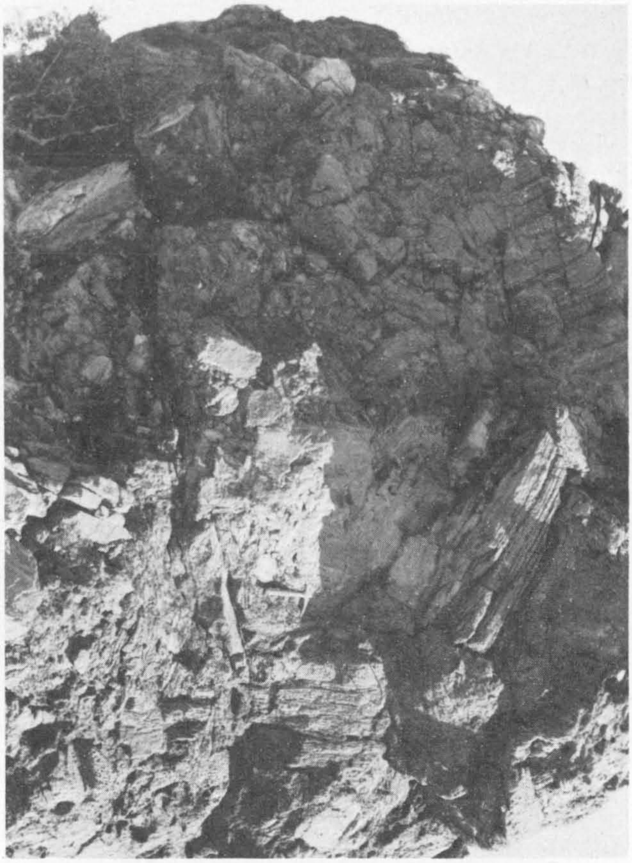


Fig. 45. Limestone breccia in the Headleys Limestone is interbedded with blocky to massive crystalline limestone at grid ref. 525097, Limbunya Sheet area.

cally the Nelson Shale is a grey shale and brown mudstone sequence which in part resembles the Panton Formation, from which it is distinguished by its stratigraphic position between the Headleys and Linnekar Limestones.

Linnekar Limestone

The name is derived from Linnekar Creek in the Dixon Range Sheet area. Traves (1955) applied the term to the second limestone unit of the Negri Group. At the type locality, abundant well preserved specimens of *Redlichia forresti* indicate a Middle Cambrian age. The unit has been mapped in the Hardman Basin (Dow et al., 1964).

The Linnekar Limestone crops out as a dip-slope belt, 25 m to 5 km wide, around the Hardman Basin in the northwest corner of the Limbunya Sheet area.

Lithology: The Linnekar Limestone consists of about 20 m of grey flaggy crystalline limestone with interbedded siltstone and shale. Chert nodules are abundant in the basal part of the unit, and Traves (1955) reported a thin band of *Girvanella* limestone about 3 m above the base. Numerous Middle Cambrian fossils have been found in the upper part of the formation.

A section through the formation 3.5 km southeast of Blackfella Rockhole at grid ref. 512077 includes 22 m of flaggy to massive, grey limestone (Section 36, Appendix I).

The basal limestone band crops out abundantly and commonly forms extensive benches and scarps. Chert nodules and *Girvanella* structures 10 to 15 cm in diameter are abundant.

The Linnekar Limestone appears as a light to medium-toned banded grey photogeological unit. It persistently forms small cuestas where it crops out in the Hardman Basin. The unit is the second limestone band (the first is Headleys Limestone) in the Negri Group.

Panton Formation

The Panton Formation forms a large part of the Negri Group. It consists of a siltstone sequence with a middle limestone zone containing several Middle Cambrian fossils. The unit weathers to low-relief soil plains covered with buckbush ('roly-poly') and much of this land has undergone severe soil erosion through overgrazing. The formation includes the Panton Shale, Shady Camp Limestone, Negri River Shale, and Corby Limestone of Traves (1955). In our mapping we have also included the Hudson Shale of Traves (1955) in the Panton Formation; the 'shale' is mostly siltstone, and was included by Dow & Gemuts (1967) in the Hudson Formation.

Lithology: Traves (1955) estimated a thickness of at least 100 m for the Panton Shale, Shady Camp Limestone, Negri River Shale, and Corby Limestone. Thus the Panton Formation as mapped by us consists of 90 m of shale, siltstone, and limestone overlain by nearly 200 m of siltstone (Traves' Hudson Shale).

The lower siltstone (Traves' Panton Shale) crops out on the lower slopes of Mount Panton, where it is 59 m thick. It consists of purple to green, fissile to flaggy, coarse micaceous siltstone which becomes finer-grained towards its upper and lower contacts. Gypsum crystals in irregular bands 0.5 to 8 cm thick occur in the lower part of the siltstone. In other areas it is commonly covered by alluvium and soil, and fresh exposures of the sequence are rare.

The limestone and siltstone forming the middle part of the Panton Formation form prominent outcrops because of the resistant nature of the limestone. Matheson & Teichert (1948) and Traves (1955) reported *Redlichia* sp., *Xystridura* sp., and *Billingsella* cf. *humbolti* from the upper part of the sequence at Mount Panton. This assemblage was considered by Öpik (1966) to be lower Middle Cambrian. The lowermost limestone in this part of the sequence is characterized by abundant *Girvanella* and crops out extensively in the Limbunya Sheet area, particularly near Mistake Creek (Traves' Shady Camp Limestone). The limestone consists of sparite aggregates, with zones of recrystallized calcite infilling the chitinous fossil remnants. About 5 percent of the rock consists of quartz, commonly in association with sparite and forming fine-grained aggregates. There are very few opaques and accessory minerals. The limestone is classed as biosparite (classification of Folk, 1962).

Above the limestone is a further 67 m of poorly exposed shale and siltstone (Traves' Negri River Shale), capped by a thin grey crystalline limestone. This limestone marks the start of the upper siltstone (Traves' Hudson Shale), which has a maximum thickness of 188 m (Traves, 1955). The siltstone contains several fine-grained glauconitic sandstone beds interbedded with fine to coarse, grey and green, fissile shale and siltstone and minor thin pink limestone.

Palaeogeographic significance: The Panton Formation contains several shallow-water limestone bands, and the presence of gypsum in the sequence would suggest that a warm-water environment prevailed at the time of the deposition. The abundance of *Girvanella,* a 'concretionary' algal growth in the sequence, indicates also that the limestone is of shallow-water origin.

Hudson Formation

The Hudson Shale of Traves (1955) was discarded in favour of Hudson Formation by Dow et al. (1964) and Dow & Gemuts (1967), who found an unconformity in the sequence. The Hudson Shale and part of Traves' Elder Sandstone constitute the Hudson Formation. The remainder of the Elder Sandstone (i.e. above the unconformity) is considered by Dow & Gemuts to be of Devonian age. The Hudson Formation consists of reddish brown flaggy thin-bedded sandstone and is the final record of Middle Cambrian sedimentation in the Hardman Basin.

The unit lies conformably on the Panton Formation, there being a lithological gradation from siltstone up into fine-grained sandstone. A paraconformable contact (Dow et al., 1964) separates the sequence from the overlying Devonian Elder Sandstone. Farther west in the Dixon Range Sheet area, the contact is reported by Dow et al. (1964) to be discordant.

Lithology: The unit consists of flaggy to blocky, red-brown medium-grained well sorted feldspathic sandstone and arkose. It is commonly friable, concretionary, cross-bedded, and contains mud flakes. There is much iron oxide staining throughout the unit and hematite bands are abundant.

The thickness of the unit is estimated from aerial photographs to be about 75 m. The basal beds consist of flaggy to blocky, fine-grained feldspathic sandstone and arkose with rare reddish brown silty crystalline limestone. The unit becomes massive in its upper part. Small (2 cm diameter) hollow nodules are common on weathered surfaces.

The rock consists of angular quartz and feldspar grains, all of which show low sphericity but are well graded. The quartz is unstrained and the feldspar is labradorite or calcic andesine, with some alteration to sericite. The matrix consists of fragments of volcanic glass, muscovite, chlorite, and hematite.

The sandstone is recognized on aerial photographs by its mottled medium-toned appearance and prominent bedding trends. It forms low-relief areas with rounded topography.

The sandstone represents the last sedimentation in Middle Cambrian time and the mineralogical composition suggests that it was, in part, derived from basalt. The angular grains and fresh feldspars suggest that the source area was relatively close to the site of deposition.

DEVONIAN(?)

Elder Sandstone

The name is derived from Mount Elder in the Dixon Range Sheet area. The name 'Mount Elder Series' was first proposed by Mahony (*in* Hobson, 1936), and used by Matheson & Teichert (1948) for the shale and sandstone overlying the uppermost limestone in the Negri Group. There have been several subsequent modifications to the nomenclature (Dow et al., 1964). Traves (1955) first used the term Elder Sandstone for the massive sandstone overlying his Hudson Shale.

The formation is the uppermost unit of the succession in the Hardman Basin and consists of flaggy to massive feldspathic sandstone. It was previously termed the Buchanan Sandstone by Dow et al. (1964), but the term Elder Sandstone is preferred owing to its established place in the literature. Although shown to be extensive in the Dixon Range Sheet area (Dow & Gemuts, 1967), it crops out over a very small area farther east.

The Elder Sandstone overlies the Hudson Formation with apparent conformity. However, because an angular unconformity between the two units has been recognized in Western Australia, a paraconformity must exist between the two formations in the east. The position of this unconformity is a matter of debate, and the position at which it has been placed in the Limbunya Sheet area (at a prominent bedding-plane parting which coincides with a change in photo-pattern) is different from that at which Dow & Gemuts (1967) placed it.

Lithology: The formation consists of blocky to massive, white to red-brown unfossiliferous feldspathic sandstone which has a maximum thickness of about 200 m in the areas examined.

In a scarp 8 km west of the Negri River/Stirling Creek junction about 40 m of the formation is well exposed; 3 m of flaggy beds crop out 10 m from the base of the cliff. The sandstone is friable, fine to medium, and contains up to 20 percent feldspar. Iron-rich nodules about 25 cm in diameter are common throughout the section. Similar concretions are abundant in the Devonian Cockatoo Sandstone to the north. The sandstone is well jointed, cross-bedding is abundant, and silicification has commonly affected its surface.

The rock consists of about 50 percent quartz, 20 percent feldspar, 20 percent other mineral grains, and 10 percent iron oxides. The quartz occurs as fractured subangular grains and shows no crystallographic straining. Many grains are composed of fine mosaics and were possibly derived from vein quartz. Much of the feldspar, which appears to be in the labradorite-andesine range, is partly altered; the rock also contains some antiperthite, pyroxene, and tourmaline grains, and rounded volcanic glass fragments. The iron oxides are found as irregularly shaped interstitial fragments consisting of magnetite(?) and hematite.

The rock is an immature quartz-feldspar sandstone, and by Pettijohn's classification (1957) should be termed an arkose.

Distinguishing features: The formation is a medium to dark-toned photo-geological unit showing bedding and jointing. It forms scarps, flat-topped plateaux, and sand-covered plains. It is difficult to distinguish from the underlying Middle Cambrian Hudson Formation because of similar lithology and the absence of an obvious unconformity. Petrologically its texture and composition are distinctive, but on the present meagre evidence this would not be a criterion on which to base a boundary.

MESOZOIC

Mullaman Beds

The Mullaman Beds underlie a large area in the eastern Wave Hill and Victoria River Downs Sheet areas, but crop out sparsely, generally along the margin of the Sturt Plateau. They were not examined during this survey, but have been described by Randal & Brown (1967). No outliers of Mullaman Beds were found west of the Victoria River.

CAINOZOIC

Laterite

Ferruginous laterite crops out extensively at the margin of the Sturt Plateau, particularly in the central and northern Limbunya Sheet area where there are numerous outliers. Complete lateritic profiles are developed in many places, particularly where the laterite has formed on basalt. Where underlain by Precambrian sedimentary rocks, the various zones of the profile are not well developed and the ferruginous zone is thin.

Although no analyses have been made, the laterite is thought to be strongly ferruginous, but not bauxitic. It is usually a deep reddish purple colour.

The complete profile probably exceeds 30 m in thickness in some areas, but the ferruginous zone is generally only 1 to 3 m thick.

Age of the laterite: Laterites in many parts of Australia have been regarded as Lower Tertiary, but few accurate age estimates are available. The youngest rocks affected by lateritization are the Lower Cretaceous Mullaman Beds; the laterite could therefore have been formed partly or wholly within the Cretaceous; however, because it has been regarded as Cainozoic in many areas, it is designated Tl on the enclosed maps. The laterite is almost certainly older than the Camfield Beds, which have been dated as middle to upper Miocene (Plane & Gatehouse, 1968).

Camfield Beds

The Camfield Beds crop out at several localities in the Wave Hill Sheet area, and are at lower topographic levels than the laterite and never in contact with it. Two outcrops of limestone in the southeast corner of the Waterloo Sheet area have been mapped as Camfield Beds; they are younger than the laterite and place an upper age limit on it.

The main outcrops of the Camfield Beds were not examined during this survey; they were described by Randal & Brown (1967), and Plane & Gatehouse (1968) dated them as middle to upper Miocene.

The Camfield Beds in the Waterloo Sheet area are white massive limestone. Some beds consist of compact finely crystalline limestone; others are probably calcarenite and calcirudite. Patches of very coarsely crystalline calcite and irregular chert nodules occur throughout.

Superficial sediments

A variety of sediments, both Quaternary and Tertiary, are included in this category. The most widespread are black soil developed mostly on volcanic rocks (Czb), sand, soil, and colluvium (Czs), and alluvium (Qa). Other sediments include slightly older alluvium (Qt) which forms a terrace about 15 to 20 m above river level, and travertine (Czt).

GEOPHYSICAL SURVEYS

A 1967 regional gravity survey of the northern part of the Northern Territory included the southern Victoria River region (Whitworth, 1970). The results show a slight gravity ridge of 20 mgal trending north-south from about the centre of

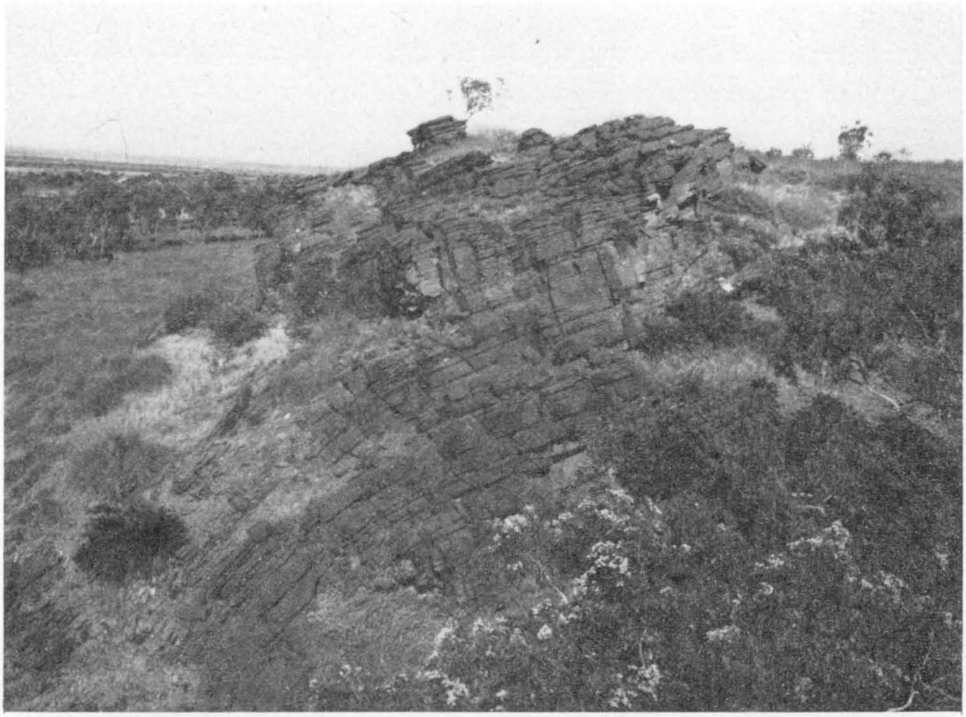


Fig. 46. Monocline in Headleys Limestone, which is more flaggy and fissile in the upper part of the section, 2 km northwest of Blackfella Rockhole at grid ref. 510079, Limbunya Sheet area.

the Limbunya Sheet area southwards. This, in conjunction with geological results, shows that there is a zone of shallow basement in this area.

A small gravity depression over the Hardman Basin exhibits a variation of some 30 mgal from the centre of the basin to the northeastern margin, but the variation is only 10 mgal on the southwestern side. The remainder of the area contains only minor anomalies and is considered to be a gravity shelf.

In 1966 Geophysical Resources Development Co., under contract to BMR, carried out a detailed survey of total magnetic intensity over the Victoria River Downs and Wave Hill Sheet areas (BMR, 1969a, 1969b). A similar survey over the Waterloo and Limbunya Sheet areas was carried out by Adastra-Hunting Geophysics Pty Ltd (BMR, 1971a, 1971b). Depth-to-basement calculations will be reported by Taylor & Rees (in prep.).

Most of the magnetic features delineated by the surveys are explicable in terms of known geological structure and stratigraphy. Areas occupied by Antrim Plateau Volcanics are characterized by a complex series of short-wavelength anomalies of 40 to 200 gammas amplitude, and the Hardman Basin is identifiable as a broad magnetic trough. Magnetic ridges along a zone of steep magnetic gradient southwest of the basin correspond to the faulted monocline which bounds that edge of the basin.

In the central Limbunya Sheet area several anomalies with an amplitude of 200 to 400 gammas correspond to the complex zone of faulting in the Limbunya Group. A magnetic ridge with an amplitude of about 450 gammas in the southwest

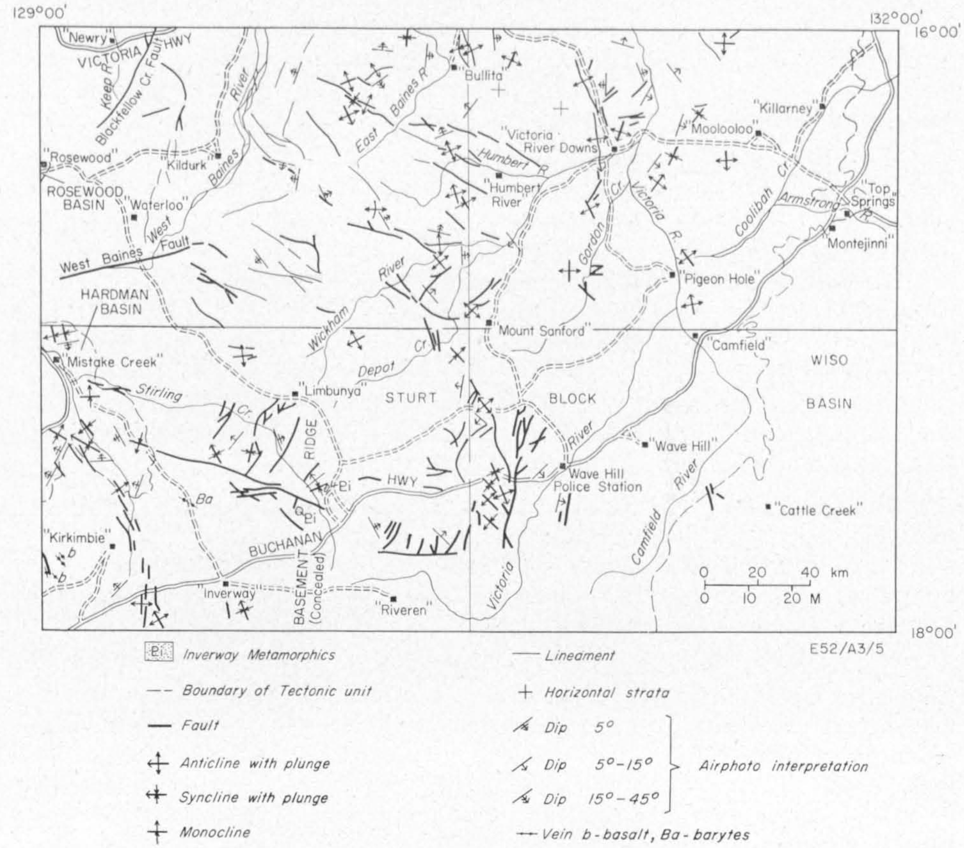


Fig. 47. Structural sketch map.

corner of the Limbunya Sheet area does not coincide with any outstanding features of surface geology. It could be related to a basic intrusive body at depth (P. Shelley, pers. comm.).

A well defined narrow magnetic ridge with an amplitude of up to 400 gammas trends northeast from Rosewood homestead in the Waterloo Sheet area. It is believed to be a subsurface fault coinciding with the extension of the northern margin of the Rosewood Basin. It is surprising that no surface lineament or fault is visible in the area northeast of Rosewood homestead.

STRUCTURE

The major structural features and tectonic units in the area are shown in Figure 47.

Tectonic Units

The area is divided into three major tectonic units, the Wiso Basin, the Hardman Basin, and the Sturt Block.

The *Wiso Basin* consists of a sequence of flat-lying to gently dipping Cambrian marine sediments and Cretaceous marine and non-marine sediments. The sequence thickens eastwards from the basin margin to a maximum of 100 m in the southeastern Wave Hill Sheet area (Randal & Brown, 1967). Structure contours drawn on the base of the lower Middle Cambrian, from outcrop and bore data, show that the unit was deposited on a gently sloping surface with some 30 m relief, and post-depositional tilting has occurred.

Only the eastern part of the *Hardman Basin* lies within the map area; the remainder is in the East Kimberley region of Western Australia. Its southwestern margin in the Limbunya Sheet area consists of a fault-monocline structure which downthrows the Palaeozoic sediments to the northeast. The Palaeozoic sequence of shallow-water marine limestone, shale, and sandstone (Negri Group) formerly had a more extensive distribution (forming the Ord Basin), but is now preserved only in downfaulted or folded structural basins (the Hardman, Rosewood, and Argyle Basins).

Palaeozoic limestone and shale crop out in the *Rosewood Basin* near Rosewood homestead in the Waterloo Sheet area. The outcrop is part of a small structural basin, the major part of which lies in Western Australia.

The *Sturt Block* occupies much of the area mapped, and has acted as a relatively stable block since early Carpentarian. The basement rise in the Limbunya Sheet area is manifested as two small inliers of quartz-muscovite schist in the central part of the Sheet area. Whitworth (1970) suggested that the metamorphics continue at a shallow depth southward.

Epeirogenic movements have taken place at several intervals between the Carpentarian and the Cainozoic, and folding is associated with these movements in many areas. The Sturt Block is composed of Proterozoic shallow-water marine sediments dipping gently to north and east from the centre of the Limbunya Sheet area. In the eastern and western parts of the region extensive Lower Cambrian tholeiitic basalt flows overlie the Proterozoic rocks. The volcanics are only slightly tilted but are intersected by several major faults.

FOLDING

Folding in the region is generally localized in small areas of older rocks, dolomite beds, or in zones adjacent to large faults. A general decrease in intensity of folding with time can be seen in the Precambrian rock groups.

The Lower Proterozoic sediments exhibit a penetrative cleavage striking 165°. Several minor kink folds are present in the fine-grained rocks. In the area 31 km west of Inverway (grid ref. 536019) the Bunda Grit has been folded twice, the later axis of folding being displaced some 600 m east from the position of the former axis. Both axes trend north and have a similar concentric style. The Limbunya Group sandstones exhibit low to moderate dips on the limbs of the fold, whereas the underlying Bunda Grit has high-angle, vertical, and inverted dips. Bedding-plane slickensiding is abundant on the limbs of the fold within the Bunda Grit.

The second phase of folding affected the Limbunya Group. Conjugate joints have formed in the more massive dolomites in response to the release of fold stress. Axes of secondary folding vary in trend from north-northwest to north-northeast. The folds show up no regional pattern and are only found in restricted areas in the Sturt Block. The thick dolomite beds in the Proterozoic sequence appear to be preferentially folded. The Skull Creek and Timber Creek Formations around Victoria River Downs and Bullita stations are folded along approximately north and northwest axes, and the folds vary in wavelength from 2 to 24 km.

A large number of folds associated with major faults and regional lineaments have a variable wavelength and amplitude, but are generally concentric folds with a variable plunge. Small domes are particularly abundant along the regional lineaments, but basins are absent. Several small domes commonly lie along one lineament. The general sporadic distribution, style, and nature of the folds suggest that they may be caused by diapiric movements along zones of weakness. However, no suitable source rocks are known and the folds may simply be the reaction of dolomitic cover-rocks to basement faulting.

Monoclines are abundant in both the Proterozoic sequence and the Palaeozoic sediments of the Hardman Basin; the structures reflect a discontinuity in the underlying rocks. In many places a monocline within younger rocks may be traced laterally into a fault in the beds beneath (e.g. at grid ref. 539077). The massive Headleys Limestone is folded into monoclines at four separate localities and the limestone forms an upstanding wall where the flat-lying upper limb has been removed by erosion. Figure 46 illustrates a monocline 2 km northwest of Blackfella Rockhole. Near 'The Caves' (grid ref. 526062) the Headleys Limestone is folded and the sequence is repeated by faulting.

FAULTING

Faulting is largely confined to the Sturt Block, particularly to the sediments of the Bullita, Wattie, and Limbunya Groups. Most faults are normal. Many formed in response to tensional stresses associated with the folding in the area, but the larger faults are more likely to be related to pre-existing basement structures. Large quartz-filled fractures are present in the Inverway Metamorphics. In the younger Proterozoic sedimentary rocks faulting is widespread, but is rarely accompanied by quartz veining. Brecciation is common and in some places extensive silicification has occurred in and near fault zones. The dominant trend of faults in the Sturt Block is east-southeast. Displacements are mainly downthrows to the north-northeast.

The southeast-trending fault-monocline which marks the southwest margin of the Hardman Basin can be traced southwards into a series of north-trending faults and folds. A similar structure occurs between the upper reaches of the Wickham and Victoria Rivers, where a series of faults which downthrow to the northeast can be traced southwards into the western part of the Wave Hill Sheet area. Numerous small folds are associated with this regional lineament.

North of the headwaters of the Victoria River in the Limbunya Sheet area, rocks of Antrim Plateau Volcanics are abruptly terminated by a large east-trending fault. A major east-southeast-trending fault cuts the volcanics 7 km north of Bigley Springs. Farther south at grid ref. 554056, a barite vein trending north-northwest can be traced for 4 km in the volcanics. In the southwest corner of the Limbunya Sheet area near Kirkimbie homestead, a number of north-northwest-trending faults and basalt dykes are parallel to the major regional lineament which forms the southwest margin of the Hardman Basin. In the Waterloo Sheet area a dominant north-northwest trend may be seen in the faults affecting the Antrim Plateau Volcanics. This is exemplified by the Blackfellow Creek Fault and the series of faults and lineaments between Valentine and Waterloo Creeks. The headwaters of the West Baines River follow a large east-northeast-trending fault which downthrows to the south. This structure continues into the Proterozoic rocks to the east.

The Palaeozoic basins are little affected by faulting. Minor faults occur along the margins of the Hardman Basin and in the area 20 km east of Cattle Creek station.

GEOLOGICAL HISTORY

The Victoria River region is underlain by Lower Proterozoic or Archaean igneous and metamorphic basement rocks whose history is virtually unknown as they are exposed in only two small areas in the south and in several minor outcrops in the north.

A long period (several hundred million years) elapsed before the rocks which are still preserved and exposed at the surface were laid down on the basement. The oldest unit is the Bunda Grit, probably of Carpentarian age; it is a shallow marine or fluvial unit laid down rapidly, with little time for size-sorting or rounding of grains. After consolidation, the Bunda Grit was moderately folded and some of it eroded. It was either completely eroded from the eastern part of the area or was never deposited there.

In early Adelaidean or late Carpentarian time a major transgression across the whole area resulted in a blanket of sand being deposited on the basement. The sand may be both fluvial and marine, and was overlain by carbonate mud and terrigenous silt. Sedimentation and subsidence continued at about the same rate for a long period, resulting in a sequence of about 1500 m of silt and carbonate. The sediment surface was at sea level much of the time, and algal colonies proliferated on intertidal carbonate mud flats. The sequence is preserved as sandstone, siltstone, stromatolitic dolomite, and dolarenite of the Limbunya Group.

A period of folding buckled the rocks throughout the area. Deformation was more severe in the west, where it formed several synclines and anticlines, than in the east where the rocks dip gently and steeper attitudes are associated with monoclines and faults. During erosion of the Limbunya Group, karst topography developed on the more massive dolomite formations.

The second major transgression through the area began a long period of deposition of sand and silt. These sediments were also deposited in both marine and non-marine environments, and several minor transgressions and regressions occurred. Although the sequence is mainly detrital in the lower part (Wattie Group), it contains roughly equal proportions of authigenic minerals (mainly carbonates) and detritus in the upper part (Bullita Group). Cyclic deposition took place during the latter period, especially during deposition of the Timber Creek, Skull Creek, and Bynoe Formations. At least one major transgression (Supplejack Dolomite Member) was superimposed on the cyclic processes. The sea may have receded again after deposition of carbonate mud of the upper Skull Creek Formation; a siliceous crust formed on the mud either as a soil layer (subaerial) or as a marine process (subaqueous). During the process at least 30 m of carbonate was replaced by silica, mostly preserving internal structures including stromatolites.

The characteristics of the upper formations of the Bullita Group beginning with the Bynoe Formation indicate sedimentation under similar conditions as before, with some influxes of clastic material giving rise to the sandy units. The ferruginous and manganiferous carbonates of the Battle Creek Formation may have formed in deeper water.

Sedimentation ended and a period of gentle folding ensued, the only movements of any magnitude since the Limbunya Group was folded. The style of deformation in the Wattie and Bullita Groups is distinctive, with large areas of flat or gently undulating strata and linear zones of steeply dipping rocks associated with monoclines and anticlinal domes which are almost invariably faulted along their axes.

After planation of the surface the sea advanced again, and glauconitic sand, clay, and mud were deposited (Wondoan Hill and Stubb Formations). Another period of uplift and erosion was succeeded by yet another transgression, resulting in the deposition of a sand blanket across the area, forming the most extensive Precambrian unit mapped in the basin (Jasper Gorge Sandstone). The sea depth increased again and glauconitic and chloritic silt was deposited (Angalarri Siltstone). A return to shallow-water conditions caused formation of oolitic dolomite and sand layers (Saddle Creek Formation and Pinkerton Sandstone). Evidence of later Auvergne Group deposition is preserved only in the Auvergne Sheet area (Pontifex & Sweet, 1972).

Only very gentle warping occurred after the close of Auvergne Group sedimentation; the Jasper Gorge Sandstone is flat-lying in the southeast and gently dipping in the northwest. In the northwestern corner of the Waterloo Sheet area the Auvergne Group forms a gently plunging anticline.

Erosion removed all but the older part of the Auvergne Group before a change to a much colder climate caused rapid advance of an ice sheet over at least the northern part of the area. A temporary retreat of the ice caused deposition of fluvioglacial sand and conglomerate (Skinner Sandstone) and later of till (after a second advance). A short period of erosion (perhaps the result of uplift after another glacial retreat) removed part of the till (Fargoo Tillite), but ice later deposited a much more widespread sheet of till (Moonlight Valley Tillite). Sand and ferruginous silt and clay were deposited in post-glacial lakes or seas (Ranford Formation). Virtually no folding or warping took place and the glacial rocks (Duerdin Group) are almost flat-lying, except in the extreme northwest adjacent to the Halls Creek Fault where mild folding is evident.

The whole record of Precambrian sedimentation and earth movements shows that the area was a craton and that the depositional basins were broad platforms, either stable shelf seas or low-lying land areas.

The most significant post-Precambrian event was the pouring out of vast quantities of tholeiitic lava over an enormous area during the Early Cambrian. Brief periods of marine and fluvial or aeolian sedimentation gave rise to limestone, chert, and sandstone interbeds in the volcanics.

Crustal downwarping in the west and east resulted in the formation and filling of the Ord and Wiso Basins, respectively. Sedimentation may have occurred right across the zone separating the present outcrops, but all evidence has been removed completely. Folding occurred in the west, probably as an effect of continued movement on the Halls Creek Fault, and has resulted in the preservation of the Hardman and Rosewood structural basins.

Although sediments may have been deposited during the Palaeozoic and much of the Mesozoic, no trace remains. During the Early Cretaceous fluvial and marine silts and sands blanketed the area, and were lateritized in the Cretaceous or early Tertiary. The area has been land for all of the Cainozoic Era, and erosion is gradually destroying the laterite. For a short period during the Miocene, fresh-water lakes or swamps received carbonate detritus or precipitates; many marsupials were trapped and preserved in these sediments (Camfield Beds).

Only minor uplift has occurred during the Quaternary Period; it may be responsible for the development of one noticeable terrace along the middle reaches of the Victoria River.

MINERAL RESOURCES

Until 1970, when a barite deposit was developed, no mineral deposit had been worked on a commercial basis in the southern Victoria River region. Copper, barite, and gemstones are all found in the Antrim Plateau Volcanics and are the minerals most likely to be exploited.

Copper

Minor copper mineralization has been reported from numerous localities in the Antrim Plateau Volcanics. Native copper occurs either as rare amygdale-fillings or as sparse disseminations in massive basalt, and malachite staining is common in vesicles and along joint planes.

Small amounts of malachite, azurite, and chalcocite commonly occur in the basal portions of the Headleys and Montejinni Limestones and more rarely in the upper heavily weathered vesicular portions of the underlying basalt. The richest concentrations are in 'The Caves' area southeast of Blackfella Rockhole in the Limbunya Sheet area (grid ref. 526062), the Rosewood 'Wall' (grid ref. 500180), and in a small outcrop of Headleys Limestone 15 km southeast of Rosewood homestead.

In 'The Caves' area malachite, chalcocite, azurite, and cuprite(?) are concentrated in the upper portion of an extensively altered agglomerate layer, and, to a lesser extent, in the overlying Headleys Limestone. Locally, exposures are richly mineralized. The copper mineralization appears to be concentrated adjacent to, and in, a number of minor faults in the Antrim Plateau Volcanics and overlying Headleys Limestone in this area.

Most of the Antrim Plateau Volcanics have been covered by stream-sediment sampling programs by private companies. Although some anomalous areas have been delineated, no workable deposits have been found.

Semi-precious gems

Geodes and amygdales in the basalts are commonly lined and filled with prehnite, agate, chalcedony, quartz, amethyst, smoky quartz, and calcite. Gem-quality material is scarce. Fragments of poor-quality amethyst and prehnite occur at the surface south of Wave Hill (Traves, 1955). Small blocks of agate commonly occur at the surface around Pigeon Hole outstation. Between Hooker Creek and Inverway homesteads abundant calcite lies on the surface (Traves, 1955). Quartz crystals are common northeast of Mistake Creek. Small agates are very common on the basalt surface in areas adjacent to overlying limestone. Numerous localities have been examined in both the western and eastern belts, and almost invariably abundant small agates were found on the basalt surface close to the Headleys and Montejinni Limestones. The agates have weathered out of vesicular basalt immedi-

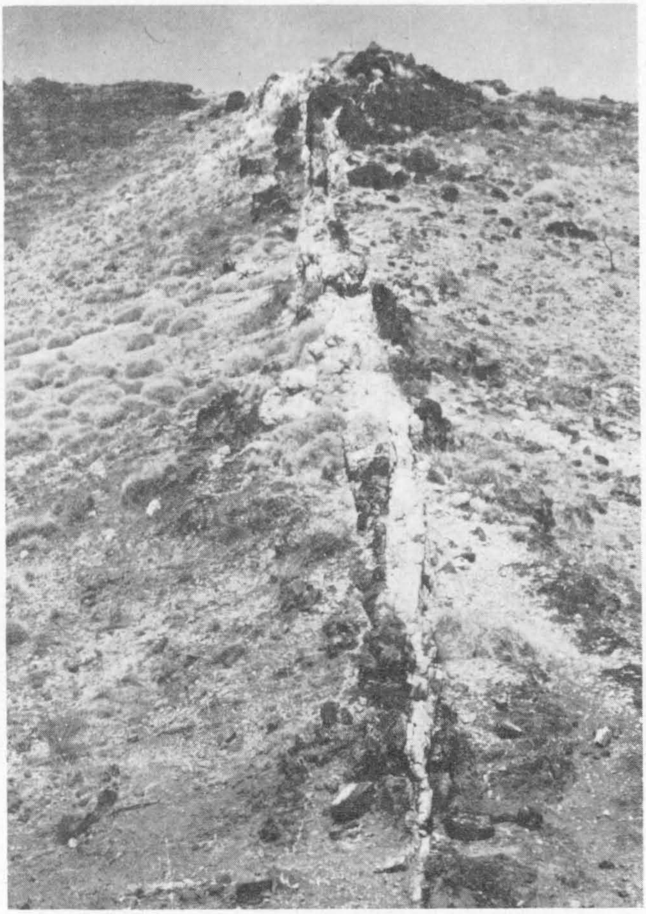


Fig. 48. Narrow vein of barite in the Antrim Plateau Volcanics, 32 km north of Nicholson homestead and 2 km east of the Duncan Highway, Dixon Range Sheet area.

ately underlying the limestone. Naturally polished agates form clasts in the basal conglomerate in the Camfield Beds. 'Zebra-stone' similar to that in Figure 34 may be found in other outcrops of the Ranford Formation. The original deposits in Western Australia have been worked, and there appears to be a market for specimens as souvenirs.

Barite

Deposits of *barite* have been found in veins cutting the volcanics north of Inverway homestead. South Australian Barytes Limited is at present mining barite from a vertical vein deposit, but no figures on ore reserves are available (the company quotes reserves only as 10 000 tons per vertical foot).

Small veins and pods of barite, commonly with associated quartz and calcite, cut the volcanics west and northwest of Kirkimbie homestead. A relatively large northwest-trending (310°) vein of quartz and barite crops out about 26 km west-southwest of Kirkimbie homestead. On aerial photographs the vertical vein shows up as a white linear feature and can be traced for about 8 km. At its northern end the vein is 1.5 m wide and projects up to 1.5 m above the enclosing basalt. A lenticular vein of coarsely crystalline barite with minor calcite is exposed 2 km east of the Duncan Highway at 17°44′S, 128°52′E, in the adjoining Dixon Range Sheet area to the west. The vein (Fig. 48) is vertical and has a maximum exposed thickness of 1.5 m. Surface outcrops can be traced for at least 1 km. Slickensides (Fig. 44) are well developed along the outer faces of the vein. They occur both in the barite and in the finely brecciated basalt, forming a thin (less than 1 m) irregular outer lining to the vein. The heavily altered basalt adjacent to the vein is either very steeply dipping or vertical; away from the vein the lava flows are practically flat-lying. Angular fragments of heavily altered basalt are incorporated within the barite vein itself. Smaller veins and pods of barite occur nearby.

Barite is not restricted to the Antrim Plateau Volcanics. A vein up to 1.5 m wide and 100 m long occupies a vertical fault in Fargoo Tillite 12 km east-southeast of Newry homestead at grid ref. 540222. Similar veins are known in the Auvergne Sheet area (Sweet et al., in press, b), and it is likely that more veins will be found.

Manganese

Manganese in the form of pyrolusite occupies joints and fissures in the Battle Creek Formation (Appendix II), but does not occur in economic quantities.

Lead

Galena has been found in the upper portion of the Skull Creek Formation, and geochemical surveys are at present being conducted by Australasian Minerals Inc. in the Victoria River Downs area. No deposits have been located.

Water

Because of the seasonal rainfall and semi-arid climate, the supply of surface water is not only inadequate for full pastoral development but is unreliable. Consequently, it has to be supplemented by groundwater supplies. The demand for water is greatest in extensive tracts of good-quality grazing lands in the black soil plain areas such as the central Victoria River Downs, central and western Wave Hill, western Waterloo, and southern Limbunya Sheet areas. Most of this country is underlain by the Antrim Plateau Volcanics. Consequently, from a groundwater point of view, the most important basement rocks in the four Sheet areas are the Lower Cambrian volcanics. Extensive black-soil plains are developed on the volcanics in the central Victoria River Downs and central and western Wave Hill Sheet areas. They form excellent grazing lands with extensive stands of good-quality Mitchell and Flinders grasses established on the pedocalcic soils developed on the volcanics. Randal (1973) made a detailed study of the groundwater resources of the eastern and central Wave Hill and Victoria River Sheet areas. His comments and conclusions on the water-yielding potential of the Antrim Plateau Volcanics in those areas are applicable to the volcanics farther to the west.

Water is stored in joints and fracture zones in the volcanics and also in interbedded sediments. Chert lenses, limestone lenses, and sandstone interbeds are widespread in the volcanics. The chert lenses are frequently well jointed, brecciated, and vuggy with large openings. The physical characteristics of the interbedded sandstones are ideal for containing and transmitting water (Randal, 1973). The upper and basal portions of most basalt flows are vesicular and the vesicular layers may also act as aquifers. Water supplies are related to the incidence of aquifers below the water-table in the bore-hole intersections and to the presence of recharge paths to them. The amount of water obtained from the bores is variable. Barclay (*in* Barclay & Hays, 1965) reported that of the total number of bores drilled solely in basalt on Wave Hill station, 50 percent were dry and 25 percent yielded less than 76 litres/minute. With few exceptions, the water from the volcanics is of very good quality, generally containing less than 1000 ppm of total dissolved salts (Randal, 1973). Many bores drilled in Precambrian rocks have been successful. The results of drilling are summarized in the Explanatory Notes on the Limbunya (Mendum, 1972), Wave Hill (Bultitude, 1972), Waterloo (Sweet, 1973 a), and Victoria River Downs (Sweet, 1973 b) Sheet areas.

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APPENDIX I — STRATIGRAPHIC SECTIONS

This appendix contains descriptions of most sections measured in the field and a few estimated in the office with the aid of aerial photographs and measured dips.

Most sections were measured using a 100-ft tape and Brunton compass; a few were paced. Appropriate corrections were made for slope of land, dip, and deviation from the ideal cross-strike direction. Some sections were measured with an aneroid barometer and were corrected for errors caused by diurnal pressure variations. All sections were measured in feet (to the nearest foot) and subsequently converted to the nearest 0.5 m.

Lithological descriptions have been set out, as far as possible, in the following manner: nature of parting (massive more than 100 cm, blocky 15-100 cm, flaggy 1-15 cm, fissile less than 1 cm), nature of bedding (thick-bedded more than 30 cm, medium-bedded 10-30 cm, thin-bedded 1-10 cm, laminated less than 1 cm), after Dunbar & Rodgers (1957, p. 57). Colour, texture, rock type, sedimentary structures, and other data are included. The grade-scale used for sandstone descriptions is that of Wentworth (1922) as it appears in Pettijohn (1957). Calcareous rocks have been classified using the system of Folk (1962). Finely crystalline carbonate rocks have generally been called dolomite or limestone rather than micrite.

SECTION 1. Margery Formation (type section) — paced 3.5 km northwest of No. 19 Bore, Limbunya Sheet area.

Thickness (m)	*Unconformably overlain by chert of the Antrim Plateau Volcanics*
61	Estimated only — outcrop concealed beneath chert
20	*Chert:* khaki, flaggy, thin-bedded to laminated, some fine cross-bedding
15	*No outcrop:* probably claystone
18.5	*Chert breccia:* medium-bedded; the bedding has undergone considerable small-scale folding. The chert fragments are mostly about 2 cm long and are white, green-brown, and red. The matrix is white partly silicified claystone
10.5	*Bedded chert breccia* as above but much of it has been completely disrupted so that no bedding is apparent
Total 125	Underlain by Stirling Sandstone

SECTION 2. Amos Knob Formation (type section) — measured 1.6 km southeast of Swan yard, Limbunya Sheet area.

Thickness (m)	*Overlain by Mallabah Dolomite*
10.5	No outcrop
1.5	*Dolomite:* yellow-brown, blocky to flaggy, thin-bedded, stromatolitic, coarsely crystalline
1.5	No outcrop
1.5	*Dolomite:* yellow-brown, flaggy, laminated
1.5	No outcrop
1.5	*Dolomite:* grey, flaggy, thin-bedded, finely crystalline; weathers to yellow-brown
1.5	No outcrop
3	*Dolomite:* yellow-brown, flaggy to fissile, laminated
3	No outcrop
3	*Dolomite:* yellow-brown, flaggy, laminated
6	No outcrop — pebbles of pale grey shale
3	Interbedded (a) *Dolomite:* brown, flaggy, laminated; and (b) *Shale:* pale grey-green
3	*Dolomite:* buff, blocky, laminated to thin-bedded, stromatolitic
6	No outcrop
1.5	*Dolomite:* grey, blocky, laminated, with large stromatolites
1.5	No outcrop
Total 49.5	Underlain by Pear Tree Dolomite

SECTION 3. Amos Knob Formation — measured near Farquharson Gap, Wave Hill Sheet area.

Thickness (m)	*Overlain by Mallabah Dolomite*
6	*Shale:* green, fissile, and soft
12	*Dolomite:* red-brown, fissile to massive, medium-grained
4.5	*Siltstone:* green and fissile
6	*Dolomite:* red-brown, flaggy, thin-bedded, fine-grained
4.5	No outcrop — probably siltstone
7.5	Thin interbeds of: (a) *Siltstone:* light green, soft, laminated, fissile, and flaggy (b) *Siltstone:* green, hard, flaggy, with current lineations (c) *Sandstone:* grey, flaggy, medium to coarse, poorly sorted. It contains grains 0.1 to 5 mm long of red-brown and white, fine-grained siltstone (possibly metamorphosed), soft white siltstone, fine chert, and medium-grained quartzite. The quartz and quartzite grains are well rounded. Other grains are mostly subrounded or subangular. The rock is cemented by silica
Total 40.5	Underlain by Pear Tree Dolomite

SECTION 4. Mallabah Dolomite — measured 1.6 km north of Farquharson Gap, Wave Hill Sheet area.

Thickness (m)	*Overlain by Kunja Siltstone*
4.5	*Dolomite:* red-brown, flaggy, laminated, with cross-bedded units a few millimetres thick. Much of it is intraformational conglomerate with vaguely defined fragments up to 5 cm long and 3 mm thick. Thin sections show that the laminations are produced by varying quantities of iron oxide. The grainsize is about 0.1 mm. The fragments are vaguely defined, and probably the rock has been recrystallized
9	*Dolomite:* pink, laminated, flaggy
Total 13.5	Underlain by Amos Knob Formation

SECTION 5. Mallabah Dolomite (type section) — measured 1.6 km east of Swan yard, Limbunya Sheet area.

Thickness (m)	*Overlain by Kunja Siltstone*
6	*Dolomite:* grey-pink, flaggy, laminated to thin-bedded
23	*Dolomite:* grey-buff, flaggy and fissile, laminated. Some silty dolomite
45.5	*Dolomite:* purple, buff, and grey, blocky, thin-bedded to laminated. Grainsize is about 0.01 mm
26	*Dolomite:* pink and purple, flaggy, laminated to thin-bedded. In thin section the rock consists entirely of carbonate with an average grainsize of about 0.05 mm
Total 100.5	Underlain by Amos Knob Formation

SECTION 6. Kunja Siltstone (type section) — measured 2 km east of Swan yard, Limbunya Sheet area.

Thickness (m)	*Overlain by Farquharson Sandstone*
9	No outcrop
6	Interbeds of *siltstone:* purple and green, soft and fissile; green, flaggy, indurated *siltstone:* green and white, flaggy and fissile; and *dolomite* with scattered quartz grains
46	Poor outcrop: probably siltstone
Total 61	Underlain by Mallabah Dolomite

SECTION 7. Part of Limbunya Group and Wickham Formation — measured 7 km east of Kirkimbie homestead, Limbunya Sheet area.

Group	*Formation name*	*Thickness (m)*	*Top of section — no further outcrop*
WATTIE GROUP	Wickham Formation	10	*Chert:* massive to blocky, white milky
		305	*Sandstone:* massive, flaggy in parts near base, thick-bedded to thin-bedded, medium-grained, feldspathic, well sorted, grains subrounded; bed frequently crops out as small hills on flatter sandstone surface (gives spotty appearance on air-photographs)
LIMBUNYA GROUP	Killaloc Formation	23	*Claystone:* pink to grey and white; fine-grained spotted *siltstone,* probably dolomitic
	Fraynes Formation	106	*Marl* and flaggy *dolomite* sequence, silicification common; some folding and slump structures in dolomite; sequence more dolomitic near base, pink and grey crystalline dolomite with some small stromatolites; about 20 m of marl and flaggy dolomite beds at base
	Campbell Springs Dolomite (376 m)	194	*Dolomite and siltstone:* Interbedded flaggy and fissile, thin-bedded and laminated, grey and purple respectively; some grey and yellow flaggy dolomite with dark grey dolomite concretions; purple and grey dolomite interbedded with fissile laminated dolomite siltstone near base; 15 m of dark red dolomitic shale at base
		182	*Dolomite:* fissile, laminated, pink to grey and purple, crystalline; becomes flaggy and blocky lower down; one massive bed with poorly preserved stromatolites; flaggy dolomite and a massive, very weathered dark grey coarsely crystalline band and some more marly beds near base; flaggy, laminated crystalline dolomite at base
	Blue Hole Formation (303 m — type section)	30	*Shale:* fissile laminated, dolomitic, purple, interbedded with dark brick red stromatolitic (large domes) flaggy to massive dolomite
		36	*Shale:* thinly fissile, laminated, dark purple, grey, and green
		61	*Siltstone:* purple, flaggy, dolomitic, fissile in parts, thin-bedded
		97	*Dolomite:* grey and purple, flaggy to blocky, thin-bedded to medium-bedded, with interbedded purple *dolomitic shale;* folding in shale bands. Conical structure in dolomite beds (Figs 8 and 9)
		79	*Siltstone:* purple, flaggy, overlying *shale* with greater fissility; shale is dark purple with grey laminated beds with abundant hematite; micaceous beds
	Farquharson Sandstone	79	*Siltstone:* purple, micaceous, fissile, laminated; underlain by blocky, fine-grained, indurated, mud-flaked and mud-cracked *sandstone;* below sandstone are fine-grained, purple-brown, flaggy *silty sandstone* and rare stromatolitic silty *dolomite;* basal beds are sandy, purple, fissile and flaggy *siltstone*
	Kunja Siltstone	12+	*Shale:* purple, fissile, laminated
			Base of section — core of anticline

SECTION 8. Farquharson Sandstone (type section) — measured at Farquharson Gap, Wave Hill Sheet area.

Thickness (m)	Overlain by Blue Hole Formation
107	*Sandstone:* red-brown and grey, massive and blocky, fine-grained, thin-bedded, poorly to moderately sorted. It contains about 5% of a white clay matrix which makes the rock friable. Numerous beds are crammed with mudflakes up to 2 cm long
4.5	*Sandstone:* similar to the overlying sandstone but better sorted. It contains less clay matrix but contains up to 10% white and red-stained grains of clay. Mud cracks and a few faint oscillation ripples also seen Thin sections show it to be moderately to poorly sorted with grains up to 0.1 mm diameter and subangular to subrounded. They are mostly of quartz, but chert (quartz crowded with fine sericite and iron oxide), tourmaline, and iron oxide form about 10 % of the rock. The matrix is partly of silica in the form of syntaxial rims, and partly of sericite and fine iron oxide.
Total 111.5	Underlain by Kunja Siltstone

SECTION 9. Farquharson Sandstone — 2.5 km east-northeast of Swan yard, Limbunya Sheet area.

Thickness (m)	Overlain by Blue Hole Formation
3	*Sandstone:* grey and fawn, blocky to flaggy, thin to medium-bedded, very poorly sorted, fine to coarse. Contains numerous mud flakes, chips of dolomite, large quartz grains
13.5	*Sandstone:* brown and cream, blocky to flaggy, but massive near top, thin to medium-bedded, fine to medium
9	*Interbedded:* (i) Fine flaggy *sandstone* which in thin section is similar to the sandstone at Farquharson Gap, but contains up to 5 percent of feldspar (mainly plagioclase) and minor zircon (ii) Fawn fissile *siltstone* containing grains of quartz, plagioclase, microcline, a yellow-brown clay mineral, opaques, and tourmaline, and flakes of muscovite in a matrix of sericite
16.5	*Sandstone:* fawn, flaggy, thin to medium-bedded, fine-grained
Total 42	Underlain by Kunja Siltstone

SECTION 10. Blue Hole Formation — measured 3 km northeast of Swan yard, Limbunya Sheet area.

Thickness (m)	Overlain by Campbell Springs Dolomite
6	*Siltstone:* fawn, flaggy, laminated, extremely well indurated by siliceous matrix; about 10% quartz and feldspar sand grains of 0.3 mm diameter interbedded with *dolomite:* grey and brown, blocky and massive, thin-bedded; almost entirely composed of stromatolites
3	No outcrop
30.5	Interbedded *dolarenite;* pink-grey, fissile, laminated *silty dolomite;* and grey flaggy *dolomite*
27.5	*Dolomite:* greyish purple, flaggy and blocky, thin-bedded to medium-bedded; interbedded with purple, flaggy and fissile, thin-bedded and laminated *siltstone;* siltstone predominates in lower part
3	*Silty dolomite* and *dolomite:* greyish purple, flaggy, laminated and thin-bedded; up to 10% quartz silt grains
49	No outcrop (probably siltstone)
21.5	*Dolomite:* dark red, flaggy, laminated
9	*Dolomite:* pink-grey, flaggy to blocky; abundant chert nodules and lenses
4.5	*Silty dolomite:* pale grey, fissile, laminated, interbedded with laminated to thin-bedded *dolomite*
3	*Dolomite and dolarenite:* interbedded; latter contains dolomite clasts 0.1-3.0 mm in diameter in a micrite matrix
3	*Dolarenite:* dolomite fragments up to 1 cm, and subangular to subrounded quartz, quartzite, and iron oxide grains up to 1 mm. Matrix of dolomitic siltstone with 50% quartz grains
Total 160	Underlain by Farquharson Sandstone

SECTION 11. Blue Hole Formation — estimated from aerial photographs and measured dips at Farquharson Gap, Wave Hill Sheet area.

Thickness (m)	*Overlain by Wickham Formation*
70	No outcrop — probably siltstone
70	*Dolrudite:* reddish purple, flaggy to blocky, with fragments up to 10 cm x 0.5 cm
3	*Siltstone:* dark grey, fine, fissile, interbedded with reddish brown *silty dolomite;* latter contains discontinuous green shale laminae, and is about 50% brown-stained dolomite and 50% angular quartz grains (0.03 mm diameter)
174	*Siltstone:* reddish brown and pink, flaggy to blocky, laminated, little outcrop
Total 317	Underlain by Farquharson Sandstone

SECTION 12. Wickham Formation (type section) — paced along southern side of Wattie Creek 22 km west of its confluence with the Victoria River, Wave Hill Sheet area.

Thickness (m)	*Overlain by Burtawurta Formation*
46	No outcrop
30	*Sandstone:* strongly cross-bedded
9	No outcrop
15	*Sandstone:* blocky, brown-stained, medium-grained, with minor white grains
15	No outcrop
10	Blocky sandstone
46	*Sandstone:* massive, white, thin-bedded, with 2% feldspar grains
15+	*Chert:* bedded, partly brecciated
Total 176+	Underlain by Campbell Springs Dolomite

SECTION 13. Mount Sanford Formation — measured at Neave Creek, Wave Hill Sheet area.

Thickness (m)	*Overlain by Neave Sandstone*
12	*Siltstone:* thin beds; grey-green, purple, and brown. Flaggy beds of *?ashstone*
1	*Dolomite:* massive, light grey, with chert nodules
1	*Siltstone:* purple and grey bands, fine-grained, thin-bedded, massive
0.5	*Siltstone:* purple and greyish green
9	*Dolomite:* blocky and massive, interbedded with fissile *siltstone* and fine-grained flaggy *sandstone*
Total 23.5	Underlain by Hughie Sandstone

SECTION 14. Type section of Mount Sanford Formation — measured on western side of Depot Creek (grid ref. 651124), Waterloo Sheet area.

Thickness (m)	*Overlain by Neave Sandstone*
1.5	*Chert* and silicified *claystone*
4.5	*Dolomite:* flaggy; interbedded with dolomitic *siltstone*
1.5	*Dolomite:* massive, grey, fine crystalline
4.5	*Dolomite:* flaggy; and dolomitic *siltstone*
2	*Dolomite:* massive
38.5	*Siltstone:* flaggy, purple and greyish green; fine *sandstone* and a few white *marl* and flaggy *dolomite* beds
Total 52.5	Underlain by Hughie Sandstone

SECTION 15. Type section of Gibbie Formation — measured at Neave Creek, Wave Hill Sheet area.

Thickness (m)	*Overlain by Seale Sandstone*
12	*Sandstone:* white, blocky and flaggy, fine and medium-grained; thin interbeds of red micaceous *siltstone.* About 80% of the sequence is sandstone
1	*Siltstone:* green and purple, contains muscovite and medium-grained quartz sand grains
12	*Sandstone:* flaggy with small mud pellets
Total 25	Underlain by Neave Sandstone

SECTION 16. Type section of Seale Sandstone — measured at Neave Creek (grid ref. 675046), Wave Hill Sheet area.

Thickness (m)	*Overlain by Timber Creek Formation*
16	*Sandstone:* white and fawn, blocky, thin-bedded
16	*Sandstone:* grey and white, massive; cross-bedded units up to 1 m thick; mud flakes
24	*Sandstone:* as above, many mud flakes, appreciable iron oxide content
45	*Massive sandstone:* passes down into blocky sandstone with micaceous parting planes
Total 101	Underlain by Gibbie Formation

SECTION 17. Composite section of Timber Creek Formation — measured in southwestern Victoria River Downs Sheet area.

Thickness (m)	*Overlain by Skull Creek Formation*
15	*Dolomite:* flaggy and blocky, pink to grey, finely crystalline, with interbeds of coarse, purple and grey *siltstone*
1	*Dolomite:* blocky, medium to thin-bedded, pink, finely crystalline. Chert nodules abundant
1	*Dolomitic siltstone:* grey and pink, flaggy, thin-bedded
1	*Dolomite* with chert nodules; blocky and flaggy, thin-bedded, pale pink-purple
4.5	*Dolomitic siltstone:* flaggy and fissile, thin-bedded and laminated, pink and white. Top 1.5 m is coarser than remainder
0.5	*Dolomite* with chert: flaggy, grey, thin-bedded
8	*Dolomitic siltstone:* As for 4.5 m of siltstone above; 2 m from base is 0.5 m bed of brown, fine dolomitic siltstone
0.5	*Dolomite:* flaggy, thin-bedded, grey, with chert nodules
20.5	Interbedded *dolomitic siltstone* and grey *dolomite*
9	*Dolomite:* massive, light grey, finely crystalline in lower part; dark grey, coarsely crystalline above; laminated throughout
6	Interbedded *siltstone* and flaggy *dolomite*
0.5	*Dolomite:* blocky, grey, finely crystalline
50.5	Thinly interbedded micaceous *dolomitic siltstone,* fine *sandstone,* and *dolomite* with ripple marks, mud flakes, and halite casts
Up to 50	Unknown thickness of Timber Creek Formation, not measured
1	Flaggy, fine *dolomite*
4.5	Thinly interbedded, flaggy and fissile, grey and purple *siltstone* with flaggy, dolomitic, red-brown and purple *sandstone* and grey *dolomite*
1	*Cherty dolomite:* flaggy and blocky, thin-bedded
1	Massive, thin-bedded, grey *dolomite.* Chert nodules abundant in some beds
10.5	*Micaceous siltstone:* fissile and flaggy, laminated and thin-bedded, friable, purple with thin interbeds of fine *sandstone* and *dolomite*
1.5	*Dolomitic sandstone:* fissile, laminated and thin-bedded, white, fine-grained, micaceous
22	Interbedded coarse purple *siltstone* and fine white and purple-brown *sandstone* which is flaggy, friable, and spotted. Rare thin *dolomite* bands
0.5	*Micaceous sandstone:* blocky, thin-bedded, friable, white, fine, some medium cross-beds
2.5	*Dolomitic siltstone:* flaggy, laminated and thin-bedded, spotted, purple
0.5	*Dolomite:* fissile, laminated, grey, silty, white where weathered
6.5	*Sandy siltstone:* fissile and flaggy, laminated and thin-bedded, coarse, purple, coarser near base. Rare thin *dolomite* beds
4.5	*Dolomitic sandstone:* flaggy, thin-bedded, with rare silty beds
Total 174-224	Underlain by Seale Sandstone

SECTION 18. Upper part of the Skull Creek Formation — measured 4 km southwest of Humbert River homestead, Victoria River Downs Sheet area.

Thickness (m)	*Overlain by Bynoe Formation*
3	*Dolomite:* massive, laminated, grey, finely crystalline. A few dolarenite laminae
16	Poor outcrop — probably *dolomitic siltstone* and flaggy *dolomite*
14.5	Two prominent massive, coarsely crystalline, grey *dolomite* beds. May be a thin siltstone bed at the base
Total 33.5	Underlain by Supplejack Dolomite Member

SECTION 19. Middle and lower part of Skull Creek Formation — measured 15 km west-northwest of Humbert River homestead, Waterloo Sheet area.

Thickness (m)	*Overlain by upper part of Skull Creek Formation* (see Section 18)
12	*Supplejack Dolomite Member:* massive, grey, coarsely crystalline
5.5	*Dolomite:* flaggy, grey, with streaks and nodules of chert
5.5	Scree and travertine
2.5	*Dolomite:* fine-medium, crystalline; some chert
3.5	No outcrop; some marly scree
1.5	*Dolomite:* flaggy; top 0.3 m is dolrudite with 2-5 cm clasts
4	Blocky grey *dolomite* with chert
4	No outcrops; scree and travertine
2	*Dolomite:* flaggy and blocky, fine and medium, thin-bedded
2.5	No outcrop
3.5	*Dolarenite* with chert
6	No outcrop
0.5	*Dolomite:* flaggy, grey, finely crystalline, with thin chert laminae and spheres 1-2 mm across
2.5	No outcrop
13.5	Blocky *dolomite* with spheres and halite casts
11	Travertine
0.5	*Dolomite* with halite casts
15	No outcrop
1	*Dark grey dolomite:* fetid odour when split
31.5	No outcrop
1.5	*Dolomite:* blocky, with chert; basal 1.0 m is coarsely crystalline, pink to mauve dolomite with slightly fetid odour when split. Top 0.5 m is almost completely silicified, and contains close-packed, rod-like structures 1-2 cm across and 7-20 cm high. They are probably stromatolites
Total about 130	Underlain by Timber Creek Formation

Including Section 18 the formation totals *164* m.

SECTION 20. Skull Creek Formation — measured at the southern end of Fitzgerald Range, 9 km north of Victoria River Downs homestead.

Thickness (m)	*Top of hill*
3	*Bardia Chert Member:* massive, laminated chert
24.5	Interbedded flaggy *dolomite* and *dolomitic siltstone*
9	*Dolomite:* massive, well laminated; contains columnar stromatolites up to 0.3 m across and 0.6 m high
13	Interbedded siltstone and dolomite
10	*Supplejack Dolomite Member:* massive crystalline dolomite; stromatolitic at top
30	*Dolomite:* blocky, grey, finely crystalline, with chert nodules; halite casts and small siliceous spheres (1-5 mm) in lowermost beds; thinly interbedded flaggy dolomitic siltstone
9	Poor outcrop of siltstone with rare flaggy *dolomite* interbeds
Total 98.5	Bottom of hill

SECTION 21. Bynoe Formation — measured at Station Hill, 14 km northwest of Victoria River Downs homestead, Victoria River Downs Sheet area.

Thickness (m)	*Overlain by Jasper Gorge Sandstone*
17.5	Soft *siltstone,* numerous thin sandy interbeds
0.5	*Sandstone:* fine-grained, thinly cross-bedded, some carbonate cement
24.5	*Siltstone:* red, brown, and purple micaceous siltstone. Numerous interbeds of fine-grained glauconitic *sandstone;* ripple marks and primary current lineations. Basal 0.1 m bed of *sandstone:* purple-brown, with prominent laminae and ripple marks
54.5	Interbedded siltstone and sandstone. *Siltstone:* purple, massive, poorly outcropping; some grey-green interbeds. *Sandstone:* thin, flaggy and fissile, fine-grained, silty, purple-brown
0.5	*Sandstone:* single massive bed, well indurated, purple-brown; contains numerous small holes (probably calcite leached out)
9.5	*Siltstone:* poorly outcropping
0.5	*Sandstone*
4	Grey-green *siltstone*
0.5	*Sandstone:* grey, friable, very fine-grained, some argillaceous matrix
Approx. 10	*Siltstone:* massive, non-laminated, coarse-grained, chocolate or red-brown with circular patches of grey-green; some interbeds of soft flaggy grey-green *siltstone*
Total about 120	Underlain by Skull Creek Formation

SECTION 22. Upper part of type section of Battle Creek Formation — measured immediately west of Waterbag Creek, 11 km west of Moolooloo outstation, Victoria River Downs Sheet area.

Thickness (m)	*End of outcrop*
9	*Sandstone:* blocky, brown, coarse to gritty, friable, quartz-rich; indurated in part, moderately well sorted, rounded grains
6	No outcrop; boulders of flaggy sandstone
3	*Sandstone:* flaggy, brown, medium-grained
8	*Sandstone:* blocky, medium-bedded, grey-brown, fine to medium; mud flakes and rare cross-bedding
1	*Sandstone:* flaggy, thin-bedded, friable, fine-grained
Total 27	Underlain by siltstone of same formation

SECTION 23. Upper part of Battle Creek Formation 7 km northwest of Section 22.

Thickness (m)	*Overlain by Antrim Plateau Volcanics*
6	*Sandstone:* flaggy, white, fine-grained
12	*Sandstone:* white and brown, coarse-grained, cross-bedded; grit bands and conglomerate
15	*Sandstone:* flaggy, thin-bedded, medium-grained
3	*Sandstone:* blocky, red-brown to white, fine to medium
Total 36	Underlain by siltstone of same formation

SECTION 24. Part of Battle Creek Formation — measured 1.5 km northwest of O.D. Bore, Victoria River Downs Sheet area.

Thickness (m)	*Top of hill*
3	*Dolomite:* red-brown, blocky, thin-bedded, with hematite and stromatolites
4.5	*Dolomitic siltstone:* white to red-brown and grey, fissile, laminated
2	*Dolomite:* red-brown, blocky to flaggy, medium-bedded, highly stromatolitic
8	*Dolomite:* red-brown, flaggy, silty
Total 17.5	Base of hill

SECTION 25. Battle Creek Formation — measured between Waterbag and Battle Creeks at grid ref. 748208, Victoria River Downs Sheet area.

Thickness (m)	*Top of hill*
4.5	*Dolomite:* dark purple, blocky, medium-bedded; minor *siltstone;* chertification common
0.5	*Dolomite:* dark brown and purple, crystalline
2	*Siltstone:* purple and green, coarse-grained
3.5	*Siltstone:* grey-green and purple, overlain by grey-green, fissile, friable, fine-grained *sandstone*
0.5	*Dolomite:* dark purple, ferruginous, glauconitic
3	*Siltstone:* grey-green, fissile, laminated, coarse-grained
Total 14	Base of hill

SECTION 26. Type section (upper part) of Nero Siltstone — measured 5 km southwest of Mount Gordon, Wave Hill Sheet area.

Thickness (m)	*Overlain by Mount Gordon Sandstone*
14	*Siltstone:* cream, fissile, with purple and brown, flaggy to fissile, micaceous fine-grained *quartz sandstone* interbeds
24	*Shale:* uniform purple and green, fissile, friable, laminated
12	*Siltstone:* olive-green, minor cream and purple, micaceous, friable, and fissile, laminated, medium-grained
6	*Siltstone:* olive-green, very micaceous, friable, fissile, laminated, fine-grained
3	*Quartz siltstone:* grey-green, fissile, thin-bedded
Total 59	Base not seen

SECTION 27. Type section of Jasper Gorge Sandstone — measured 1 km north of Jasper Gorge at grid ref. 684234, Delamere Sheet area.

Thickness (m)	*Top of hill*
12.5	*Sandstone:* flaggy to blocky, red-brown to white, medium-bedded, well sorted, grains well rounded, cross-bedded
18	*Sandstone:* massive, thick-bedded, medium-grained, red-brown to white, large-scale slump folds (1 m high) abundant
17	*Sandstone:* flaggy, thin-bedded, fine to medium, red-brown. Massive band 1 m thick lies 1 m below top of this section
5.5	*Sandstone:* blocky, medium-bedded, medium-grained, white, grains well rounded
3	*Quartz siltstone:* fissile, laminated, brown; fine-grained *sandstone*
2	*Sandstone:* flaggy, thin-bedded, brown to white, fine-grained, interference ripples common
2	*Sandstone:* blocky, medium-bedded, friable, white, becoming flaggy towards base
4.5	*Sandstone:* flaggy, thin-bedded, friable, white, becoming flaggy towards base
6	*Sandstone:* blocky, medium-bedded, medium-grained, red-brown to white. Small-scale cross-bedding with amplitude 5 to 15 cm
6	*Sandstone:* flaggy, thin-bedded, fine-grained, white; minor coarse silty bands and purple *sandstone* bands
1.5	*Sandstone:* blocky, medium-bedded, fine to medium, white to red-purple
4	*Sandstone:* massive, thick-bedded, medium-grained, white to red-brown, cross-bedded, grains well rounded, well sorted
Total 82	Underlain by Stubb Formation

SECTION 28. Angalarri Siltstone — measured at grid ref. 576147, 44 km south of Kildurk homestead, Waterloo Sheet area.

Thickness (m)	*Angalarri Siltstone* (see Section 29)
4.5	*Sandstone:* blocky, mottled brown and pale purple, micaceous, some interference ripple marks (probably the same sandstone as at base of Section 29)
10.5	No outcrop
4.5	*Siltstone:* quartz-rich, laminated, fissile, purple and grey-green
13.5	*Shale:* fissile, chocolate and green
Total 33	Underlain by Jasper Gorge Sandstone

SECTION 29. Angalarri Siltstone — measured at grid ref. 571147, 44 km south of Kildurk homestead, Waterloo Sheet area.

Thickness (m)	*Top of hill*
3	*Sandstone:* very fine, some silt, cross-bedded, massive and blocky, extremely friable
97.5	*Siltstone:* very coarse, poorly outcropping except for one ledge comprising large-scale cross-bedded silty sandstone (Fig. 32) with mud cracks
0.5	*Sandstone:* fine to medium orthoquartzite; contains spots 2-3 mm across of limonite-cemented sand grains
18	*Silty sandstone* or *sandy siltstone:* flaggy and massive, ripple marks, mud flakes, skip and flute casts, limonite spots
12	No outcrop
1	*Sandstone:* massive, very fine-grained, clayey matrix
27.5	No outcrop except 1 m of flaggy, fine *sandstone* with mud-flaked surface
1.5	*Silty sandstone:* massive, weathers red-brown, thin-bedded with brown laminae, micaceous partings, numerous limonite spots
38	No outcrop: scree of fissile green siltstone
1	*Sandstone:* medium-grained, extremely friable, limonitic (see sandstone at top of Section 28)
Total 215	Base of hill (for lower beds see Section 28)

SECTION 30. Type section of Blackfella Rockhole Member of Antrim Plateau Volcanics — measured at Blackfella Rockhole, Limbunya Sheet area.

Thickness (m)	*Overlain by Headleys Limestone*
24.5	*Basalt:* extensively altered, soft, vesicular in upper part of flow with thin lenses of more massive basalt; grades downwards into massive basalt (highly ferruginized)
1	*Agglomerate(?)* with sandstone lenses
6	Highly vesicular *basalt* containing large vugs lined with quartz; grades downwards into slightly to moderately vesicular basalt
39.5	*Agglomerate* — flat-lying and forming steep-sided cliffs bordering creek bed. Dark red-brown colour
Total 71	Underlain by basalt

SECTION 31. Section of Blackfella Rockhole Member of Antrim Plateau Volcanics — measured on west bank of Negri River (at grid ref. 530059), 15 km southwest of Bigley Springs, Limbunya Sheet area.

Thickness (m)	*Overlain by Headleys Limestone*
6	Upper part of flow consists of soft, highly vesicular *basalt;* grades downwards into fine-grained massive basalt. Fragments of quartz and agate abundant
24.5	*Agglomerate* with minor medium to fine *sandstone* in the upper part
Total 30.5	Underlain by medium-grained basalt

SECTION 32. Blackfella Rockhole Member of Antrim Plateau Volcanics — measured at grid ref. 519102 on hillside bordering Stirling Creek, 16 km southeast of Mistake Creek homestead, Limbunya Sheet area.

Thickness (m)	*Overlain by Headleys Limestone*
9	*Basalt:* fine-grained, vesicular towards top
3	*Sandstone*
4.5	*Agglomerate*
24.5	*Basalt:* soft, crumbly, extensively altered, vesicular, becoming massive towards base
17	*Agglomerate*
Total 58	Underlain by 13.5 m of vesicular basalt

SECTION 33. Part of Antrim Plateau Volcanics (including all the Bingy Bingy Basalt Member) — measured at grid ref. 526062 about 7 km northeast of Bingy Bingy Springs, Limbunya Sheet area.

Thickness (m)	*Top of hill*
18.5	*Agglomerate*
24.5	*Basalt:* soft, highly weathered, vesicular, grading down into hard, massive basalt
39.5	*Bingy Bingy Basalt Member:* Plagioclase phenocrysts prominent in massive parts. Highly vesicular *basalt* at the top of flow with abundant quartz-filled vugs; quartz, agate, and minor calcite occur in vesicles and cover weathered surfaces. Spheroidal weathering towards top of flow. Grainsize decreases towards base
58	*Basalt:* thick sequence of soft, crumbly, heavily decomposed, highly vesicular basalt containing thin bands of more massive *basalt*
Total 140.5	Base of hill — underlain by basalt

SECTION 34. Part of Antrim Plateau Volcanics (including Bingy Bingy Basalt Member) — measured about 26 km southwest of Mount Napier, Limbunya Sheet area.

Thickness (m)	
23	*Agglomerate*
24.5	Very little outcrop. Mainly soft, heavily altered, vesicular *basalt* with more massive basalt characterized by spheroidal weathering towards base
1	*Agglomerate* with minor admixed sandstone
9	*Bingy Bingy Basalt Member:* Highly vesicular, extensively altered *basalt* with small quartz-filled vugs; quartz, agate, and calcite common; grades into massive, porphyritic basalt. Cut by small *basalt dyke:* massive, heavily altered; about 1.5 m wide and 90 m long; extends only to the base of the agglomerate band
30.5	*Basalt:* massive, medium to coarse, porphyritic
Total 88	Underlain by basalt

SECTION 35. Nelson Shale — measured 8 km north of Mount Panton, Limbunya Sheet area.

Thickness (m)	*Overlain by Linnekar Limestone*
6.5	*Siltstone:* red-brown, massive to flaggy, nodular, micaceous, coarser-grained bands are more resistant to weathering
0.5	*Calcarenite:* fawn to grey, laminated fissile; finely crystalline *limestone;* some halite pseudomorphs
2	*Calcareous shale:* grey, fissile, laminated
4.5	*Siltstone* and *mudstone:* red-brown, blocky to fissile, poorly bedded; thin grey *shale* bands
Total 13.5	Base not exposed

SECTION 36. Linnekar Limestone — measured 3 km southeast of Blackfella Rockhole, Limbunya Sheet area.

Thickness (m)	*Overlain by Panton Formation*
1.5	*Limestone:* grey to fawn, flaggy crystalline, some finely banded chert at the top
1.5	*Limestone:* grey, massive, crystalline
0.5	*Limestone:* grey, blocky, crystalline
5.5	*Limestone:* grey, flaggy, thin-bedded, crystalline
6.5	*Calcareous siltstone and shale:* cream, fissile, thin-bedded to laminated, soft
1	*Limestone:* grey, blocky to flaggy, crystalline, some chert nodules
2	*Limestone:* grey, blocky, medium-bedded, crystalline, chert nodules, some stromatolites
3.5	*Limestone:* grey, blocky to flaggy, thin-bedded, crystalline
Total 22	Underlain by Nelson Shale

REFERENCES

DUNBAR, C. O., & RODGERS, J., 1957—PRINCIPLES OF STRATIGRAPHY. *N.Y., Wiley.*

FOLK, R. L., 1962—Spectral subdivision of limestone types. *In* Ham, W. E. (ed.)—Classification of carbonate rocks: A symposium. *Mem. Amer. Ass. petrol. Geol.,* I.

PETTIJOHN, F. J., 1957—SEDIMENTARY ROCKS. *N.Y., Harper.*

WENTWORTH, C. K., 1922—A scale of grade and class terms for clastic sediments. *J. Geol.,* 30, 371-92.

APPENDIX II — GEOCHEMICAL SAMPLING RESULTS

Sixty-three samples of rock chips were collected from Bullita Group rocks in the Waterloo and Victoria River Downs Sheet areas. They were analysed for Fe, Zn, Cu, Pb, Mn, Ni, and Co; the results were reported by Claxton & Weekes (1971).

Table I contains results of the sampling of Skull Creek Formation at the southern end of the Fitzgerald Range at the same locality as Section 20 (Appendix I). Each sample consisted of rock chips taken from outcrops over 15-m intervals. Because the dolomite crops out more strongly than the interbedded siltstone there is a bias toward the dolomite in sampling. The only anomalous value obtained was 45 ppm Pb for 7077 0272E; this represents dolomite at the base of, or just below, the Supplejack Dolomite Member.

The Skull Creek Formation was also sampled 2 km south of the Wickham River 7 km southwest of Victoria River Downs homestead. Because the rocks dip at about 45° at the beginning of the section (7077 0247A) and at 20° at the end (sample 7077 0274T), the samples (taken over 30-m intervals) represent stratigraphic intervals of between 20 m and 10 m, respectively. The results, which are presented in Table II, show only slightly higher values for lead in approximately the position of the Supplejack Dolomite Member.

Results for the Bynoe Formation, which was sampled in three localities, are presented in Table III. Samples 7077 0275B-F and 7077 0277A-D are from mesas 2.5 and 15 km east and south of Bullita homestead, respectively; 7077 0275A is from the Wondoan Hill Formation. The samples each represent a 15-m thickness of the formation. The only notable values are for Cu recorded from the top of the Bynoe Formation, but these are regarded as higher background values rather than anomalous. The 131 ppm Cu in 7077 0275F is the highest recorded value.

Table IV contains results of analyses of samples from the Battle Creek Formation.

REFERENCE

CLAXTON, C. W., & WEEKES, J., 1971—Analysis of carbonate rocks from Victoria River Area, N.T. *Lab. Rep.* 56 *in Bur. Miner. Resour. Aust. Rec.* 1971/37 (unpubl.).

TABLE I. Analyses of Skull Creek Formation from southern end of Fitzgerald Range (all values in ppm except Fe).

Reg. No.	*Fe (%)*	*Zn*	*Cu*	*Pb*	*Mn*	*Ni*	*Co*
7077 0727A	0.78	1	6	1	1635	3	3
7077 0272B	0.5	8	3	3	395	3	3
7077 0272C	0.7	8	5	3	1208	1	1
7077 0272D	0.68	9	6	8	1145	4	1
7077 0272E	0.63	10	6	45	258	1	1
7077 0272F	0.68	10	5	10	184	3	1
7077 0272G	0.65	7	11	3	175	1	1

TABLE II. Analyses of Skull Creek Formation from section 7 km southwest of Victoria River Downs homestead (all values in ppm except Fe)

Reg. No.	*Fe (%)*	*Zn*	*Cu*	*Pb*	*Mn*	*Ni*	*Co*
7077 0247A	1.05	10	55	3	918	4	6
7077 0247B	0.83	10	5	3	1400	1	1
7077 0247C	0.68	15	8	3	1698	1	3
7077 0247D	0.78	17	4	40	1950	1	1
7077 0247E	0.70	6	5	25	1480	3	1
7077 0247F	0.63	3	3	35	1000	3	1
7077 0247G	0.63	8	3	1	918	3	1
7077 0247H	0.78	8	9	10	1980	1	1
7077 0247I	0.70	4	4	5	1518	1	1
7077 0247J	0.63	10	3	3	1215	3	1
7077 0247K	0.68	8	6	3	396	5	1
7077 0247L	0.68	6	6	1	268	1	1
7077 0247M	0.68	7	4	1	240	3	1
7077 0247N	0.83	7	9	8	450	1	1
7077 0247O	0.68	11	5	1	298	5	3
7077 0247P	0.58	4	14	3	375	5	1
7077 0247Q	0.70	8	4	3	240	4	3
7077 0247R	0.65	7	13	5	248	3	1
7077 0247S	0.55	6	3	1	180	5	4
7077 0247T	0.40	5	8	3	158	1	4

TABLE III. Analyses of Bynoe Formation (all values in ppm except Fe).

Reg. No.	*Fe (%)*	*Zn*	*Cu*	*Pb*	*Mn*	*Ni*	*Co*
7077 0275A	4.08	22	35	5	55	8	8
7077 0275B	1.3	14	26	3	1563	8	5
7077 0275C	1.3	12	68	3	1460	6	4
7077 0275D	1.8	18	4	5	988	8	8
7077 0275E	1.25	11	4	1	1080	7	4
7077 0275F	0.93	8	131	5	168	5	1
7077 0276A	1.05	21	4	5	1215	8	4
7077 0276B	1.38	19	25	3	960	10	4
7077 0276C	2.42	28	5	8	628	10	5
7077 0276D	1.75	23	3	43	740	10	3
7077 0276E	0.68	17	5	1	715	8	4
7077 0276F	1.25	24	4	1	593	6	5
7077 0276G	1.3	21	9	3	593	10	8
7077 0276H	0.83	16	10	1	480	6	3
7077 0276I	0.85	15	18	3	535	6	4
7077 0276J	1.05	13	6	3	458	6	5
7077 0276K	0.98	18	11	5	513	8	8
7077 0276L	1.08	19	10	3	480	8	4
7077 0277A	1.40	25	31	3	848	10	8
7077 0277B	1.20	20	10	18	780	8	5
7077 0277C	1.43	19	5	5	780	8	8
7077 0277D	1.48	18	3	38	818	8	1

TABLE IV. Trace element analyses of dolomites in the Battle Creek Formation and Lily Hole Sandstone (all values in ppm except Fe).

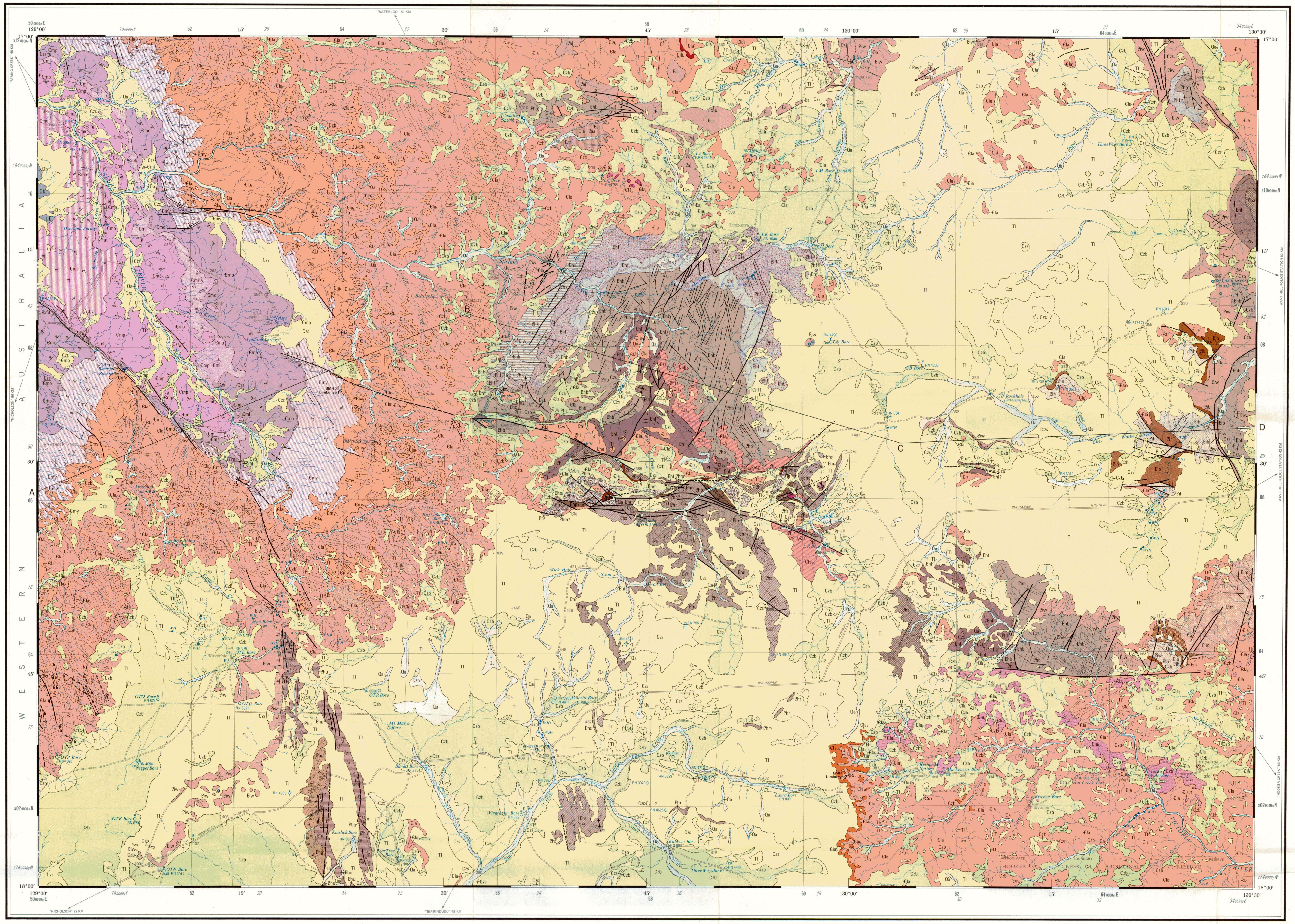
Reg. No.	*Grid Ref. (metric)*	*Rock Type*	*Location*	*Fe (%)*	*Zn*	*Cu*	*Pb*	*Mn*	*Ni*	*Co*
7077 0273	748208	Dark red crystalline dolomite, veins of pyrolusite	5 km NW of Lily Hole Bore	1.05	8	29	5	89 000	3	4
7077 0273	748208	Dark red crystalline dolomite	5 km NW of Lily Hole Bore	0.88	8	5	5	1 875	3	8
7077 0273	748208	Glauconitic red crystalline dolomite	5 km NW of Lily Hole Bore	1.88	5	13	1	10 200	1	5
7077 0278	734182	Red-brown dolomite	8 km ENE of Mount Fisher	0.58	7	1	15	438	3	5
7077 0279	728221	Fawn dolomite	4 km NE of Anderson Lagoon	2.75	7	8	18	1 745	6	10
7077 0280	740189	Brown-red dolomite	On Top Springs Road 15 km E of Victoria R Crossing	1.08	13	11	138	4 000	5	10
7077 0281	742195	Red-brown dolomite	18 km E of Innoculation yard on O.D. Cr	1.58	17	103	10	10 200	10	20
7077 0281	742195	Red-brown dolomite	18 km E of Innoculation yard on O.D. Cr	1.40	12	14	10	4 500	5	8
7077 0281	742195	Red-brown dolomite	18 km E of Innoculation yard on O.D. Cr	1.08	6	11	13	6 875	4	13
7077 0282	749207	Glauconitic red-brown dolomite	19 km E of Weaner Crossing	1.95	7	8	3	8 900	3	5
7077 0283	753194	Red dolomite (Lily Hole Sandstone)	16 km W of Moolooloo	7.20	7	9	5	4 000	5	10
7077 0284	702138	Grey dolomite	8 km SSW of Gregorys Remarkable Pillar	0.40	6	18	1	605	3	1

LIMBUNYA

NORTHERN TERRITORY

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

SHEET SE 52-7



- Geological boundary
- Anticline showing plunge
- Syncline showing plunge
- Monocline
- Fault (D,U indicate relative movement down, up; q—indicates quartz filled fault)

Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes

- Strike and dip of strata
- Prevailing strike and dip of strata
- Strike and dip of strata, facing not known
- Vertical strata
- Horizontal strata
- Dip < 5° (air-photo interpretation)
- Dip 5°–15° (air-photo interpretation)
- Dip 15°–45° (air-photo interpretation)
- Dip > 45° (air-photo interpretation)
- Lineament (air-photo interpretation)
- Trend line (air-photo interpretation)
- Joint pattern (air-photo interpretation)
- Vertical foliation
- Type section locality
- Dyke or vein; b—basic, q—quartz
- Mine
- • Cu — Minor mineral occurrence
- Ba — Barite
- Cu — Copper
- ⊗St — Stratigraphic hole
- RN 809 ○pe — Bore (pe indicates equipped with pump engine)
- Abandoned bore
- Bore with windpump
- □E — Earth tank
- WH — Waterhole
- Sink hole
- Spring

RN809 refers to bore registration number of Mines and Water Resources Branch, Northern Territory Administration

- Road
- Vehicle track
- Fence
- "Limbunya" — Homestead
- Building
- Landing ground
- □Yd — Yard
- Astronomical station
- • 407 — Elevation in metres
- pa — Position approximate
- pd — Position doubtful

Reference

			Unit	Symbol	Description
CAINOZOIC	QUATERNARY			Qa	Alluvium
				Czb	Black and grey residual clay soils, minor alluvium
				Czs	Sand, silt, soil and colluvium. Minor travertine
	TERTIARY			Tl	Pisolitic laterite, ferruginous rubble and soil
PALAEOZOIC	DEVONIAN		Elder Sandstone	Db	White and red-brown feldspathic sandstone
	MIDDLE CAMBRIAN	Negri Group	Hudson Formation	Ꞓme	Red and brown medium feldspathic sandstone and minor siltstone
			Panton Formation	Ꞓmp	Purple and green siltstone, minor shale, gypsum bands, fossiliferous limestone
			Linnekar Limestone	Ꞓml	Grey, flaggy, fossiliferous limestone, minor siltstone interbeds
			Nelson Shale	Ꞓmo	Grey and red calcareous shales with gypsum bands and mudstones
			Headleys Limestone	Ꞓmy	Grey crystalline limestone
	LOWER CAMBRIAN		Antrim Plateau Volcanics	Ꞓla	Massive porphyritic and tholeiitic basalt
			Blackfella Rockhole Member	Ꞓla1	Interbedded basalt and agglomerate, minor intercalated sandstone and siltstone beds
				Ꞓla2	Friable cross-bedded quartz sandstone with some surface silicification
				Ꞓla3	Laminated chert
				Ꞓla4	Interbedded chert and sandstone
				Ꞓla5	Grey tuffaceous sandstone with angular chert fragments near base, minor dark grey chert interbeds
			Bingy Bingy Basalt Member	Ꞓla6	Medium porphyritic basalt with plagioclase phenocrysts
				Ꞓla7	Agglomerate, highly weathered and lateritized in places
PROTEROZOIC	ADELAIDEAN	Auvergne Group	Angalarri Siltstone	Ꝑaa	Khaki and green siltstone with sandstone interbeds
			Jasper Gorge Sandstone	Ꝑaj	Cross-bedded red-brown quartz sandstone, chert fragments near base
		Wattie Group	Seale Sandstone	Ꝑim	Massive to blocky sandstone
			Gibbie Formation	Ꝑig	Interbedded micaceous siltstone and fine sandstone
			Neave Sandstone	Ꝑin	Fine and medium sandstone
			Mount Sanford Formation	Ꝑio	Purple and grey-green siltstone, dolomite. Minor claystone and fine sandstone
			Hughie Sandstone	Ꝑih	Fine to medium quartz sandstone
			Burtawurta Formation	Ꝑib	Micaceous siltstone and fine sandstone
			Wickham Formation	Ꝑiw	Feldspathic sandstone, laminated and brecciated chert interbeds
	CARPENTARIAN OR ADELAIDEAN	Limbunya Group	Undivided	Ꝑhu	Quartz sandstone, shale and dolomite, stromatolites, chert nodules and lenses
			Killaloc Formation	Ꝑhk	Siltstone, interbedded dolomite and minor sandstone
			Fraynes Formation	Ꝑhf	Chert and minor dolomite, brecciated in places; Siltstone and silty dolomite, minor dolomite, chert lenses and nodules
			Campbell Springs Dolomite	Ꝑhb	Grey massive dolomite, minor dolarenite, abundant stromatolites
			Blue Hole Formation	Ꝑhl	Pink, grey and purple silty dolomite, siltstone and dolomite, stromatolitic in places
			Farquharson Sandstone	Ꝑha	Fine and medium quartz sandstone, minor siltstone
			Kunja Siltstone	Ꝑhj	Purple and green siltstone and silty dolomite
			Mallabah Dolomite	Ꝑhm	Grey and buff dolomite
			Amos Knob Formation	Ꝑho	Dolomite and green siltstone, minor sandstone and shale
			Pear Tree Dolomite	Ꝑhp	White, grey and brown chert, stromatolitic in places; Dolomite and dolarenite
			Margery Formation	Ꝑhr	Siltstone and claystone, minor dolomite, chert at top and base
			Stirling Sandstone	Ꝑhs	White and brown quartz sandstone, basal grit and minor conglomerate
	CARPENTARIAN?		Bunda Grit	Ꝑbg	Coarse quartz sandstone and grit, minor fine sandstone and chert
	LOWER PROTEROZOIC?		Inverway Metamorphics	Ꝑi	Red and brown muscovite quartz schist

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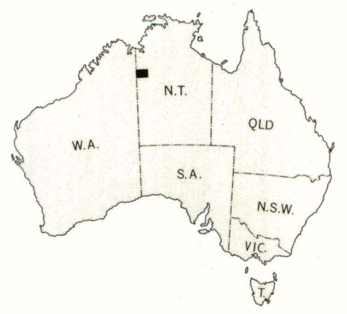

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LANSDOWNE SE 52-5	DIXON RANGE SE 52-6	LIMBUNYA SE 52-7	WAVE HILL SE 52-8	NEWCASTLE WATERS SE 53-5
MOUNT RAMSAY SE 52-9	GORDON DOWNS SE 52-10	BIRRINDUDU SE 52-11	WINNECKE CREEK SE 52-12	SOUTH LAKE WOODS SE 53-9
MOUNT BANNERMAN SE 52-13	BILLILUNA SE 52-14	TANAMI SE 52-15	TANAMI EAST SE 52-16	GREEN SWAMP WELL SE 53-13

ANNUAL CHANGE 0°30'W

Scale 1:250,000

5 0 5 10 15 20 25 KILOMETRES

5 0 5 10 MILES

GREY NUMBERED LINES ARE 20,000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID, ZONE 52
GREY TICKS WITH ITALIC NUMBERS INDICATE THE 20,000 YARD GRID, ZONE 4 (AUSTRALIA SERIES)
TRANSVERSE MERCATOR PROJECTION

Section

Cainozoic sediments omitted from section

Scale: $\frac{V}{H} = 4$

Geology 1969 by C. M. Morgan, I. P. Sweet, J. R. Mendum, R. J. Bultitude
Compiled 1970 by J. R. Mendum, C. M. Morgan, R. J. Bultitude, L. Kerslake
Cartography by Geological Branch BMR
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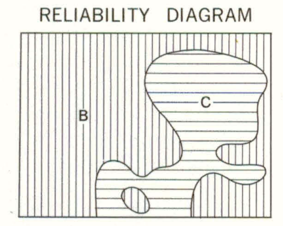
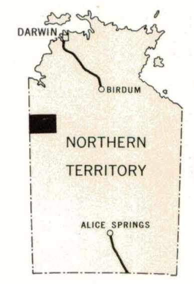
Printed by Mercury-Walch Pty Ltd, Hobart, Australia

RELIABILITY DIAGRAM

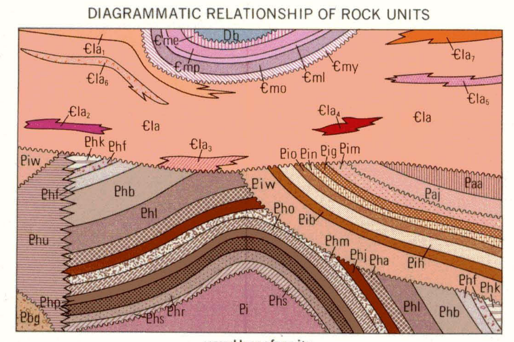


Geology B Detailed reconnaissance: numerous traverses and air-photo interpretation

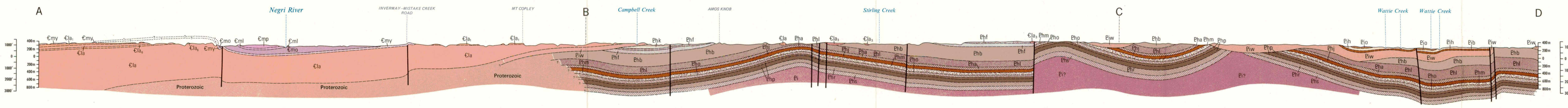
C General reconnaissance: few traverses, mainly air-photo interpretation



DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



Unconformity



FIRST EDITION 1972

LIMBUNYA

SHEET SE 52-7

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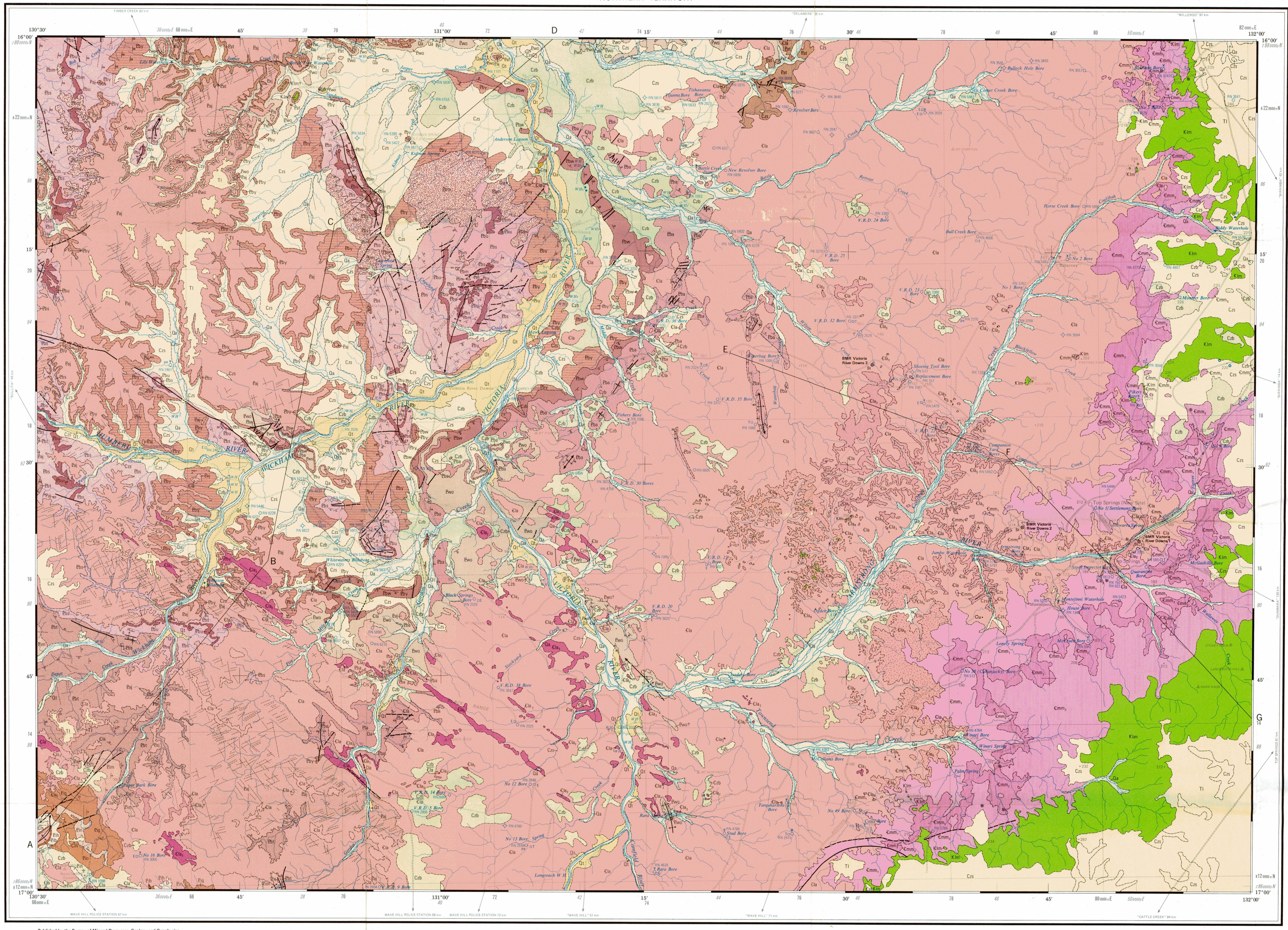
AUSTRALIA 1:250,000 GEOLOGICAL SERIES

VICTORIA RIVER DOWNS

NORTHERN TERRITORY

SHEET SE 52-4



Reference

CAINOZOIC	QUATERNARY		Qa	Gravel, sand, silt : alluvium
			Qt	Older alluvium, mostly silt : terrace deposits
			Czb	Dark grey clayey soil; some alluvium
			Czs	Sand, soil, colluvium, travertine
			Czg	Gravel, pebble and cobble conglomerate; fossil wood fragments
			Tl	Laterite, ferruginous rubble with soil cover in places
MESOZOIC	LOWER CRETACEOUS	Mullaman Beds	Klm	White buff and pink claystone and siltstone, glauconitic sandstone with burrows, ferruginous siltstone and sandstone, ferruginous conglomerate with plant fossils
PALAEOZOIC	MIDDLE CAMBRIAN	Montejinni Limestone	€mm₃	Light brown and grey fossiliferous calcilutite with pink and yellow dolomite patches; persistent stromatolite band at base (shown as €mm in section)
			€mm₂	Red and buff calcareous mudstone, argillaceous limestone; some chert nodules; siliceous breccia at base (shown as €mm in section)
			€mm₁	Mottled calcilutite overlain by thin-bedded calcarenite; chert nodules near base; some dolomite (shown as €mm in section)
	LOWER CAMBRIAN	Antrim Plateau Volcanics	€la	Massive and porphyritic basalt, vesicular and amygdaloidal basalt
			€laₐ	Agglomerate
			€la₂	Friable, cross-bedded quartz sandstone; some surface silicification
			€la₃	Laminated red grey and white chert, minor black crystalline limestone with abundant chert nodules
PROTEROZOIC	ADELAIDEAN	Auvergne Group: Jasper Gorge Sandstone	Paj	Massive and blocky medium friable quartz sandstone; minor siltstone, pebbly sandstone
		Auvergne Group: Stubb Formation	Pat	Interbedded dark grey shale and siltstone; massive quartz sandstone interbeds near top
		Wondoan Hill Formation	Pwo	Glauconitic quartz sandstone, white claystone and siltstone, brown mudstone
		Bullita Group: Battle Creek Formation	Pba	Flaggy red and grey dolomite, green siltstone; minor shale; stromatolitic near base; blocky sandstone at top
		Bullita Group: Weaner Sandstone	Pbw	Coarse quartz sandstone, grit, pebbly beds near base
		Bullita Group: Bynoe Formation	Pby	Interbedded reddish brown and greyish green dolomitic siltstone; grey dolomitic sandstone and dolomite
		Bullita Group: Skull Creek Formation	Pbs	Massive and blocky grey fine and medium crystalline dolomite; minor dolomitic siltstone and sandstone, chert
		Bullita Group: Bardia Chert Member	Pbm	Massive pink laminated and brecciated chert (shown as Pbs in section)
		Bullita Group: Supplejack Dolomite Member	Pbu	Extremely massive dark grey medium crystalline dolomite; minor finely crystalline dolomite; persistent stromatolite band at top (shown as Pbs in section)
		Bullita Group: Timber Creek Formation	Pbt	Interbedded dolomite, dolomitic sandstone and siltstone
		Wattie Group: Seale Sandstone	Pim	Massive and blocky medium quartz sandstone
		Wattie Group: Gibbie Formation	Pig	Flaggy and fissile siltstone, fine sandstone; minor dolomite
		Wattie Group: Neave Sandstone	Pin	Blocky, fine and medium quartz sandstone; minor pebbly beds near base
		Wattie Group: Mt Sanford Formation	Pio	Interbedded flaggy dolomitic siltstone, dolomite and fine sandstone; minor silicified claystone
		Wattie Group: Hughie Sandstone	Pih	Massive fine and medium quartz sandstone
		Wattie Group: Burtawurta Formation	Pib	Flaggy siltstone, fine sandstone; minor dolomitic siltstone, dolomite
		Wattie Group: Wickham Formation	Piw	Massive and blocky fine and medium quartz sandstone
	CARPENTARIAN OR ADELAIDEAN	Limbunya Group	Phu	Dolomite, siltstone, sandstone, chert. Section only

Geological boundary
Anticline, showing plunge
Syncline
Monocline
Fault

Where location of boundaries, folds and faults is approximate, line is broken; where faults are inferred, queried; where concealed, folds are dotted, faults are shown by short dashes

Basin
Dome
Strike and dip of strata
Dip< 5° (air-photo interpretation)
Dip 5°–15° (air-photo interpretation)
Dip 15°–45° (air-photo interpretation)
Dip > 45° (air-photo interpretation)
Lineament (air-photo interpretation)
Trend lines (air-photo interpretation)
Joint pattern (air-photo interpretation)

Macrofossil locality
Microfossil locality
Plant fossil locality
Type section locality
Sample locality for age determination

•Cu Minor mineral occurrence
Cu Copper
Mn Manganese

Pb Lead
⊗St Stratigraphic hole

Bore
Abandoned bore
RN 1101 Reg. No. (Water Resources Branch, N.T. Administration)
Windpump
T Water tank
E Earth tank
Dam on stream
WH Waterhole
Sink hole
Spring
pe Pump engine

Highway
Road
Vehicle track
"Montejinni" Homestead
Building
Landing ground
Yd Yard
Fence
Settlement
Trigonometrical station
Astronomical station
•622 Elevation in metres, approximate

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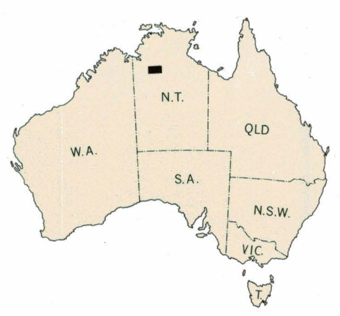
Base map compiled by the Division of National Mapping from aerial photographs at 1:50,000 scale.



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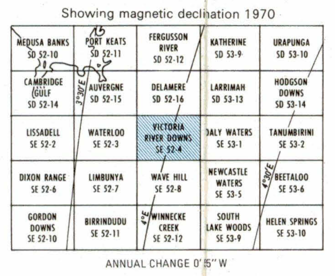


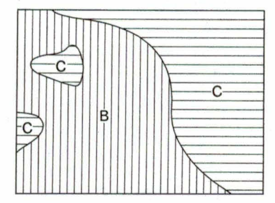
Scale 1:250,000

5 0 5 10 15 20 25 KILOMETRES

5 0 5 10 MILES

GREY NUMBERED LINES ARE 20,000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID, ZONE 52
GREY TICKS WITH ITALIC NUMBERS INDICATE THE 20,000 YARD GRID, ZONE 4 (AUSTRALIA SERIES)
TRANSVERSE MERCATOR PROJECTION

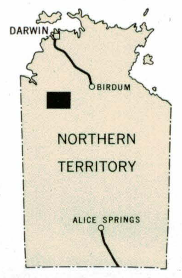
RELIABILITY DIAGRAM



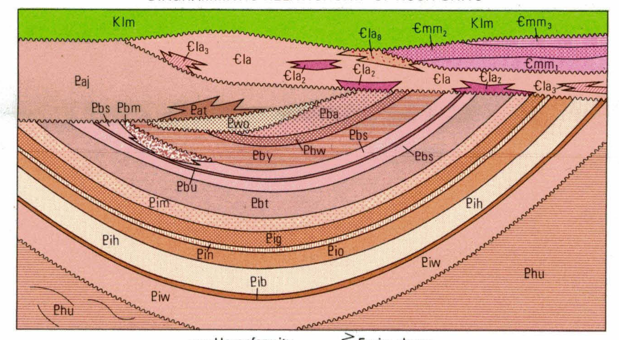
Geology B Detailed reconnaissance: numerous traverses and air-photo interpretation

C General reconnaissance: few traverses, mainly air-photo interpretation

Phanerozoic geology 1966 by M.C. Brown, C.G. Gatehouse, M.A. Randal, W.J. Perry, S.K. Skwarko
Photo-geological interpretation 1966 by W.J. Perry
Proterozoic geology 1969 by J.R. Mendum, I.P. Sweet, R.J. Bultitude, C.M. Morgan
Compiled 1970 by J.R. Mendum, J.M. Wedgbrow
Cartography by Geological Branch, BMR
Drawn by Mercury Walch Pty Ltd, Hobart, Australia
Printed by Mercury–Walch Pty Ltd., Hobart, Australia



DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

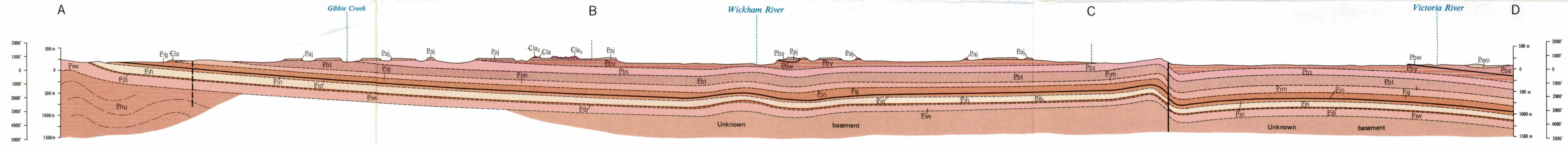


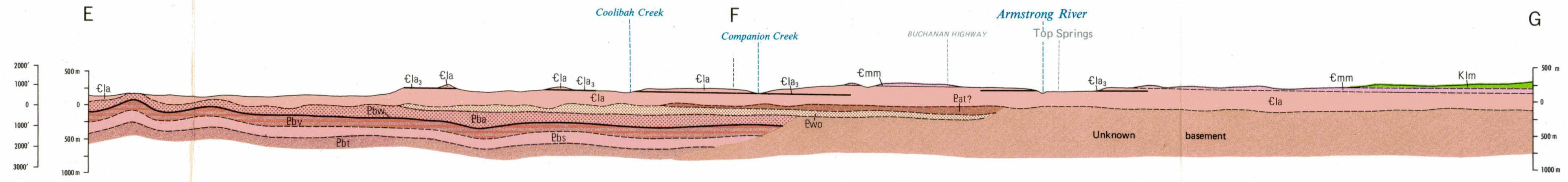
Unconformity
Facies change

Sections

Cainozoic sediments omitted. Attitude of faults unknown

Scale: $\frac{V}{H} = 4$





FIRST EDITION 1973

VICTORIA RIVER DOWNS

SHEET SE 52-4

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AUSTRALIA 1:250 000 GEOLOGICAL SERIES

WATERLOO

NORTHERN TERRITORY

SHEET SE 52-3

Reference

- Geological boundary
- Anticline, showing plunge
- Syncline, showing plunge
- Monocline
- Fault (D, U indicate relative movement down, up)

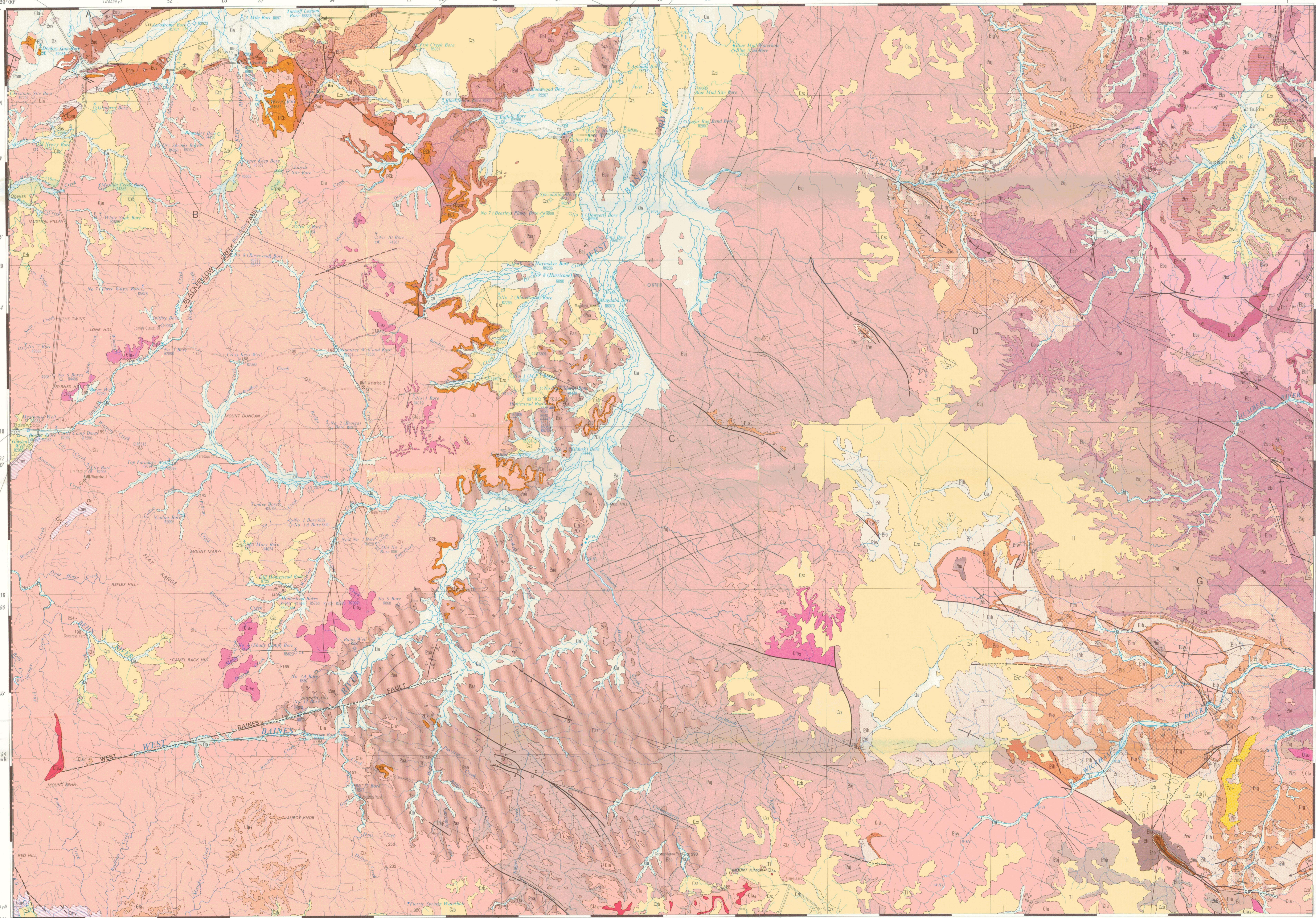
Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes

- Strike and dip of strata
- Prevailing strike and dip of strata
- Horizontal strata
- Dip < 5° } air-photo interpretation
- Dip 5–15° } air-photo interpretation
- Dip 15–45° } air-photo interpretation
- Dip > 45° } air-photo interpretation
- Trend line } air-photo interpretation
- Lineament } air-photo interpretation
- Joint pattern } air-photo interpretation

- Type section locality
- ⊗St Stratigraphic hole
- •Cu Minor mineral occurrence
- Ba Barite
- Cu Copper

- Bore
- Abandoned bore
- Well
- Abandoned well
- R6237 Reg. No. (N.T. Admin.)
- Windpump
- ▫T Water tank
- ▫E Earth tank
- Dam on stream
- WH WH Waterhole
- Spring
- —115m— High water mark of Lake Argyle
- pe Pump engine

- Highway
- Vehicle track
- Landing ground
- "Bullita" Homestead
- Building
- ▫Yd Yard
- Fence
- Astronomical station
- • 252 Elevation in metres – approximate
- abd Abandoned



Reference

CAINOZOIC	QUATERNARY		Qa	Alluvial mud, sand and gravel
			Czb	Black and grey residual soil; some alluvium
			Czs	Sandy and silty residual soils, colluvium; minor calcrete
	TERTIARY	Camfield Beds	Tc?	White, finely crystalline limestone, intraformational conglomerate
			Tl	Laterite, ferruginous lateritic soils
PALAEOZOIC	MIDDLE CAMBRIAN	Headleys Limestone	€my	Grey, massive, finely crystalline limestone
	LOWER CAMBRIAN	Antrim Plateau Volcanics	€la	Massive and porphyritic basalt, vesicular and amygdaloidal in places
		Blackfella Rockhole Member	$€la_1$	Agglomerate, brecciated flow tops
			$€la_2$	Reddish brown sandstone
			$€la_4$	Sandstone, pink and reddish brown laminated chert
	UPPER ADELAIDEAN OR LOWER CAMBRIAN	Kinevans Sandstone	P€k	Reddish brown medium sandstone; minor calcareous sandstone
PROTEROZOIC	ADELAIDEAN	Duerdin Group: Ranford Formation	Pos	Purple ferruginous siltstone, white siltstone and claystone; minor sandstone
		Jarrad Sandstone Member	Poj	Fine and medium quartz sandstone
		Moonlight Valley Tillite	Pom	Tillite, laminated dolomite at top
		Blackfellow Creek Sandstone	Pol	Medium quartz sandstone
		Fargoo Tillite	Pof	Tillite, dolomite, conglomerate
		Skinner Sandstone	Poi	Medium and coarse quartz sandstone, dolomitic sandstone, conglomerate; minor tillite
		Auvergne Group: Pinkerton Sandstone	Pap	Fine and medium quartz sandstone
		Saddle Creek Formation	Pad	Basal, blocky quartz sandstone, brown oolitic dolomite
		Angalarri Siltstone	Paa	Khaki and green siltstone, interbeds of fine sandstone and shale; minor limestone
		Jasper Gorge Sandstone	Paj	Medium quartz sandstone
		Stubb Formation	Pat	Fine and silty sandstone
		Wondoan Hill Formation	Pwo	Green siltstone and shale; interbeds of glauconitic sandstone
		Bullita Group: Bynoe Formation	Pby	Greyish green and reddish brown siltstone, dolomitic sandstone, dolomite
		Skull Creek Formation	Pbs	Interbedded dolomite and dolomitic siltstone; minor sandstone and chert
		Bardia Chert Member	Pbm	Pink and reddish brown chert, brecciated in part
		Supplejack Dolomite Member	Pbu	Massive interbedded fine to coarse clastic dolomite; stromatolite bed at top
		Timber Creek Formation	Pbt	Interbedded fine grained sandstone, dolomitic siltstone, dolomite
		Wattie Group: Seale Sandstone	Pim	Massive fine and medium quartz sandstone
		Gibbie Formation	Pig	Interbedded chocolate and greyish green siltstone and fine sandstone
		Neave Sandstone	Pin	Fine and medium quartz sandstone; minor conglomeratic sandstone
		Mount Sanford Formation	Pio	Chocolate and green siltstone, interbedded fine sandstone; minor dolomite and claystone mainly near top
		Hughie Sandstone	Pih	Massive quartz sandstone
		Burtawurta Formation	Pib	Chocolate and greyish green siltstone, interbedded fine sandstone
		Wickham Formation	Piw	Massive quartz sandstone, laminated and brecciated chert interbeds
	CARPENTARIAN OR ADELAIDEAN	Limbunya Group: Undivided	Phu	Dolomitic siltstone, silicified dolomite
		Campbell Springs Dolomite	Phb	Pink and grey, massive to flaggy dolomite
		Blue Hole Formation	Phl	Dolomitic siltstone
		Farquharson Sandstone	Pha	Medium quartz sandstone
		Kunja Siltstone	Phj	Siltstone, dolomitic siltstone
		Mallabah Dolomite	Phm	Dolomite, section only
		Amos Knob Formation	Pho	Interbedded dolomite and silty dolomite
		Pear Tree Dolomite	Php	Brecciated chert; Dolomite (section only)
		Margery Formation	Phr	Chert and claystone (section only)
		Stirling Sandstone	Phs	Sandstone (section only)

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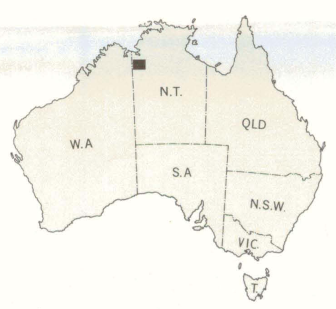
Base map compiled by the Division of National Mapping from aerial photography at 1:50 000 scale.



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ASHTON SD 52-13	CAMBRIDGE GULF SD 52-14	AUVERGNE SD 52-15	DELAMERE SD 52-16	LARRIMAH SD 53-13
MOUNT ELIZABETH SE 52-1	LISSADELL SE 52-2	WATERLOO SE 52-3	VICTORIA RIVER DOWNS SE 52-4	DALY WATERS SE 53-1
LANSDOWNE SE 52-5	DIXON RANGE SE 52-6	LIMBUNYA SE 52-7	WAVE HILL SE 52-8	NEWCASTLE WATERS SE 53-5
MOUNT RAMSAY SE 52-9	GORDON DOWNS SE 52-10	BIRRINDUDU SE 52-11	WINNECKE CREEK SE 52-12	SOUTH LAKE WOODS SE 53-9

ANNUAL CHANGE 1'05"W

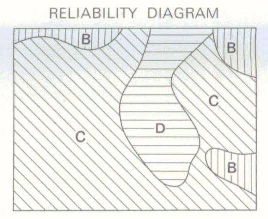
Scale 1:250 000

5 0 5 10 15 20 25 KILOMETRES

5 0 5 10 MILES

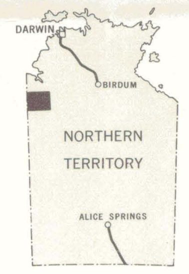
GREY NUMBERED LINES ARE 20 000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID, ZONE 52
GREY TICKS WITH ITALIC NUMBERS INDICATE THE 20 000 YARD GRID, ZONE 4 (AUSTRALIA SERIES)
TRANSVERSE MERCATOR PROJECTION

RELIABILITY DIAGRAM

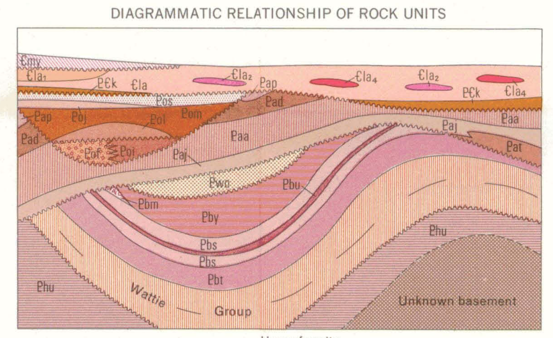


Geology
B Detailed reconnaissance: numerous traverses and air-photo interpretation
C General reconnaissance: some traverses and air-photo interpretation
D Air-photo interpretation

Geology 1970 by I. P. Sweet, R. J. Bultitude, J. R. Mendum, C. M. Morgan
Compiled 1970 by I. P. Sweet, P. R. Burroughs
Cartography by Geological Branch, B.M.R.
Drawn by Cartographic Drafting Services, Bendigo, Victoria
Printed by Leigh-Mardon Pty. Limited, Melbourne

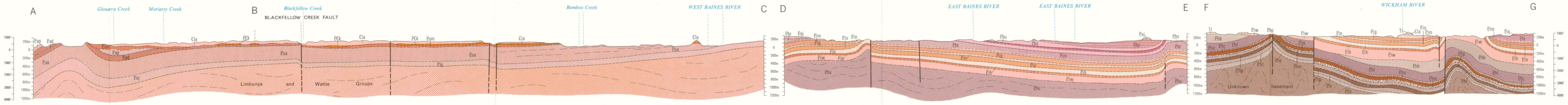


DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



Sections

Superficial Cainozoic sediments omitted. Folding schematic.
Attitude of faults not known
Scale: $\frac{V}{H} = 5$



FIRST EDITION 1972

WATERLOO
SHEET SE 52-3

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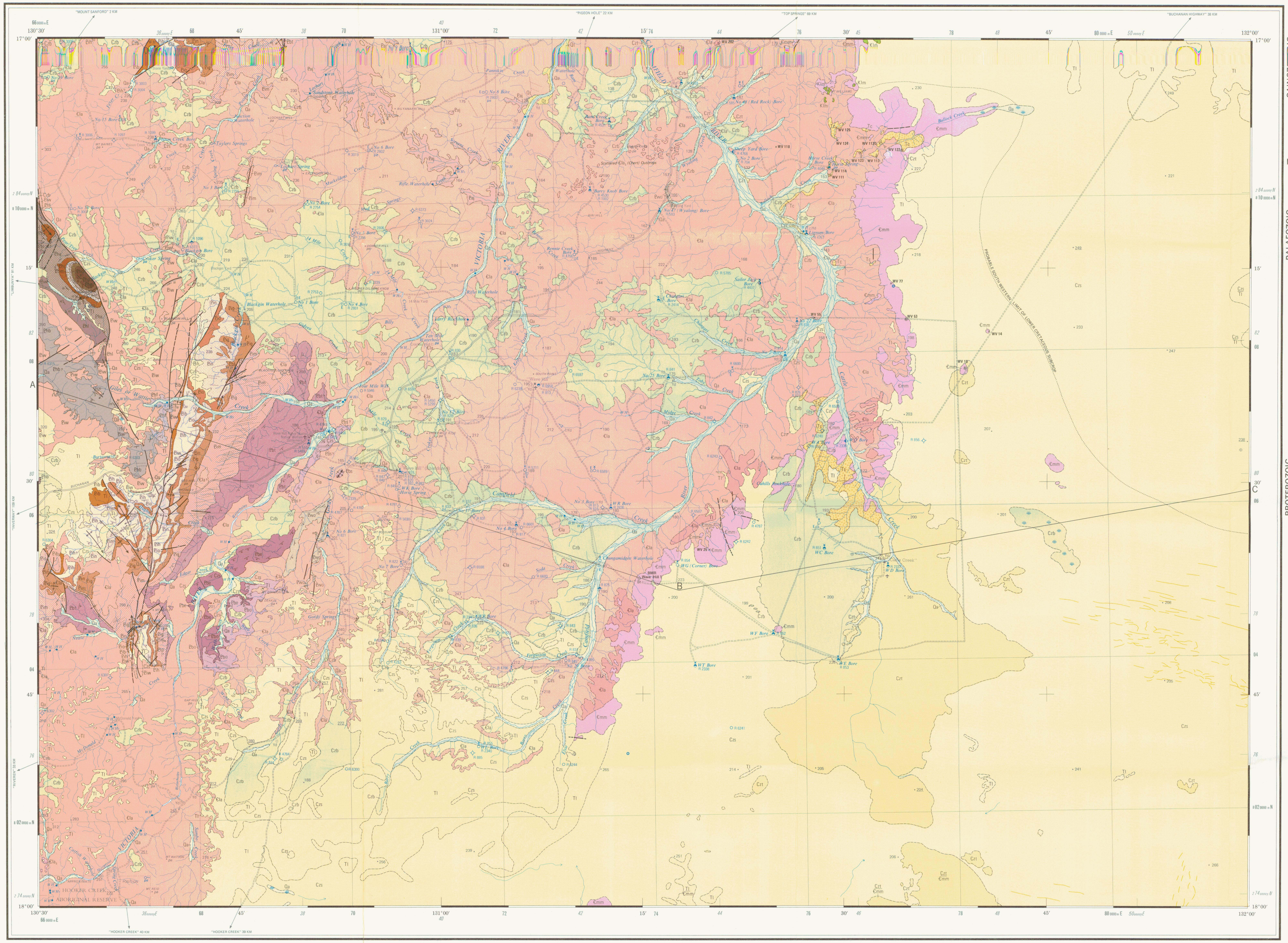
WAVE HILL

NORTHERN TERRITORY

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

SHEET SE 52-8



Reference

CAINOZOIC	QUATERNARY		Qa	Alluvium
			Qt	Older alluvium—terrace deposits, mostly silt
	TERTIARY TO QUATERNARY		Czb	Black and grey residual soil, minor alluvium
			Czs	Sand and silt, soil, some alluvium and colluvium, travertine
			Czt	Travertine, some sand and clayey soil
	TERTIARY	Camfield Beds	Tc	Conglomeratic limestone, chalcedonic limestone, calcareous sandstone, siltstone, basal conglomerate
			Tl	Laterite, ferruginous rubble, some soil and sand cover
MESOZOIC	LOWER CRETACEOUS	Mullaman Beds	Klm	Sandstone, siltstone and claystone; minor conglomerate
PALAEOZOIC	MIDDLE CAMBRIAN	Merrina Beds	€me	Silcrete and chert rubble on surface, sandstone and carbonate rocks subsurface. (Section only)
		Montejinni Limestone	€mm	Fossiliferous calcilutite; calcarenite, dolomitic limestone, dolomite, calcareous mudstone and siltstone
	LOWER CAMBRIAN	Antrim Plateau Volcanics	€la	Massive and amygdaloidal tholeiitic basalt, minor chert, sandstone and agglomerate
			€la	Chert, silicified carbonate rocks; tuff and agglomerate, sandstone, minor basalt
			€la$_3$	Laminated red and white chert
			€la$_5$	Grey tuffaceous sandstone with fragments of chert and vesicular basalt, dark grey chert
PROTEROZOIC	ADELAIDEAN	Auvergne Group, Jasper Gorge Sandstone	Paj	White and brown quartz sandstone
	CARPENTARIAN OR ADELAIDEAN	Wondoan Hill Formation	Pwo	White and purple quartz sandstone, fine siltstone
		Bullita Group: Mount Gordon Sandstone	Pbo	Blocky, white and yellow, medium quartz sandstone
		Bullita Group: Nero Siltstone	Pbe	Purple and olive green siltstone and shale, minor quartz siltstone and quartz sandstone
		Bullita Group: Skull Creek Formation	Pbs	Dolomite with dolomitic siltstone interbeds, minor sandstone and chert
		Bullita Group: Timber Creek Formation	Pbt	Siltstone, dolomitic siltstone with thin sandstone interbeds, dolomite
		Wattie Group: Seale Sandstone	Pim	Fine to medium feldspathic sandstone
		Wattie Group: Gibbie Formation	Pig	Sandstone and siltstone
		Wattie Group: Neave Sandstone	Pin	Fine and medium quartz sandstone, minor conglomeratic sandstone
		Wattie Group: Mount Sanford Formation	Pio	Chocolate and green siltstone, dolomite with chert nodules interbedded with siltstone and sandstone, claystone
		Wattie Group: Hughie Sandstone	Pih	Quartz sandstone
		Wattie Group: Burtawurta Formation	Pib	Siltstone, minor fine sandstone, mudstone, dolomite
		Wattie Group: Wickham Formation	Piw	Quartz sandstone, micaceous siltstone and chert, basal conglomerate
		Limbunya Group: Fraynes Formation	Phf	Silty dolomite, minor dolomite
		Limbunya Group: Campbell Springs Dolomite	Phb	Stromatolitic dolomite
		Limbunya Group: Blue Hole Formation	Phl	Siltstone, silty dolomite, dolarenite, dolrudite
		Limbunya Group: Farquharson Sandstone	Pha	Fine to medium quartz sandstone, minor siltstone
		Limbunya Group: Kunja Siltstone	Phj	Siltstone and silty dolomite
		Limbunya Group: Mallabah Dolomite	Phm	Dolomite and ferruginous dolomite, intraformational conglomerate
		Limbunya Group: Amos Knob Formation	Pho	Dolomite and green siltstone, shale, minor sandstone
		Limbunya Group: Pear Tree Dolomite	Php	Dolarenite, minor dolomite and sandstone; White, grey and brown chert, stromatolitic, brecciated in places

Geological boundary
Anticline, showing plunge
Syncline
Monocline
Fault

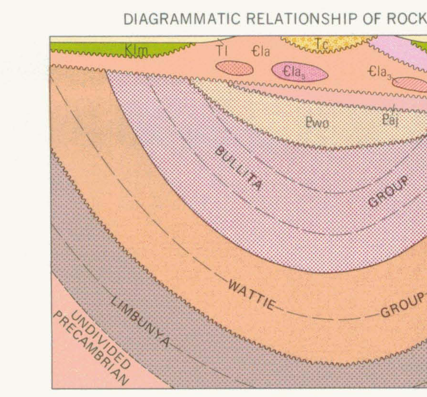
Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted; faults are shown by short dashes

Strike and dip of strata
Prevailing strike and dip of strata
Horizontal strata
Dip < 5°
Dip 5°–15°
Dip 15°–45°
Trend line
Joint pattern
Lineament
(Dip < 5° to Lineament: *air-photo interpretation*)

Macrofossil locality
Fossil vertebrate locality
×WV 25 *Specimen locality and text reference number*
Type section
⊗St *Stratigraphic hole*
Sand dunes

R 841 *Bore*
Bore, salinity < 2,500 p.p.m.
Bore, salinity 2,500–10,000 p.p.m.
pe *Bore equipped with pump engine*
Bore with windpump
Abandoned bore
Abandoned saline bore
(R 841 *refers to bore registration number of Mines and Water Resources Branch, Northern Territory Administration*)
E *Earth tank*
Dam on stream
WH *Waterhole*
Sink hole
Spring
Swamp
Highway
Road
Vehicle track
"Wave Hill" *Homestead*
Building
Landing ground
Yd *Yard*
Fence
Astronomical station
• 193 *Elevation in metres — accurate*
• 398 *Elevation in metres — approximate*
pa *Position approximate*

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



Unconformity

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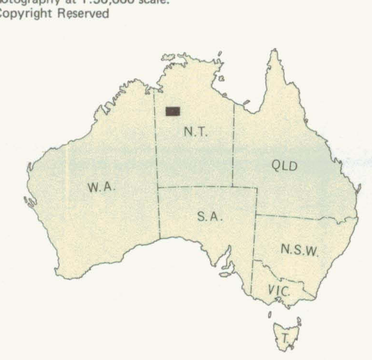

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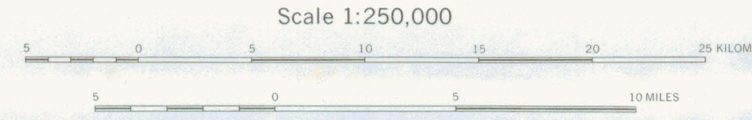
LISSADELL SE 52-2	WATERLOO SE 52-3	VICTORIA RIVER DOWNS SE 52-4	DALY WATERS SE 53-1	TANUMBIRINI SE 53-2
DIXON RANGE SE 52-6	LIMBUNYA SE 52-7	WAVE HILL SE 52-8	NEWCASTLE WATERS SE 53-5	BEETALOO SE 53-6
GORDON DOWNS SE 52-10	BIRRINDUDU SE 52-11	WINNECKE CREEK SE 52-12	SOUTH LAKE WOODS SE 53-9	HELEN SPRINGS SE 53-10
BILLILUNA SE 52-14	TANAMI SE 52-15	TANAMI EAST SE 52-16	GREEN SWAMP WELL SE 53-13	TENNANT CREEK SE 53-14

ANNUAL CHANGE 0°30'W

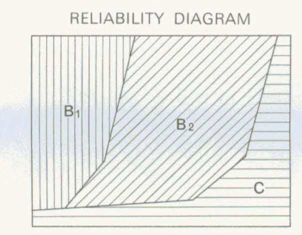
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, DEPARTMENT OF NATIONAL DEVELOPMENT, AUSTRALIA

Scale 1:250,000



GREY NUMBERED LINES ARE 20,000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID, ZONE 52
GREY TICKS WITH ITALIC NUMBERS INDICATE THE 20,000 YARD GRID, ZONE 4 (AUSTRALIA SERIES)
TRANSVERSE MERCATOR PROJECTION

RELIABILITY DIAGRAM



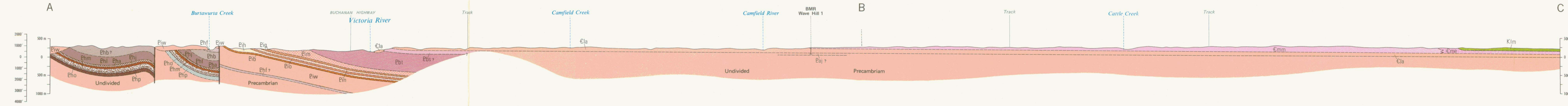
Geology
B1 Detailed reconnaissance: numerous traverses and air-photo interpretation
B2 General reconnaissance: some traverses and air-photo interpretation
C Air-photo interpretation

Geology 1966 by M. A. Randall and C. G. Gatehouse
1969 by R. J. Bultitude, J. R. Mendum, C. M. Morgan and I. P. Sweet
Compiled 1969 by R. J. Bultitude and J. M. Wedgbrow
Cartography by Geological Branch, BMR
Drawn by Mercury-Walch Pty Ltd, Hobart, Australia
Printed by Mercury-Walch Pty Ltd, Hobart, Australia

Section

Cainozoic sediments omitted

Scale: $\frac{V}{H} = 4$



FIRST EDITION 1972

WAVE HILL
SHEET SE 52-8

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