REPORT 152

The Geology of the Lansdowne 1:250 000 Sheet Area, Western Australia

D. C. GELLATLY, G. M. DERRICK AND K. A. PLUMB

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SUMMARY

The Lansdowne 1:250 000 Sheet area lies in the East Kimberley Division of Western Australia. The topography over most of the area is rugged and exposures in general are good. The King Leopold and Durack Ranges dominate the area physiographically.

Precambrian rocks cover most of the area except in the southwest where rocks of Palaeozoic age crop out and Cainozoic soils occupy scattered areas. The Precambrian formations are provisionally separated into Archaean, Lower Proterozoic, Carpentarian, and Adelaidean divisions. Most of the rocks in the area are assigned to the Carpentarian.

The oldest rocks belong to the Halls Creek Group of ?Archaean age, which consists of shales and greywackes which have been tightly folded and metamorphosed to low greenschist facies. It is unconformably overlain by the Lower Proterozoic Whitewater Volcanics. Granites of the Lamboo Complex, of uncertain age, intrude the Halls Creek Group and Whitewater Volcanics.

The Whitewater Volcanics are overlain with slight angular unconformity by the Carpentarian Kimberley Basin succession comprising the Speewah, Kimberley, and Bastion Groups. These form part of a continuous sequence and consist respectively of feldspathic arenite and lutite; arenite and basic volcanics with minor lutite and carbonate; and lutite. The succession is extensively intruded by dolerite and minor associated granophyre.

Adelaidean rocks, lying unconformably on the Kimberley Group, are assigned to the Mount House Group, which includes tillite, dolomite, lutite, and arenite.

The Palaeozoic rocks, consisting of Devonian reef limestone and Devonian to Permian conglomerate, lie unconformably on Lamboo Complex granite.

Strong folding along axes plunging northeast and west-northwest has twice affected the area. The first folds are tight and mostly similar, and are found only in the Halls Creek Group. The second folds have deformed the Carpentarian but not the Adelaidean rocks. The second folds are mainly open concentric folds which decrease in intensity northwards. Faulting has taken place predominantly along trends parallel to the fold axes and is closely related to the folding. The fault movements are associated mainly with the second period of folding.

Mineral deposits of economic interest include copper in the Carson Volcanics and Elgee Siltstone, heavy-mineral sands (including anatase, monazite, and zircon) in the Warton Sandstone, and radioactive minerals in the King Leopold Sandstone. In addition, traces of copper and lead have been found in quartz veins in the Whitewater Volcanics and Hart Dolerite, and small veins of fluorite occur locally near faults. Surface water persists throughout the year in scattered rock holes and springs, and is supplemented for stock watering by wells and shallow bores.

INTRODUCTION

This Report and the geological map are based on a joint survey carried out in 1964 by the Bureau of Mineral Resources (BMR) and the Geological Survey of Western Australia (GSWA) as part of a program begun in 1962 to map the Precambrian rocks of the Kimberley Division at 1:250 000 scale. The adjoining Sheets to the east, Gordon Downs, Dixon Range, and Lissadell, were mapped in 1962 and 1963, and the Mount Ramsay Sheet to the south in 1964. The Lansdowne Sheet area was mapped by K. A. Plumb, D. C. Gellatly, G. M. Derrick, J. F. Ivanac (BMR), and A. D. Allan (GSWA).

Location and access

The Lansdowne 1:250 000 Sheet area lies in the Kimberley Land Division in the northeast corner of Western Australia. It is bounded by longitudes 126° and 127°30′E and by latitudes 17° and 18°S.

Lansdowne homestead, situated near the geographical centre of the Sheet area, is about 480 km by road from Derby and 550 km from Wyndham. These towns are connected via Halls Creek by a gravel road from which station tracks give access to the Lansdowne Sheet area from Fitzroy Crossing, and from near Halls Creek. Access to the northwest part of the Sheet area from Derby is by way of Mount House. Within the area graded station tracks connect the homesteads, from which sparse subsidiary tracks radiate to bores and stockyards. All roads in the region are impassable at times during the wet season.

The homesteads in the area are served by fortnightly air services from Derby and Wyndham, and these in turn have frequent connexions with Perth and Darwin. Light aircraft are available for charter at Derby and Wyndham.

Population and industry

The only centres of permanent habitation are the homesteads of Glenroy, Tableland, Mornington, Bedford Downs, and Lansdowne. Elgee Cliffs, a small property 38 km southwest of Bedford Downs, is now abandoned. The population is estimated to be about 250, the majority being Aboriginals employed as stockmen on the stations. Cattle raising is the only industry of any importance.

Climate and vegetation

The Lansdowne Sheet area lies in a region with a semi-arid to arid monsoonal climate (Fitzpatrick & Arnold, 1964). There are two distinct seasons separated by a short transitional period. The wet season extends from December to March, generally heralded during October and November by increased temperatures, higher humidity, and more frequent thunderstorms. The latter, together with the more important cyclonic and monsoonal disturbances, contribute the bulk of the annual rainfall. During the dry season the Kimberleys come under the influence of a large anticyclone system, resulting in hot cloudless days, and during June, July, and August in cool to cold nights. The prevailing winds are easterly during the dry season, and both easterly and westerly during the wet season, though westerly winds predominate in areas closer to the coast. In the latter half of the dry season 'willy-willys' and dust storms are frequent.

The Lansdowne Sheet area lies almost entirely between the 500 mm and 625 mm isohyets. The mean annual rainfall ranges from 450 to 500 mm at Lansdowne in the central south to near 625 mm at Glenroy in the northwest, almost all of the rain falling between December and March.

Maximum temperatures during the day are uniformly high throughout most of the year, ranging between 32°C and 38°C for all months except June, July, and August, when the mean maximum temperature is about 27°C. Mean minimum temperatures for the same periods are 24°C and 10°C respectively, though homesteads such as Tableland, on the Kimberley plateau, often record frosts during July, the coldest month. November is the hottest month, with a mean maximum temperature of 38°C. Evaporation is about 2.5 m per year, and highest during September, October, and November. As a result, most waterholes are semi-permanent.

The distribution of vegetation depends on a complex interaction of regional climatic variation, evaporation/rainfall balance, and nature of the soil and hence of the bedrock. Perry & Lazarides (1962) and Speck & Lazarides (1964), after detailed investigation of these factors, concluded that depth of soil (and hence type of bedrock) may control vegetation types more than the chemical properties of the soil. Roberts, Halligan, & Gemuts (1965) presented an example from the Mount Ramsay Sheet area of this particular conclusion. Chemical control of vegetation, however, is well illustrated throughout the Lansdowne Sheet area by the extensive areas of basalt and dolerite which support a single type of spinifex, *Triodia wiseana*, which apparently favours a calcareous environment (Speck & Lazarides, 1964).

The northern plateaux support open woodlands with scattered eucalypts, scrub, and grasses, while to the south, scrub and spinifex are more common and the eucalypts more stunted. Along most watercourses there are moderately dense stands of eucalypts, while many of the spring-fed gorges within the King Leopold and Durack Ranges contain abundant ferns and pandanus palms. *Eucalyptus brevifolia*, or snappy gum, is common throughout the area.

The basalts generally support fine grasses, box and coolibah (*E. microtheca*), and bloodwoods (*E. pyrophora* and *E. terminalis*). Woolly butt (*E. miniata*), messmate (*E. tetradonta*), and cypress pine (*Callitris verrucosa*) are common on sandstone (Teakle, 1944; Jutson, 1950). The baobab or bottle tree is common on the limestone in the plateau region, and in open sandy watercourses in granite and sandstone.

Survey methods

Most of the geological investigations were carried out using four-wheel-drive vehicles and traverses on foot, but the more inaccessible areas were covered by helicopter reconnaissance. Aerial photographs flown in 1949 at a scale of 1:50 000 and airphoto mosaics covering the area were made available by the Royal Australian Air Force. Geological data were plotted initially on 1:50 000 scale Royal Australian Survey Corps topographic base maps prepared from aerial photographs. These maps were then photographically reduced to a scale of 1:250 000 and redrawn, using a Royal Australian Survey Corps topographic basemap on this scale, compiled in 1961 from the 1949 aerial photographs.

Previous work

Very little previous geological work has been carried out in the Lansdowne Sheet area, unlike adjoining areas to the south and east. This can be attributed to the inaccessibility of the area relative to the Derby/Halls Creek/Wyndham road, the rugged escarpment of the King Leopold Ranges, and the absence of mineral deposits. Reconnaissance of a non-geological nature was carried out by Hann (1901), who explored much of the country to the west and northwest of Lansdowne and named many of the topographical features in the area. Some features named by him include Mount Clifton, the Traine River, and Lake Gladstone. Hann was preceded by Robert Buttons, who gave his name to Buttons Creek near Mount Warton.

Jack (1906) wrote on the prospects of obtaining artesian water in the Kimberley district. Although this work did not include areas on the Lansdowne Sheet area, the included geological map recorded property boundaries near the present site of Bedford Downs homestead, but reports of this land survey have not been located. Easton (1922), a surveyor, wrote in very general terms on the geology of the Kimberley Plateau; he recorded 'basalt' and 'sandstone', and noted that the 'grasses are better on basaltic rather than on the sandstone soils'. Maitland (1928) wrote briefly on the volcanic rocks of the region, and Jutson (1950) carried out a physiographical study of the Kimberleys. Edwards (1943) enlarged on the comments of Maitland and presented the first detailed petrological study of the basic volcanic rocks of the area. Guppy, Lindner, Rattigan, and Casey (1958), working in the West Kimberley to the south of Lansdowne were primarily concerned with mapping the sediments of the Canning Basin, but also mapped areas of Kimberley Basin sediments and subdivided them for the first time. Harms (1959) extended their work by mapping the major Precambrian rock units throughout the Kimberley region. His work has provided the framework for all subsequent work on the Precambrian rocks in the Kimberleys.

The Devonian reef complex, which crops out in the extreme southwest corner of the Lansdowne Sheet area, has been studied in detail by Playford and Lowry of the Geological Survey of Western Australia, who have kindly provided their notes and map for incorporation into this Report and on the accompanying map.

PHYSIOGRAPHY

Observations in the Lansdowne Sheet area are in agreement with those of Dunnet & Plumb (1964) in the Lissadell Sheet area, who found that the physiography is closely related to the geology. The physiographic divisions are a natural continuation of those delineated in the East Kimberley by Dow, Gemuts, Plumb, & Dunnet (1964) and Traves (1955), though certain of the divisions have been renamed.

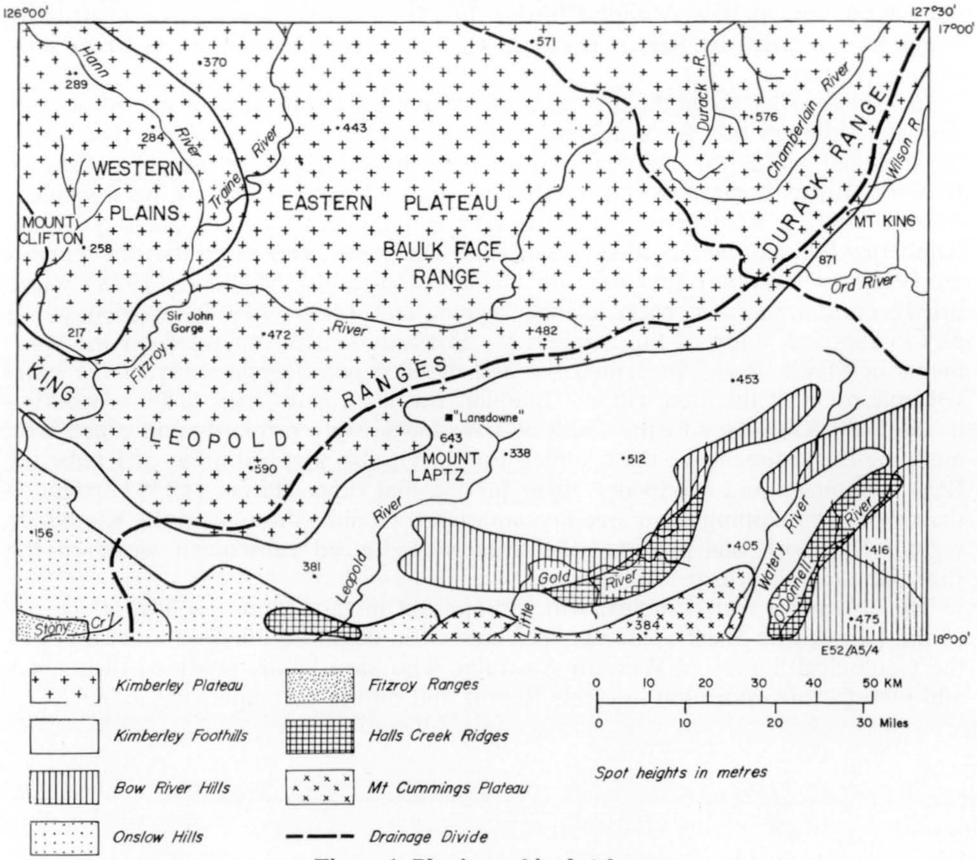


Figure 1. Physiographic sketch map

Wright (1964) recognizes two broad divisions, a *North Kimberley Division* and a *Fitzroyland Division.* Within the Lansdowne Sheet area they consist of the Kimberley Plateau Province and the Kimberley Foreland Province on the one hand, and the Fitzroy Upland Province and Fitzroy Plains Province on the other. The divisions recognized are:

This Report (Fig. 1)	*Wright (1964)*
(a) Kimberley Plateau	Kimberley Plateau Province
(b) Mount Cummings Plateau (c) Kimberley Foothills	Kimberley Foreland Province
(d) Bow River Hills (e) Onslow Hills (f) Halls Creek Ridges	Fitzroy Uplands Province
(g) Fitzroy Ranges	Fitzroy Plains Province

(a) *The Kimberley Plateau* occupies more than half of the Sheet area, and is the main physiographic unit in the North Kimberley Division of Jutson (1950) and Wright (1964). The southern margin is a line of rugged cliffs with elevations ranging from 420 to 840 m above sea level, the average elevation of the plateau being between 450 and 600 m. The Kimberley Plateau is an uplifted peneplain which can be subdivided into the *Eastern Plateau* and the *Western Plains* (Wright, 1964). The former represents the *High Kimberley Surface* of Wright, and consists of structural benches, gently dipping cuestas, and plateaux bounded by scarps up to 90 m high, with bedrock predominantly of resistant sandstone.

The plateaux are generally developed on Mount Clifton, the Baulk Face Range, and in the headwaters of the Durack River, where shale and siltstone underlie resistant sandstone. The distribution of the isolated plateaux reflects the gentle warping of the Kimberley Plateau which took place during the Tertiary. Erosional remnants of the Eastern Plateau province occur in the south and southeast. Wright also recognizes a *Low Kimberley Surface* forming dissected plains (30 to 45 m) in the main headwater valleys of the eastern plateau, but this surface has generally been obscured by a further cycle of erosion which developed his *Fitzroy Surface*. In the Kimberley Plateau region this surface is represented by the subsequent valleys of the Chamberlain and Upper Fitzroy Rivers, and by the Western Plains, which have an average elevation of 270 m and relief of about 30 m. The Western Plains to the west of the Hann River have been formed on the softer, weaker siltstone and shale of the Mount House Group.

The main streams are superimposed, with consequent, subsequent, and obsequent drainage patterns. The Fitzroy River below its junction with the Hann River is deeply incised in the resistant sandstone of the King Leopold Ranges, as in the Sir John Gorge. The minor streams have a dendritic drainage pattern in areas of flat-lying rocks, or a parallel and rectangular pattern in areas of dipping rocks, controlled by jointing and bedding. Away from the river valleys there is a scattered cover of thin soil and sparse vegetation.

(b) *The Mount Cummings Plateau* occurs only along the southern Sheet boundary, but is more extensively developed in the Mount Ramsay Sheet area to the south (Roberts et al., 1965). It forms part of the Kimberley Foreland Province of Wright's (1964) North Kimberley Division. It is essentially an outlier of the Kimberley Plateau and consists of mesas and gently dipping cuestas with an average elevation of about 360 m. The drainage is deeply incised, dendritic, and essentially obsequent.

(c) *Kimberley Foothills* coincide with the Kimberley Foreland Province Division of Jutson (1950) and Wright (1964), which extends from the King Leopold Ranges southwards and westwards into the Fitzroy Basin. The foothills range in elevation from 30 to 450 m above sea level, with an average elevation of 390 m, and form a complex system of hogbacks and cuestas interspersed with extensive tracts of undulating hills and broad valleys developed on outcrops of dolerite. In places the dolerites are covered with black soil, which generally yields fair pastures. The foothills, according to Wright (1964), are part of the Low Kimberley erosional surface, but mesas with relief of up to 150 m are erosional remnants of a previously more extensive Kimberley Plateau (or High Kimberley) surface.

Subsequent drainage is common, controlled by bedding and jointing in the bedrock, but because of the variable nature of rock type and topographic forms, no single drainage type predominates.

(d, e) *The Bow River Hills and Onslow Hills* are characteristically developed on granitic terrain, and differ only in distribution and elevation. They are natural subdivisions of the Fitzroy Uplands Province and coincide respectively with the

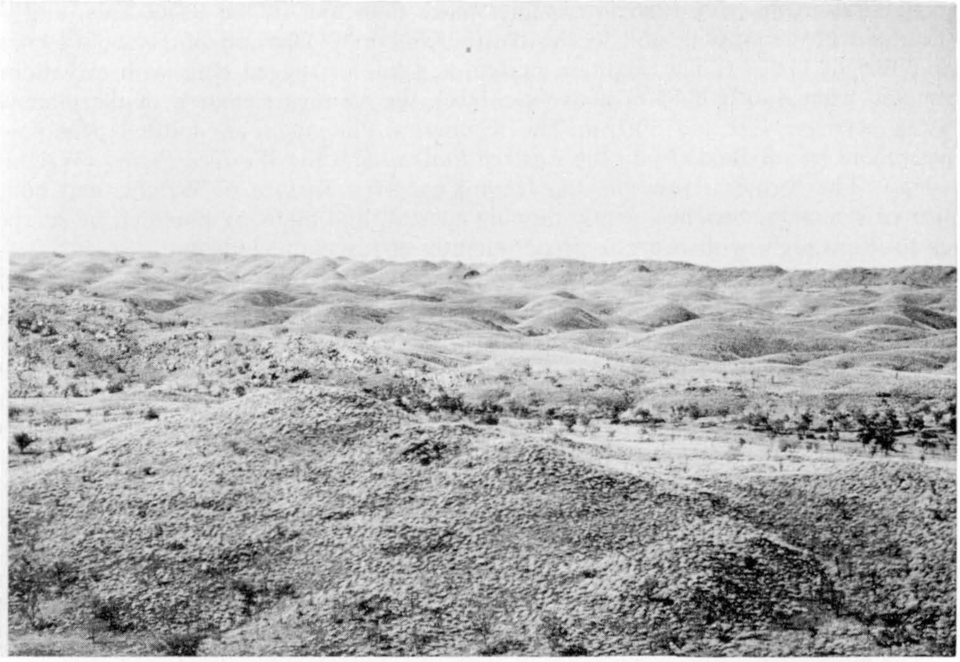


Figure 2. Typical physiography of the southern part of the Lansdowne Sheet area. Whitewater Volcanics and Hart Dolerite in the foreground are faulted against the Halls Creek Group in the middle distance, which shows typical 'hummocky' topography; vertical Speewah Group in the distance. Locality 13 km east-northeast of Pyra Gorge looking east.

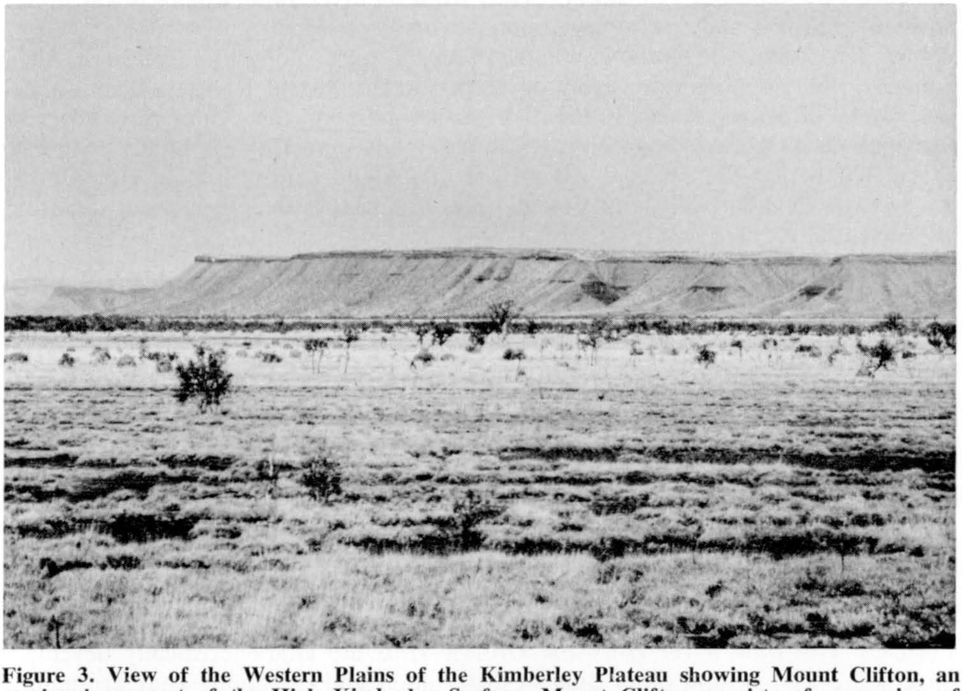


Figure 3. View of the Western Plains of the Kimberley Plateau showing Mount Clifton, an erosional remnant of the High Kimberley Surface. Mount Clifton consists of a capping of Estaughs Formation overlying the more easily eroded Throssell Shale; near Glenroy homestead.

Eastern Uplands and Northeastern Mountain Ranges of Wright (1964). They are areas of relatively low relief formed on crystalline basement rocks cropping out in the southeast, south, and southwest. Both divisions are characterized by low rounded bouldery hills and isolated tors, separated by narrow pediments and pockets of alluvium and sandy soil supporting sparse vegetation. The drainage is markedly dendritic, but in the Onslow Hills it is partly controlled by joints. The Bow River Hills have an average elevation of about 420 m and the Onslow Hills average about 240 m. Wright (1964) noted that both divisions represent the Low Kimberley erosion surface, and it seems probable that the lower elevation of the Onslow Hills is due to transgression of the Fitzroy erosion surface from the south, where it forms broad plains as a result of complete dissection of the Low Kimberley surface.

(f) *The Halls Creek Ridges* are a subdivision of Fitzroyland, and form part of the Eastern Uplands of Wright (1964). They are developed exclusively on isoclinally folded metasediments of the Halls Creek Group.

The tightly folded nature of the rocks has produced a series of discontinuous ridges and subparallel subsequent valleys, in which the minor drainage is developed. Gullying on the sides of the subsequent valleys is common. As a result of head-water erosion in these gullies, the ridges are breached and downcutting at these points has produced a major drainage pattern at right angles to the structural grain of the sediments. The main streams are locally meandering and appear to be superimposed. The average elevation of the Halls Creek Ridges is 300 m, and relief of the low rounded hills is between 30 and 90 m. The soil on the steeply dipping bedrock supports a thick cover of spinifex and rare stunted eucalypts.

(g) *The Fitzroy Ranges*, which are best developed in the Mount Ramsay Sheet area, extend into the far southwest corner of the Lansdowne Sheet area. The ranges consist of broad sandy plains from which walls of massive Devonian reef limestone rise sharply to a height of about 30 m.

STRATIGRAPHY

A summary of the stratigraphy is given in Table 1. The nomenclature used is fully defined in Dow & Gemuts (1969) and Appendix 2. The current usage is based essentially on that of Guppy et al. (1958) and Harms (1959), although some of their units have been subdivided.

The classification of the Precambrian formations into Archaean, Carpentarian, and Adelaidean is based on preliminary radiometric dating carried out by BMR in conjunction with the Australian National University (V. M. Bofinger, pers. comm.). The upper limits of the Archaean, Lower Proterozoic, Carpentarian and Adelaidean in North Australia are provisionally taken at 2500, 1800, 1400 and 600 m.y. respectively.

Most rocks exposed are Precambrian, but minor outcrops of Palaeozoic rocks are found in the southwest corner. All the Precambrian rocks are assigned to the Lower Proterozoic & Carpentarian*, with the exception of the Halls Creek Group and Tickalara Metamorphics, which are tentatively regarded as Archaean, and the Adelaidean Mount House Group.

*The ages assigned to rock units have been modified by Plumb & Derrick (in press) in accordance with new data obtained since preparation of the Lansdowne 1:250 000 geological map and this Report. The Lamboo Complex, Speewah and Kimberley Groups, and the Hart Dolerite are now assigned to the Lower Proterozoic.

TABLE 1. STRATIGRAPHIC TABLE LANSDOWNE SHEET AREA

	Rock unit and Symbol	*Thickness (m)*	*Lithology*	*Topography*	*Distribution*	*Remarks*
Quaternary	Qa	—	Alluvium, boulder gravel, and fluviatile sand	Narrow riverside flats	Mainly along Fitzroy, Hann, and Chamberlain Rs and small creeks in granite country in SE and SW	
TERTIARY TO QUATERNARY	Czs	—	Residual soil (undifferentiated), red and grey soil, sand, and ferricrete	Pediments and featureless plains	Throughout but mainly on Kimberley Plateau	Mainly red-brown soils associated with basalt, dolerite, and granophyre; grey soil with granitic terrain; sandy soils and underlying ferricrete with arenite
	Czb	—	Residual black soil	Pitted stony plains	Sporadic	Mainly on dolerite and basalt outcrops locally on limestone
			UNCONFORMITY			
Devonian–?Permian	(Undifferentiated conglomerates) D/Pc	—	Conglomerate: rounded pebbles, cobbles, and boulders of quartzite set in arkosic matrix	Prominent rounded hills with dendritic drainage	Extreme SW	Part Upper Devonian; part ?Permian, unconformable on Devonian rocks
?Devonian	Stony Creek Conglomerate (Ds)	150	Conglomerate: cobbles and pebbles of granite, minor quartz, quartzite and sheared acid volcanics	Prominent rounded hills with dendritic drainage	Extreme SW	Interfingers with reef complex. Overlain by conglomerates of ?Permian age
Devonian	Windjana Limestone (Dw)	—	Limestone: reef facies; colonial organisms with interstitial calcareous sediments; partly dolomitized	Prominent massive outcrops, sparse vegetation cover	Extreme SW	Discontinuous band between Pillara Limestone and Napier Formation

TABLE 1—(*Cont'd*)

		Rock unit and Symbol	*Thickness (m)*	*Lithology*	*Topography*	*Distribution*	*Remarks*
Devonian		Pillara Limestone (Dp)	150	Limestone: back reef facies; well bedded stromatoporoid limestone; partly dolomitized		Extreme SW	Interfingers with Windjana Limestone, Stony Creek Conglomerate, and locally with Napier Formation
		Napier Formation (Dn)	—	Limestone: fore reef to inter-reef facies, calcarenite and calcirudite; partly dolomitized		Extreme SW	Essentially a talus unit; interfingers with Stony Creek Conglomerate and Windjana Limestone
				UNCONFORMITY			
Adelaidean	MOUNT HOUSE GROUP	Estaughs Formation (Ᵽhe)	80+	Hematitic quartz sandstone and siltstone; purple to green micaceous siltstone and fine-grained subgreywacke	Caps Mt Clifton Plateau and forms marginal scarp	Confined to top of Mt Clifton Plateau in W	Distinctive beds with complex intraformational folding at base
		Throssell Shale (Ᵽht)	175	Uniform flaggy grey-green chloritic-micaceous shale. Lenticular interbeds of flaggy, fine-grained, grey-green micaceous sandstone	Scattered outcrops on soil-covered plain and on scree slope beneath Estaughs Formation scarp	Around headwaters of Throssell R	Green shales are distinctive, upper and lower contacts gradational
		Traine Formation (Ᵽha)	5 to 15+	Blocky grey to buff chloritic dolomitic sandstone; dolomite breccia; massive ferruginous sandstone, purple shale; flaggy buff dolomite	Forms scarp in Traine R area; crops out poorly in soil-covered plains in W	In NW between Traine R and Mt Clifton Plateau	Marked facies changes. Prominent sandstone in NE. Pyrite pseudomorphs in basal beds
		Walsh Tillite (Ᵽhw)	5 to 60	Tillite; flaggy pink to yellow fine-grained dolomite, quartz sandstone lenses	Crops out poorly in creeks or soil covered plains and in scarp beneath Traine Formation		Marked lateral variations in thickness. Pink dolomite is excellent marker bed. Outcrops rare. Pyrite pseudomorphs in dolomite

TABLE 1—(*Cont'd*)

		Rock unit and Symbol	*Thickness (m)*	*Lithology*	*Topography*	*Distribution*	*Remarks*
				UNCONFORMITY			
		Hart Dolerite (Pdh)	Up to ca 3000	Dark grey to black tholeiitic dolerite and gabbro; pink to pale red-brown pyroxene-bearing granophyre	Low rounded boulder-strewn hills with minor black-soil plains. Granophyre forms slightly more resistant outcrops and is associated with red-brown soils	Throughout Sheet area except in NW	Dolerite outcrops have uniform grey tone on aerial photographs. Granophyre locally caps overlying dolerite at several different horizons. Intrudes up to Pentecost Sandstone, mainly Speewah Group
CARPENTARIAN	BASTION GROUP	Mendena Formation (Ptm)	?30	Purple siltstone, quartz sandstone, dolomitic siltstone, micaceous feldspathic sandstone	Gently undulating plains; partly soil-covered	NE margin; NE of Tableland homestead	Mapped from photo-interpretation only. Only lowest beds present
CARPENTARIAN	KIMBERLEY GROUP	Pentecost Sandstone (Pkp)	ca 1000	Cross-bedded white quartz sandstone; grey siltstone and glauconitic sandstone; white to pale brown feldspathic sandstone	Undulating and hilly plateau country with rounded mesas and cuestas. Basal beds form low cliffs	NE; Baulk Face Range; SE of Pyra Gorge	Not completely measured on ground owing to inaccessability
CARPENTARIAN	KIMBERLEY GROUP	Elgee Siltstone (Pke)	216* (including Teronis Member)	Red-brown friable siltstones with grey-green reduced zones; brown to white quartz sandstones	Steep easily eroded escarpments preserved by hard capping of Pentecost Sandstone	Narrow outcrops peripheral to areas of Pentecost Sandstone	Siltstone grades upward into sandstone
CARPENTARIAN	KIMBERLEY GROUP	Teronis Member (Pkt)	23*–90*	Grey micaceous siltstone with thin feldspathic sandstone interbeds; limestone and dolomite with algal structures	Poorly exposed gently dipping pediments with low limestone outcrops	As Elgee Siltstone above	Forms basal beds of Elgee Siltstone; intruded by Hart Dolerite in N
CARPENTARIAN	KIMBERLEY GROUP	Warton Sandstone (Pkw)	275–365	Cross-bedded white to pale purple and pale brown quartz sandstone; upper part is pink and pale brown feldspathic sandstone	Gentle cuestas. Basal beds scarp-forming	N-central and NE; narrow outcrop south east of Pyra Gorge	Thickness calculated from aerial photo-measurement. Upper beds have darker photo pattern. Cross-bedding indicates NE source

TABLE 1—(*Cont'd*)

		Rock unit and Symbol	*Thickness (m)*	*Lithology*	*Topography*	*Distribution*	*Remarks*
CARPENTARIAN	KIMBERLEY GROUP	Carson Volcanics (Pkc)	270–700	Tholeiitic basalt and spilite, amygdaloidal in part; andesine basalt; agglomerate; lapilli tuff with several thin interbeds of clean-washed and silty feldspathic sandstone; upper 60 m consist of thin limestone, chert and siltstone grading upwards into silty sandstone	Crops out poorly; low cuestas, largely soil covered, within major valleys with subsequent drainage. Upper beds form steep scarp slope preserved by hard capping of overlying Warton Sandstone	Valleys of Chamberlain and Fitzroy Rs; Paddys Paddock; Goanna Spring/Pyra Gorge area; small scattered outcrops N of Baulk Face Ra	Characteristic highly amygdaloidal flow near base contains sporadic small vesicle infillings of chalcopyrite. Upper 60 m poorly exposed. Only 230 m in Lissadell area, thickens westward to 400 m NW of Bedford Downs hst and 700 m N of Colass yard
		King Leopold Sandstone (Pkl)	275–1350	Massive cross-bedded pale purple, white, and pale brown poorly sorted quartz sandstone; local pebble and cobble conglomerate, granule sandstone, and siltstone	Rugged mountainous terrain. Cliff-forming where dips are gentle. Residual vertical-sided mesas in flat-lying areas. Drainage mainly consequent and controlled by N-trending faults and joints	King Leopold and Durack Ras; Goanna Spring/Pyra Gorge area; small outcrops in Carola Syncline	Poor sorting of lower part is characteristic. Cross-bedding indicates NE and NW source
	SPEWAH GROUP	Luman Siltstone (Ppl)	73*	Purple-grey and green-grey micaceous shale and siltstone with thin sandstone interbeds, especially near top	Steep scarp-slopes below King Leopold Sandstone cliffs	Broad complex arcuate belt concave to N in S and E	In Carola Syncline and at Pyra Gorge upper part is feldspathic sandstone
		Lansdowne Arkose (Ppo)	400–600	Buff to pale pink cross-bedded feldspathic sandstone and arkose; purple-grey quartz sandstone; purple-grey and green-grey micaceous siltstone and shale	Series of parallel ridges with dip and scarp slope features; low cliffs present locally. Topmost member has smooth rounded topography	Broad complex arcuate belt concave to N in S and E	Comprises 2 siltstone and 4 arenite units. Third arenite (from base) has distinctive cross-bedding with thick cross-bedded units and forms low cliffs useful marker horizon. Cross-bedding indicates NE source

TABLE 1—(*Cont'd*)

		Rock unit and Symbol	*Thickness (m)*	*Lithology*	*Topography*	*Distribution*	*Remarks*
CARPENTARIAN	SPEEWAH GROUP	Valentine Siltstone (Ppv)	10–46*	Dark grey and grey-green blocky mudstone and cherty non-micaceous siltstone; minor rhyolitic tuff and feldspathic sandstone	Low gentle scarp slope preserved by capping of harder basal Lansdowne Arkose	Broad complex arcuate belt concave to N in S and E	Tuffs are characteristic. Over most of the area other siltstones are micaceous. Intruded by Hart Dolerite
		Tunganary Formation (Ppt)	216*–265*	Buff to pale grey feldspathic sandstone, and quartz sandstone; pale pink arkose; minor interbeds of brown granule sandstone, grey to purple-grey shale, and flaggy purple micaceous sandstone and siltstone	Gently dipping rounded cuestas and strike ridges with both consequent and subsequent drainage	Broad complex arcuate belt concave to N in S and E	Rock types similar to Lansdowne Arkose. Upper beds locally ripple-marked, e.g. near Bluff yard
		O'Donnell Formation (Ppn)	90–232*	*Upper O'Donnell:* Grey-green to khaki shale and siltstone, with minor interbeds of sandstone and greywacke (100 m) *Lower O'Donnell:* White to pale purple and pale brown coarse silica-cemented quartz sandstone, localized interbeds of green-grey silt and glauconitic sandstone. In E also localized feldspar porphyry, granule sandstone, and conglomerate (8–130 m)	Lower part forms erosion resistant ridge, upper part mainly forms narrow valley	Broad complex arcuate belt concave to N in S and E	Two distinctive mappable units. Thickness of lower O'Donnell Formation varies greatly but that of upper relatively constant. Upper O'Donnell more arenaceous in extreme W. Unconformable on Whitewater Volcanics. Strong angular discordance rare, but O'Donnell overlaps onto Halls Creek Group in several places
				UNCONFORMITY			
L. PROT.		Little Gold River Porphyry (Pwl)	—	Dark grey orthopyroxene feldspar porphyry with sporadic phenocrysts of quartz. In places strongly xenolithic	Low rounded hills forming a dissected peneplain. Water courses controlled by faults and joints	Southern boundary of Sheet area about longitude 126°38'E	Dark grey colour and paucity of quartz phenocrysts diagnostic features. Intrudes Whitewater Volcanics

TABLE 1—(*Cont'd*)

		Rock unit and Symbol	Thickness (m)	Lithology	Topography	Distribution	Remarks
		Whitewater Volcanics (Pw)	?2000–3000	Quartz-feldspar porphyry, feldspar-pyroxene porphyry; minor lapilli tuff, volcanic conglomerate, and siltstone interbeds	Low rugged hill country and sandy pediments with isolated low residual hills; minor drainage predomininantly reticulate	Arcuate belt in S and SE	Probably mainly ash-flow tuff. Quartz veins common along major joints. Unconformable between Halls Creek Group and O'Donnell Formation
				UNCONFORMITY			
LOWER PROTEROZOIC	LAMBOO COMPLEX	Bickleys Porphyry (Pbb)	—	Grey acid porphyry and porphyritic microgranite with quartz and feldspar phenocrysts	Low rounded hills consisting of large residual blocks	Small outcrops in SW, S of Torrens yard, and S of Diamond Gorge	Similar to Whitewater porphyry but intrusive into it. Post-dates shear zones which affect Whitewater Volcanics
		Mulkerins Granite (Pbu)	—	Coarse and even-grained white non-porphyritic biotite-bearing granite	Very low rounded hills with sandy pediments	S of Saddlers yard	Forms discrete elliptical outcrop. Dykes of tourmaline-bearing aplite and pegmatite, and quartz veins are common throughout. Intrudes Lerida Granite and Whitewater Volcanics
		Lerida Granite (Pbl)	—	Grey to pink-grey porphyritic biotite granite with euhedral phenocrysts of pale green feldspar and quartz. Phenocrysts of pale pink feldspar present locally	Low rugged hills with rectilinear drainage pattern. Sandy pediments developed locally	In SE immediately underlying O'Donnell Formation	Overlain unconformably by O'Donnell Formation. Intruded by Bickleys Porphyry. Possibly intrudes Whitewater Volcanics
		Chaneys Granite (Pby)	—	Coarse and even-grained grey biotite granite, commonly foliated and locally sheared	Low rounded 'whale-back' outcrops, with isolated residual tors	Mainly N and NW of Long Hole Bore	Even-grained nature and pale grey quartz are characteristic

TABLE 1—(*Cont'd*)

		Rock unit and Symbol	*Thickness (m)*	*Lithology*	*Topography*	*Distribution*	*Remarks*
LOWER PROTEROZOIC	LAMBOO COMPLEX	Long Hole Granite (Pbg)	—	Grey coarse-porphyritic biotite granite, pink-grey biotite gneiss, and augen gneiss	Very low easily weathered outcrops with broad sandy pediments	Forms an elongate outcrop in SW, mainly underlying Devonian conglomerates	Blue-grey quartz is characteristic Pink feldspar, where present, also helps distinguish it from other gneissic biotite granites. Appears to be deeper-level granite than others in Sheet area
		Violet Valley Tonalite (Pbv)	—	Medium-coarse tonalite	Low residual bouldery hills	Small outcrops in SE	Distinctive dark grey photo-pattern. Probably younger than Bow River Granite
		Bow River Granite (Pbo)	—	Coarse grey biotite granite, and coarse pink porphyritic biotite granite	Low tors with sandy pediments	Forms almost entire SE corner	Grey granite is xenolithic. Pink porphyritic type found mainly near Tumagee
		Tickalara Metamorphics (Pbt)	—	Biotite paragneiss with cordierite, sillimanite, and staurolite	Low residual bouldery hills	Two small inliers in SE	Dark grey tone on aerial photographs. Occur only within granites
ARCHAEAN OR PROTEROZOIC	HALLS CREEK GROUP	Olympio Formation (Aho)	—	Phyllitic shale and siltstone with interbedded greywacke; minor quartzite and limestone	Very distinctive rounded hills-hummocky topography. Meandering watercourses predominate	S and SE	Isoclinally folded. Intruded by minor quartz veins. Unconformity with overlying Whitewater is locally angular, in most places inferred from differing intensities of folding

* Thickness derived from section measured with Abney level and tape. Other thicknesses estimated from aerial photographs.

ARCHAEAN

Halls Creek Group

The greywackes and phyllites of the Halls Creek Group are the oldest rocks and are tentatively assigned to the Archaean on the basis of preliminary radiometric dating (V. M. Bofinger, pers. comm.). Their base is not exposed and they are unconformably overlain by Lower Proterozoic and Carpentarian rocks. The Halls Creek Group rocks in this area are referred to the *Olympio Formation*, which is the topmost of the five formations of the Halls Creek Group in the Gordon Downs and Dixon Range Sheet areas to the east.

The name Halls Creek Group was first used by Matheson & Guppy (1949) for rocks which had previously been included in the 'Mosquito Creek Series' (Matheson & Teichert, 1948). The term 'Olympio Creek Formation' was used by Smith (1963) and Dow et al. (1964), who put forward a subdivision of the Halls Creek Group, including in it the 'McLintock Greenstones' of Matheson & Guppy. The name has now been changed to Olympio Formation, and is included in the revised stratigraphical succession of the Halls Creek Group (Dow & Gemuts, 1964).

The formation crops out in the south in the cores of several large anticlines. The outcrops are scattered over a belt 110 km long and have a total area of about 725 km^2. The rocks are strongly folded and no estimate of thickness can be made.

The topography on the Halls Creek Group consists of irregular low rounded hills with densely spaced subsequent minor streams and larger meandering consequent streams deeply incised in the bedrock.

The Olympio Formation is generally overlain by the Whitewater Volcanics. Although the strike of the two formations is generally parallel at the contact, an unconformity is inferred because of local differences in dip and because of the much greater deformation of the underlying rocks. However, 16 km southeast of Torrens yard there is a strong angular unconformity between the two formations. In certain places in the southeast the Olympio Formation is overlain with strong angular unconformity by the O'Donnell Formation and by the King Leopold Sandstone. The Olympio Formation is intruded by granites of the Lamboo Complex and by dykes of porphyry similar to those of the Whitewater Volcanics.

The Olympio Formation consists mainly of grey, purple-grey, green-grey, and red-brown subgreywacke and shale with rare beds of dark grey and finely banded purple limestone, 25 cm to 1 m thick, near the top of the sequence, and subordinate banded siliceous siltstone and fine-grained sandstone. The shale and subgreywacke are mostly interbedded, with subgreywacke predominating near the top of the sequence, and shale lower down. Slight dynamic metamorphism has resulted in the production of slate and phyllite from the more argillaceous rocks. Intersection of cleavage and bedding has locally given rise to blade-shaped cleavage fragments. The subgreywackes are relatively unaffected, and the original beds, which are 15 to 45 cm thick, are generally preserved even where the shales are strongly cleaved. The more massive subgreywackes are jointed with thin quartz veinlets infilling *ac* joints.

Petrography. The lithic quartzose subgreywacke consists mainly of poorly sorted quartz grains, and fragments of shale and acid and basic volcanics set in a very fine-grained quartz-sericite-chlorite matrix.

The fine-grained sediments consist predominantly of siltstone composed mainly of quartz with interstitial patches of sericite and pale yellow-brown chlorite. In some specimens the sericite and chlorite form anastomosing films which indicate incipient cleavage or schistosity. The late muscovite flakes present in certain specimens contain poikiloblastic inclusions of quartz. The porphyritic dyke rocks cutting the Halls Creek Group contain phenocrysts of quartz, feldspar, highly altered biotite, and pyroxene set in a very fine-grained quartzofeldspathic matrix.

A thermally metamorphosed rock from the contact with Bow River Granite consists of large poikiloblasts of cummingtonite and glomeroporphyroblastic aggregates of phlogopitic biotite, andalusite(?), chondrodite, and quartz, with accessory magnetite.

LOWER PROTEROZOIC

Lamboo Complex

The name Lamboo Complex is derived from Lamboo homestead, about 50 km southwest of Halls Creek. The term was used informally by Matheson & Guppy (1949), and was later defined by Guppy et al. (1958). The complex consists of granite, granite gneiss, and undigested remnants of metasediment.

The Lamboo Complex crops out principally in the southeast and southwest, but small outcrops are also found near Pyra Gorge and near Mad Gap yard. It consists almost entirely of intrusive granitic rocks and associated dykes and veins. Metamorphic rocks are confined to narrow zones of hornfels in the sedimentary and igneous rocks, though small areas of metamorphics (Tickalara Metamorphics) crop out as roof pendants in the granites in the southeast. Low rounded hills and residual tors with sandy pediments are the characteristic topographical forms.

Granites of the Lamboo Complex cut the Halls Creek Group and Whitewater Volcanics, and are overlain unconformably by the Speewah Group. Their age ranges from Lower Proterozoic to Carpentarian, but some younger intrusives may be present. The age relations between the intrusives have been determined from field observations in most cases, though some must await age determination for confirmation.

Seven granitic types are recognized, all apparently of magmatic origin except the Long Hole Granite which may also include metasomatic rocks. The nomenclature used in the east follows that of Dow & Gemuts (1969), but a different nomenclature has been adopted in this Report for the granites in the west because it is undesirable to continue the subdivision of the granites used in the East Kimberley region indefinitely westwards and because the granites in the Lansdowne Sheet area are more varied in type. The five types recognized in the west, in order of decreasing age are the Long Hole, Chaneys, and Lerida Granites, Bickleys Porphyry, and the Mulkerins Granite. Of these, the Long Hole and Chaneys Granites may be equivalent to the Bow River and Violet Valley Tonalite in the east. Bickleys Porphyry is similar to the Castlereagh Hill Porphyry in the Lissadell Sheet area, but it is almost 160 km from the nearest outcrop of Castlereagh Hill Porphyry.

The Long Hole, Chaneys, and Bow River Granites are all biotite granites characterized by the presence of perthitic feldspar, zoned plagioclase, myrmekite, intergranular albite, and albite rims on the microperthite, and by the pink colour of the accessory zircon.

Tickalara Metamorphics

The Tickalara Metamorphics (Dow et al., 1964) were named after Tickalara Bore in the Dixon Range Sheet area. In the Lansdowne Sheet area there are only two small outcrops in the southeast where they form roof pendants in the coarse-grained biotite granite (Bow River Granite). The most common rock types are foliated and compositionally banded cordierite/sillimanite and sillimanite/staurolite-bearing paragneisses. The contacts between the xenoliths and granitic host rocks are sharp, and there are no obvious contact effects. The sillimanite, cordierite, and garnet were formed before the gneisses were foliated and not as a result of emplacement of the granites.

Bow River Granite (new name)

The name Bow River Granite is derived from Bow River in the southern part of the Lissadell Sheet area. It is the most widespread mass in the southeast corner of the Lansdowne Sheet area, and intrudes the Tickalara Metamorphics, Halls Creek Group, and Whitewater Volcanics. It includes coarse-grained grey biotite granite, minor granodiorite, and pink porphyritic biotite granite, and is intruded by quartz reefs and dolerite and aplite dykes.

Lenticular xenoliths up to 20 cm in diameter of fine-grained biotite granite are common, while xenoliths of still recognizable sedimentary rock predominate near the contact with the Halls Creek Group. Towards the contact the granite, normally massive, becomes foliated locally and finer-grained. The irregular nature of the contact and the restricted foliation in the Bow River Granite suggests absence of major movement at the time of its intrusion.

The Bow River Granite has a hypidiomorphic-granular texture, and consists of zoned plagioclase (An_{30-10}), perthitic potash feldspar, chloritized biotite, and accessory zircon and apatite. The plagioclase is sericitized and epidotized, and has myrmekitic rims. In the narrow contact zone the rock has a xenomorphic-granular texture and contains large anhedral flakes of muscovite and scattered grains of tourmaline in addition to the mineral assemblage listed above. The development of muscovite may reflect contamination of the granite by pelites of the Halls Creek Group.

Violet Valley Tonalite (new name)

This tonalite is named after the Violet Valley Bore (lat. 17°14′S, long. 128°00′E) in the Dixon Range Sheet area. In the southeast corner of the Lansdowne Sheet area it crops out as small intrusions of medium-grained biotite-hornblende granite or granodiorite, which have a distinctive dark grey pattern on aerial photographs. It intrudes the Halls Creek Group, and is apparently later than the Bow River Granite. Dow et al. (1964) tentatively considered that the Violet Valley mass is a finer-grained biotite-rich phase of the Bow River Granite.

Long Hole Granite (new name)

The name is derived from Long Hole Bore (lat. 17°58′S, long. 126°04′E), about 10 km west of the main outcrop.

The rock is a coarse-grained grey biotite granite which in places contains equidimensional phenocrysts and possible augen of pink and white potash feldspar up to 4 cm across and quartz grains up to 1 cm. The presence of slightly turbid pale blue-grey quartz and pink potash feldspar serves to distinguish the rock.

In thin section, the rock has a hypidiomorphic-granular texture. The zoned plagioclase crystals range from An_{35-40} to An_{8-12}. The calcic cores are generally altered to a fine-grained aggregate of sericite, clinozoisite, and zoisite. The potash feldspar is microcline microperthite. Intergranular sodic plagioclase in optical and structural continuity with exsolved plagioclase in the perthite, and small areas of myrmekite, are developed locally.

The biotite generally contains oriented inclusions of rutile(?) arranged in a triangular pattern, as well as hyacinth-pink zircons, which are surrounded by pleochroic haloes. The rutile inclusions are deformed by kink folding in the biotite. Small amounts of granophyric material are present, and apatite is a common accessory.

Myrmekite and albitic(?) rims are sporadically associated with altered plagioclase, set in potash feldspar. The myrmekitic intergrowths grade outwards from the altered plagioclase core into the albitic rims. The albitic rims are continuous around the plagioclase margins, but myrmekite generally occurs only in the direction of the crystallographic axis of the plagioclase. Phillips (1964) described similar features in the New England Batholith, N.S.W. Where plagioclase grains are in contact with quartz or other plagioclase grains the untwinned sodic rims of plagioclase and/or zones of myrmekite are generally absent. This suggests that the rims are not a product of normal igneous zoning, and that the perthitic potash feldspar, with which the myrmekite is invariably associated, has played a part in the development of the myrmekite.

Chaneys Granite (new name)

The Chaneys Granite is a coarse to medium, even-grained grey biotite granite which crops out in the southwest part of the Lansdowne Sheet area. It is commonly foliated and appears gneissic in localized zones of shearing.

In thin section plagioclase (An_{35}) is common, and is associated with large grains of perthitic potash feldspar. The plagioclase is zoned, and has highly altered crystal cores, and marginal developments of myrmekite. Biotite is generally slightly deformed and chloritized; pink zircon is a common accessory.

Lerida Granite (new name)

The Lerida Granite is named after Lerida Gorge, latitude 17°54′S, longitude 126°15′E. It crops out in the southwest corner of the Lansdowne Sheet area, where it is overlain by sedimentary rocks of the Speewah Group, and near Mad Gap yard where it is in contact with Whitewater Volcanics. Small fault-blocks of Lerida Granite are found a few kilometres west of Pyra Gorge. Relations between the Lerida Granite and the Long Hole and Chaneys Granite are unknown, but it is known to be older than Bickleys Porphyry and Mulkerins Granite.

It is a porphyritic, relatively dark grey-green biotite granite, containing pale olive-green phenocrysts of plagioclase. In thin-section it shows a hypidiomorphic-granular texture and is characterized by the development of granophyric intergrowths. Cores of unaltered plagioclase of An_{30} with more sodic rims are present. In general the plagioclase is more intensely sericitized than in other granite masses, and biotite flakes are almost completely chloritized. Tourmaline, zircon, and epidote are common accessories. The Lerida Granite occupies part of a broad shear zone and is consequently foliated and highly gneissic. The foliated rock is characterized by strained augen of quartz, highly altered grains of feldspar, flakes of chlorite replacing biotite, and large grains of pale green actinolite.

The Lerida Granite can be distinguished from the other granites of the Lamboo Complex by its small phenocryst size, pale olive-green plagioclase phenocrysts, white potash feldspar, and relatively high biotite content.

Bickleys Porphyry (new name)

The Bickleys Porphyry is named after Bickleys Creek (lat. 17°44′S, long. 126°00′E) which crosses one of the main outcrops in the Lansdowne Sheet area. It consists of porphyry and porphyritic microgranite, and crops out as small discrete bodies within the Lerida Granite, south of Torrens yard and near Bickleys yard.

The topography on the Bickleys Porphyry consists of upstanding rounded hills with sparse soil development on and between the hills. Large residual boulders which cover the hill slopes are devoid of vegetation and produce characteristic small dark patches on aerial photographs.

In hand-specimen the rocks, which locally resemble the Whitewater Volcanics, are pale grey to pale pink porphyries containing phenocrysts of quartz up to 1 cm across, pale olive-green plagioclase and white to pink potash feldspar up to 2 cm long, and flakes of biotite 2 to 3 mm across in an extremely fine-grained matrix.

Contacts with the enclosing Lerida Granite have not been found, but xenoliths in the porphyry suggest an intrusive relation. About 8 km south of Torrens yard highly sheared Whitewater Volcanics have been traced along strike almost to the margin of the Bickleys Porphyry, which is completely undeformed and is thus later than the Volcanics.

However, broad shear zones up to 1 km wide have been found elsewhere within the porphyry, which becomes gneissic in character. Large phenocrysts of quartz and feldspar become strongly aligned and locally form augen. Along narrow shear zones up to 1 m wide, deformation is more intense and the porphyry becomes phyllonitic.

In thin section phenocrysts of quartz show prominent strain shadows and marginal resorption embayments. Feldspar phenocrysts consist predominantly of equidimensional unzoned plagioclase of An_{35} composition and, like those of other granitic rocks in the southwest, are highly altered to fine-grained aggregates of sericite and epidote. Subordinate amounts of microperthitic potash feldspar phenocrysts with marginal zones rich in small included grains of quartz are also present. Thick flakes of biotite, 2 to 3 mm in diameter, are partly chloritized and show kink folding in slightly deformed specimens. Rare phenocrysts of orthopyroxene are partly altered to chlorite and a pale green amphibole.

Bickleys Porphyry is distinguished from the Whitewater Volcanics by its slightly larger phenocrysts, and its holocrystalline matrix. It is distinguished from the Lerida Granite by its finer-grained matrix and less mafic character. Pink potash feldspar phenocrysts are also diagnostic of Bickleys Porphyry. Distinctive petrographic features are the presence of orthopyroxene, the marginal quartz inclusions in the microperthite, and the less altered nature of the biotite.

Mulkerins Granite

The name is derived from Mulkerins Gap (lat. 17°54′S, long. 126°17′E), about 6 km north of the northern boundary of the mass. The Mulkerins Granite is a leucocratic coarse-grained non-porphyritic biotite granite. It is an intrusive mass, elliptical in outcrop form, and crops out to the south and southwest of Saddlers yard in the southwest corner and extends into the northwestern part of the Mount Ramsay Sheet area. The rock is very friable and consequently crops out as low undulating hills and isolated tors, separated by broad sandy pediments. These low outcrops are traversed by upstanding ridges consisting of erosion-resistant quartz veins.

The Mulkerins Granite intrudes the Lerida Granite and Whitewater Volcanics and has sharp contacts with them. Contacts with the other granites have not been observed in the field, but the Mulkerins Granite transgresses shear zones which have deformed the other granites and therefore postdates them.

The granite is white to very pale grey and consists of pale grey quartz, white potash feldspar, very pale yellow-green plagioclase, and minor amounts of biotite. It is massive, unfoliated, and generally contains few xenoliths. A large roof pendant of Lerida Granite, more than 0.4 km in diameter, is present near the northeast margin. Where it is in contact with Lerida Granite, Mulkerins Granite has a contact zone 1 to 2 m wide, which is slightly coarser-grained and contains pegmatitic quartz-feldspar intergrowths and elongate bladed crystals of biotite. The outermost 50 mm of this contact zone is partly granophyric.

In thin section the granite shows a typical hypidiomorphic-granular texture. Plagioclase is zoned, and highly altered to sericite and epidote. Albitic rims and myrmekite are common and intergranular albite occurs between grains of perthitic potash feldspar. Fresh undeformed biotite, and small euhedral crystals of epidote are minor accessories.

Quartz veins up to 3 km long and about 3 m thick cut the granite. They are mostly barren, but traces of copper have been noted locally.

Dykes and veins

Minor intrusions include dolerite, dacite, granophyre, aplitic and pegmatitic dykes, and quartz veins. Except for the quartz veins, most, but not all, only cut rocks af the Lamboo Complex. Their age is uncertain. Some are almost certainly related to the Lamboo Complex granites, and others may be related to the Carson Volcanics and the Hart Dolerite.

(a) *Dolerite.* Dolerite dykes up to 6 km long and 6 m wide intrude the biotite granites in the southeast and southwest. They are dark grey, fine-grained, and commonly show small-scale igneous banding in which magnetite-rich bands are prominent. In the southeast, most of the dolerite dykes trend northwest and apparently fill joints of a conjugate fracture system in the Bow River Granite.

In thin section the dolerite shows a subophitic texture and consists of plagioclase (An_{60}) laths up to 1 mm long, augite, minor accessory magnetite, and rare pyrite.

The origin of the dolerite dykes is uncertain. They may have been feeder dykes for the Carson Volcanics or the Hart Dolerite.

(b) *Dacite.* Dacitic dykes intrude the Lerida Granite 6 km east of Saddlers yard, and the Whitewater Volcanics 5 km south of Six Mile yard. They are grey-green, vesicular, and fine-grained. The dyke from the Six Mile yard area is a composite body which includes a narrow northern margin of vesicular purple-grey calcite-bearing basalt.

In thin section the dacite from near Saddlers yard consists of twinned microlites of plagioclase which show a felted texture, and are associated with anhedral to subhedral grains of quartz, blebs of iron ore, and small flakes of muscovite and chlorite. Amygdales, which show a preferred orientation, consist of coarse-grained aggregates of calcite, quartz, and rare plagioclase and muscovite.

(c) *Granophyre.* A dyke of granophyre which intrudes Lerida Granite near Saddlers yard is partly sheared and associated with small veins of amethyst quartz. It is fine-grained, dark-grey, and porphyritic with tabular phenocrysts of pale green-grey plagioclase up to 5 mm long.

In thin section the plagioclase phenocrysts, which show slight zoning, have a composition of around An_{15} and are highly sericitized. The matrix consists of completely sericitized feldspar, graphically intergrown with quartz. Minor accessory minerals include abundant minute clusters of pale brown biotite surrounding a grain of iron ore, rare apatite and zircon, and, more commonly, zoned tourmaline with grey-blue cores and pale amber-brown margins.

(d) *Aplite and pegmatite.* Dykes and veins of aplite, pegmatite, and tourmaline granite in the southwest mainly cut Mulkerins Granite. A few aplite dykes also cut Chaneys Granite. These dykes, which are predominantly aplitic, contain tourmaline-rich segregations up to 75 mm in diameter, and have a typical saccharoidal texture with granular quartz, plagioclase, and microperthite constituting the bulk of the rock. Biotite and tourmaline are accessory minerals. The tourmaline, which locally forms a coarse symplectite with quartz and feldspar, is mainly orange-brown but has localized blue-grey areas, and is strongly pleochroic from brown (or blue-grey) to very pale brown.

An aplite dyke which cuts the Bow River Granite in the southeast is exceptional in that it contains minor amounts of pleochroic pale rose-pink andalusite which is partly altered to (?)gibbsite.

(e) *Quartz veins.* Quartz veins cut most formations and are most common within parts of the Bow River Granite, Halls Creek Group, Mulkerins Granite, Whitewater Volcanics, and locally in the Hart Dolerite, and are also found extensively as fault-fissure fillings in other formations.

The veins cutting the Mulkerins Granite are up to 3 km long and average about 3 m thick. They are mostly barren, but traces of copper have been noted locally. Quartz veins are particularly abundant in the pink porphyritic phase of the Bow River Granite near Tumagee yard, where they are of similar dimensions and completely barren.

Quartz veins are also abundant in areas of the Whitewater Volcanics, especially east of Goads yard and west and southwest of Six Mile yard. In these areas minute traces of chalcopyrite and galena have been noted and also some minor limonitic boxworks east of Goads yard. The quartz veins rarely exceed 0.8 km in length and 2 m in thickness and are generally much smaller.

The quartz veins cutting the Hart Dolerite usually extend for only 10 to 20 m and have an average thickness of about 0.3 m. Trace amounts of chalcopyrite and galena are widespread.

Quartz veins found as fault infillings are of greater linear extent and generally thicker than the other quartz veins in the area. For example, in the Greenvale Fault north of Tumagee yard, a prominent quartz reef up to 25 m thick extends for about 10 km. This reef is brecciated in parts and the breccia zones are cut by later undeformed veins.

An interesting example of a fault-fissure quartz reef has been noted cutting the Warton Sandstone 11 km southeast of Reed Spring yard. Here a complete gradation can be traced from unaltered quartz sandstone into quartz sandstone with randomly oriented quartz veinlets, and finally through an increase in the number and thickness of these veinlets and gradual silicification of the sandstone, into a reef of massive quartz.

Most of the quartz reefs in fault-fissures are found within areas of acid rocks and may have been formed at least partly through *in situ* transformation of the host rock. These reefs are barren except for small amounts of malachite noted in the marginal brecciated phase of the large vein in the Greenvale Fault, 5 to 6 km northwest of Tumagee yard.

Whitewater Volcanics

The *Whitewater Volcanics*, named by Smith (1963), form a thick series of acid to intermediate porphyries which crop out as a discontinuous arcuate belt in the south of the Sheet area from near Diamond Gorge in the west to the eastern Sheet margin south of Bedford Downs homestead. They are exposed mainly in anticlinal inliers surrounded by Speewah Group sediments. They overlie the Halls Creek Group unconformably and are themselves unconformably overlain by the O'Donnell Formation. They are intruded by granites of the Lamboo Complex, and by dykes of fine-grained intermediate to basic igneous material which are probably feeder dykes of the Carson Volcanics.

The most abundant rock types, which range in composition from rhyodacitic to andesitic, are red-brown and grey-green quartz-feldspar porphyries which are apparently mainly ash-flow tuffs. Pyroxene-bearing feldspar porphyry, epidosite breccia (probably formed through secondary alteration of intermediate to basic agglomerate), lapilli tuff, and volcanic conglomerate are also represented. Sparse interbedded sediments include shale, siltstone, ferruginous sandstone and greywacke grit. Rare intrusive acid rocks have been found in the sequence, but are not readily recognizable in the field.

The porphyries are mainly massive and structureless, but localized bedding or flow structures, outlined by lenticles of fine-grained non-xenocrystic acid material 5 to 15 mm thick and 75 to 100 mm across, serve to outline the structure where they are present. These tend to be aligned parallel or subparallel to the contact of the overlying O'Donnell Formation. In places the porphyries are highly sheared, especially in the western part of the area, and may resemble sheared granites in hand-specimen.

In most places where the contact with the Halls Creek Group has been examined, strike trends of the two groups are parallel, but an unconformity may be inferred from the intense isoclinal folding in the Halls Creek Group and the simple open folding of the Whitewater Volcanics. A strong discordance has been noted south-southwest of Gap yard, which confirms the presence of an unconformity.

The relation with the overlying O'Donnell Formation is also unconformable and is particularly well displayed 13 km west of Pyra Gorge, where a strong discordance is seen. Elsewhere, however, the strike of the two formations is concordant or only slightly discordant, and the O'Donnell Formation transgresses onto the Halls Creek Group in several places.

In certain places, for example near Dingo Well, and extending as far west as longitude 126°40′E, a series of greywacke grits overlies the Whitewater Volcanics and overlaps onto the Halls Creek Group. These grits are composed of material derived from, and lithologically similar to, the Whitewater Volcanics. They are overlain apparently conformably by rocks of the O'Donnell Formation with which they are included on structural grounds, rather than with the Whitewater Volcanics on lithological grounds.

The maximum thickness of the Whitewater Volcanics is uncertain, principally because of lack of structural information. Where it has been possible to obtain dip values from bedding, flow-structures, and interbedded sediments, for example west of Carola yard, a thickness of about 2000 m has been calculated. A less reliable estimate of about 3000 m, based on the dip of the overlying O'Donnell Formation has been obtained southwest of Tunganary Gorge, but because of the unconformable relation with the O'Donnell Formation this thickness is probably less than the true maximum.

The basal beds of the Whitewater Volcanics are variable lithologically and almost certainly diachronous. They include normal tuffaceous acid porphyry which is the predominant rock type, intermediate pyroxene-bearing feldspar porphyry, tuffaceous sandstone, volcanic-derived pebble conglomerate, and cryptogenetic greywacke boulder beds.

These basal boulder beds, which overlie the Halls Creek Group with strong angular unconformity, have been found 10 km south-southwest of Gap yard and 6 km south of Melon Patch Creek in the Lansdowne Sheet area, and similar rocks have been noted a few kilometres to the southeast in the Mount Ramsey Sheet area. The outcrop near Gap yard consists of rounded to elliptical cobbles and boulders of quartzite and feldspathic greywacke up to 300 mm long in a very fine-grained highly sheared quartzose subgreywacke matrix. The presence of such large polymict boulders in a fine-grained matrix suggests a tillite. Insufficient evidence is available to comment further on this possibility.

In some places, volcanic conglomerate overlies the basal boulder beds, for example near Pyra Gorge and west of Carola yard. It consists of 25 to 50 mm fine-grained acid volcanic pebbles in a siliceous matrix, and passes laterally into tuffaceous greywacke rich in rounded rhyolitic fragments. In other localities, especially in the east, the basal rocks consist of pyroxene-bearing feldspar porphyry and quartz-feldspar porphyry.

In the Tumagee-Tunganary area there is a generalized gradation upwards in the

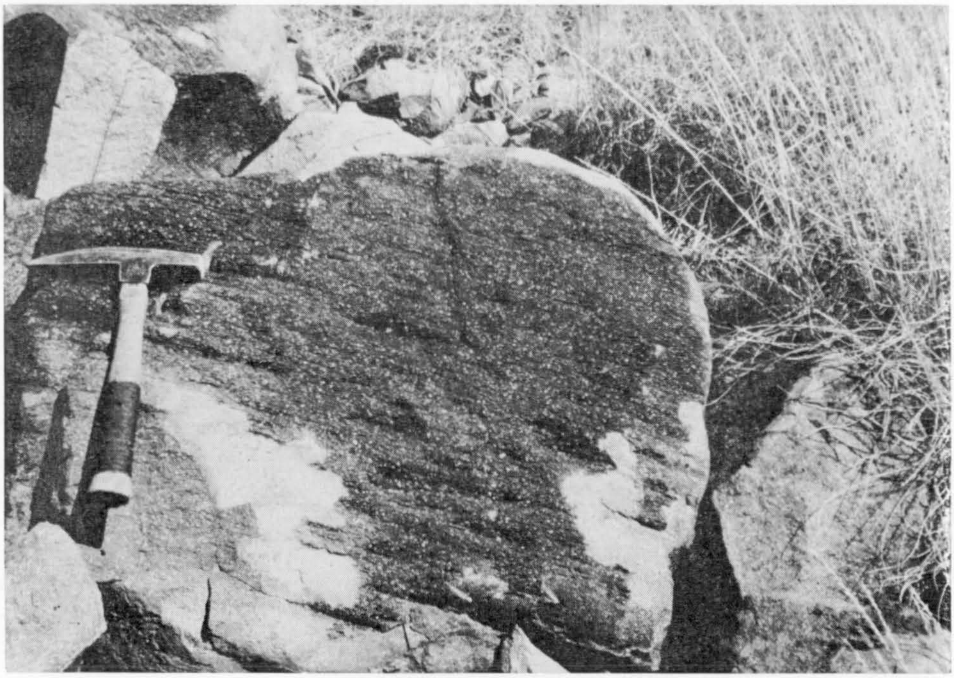


Figure 4. Probable compaction-bedding or flow-banding in acid porphyritic ash-flow tuff of Whitewater Volcanics. The ?bedding is outlined by small lenses of non-porphyritic volcanic material.

sequence from basal feldspar-pyroxene porphyry into quartz-bearing feldspar porphyry through to quartz-feldspar porphyry which makes up most of the sequence. Within the basal feldspar-pyroxene porphyry a volcanic conglomerate bed is well displayed 0.8 km north of Tumagee yard. This generalized succession is interrupted about half way up the exposed sequence by localized beds of siltstone and tuff with scattered lapilli, and near the top by a reappearance of feldspar-pyroxene porphyry. Elsewhere the succession is remarkably uniform and shows little variation except for the presence of feldspar-pyroxene porphyry near the base and also near the top. Lapilli tuff and agglomerate occur near the top of the sequence in widely separated localities, such as 19 km northeast of Old Bedford homestead and 13 km west-southwest of Pyra Gorge, where they are associated with rhyolite, rhyolitic tuff, and siltstone.

Petrographic examination shows that most specimens from the Whitewater Volcanics are tuffaceous quartz-feldspar porphyry with less abundant pyroxene-bearing feldspar porphyry. Glass shards occur in one specimen, but the only feature suggestive of a tuffaceous origin in most of the others is the presence of small elongate splinters and angular fragments of quartz and feldspar. In general, most quartz-feldspar porphyry is tuffaceous and is probably ash-flow tuff, whereas the feldspar-pyroxene porphyry lacks tuffaceous textures and may represent lava flows.

The phenocrysts in the quartz-feldspar porphyry are quartz, plagioclase, and potash feldspar, with rare altered pyroxene and biotite. In the feldspar porphyry, only plagioclase, altered pyroxene, and rare altered biotite occur as phenocrysts. Quartz forms subhedral grains commonly up to 5 mm across, and shows conspicuous resorption embayments. Plagioclase predominates over potash feldspar and occurs as euhedral short prismatic grains up to 3 mm, which are mostly highly sericitized and locally replaced by carbonate. Where the plagioclase is relatively unaltered, its composition is about An_{25-30}. Potash feldspar, which occurs as subhedral grains up to 2 mm, is a slightly turbid variety of microperthite, probably orthoclase-microperthite, containing minute irregularly shaped flecks of exsolved plagioclase. Alteration to sericite is absent, but some specimens are partly replaced by carbonate. Pyroxene pseudomorphs have prismatic habit and are up to 2 mm in length. Original pyroxene is completely replaced by chlorite, especially a variety with low anomalous birefringence, and minor amounts of associated secondary sphene, epidote, and carbonate. Biotite flakes up to 2 mm across are completely replaced by interlayered chlorite and muscovite with small amounts of associated (?)sphene.

Petrographically the intrusive rock is similar to the more basic members of the Whitewater Volcanics except that pyroxene is abundant and fresh, whereas in the extrusives pyroxene is completely chloritized. Small equidimensional grains of apatite and zircon, mainly associated with altered pyroxene, are minor accessories.

The matrix is mainly a structureless cryptocrystalline mosaic, probably a devitrified glass, consisting of quartz, feldspar, and chlorite and commonly contains small splinters of quartz and feldspar. Traces of flow streaks around phenocrysts occur in several specimens, and cuspate glass shards in one specimen. Because of the high percentage of matrix of indefinite mineralogy, the petrological classification of the Whitewater Volcanics is uncertain. Based on relative percentages of the various xenocrysts and phenocrysts they appear to range from rhyodacite to andesite. Most are probably dacites.

*Little Gold River Porphyry**

The *Little Gold River Porphyry* is a discrete mass of apparently intrusive dark grey Whitewater-type rock which crops out athwart the boundary of the Lansdowne and Mount Ramsay Sheet areas at about longitude 126°37′E, latitude 18°00′S. It intrudes the Whitewater Volcanics and is overlain unconformably by the O'Donnell Formation. It has a sharp contact with the Whitewater Volcanics and is darker and finer at the contact. The name is derived from the Little Gold River (= Watery River) which crosses the outcrop. The intrusion is apparently a flat-lying sill which has an elliptical outcrop and an extent of about 60 km^2. Because of the lack of structural features, the thickness cannot be estimated accurately, but it is probably at least 60 to 90 m. It crops out as low rounded hills dissected by a joint-controlled rectilinear drainage pattern.

The Little Gold River Porphyry is a relatively homogeneous mass of fine-grained dark grey rock with sporadic phenocrysts of quartz, and locally contains abundant angular xenoliths of cognate material 25 to 50 mm across. In thin section the rock consists mainly of euhedral phenocrysts up to 2 mm long of slightly pleochroic very pale pink to colourless orthopyroxene, and equant grains of completely sericitized plagioclase up to 1 mm across, which together make up about 40 percent of the rock, in a very fine-grained feldspathic matrix. Sporadic fresh phenocrysts of magnetite 0.5 mm long, with coronas of small biotite flakes, euhedral embayed quartz, and small flakes of red-brown biotite are the other phenocrysts. Minor accessory minerals include apatite and pale pink zircon, together with secondary chlorite and fibrous amphibole derived by alteration of pyroxene.

* This unit was originally named '*Watery River Porphyry*' but has subsequently been changed to *Little Gold River Porphyry* to agree with usage in name of the river itself.

TABLE 2. NOMENCLATURE OF KIMBERLEY BASIN SUCCESSION

This Report		*Dow et al. (1964)*		*Harms (1959)*	*Guppy et al. (1958)*
Estaughs Formation Throssell Shale Traine Formation Walsh Tillite	Mount House Group			Mount House Beds Walsh Tillite	Mount House Beds Walsh Tillite
UNCONFORMITY					
(Higher beds not represented) Mendena Formation	Bastion Group	Cockburn Sandstone Wyndham Shale Mendena Formation	Bastion Group	(Mount House Beds)	
				UNCONFORMITY	
Pentecost Sandstone Elgee Siltstone Warton Sandstone Carson Volcanics King Leopold Sandstone	Kimberley Group	Pentecost Sandstone Elgee Siltstone Warton Sandstone Carson Volcanics King Leopold Sandstone	Kimberley Group	Pentecost Sandstone Elgee Shale Warton Sandstone Mornington Volcanics	Warton Beds Mornington Volcanics
		(?) UNCONFORMITY			
Luman Siltstone Lansdowne Arkose Valentine Siltstone Tunganary Formation O'Donnell Formation	Speewah Group	Luman Siltstone 'Looningnin Arkose' Valentine Siltstone ANGULAR UNCONFORMITY Liamma Beds ANGULAR UNCONFORMITY O'Donnell Formation	Speewah Group	King Leopold Sandstone	King Leopold Beds
UNCONFORMITY					
Whitewater Volcanics, Halls Creek Group, and Lamboo Complex					

CARPENTARIAN

Kimberley Basin Succession

The Kimberley Basin is a large structural basin underlying the whole of the Kimberley Plateau. It includes the areas of Speewah and Kimberley Group sediments exposed in the foothills of the plateau. Rocks of the Kimberley Basin succession are strongly folded along the margins of the plateau, but elsewhere are relatively undisturbed. They consist mainly of arenite with subordinate lutite, basic volcanics, and carbonates, and have a total thickness in this area of about 3500 m.

The Kimberley Basin stratigraphy put forward by Dow et al. (1964) has been amended as a result of work in the Lansdowne Sheet area and a subsequent re-examination of parts of the Lissadell Sheet area. The principal differences are in the lower part of the sequence.

It has been found that the reported unconformity between the Liamma Beds and the O'Donnell Formation is a reverse fault and that the Liamma Beds are the faulted equivalents of part of the O'Donnell Formation of Dow et al. (op. cit.). The O'Donnell succession described by them included beds now defined as the Tunganary Formation, the Valentine Siltstone, and the basal member of their 'Looningnin Arkose', and is now redefined. The term O'Donnell is retained, but is now restricted to the lower 297 m of the sequence listed by Dow et al. (op. cit.). The beds lying between the O'Donnell (as redefined) and the Valentine Siltstone have been removed from the original O'Donnell Formation and renamed the Tunganary Formation. The Valentine Siltstone has been redefined and is now restricted to the upper 84 m of the original type section. The lower 23 m of the type section is now included in the Tunganary Formation. The conformable relation of the Valentine Siltstone to the underlying beds is now recognized.

Because of confusion in the spelling of Looningnin the name has been changed to Lansdowne. The Lansdowne Arkose now includes the lower 102 m of the Luman Siltstone as originally defined. This change has been made because of lateral facies changes and the difficulty of recognizing the original Luman/Lansdowne (Looningnin) boundary.

The units of the Kimberley Group remain as defined by Dow et al. (op. cit.) who suggested the presence of an unconformity in the Lansdowne area between the King Leopold Sandstone and the Luman Siltstone. Recent work has shown that over most of the Lansdowne area the King Leopold Sandstone lies conformably on the Luman Siltstone, although in one locality in the southeast it lies unconformably on the Tunganary Formation and on the Halls Creek Group.

The Mount House Beds of Guppy et al. (1958) and Harms (1959) have now been subdivided into three formations and are included in a newly defined Mount House Group which also includes the Walsh Tillite.

Speewah Group

The Speewah Group is a succession of quartzose and feldspathic arenite interbedded with chloritic lutite and minor acid volcanics. It crops out in a broad arc concave to the north in the northeastern, southeastern, and southern parts of the Sheet area and contains about 1000 m of sediments. The rocks are openly folded and extensively intruded by dolerite. The Speewah Group lies unconformably on rocks of the Lamboo Complex, Halls Creek Group, and the Whitewater Volcanics with which it exhibits a slight angular discordance, and is conformably overlain by rocks of the Kimberley Group, except in the area west of Tumagee yard where the relation with the overlying Kimberley Group is unconformable.

The Speewah Group consists of the Luman Siltstone, Lansdowne Arkose, Valentine Siltstone, Tunganary Formation and O'Donnell Formation.

O'Donnell Formation (old name redefined)

The O'Donnell Formation is the basal unit of the Speewah Group. The name is derived from the O'Donnell Range (lat. 16°24'S, long. 128°12'E) in the Lissadell Sheet area. The reference section is in the Lissadell Sheet area latitude 16°31'48"S, longitude 128°02'18"E. The O'Donnell Formation as redefined includes the lower 297 m of the original reference section (Dow et al., 1964). The overlying beds originally assigned to the O'Donnell now belong to the Tunganary Formation, the Valentine Siltstone, and the Lansdowne Arkose.

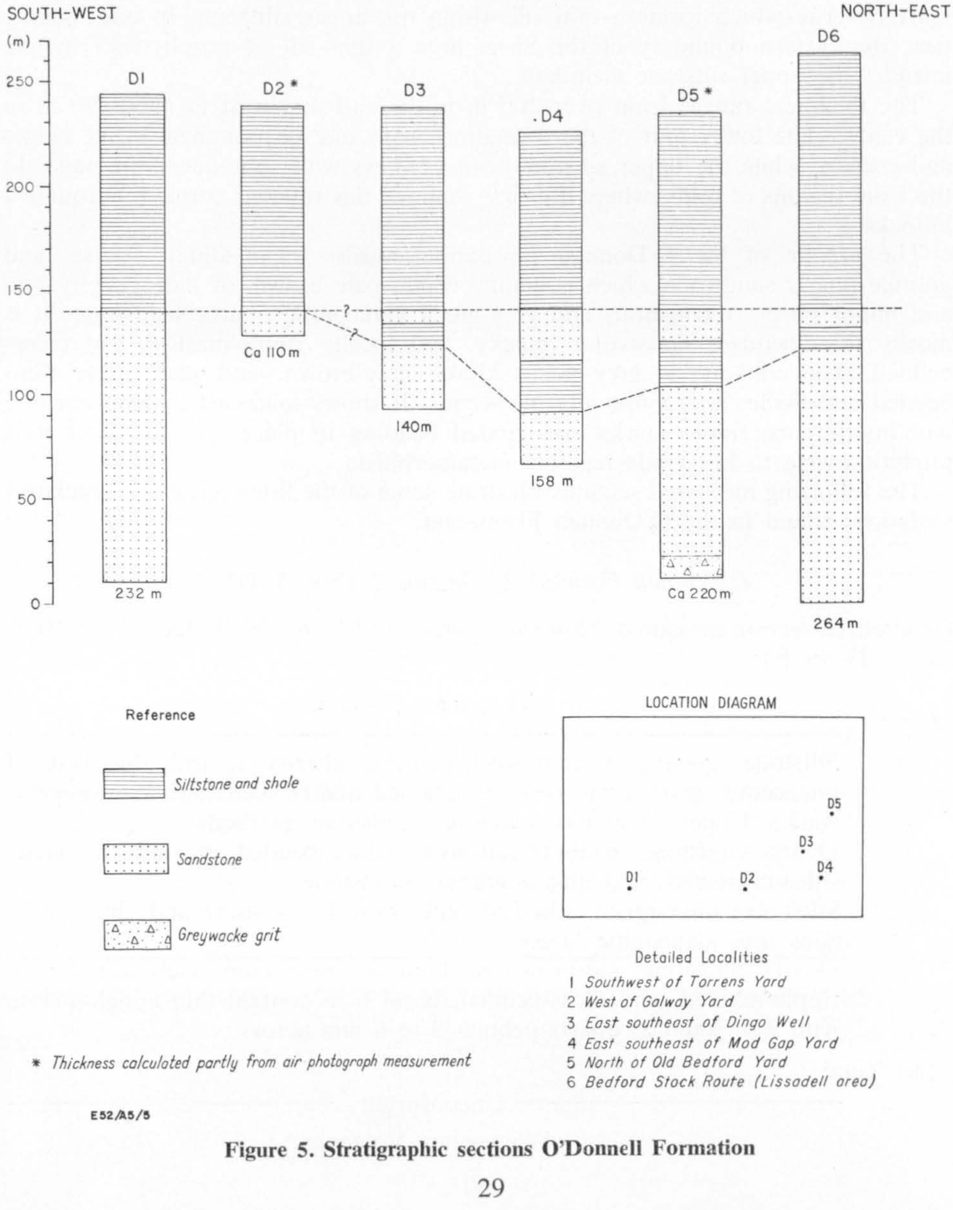


Figure 5. Stratigraphic sections O'Donnell Formation

The O'Donnell Formation lies unconformably on the Whitewater Volcanics, the Halls Creek Group, and granites of the Lamboo Complex in the southwest part of the Lansdowne Sheet area. It is conformably overlain by the Tunganary Formation, except in one locality in the southeast where it is unconformably overlain by the King Leopold Sandstone.

The formation crops out in a narrow strip 210 km long extending from the western boundary of the Sheet area to near the northeast corner. For the most part the outcrop of the O'Donnell Formation follows the southern margin of the broad arcuate belt of the Speewah Group. It consists essentially of two members, a lower quartz sandstone member, and an upper siltstone member. A thin discontinuous greywacke grit succession locally forms the basal part of the sequence, especially in the east. A thin siltstone near the top of the quartz sandstone member occurs only in the east (Fig. 5). The formation is locally intruded by the Hart Dolerite which forms a thin sill within the upper siltstone. In one locality near the eastern boundary of the Sheet area a thin sill of porphyritic rhyolite intrudes the upper siltstone member.

The thickness ranges from over 200 m in the east and west to about 90 m in the centre. The lower part of the formation crops out as prominent strike ridges and cuestas, while the upper siltstone forms valleys with subsequent drainage. In the axial regions of folds, where dips are shallow, this siltstone forms low rounded hillocks.

The arenite of the O'Donnell Formation consists of medium, coarse, and granule quartz sandstone which is mainly white, pale brown, or pale purple-grey, and minor purple ferruginous and grey-green glauconitic quartz sandstone. It is mostly thick-bedded, massive to blocky, and locally ripple-marked and cross-bedded. The siltstone is grey-green, khaki, grey-brown, and dark grey, thin-bedded and fissile, and commonly micaceous. It shows load-casts, wave, current, and interference ripple marks and graded bedding in places. In the west it is phyllitic owing to low-grade regional metamorphism.

The following measured sections illustrate some of the lithological and thickness variations found in the O'Donnell Formation:

O'Donnell Formation—Section 1 (Fig. 5, D3)

Generalized section measured 7 km east-southeast of Dingo Well (lat. 17°41′30″S, long. 127°11′E).

Metres	Tunganary Formation
95	Siltstone: green-grey, thin-bedded, fissile, alternating with thin beds of micaceous, green-grey, very fine-grained quartz sandstone and subgreywacke. Upper 18 m has numerous sandstone interbeds
6	Quartz sandstone: white to red-brown, thick-bedded, medium to coarse, silica-cemented; and quartz granule sandstone
10	Siltstone: olive-green, silicified; fine-grained sandstone and shale; contains thin glauconitic layers
29	Quartz sandstone: red-brown, medium to coarse, moderately well sorted, ripple-marked, and cross-bedded; basal 6 m contain thin conglomerate with well rounded quartz pebbles 3 to 6 mm across
140 Total	
	Unconformity
	Whitewater Volcanics

O'Donnell Formation—Section 2 (Fig. 5, D1)

Generalized section measured 2 km southwest of Torrens yard (lat. 17°41′S, long. 126°11′E).

Tunganary Formation

Metres	
101	Siltstone and shale: thin-bedded, grey-green to khaki, flaggy, micaceous, with load-casts and ripple-marks. Rare thin interbeds of fine-grained quartz sandstone, becoming increasingly abundant towards the top of the section
8	Quartz sandstone: pale grey, medium-grained, thick-bedded, slightly glauconitic, silica-cemented
55	Quartz sandstone: pale brown to white, coarse-grained, poorly-sorted, thick-bedded
68	Quartz sandstone: white, buff, and pale grey, coarse to fine, thin to thick-bedded, silica-cemented
232 Total	

Unconformity

Lamboo Complex (Lerida Granite)

O'Donnell Formation—Section 3 (Fig. 5, D4)

Generalized section measured 6 km east-southeast of Mad Gap yard (lat. 17°48′30″S, long. 127°11′E), distances paced.

King Leopold Sandstone

Unconformity

Tunganary Formation (33 m)

Metres	
83	Shale, siltstone, and mudstone: grey-green and dark grey, very thin-bedded, fissile, micaceous
24	Quartz sandstone: white to pale grey, coarse-grained, thick-bedded, hard silica-cemented
25	Siltstone: grey-green, thinly laminated to flaggy, glauconitic, thin interbeds of fine-grained grey-green quartz sandstone and shale
3	Quartz sandstone: white, coarse-grained, thick-bedded, silica-cemented
23	Quartz sandstone: purple-grey, coarse-grained, thin to thick-bedded, silica-cemented
158 Total	

Angular Unconformity

Halls Creek Group

O'Donnell Formation—Section 4 (Fig. 5, D5)

Generalized section estimated from aerial photographs about 4 km north of Old Bedford yard (lat. 17°33′S, long. 127°22′E).

Tunganary Formation

Metres	
91	Siltstone: khaki, micaceous, thin-bedded, load casts; blocky interbeds of fine-grained quartz sandstone near top of sequence

15	Quartz sandstone and quartz granule sandstone: white to purple, coarse-grained, poorly-sorted, and quartz granule sandstone
23	Siltstone: khaki, micaceous, thin-bedded, ripple marks and load casts
82	Quartz sandstone: ferruginous, coarse-grained; purple, glauconitic sub-greywacke; rock fragments common; conglomerate
9	Arkosic greywacke, grits, and conglomerate
220 Total	

——— Unconformity ———

Whitewater Volcanics

The thickness variations of these and two other sections are apparent in Figure 5. Although the formation thins towards the centre, both from the northeast and southwest, almost all of the thickness variation can be accounted for by changes in the lower (arenite) part of the formation which varies from a maximum 142 m down to 12 m. The lower siltstone is confined to the east, but an additional thin siltstone is present near the base of the succession at the Fitzroy River in the extreme west. The upper siltstone member becomes progressively more arenaceous westwards, between Torrens yard and the Fitzroy River, where it is represented by poorly sorted coarse-grained grey silty quartz sandstone. It has not been possible to estimate the thickness of the formation there because of complex folding. The variation in the lower part of the succession probably indicates that the base of the O'Donnell Formation is diachronous and that submergence in the central part of the Sheet area was later than elsewhere.

In certain areas, particularly in the east in the Dixon Range Sheet area and extending westwards to near Coolan Creek yard, a variable greywacke, siltstone, sandstone, and conglomerate sequence underlies the normal clean-washed basal sandstone of the O'Donnell Formation. It overlaps from the Whitewater Volcanics onto the Olympio Formation near Dingo Well and is thus unconformable on the Whitewater Volcanics. Its relation with the overlying O'Donnell Formation is uncertain. There is no apparent discordance between the two units but the arkosic grit is laterally discontinuous and this fact, together with the sudden change in lithology, suggests that there may be a paraconformity or possibly a slight unconformity between them.

The dominant lithologies of these basal beds are greywacke grit, occurring at the base of the sedimentary succession, purple ferruginous sandstone, flaggy purple-brown granule quartz sandstone, pebble and cobble conglomerate, and purple ferruginous silt. These sediments reach their maximum development in the Dixon Range Sheet area, but only the greywacke grit is represented in the Lansdowne Sheet area. The basal beds are only about 35 m thick. The thickness of the greywacke grit varies from about 3 to 10 m. It varies from purple and grey-green to red-brown and consists of angular grains of quartz and feldspar up to 3 mm across in a fine-grained silty matrix. It closely resembles the Whitewater Volcanics and has clearly been derived from them.

The sandstones are mostly well sorted coarse to medium quartz sandstones with grainsize mainly in the range 1 to 0.1 mm. Minor granule sandstone is poorly sorted and contains rounded to subrounded quartz grains with optically continuous overgrowths of silica cement, which is the only matrix material in most specimens. Hematite is present in the matrix of a ferruginous arenite which is a sub-greywacke. Rock fragments, present in very small amounts in most sandstones, include rhyolite, quartzite, quartz mylonite, siltstone, ironstone, and ferruginous mudstone. Grains of glauconite and rare altered feldspar are present in some specimens. Minor accessory minerals include zircon, sphene, epidote, rutile, muscovite, amphibole, and green-brown tourmaline.

An example of a siltstone consists of 0.5 mm subangular quartz grains and heavily kaolinized feldspar in a copious matrix of yellow-brown clay material. Minor accessories are muscovite and rare zircon, apatite, and sphene. Where the siltstone is slightly metamorphosed, an axial-plane cleavage is well developed in the more micaceous bands, the cleavage being outlined by recrystallized chlorite and muscovite which show preferred planar orientation.

Tunganary Formation (new name)

The Tunganary Formation is predominantly a feldspathic arenite sequence within the Speewah Group. The name is derived from Tunganary Gorge, latitude 17°39′8″S, longitude 127°19′E, where a typical section of the formation crops out. The reference section is in the Lansdowne Sheet area at latitude 17°41′30″S, longitude 127°11′15″E. The Tunganary Formation is overlain conformably by the Valentine Siltstone, and conformably underlain by the O'Donnell Formation. It crops out in a broad arcuate zone extending across the southern part of the Sheet area, Thicknesses of 216 to 227 m have been measured near Torrens yard and Dingo Well. A thickness estimate from aerial photographs suggests that the formation thickens near the eastern boundary of the Sheet area.

Topographically the Tunganary Formation generally forms cuestas of variable slope. The dip-slopes are undulating and terraced owing to thin siltstone units interbedded with the sandstone. Consequent drainage predominates, but owing to the presence of the more easily eroded siltstone members subsequent drainage is also developed.

Generalized measured sections are as follows:

Tunganary Formation—Section T1

Measured near Torrens yard latitude 17°15′30″S, longitude 126°19′30″E.

Metres	Valentine Siltstone
65	Pink to buff arkose, purple to pale grey blocky to flaggy feldspathic sandstone. Arkose dominant at top. Interbedded flaggy purple and grey micaceous shale
49	Feldspathic sandstone: coarse to medium, buff, grey, and purple, thin-bedded, and friable
1.5 (A)	Feldspathic sandstone: pale grey, coarse, blocky to massive, grading into silica-cemented quartz sandstone
40	Feldspathic sandstone: pink to buff, blocky and thin-bedded, interbeds of pale grey-green quartz sandstone
23	Feldspathic sandstone: silica-cemented, pale purple-grey to pale pink, massive, blocky, locally flaggy
1.5	Quartz sandstone: white to pale grey, silica-cemented, medium-grained
34	Feldspathic sandstone: alternating pale purple grey and pale pink, thin-bedded, medium-grained
13	Feldspathic sandstone: deep purple to buff and brown, blocky, clay pellets common
227 Total	
	O'Donnell Formation

Tunganary Formation—Section T2 (Reference Section)

Measured 10 km east-southeast of Dingo Well latitude 17°41′30″S, longitude 127°11′15″E.

Valentine Siltstone

Metres	
50	Arkosic sandstone: pink, friable, upper horizons silicified
82	Feldspathic sandstone: friable, irregularly bedded with arkosic interbeds, medium to coarse, ripple marks common
12 (A)	Conglomerate (6 mm pebbles) with interbedded coarse quartz sandstone: purple to white, cross-bedded
1.5	Feldspathic sandstone: red-brown to grey, friable, cross-bedded
15	Siltstone: dark grey, fine-grained, blocky, siliceous, some sandstone interbeds
15	Feldspathic sandstone: well sorted, red-brown on weathered surface, grey to pink when fresh, friable, irregularly bedded, cross-bedded
1	Quartz sandstone: white, silicified, medium to coarse, cross-bedded, ripple-marked. Marker bed locally
40	Feldspathic sandstone: brown to dark grey, medium to coarse, thin interbeds of coarse quartz sandstone and quartzose subgreywacke in basal 6 m
216 Total	

O'Donnell Formation

Tunganary Formation—Section 3

Generalized sections, estimated from aerial photographs, 10 km south of Cattle Creek Well, latitude 7°27′S, longitude 127°27′E.

Valentine Siltstone

Metres	
45	Arkosic sandstone: pink to purple, medium-grained, ferruginous. Purple flaggy siltstone
75	Arkose, feldspathic sandstone: green-grey to light grown, medium to coarse, beds 0.3-0.5 m thick, with thin interbeds of friable silty sandstone
60 (A)	Medium to coarse quartz sandstone and granule quartz sandstone: massively bedded, cross-bedded, strongly jointed, Overlain by purple, ferruginous, friable, granule sandstone. Grades downwards into fine to medium pink massive thick-bedded blocky quartz sandstone
10	Silicified siltstone: khaki-green to white, poorly sorted, lenses of granule sandstone. Characterized by abundant tree growth
15	Granule quartz sandstone: coarse-grained, feldspathic sandstone, arkose, flaggy to massive. Cross-bedded, clay pellets common
65	Feldspathic sandstone: fine to medium, thin-bedded and flaggy, strongly cross-bedded, ripple marks common. Grades downwards into grey-green quartz sandstone with interbedded siltstone. Thin stringers of coarse-grained, feldspathic quartz sandstone common
270 Total	

O'Donnell Formation

Three broad divisions of the Tunganary Formation can be recognized in the east. Both the upper and lower members are similar in lithology and outcrop, though siltstone is more common in the upper part of the sequence. The arenite of both upper and lower members is predominantly feldspathic, buff, purple, and white, locally cross-bedded and ripple-marked, with ripple wavelengths varying from 0.1 to 0.5 m.

These two members are separated stratigraphically by a massive scarp-forming quartz sandstone (A in measured sections). This latter unit is best developed in the east near Bedford Downs, Cattle Creek Well, and Motor Car yard (see section 3), where it is expressed as a rugged dip-slope. When traced westwards it thins from 60 m in the east to 10 m on the northern margin of the Carola Syncline. In the western and central parts of the Sheet area it is represented by a prominent 1.5 m marker bed of white to pale grey quartz sandstone.

Other facies changes apparently take place laterally in the succession. For example, near Bluff yard the Tunganary Formation, which crops out as inliers in the Hart Dolerite and has a total exposed thickness of 130 m, is predominantly fine-grained pink arkose which grades upwards into a mixed sequence of buff to white, medium to coarse feldspathic sandstone. The beds at the base of this sequence are much more feldspathic and finer-grained than the Tunganary Formation beds elsewhere.

Dolerite sills intrude the Tunganary Formation extensively. Contact metamorphism of the sandstone is restricted to some recrystallization of grains and matrix at the contacts with the dolerite. The contact metamorphosed feldspathic sandstone and arkose generally have a spotted appearance and some show columnar jointing.

Petrographically the arenites vary from well sorted to poorly sorted and have grainsize varying from 5 to 0.06 mm, but most are less than 0.7 mm. Quartz, which is the predominant detrital mineral, varies from subangular to rounded, and grains commonly have optically continuous over-growths of silica cement. Feldspar, which is present in varying amounts up to 35 percent, is principally turbid potash feldspar. Chlorite, hematite, and clay minerals occur interstitially, and in a few specimens are sufficiently abundant for the rocks to be classified as subgreywacke (Appendix I). Minor accessory minerals include green tourmaline, zircon, sphene, epidote, rutile, anatase, glauconite, and muscovite. Fragments of chert and other rock types are found but are comparatively rare. Rounding of large quartz grains and slight pitting of grain boundaries noted in one specimen suggest possible aeolian abrasion in the source area, but the thin-bedded nature of the rocks and the type of cross-bedding displayed preclude aeolian deposition of the arenites.

The siltstone and mudstone are rich in chlorite, sericite, and clay minerals. The siltstone contains abundant subangular quartz grains 0.05 to 0.002 mm in size, and some show a bimodal frequency distribution of detrital grains. Minor accessory minerals include biotite, glauconite, muscovite, goethite, zircon, and authigenic pyrite. The siltstone and mudstone are commonly interbedded and in thin section show graded bedding, micro cross-bedding, and small-scale slump structures.

Valentine Siltstone (old name redefined)

This formation was named from Valentine Creek (lat. 15°45′S, long. 128°35′E) in the Cambridge Gulf Sheet area (Dow et al., 1964). The reference section in the Lissadell Sheet area is at latitude 16°28′34″S, longitude 128°3′12″E. The original definition of the Valentine Siltstone included a basal sandstone member 21 m thick, but in the redefinition of the constituent formations of the Speewah Group this member has been incorporated in the Tunganary Formation.

The Valentine Siltstone crops out discontinuously in a broad arc which extends from near Bedford Downs homestead in the northeast of the Lansdowne Sheet area to Diamond Gorge in the central southwest. It is poorly exposed, and except for a small bench developed at a tuffaceous layer it is valley-forming. The formation is overlain conformably by the Lansdowne Arkose, and underlain conformably by the Tunganary Formation. It is extensively intruded by the Hart Dolerite.

Siltstone, shale, and mudstone are the dominant rock types, with blocky interbeds of fine-grained feldspathic sandstone. Lithologically the Valentine Siltstone does not differ greatly from siltstone members in the Lansdowne Arkose and Tunganary Formation, except that it is generally less micaceous and locally contains distinctive tuffaceous beds. These beds consist of rhyolite, rhyolitic tuff, and tuffaceous siltstone, all of which are apparently lateral equivalents. These have not been recognized in all localities, and may be developed only sporadically within the Sheet area.

Sections of the Valentine Siltstone are as follows:

Valentine Siltstone—Section V1

Measured section 3 km southeast of Coolan Creek yard, latitude 17°48′S, longitude 126°35′E.

Metres	Lansdowne Arkose
7	Arkosic siltstone: buff to orange, green-pink when fresh, micaceous, well bedded, flaggy beds 25 to 50 mm thick, capped by more massive, medium-grained, buff to pink arkose
4	Vesicular rhyolite, rhyolitic tuff, tuffaceous siltstone: massive, well bedded in parts
10	Green to black mudstone: regularly interbedded with finely banded blue-green, purple, and grey, siliceous arkosic siltstone; slumping present, current ripples characteristic
1	Alternating bands of pink and green arkosic siltstone, 75 to 150 mm thick
8	Mudstone: black, grey, and purple, finely-laminated, locally conchoidal in fracture
12	Mudstone: thin-bedded, grey to black, with flaggy 25 to 50 mm interbeds of micaceous buff well bedded arkosic siltstone
42 Total	
	Tunganary Formation

Valentine Siltstone—Section V2

Composite section, with distances paced, 2 km south-southwest of Lily yard, latitude 17°27′S, longitude 127°29′E.

Metres	Lansdowne Arkose
8	Fine to medium-grained arkose, with interbedded buff, flaggy, micaceous siltstone
6	Rhyolite, rhyolitic tuff, rhyolitic agglomerate

13	Micaceous shale and siltstone: dark brown to buff, strongly laminated
4	Rhyolitic tuff: coarse-grained, well bedded, with micaceous closely jointed tuffaceous siltstone
15	Siltstone: khaki and purple, slumped, micaceous, flaggy, with thin interbeds of purple granule sandstone near base
46 Total	

Tunganary Formation

Valentine Siltstone—Section V3

Composite section 2 km west-southwest of Old Bedford yard (latitude 17°36′S, longitude 127°20′E).

Metres Lansdowne Arkose

9	Black claystone, imperfectly laminated; interbedded with siltstone: flaggy, dark green, micaceous, feldspathic, with load-casts and slump structures. Laminated siltstone contains blocky siltstone (150 to 200 mm) interbeds, khaki to buff, highly siliceous
1.5	Rhyolitic tuff: fine-grained, green-grey, medium-grained, glassy, quartz fragments common
	Dolerite sill
30	Siltstone: well laminated, feldspathic, buff to khaki, some conchoidal fracturing in interbedded poorly bedded claystone. Siltstone more blocky and siliceous towards base
41 Total	

Tunganary Formation

The Valentine Siltstone is consistently thinner in the Lansdowne Sheet area than in the Lissadell Sheet area where the average thickness is 70 m. The difference is due to a lesser development of the siltstone/shale members in the Lansdowne Sheet area where the Valentine Siltstone is consistently about 42 m thick, except locally in the south where it thins to about 10 m west of Carola yard.

West of Torrens yard the Valentine Siltstone becomes phyllitic owing to mild regional metamorphism, and can only be distinguished from the other siltstones in the sequence by its stratigraphic position.

In thin section the tuffs contain angular grains of quartz and feldspar, 0.5 to 0.1 mm across, and rhyolitic rock fragments up to 1 cm long. The fine-grained matrix of these tuffs is chloritic, quartzo-feldspathic, and vitreous, and reaction with xenocrysts of quartz and feldspar has produced resorption textures. Epidote, muscovite, sericite, sphene, and magnetite are minor accessory minerals. The siltstone contains small angular grains of quartz 0.03 mm across, together with flakes of muscovite and chloritized biotite set in a cryptocrystalline quartzo-feldspathic matrix. Segregation of the finely divided chlorite and sericite has resulted in small-scale spherulitic structures. Apatite and iron ore are rare accessories.

Lansdowne Arkose (new name)

The Lansdowne Arkose is apparently conformable between the Valentine Siltstone and the Luman Siltstone, but considerable thickness variations in the basal beds of the Lansdowne Arkose, which are locally conglomeratic, may possibly indicate a localized paraconformity between the Valentine Siltstone and the Lansdowne Arkose. The name is derived from Lansdowne homestead (lat. 17°37′S, long. 126°44′E). The Lansdowne Arkose is the new name proposed for the 'Looningnin Arkose' (Dow, et al., 1964) which has been deemed unsuitable (vide supra), but the redefined formation includes beds previously assigned to the Luman Siltstone. The reference section is a composite one measured about 3 km southeast of Lansdowne homestead near Looningnin Creek (lower part) latitude 17°37′45″S, longitude 126°45′24″E, and 3 km north of Elba Hole yard (upper part) latitude 17°34′51″S, longitude 127°53′00″E.

The Lansdowne Arkose crops out mainly in a continuous arcuate belt, concave to the north, from the northeast corner of the Lansdowne Sheet area to the western margin at Diamond Gorge, and in a subsidiary belt trending east-northeast from Pyra Gorge in the south. It is extensively intruded by the Hart Dolerite, which has rafted large blocks, several kilometres long, away from their original stratigraphical position. The thickness varies from over 600 m in the south at Pyra Gorge to 495 m in the centre and 405 m in the southwest. The formation can be subdivided into six mappable members as follows:

Member	*Lithology*	*Thickness** (m)
6	Arkose and quartz sandstone	105
5	Feldspathic sandstone	145
4	Siltstone	10
3	Feldspathic sandstone	110
2	Siltstone	50
1	Arkose and feldspathic sandstone	70

The Lansdowne Arkose forms a series of low parallel escarpments and strike ridges with intervening valleys underlain by the more easily eroded siltstone. Member 5 mostly forms distinctive low cliffs, and the topmost unit forms rounded, gentle hill-slopes with a smooth pattern on aerial photographs. Locally, for example in the south, the Lansdowne Arkose strike ridges increase in height and form prominent bluffs.

The arenites consist mainly of pale pink to buff, deep pink, and purple feldspathic sandstone and arkose, white to pale grey quartz sandstone, pale purple-grey quartz granule sandstone, and pebble to boulder conglomerate. The rocks vary from extremely friable to hard silica-cemented types. The distribution of silicified zones is highly irregular and this suggests that it is a secondary surface effect. The argillites are predominantly grey, purple-grey, and grey-green micaceous shale and siltstone with subordinate grey to grey-brown mudstone.

Cross-bedding is ubiquitous throughout the sequence, and slump structures, ripple marks, and current striations are found locally. Concentrations of clay pellets are present in certain beds, and 25 mm ball structures, probably owing to the effects of weathering, have been noted.

Considerable variations are found in the thickness of the foreset units. In the lower arenite, foresets are mostly 100 to 400 mm thick, and in member 5 they are characteristically 0.5 to 1 m thick. Slump structures are principally single overturned cross-beds within individual beds. Ripple marks, some of them asymmetrical, have wavelengths of up to 450 mm and amplitudes up to 75 mm.

* Thicknesses refer to composite measured section east of Lansdowne homestead.

The current direction indicated by the cross-bedding is from the northeast, and the dip of the depositional slope indicated by the slump structures agrees with this as the probable source direction.

In thin section arenites from the Lansdowne Arkose show considerable uniformity throughout the sequence. They consist of rounded to subangular quartz grains ranging from 0.5 to 3 mm in diameter, turbid iron-stained feldspars, and minor amounts of micropegmatite, chert, mylonite, chlorite, sericite, muscovite, zircon, and a black opaque mineral.

Quartz grains are partly of volcanic derivation with embayed margins, and commonly have optically continuous overgrowths of silica cement. Feldspar, which makes up 15 to 35 percent of most specimens, is mainly turbid potash feldspar including microperthite, and has rusty brown iron-staining in all specimens examined except from member 5, where it is also turbid but unstained. Turbid sodic plagioclase is present in some specimens, and one from the topmost unit has optically continuous overgrowths of clear secondary plagioclase.

Some rocks are clean-washed sediments containing no intergranular material other than silica cement, but others contain appreciable amounts of interstitial chlorite, sericite, clay minerals, and minute quartz grains. A noteworthy feature of the heavy-mineral assemblage is the absence of tourmaline, which is common in most of the other Speewah and Kimberley Group arenites. Sorting, which is variable in the Lansdowne Arkose arenites, is best in member 5, and poorest in member 6 in which the quartz grains are more angular than in other parts of the sequence.

The following generalized measured sections are representative of the Lansdowne Arkose and indicate some of the variations present within the formation.

Lansdowne Arkose—Section L1

Composite section measured partly 3 km southeast of Lansdowne homestead (members 1, 2, 3, 4, lat. 17°38′S, long. 126°45′30″E) and partly 3 km north of Elba Hole yard (members 5, 6, lat. 17°35′S, long. 126°54′E).

Luman Siltstone

	Lansdowne Arkose
	(6)
60	Arkose: deep pink, coarse-grained, hard, silica-cemented, with thin feldspathic siltstone interbeds
5	Siltstone: purple, micaceous
9	Feldspathic sandstone: white to pale grey and purple, medium-grained, thin-bedded, clayey; pink-brown arkose
33	Quartz sandstone: purple to grey-brown, friable, coarse-grained, thin-bedded, with 1-2 mm grains; cross-bedded with 75 to 150 mm foreset units
	(5)
17	Feldspathic sandstone: buff-coloured, medium to coarse, thick-bedded, cross-bedded with 0.3 m thick foreset units
93	Feldspathic sandstone: pale creamy-pink to buff and purple, medium-grained
36	Feldspathic sandstone: cream and purple, medium-grained, very thick-bedded, well sorted, cross-bedded, with 0.5 to 1 m foreset units

(4)

5	Siltstone: grey and purple, highly micaceous, with thin interbeds of grey-green quartz sandstone and pink arkose
2	Sandstone: fine-grained, grey-green, cherty

(3)

54	Arkose and feldspathic sandstone: pink, medium-grained, thick to thin-bedded
56	Feldspathic sandstone: pale pink to cream, medium-grained, thick to medium-bedded, minor quartz sandstone. Cross-bedding with 0.3 to 0.6 m foreset units near the base; clay pellets present locally

(2)

13	Siltstone and shale: flaggy grey to grey-green, micaceous, thin interbeds of fine-grained pink arkose and grey feldspathic sandstone
3	Arkose: pink to brown, fine-grained, with 50 mm interbeds of grey fine-grained micaceous sandstone
5	Feldspathic sandstone: dark grey, fine-grained, with interbeds of flaggy grey micaceous siltstone
15	Shale: purple, grey, and grey-green, with interbeds of flaggy grey micaceous feldspathic siltstone
11	Mudstone and shale: grey, blocky to flaggy
0.6	Feldspathic sandstone: pale grey-green to pink-grey, fine-grained
4	No exposure (?siltstone)
0.6	Quartz sandstone: pale grey-green, fine grained

(1)

13	Feldspathic sandstone: buff to pale pink, coarse to medium, thin-bedded
36	Arkose: deep to pale pink, medium-grained, thin to thick bedded
10	Quartz sandstone: coarse-grained, slightly feldspathic, with clay pellet impressions; granule quartz sandstone at base
13	Arkose: medium to coarse-grained, medium to thin-bedded, pale pink, cross-bedded with relatively thin foreset units
494 Total	

Valentine Siltstone

Lansdowne Arkose—Section 2

Generalized section measured 3 km northeast of Torrens yard (lat. 17°38′S, long. 126°45′30″E).

Metres

Luman Siltstone

Lansdowne Arkose

(6)

28	Arkose and feldspathic sandstone: coarse to fine, pink
21	Quartz granule sandstone with minor pink feldspar in upper part
0.6	Quartz pebble conglomerate: 5 to 20 mm pebbles of vein quartz in buff to pale brown quartz granule sand matrix

(5)

15	Feldspathic sandstone: white to pale cream, medium-grained, cross-bedded

26	Quartz sandstone: white, medium to coarse, slightly feldspathic; hard silica-cemented beds alternate with friable beds
104	Feldspathic sandstone: very friable, pale buff, medium-grained, thick-bedded, strongly cross-bedded; thick foreset units
	(4)
28	Siltstone: grey-brown, micaceous
	(3)
84	Feldspathic sandstone: buff to cream, friable, flaggy, very strongly cross-bedded
	(2)
45	Siltstone and shale: poorly exposed, weathered, red-brown, micaceous
	(Dolerite — 25 m)
	(1)
44	Feldspathic sandstone and arkose: white to pale pink and buff, medium to coarse
9	Arkose: buff, fine-grained, flaggy, with thin grey siltstone interbeds
405	Total

Valentine Siltstone

The measured thickness of 494 m in the central Lansdowne Sheet area is the maximum observed along the edge of the Kimberley Plateau. The section thins to 405 m in the southwest and to 415 m in the northeast on the Bedford Stock Route in the Lissadell area. Near Carola yard and at Pyra Gorge in the southern part of the Lansdowne Sheet area approximate thicknesses of 400 m and over 600 m respectively have been noted. The thickening at Pyra Gorge is accompanied by a coarsening of the arenites with the appearance of pebble conglomerate and pebbly coarse-grained sandstone, and a reduction in feldspar content. Despite this general thickening at Pyra Gorge, there is a westward and southward thinning of member 6 from 107 m east of Lansdowne to 50 m north of Torrens yard and only 8 m at Pyra Gorge.

The principal lithological variations from the quoted sections are as follows. All the arenites become less feldspathic in the south, for example in the southern part of the Carola Syncline and westwards to Pyra Gorge, and also in the west between Torrens yard and Diamond Gorge. Coarse granule sandstone and pebble conglomerate are characteristic of the Carola Syncline/Pyra Gorge area, but are not found in the extreme west. These pebble conglomerates are found principally in members 5 and 6. An isolated occurrence of boulder conglomerate has been noted in member 6 in the southern part of the Carola Syncline and probably reflects localized movements along the nearby Greenvale Fault. The 5 m-thick siltstone noted in member 6 in the reference section east of Lansdowne dies out to the southwest and thickens northeastwards to about 15 m north of Bedford Downs homestead and 50 m in the Lissadell area (Dow et al., 1964).

Luman Siltstone (old name redefined)

The Luman Siltstone, which is the topmost formation of the Speewah Group, is underlain by the Lansdowne Arkose and overlain by the King Leopold Sandstone. The name is derived from the Luman Land Division of the East Kimberley and was first used by Dow et al. (1964). The reference section is 2 km east of Mount Laptz in the Lansdowne Sheet area at latitude 17°40′42″S, longitude

126°45′00″E. As defined by Dow et al., the unit consisted of two siltstone members separated by an arkose member and was 200 m thick. Because of the discontinuity of the lower siltstone member, the formation has been redefined to comprise only the upper siltstone. The arkose and the underlying siltstone (where present) are now assigned to the Lansdowne Arkose.

The Luman Siltstone is found throughout the area as a narrow outcrop at the base of the King Leopold Sandstone cliffs, extending from the northeast corner to Diamond Gorge in the west, and also in the south in the Carola Syncline and around Pyra Gorge. Because of its ready weathering, the Luman Siltstone is poorly exposed and is commonly obscured by large detrital boulders of King Leopold Sandstone. It is commonly intruded by the Hart Dolerite and consists essentially of one uniform siltstone unit varying from 75 to less than 50 m thick. It lies conformably on the Lansdowne Arkose and is overlain, generally conformably, by the King Leopold Sandstone, into which it grades by an increase in sand content. The transitional beds of purple flaggy fine to medium micaceous sandstone are assigned to the King Leopold Sandstone. In the south, for example in the Carola Syncline and at Pyra Gorge, there is a sharp boundary between feldspathic sandstone forming the upper part of the Luman Siltstone and clean-washed quartz sandstone of the King Leopold Sandstone, and it is possible that this sharp junction may indicate a localized paraconformable relation.

The formation consists almost entirely of purple-grey and green-grey shale and siltstone, the shale predominating in the lower part of the sequence and the siltstone in the upper. The arenite found in the south, near the top of the sequence, is coarse to medium buff-coloured feldspathic quartz sandstone and subgreywacke.

In thin section the siltstone consists mainly of subangular quartz grains up to 0.05 mm, with a copious intergranular mosaic of sericite and pale green chlorite, minor muscovite, green biotite, zircon, sphene, and goethite. The arenite consists of rounded second-cycle quartz, with scattered patches of completely kaolinized feldspar, and much interstitial chlorite and clay minerals.

A generalized section of the Luman Siltstone is given below. However, the sequence thins to 50 m westwards, 6 km west-northwest of Torrens yard, and is apparently even thinner at Diamond Gorge. In the Carola Syncline and at Pyra Gorge, thin beds of feldspathic sandstone are interbedded with the siltstone and increase in abundance upwards to the total exclusion of siltstone. The exposed thickness in the Carola Syncline is 37 m, of which feldspathic sandstone forms the upper 12 m.

Luman Siltstone (Reference Section)

Generalized measured section 2 km east of Mount Laptz (lat. 17°40′30″S, long. 126°45′E).

Metres	King Leopold Sandstone
47	Siltstone: pale grey-green and pale purple-grey, micaceous
8	Siltstone: grey, green-grey, and purple-grey, micaceous, minor grey shale interbeds
7	Shale: purple-grey with thin green shale interbeds
11	Shale: grey-brown and purple-grey with thin interbeds of flaggy, micaceous siltstone
73 Total	
	Lansdowne Arkose

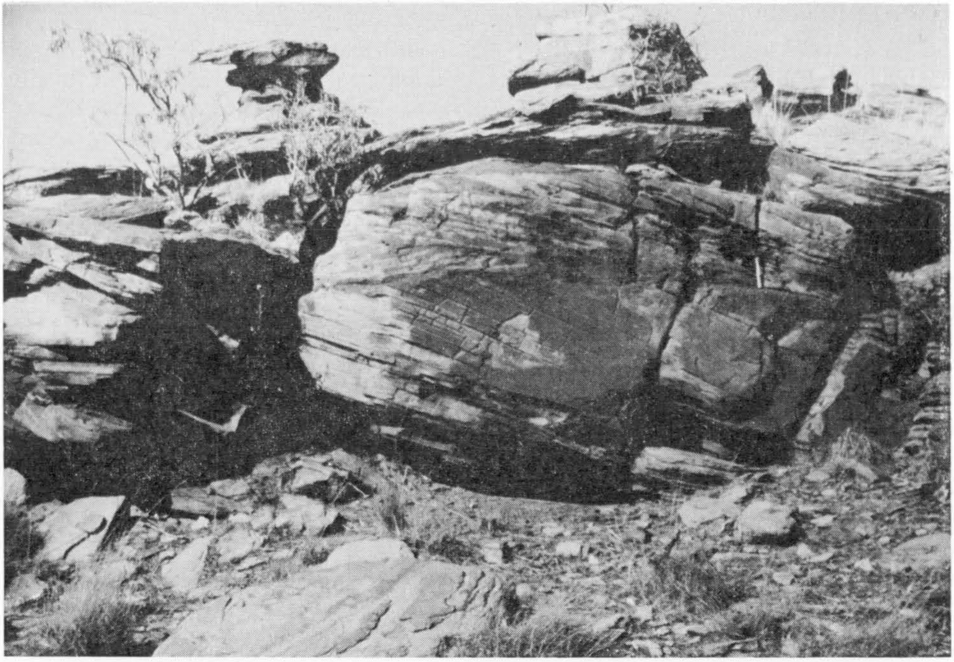


Figure 6. Strongly developed current-bedding in the Lansdowne Arkose near the Lansdowne-Fitzroy track 6 km due east of Mount Laptz summit. The 1 m-thick foreset units are typical of this member (No. 5) of the Lansdowne Arkose and distinguish it from others in the Speewah Group.

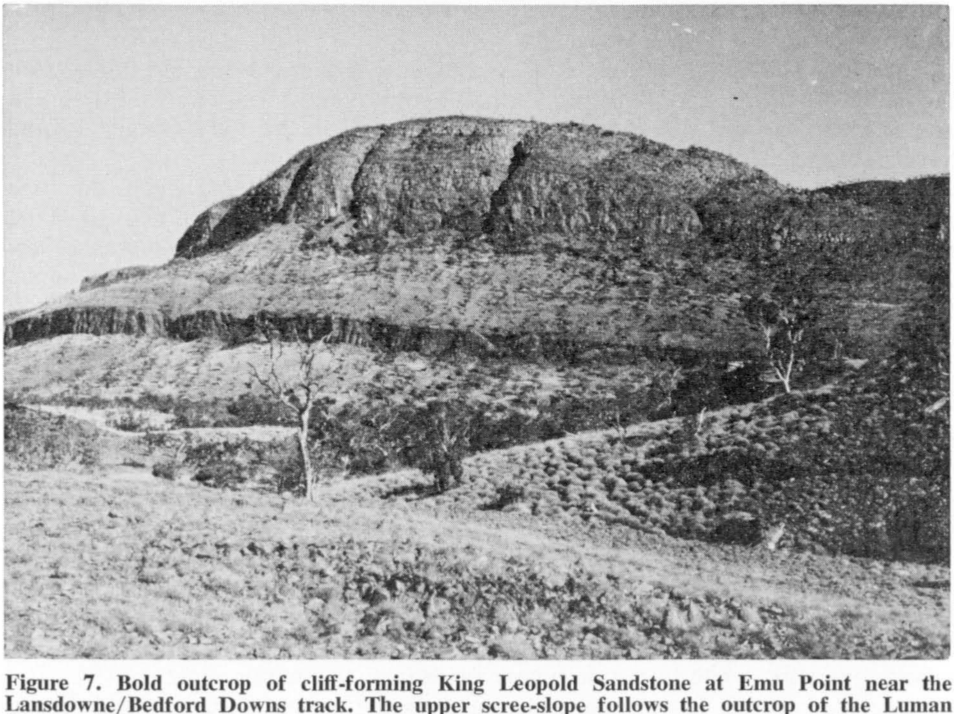


Figure 7. Bold outcrop of cliff-forming King Leopold Sandstone at Emu Point near the Lansdowne/Bedford Downs track. The upper scree-slope follows the outcrop of the Luman Siltstone. The low cliffs half way up the escarpment are the topmost exposures of Lansdowne Arkose in this section.

KIMBERLEY GROUP

The Carpentarian Kimberley Group lies conformably on the Speewah Group, except in the southeast part of the Sheet area where it is transgressive and locally lies unconformably on the Speewah Group, the Halls Creek Group, and Whitewater Volcanics. It is conformably overlain by the Bastion Group in the northeast and unconformably by the Mount House Group in the northwest.

The Kimberley Group consists essentially of sandstone with subordinate basalt, siltstone, and carbonate rocks, and is intruded locally by dolerite. Formations recognized within the group are the Pentecost Sandstone, Elgee Siltstone and Teronis Member, Warton Sandstone, Carson Volcanics, and King Leopold Sandstone.

The maximum thickness of the group in the Lansdowne Sheet area is about 3300 m, of which arenite makes up more than 2500 m.

King Leopold Sandstone

The King Leopold Sandstone overlies the Luman Siltstone, and is in turn overlain by the Carson Volcanics. The name King Leopold Beds was first used by Guppy et al. (1958) to describe the beds of the King Leopold Ranges lying stratigraphically between the Lamboo Complex and the 'Mornington' (Carson) Volcanics. The name was modified to King Leopold Sandstone by Harms (1959) and has subsequently been restricted by Dow et al. (1964) to the sandstone overlying the Speewah Group and underlying the Carson Volcanics.

The relation of the King Leopold Sandstone to the Luman Siltstone, at one time thought to be 'probably unconformable' (Dow et al., 1964), is now recognized as being generally conformable in the Lissadell and Lansdowne Sheet areas. However, the base of the King Leopold Sandstone in the southeast rests unconformably on the basal beds of the Tunganary Formation and overlaps onto the Halls Creek Group and the Whitewater Volcanics.

The King Leopold Sandstone crops out mainly in a broad belt extending from the western Sheet boundary to the northeast corner, and forms the King Leopold and Durack Ranges. Minor outcrops are also found in the Pyra Gorge/Goanna Spring area in the southeast. The thickness is about 1200 m.

It is an extremely erosion-resistant unit, generally cliff-forming where the beds are flat-lying or gently dipping, and forming prominent dip and scarp slope features (for example Mount King) where dips are steeper. Drainage courses are deeply incised and are mainly consequent and controlled by faults or joints. Subsequent valleys are developed where concordant sills of Hart Dolerite crop out within the King Leopold Sandstone.

The unit consists almost entirely of coarse-grained, commonly thin to thick-bedded, poorly sorted quartz sandstone ranging from white, pale pink, and buff to purple and pale brown. It ranges from poorly cemented friable to hard silica-cemented varieties. Strong cross-bedding is characteristic throughout the unit, with cross-bedded units mainly 0.3 to 0.4 m thick. Slump structures are developed locally.

Pebble conglomerates with 3 to 25 mm pebbles are present in the lower part of the sequence, and a marker bed of cobble to boulder conglomerate associated with quartz granule sandstone and localized siltstone is found about half way up the succession. Cobbles and boulders within the conglomerate consist of vein quartz, quartzite, white to purple quartz sandstone, and minor shale.

A detailed section has not been measured on the ground with tape and Abney Level, but the following composite stratigraphic section has been compiled from observations at several localities in the Elgee homestead/Mount Laptz area. Thicknesses are partly from field observations and partly calculated from aerial photograph measurements.

Section of King Leopold Sandstone—K1

Composite section partly measured in field with Abney Level and partly estimated from aerial photographs. Localities as follows:

(a) 19 km to 22 km southwest of Elgee homestead (lat. 17°31′S, long. 127°08′E, to lat. 17°24′S, long. 127°08′E)

(b) 13 km northeast of Elgee homestead (lat. 17°21′S, long. 127°21′E)

(c) 6 km north-northwest of Elba Hole yard (lat. 17°31′S, long. 126°43′E)

(d) 2 km east of Mount Laptz (lat. 17°40′30″S, long. 126°45′E)

	Metres	Carson Volcanics
(a, c)	40	Sandstone: pale rusty brown, medium-grained, medium to thin-bedded
(a)	210	Quartz sandstone: pale purple and pink to white, cross-bedded, coarse-grained, with ripple marks and clay pellets
(a)	60	Quartz sandstone: red-brown to purple, ferruginous, thin-bedded, fine to medium, silty
(a, c)	355	Quartz sandstone: hard, white, medium to coarse, silica-cemented; cross-bedded and massive, minor quartz pebble beds
(b)	20	Dark grey siltstone and fine-grained fissile sandstone, poorly exposed; thins out to northeast and southwest
(c)	6	Quartz sandstone: hard, white, medium to coarse, silica-cemented
(a, c)	3	Quartz granule sandstone: coarse, purple-grey, with 2 to 4 mm rounded grains; thickness up to 9 m
(a, c)	1.5	Pebble, cobble, and boulder conglomerate: purple-grey to red-brown, with inclusions of quartz sandstone, quartzite, slate, and vein quartz; thickness variable from 50 mm to 8 m
(c)	400	Quartz sandstone: white, pale pink and buff, medium to coarse, strongly cross-bedded, poorly sorted; rare pebble conglomerate with pebbles up to 25 mm
(c)	105	Quartz sandstone: cliff-forming, white to pale cream, slightly micaceous, fine to medium, clayey
(d)	15	Quartz sandstone: strongly cross-bedded, pale purple-grey to pale brown, micaceous, fine-grained, bleached spots in purple beds
	1216	Total
		Luman Siltstone

Not all the minor lithological subdivisions given in this section can be recognized throughout the area. The most useful marker bed is the conglomerate unit. Although this thins down to as little as 50 mm west and southwest of the reference area, the association of conglomerate overlain by granule sandstone is distinctive and can be recognized over a total strike length of more than 120 km.

Thickness estimates range from 1340 m north of Elba Hole yard and 1175 m a few km southwest of Elgee homestead, to 915 m north of Lansdowne homestead and 700 m at Diamond Gorge. These figures together with the estimate of 900 m (Dunnet & Plumb, 1964) for the Lissadell area indicate that the maximum thickness occurs in the central Lansdowne Sheet area and that the unit thins to the northeast and to the west. The area of maximum thickness of the King Leopold Sandstone is also the area of maximum thickness of the Lansdowne Arkose.

In the southeast a thickness of only 275 m lies unconformably on rocks of the lower Speewah and Halls Creek Groups. The thin sequence here, which includes a basal conglomerate, is probably equivalent to the topmost part of the full succession. At Pyra Gorge, however, farther to the south-southwest on the same structure, a full section is present.

In thin section, the King Leopold Sandstone consists predominantly of well rounded to subangular poorly sorted quartz grains. The matrix is mostly silica cement, optically continuous with the quartz grains, but in one specimen it is a felted aggregate of clay minerals with scattered small granules of iron ore. Up to 5 percent of feldspar is present, varying from slightly turbid pale brown potash feldspar to completely sericitized grains. Rare chert and quartz mylonite are the only rock fragments found. Minor accessory minerals are muscovite, iron ore, hornblende, and green tourmaline.

Carson Volcanics

The basic volcanics which crop out extensively around the Carson River (lat. 14°30′S, long. 126°45′E, Drysdale Sheet area) in the north Kimberley Plateau, have been renamed the Carson Volcanics by Dow et al. (1964). The original name, 'Mornington Volcanics' (Guppy et al., 1958; Harms, 1959), is invalid because of prior usage. The reference section is in the Lissadell Sheet area at latitude 16°17′25″S, longitude 127°48′50″E.

The volcanics crop out in a long arcuate belt which is continuous from the Lissadell Sheet area in the northeast to the western part of the Lansdowne Sheet area, where they form broad flat-lying sheets which are overlain unconformably by the Walsh Tillite. Elsewhere they are overlain conformably by the Warton Sandstone and conformably overlie the King Leopold Sandstone. Major streams are subsequent and generally follow the base of the Warton Sandstone escarpment, while minor streams are parallel and consequent, draining the dip-slope of the King Leopold Sandstone. Spinifex with scattered eucalypts is the dominant vegetation, particularly in areas of outcrop, but soil cover with grasses is well developed locally.

The formation consists dominantly of altered basic lavas and subordinate pyroclastics, with numerous thin discontinuous arenite interbeds which range in thickness from about 2 to 25 m. The basal flows, which have a total thickness of about 30 to 150 m, consist dominantly of altered, readily weathered dark grey and grey-green coarse-grained basalt and spilite including highly amygdaloidal types with amygdales of chlorite, epidote, quartz, calcite, and chalcopyrite. In the area north and northwest of Elgee homestead, beds of feldspathic sandstone and arkose up to 8 m thick are interbedded with the basal flows, but are absent elsewhere. Above the basal, dominantly spilitic part of the sequence, a massive medium-grained dark grey non-amygdaloidal basalt (Unit A in sections C1 & C2) up to almost

120 m in thickness probably represents a single flow. Above this flow the section is more varied both in thickness and in lithology, and flows cannot be correlated readily from area to area. The dominant rock types in this part of the succession are coarse-grained basalt with arkose interbeds, and minor pale grey-green amygdaloidal rhyolite, tuff, agglomerate, chert, and limestone. The topmost part of the sequence consists of a uniform succession of siltstone and feldspathic sandstone, 60 to 90 m thick, which forms a steep scarp slope underlying the more resistant Warton Sandstone.

The following generalized sections have been measured:

Carson Volcanics—Section C1

Fitzroy River Valley, 8 km north of Colass yard, latitude 17°28′S, longitude 126°33′E.

Metres	Warton Sandstone
91	Scree slope; poor exposure of purple siltstone and micaceous arkose
8	Limestone: thinly banded, cherty
3	Rhyolite: pale grey, amygdaloidal
15	Basaltic agglomerate: dark grey-green, with chert fragments
87	Non-amygdaloidal basalt: fine to medium-grained, dark grey, with thin interbeds of arkose and chert
27	Micaceous arkose and feldspathic sandstone: grey-pink, medium to fine-grained
78	Basalt: coarse-grained, dark grey, slightly amygdaloidal
64	Pink to brown feldspathic sandstone, arkose and flaggy micaceous siltstone
40	?Andesite: pale green-grey, fine to medium-grained, slightly amygdaloidal
6	Arkose: pale pink, flaggy, micaceous, medium-grained
17	Basalt: dark grey, fine-grained, slightly amygdaloidal
24	Arkose and feldspathic sandstone: fine-grained, pale pink to dirty grey, thin to medium-bedded
A117	Non-amygdaloidal basalt: massive dark grey, mostly fine-grained
6	Sandstone: clean-washed, feldspathic
9	Non-amygdaloidal spilite: green-grey with traces of chalcopyrite
17	Amygdaloidal spilite: pale purple-grey, amygdales of grey-green chlorite, calcite, and quartz, traces of specular hematite and chalcopyrite
24	Non-amygdaloidal spilite: grey-green with specks of chalcopyrite
29	Potash feldspar-bearing spilite; poorly exposed
662 Total	
	King Leopold Sandstone

Carson Volcanics—Section C2

Measured 6 km east of Teronis Gorge.

Metres	Warton Sandstone
55	Arkosic siltstone and fine-grained sandstone: flaggy, micaceous, cross-bedded slumped
9	Shales: purple and green, micaceous
15	Silicified tuffaceous sandstones: coarse to fine-grained, abundant bands of grey-green chert and greywacke siltstone
67	Altered basic lavas: highly amygdaloidal, with chlorite, calcite, epidote, and chalcopyrite amygdales. Some tuff and agglomerate. Rare pillow structures
A 87	Massive non-amygdaloidal basalt: grey to black, fine to medium-grained
15	Basaltic agglomerate, flow breccia, tuffaceous sandstone
37	Fine even-grained basalt with interbedded orange-brown arkose
6	Altered basalt: highly amygdaloidal, with chlorite, quartz, chalcopyrite, and epidote amygdales. Interbeds of chert. Possibly spilitic
53	Feldspathic sandstone, arkose and buff to purple-green quartz sandstone; pebbly at base, some slumping and cross-bedding at top. Thin interbedded basalt flows, fine to medium-grained, slightly amygdaloidal
27	Basalt: medium-grained, epidotized, with amygdales of chlorite, calcite, epidote, and more rarely chalcopyrite and galena
18	Basalt: green-grey, medium-grained, amygdaloidal, some quartz veins. Amygdales contain chalcopyrite traces. Potash feldspar present in amygdales in upper part of flow
389 Total	
	King Leopold Sandstone

The uppermost lavas described in Section 2 are extremely calcitized, with coarse calcite occupying pore spaces in basaltic 'froth' and amygdales in altered basalt. Amygdale trails through otherwise non-amygdaloidal basalt, and large amygdales containing chert and calcite, indicate an irregular streaming of emanations charged with silica and carbonate. This suggests local submarine extrusion, and is supported by the abundance of interbedded sediments and the presence in one locality of possible pillow structures. Likewise the basalt flows, which are dominantly spilitic and locally interbedded with sediments, may also have been extruded into water, but most flows in the Carson Volcanics appear to have been extruded subaerially. A possible vent and fissure line is located near latitude 17°20′S, longitude 127°17′E.

Sills of Hart Dolerite intrude the Carson Volcanics, particularly the basal member, and it is difficult to distinguish such sills from basalt flows. The amygdaloidal nature, generally finer grainsize, and higher degree of alteration of the basalt flows can assist in identification and separation of the two rock types.

The Carson Volcanics show rapid variation in thickness throughout the Lansdowne Sheet area, particularly in the upper part of the volcanic sequence. Measured thicknesses in the Lissadell Sheet area of 229 and 264 m (Dow et al., 1964) and those of 389 and 662 m in the Lansdowne Sheet area indicate a general thickening of the Carson Volcanics southwestwards. However, this variation is irregular; for example, a thickness of 270 m has been recorded southeast of Tullewah Hill, equidistant from the two measured sections in the Lansdowne Sheet area. A thickness of 520 m is recorded in the Little Gold River Valley immediately south of Pyra Gorge, where the section is similar to that in the Fitzroy Valley except that pyroclastics are more abundant towards the top and the siltstone is apparently absent.

In thin section the basalts are predominantly tholeiitic in composition. Both porphyritic and even-grained varieties are common, generally ranging in grainsize from fine to medium. Plagioclase phenocrysts 0.3 to 3 mm long are mostly labradorite and andesine, and are intergrown subophitically with pyroxene. The pyroxene is pigeonite, and occurs as equidimensional grains or extremely elongate prismatic forms. The even-grained basalts and the groundmass of the porphyritic varieties show an intersertal or hyalopilitic intergrowth of plagioclase, pyroxene, and devitrified glass, which contains numerous feldspar microlites.

Alteration of the basalt is widespread. Plagioclase is extensively sericitized, pyroxene is partly replaced locally by colourless chlorite, and areas of volcanic glass contain much fine-grained grey-brown clay mineral as a product of devitrification. Some of the chlorite present may pseudomorph original olivine. Minor accessories include small equant grains of magnetite, and ilmenite altering to leucoxene, slender prismatic apatite, and quartz, epidote, calcite, and chlorite which are found mainly as amygdale fillings.

Spilitic types contain phenocrysts of plagioclase (An_5) set in a matrix of small elongate plagioclase and very elongate pigeonitic pyroxene, some of which shows cruciform core structures. Devitrified glass fills interstices. Chlorite, epidote, quartz, and calcite form amygdales. Iron ore is an important accessory mineral.

Some of the amygdales contain large anhedral grains of albite intergrown with epidote, and it appears that these spilitic flows, as well as showing evidence of much hydrothermal activity, also show effects of lime and soda metasomatism. They are typically associated with narrow bands of locally ferruginous chert, and with feldspathic sandstone and arkose, which is locally slumped. This association has been commented upon by Turner & Verhoogen (1960, p. 261) and others.

The sandstone interbedded with the volcanic rocks is highly feldspathic. Quartz grains in tuffaceous sandstone are subangular to subrounded, and 0.5 to .04 mm across. Overgrowths of silica-cement are common, especially in the clean washed arenite. Other types have a matrix of chlorite and limonite. Plagioclase occurs as subrounded red-brown clouded grains. Grains of microcline are clear and unaltered. Iron ore and muscovite are common minor accessories. Thin bands of heavy minerals containing zircon and tourmaline occur throughout the sandstone. Tuffaceous sandstone and chert-rich siltstone are finely graded, and commonly contain small dropped fragments of basaltic material.

Warton Sandstone

The Warton Sandstone lies conformably on the Carson Volcanics and is overlain conformably in the east by the Elgee Siltstone and unconformably in the west by the Walsh Tillite. The term 'Warton Beds', derived from the Warton Range (lat. 17°24'S, long. 126°27'E) in the northwest part of the Lansdowne Sheet area, was used by Guppy et al. (1958) to describe rocks conformably overlying the Carson Volcanics and unconformably underlying the Walsh Tillite. The name Warton Sandstone was used by Harms (1959), who separated the 'Elgee Shale' and Pentecost Sandstone from the 'Warton Beds'.

The Warton Sandstone covers most of the north-central part of the Lansdowne

Sheet area and extends to the northeast corner. Over much of its outcrop the gently-dipping Warton Sandstone forms prominent cuestas of erosion-resistant sandstone, in which consequent streams and gorges are incised, the former showing parallel drainage pattern. Where the beds are flat-lying the topography is gently undulating with a thin veneer of sand.

The thickness, estimated from the width of outcrop on aerial photographs and dips measured in the field, is approximately 365 m about 19 km due south of Tableland homestead, and 275 m near Teronis Gorge.

Except for a slight increase in feldspar content upwards in the sequence, the rocks are uniform in appearance. The basal beds consist almost entirely of massive medium-grained white cliff-forming silica-cemented quartz sandstone with thin interbeds of thin-bedded pale purple-grey friable quartz sandstone. Locally the lower sandstone is pale rusty brown on weathered surfaces. The middle and upper parts of the succession are characterized by the appearance of grains of pale pink potash feldspar which increase in abundance upwards; these rocks vary from feldspathic sandstone to fine or medium-grained arkose. The feldspathic beds exhibit a darker tone on aerial photographs.

The Warton Sandstone is strongly current-bedded throughout the sequence. Current-bedded units are mainly 0.5 to 1 m thick in the lower part of the succession, but are mostly only 75 to 300 mm thick in the middle and upper parts. The current directions are dominantly from the north and northwest, with a spread from 240° to 75°. Ripple marks and clay pellets are found locally.

In thin section the lower part of the Warton Succession is a moderately coarse-grained well sorted quartz sandstone consisting essentially of rounded to sub-rounded quartz grains with optically continuous overgrowths of silica-cement and minor accessory turbid feldspar, muscovite, zircon, sphene, olive-green tourmaline, and interstitial sericite. The top of the sequence is a fine-grained well sorted silica-cemented arkose consisting of quartz with silica-cement overgrowths, and about 35 percent of feldspar, mostly turbid potash feldspar, but including some clear plagioclase and microcline, and minor accessory muscovite, zircon, and sphene.

Elgee Siltstone

The Elgee Siltstone is conformable between the Warton Sandstone and the Pentecost Sandstone. The name 'Elgee Shale' was used by Harms (1959) for the principal lutite member of the 'Warton Beds' of Guppy et al. (1958); Dow et al. (1964) modified the name to Elgee Siltstone. The name is derived from the Elgee Cliffs which extend for a distance of about 160 km from the northeastern Lansdowne Sheet area to the northern Lissadell Sheet area.

The Elgee Siltstone crops out in the north-central and northeast parts of the Lansdowne Sheet area in a narrow strip of country surrounding the Baulk Face Range and the southern end of the Durack River Basin, and bordering the Mount Cummings Plateau in the south. The formation may be subdivided into four lithological units, of which the two lower ones constitute the Teronis Member:

(4) Sandstone
(3) Red-brown siltstone
(2) Limestone and dolomite with algal structures
(1) Grey siltstone

The thickness is about 215 m, of which the Teronis Member in most cases constitutes less than 30 m.

The Elgee Siltstone crops out in a valley and steep escarpment underlying the erosion-resistant cliff-forming basal beds of the Pentecost Sandstone. Exposures in general are poor, but the sandstone at the base of unit 4 commonly forms a subsidiary ledge within the main escarpment slope, and the limestone of the Teronis Member locally forms massive outcrops.

Section of Elgee Siltstone

Generalized measured section; distances paced; at Boab Creek, east side of Baulk Face Range, 8 km south of Tableland-Glenroy track (lat. 17°18′30″S, long. 126°43′30″E).

Metres	Pentecost Sandstone (Hard white cliff-forming quartz sandstone)
64	Quartz sandstone: pale brown, with rare interbeds of fissile silty sandstone
15	Quartz sandstone: thin-bedded, hard to friable, pink-brown, purple-brown, and pale buff, with minor brown silty feldspathic sandstone and thin red-brown siltstone interbeds
114	Siltstone: poorly exposed, soft, friable, red-brown, with 25 to 50 mm interbeds and scattered spheroidal patches of green-grey siltstone; thin pink-grey fine-grained silty arkose at base
193 Total	
	Dolerite — 30 m
	Teronis Member
3	Limestone: mottled pale grey-green and pink-brown siliceous, with algal structures; poorly exposed
	Dolerite — 9 m
6	Siltstone with thin interbeds of pale brown feldspathic sandstone
8	Shale and siltstone: purple-grey, fissile, micaceous
6	Siltstone and shale: purple-grey, micaceous, with 50 to 150 mm interbeds of pale grey and pale brown ripple-marked micaceous feldspathic sandstone
23 Total	
	Warton Sandstone
216 Combined Total	

The lower part (unit 3) of the Elgee Siltstone proper is a thick succession of rarely exposed siltstone. It consists of soft red-brown siltstone and silty shale with 25 to 50 mm interbeds of pale green-grey siltstone and sporadic subspherical patches of green-grey siltstone, presumably derived from the red-brown siltstone by the chemical reduction of ferric oxide by small amounts of organic matter. This siltstone sequence is overlain by sandstone (unit 4). There is a moderately rapid transition from siltstone into deep pink-brown and buff-coloured sandstone with thin interbeds of red-brown and green-grey micaceous siltstone. Clay pellets are common on the sandstone bedding planes. The siltstone grades upwards into pale-brown sandstone through an increase in the sand/silt ratio, a decrease in colour intensity, and a thickening of the bedding. Thin cross-bedded units appear and become progressively thicker upwards.

The boundary with the overlying Pentecost Sandstone is taken as the base of a low cliff; above this horizon the sandstone is white and free from the silt interbeds which characterize the upper beds of the Elgee Siltstone.

The total thickness of the formation, which is 216 m in the measured section, decreases to 185 m to the northeast near Teronis Gorge, and thickens southwards to over 335 m in the Mount Ramsay Sheet area, the increase being mainly due to an increase in the thickness of the Teronis Member.

In thin section a fine-grained poorly sorted slightly feldspathic quartz sandstone from the Elgee Siltstone contains thin lenticular inclusions of sericitic shale and red-brown porphyritic volcanic glass up to 5 mm long. Quartz grains are subangular and range in size from 0.4 down to 0.004 mm with a predominance of the finer grades. Scattered patches of cementing carbonate and minor amounts of feldspar, zircon, blue-green tourmaline, and iron ore are also present.

Teronis Member (new name)

The Teronis Member is defined as a succession consisting predominantly of grey siltstone and carbonate rocks, including algal limestone, which overlies the Warton Sandstone and underlies the typical red-brown siltstone of the Elgee Siltstone escarpment sequence. The name is derived from Teronis Gorge (lat. 17°18′15″S, long. 127°15′36″E) in the Lansdowne Sheet area where the member is well developed.

The lower part (unit 1) of the Teronis Member consists mainly of purple-grey micaceous shale and siltstone with 30 to 150 mm interbeds of pale brown to buff fine-grained feldspathic sandstone, and has a sharp contact with the underlying clean-washed feldspathic sandstone and arkose of the Warton Sandstone.

The succession of limestone and dolomite (unit 2), which is variable within the Lansdowne Sheet area, has been examined in detail only around the eastern margin of the Baulk Face Range, where it is mostly only 2 to 8 m thick and consists of several thin carbonate beds with thin interbedded siltstone, for example in the following section measured on Boab Creek 2 km south of the Tableland-Glenroy track:

Metres	
0.7	Siliceous carbonate
0.3	Siltstone
0.3	Siliceous carbonate
0.3	Siltstone
0.3	Siliceous carbonate
3.6	Flaggy siltstone and silty sandstone
2.4	Carbonate

Several types of carbonate rock are present. One type, probably the most abundant, is dark brown on weathered surfaces and pale grey on fresh surfaces. Another type has a 5 to 10 mm-thick coating of powdery limonite on weathered surfaces and varies from pale grey to pale pink-brown mottled and pale grey-green when fresh. Algal limestone is extensive throughout the area, but is locally absent; it is mainly grey to grey-brown on weathered surfaces and contains abundant cylindrical algal structures 75 to 200 mm high and about 25 mm in diameter. These structures have an erosion-resistant central columella surrounded by a preferentially eroded intermediate zone and an outer erosion-resistant ring. They

Figure 8. Plan view looking down vertically onto algae in limestone of the Teronis Member of the Elgee Siltstone; note the upstanding central columella and readily eroded surrounding ring; locality 32 km east of Pyra Gorge. The scale is 15 cm long.

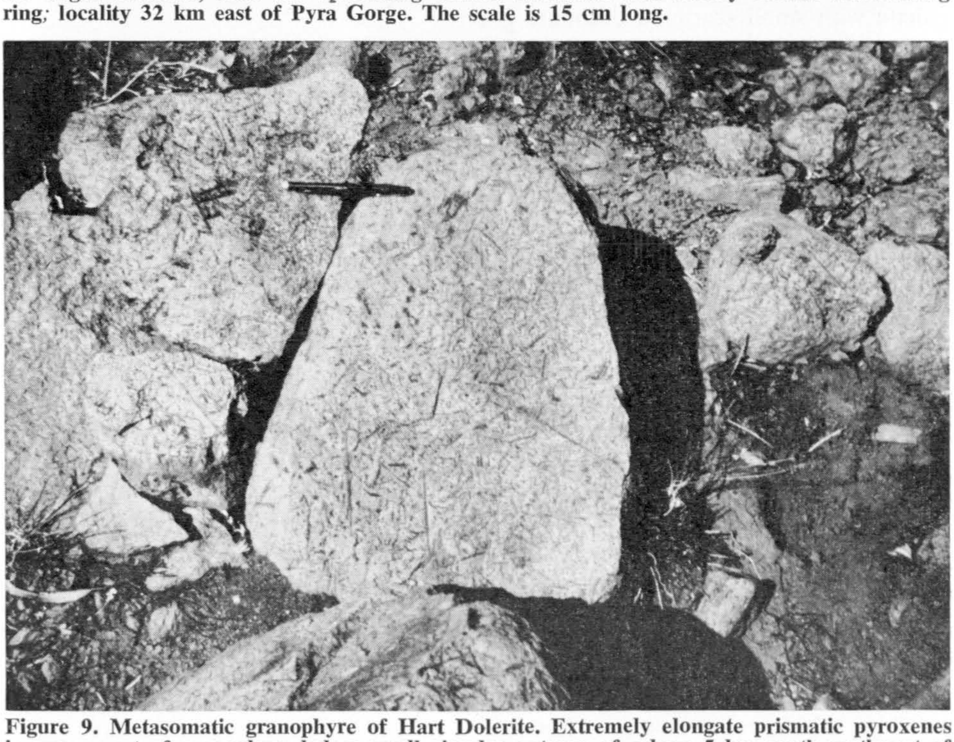


Figure 9. Metasomatic granophyre of Hart Dolerite. Extremely elongate prismatic pyroxenes in upper part of granophyre below small circular outcrop of arkose 5 km south-southwest of Lily yard (Lansdowne station). This upper part of the granophyre is probably metasomatic. It overlies Hart Dolerite and underlies Tunganary Formation arkose.

are generally found in continuous colonies with the individual algal structures only about 40 mm apart.

The thickness of the Teronis Member varies considerably within the Lansdowne and Mount Ramsay Sheet areas. The Teronis Member decreases in thickness to the northeast and dies out in the Lissadell Sheet area. It increase southwards in the Lansdowne Sheet area from 23 m in the measured section to about 45 m in the south, about 13 km south-southwest of Mad Gap yard, where the limestone is massive and about 30 m thick. Here the lower 10 m contains algae and the topmost 5 m is dark brown and limonitic. At Pyra Gorge, further west, it is about 90 m thick. In the reference section in the Margaret River area, it is 55 m thick, and farther to the northeast in the Mount Ramsay Sheet area it is 135 m thick.

Petrographically the carbonate rocks of the Teronis Member vary from almost pure limestone to almost pure dolomite. Most are apparently dominantly calcitic. Chemically determined calcite/dolomite ratios for specimens of these carbonate rocks are as follows: 1:6, 1:1, 6:1, and 7:3.

Most limestones are very fine-grained and consist typically of a fine-grained granular aggregate of calcite with scattered rhombs of dolomite and small sub-angular quartz grains. Slumped banding has been noted in one specimen which contains the laminae of silt and dolomite.

A specimen of algal limestone in thin section consists of circular algal structures up to 5 mm in diameter in a fine-grained carbonate matrix. In this rock, the algal structures, which are smaller than most, show zonal structure. The central columella and peripheral zone consist of fine-grained calcite with very small scattered grains of ?dolomite and an intermediate zone with abundant small opaque brown grains arranged in closely spaced concentric rings. The matrix consists of granular calcite with small scattered dolomite grains.

Pentecost Sandstone

The Pentecost Sandstone, which is the topmost formation of the Kimberley Group, overlies the Elgee Siltstone conformably and is conformably overlain by the Mendena Formation of the Bastion Group. The name Pentecost Sandstone, derived from the Pentecost Ranges (lat. 15°46′S, long. 127°45′E) in the south-western part of the Cambridge Gulf Sheet area, was first used by Harms (1959) for the uppermost division of the 'Warton Beds' of Guppy et al. (1958).

Within the Lansdowne Sheet area the Pentecost Sandstone crops out mainly in the northeast and north-centre, and also in the south immediately south and east of Pyra Gorge. It forms undulating and hilly plateau country, with mesas and cuestas rather poorly developed. Streams are locally deeply incised, especially in the northeast.

The formation, about 1000 m thick, has been subdivided into three informal units. Only the lower unit (Pkpl) has been measured; it is 145 m thick. The middle unit (Pkpm) is about 600 m thick and has a distinctive 20 m siltstone unit at its base. The upper unit is about 300 m and is poorly known in the Lansdowne Sheet area.

The lower boundary of the Pentecost Sandstone is gradational. The uppermost beds assigned to the Elgee siltstone are very pale brown to white quartz sandstone with rare interbedded chocolate-brown siltstone, and these grade into white quartz sandstone assigned to the Pentecost Sandstone. The boundary chosen coincides with a marked topographic change from easily eroded rocks of the Elgee Siltstone to white, cliff-forming Pentecost Sandstone.

The predominant rock types found are white to pale rust-brown quartz sandstone, buff to pale pink and white feldspathic quartz sandstone and arkose, grey-green glauconitic quartz sandstone, and purple-grey to green-grey micaceous siltstone, shale, and subgreywacke.

The sandstones are strongly cross-bedded, particularly in the lower part of the sequence, with foreset units mostly 300 to 450 mm thick. The source direction indicated by the current bedding in the lower sandstone is dominantly from the west-northwest, like that of the Warton Sandstone. The basal beds are white to very pale brown medium to coarse silica-cemented quartz sandstone which are medium to thick-bedded (0.1-0.5 m). They crop out as low cliffs up to 15 m high and form a resistant capping overlying the more easily weathered siltstone and sandstone of the Elgee Siltstone. Above the first 15 m, the sandstone becomes white, and shows blocky weathering with conchoidally fractured blocks. This grades rapidly upwards into friable off-white to pale rusty brown fine-grained quartz sandstone which persists throughout most of the sequence up to the siltstone unit.

The siltstone unit, which is poorly exposed, consists of purple-grey to green-grey ripple-marked micaceous shale and siltstone with interbedded pale grey flaggy feldspathic subgreywacke. Towards the top of the siltstone sequence a thin bed of grey-green muscovite-bearing glauconitic quartz sandstone contains about 20 percent of fresh bright green glauconite. The siltstone unit forms a useful marker bed which has been noted in the southern part of the Baulk Face Range and in the drainage basin of the Durack River. The middle sandstone unit consists of thin-bedded locally flaggy fine to medium-grained buff to pale pink feldspathic sandstone and arkose, and hard white silica-cemented quartz sandstone and feldspathic sandstone.

In the Lissadell Sheet area three siltstone units are recognized in the Pentecost Sandstone. Only the lowest has been noted in the Lansdowne area. This may be due to lensing out of the upper two siltstone units or possibly to lack of exposure and ground control in the inaccessible northeastern Lansdowne Sheet area.

In thin section, sandstone from the basal sandstone unit is well sorted and fine-grained with grainsize about 0.1 to 0.05 mm. It consists almost entirely of rounded to subangular quartz grains with optically continuous silica overgrowths, together with minor accessory feldspar, zircon, green tourmaline, and black opaque ore. A specimen from the siltstone unit is a silty quartz sandstone consisting of small (0.07 mm) angular to subangular quartz grains in a matrix of pale green chlorite, minor accessory feldspar, glauconite, tourmaline, and green biotite. The glauconitic sandstone consists of interlocking 0.2 mm silica-cemented quartz grains, rounded 1 mm grains of pale green glauconite, some partly replaced by chlorite, and minor accessory feldspar, muscovite, goethite, and limonite.

Bastion Group

Mendena Formation

In the Lansdowne Sheet area the Mendena Formation, which has a characteristic light-toned photo-pattern, has been mapped only by aerial photo-interpretation and the following lithological information comes from the Mount Elizabeth Sheet area to the north (Roberts & Perry, 1969).

The formation consists predominantly of shale and siltstone with thin interbeds of sandstone. The shale and siltstone are purple-grey, laminated, and fissile, and make up about 90 percent of the sequence. Sandstone interbeds 3 to 6 m thick are separated by lutite beds 15 to 30 m thick. The sandstone becomes less abundant upwards and varies from green and purplish fine-grained micaceous laminated flaggy feldspathic sandstone to white fine to medium-grained thin-bedded blocky quartz sandstone.

In the Lansdowne Sheet area the thickness is difficult to estimate because of the low angles of dip but it is probably not more than 30 m.

Hart Dolerite

The Hart Dolerite consists of an extensive series of anastomosing sills of dolerite and associated granophyre which, in the Lansdowne Sheet area, intrude all formations up to the Pentecost Sandstone.

The name 'Hart Basalt', derived from Mount Hart (long. 125°04′E, lat. 16°55′S) in the King Leopold Ranges, was first used by Guppy et al. (1958) for 'basalt and dolerite' found mainly in valleys in the King Leopold and Lady Forrest Ranges. The term 'basalt' was preferred because of the relatively consistent stratigraphic distribution of these basic rocks in the area mapped. The intrusive nature of these rocks was established by Harms (1959), who renamed them the Hart Dolerite.

This unit is one of the most extensively developed dolerites in the world, and is probably the most extensive Precambrian example. The total area of outcrop in the Kimberley area is about 3000 km^2, which is less than that of the Karroo Dolerite of South Africa, and is of the same order of magnitude as the Tasmanian dolerite. The total area underlain by dolerite in the Kimberley area is about 130 000 km^2, and the total volume is 125 000 km^3. At present there is little information about it compared with that available on the South African and Tasmanian dolerites.

In the Lansdowne Sheet area the Hart Dolerite crops out principally in a broad arc concave to the north-northwest, following the outcrop of the Speewah Group, but minor occurrences are found outside the belt. It forms low rounded boulder-covered hills, which have an even grey tone on aerial photographs, and treeless stony black-soil plains. The granophyre, which is slightly more resistant to weathering, forms mesas and strike ridges and is locally covered by red soil.

In general, the rock types range from olivine dolerite and gabbro through normal tholeiitic dolerite, granophyric dolerite, and diorite to granophyre. All gradations between dolerite and granophyre are noted, but basically these two rock types appear to be distinct since they are both more abundant than the intermediate types.

Field occurrence

The Hart Dolerite intrudes most Carpentarian and older formations. It is rare in rocks below the Speewah Group, but localized occurrences are present in the Halls Creek Group and Whitewater Volcanics immediately north of Pyra Gorge. A few basic dykes, possibly related to the Hart Dolerite, are found in the Lamboo Complex, particularly in the southeast. The most extensive series of sills is found throughout the Speewah Group from the upper O'Donnell Formation up to the Luman Siltstone. Within this group the dolerite shows a marked preference for siltstone beds, in which it forms anastomosing, dominantly concordant sills of considerable lateral extent, although a few small sills, some discordant, are found intruding arenites, for example 11 km southwest of Coolan Creek yard. Within the Kimberley Group the Hart Dolerite is extensively developed along a thin conglomerate bed about the middle of the King Leopold Sandstone, and is found locally within the Carson Volcanics, particularly in the southeast where it is difficult to distinguish from the Carson basalt. Thin sills are common in the lower Elgee Siltstone, and a few are present within the Pentecost Sandstone; one of them is traceable for more than 30 km. Discordant relations are partly sinuous and uncontrolled, and partly the result of splitting of the host rocks along fault and joint planes. Locally, large blocks several square kilometres in extent have been rafted out of their original position by the dolerite. The dolerite elsewhere follows individual beds for distances of up to 50 km, and a single complex outcrop of dolerite can be traced continuously for 230 km from near the Bedford stock route in the northeast to Diamond Gorge in the west.

The total area of the Hart Dolerite outcrop in the Lansdowne Sheet area is about 2220 km^2, of which about 515 km^2 is within the Kimberley Group, 1680 km^2 within the Speewah Group, and only 25 km^2 in older rocks. Of the total area of outcrop, 2080 km^2 is dolerite and 140 km^2 granophyre. The thickness of the sills is variable, mostly from 15 to 900 m, for example 19 km south of Bedford Downs homestead. The maximum thickness in the Lansdowne Sheet area is about 3000 m, northwest of Galway Valley yard.

Dolerite. In hand specimen the dolerite is mainly a medium to coarse-grained dark grey even-textured rock, which locally has a spotted appearance owing to the presence of large ophitic pyroxenes. A distinctive coarse-grained dolerite or gabbro with elongate dark green pyroxene is found in many widely separated localities as small discrete intrusions which generally overlie granophyre. In places this type forms pegmatitic veins within coarse-grained dolerite. Isolated schlieren of granophyric dolerite have been noted in the dolerites of the Speewah Valley in the Lissadell Sheet area, where they are relatively low in the Speewah Group sequence. These rare localized granophyre enrichments may possibly be due to the assimilation of acid xenoliths.

Late-stage hydrothermal alteration has resulted in the formation of epidote veins within the dolerite and in localized occurrences of prehnitized dolerite. Sporadic veins of calcite, some with individual crystals up to 150 mm across, and minor quartz veins carrying traces of chalcopyrite are also found.

Contact metamorphism of country rocks at the margin of the dolerite intrusions is slight. Siltstone is altered to hard blocky hornfels, and arkose is indurated for a distance of only 0.5 to 1 m from the contact.

Igneous flow lamination has been noted in a number of places, but is not common. It is best developed about 5 km east of Mud Spring and 6 km southeast of Lily yard. It is also well developed relatively high in the dolerite sequence in the Speewah Valley. Such lamination implies the presence of a planar boundary to control the plane of flow, and could be the result of two-stage intrusion in which flow lamination in the later intrusion has developed along the upper contact of the earlier intrusion, or could be interpreted as the result of flow conditions developing within a partly settled magma.

Granophyre. In almost all known outcrops the granophyre forms a flat-lying sheet either at or near the top of a dolerite sill. A few exceptions to this are known; about 3 km northwest of Lily yard a plug of granophyre has apparently intruded dolerite; 5 km south-southwest of Bedford Downs homestead, granophyre which is not in contact with dolerite has intruded arenite of the Lansdowne Arkose; 2 km east-southeast of Piantis yard a thin dyke of granophyre cuts dolerite lying above a granophyre layer; and a short distance west of Piantis yard a thin dyke of granophyre cuts dolerite.

The occurrence of granophyre does not directly depend on the thickness of the associated dolerite sills, but is at least partly related to it. For example, the very thin dolerite sills, especially the transgressive ones, do not have any associated granophyre and most, but not all, of the thick ones do have granophyre. Sills 750 m thick 19 km south of Bedford Downs homestead and 6 km northwest of Twenty Mile yard, and 600 m thick 10 km east of Lansdowne homestead show no development of granophyre. Similarly, the relative thickness of the dolerite and granophyre are variable. Northwest of Galway Valley yard, only 30 to 60 m of granophyre overlies dolerite estimated to be more than 3000 m thick, whereas in the Red Valley, a short distance to the west, 230 m of dolerite is overlain by 150 m of granophyre.

Previous work in the Lissadell Sheet area had suggested that the granophyre occurs only at one stratigraphic level, that is overlying dolerite intruded into or along the contact of the Valentine Siltstone. However, recent work in the Lansdowne Sheet area has shown that granophyre has been developed above dolerite at no less than six different horizons within the Speewah and Kimberley Groups, namely:

(6) Within the lower King Leopold Sandstone succession, for example 8 km west-northwest of Lansdowne homestead
(5) Within the Luman Siltstone, for example 2 km southwest of Melrod yard
(4) Between the middle and upper Lansdowne Arkose, (between units 5 and 6), for example east of Old Bedford yard
(3) Within the lower siltstone (unit 2) of the Lansdowne Arkose
(2) At the lower contact of, or within the Valentine Siltstone
(1) Within the Tunganary Formation, probably at different levels, for example about the top of the sequence near Lansdowne airstrip, and near the base 10 km southeast of Goads yard.

Granophyre has not been found at horizons lower than the Tunganary Formation or higher than the King Leopold Sandstone. This is probably because the thickest sills are found within the Speewah Group. Granophyre is more commonly associated with the Tunganary Formation and the Valentine Siltstone than with other units.

The granophyre is red-brown to pale pink-brown, mostly medium-grained, and commonly mesocratic. Porphyritic phases with phenocrysts of pyroxene and off-white plagioclase in a pink granophyre matrix are uncommon. One type of granophyre with slender pyroxene up to 100 mm long and locally forming 'comb' or 'herring-bone' structure is developed sporadically overlying normal granophyre and underlying arkose.

Contact alteration of siltstone by the granophyre is restricted to slight induration, but arkose is strongly indurated for distances of 6 m or more from the contact and generally has a spotted appearance owing to the segregation of the feldspathic components of the arkose into 5 mm spheroidal nodules surrounded by narrow siliceous borders. On a small scale the contact between arkose and granophyre is irregular and sinuous and is gradational over a zone 5 mm wide. In places elongate crystals of pyroxene have grown into the arkose.

Dolerite grades into granophyre in one locality about 5 km north of Mud Spring. Such gradations may be general, but the intermediate rocks are more readily weathered than either the dolerite or the granophyre and there is commonly an area of no outcrop between the two rock types.

About 2 km east of Piantis yard a thin granophyre dyke traced for over 90 m cuts coarse-grained dolerite and shows gradational contacts with it. The dolerite is considerably enriched in micropegmatite in a 150 mm-wide contact zone adjacent to the dyke, and this, together with the gradational nature of the contact, suggests that the dyke was intruded into only partly consolidated dolerite, as otherwise no appreciable metasomatism of dolerite would be expected. This indicates contemporaneity of dolerites and granophyre in at least part of the area.

Petrography. In thin section the dolerite is coarse to medium-grained with texture varying from ophitic to poikilitic and hypidiomorphic-granular. Most specimens are ophitic or sub-ophitic, but slightly granophyric types are mostly hypidiomorphic. The dolerites consist principally of fresh elongate plagioclase (An_{55-60} zoned to An_{40-45} margins), and ophitic grains of pale grey-brown to pale purple-brown clinopyroxene which is mainly pigeonite, and is locally accompanied by subordinate amounts of calcic augite. Pyroxene commonly shows slight marginal alterations to a pale green fibrous amphibole. Small amounts of olivine, altered to pale green chlorite, antigorite, and specks of iron ore are present in most specimens, which also contain accessory amounts of micrographic quartz-feldspar intergrowths. Minor accessory minerals include magnetite, which is ubiquitous, brown biotite, apatite, and sphene. Secondary minerals include chlorite, calcite, sericite formed through partial alteration of plagioclase and, in one example, prehnite.

The granophyre is mineralogically similar to the dolerite and differs from it mainly in the relative amounts of the various constituents present. It consists principally of phenocrysts of plagioclase and pyroxene in a matrix of moderately coarse-grained micropegmatite. The micropegmatite, which is the most abundant constituent, consists of pale rusty brown turbid microperthite micrographically intergrown with quartz. Discrete grains of microperthite are found, and also microperthite overgrowths on plagioclase. Free quartz occurs locally.

Plagioclase varies in composition from the intermediate granophyric rocks to the end-stage granophyre and is mostly strongly zoned, with cores An_{45-30} and margins An_{35-20}, and is bordered by microperthite or micropegmatite. Pyroxene, as in the dolerite, is mainly pigeonite, but diopsidic augite is also present. Pigeonite is locally partly surrounded by hornblende. Irregular patches of chlorite associated with subordinate small hackly granules of magnetite probably pseudomorph olivine. Minor accessory and secondary minerals include amphibole, epidote, calcite, magnetite, apatite, sphene, chlorite, sericite, and goethite.

Little is as yet known about the petrographic variations of the sills in vertical section, but three specimens from the above-mentioned gradational sequence near Mud Spring have been examined. In the sequence there is an upward increase in the amount of micropegmatite; a decrease in the amounts of pyroxene, magnetite, and olivine pseudomorphs; a decrease in the amount of plagioclase; and a decrease in the anorthite content of plagioclase from about An_{45} to An_{20}.

The contact-metamorphosed arkoses adjacent to the granophyre are characterized by the development of small amounts of interstitial micropegmatite. These 'meta-arkoses', which consist mainly of quartz, potash feldspar, and minor chlorite, show marginal recrystallization of quartz grains resulting in the formation of a series of peripheral pyramidal terminations on each detrital quartz grain. The recrystallized quartz grain margins have been locally penetrated by potash feldspar to give small patches of finely crystalline micropegmatite which makes up about 5 per cent of the rock.

There is no definite evidence that the newly formed micropegmatite has been introduced from the granophyre, but because the granophyre has caused more intense contact alteration than the dolerite the contact metamorphism caused by the granophyre cannot be a purely thermal effect. Small amounts of volatiles, especially water, were probably introduced from the granophyre and assisted the recrystallization processes.

Petrogenesis. Several possibilities must be considered regarding the origin of the granophyre. The principal ones are:

(1) *Crystallization differentiation by crystal settling from a normal tholeiitic magma, possibly aided by filter pressing of the residium.* This seems the

most likely origin. The principal problem in this respect is whether there is sufficient dolerite to account for the volume of granophyre developed. Data presented by Nockolds (1954) indicate that the average tholeiite contains 3.5 percent normative quartz and 5.0 percent orthoclase. Thus if an average tholeiitic magma differentiated completely into its acid and basic fractions, the relative proportions of acid to basic would be about 1 to 12. In parts of the Lansdowne Sheet area the proportion of granophyre is very much less than this and in parts it is very much greater.

In many places the Hart Dolerite contains 5 to 10 per cent micropegmatite and locally considerably more, so it appears that over these areas little or no differentiation can have taken place, if it is assumed that the original magma was similar in composition to the average tholeiite. The most abundant type of dolerite, however, contains only about 1-2 percent of interstitial quartz and potash feldspar. If the original magma was a normal tholeiitic one, it could therefore have differentiated to form granophyre, plus dolerite relatively impoverished in salic constituents. The relations in areas where the granophyre/dolerite ratio is much greater than 1:12, such as Red Valley where it is 2:3, still require explanation. Perhaps the most likely explanation is that the Red Valley granophyre originated elsewhere, possibly to the east in the area north of Mud Spring, probably as a result of crystallization differentiation and was intruded into its present position by lateral injection along a pre-existing dolerite/sediment contact.

(2) *Contact metasomatism and/or assimilation of arkose in situ.* Assimilation seems to have been relatively unimportant because at dolerite/sediment junctions there are no contact effects, either thermal or metasomatic, other than slight induration. If assimilation of xenoliths had occurred, localized inhomogeneities might be expected, owing to incomplete assimilation or incomplete dissipation of assimilated products, but these are not found except in one locality in the Speewah Valley. Evidence for assimilation is generally lacking in most dolerites (Walker, 1958). In this context, the possibility of assimilation or metasomatism caused by the granophyre itself must be considered. Although this possibility cannot provide an explanation for primary development of granophyre, it is possible that the amount of granophyre may have been increased by assimilation and metasomatism of arkose. The compositional changes required to convert arkose to a relatively leucocratic granophyre are comparatively minor. In one locality it has been noted that very elongate crystals of pyroxene have grown into the arkosic host rock from the intruding granophyre, and in several places the development of granophyric textures is found in the contact altered arkose. In several places a distinct variant of the granophyre containing slender elongate pyroxenes overlies normal granophyre and underlies arkose. The fact that elongate pyroxenes have been found growing in contact-altered arkose, and the position at which this unusual type of granophyre is developed, strongly suggest that it may have originated in situ by metasomatism of arkose. A similar granophyre with elongate pyroxenes figured by Walker & Poldervaart (1949, plate 10) is described by them as metasomatic.

(3) *Direct intrusion of two separate magmas accompanied by partial mixing.* On a small scale the existence of a separate acid magma in the Lansdowne Sheet area is indicated by dykes of granophyre intruding dolerite, and by the porphyritic nature of some of the granophyres, which suggests slow

partial crystallization at depth, followed by more rapid crystallization on intrusion. Such an origin would necessitate the derivation of intermediate rocks by partial mixing of acid and basic magma. This is not consistent with the known temperature differences between these two magmas and the fact that in other areas of the world where they have come in contact the effect has been one of chilling of the basic magma by the acid rather than of mixing (Blake et al., 1964). Because of this objection and the comparative paucity of intrusive granophyres, this possibility is not favoured for the origin of the granophyre as a whole, but it is possible that minor amounts of acid magma were intruded independently.

Age. The age of the Hart Dolerite is uncertain*. In most places it is apparently earlier than the main folding and faulting of the area, but it probably postdates the earliest faulting. Uniformly thick dolerite sills with overlying granophyre, which maintains a uniform thickness on both crest and limbs of fold structures, for example as in Red Valley, indicate that in general the dolerite antedates the folding. This is supported by the fact that the granophyre sheets, which presumably must have developed in a horizontal or subhorizontal position, are now mostly inclined and are parallel to the adjacent dipping sediments.

Evidence for a pre-faulting age is provided by faulted dolerite/sediment sequences in several places, especially south of Lansdowne airstrip and immediately north of Pyra Gorge. In the central part of the area, however, it appears that the dolerite has split apart the sediments along pre-existing north-trending faults and joints, which subsequently have been reactivated and have faulted the dolerite itself.

In the King Leopold Ranges between Torrens yard and Diamond Gorge, strike faulting has been postulated (see Structure) to explain repetition of the sequence, but no evidence of these faults has been observed on the ground and it is possible that the dolerite at this locality has been intruded along pre-existing faults which have been obscured in the process.

* Bofinger (1967) has determined a Rb-Sr total-rock and mineral isochron of 1800± 25 m.y. for the Hart Dolerite. This provides a minimum age for the Kimberley Basin succession and older units.

ADELAIDEAN

MOUNT HOUSE GROUP (old name redefined)

The Mount House Group contains the youngest Precambrian rocks in the Lansdowne Sheet area and consists of the Estaughs Formation, Throssell Shale, Traine Formation, and Walsh Tillite. The name is derived from Mount House (lat. 17°08′S, long. 125°44′E) in the Lennard River Sheet area to the west. The rocks of the group were originally named the 'Mount House Beds' and 'Walsh Tillite' by Guppy et al. (1958); the beds have now been raised to group status and the Walsh Tillite included. The reference area for the group is in the scarp at the southeastern side of the Mount Clifton Plateau, about latitude 17°24′S, longitude 126°02′E.

In the Lansdowne Sheet area the Mount House Group overlies the Kimberley Group with a slight angular unconformity. It is overlain only by Cainozoic soil cover. The group is considered to be a stratigraphic equivalent of the Duerdin Group in the Dixon Range Sheet area. (Dow & Gemuts, 1969) and the Kuniandi Group in the Mount Ramsay Sheet area (Roberts et al., 1965).

Outcrops are confined to the northwest corner of the Lansdowne Sheet area, bounded roughly by the Traine River in the east, and from there by a line extending southwest through Glenroy homestead to the western Sheet boundary immediately south of the Mount Clifton Plateau. The topmost beds of the group have been removed by erosion and the maximum preserved thickness is estimated to be about 275 m.

Rocks of the group, which are mostly flat-lying and essentially undeformed, consist mainly of flaggy micaceous green shale. Massive tillite at the base of the group is overlain by dolomite and sandstone. The sequence of tillite overlain by dolomite and green shale is diagnostic. Within the overlying shale, interbeds of flaggy sandstone are found near the base and blocky quartz greywacke at the top. Most of the rocks in the group are very easily eroded, so that most of the area underlain by them consists of wide low-lying plains with only sporadic outcrops amongst the soil cover. The blocky quartz greywacke at the top of the succession crops out strongly to cap a prominent scarp, about 150 m high, which borders the Mount Clifton Plateau.

Preliminary radiometric dating of rocks from the Duerdin Group and Kuniandi Group indicates a late Adelaidean age (Bofinger, pers. comm.). As the Mount House Group is correlated with these groups it is also considered to be Adelaidean.

The following composite section was measured near Mount Clifton and contains the reference sections for most of the constituent formations.

Composite Section of Mount House Group—H1

Unit		*Thickness* (m)	*Description*
Estaughs Formation	(1)	15+	Top of unit eroded. Flaggy cross-bedded purple micaceous siltstone with interbeds of blocky fine-grained subgreywacke
		12	Blocky to massive, purple hematitic subgreywacke and purple-brown flaggy feldspathic-micaceous-quartz siltstone. Clay pellets and ripple marks. Forms a prominent scarp.

		50	Flaggy to blocky, laminated grey-green fine-grained micaceous subgreywacke alternating with flaggy grey-green micaceous siltstone. Arenite beds 2 to 3 m thick, siltstone beds 5 to 10 m thick. Some ripple-marks. Probable slump structures in the lower beds. This bed is transitional into the underlying unit.
	Total	77+	
Throssell Shale	(2)	149	Uniform flaggy grey-green to blue-grey chloritic and micaceous shale with lenticular flaggy interbeds of laminated micro-cross-bedded fine-grained grey-green micaceous sandstone
		26	Very poorly exposed flaggy green siltstone and fine-grained sandstone with flaggy brown sandstone interbeds near the base
	Total	175	
Traine Formation	(3)	4	Blocky blue-grey dolomitic chloritic sandstone
		2	Dolomite breccia
		1	Massive green-brown, medium-grained, dolomitic, chloritic sandstone with large scattered pyrite pseudomorphs
	Total	7	
Walsh Tillite	(4)	4	Flaggy to blocky, pink to yellow, fine-grained thin-bedded dolomite. Abundant pyrite in bedding planes
		0.5	Algal dolomite
		14	Massive tillite
	Total	18.5	
			Carson Volcanics

(1) Eastern side of Mount Clifton (lat. 17°18′10″S, long. 126°1′50″E)
(2) Near Mount Clifton (lat. 17°24′18″S, long. 126°2′20″E)
(3) Southeastern corner of Mount Clifton (lat. 17°24′18″S, long. 126°2′42″E)
(4) Throssell River (lat. 17°24′00″S, long. 128°2′50″E)

Walsh Tillite (old name)

The Walsh Tillite was first named by Guppy et al. (1958), who named the overlying sediments the 'Mount House Beds'. The 'Mount House Beds' have now been raised to group status and the Walsh Tillite is included in the group. The name is derived from Walsh Creek (lat. 17°12′S, long. 125°35′E) in the Lennard River Sheet area to the west.

The tillite is the basal unit of the group. It is conformably overlain by the Traine Formation and unconformably overlies rocks of the Warton Sandstone, and transgresses onto the Carson Volcanics.

The Walsh Tillite consists of massive tillite, flaggy thinly bedded pink to yellow fine-grained dolomite, and algal dolomite. In the extreme northeast a greenish-white quartz sandstone crops out. A typical section of the tillite is described in the measured section above. Within the Lansdowne Sheet area the Walsh Tillite is less than 5 to about 60 m thick. It is exposed in a line of scattered outcrops, which in general follow the western side of the Traine River to its confluence with the Hann River, and then trend westwards past Glenroy homestead to the western Sheet boundary south of Mount Clifton. It also crops out along the northern Sheet boundary west of the Traine River and in an outlier in the Warton Range area. The tillite is poorly exposed and is generally observed only in scarps beneath the more resistant Traine Formation or in stream sections. Good exposures occur in a few localities, for example south of Mount Clifton; on the track to Mornington No. 1 Bore at the Station Creek Crossing; on the Glenroy/Tableland road 1 km northeast of the Hann River Crossing; and in the scarp below the Traine Formation west of the Traine River. Elsewhere, its presence is indicated only by areas of glacial boulders within soil cover. The pink dolomite at the top of the unit provides a useful marker bed.

The tillite consists of very poorly sorted particles ranging from grit size up to boulders 1 m in diameter, set in a matrix of distinctive green clay or fine greywacke. The boulders are subangular to subrounded, the corners generally being rounded, and the larger specimens are polished. Faint striae are visible on some specimens. The boulders consist almost entirely of pink fine-grained quartz sandstone similar to the Pentecost Sandstone, and white fine-grained sandstone similar to the Warton Sandstone. Other rock types include basalt (Carson Volcanics?), dolomite, black dolomitic sandstone, ferruginous grit, green chert, quartz, and flaggy laminated green siltstone (Bastion Group?). Most, if not all, of the boulders are apparently derived from the Kimberley and Bastion Groups. Granitic and metamorphic rocks are absent.

The tillite is best exposed in the measured section in the bank of the Throssell River, south of Mount Clifton. Here the matrix consists of a massive green very fine-grained greywacke or clay. Towards the top of the tillite, bedding develops, and the tillite grades into 0.5 m of overlying purple shale. Accompanying this gradation is a decrease in the size and number of boulders.

The matrix of the tillite includes numerous lenses of reddish fine-grained sandstone which are irregular in shape and difficult to identify as lenses rather than erratics; proof of their origin as lenses is found in the presence of glacial erratics within them and even lying across the sandstone/green clay contact. They vary in size from lenses 0.5 to 1 m in diameter to elongate bodies several metres long and up to 1 m thick.

Near the base of the tillite in the Station Creek exposure, the matrix is disposed in large 'bedding-rolls' or folds with an amplitude of about 450 mm and wavelength of 0.5 m. They are symmetrical in cross-section and apparently cross-folded. A short distance away the same beds show a complex rectangular 'bedding-roll' pattern, reminiscent of interference ripple-marks. Here the amplitude is 75 to 100 mm. The structures may possibly be the result of folding of the plastic matrix material owing to compression caused by the advance of ice.

In the Traine River/Warton Range area, tillite is preserved as boulder-covered hills with very little outcrop. Here the inclusions in the tillite consist exclusively of quartz sandstone, apparently derived locally from the Warton Sandstone.

North of the Glenroy-Tableland track a white quartz sandstone overlies the tillite and underlies the pink dolomite. The sandstone persists to the northern Sheet boundary, but the overlying dolomite dies out northeastwards.

Tillite within the formation shows the following marked lateral variations in thickness:

	Metres
(1) Area southeast of Mount Clifton	13
(2) 6 km northeast of (1)	Nil
(3) Station Creek	6
(4) Traine River area north of Tableland-Glenroy track	3-6
(5) Warton Range	60

Variations in lithology along the northern Sheet boundary are shown in the following sections:

Macnamara Creek area *West*	*East*	*Traine River area*
Traine Formation	Traine Formation	Traine Formation
Metres	*Metres*	*Metres*
5 — Flaggy pink dolomite. Algae at base		
3 — Thin, flaggy, green-white quartz sandstone	9 — Massive white quartz sandstone	3 — Blocky quartz sandstone
3 — Tillite		6 — Tillite
Carson Volcanics	Carson Volcanics	Warton Sandstone

The dolomite at the top of the formation is readily recognized by its pink colour, very fine grainsize, and regular very thin to laminated bedding. In thin section the rock consists of a very fine-grained (0.01 mm) aggregate of carbonate crystals with rare patches of quartz. In the Throssell River exposure the dolomite shows scattered bedding laminae containing abundant goethite pseudomorphs after euhedral pyrite. The crystals are about 3 mm across and cover up to 50 percent of the area of some bedding planes. The dolomite is generally uniform in thickness, but dies out in the extreme northeastern part of the Mount House Group outcrop.

The dolomite is immediately underlain by 0.5 m of algal dolomite. The algal structures consist of irregularly folded siliceous laminae, apparently forming moderately spaced hemispherical domes. Cross-sections have not been observed. In many places the laminae are dislocated and brecciated. The upper and lower contacts of the algal beds are planar and sharp.

Traine Formation (new name)

The Traine Formation conformably overlies the Walsh Tillite and is conformably overlain by the Throssell Shale. It crops out on a low plateau immediately to the northwest of the Traine River, from where the name is derived, and from there a narrow line of outcrops extends southwestwards via Glenroy homestead to the

Figure 10. Walsh Tillite. Sandstone lenses within green siltstone matrix; sandstone erratics throughout the matrix; sandstone lens in centre of photograph. Locality on the Throssell River 8 km southwest of Glenroy homestead.

Figure 11. Algal dolomite overlying Walsh Tillite. Vertical section of dolomite bed showing irregular dome-shaped algae with silicified laminae; the algal structures are intensely brecciated in places. Locality on the Throssell River 8 km southwest of Glenroy homestead.

southeastern corner of the Mount Clifton Plateau. In the latter locality it is about 7 m thick (reference section), and in the Traine River area it exceeds 15 and may be as great as 60 m, but the full thickness cannot be determined accurately. In the west, the rocks of the formation are poorly exposed, but in the Traine River area a prominent sandstone forms a low plateau, with a bordering scarp up to about 45 m high.

The Traine Formation consists of blocky blue-grey to buff chloritic dolomitic sandstone, dolomite breccia, massive purple-brown ferruginous sandstone, purple shale, and flaggy buff dolomite. The lithology and thickness vary laterally over relatively short distances.

In the northeast, between the Hann and Traine Rivers, the formation consists of massive fine to medium-grained purple-brown ferruginous sandstone, which characteristically weathers into large rounded boulders 2 to 3 m in diameter. The thickness cannot be accurately estimated as the sandstone forms a wide plateau area with a very low angle between the dip of bedding and the land surface. More than 15 m of sandstone is exposed in the bordering scarps and the total thickness of sandstone may be as great as 60 m.

Between the Hann River and Glenroy homestead, the formation is poorly exposed and the dominant rock is purple shale, which is interbedded with flaggy to blocky buff dolomite, purple-brown dolomitic sandstone, and sporadic dolomite breccia. The sandstone shows load-casts and bedding rolls. The thickness is probably less than 15 m.

In the measured reference section on the southeastern edge of the Mount Clifton Plateau, the base of the unit is massive green-brown medium-grained chloritic dolomitic sandstone with scattered pyrite pseudomorphs up to 5 mm across. Small dolomite fragments within the sandstone grade upwards into a dolomite breccia consisting of abundant angular dolomite fragments up to 50 mm long set in a sandstone matrix. When weathered, the dolomite is leached out to leave a boxwork of sandstone.

The upper sandstone of the formation is seen in thin section to contain about 50 to 60 percent of subrounded silica-cemented quartz grains 0.2 to 0.6 mm in diameter and scattered grains of turbid feldspar, granophyre, and chert. The interstitial matrix material is mainly pale green chlorite with minor dolomite. Fine-grained iron oxide, goethite, and possible barite are accessories.

Adjacent to Glenroy homestead the only outcrops of the Traine Formation consist of about 6 m of massive white fine-grained quartz sandstone with numerous limonite-filled holes, probably resulting from the weathering of pyrite.

The Traine Formation is distinguished by the abundance of sandstone and associated carbonates, but in the Hann River/Glenroy area it is characterized by purple shale interbedded with sandstone and dolomite, as compared to green siltstone of the Throssell Shale. The base of the formation is defined by the top of the pink dolomite at the top of the Walsh Tillite. The upper boundary is defined by the gradational change from sandy sediments to the green micaceous shale with sandy interbeds of the Throssell Shale.

Throssell Shale (new name)

The Throssell Shale is the most characteristic unit of the Mount House Group. It lies conformably on the Traine Formation and is conformably overlain by the Estaughs Formation. The Throssell Shale is poorly exposed within the soil-covered plains around the headwaters of the Throssell River, from where the name is derived, and in the scarp bordering the Mount Clifton Plateau. Except for a few outcrops immediately to the east, outcrops of the shale are confined to the area west of the Hann River. In the reference section near Mount Clifton it is 175 m thick.

The Throssell Shale consists dominantly of uniform flaggy grey-green to blue-grey chloritic/micaceous shale or siltstone with lenticular flaggy interbeds of laminated micro-cross-bedded fine-grained grey-green micaceous sandstone. Within the lower 15 m or so of the formation scattered interbeds of blocky to coarse flaggy buff to green-brown fine-grained sandstone occur. These decrease in number upwards from the base, and associated siltstone gives way to shale.

In thin section a specimen of the siltstone consists of small angular quartz grains (about 0.006 mm) set in a clay matrix with abundant small flakes of muscovite and pale green chlorite pseudomorphing biotite and lying parallel to the bedding. Fine-grained iron oxide is accessory.

A measured section of the Throssell Shale is given on page 63. There are no significant lateral variations within the Lansdowne Sheet area. The green shales are distinctive, but both the upper and lower contacts of the Throssell Shale are gradational. The base is marked by the appearance of green shale as the dominant lithology, while the top is marked by the development of the blocky subgreywacke interbeds of the Estaughs Formation. The upper contact coincides with a conspicuous physiographic change.

Estaughs Formation (new name)

This formation is the topmost unit of the Mount House Group. It overlies the Throssell Shale and is overlain only by Cainozoic soils. The name is derived from 'The Estaughs' (lat. 17°25'S, long. 125°58'30"E), a prominent pair of mesas capped by rocks of the formation immediately west of the Sheet boundary.

Within the Lansdowne Sheet area, outcrops of the Estaughs Formation are confined to the top of the Mount Clifton Plateau on the western edge of the Sheet area. Massive siltstone and subgreywacke beds crop out boldly to form small cliffs at the top of the bordering scarp. In the reference section on the eastern side of Mount Clifton, the formation is 77 m thick, but as the top has been eroded the original thickness of the formation is not known.

The formation consists of interbedded flaggy purple to green micaceous siltstone and fine-grained subgreywacke alternating with prominent interbeds of blocky to massive purple hematitic subgreywacke. Beds of flaggy fine-grained subgreywacke near the base of the formation contain complex intraformational folds, are intensely contorted, and lens out rapidly. The folds may be slump structures or sedimentary structures such as large flow-casts or scour-and-fill structures, subjected to later compaction and flowage.

In thin section a specimen of the feldspathic/micaceous quartz siltstone consists mainly of subrounded quartz grains about 0.4 mm across, partly cemented by silica. It contains scattered grains of sericitized feldspar and accessory fine-grained goethite, tourmaline, sphene, black iron oxide, and mica and chlorite which lie parallel to the bedding.

The formation is characterized by the blocky subgreywacke interbeds. The lower contact is gradational and is marked by the first bed of blocky subgreywacke. This basal bed is distinctive owing to the intraformational folding described above.

PALAEOZOIC

The Palaeozoic units represented in the Lansdowne Sheet area are the Windjana Limestone, Pillara Limestone, and Napier Formation, which together constitute a Devonian reef complex; the Stony Creek Conglomerate of Devonian age; and undifferentiated conglomerates of Devonian and ?Permian age. The reef complex in this area has not been dated accurately but is regarded as being Frasnian and/or Famennian (Upper Devonian). Middle Devonian is not believed to be present. The total thickness of the various facies of the reef complex in this area is not known precisely, but it is unlikely to exceed 150 m.

Windjana Limestone

This formation is the reef facies, consisting of massive limestone which is commonly dolomitized. The limestone is built up of a framework of colonial organisms, especially algae and stromatoporoids, the interstices between the organisms being filled with calcarenite or calcilutite. The Windjana Limestone forms a discontinuous band between the Pillara Limestone and the Napier Formation and interfingers with each. It also interfingers with the Stony Creek Conglomerate.

Pillara Limestone

The Pillara Limestone is the back-reef facies of the reef complex. It consists predominantly of well bedded biostromes of stromatoporoid limestone with some beds made up largely of algal nodules (oncolites). Dolomitization of the limestones is common. The unit interfingers with the Windjana Limestone and with the Stony Creek Conglomerate. In areas where the reef (Windjana Limestone) is absent it interfingers directly with the Napier Formation.

Napier Formation

This formation constitutes the forereef and interreef facies of the complex. The poorly exposed area of outcrop south of Long Hole Bore is referred to as the interreef facies; the rest is forereef facies which is essentially a talus unit built up of calcarenite and calcirudite derived by erosion of the growing reef, together with contributions from organisms which grew on the forereef slope. The limestone is dolomitized in some localities.

The forereef facies is crudely bedded to well bedded and shows depositional dips of 30° or more away from the reef. The interreef facies contains relatively little material derived from the reef and is made up of silty limestone and calcareous siltstone, shale, and sandstone. The interreef deposits are mostly red, in contrast to the light grey and yellow limestone and dolomite of the other parts of the reef complex. The Napier Limestone interfingers with the Stony Creek Conglomerate and the Windjana Limestone. In those areas where the reef (Windjana Limestone) is absent it interfingers directly with the Pillara Limestone.

Stony Creek Conglomerate

The Stony Creek Conglomerate is composed of angular to subangular boulders, cobbles, and pebbles of granite with lesser amounts of quartz, quartzite, and sheared acid volcanic rocks set in a matrix of very coarse arkose and believed to have been transported only a short distance from the adjacent Precambrian rocks. The thickness of the formation is not known precisely, but it is estimated to be about 150 m. The conglomerate interfingers with the reef complex and is overlain by conglomerate of possible Permian age.

Undifferentiated conglomerate

Evidence in adjacent areas has shown that conglomerates previously mapped by Guppy et al. (1958) as the Sparke, Mount Elma, and Barramundi Conglomerates include some Upper Devonian conglomerate and another conglomerate resting with angular unconformity on the Devonian rocks which could be Permian, perhaps equivalent to part of the Grant Formation. As the boundaries between these two conglomerates have not been mapped, they are combined as 'undifferentiated conglomerate'. In this area they consist predominantly of rounded quartzite pebbles and cobbles, with some boulders, set in an arkosic matrix.

CAINOZOIC

Alluvium, eluvium, and residual soils are developed sparsely throughout the Sheet area, and are probably Tertiary to Quaternary.

Residual black soil is found mainly on outcrops of dolerite, basalt, and less commonly on limestone. Where it occurs on dolerite it is strewn with residual dolerite boulders and contains abundant small sinkholes. It supports a good cover of fodder grasses where these have not been stripped by heavy grazing.

Residual soils (undifferentiated) include several soil types which are closely controlled by the source rocks. Red-brown soil predominates on granophyre, and locally on basalt and dolerite, particularly where there is some additional source material from more acid rocks which effectively inhibits the formation of black soil. Large bulbous anthills are characteristic of the red soils. Sandy grey soils are characteristic of the granite terrain and of outcrops of the Whitewater Volcanics and Halls Creek Group. They support sparse vegetation and, where best developed, are characterized by abundant small anthills. Residual sands and sandy soils are formed on sandstone outcrops, particularly on the Kimberley Plateau. In places they are underlain by yellow-brown nodular ferricrete.

Alluvium is restricted principally to sand and gravel in or immediately adjacent to watercourses, but fossil river terraces are found along the course of the Hann River near Glenroy. Gravels, partly derived from the Walsh Tillite, are common in the courses of the Hann and Traine Rivers, but elsewhere sands predominate in the river beds.

Thin coverings of eluvium consisting mainly of large fallen blocks of sandstone are found on most scarp slopes and commonly obscure outcrops of the Luman and Elgee Siltstones and the siltstones at the top of the Carson Volcanics.

STRUCTURE

Structurally the Lansdowne Sheet area may be divided into two distinct units, the stable Kimberley Block to the north, and the fringing Mobile Zone to the south. The Mobile Zone forms a broad arcuate belt, concave to the north, and includes part of the northeast-trending East Kimberley Halls Creek Mobile Zone and part of the West Kimberley King Leopold Mobile Zone (see Traves, 1955, p. 91). Within the Lansdowne Sheet area these two mobile zones coalesce and have no definite boundary, hence their specific names are not used here. The coalescing of the two Mobile Zones provides an opportunity to study the interaction of their two principal fold trends and makes this an area of great structural importance in the Kimberley Division.

The Mobile Zone and the Kimberley Block have been affected essentially by the same tectonic events, but to differing degrees. The division between them is indefinite and is based primarily on the gradual decrease in intensity of deformation northwards. In general the southern boundary of the stable Kimberley Block approximates to the southern margin of the Speewah Group outcrop. In the Lissadell Sheet area (Dow et al., 1964) the Greenvale Fault has been taken as the southeastern margin of the Kimberley Block, but in the Lansdowne Sheet area highly deformed rocks and extensive areas of Halls Creek Group metamorphics and Whitewater Volcanics are found to the north of the Greenvale Fault, and it can thus no longer be regarded as the boundary.

In the Mobile Zone, folds of several different ages with fold trends parallel to the trends of both the Halls Creek and King Leopold Mobile Zones are recognized. Faulting along three principal directions is found, the most important being the northeast trend. The other fault trends are west-northwest and north. Within the Mobile Zones the trends of both folds and faults tend to be parallel.

Folding

Halls Creek Group structures. The most highly deformed rocks in the area are the shale and greywacke of the Halls Creek Group which in general show isoclinal folding. Their strike varies from northeast in the eastern part of the area, to east in the centre, and west-northwest in the west. This change in strike, which follows the change in the regional structures from north-northeast in the Halls Creek Mobile Zone to west-northwest in the King Leopold Mobile Zone, is accompanied by a marked change in the direction of plunge of one group of fold axes.

Three principal fold trends can be recognized, especially in the southeast where three sets of minor fold axes (Fig. 15.1) plunge respectively to the northeast at about 35°, to the south-southwest at about 30°, and approximately vertically. Evidence of post-Whitewater structures indicates that the near-vertical folds are apparently the latest. The relative ages of the other two are uncertain.

The same trends can be recognized in the central (Fig. 15.2, 15.4) and western areas (Fig. 15.3). From east to west, however, there is a progressive northward deflection of the direction of plunge of the Group I folds, probably owing to refolding. As a result of this deflection, the Group I folds, which plunge to the south-southwest in the east (Fig. 15.1), plunge to the west in the central area (Fig. 15.2), and to the northwest in the west (Fig. 15.3). The position of the fold axis responsible for this later deformation must be on the radius of the great circle, between the great circle and its pole (* in Fig. 15.3). It is clear that the steeply plunging folds (Group 3) are responsible for this deformation. The refolding noted in the central area (Fig. 15.4) could also have been caused by these steeply

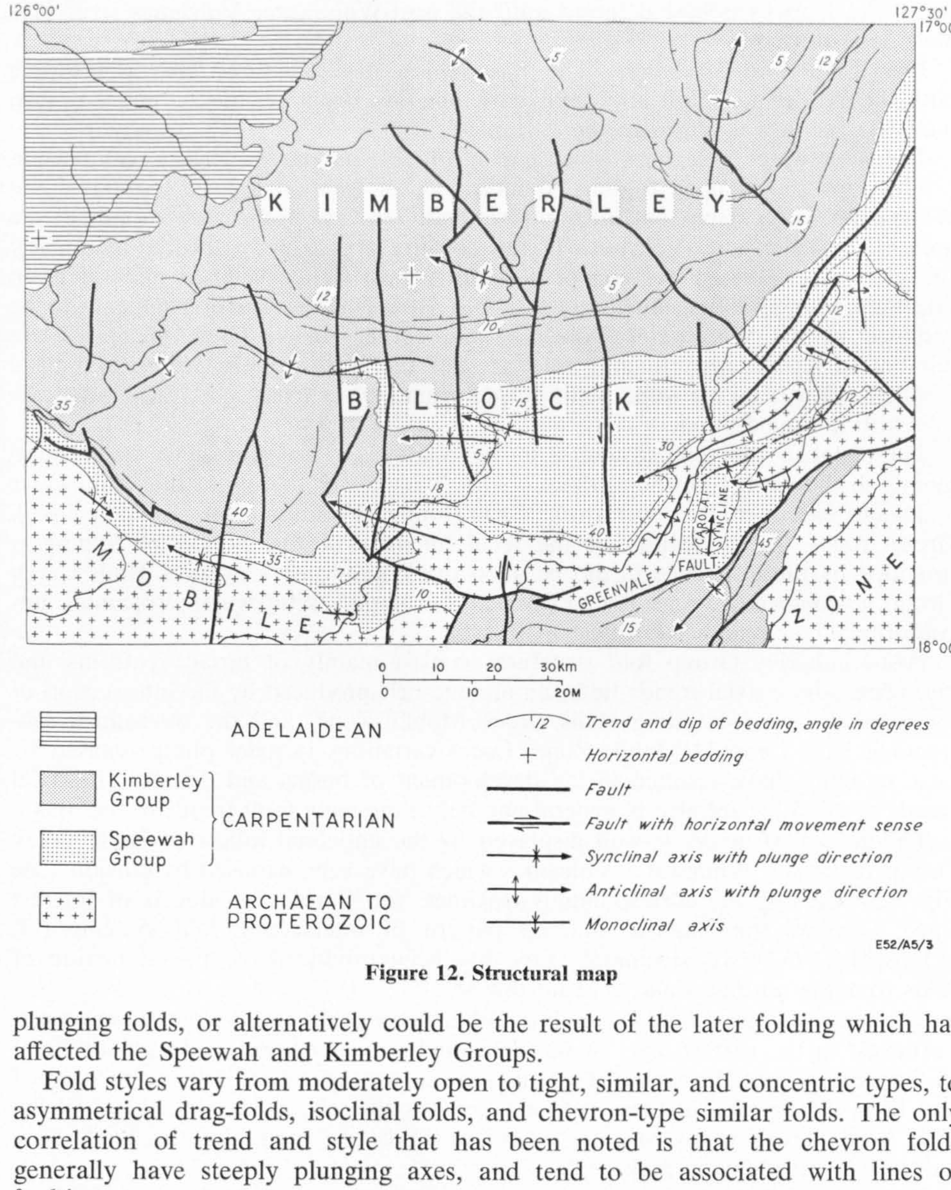


Figure 12. Structural map

plunging folds, or alternatively could be the result of the later folding which has affected the Speewah and Kimberley Groups.

Fold styles vary from moderately open to tight, similar, and concentric types, to asymmetrical drag-folds, isoclinal folds, and chevron-type similar folds. The only correlation of trend and style that has been noted is that the chevron folds generally have steeply plunging axes, and tend to be associated with lines of faulting.

Axial plane cleavage is moderately well developed locally, especially in the more argillaceous beds, but tends to be less conspicuous and is refracted in the more arenaceous beds. *ac* joints, commonly infilled with thin quartz veinlets, are found mainly in the arenite. In one locality, three sets of *ac* joints are present in the same exposure, and can be related to the three principal eastern area fold directions mentioned above.

Problems of structural interpretation exist because the fold axes, though varying in degree of plunge, are almost co-planar in places, and because the various folds do not deform each other. The variations in trend may be due to deformation of a single early fold system by a later one with differing trend, or the three fold phases may exist in their own right. Because of this, interpretation of the structure of the

Halls Creek rocks is best deferred until the post-Whitewater Volcanics structures have been described.

Post-Whitewater structures. The post-Whitewater structures mainly postdate both the Whitewater Volcanics and the Kimberley Basin sediments, but they also include structures confined to the volcanics.

The Whitewater Volcanics, which unconformably overlie the Halls Creek Group, exhibit only simple open folding, as indicated for example by the folding of the Whitewater/Halls Creek unconformity west of Gap yard in the western part of the area. The Whitewater Volcanics in this locality are strongly sheared on nearly vertical west-northwest-trending planes which have well developed mineral grain lineations plunging west-northwest at about 70°. This deformation appears to be confined to the Whitewater Volcanics and earlier rocks. These lineations are parallel to the steeply plunging fold axes of the Halls Creek Group, and have resulted either from the same period of deformation, or from subsequent deformation with the same trend.

These steeply plunging structures in the Whitewater Volcanics have been found mainly in the west. Elsewhere, there is little evidence of folding of the Whitewater Volcanics except for the overlap of the O'Donnell Formation on the Halls Creek Group rocks. An indication of the local intensity of this period of folding is provided by the difference in dip between the Whitewater Volcanics/Halls Creek Group unconformity, and the O'Donnell Formation/Whitewater Volcanics unconformity (see map section DEF).

Post-Kimberley Group fold structures consist mainly of broad synforms and antiforms whose axial trends lie in an arcuate belt produced by the intersection of the north-northeast-trending Halls Creek Mobile Zone, and the west-northwest-trending King Leopold Mobile Zone. Local variations in axial plunge caused by later refolding have resulted in the development of basins and domes. The axial trends of the folds are also in general parallel to the main fault trends of the area.

The general structure is well displayed by the anticlinal inliers of Halls Creek Group rocks and Whitewater Volcanics which have been exposed by erosion (see Fig. 12). Among the corresponding synclines, the Carola Syncline is of interest since it shows the classical outcrop pattern of intersecting fold systems (cf. O'Driscoll, 1962). Its sigmoidal shape has been produced by the interaction of folds trending northeast and west-northwest.

The main plunge directions in Post-Whitewater rocks are northeast and west-northwest in the eastern part of the area, and west-northwest and east-southeast in the western part. In each of these two areas two separate trends are recognized and local interference of these is found, for example about 3 km northeast of Six Mile yard, where eastward-plunging minor folds are found on the flank of a west-northwest-plunging major fold.

The style of these folds varies from concentric to similar. Most minor folds of the northeast-plunging group have well developed *a* lineations owing to bedding plane slip during folding and are probably similar folds of the 'bending type'. This type of folding is particularly well displayed in siltstone of the O'Donnell Formation, for example near Dingo Well, and 3 km west of Carola yard. In the western part of the Sheet area, minor similar folds predominate. Major structures include monoclinal folds which are present on the fringe of the fold belt and have axial planes dipping to the northeast.

In the Adelaidean rocks, folding is very gentle and dips are apparently nowhere greater than 10°. The principal folding noted in these rocks is in the extreme northwest, north of the Hann River, where the strike of the Adelaidean rocks is parallel to that of the underlying Kimberley Group. It appears that this post-

Figure 13. Major drag fold in King Leopold Sandstone. Fold axes plunge gently northwest (left) and axial planes dip steeply northeast (away from camera). Locality about 16 km northwest of Torrens yard. This style of folding is typical of the Middle Proterozoic rocks in the western Lansdowne Sheet area.

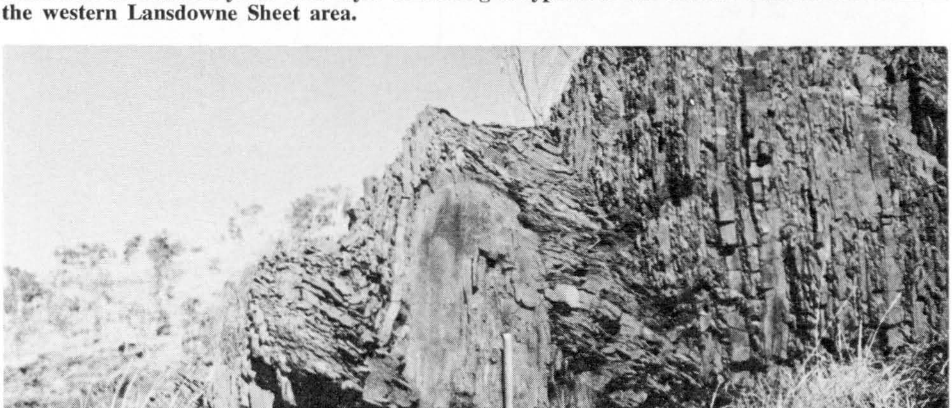
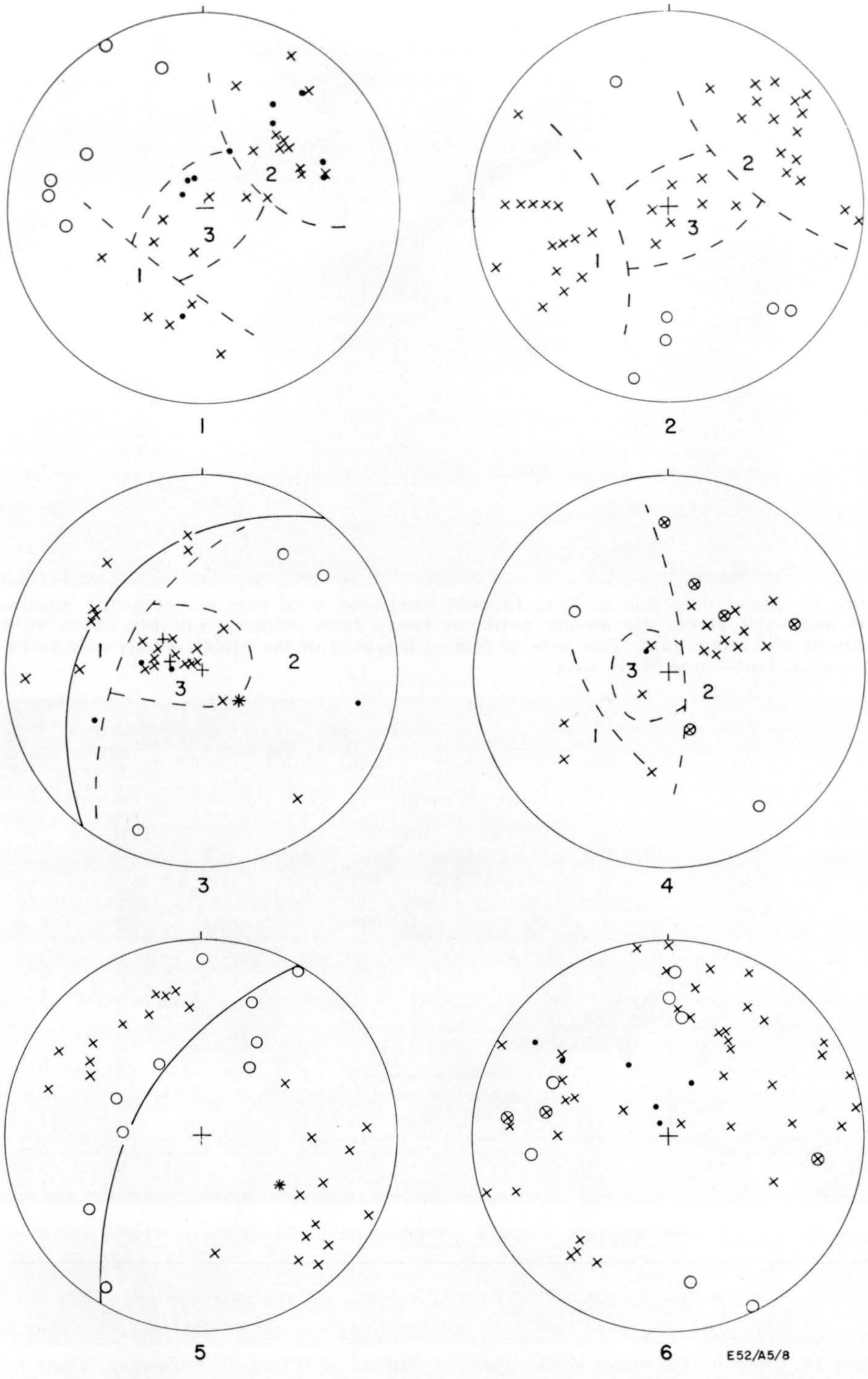


Figure 14. Chevron-type minor similar folds in siltstone of O'Donnell Formation. These folds are associated with a reverse-fault zone; their axial planes dip northwest and are parallel to the fault plane in this vicinity. Locality 8 km east-northeast of Pyra Gorge.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Adelaidean period of folding has been caused by further tightening of the earlier post-Kimberley Group anticline on the flanks of which lie the folded Adelaidean rocks.

Synthesis. The fold axis projections (Fig. 15) indicate that the fold trends in the Halls Creek Group are similar to those in the later rocks, but the differences in style, from isoclinal folds on the one hand to open folds on the other, indicate that the fold phases represented are distinct. Where the fold trends in the Halls Creek Group coincide with those in the later rocks, this is thought to be due to reactivation of folds along earlier trends. A possible exception to this, however, is provided by the steeply plunging folds in the western outcrop of the Halls Creek Group. The axes of these steeply plunging folds are parallel to lineations in sheared Whitewater Volcanics, and this folding of the Halls Creek Group rocks may be of post-Whitewater age.

Of the two post-Kimberley Group fold trends, the west-northwest-plunging system has deformed the northeast-trending one. The superposition of these two fold trends is responsible for the general arcuate strike trend of the major rock units in the Lansdowne Sheet area. Major northeast-plunging fold structures in the east have had broad west-northwest-plunging folds superimposed on them. This apparently indicates that the northeast-plunging folds are the earlier. However, in the southwest where the northeast trend has swung round to southeast, an early axial-plane cleavage (Fig. 15.5) has been deformed by later southeast-plunging folds suggesting reactivation of this trend.

The two trends thus appear to be closely related in time and appear to agree with currently held views on cross-folding caused by transcurrent shear movement (O'Driscoll, 1962; 1964, pers. comm.). O'Driscoll demonstrates that unidirectional movement accompanied by relative transcurrent shear along a vertical plane may be expressed by the development of a set of folds at an angle of 45° to the direction of movement. Reversal of the relative sense of the shear movement (but not of the actual movement) results in the development of a complementary set of second folds perpendicular to the first. Further reversals of the sense of shear would result in repetitive folding along the same or similar trends and could give rise to conflicting evidence as to the relative ages of the two sets of folds. Folding of this type would be expected to develop in a relatively plastic sedimentary cover overlying a deep-seated shear zone.

In the Lansdowne Sheet area the two main fold trends are approximately at right angles and folds of both trends show evidence of repetition of movement. The trends suggest movement from a general northerly direction. North-trending faults with transcurrent displacement (see below) could be the surface expression of movement along a deep-seated north-trending shear zone responsible for the development of the two complementary fold trends.

Fig. 15. Structural diagrams.

1-4. Minor structures, Halls Creek Group: 1, eastern area; 2, control area; 3, western area—great circle indicates folding of early folds by steeply plunging post-Whitewater fold system (+ lineations in nearby Whitewater Volcanics); 4, 9.6 km southwest of Carola Yard.

5, 6. Post-Whitewater minor structures: 5, east of longitude 126°45′E; 6, west of longitude 126°45′E—great circle indicates refolding of early axial-plane cleavage.

Lower hemisphere projection, Wulff net; × axis of minor fold (includes those measured directly and those calculated from intersection of bedding planes within single exposures); • intersection of bedding and cleavage; + lineation; ○ pole of axial-plane cleavage; * pole of great circle.

FAULTING

Faulting along three main trends is recognized: northeast, west-northwest, and north.

Northeast trend. The main fault of the northeast-trending system is the Greenvale Fault which cuts across the southeastern part of the area. The trend at the eastern boundary is northeast, but farther west it gradually changes to the east, and finally to west-northwest near Goads yard where it loses its identity and is replaced by several minor faults of diverse trend. In most places the Greenvale Fault is not a single fault, but forms a complex zone of two or more faults. It is apparently partly a transcurrent fault with sinistral displacement, especially in the east. Farther west it has an essentially vertical displacement and is variously a normal fault or a reverse fault. The direction of downthrow is to the southeast or south. The maximum vertical displacement in the Lansdowne Sheet area is apparently at least 4500 m, 10 km northeast of Mad Gap yard, but diminishes rapidly westwards. Prominent quartz reefs and infaulted lenses of basal O'Donnell sandstone occur throughout its length. West of Pyra Gorge it is displaced by a northeast-trending reverse fault with a throw to the southeast of about 1200 m. Along part of its length in the Lansdowne Sheet area the Greenvale Fault is a faulted asymmetrical anticline, and much of the movement has been taken up by folding preceding the faulting, so that the throw of the fault in places is comparatively small. This is particularly true of the area between Pyra Gorge and the southern end of the Carola syncline.

Other faults with a northeasterly trend are less important. Some are thought to be partly sinistral transcurrent, while others may have vertical displacement. Vertical components of downthrow are generally to the southeast.

Northwest trend. Faults of this trend are common throughout the area, except in the northwest corner. Their lateral extent varies from 2 to more than 30 km. The direction of downthrow is to the southwest and they are associated locally with monoclinal folds, such as the complex monoclinal fold and fault system which passes south of Colass yard. These monoclines have axial planes dipping to the northeast and show a sense of vertical movement, similar to that of the associated faults indicating compression from north or northeast.

The throw of these northwest-trending faults is usually small, but in the King Leopold Ranges northwest-trending faults, which have caused repetition of part of the succession, have throws of up to 1800 m (see map section ABC).

North-trending faults are prominent especially in the central and southwestern parts of the area. Some extend for over 50 km, but displacements are apparently small. Sinistral transcurrent movement has been noted on two faults and may be present in others. The displacement on most north-trending faults, however, may be interpreted as indicating either a sinistral transcurrent movement or a normal movement with downthrow to the west.

Age of faulting

Within the Lansdowne Sheet area evidence of the age of the faulting is scanty. The northeast-trending faults are apparently related to the northeast-trending folds, and are thus thought to be earlier than the northwest-trending faults which are similarly related to the northwest-trending folds. The north-trending faults cut both the northeast and northwest sets and are thus the latest. However, it is possible that all three trends are inter-related and that the time differences involved are insignificant.

From the evidence of the unconformity between the Tunganary Formation and King Leopold Sandstone southwest of Goanna Spring, and the boulder conglomerates in the upper Lansdowne Arkose at the southern end of the Carola Basin, it appears that movements connected with the Greenvale Fault were in operation in Carpentarian time when the direction of downthrow was to the northwest, in contrast to the later movements which took place in the opposite sense.

Faults of all trends cut the Hart Dolerite. The Hart Dolerite was apparently intruded in part along pre-existing north-trending faults, and is also cut by these faults, so that both pre and post-dolerite movements are recognized. Both pre and post-dolerite movement is also inferred for the other fault systems, but is less well substantiated. Deformation affecting Adelaidean rocks in the Lennard River Sheet to the west is thought to be Cambrian. The latest fault movements appear to be post-Devonian.

TECTONIC HISTORY

A summary of the tectonic history of the area is given in Table 3.

The oldest rocks of the area, the Halls Creek Group, originated in an Archaean geosyncline, and in Archaean or Lower Proterozoic time were intensely folded, slightly metamorphosed, and eroded, before the eruption and deposition of late Lower Proterozoic acid to intermediate ash-flow tuffs and lavas of the Whitewater Volcanics.

After a period of gentle folding, strong shearing, and erosion, sedimentation resumed in early Carpentarian time. Except for minor earth movements in the southeast, probably associated with movements on the Greenvale Fault, sedimentation was then apparently continuous throughout the Carpentarian, when the Speewah, Kimberley, and Bastion Groups were deposited. These sediments are mainly shallow-water arenites and lutites. There appears to have been little if any interruption of sedimentation during the extrusion of the Carson Volcanics, since no unconformity is recognized and some of the lavas were submarine.

Strong folding, faulting, dolerite intrusion, uplift, and erosion followed the Carpentarian sedimentation and preceded deposition in Adelaidean time of the Walsh Tillite and subsequent shallow-water arenite and lutite of the Mount House Group.

Following Adelaidean sedimentation, the area was uplifted and since then erosion has apparently persisted over the whole area, except in the southwest where a short period of limestone reef formation and conglomerate deposition took place in Middle Palaeozoic time.

TABLE 3. TECTONIC HISTORY—LANSDOWNE SHEET AREA

CAINOZOIC		Erosion—Development of soils and alluvium	
PALAEOZOIC		EPEIROGENIC UPLIFT Limestone reef complex and conglomerate deposition in SW — Erosion of other parts of area	
		Subsidence and marine transgression in SW	
		Erosion	
ADELAIDEAN	MOUNT HOUSE GROUP	Folding and epeirogenic uplift; possible Cambrian deformation along Mobile Zone	
		Shale, sandstone, and dolomite deposition	Upper part of Walsh Tillite; Estaughs Formation, Throssell Shale, and Traine Formation
		Subsidence	
		Tillite deposition	Walsh Tillite
		Erosion	
CARPENTARIAN		Strong folding and faulting	
		Intrusion of dolerite and development of granophyre	Hart Dolerite
	BASTION GROUP	Lutite deposition	Mendena Formation
	KIMBERLEY GROUP	Arenite, lutite, and carbonate deposition Volcanism: basic lavas Arenite deposition	Elgee Silstone, Warton and Pentecost Sandstone Carson Volcanics King Leopold Sandstone
		Minor uplift and erosion: Probably in SE only	

TABLE 3—(*Cont'd*)

CARPENTARIAN	SPEEWAH GROUP	Arenite deposition Lutite deposition Arenite deposition	King Leopold Sandstone Luman Siltstone Upper Lansdowne Arkose
		Minor uplift and erosion: Probably in SE only	
		Arenite and lutite deposition Minor volcanism and lutite deposition Arenite and lutite deposition	Lower and middle Lansdowne Arkose Valentine Siltstone Tunganary and O'Donnell Formations
		Subsidence and marine transgression	
LOWER PROTEROZOIC		Erosion	
		Granite emplacement	Granites in SW
		Folding and shear belt development	
		Granite emplacement and localized metamorphism	Bow River Granite, Granites in SW
		Major volcanism—acid porphyries	Whitewater Volcanics
		Erosion	
		Folding and regional metamorphism: ?granite emplacement	Folding and metamorphism of Halls Creek Group; Tickalara Metamorphics
ARCHAEAN OR PROTEROZOIC		Deposition of geosynclinal sediments	Olympio Formation; ?Part of Bow River Granite

ECONOMIC GEOLOGY

At the time this survey was carried out no economic mineral deposits were known in the area and exploration work was confined to routine geochemical stream-sediment sampling of Archaean and Lower Proterozoic rocks in the south by Pickands Mather International Co. Ltd. Several small showings of economic minerals were noted during the BMR 1964 survey, and in a brief Record reporting orientation geochemical data (Gellatly, 1967) recommendations were made for further prospecting in the area. The principal recommendation was for prospecting of the conglomerates in the King Leopold Sandstone. Shortly after Gellatly's Record was released, Temporary Reserves were taken up over large parts of the Durack and King Leopold Ranges by Planet Gold and subsequently by other companies. Prospecting of these Temporary Reserves by Planet Gold* has revealed several prospects of economic significance. These are (1) uranium and thorium in the conglomerates of the King Leopold Sandstone; (2) copper in the Carson Volcanics; (3) anatase, zircon, and monazite-rich heavy-mineral sands in the Warton Sandstone; (4) copper in the Elgee Siltstone.

Groundwater is one of the principal mineral resources of the area and is being actively exploited by means of bores and wells for stock watering. Constructional materials may be of future importance in connexion with the possible future development of the Fitzroy Irrigation Scheme, for which feasible damsites are known within the Lansdowne Sheet area in gorges cutting the King Leopold Ranges.

Minerals

Copper. In the Carson Volcanics small grains and vesicle fillings of chalcopyrite are extensive. Such traces are particularly abundant in the lowest flows in the northern outcrop of the Carson Volcanics east of 126°30′E, and have also been noted in the basal flows in the southeast about 6 km east-southeast of Mad Gap yard. At 'Fishermans Bend' (exact location unknown) Planet Gold have encountered significant disseminated copper mineralization in both altered basalt and sandstone interbeds of the Carson Volcanics. The best intersection recorded to date is 34 m of 0.89 percent. The average grade is about 0.55 percent.

In the Elgee Siltstone, about 37 km northeast of Tableland homestead, Harms (1959) noted copper mineralization at the contact with a dyke of Hart Dolerite. The shales at the sides and roof of the dyke have been baked at the contact and thin veins of chalcocite up to 3 m long and 6 mm wide have impregnated the contact zone: secondary carbonates have stained the shale for widths of up to 0.3 m. Harms assumes that the copper here, and in a similar occurrence in the Pentecost Sandstone, has been derived from the dolerite. Discoveries of cupriferous sediments in the Pentecost Sandstone by Roberts, Derrick, & Ivanac (1966) and Planet Gold in the Elgee Siltstone indicates that the mineralization noted by Harms is the result of remobilization of copper from the Elgee Siltstone.

Copper mineralization found by Planet Gold in the Teronis Member of the Elgee Siltstone is apparently in the same general location as that described by Harms. Results of preliminary diamond drilling reported in the prospectus for Durack Mines N.L. (November, 1970) indicate values of from 0.04 to 0.13 percent Cu over widths of about 5 to 8 m.

Traces of chalcopyrite and malachite have been noted in quartz veins cutting the Whitewater Volcanics and the Hart Dolerite, mainly in the area south and southwest of Mount Laptz. Chrysocolla, malachite, bornite, and chalcopyrite occur

* Australian Miner, 30 Nov. 1970. Prospectus for Durack Mines.

in veins in the Lamboo Complex granites in the southwest corner of the Sheet area.

Some quartz veins cutting porphyry of the Whitewater Volcanics about 7 km east of Goads yard contain boxworks of powdery earthy brown limonite with associated specks of malachite. These veins are up to 1 m thick and 0.8 km long, but boxworks make up only a small proportion of each vein. Values up to 0.5 percent Cu have been recorded from these veins.

Small amounts of malachite have been found as fracture infillings in vein quartz associated with the Greenvale Fault cutting Whitewater Volcanics about 3 km east-northeast of Goanna Spring.

Several minor occurrences of copper minerals have been found associated with the Hart Dolerite. These are mainly traces of chalcopyrite and malachite in small quartz veins within dolerite, especially near Coolan Creek yard.

Titanium. Thin beds of heavy-mineral sands rich in anatase, zircon, and monazite have been found in sandstone interbeds in the Carson Volcanics mainly between latitudes 17°05′ and 17°15′S. Further heavy-mineral sands are found in the same area in purple sandstone at the base of the overlying Warton Sandstone. Grades of these minerals have not been announced. Planet Gold quotes a total strike length of over 190 km for these occurrences.

Uranium and Thorium. Radiometric anomalies have been reported from the conglomerate bed and associated coarse-grained purple sandstone in the King Leopold Sandstone in the King Leopold and Durack Ranges northeast of Lansdowne homestead, in coarse-grained purple quartz sandstone in the topmost member of the Lansdowne Arkose, and in near-basal sandstone of the O'Donnell Sandstone near Tunganary yard. An early report by Planet Gold quoted values of 0.9 kg of uranium per tonne, but later reports mention an average uranium content in drill holes of only 31 ppm. It appears that the initial value was a radiometric equivalent value and that the greater part of the radioactivity was caused by thorium minerals. The mineral thorogummite has been identified from the King Leopold Sandstone conglomerate by the Australian Atomic Energy Commission (Stewart, pers. comm.).

In addition, the heavy-mineral sands mentioned above contain 1.18 kg per tonne of uranium and 2 percent of thorogummite, these values apparently being associated with the monazite content of the sands.

Lead. Minor amounts of galena, mostly associated with chalcopyrite, have been recorded from quartz veins cutting the Whitewater Volcanics in the southwest. Similar occurrences have also been noted in the Hart Dolerite, particularly in calcite veins near Coolan Creek yard. Traces of galena have been noted in the Carson Volcanics in the northeast where they form rare vesicle infillings.

Fluorite. Two small occurrences of fluorite are known. One is 3 km east-northeast of Goanna Spring, where 13 to 25 mm-thick veins of fluorite cut weathered porphyry of the Whitewater Volcanics adjacent to the Greenvale Fault. The other, about 0.4 km north of a fault separating the granite from Devonian limestone, consists of fluorite veins 75 to 100 mm thick, in a quartz-feldspar-muscovite dyke rock cutting the Long Hole Granite.

Ironsand. A veneer of titaniferous magnetite sand is found in the beds of small creeks where dolerite is the predominant source rock. These deposits are of no foreseeable economic value.

Constructional and agricultural materials

Building stone. Rocks suitable for use as building stone are abundant. The most suitable is the relatively thin-bedded feldspathic sandstone of the Tunganary

Formation and the Lansdowne Arkose, and the upper part of the Warton Sandstone. Most other rocks are too massive to be worked conveniently.

Roadmetal. The Hart Dolerite, which crops out extensively, is suitable for use as roadmetal, as are the porphyries of the Whitewater Volcanics. Some of the Lamboo Complex Granites and Carson Volcanics basalts might also be used. Except the northwest corner, no place is more than about 25 km from an outcrop of igneous rock, and therefore from a potential source of roadmetal.

Sand and gravel. Sand and/or gravel deposits are present in most large rivers. Coarse-grained, relatively clean-washed quartz sands are present in river courses draining the areas of granite outcrop in the southeast and southwest, particularly in the O'Donnell River and around Saddlers yard. Fine to medium-grained sands, mainly derived from pre-existing sandstones, are present in the Little Gold River, especially south of Mud Spring, and in many small rivers on the Kimberley Plateau.

Cobble and boulder gravels are found mainly in the Hann, Traine, and Fitzroy Rivers in the northwest. Of particular importance are deposits in and alongside the Fitzroy River immediately upstream from Diamond Gorge. The Hann River is locally bordered by terraces of gravel which are probably the most extensive gravel deposits in the area. The Devonian conglomerates of the Burramundi Range might also be worked as a source of gravel, but their consolidated nature and relatively large cobble size are disadvantages.

Limestone. Lime for agricultural purposes may be required in future in connexion with the proposed Fitzroy Irrigation scheme. Adequate supplies are present in the Devonian rocks in the southwest and in contiguous areas, especially in the Lennard River area.

Water Supply

(by A. D. Allan, Geological Survey of West Australia)

The Lansdowne Sheet area has an average annual rainfall decreasing from 685 mm in the north to 508 mm in the south. The rainfall is received mainly during the wet season from November to April, and the rest of the year is relatively dry. Annual potential evaporation is 2500 to 2800 mm.

The headwaters and a number of tributaries of the Fitzroy River, Ord River, and Pentecost River drainage systems, which are major drainage features of the region, lie within the Lansdowne Sheet area. They flow only during the wet season and for the rest of the year exist as lines of sporadic waterholes, particularly in the more rugged country.

Twenty-nine bores or wells operate in the area. Their relative scarcity is due mainly to the unsuitability of a large part of the area for pastoral purposes and to the relative abundance of natural water. Three distinct groundwater provinces can be recognized:

1. Kimberley Province
2. Halls Creek Province
3. Canning Basin Province

These three divisions, which are shown in Figure 16, correspond to (1) Carpentarian and Adelaidean rocks of the Kimberley Basin succession; (2) the Archaean to Lower Proterozoic (pre-Speewah Group) rocks, and (3) the Palaeozoic rocks.

1. Kimberley Province

The Kimberley Province is underlain by sedimentary and basic igneous rocks which range from Carpentarian to Adelaidean and make up the Speewah, Kimberley, Bastion, and Mount House Groups. The sedimentary rocks are dominantly

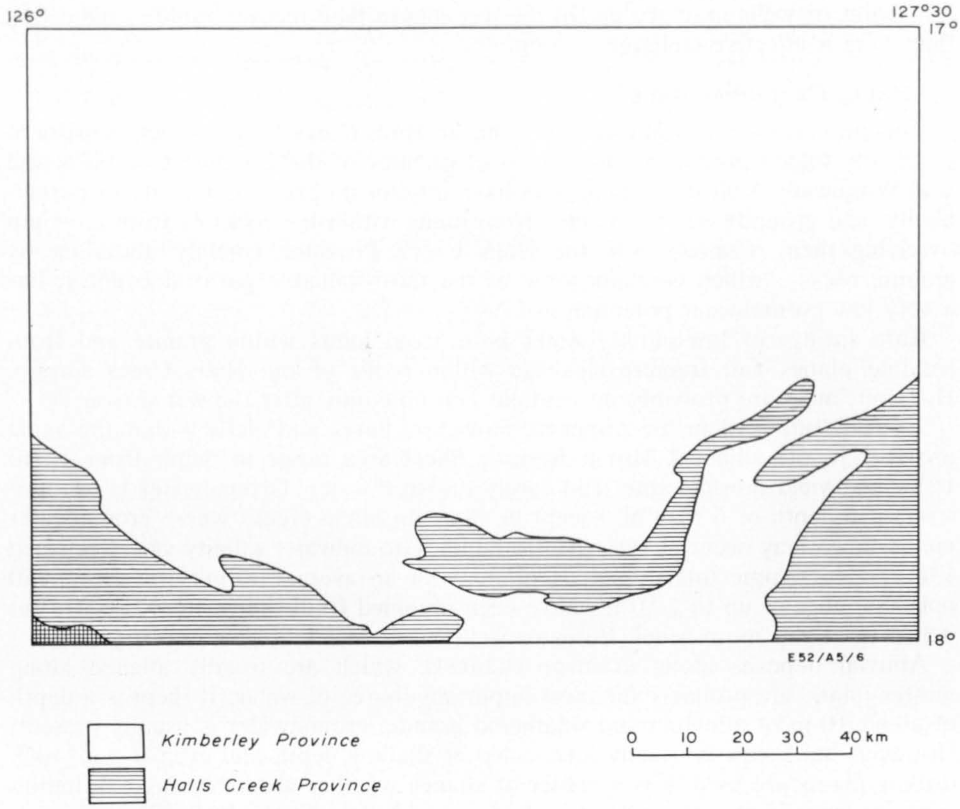

Figure 16. Groundwater divisions

feldspathic and quartzose sandstone with minor siltstone. They are hard and silicified in outcrop and in general appear to have a low primary porosity and permeability, although this may not be so at depth. The basic igneous rocks, comprising dolerite and volcanics, are well jointed and less resistant to weathering, and commonly have residual blacksoil plains developed over them.

Perennial and intermittent springs are frequent where rivers have formed gorges in strata dipping at 30° or more, and these may sustain waterholes. Other springs (rockholes) occur along fault lines, particularly in the flat-lying King Leopold and Pentecost Sandstones; in such situations the groundwater salinity is generally exceptionally low, with values of 100 ppm total dissolved solids or less.

There are 27 bores or wells within the province. They are mostly 12 to 18 m deep, with static water levels 6 to 9 m below the surface. The groundwater is usually non-pressure water, but locally pressure water may be obtained from confined joints or bedding planes; salinity on the average is 450 ppm total dissolved solids. Supplies vary but average yields are about 0.94 l/s.

The most important aquifers are the Hart Dolerite and Carson Volcanics, mainly because they are usually easier to drill by percussion cable-tool plants, and also because they have a greater number of potential water-bearing fractures than the sandstones.

Groundwater levels usually decline during the dry season owing to water lost by evapo-transpiration and pumping. Occasionally after several years of low rainfall, bores or wells may dry up. In the wet season they recover rapidly, indicating that there is effective recharge by rainfall.

2. HALLS CREEK PROVINCE

This province is underlain by the Archaean Halls Creek Group which consists of isoclinally folded greywacke and siltstone, granites of the Lamboo Complex, and acid Whitewater Volcanics. The rocks have little or no primary porosity or permeability, and groundwater is obtained from joints within the rocks or from alluvium overlying them. Consequently the Halls Creek Province (mainly underlain by granitic rocks), which contains some of the most valuable pastoral country, has a very low groundwater potential.

Rare springs of low-salinity water issue from joints within granite and from bedding planes and fracture cleavage within rocks of the Halls Creek Group. However, most are probably intermittent and flow only after the wet season.

There is one well in the province. However, bores and wells within the same province in the adjacent Mount Ramsay Sheet area range in depth from 10 to 15 m and yield non-pressure, and rarely pressure water. Groundwater is encountered at a depth of 6 to 9 m, except in alluvium along creeks where groundwater (underflow) may occur at very shallow depth. Groundwater salinity varies between 150 and 4500 ppm total dissolved solids, with an average salinity of about 450 ppm. Supplies of up to 2.50 l/s have been obtained from the fractured rocks, but 0.3 to 0.7 l/s is more usual. Bores or wells in alluvial may give higher yields.

Alluvial deposits along drainage channels, which are usually aligned along master joints, are probably the most important source of water. If there is a depth of about 10 m of alluvium and weathered granite, groundwater is usually present. However, hard rock is usually intersected at shallow depth and even if hard-rock drilling plants are used, it is a matter of chance whether water-bearing exfoliation joints or cross joints are intersected. In areas underlain by the Halls Creek Group, greywackes are potential sources of supply.

Fluctuations of groundwater levels and conditions of recharge are similar to those in the Kimberley Province.

3. CANNING BASIN PROVINCE

The Canning Basin Province occurs only in the extreme southwest where it is represented by Devonian to Permian limestone and conglomerate.

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APPENDIX 1

CLASSIFICATION AND DESCRIPTION OF SANDSTONES

Grainsize terms used in the text are those given by Pettijohn (1949, p.13)

Standard Terms for the thickness of stratification and parting units.

In order to standardize the descriptions of bedding characteristics in the sediments, it was necessary to define a simple set of terms.

Using McKee & Weir's (1953) and Ingram's (1954) definitions as a starting point, the following simplified and modified classification has been adopted:

Terms to describe stratification	*Thickness* (cm)	*Terms to describe parting units*
Very thick bedded	100	Massive
Thick bedded	15-100	Blocky
Thin bedded	1-15	Flaggy
Laminated	1	Fissile

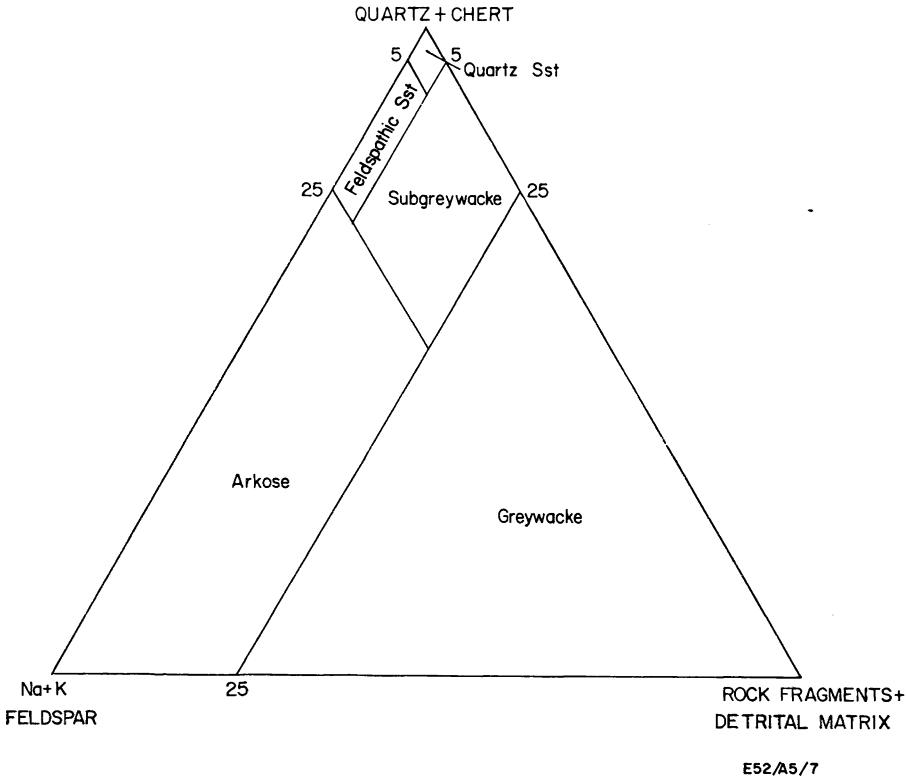

Figure 1. Classification of Sandstone

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APPENDIX 2

DEFINITIONS OF ROCK UNITS

The following stratigraphic names have appeared in several publications, but their definitions are published here for the first time. All units belonging to the Kimberley Basin succession have been included, although several do not occur in the Lansdowne Sheet area and are not described in the main body of this Report. They have been described in appropriate Records and Explanatory Notes, and will be fully described in the proposed Bulletin on the Kimberley Basin.

Speewah Group (new name)

Distribution: Exposed along southeastern and southwestern margins of Kimberley Basin in southern Cambridge Gulf, western Lissadell, northwestern Dixon Range and Mount Ramsay, Lansdowne, northeastern Lennard River and Charnley, and Yampi 1:250 000 Sheet areas.

Derivation of name: From old Speewah homestead (about lat. 16°25′S, long. 127°55′E) in Lissadell 1:250 000 Sheet area.

Stratigraphic relations: Unconformably overlies Lamboo Complex, Whitewater Volcanics, or Halls Creek Group. Overlain, generally conformably, by Kimberley Group. Local angular unconformity in southeast. Extensively intruded by Hart Dolerite.

Constituent Units:
- Luman Siltstone
- Lansdowne Arkose
- Valentine Siltstone
- Tunganary Formation
- O'Donnell Formation

Thickness: 360-1340 m; average about 845 m.

Distinguishing features: Intimate association of generally feldspathic arenites and interbedded lutites, combined with stratigraphic position, is diagnostic.

Age: Late Lower Proterozoic.

O'Donnell Formation (new name)

Distribution: Exposed along southeastern and southwestern margins of Kimberley Basin, from O'Donnell Range in Lissadell 1:250 000 Sheet area, southwest into Lansdowne, northwestern Dixon Range and Mount Ramsay, and northeastern Lennard River and Charnley 1:250 000 Sheet areas.

Type section: In Lissadell Sheet area at lat. 16°31′48″S, long. 128°02′18″E.

Derivation of name: From O'Donnell Range, in Lissadell 1:250 000 Sheet area, about lat. 16°24′S, long. 128°12′E.

Stratigraphic relations: Overlies Whitewater Volcanics, Lamboo Complex and Halls Creek Group with angular unconformity. Conformably overlain by Tunganary Formation.

Lithology: Blocky quartz sandstone, granular sandstone. Flaggy laminated green and khaki micaceous siltstone and fine-grained sandstone.

Thickness: 16-523 m; average about 200 m. Type section 297 m.

Distinguishing features: Stratigraphic position diagnostic. Basal sandstone overlain by distinctive laminated green micaceous siltstone and fine-grained sandstone diagnostic in most areas.

Age: Late Lower Proterozoic.

Tunganary Formation (new name)

Distribution: Exposed along southeast and southwest margins of Kimberley Basin in southern Cambridge Gulf, western Lissadell, northwestern Dixon Range and Mount Ramsay, Lansdowne, and northeastern Lennard River and Charnley 1:250 000 Sheet areas.

Type section: In Lansdowne Sheet area at lat. 17°41′30″S, long. 127°11′15″E.

Derivation of name: From Tunganary Gorge, in Lansdowne Sheet area at lat. 17°39′S. long. 127°19′E.

Stratigraphic relations: Conformably overlies O'Donnell Formation; conformably overlain by Valentine Siltstone.

Lithology: Blocky feldspathic sandstone and arkose; quartz sandstone; granular sandstone. Minor green, grey, and black siltstone and fine-grained quartz greywacke. Some green chert.

Thickness: 80-500 m; average about 250 m. Type section 216 m.

Distinguishing features: Stratigraphic position diagnostic. Sequence of mainly feldspathic sandstones distinctive but in some areas can be confused with Lansdowne Arkose.

Age: Late Lower Proterozoic.

Valentine Siltstone (new name)

Distribution: Exposed along southeast and southwest margins of Kimberley Basin in southern Cambridge Gulf, western Lissadell, northwestern Dixon Range and Mount Ramsay, Lansdowne, and northeastern Lennard River and Charnley 1:250 000 Sheet areas.

Type section: In Lissadell Sheet area at lat. 16°28′34″S, long. 128°3′12″E.

Derivation of name: From Valentine Creek, in Cambridge Gulf Sheet area at lat. 15°45′S, long. 128°35′E.

Stratigraphic relations: Conformably overlies Tunganary Formation; conformably overlain by Lansdowne Arkose.

Lithology: Flaggy green chloritic siltstone and siliceous siltstone. Possibly tuffaceous. Discontinuous rhyolitic ashstone and rhyolitic tuff.

Thickness: 0-80 (type section) m: average about 50 m.

Distinguishing features: Uniform flaggy olive-green siltstone with thin discontinuous bands of acid volcanics diagnostic.

Age: Late Lower Proterozoic.

Lansdowne Arkose (new name)

Distribution: Exposed along southeast and southwest margins of Kimberley Basin in southern Cambridge Gulf, western Lissadell, northwestern Dixon Range and Mount Ramsay, Lansdowne, and northeastern Lennard River and Charnley 1:250 000 Sheet areas.

Type section: Composite section near Looningnin Creek in Lansdowne Sheet area at lat. 17°37′45″S, long. 126°45′24″E (lower part) and lat. 17°34′51″S, long. 127°53′E (upper part).

Derivation of name: From Lansdowne homestead at lat. 17°37′S, long. 126°44′E.

Stratigraphic relations: Conformably overlies Valentine Siltstone; conformably overlain by Luman Siltstone.

Lithology: Blocky, pink to purple-brown, feldspathic sandstone, arkose, and quartz sandstone. Minor brown siltstone, micaceous siltstone, and glauconitic arkose.

Thickness: 30-850 m; average about 450 m. Type section 494 m.

Distinguishing features: Highly feldspathic arenites with massive outcrop and abundant large cross-beds, combined with stratigraphic position, diagnostic. Rocks commonly form diagnostic thinly-banded sandstone pattern on aerial photographs.

Age: Late Lower Proterozoic.

Luman Siltstone (new name).

Distribution: Exposed along southeast and southwest margins of Kimberley Basin in southern Cambridge Gulf, western Lissadell, northwestern Dixon Range and Mount Ramsay, Lansdowne, and northeastern Lennard River and Charnley 1:250 000 Sheet areas.

Type section: 2 km east of Mount Laptz in Lansdowne Sheet area at lat. 17°40′42″S, long. 126°45′00″E.

Derivation of name: From Luman Land Division of East Kimberley, W.A.

Stratigraphic relations: Conformably overlies Lansdowne Arkose. Overlain, generally conformably, by King Leopold Sandstone; local angular unconformity in south.

Lithology: Flaggy green to brown slightly micaceous siltstone and grey shale.

Thickness: 3-95 m; average about 60 m. Type section 73 m.

Distinguishing features: Stratigraphic position diagnostic.

Age: Late Lower Proterozoic.

Kimberley Group (new name).

Distribution: Throughout Kimberley Basin of north Western Australia. Outcrops broadly bounded by Halls Creek Mobile Zone in southeast and King Leopold Mobile Zone in southwest.

Derivation of name: From Kimberley Plateau of north Western Australia, which is almost entirely underlain by rocks of Group.

Stratigraphic relations: Conformably overlain by Bastion and Crowhurst Groups; overlies Speewah Group, generally conformably, or locally with angular unconformity in southeast. Intruded by Hart Dolerite. Locally overlies Halls Creek Group unconformably and locally overlain unconformably by Glidden, Carr Boyd, Mount House and Kuniandi Groups.

Constituent units:

- Pentecost Sandstone
  - Yampi Member (of Pentecost Sandstone)
- Elgee Siltstone
  - Teronis Member (of Elgee Siltstone)
- Warton Sandstone
  - Buckland Point Member (of Warton Sandstone)
- Carson Volcanics
- King Leopold Sandstone.

Thickness: Up to 3350 m; about 2775 m average.

Distinguishing features: Predominance of quartz-rich arenites distinctive. Overall succession of rock-types unique in Kimberley region.

Age: Late Lower Proterozoic.

King Leopold Sandstone (old name redefined).

Distribution: Throughout Kimberley Basin of north Western Australia.

Type section: King Leopold Ranges in Lennard River 1:250 000 Sheet area, about lat. 17°21′S, long. 125°25′E (Guppy et al., 1958).

Derivation of name: From King Leopold Ranges, in West Kimberley, (lat. 17°21′S, long. 125°25′E).
Guppy et al. (1958) used King Leopold Beds for rocks unconformably overlying Lamboo Complex and conformably underlying Mornington (i.e. Carson) Volcanics in the Lennard River 1:250 000 Sheet area. Harms (1959, 1965) retained same definition and proposed term King Leopold Sandstone. Harms noted shales and acid volcanics in lower part of the section in Lansdowne and Lissadell Sheet areas and suggested these beds may be older than the basal beds in the west, but included them in the original King Leopold Beds. Present survey has mapped these lower beds as Speewah Group, and recognized them in the Lennard River Sheet area as well.

Stratigraphic relations: Conformably overlain by Carson Volcanics; overlies Speewah Group, generally conformably, or with local unconformity in southeast. Locally overlies Halls Creek Group unconformably.

Lithology: Blocky to massive, quartz sandstone and feldspathic sandstone with scattered quartz pebbles. Irregular lenses of granule sandstone and conglomerate.

Thickness: 0-1340 m; about 890 m average. Type section 823 m.

Distinguishing features: Thick uniform sequence of massive jointed quartz sandstone, distinctive pattern on aerial photographs, and stratigraphic position diagnostic.

Age: Late Lower Proterozoic.

Carson Volcanics (new name replacing invalid name)

Distribution: Throughout Kimberley Basin of north Western Australia.

Type section: Durack Range, in Lissadell Sheet area, at lat. 16°17′25″S, long 127°48′ 50″E.

Derivation of name: From Carson River, in Drysdale Sheet area, about lat. 14°30′S, long. 126°45′E, the valley of which occurs in the volcanics throughout most of its length. Unit defined and named Mornington Volcanics by Guppy et al. (1958) and continued by Harms (1959, 1965). Name invalid owing to prior usage in Victoria.

Stratigraphic relations: Conformably overlain by Warton Sandstone; conformably overlies King Leopold Sandstone.

Lithology: Massive saussuritized and chloritized basalt; blocky cross-bedded feldspathic sandstone, chloritic siltstone and green chert.

Thickness: 60-1140 m; about 490 m average. Type section 228 m.

Distinguishing features: Basic volcanics and associated sediments are diagnostic in Kimberley Group.

Age: Late Lower Proterozoic.

Warton Sandstone (old name redefined)

Distribution: Throughout Kimberley Basin of north Western Australia.

Type section: Durack Range, in Lissadell Sheet area, at lat. 16°17′40″S, long. 127°48′ 30″E.

Derivation of name: From Warton Range, in Lansdowne Sheet area about lat. 17°24′S, long. 126°27′E.
Name first used by Guppy et al. (1958) as Warton Beds, to include present Pentecost Sandstone, Elgee Siltstone, and Warton Sandstone. Harms (1959, 1965) subdivided these and used Warton Sandstone for sandstone unit cropping out in Warton Range.

Stratigraphic relations: Conformably overlain by Elgee Siltstone; conformably overlies Carson Volcanics.

Lithology: Blocky to massive, medium-grained quartz sandstone and feldspathic sandstone. Minor granule sandstone and purple shale.

Thickness: 60-600 m (excluding Buckland Point Member); average about 320 m. Type section 211 m.

Distinguishing features: Thin, but laterally consistent and continuous sandstone unit combined with stratigraphic position is diagnostic.

Age: Late Lower Proterozoic.

Buckland Point Member (of Warton Sandstone) (new name)

Distribution: Confined to western coastal region of Kimberley Plateau between Wilson Point and Doubtful Bay, and on Byam Martin and Degerande Islands, in Prince Regent and Camden Sound 1:250 000 Sheet areas.

Type section: Southern shore of Deception Bay, in Camden Sound Sheet area, about lat. 15°35′S, long. 124°25′E.

Derivation of name: Buckland Point (lat. 15°38′S, long. 124°25′E) in Camden Sound Sheet area.

Stratigraphic relations: Conformable member occupying upper half of Warton Sandstone. Conformably overlain by Elgee Siltstone.

Lithology: Blocky to flaggy white medium-grained quartz sandstone alternating with flaggy red-brown ferruginous fine-grained sandstone and siltstone.

Thickness: 550 m.

Distinguishing features: Alternating quartz and ferruginous sandstones distinguish unit from rest of Warton Sandstone and produce distinctive banded pattern on aerial photographs.

Age: Late Lower Proterozoic.

Elgee Siltstone (old name redefined)

Distribution: Throughout Kimberley Basin of north Western Australia.

Type section: Elgee Cliffs, along Chamberlain River, in northwestern Lissadell Sheet area at lat. 16°02′05″S, long. 127°52′15″E.

Derivation of name: From Elgee Cliffs, which follow Chamberlain River between lat. 17° 15′S, long. 127°15′E, and lat. 16°00′S, long. 127°52′E. Guppy et al. (1958) included strata within Warton Beds and Harms (1959, unpubl.) subdivided Warton Beds into Pentecost Sandstone, Elgee Shale, and Warton Sandstone. Dow et al. (1964, unpubl.) and Harms (1965) changed Elgee Shale to Elgee Siltstone.

Stratigraphic relations: Conformably overlain by Pentecost Sandstone; conformably overlies Warton Sandstone.

Lithology: Massive reddish-purple to cherry-red siltstone with minor interbeds of flaggy laminated fine-grained purple-brown sandstone. Minor green shale, micaceous sandstone and shale, flaggy dolomite.

Thickness: 0-480 m; average about 150 m. Type section 184 m.

Distinguishing features: Uniform laterally consistent massive red siltstone is distinctive; cherry-red colour of fresh exposures is unique in Kimberley region.

Age: Late Lower Proterozoic.

Teronis Member (of Elgee Siltstone) (new name)

Distribution: Local development in southeastern part of Kimberley Basin, in Mount Ramsay, Lansdowne, and southwestern Lissadell Sheet areas.

Type section: Margaret Gorge (lat. 18°26′18″, long. 126°34′54″E) in Mount Ramsay Sheet area.

Derivation of name: From Teronis Gorge (lat. 17°18′15″S, long. 127°15′36″E) in Lansdowne Sheet area.

Stratigraphic relations: At base of Elgee Siltstone, of which it is a member.

Lithology: Stromatolitic dolomite, flaggy dolomite and dolomitic siltstone, purple-brown siltstone and fine-grained sandstone.

Thickness: 0-140 m; about 40 m average. Type section 55 m.

Distinguishing features: Stromatolites and flaggy dolomite distinguishes member from remainder of Elgee Siltstone.

Age: Late Lower Proterozoic.

Pentecost Sandstone (old name redefined)

Distribution: Throughout Kimberley Basin of north Western Australia.

Type section: 21 km east-southeast of junction of Pentecost and Salmond Rivers, at lat. 15°59′00″S, long. 128°5′20″E, near southern margin of Cambridge Gulf Sheet area.

Derivation of name: From Pentecost Range (lat. 15°46′S, long. 127°45′E) in southwestern Cambridge Gulf Sheet area. Originally included within Warton Beds by Guppy et al. (1958). Harms (1959, unpubl.) subdivided beds into three units; Pentecost Sandstone, Elgee Shale, and Warton Sandstone.

Stratigraphic relations: Conformably overlain by Mendena Formation; conformably overlies Elgee Siltstone.

Lithology: Mainly fine to medium-grained blocky to massive pink to pale purple-brown quartz sandstone and flaggy fine-grained white quartz sandstone with scattered feldspar. Minor flaggy purple-brown micaceous fine-grained sandstone and siltstone, flaggy pale green fine-grained sandstone and shale, glauconitic sandstone, ferruginous sandstone, purple siltstone.

Thickness: 600-1350+ m; average about 950 m. Type section 1135 m.

Distinguishing features: Stratigraphic position and dominance of distinctive pink and yellowish sandstones with scattered feldspar and clay cement.

Age: Late Lower Proterozoic.

Bastion Group (new name)

Distribution: Only preserved in eastern part of Kimberley Basin of north Western Australia, in western parts of Lissadell and Cambridge Gulf and eastern parts of Lansdowne, Mount Elizabeth, and Ashton Sheet areas.

Derivation of name: From Bastion Range at Wyndham, which consists of rocks of the group.
Traves (1955) and Harms (1959, unpubl.) considered rocks of the group to belong to Mount House Beds (present Mount House Group), but Harms (1965) showed them as Wyndham Siltstone and Cockburn Sandstone, which he correlated with Mount House Beds. Our mapping has shown group to be conformable part of Kimberley Basin succession.

Stratigraphic relations: Conformably overlies Kimberley Group; unconformably overlain by Lower Cambrian Antrim Plateau Volcanics. Inferred to be overlain unconformably by Carr Boyd Group. Correlated with Crowhurst Group.

Constituent units:
Cockburn Sandstone.
Wyndham Shale.
Mendena Formation.

Thickness: About 1300 m; top eroded.

Distinguishing features: Predominance of lutites distinguishes group from Kimberley Group; green and grey colour of most lutites when freshly exposed distinctive.

Age: Late Lower Proterozoic.

Mendena Formation (new name)

Distribution: Only preserved in eastern part of Kimberley Basin of north Western Australia, in western parts of Lissadell and Cambridge Gulf, and eastern parts of Lansdowne, Mount Elizabeth, and Ashton Sheet areas.

Type section: On Pentecost River, in Cambridge Gulf Sheet area, at lat. 15°45′55″S, long. 127°51′28″E.

Derivation of name: From Mendena Creek, in Cambridge Gulf Sheet area, which cuts formation at about lat. 15°02′S, long. 127°49′E near Forrest River Mission.
Traves (1955) and Harms (1959) incorrectly included these rocks in Mount House Beds (see Bastion Group). Harms (1965) included them in Wyndham Siltstone; we consider them to be a useful unit in mapping and synthesis.

Stratigraphic relations: Conformably overlain by Wyndham Shale; conformably overlies Pentecost Sandstone.

Lithology: Blocky white quartz sandstone alternates with interbedded flaggy green and purple siltstone, flaggy green, grey, and purple laminated fine-grained micaceous sandstone, flaggy green to pink dolomitic sandstone, flaggy white fine to medium-grained quartz sandstone, and blue-grey, green, buff, and pink dolomite and oolitic dolomite.

Thickness: 108 (type section)—150 m.

Distinguishing features: Transitional unit between Pentecost Sandstone and Wyndham Shale; alternation between blocky sandstone and poorly outcropping siltstones and dolomites distinguishes unit from both underlying and overlying units.

Age: Late Lower Proterozoic.

Wyndham Shale (old name redefined)

Distribution: Only exposed in Cambridge Gulf and northern part of Lissadell Sheet areas of East Kimberley region, north Western Australia.

Type section: West side of Cockburn Range, in Cambridge Gulf Sheet area, at lat. 15°41′54″S, long. 127°55′30″E.

Derivation of name: From township of Wyndham (lat. 15°27′S, long. 128°05′E), situated on bedrock of the shale.
Jack (1906) referred to rocks at Wyndham as Wyndham Beds. Traves (1955) and Harms (1959) incorrectly included the rocks in Mount House Beds (see Bastion Group). Harms, however, had designated the rocks as Wyndham Shale on his unpublished field sheets in 1958, but changed them to Mount House Beds in his report in 1959 and then subsequently referred to them as Wyndham Siltstone (Harms, 1965). We prefer Wyndham Shale.

Stratigraphic relations: Conformably overlain by Cockburn Sandstone; conformably overlies Mendena Formation.

Lithology: Fissile green, grey, and black shale and siltstone with regular minor interbeds (5-30 cm thick) of laminated green and grey fine-grained sandstone. Minor black to grey sandstone, bedded limestone and elliptical concretions, up to 60 cm diameter, of black calcite. Micaceous laminae in the shales; mud cracks, load casts, and irregular 'wavy' bedding common.

Thickness: 700 m (type section).

Distinguishing features: Thick monotonous grey-green shale with regular fine-grained sandstone interbeds, combined with stratigraphic position, diagnostic.

Age: Late Lower Proterozoic.

Cockburn Sandstone (old name redefined)

Distribution: Erosional remnants cap Cockburn, Bastion, and Tier Ranges, and House Roof and False House Roof Hills, in Cambridge Gulf and northernmost Lissadell Sheet areas of East Kimberley region, north Western Australia.

Type section: Central Cockburn Range, about lat. 15°50′18″S, long. 128°0′5″E, in Cambridge Gulf Sheet area.

Derivation of name: From Cockburn Range, about lat. 15°45′S, long. 128°00′E. Traves (1955) and Harms (1959, unpubl.) incorrectly included rocks in Mount House Beds (see Bastion Group) but Harms (1965) referred to them as Cockburn Sandstone.

Stratigraphic relations: Top of Bastion Group; top eroded. Conformably overlies Wyndham Shale; unconformably overlain by Lower Cambrian Antrim Plateau Volcanics.

Lithology: Fine to medium-grained white quartz sandstone. Ripple-marks and cross-bedding common; some clay pellets. Minor interbeds of purple-brown and grey fine-grained sandstone; thinly bedded green-grey micaceous siltstone and green shale; silty and clayey sandstones.

Thickness: 500 m + (type section) (top eroded).

Distinguishing features: Uniform massive cliff-forming mesa-capping sandstone, and stratigraphic position, diagnostic.

Age: Late Lower Proterozoic.

Crowhurst Group (new name)

Distribution: Exposures restricted to O'Donnell Syncline area, extending 20 km west, 40 km east, 20 km north, and 3 km south of junction of Margaret and O'Donnell Rivers, in northern part of Mount Ramsay Sheet area, East Kimberley region, north Western Australia.

Derivation of name: From Crowhurst Gorge, located on west-flowing course of Margaret River within King Leopold Range, Mount Ramsay Sheet area.

Stratigraphic relations: Conformably overlies Kimberley Group; unconformably overlain by either Colombo Sandstone or Egan Formation. Correlated with Bastion Group.

Constituent units:
Hibberson Formation.
Collett Siltstone.
Liga Shale.
Hilfordy Formation.

Thickness: About 145 m, top eroded.

Distinguishing features: Predominance of lutites and carbonates distinguishes group from underlying Kimberley Group.

Age: Late Lower Proterozoic.

Hilfordy Formation (new name)

Distribution: O'Donnell Syncline area, extending 20 km west, 40 km east, 20 km north, and 3 km south of junction of Margaret and O'Donnell Rivers, in the northern part of Mount Ramsay Sheet area, East Kimberley region, north Western Australia.

Type section: 10.6 km north 10° east of confluence of Margaret and O'Donnell Rivers, at lat. 18°15′12″S, long. 126°37′18″E.

Derivation of name: From Hilfordy Creek, a newly named tributary of Margaret River.

Stratigraphic relations: Conformably overlies Pentecost Sandstone; conformably overlain by Liga Shale.

Lithology: Interbedded medium-grained purplish quartz sandstone (pebbly in places), purple and green siltstone, and green shale. Ripple marks common.

Thickness: 28-30 m (type section).

Distinguishing features: Base taken at first appearance of flaggy purple siltstone or purple sandstone beds; top marked by disappearance of arenites.

Age: Late Lower Proterozoic.

Liga Shale (new name)

Distribution: O'Donnell Syncline area, extending 20 km west, 26 km east-northeast, and 15 km west-southwest of junction of Margaret and O'Donnell Rivers, in northern part of Mount Ramsay Sheet area, East Kimberley region, north Western Australia.

Type section: 10.4 km north 10° east of confluence of Margaret and O'Donnell Rivers, at lat. 18°15′24″S, long. 126°37′18″E.

Derivation of name: From Liga Creek, a newly named tributary of O'Donnell River.

Stratigraphic relations: Conformably overlies Hilfordy Formation; conformably overlain by Collett Siltstone.

Lithology: Green shale.

Thickness: 40-45 m (type section).

Distinguishing features: Distinguished from Hilfordy Formation by lack of sandstone interbeds; distinguished from Collett Siltstone by colour (green versus purple) and appearance in Collett Siltstone of lenticular carbonate bands.

Age: Late Lower Proterozoic.

Collett Siltstone (new name)

Distribution: O'Donnell Syncline area, extending 20 km west, 25 km east-northeast, and 15 km west-southwest of junction of Margaret and O'Donnell Rivers, in northern part of Mount Ramsay Sheet area, East Kimberley region, north Western Australia.

Type section: East side of Margaret River in Crowhurst Gorge, at lat. 18°17′00″S, long. 126°25′50″E.

Derivation of name: From Collett Cliffs, a newly named feature along Margaret River.

Stratigraphic relations: Conformably overlies Liga Shale; conformably overlain by Hibberson Dolomite.

Lithology: Purple siltstone with bands and lenses of dolomite (?) and green siltstone near base, and thin interbeds of pyritic cherty siltstone and fine-grained sandstone near top.

Thickness: 61 m (type section).

Distinguishing features: Base marked by appearance of purple siltstone with bands and lenses of dolomite (?); top marked by appearance of thick-bedded dolomite or dolomite-breccia.

Age: Late Lower Proterozoic.

Hibberson Dolomite (new name)

Distributions O'Donnell Syncline area, extending 20 km west, 16 km north-northeast, and 15 km west-southwest of junction of Margaret and O'Donnell Rivers, in northern part of Mount Ramsay Sheet area, East Kimberley region, north Western Australia.

Type section: East side of Margaret River in Crowhurst Gorge, at lat. 18°17′00″S, long. 126°25′45″E.

Derivation of name: From Hibberson Bluff, a newly named feature along Crowhurst Gorge.

Stratigraphic relations: Top of Crowhurst Group; top eroded. Conformably overlies Collett Siltstone; unconformably overlain by Colombo Sandstone.

Lithology: Pink to cream dolomite and dolomite-breccia.

Thickness: 145 m + (type section).

Distinguishing features: Base distinguished by presence of thick-bedded dolomite or dolomite-breccia in contrast with underlying purple siltstone.

Age: Late Lower Proterozoic.

Hart Dolerite (old name redefined)

Distribution: Throughout Kimberley Basin; most extensive along southeastern and southwestern margins, intruding Speewah Group.

Type locality: Exposures about 4 km southwest of Mount Hart.

Derivation of name: From Mount Hart (lat. 16°55′S, long. 125°04′E) in Charnley Sheet area. Guppy et al. (1958) proposed Hart Basalt, which was changed to Hart Dolerite by Harms (1959, unpubl.), who established intrusive origin of rocks.

Stratigraphic relations: Sills intrude all units of Kimberley and Speewah Groups, and sometimes Whitewater Volcanics; unconformably overlain by Mount House Group.

Lithology: Massive dolerite, quartz dolerite, gabbro, diorite, and granophyre.

Distinguishing features: Lithology and structural position diagnostic.

Age: Late Lower Proterozoic (isotopic age determination).

Mount House Group (old name redefined)

Distribution: Headwaters of Adcock, Throssell, and Hann Rivers of eastern Lennard River and western Lansdowne Sheet areas, extending into Traine—Chapman—Hann Rivers watershed area of southwestern Mount Elizabeth and Beverley Springs homestead area of eastern Charnley Sheet areas.

Derivation of name: From Mount House (lat. 17°08′S, long. 125°44′E), in Lennard River Sheet area.
Guppy et al. (1958) used Mount House Beds for strata overlying Walsh Tillite and which are now subdivided into several formations; group now expanded to include tillite.

Stratigraphic relations: Unconformably overlies Kimberley Group and Hart Dolerite; top eroded, no directly overlying units. Correlated with Duerdin and Kuniandi Groups of East Kimberley.

Constituent units:
- Estaughs Formation.
- Throssell Shale.
- Traine Formation.
- Walsh Tillite.
  - Beverley Springs Member (of Walsh Tillite).

Thickness: 275 — 515+ m; top eroded.

Distinguishing features: Association of glacigene sediments and overlying green shales diagnostic.

Age: Adelaidean.

Walsh Tillite (old name redefined)

Distribution: Around headwaters of Adcock, Throssell, and Hann Rivers of eastern Lennard River and western Lansdowne Sheet areas, and Traine—Chapman—Hann Rivers watershed area of southwestern Mount Elizabeth Sheet area.

Type section: Walsh Creek, about lat. 17°12′S, long. 125°35′E (Guppy et al., 1958).

Derivation of name: From Walsh Creek (lat. 17°12′S, long. 125°35′E) in Lennard River Sheet area. Originally defined by Gupppy et al. (1958) as overlain by Mount House Beds. Redefined as part of Mount House Group.

Stratigraphic relations: Unconformably overlies Kimberley Group and Hart Dolerite; conformably overlain by Traine Formation or Throssell Shale.

Lithology: Massive tillite. Minor flaggy pink to purple-brown dolomite, sandstone, green siltstone, stromatolitic dolomite.

Thickness: 5 — 160+ m; average about 80 m.

Distinguishing features: Consistent association of glacigene sediments overlain by distinctive flaggy dolomite diagnostic.

Age: Adelaidean.

Beverley Springs Member (of Walsh Tillite) (new name)

Distribution: Scattered outliers extending up to 25 km south and 10 km west of Beverley Springs homestead in Charnley Sheet area.

Type section: Exposures 3 km west of Beverley Springs homestead, about lat. 16°34′S, long. 125°27′E.

Derivation of name: From Beverley Springs homestead.

Stratigraphic relations: Unconformably overlies Carson Volcanics and King Leopold Sandstone of Kimberley Group; top eroded. Regarded as facies equivalent of basal beds of Walsh Tillite, although exposures not continuous.

Lithology: Poorly sorted pebbly quartz sandstone.

Thickness: 50 m.

Distinguishing features: Stratigraphic position diagnostic.

Age: Adelaidean.

Traine Formation (new name)

Distribution: Headwaters of Throssell, Hann, Traine, and Chapman Rivers of western Lansdowne and Mount Elizabeth Sheet areas; dies out westwards in northeast Lennard River Sheet area.

Type section: Base of scarp, east side of Mount Clifton, lat. 17°24′18″S, long. 126°2′42″E, in Lansdowne Sheet area.

Derivation of name: From Traine River, which follows base of formation in Lansdowne Sheet area.

Stratigraphic relations: Conformably overlies Walsh Tillite; conformably overlain by Throssell Shale; lenses out westwards.

Lithology: Massive green to brown lithic sandstone; scattered glacial erratics. Minor flaggy dolomite, sandy dolomite, dolomitic sandstone, dolomite breccia, purple-brown and green siltstone.

Thickness: 0-60 m; about 50 m average. Type section 7 m.

Distinguishing features: Sandstone and dolomite, and purple-brown siltstone, distinguish unit from Throssell Shale.

Age: Adelaidean.

Throssell Shale (new name)

Distribution: Headwaters of Throssell, Hann, and Adcock Rivers, in western Lansdowne and eastern Lennard River Sheet areas.

Type section: Scarp on east side of Mount Clifton at lat. 17°24′18″S, long. 126°2′20″E, in Lansdowne Sheet area.

Derivation of name: From Throssell River, which rises within outcrops of the formation in Lansdowne Sheet area.

Stratigraphic relations: Conformably overlies Traine Formation or Walsh Tillite; conformably overlain by Estaughs Formation.

Lithology: Flaggy grey-green micaceous shale and siltstone; minor fine-grained sandstone interbeds.

Thickness: 175 m (type section)—235 m.

Distinguishing features: Combination of thick sequence of grey-green shale and stratigraphic position diagnostic.

Age: Adelaidean.

Estaughs Formation (new name)

Distribution: Caps mesas of Mount Clifton and Mount House around boundary between Lansdowne and Lennard River Sheet areas.

Type section: Scarp on east side of Mount Clifton at lat. 17°18′10″S, long. 126°1′ 50″E, in Lansdowne Sheet area.

Derivation of name: 'The Estaughs', a pair of mesas near boundary between Lansdowne and Lennard River Sheet areas which are capped by the formation.

Stratigraphic relations: Upper unit of Mount House Group. Conformably overlies Throssell Shale; top eroded.

Lithology: Massive purple ferruginous sandstone, flaggy micaceous quartz greywacke, flaggy grey-green micaceous siltstone.

Thickness: 77 + m (type section) — 105 m; top eroded.

Distinguishing features: Massive sandstone interbeds distinguish unit from Throssell Shale.

Age: Adelaidean.

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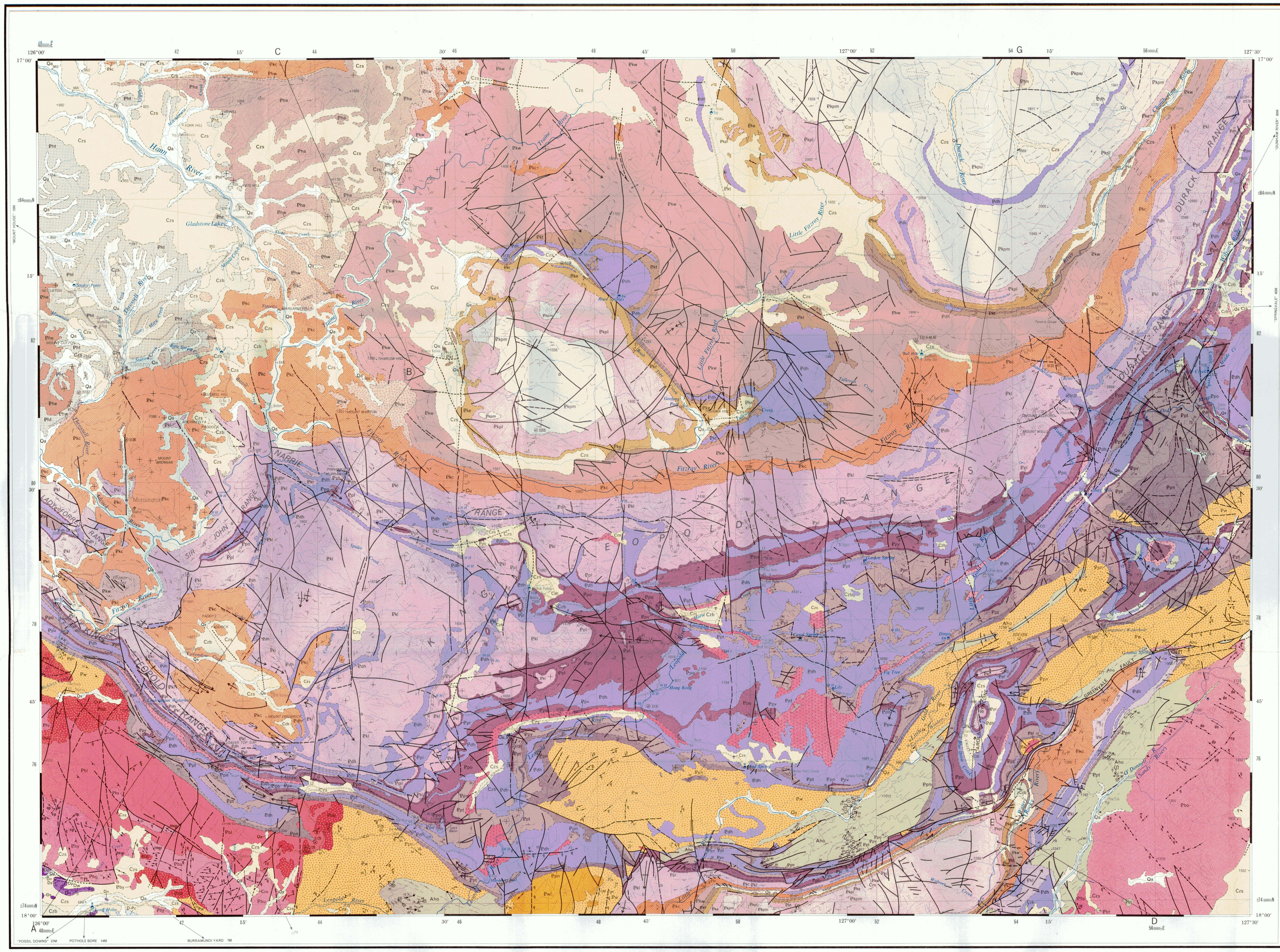


Reference

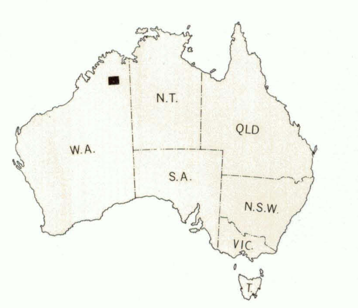
- Geological boundary
- Anticline, showing plunge
- Syncline, showing plunge
- Monocline, showing plunge
- Plunge of minor anticline
- Plunge of minor syncline
- Plunge of drag fold
- Plunge of fold axes
- Fault, showing relative horizontal movement (q-indicates quartz filled); D-indicates downthrown side
- Vertical fault
- Inclined fault
- High-angle reverse fault
- Shear zone
- 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
- Vertical strata
- Horizontal strata
- Overturned strata
- Horizontal strata; Trend lines; Joint pattern — air-photo interpretation
- Vertical cleavage
- Strike and dip of foliation
- Prevailing strike and dip of foliation
- Vertical foliation
- Inclined platy flow
- Strike and dip of joints
- Strike and dip of cleavage
- Plunge of lineation
- Lineation on bedding
- Macrofossil locality
- Type section locality
- D1 Measured section with reference number
- 5131 Sample locality for age determination with reference number
- Dyke: q-quartz, do-dolerite, rd-rhyodacite, tm gr-tourmaline-granite, ap-aplite, rh-rhyolite
- •Pb Minor mineral occurrence
- Cu Copper
- Fl Fluorite
- Pb Lead
- Bore, salinity < 2500 ppm
- Well, salinity < 2500 ppm
- T Tank
- E Earth Tank
- Windpump
- pe Equipped with pump engine
- Spring
- WH Waterhole
- Road
- Vehicle track
- Fence
- "Lansdowne" Homestead
- Landing ground
- Yd Yard
- Astronomical station
- Trigonometrical station
- •1005′ Height in feet; datum: mean sea level

Reference

CAINOZOIC	QUATERNARY		Qa	Alluvium: boulder gravels, fluviatile sand
CAINOZOIC	UNDIFFERENTIATED		Czs	Residual red and grey soils, sand, and ferricrete
CAINOZOIC	UNDIFFERENTIATED		Czb	Residual black soil
PALAEOZOIC	DEVONIAN & PERMIAN (?)		D-Pc	Conglomerate: mainly pebbles, cobbles, and boulders of quartzite set in arkosic matrix
PALAEOZOIC	DEVONIAN	Stony Creek Conglomerate	Ds	Conglomerate: pebbles, cobbles, and boulders of granite, quartz, quartzite, and sheared acid volcanics
PALAEOZOIC	DEVONIAN – GIVETIAN(?) TO FAMENNIAN	Windjana Limestone	Dw	Reef facies: limestone with colonial organisms and interstitial calcareous sediment; partly dolomitised
PALAEOZOIC	DEVONIAN – GIVETIAN(?) TO FAMENNIAN	Pillara Limestone	Dp	Black-reef facies: well-bedded stromatoporoid limestone, partly dolomitised
PALAEOZOIC	DEVONIAN – FAMENNIAN	Napier Formation	Dn	Fore-reef to inter-reef facies: silty limestone, calcarenite and calcirudite; partly dolomitised
PROTEROZOIC	ADELAIDEAN (UPPER PROTEROZOIC*)	Mount House Group: Estaughs Formation	Ƥhe	Hematitic quartz sandstone and siltstone, purple green micaceous siltstone and fine-grained subgreywacke
PROTEROZOIC	ADELAIDEAN (UPPER PROTEROZOIC*)	Mount House Group: Throssell Shale	Ƥht	Chloritic micaceous shale, grey-green micaceous sandstone, dolomitic sandstone, dolomitic breccia, flaggy dolomite
PROTEROZOIC	ADELAIDEAN (UPPER PROTEROZOIC*)	Mount House Group: Traine Formation	Ƥha	Purple-brown ferruginous sandstone
PROTEROZOIC	ADELAIDEAN (UPPER PROTEROZOIC*)	Mount House Group: Walsh Tillite	Ƥhw	Tillite, pink dolomite and quartz sandstone
PROTEROZOIC	ADELAIDEAN OR CARPENTARIAN (UNDIFF.)	Hart Dolerite		Pyroxene-bearing granophyre
PROTEROZOIC	ADELAIDEAN OR CARPENTARIAN (UNDIFF.)	Hart Dolerite	Ƥdh	Tholeiitic dolerite and gabbro
PROTEROZOIC	CARPENTARIAN (MID. PROT.)	Bastion Group: Mendena Formation	Ƥtm	Purple siltstone, quartz sandstone, micaceous feldspathic sandstone
PROTEROZOIC	CARPENTARIAN (LOW. MID. PROT.)	Kimberley Group: Pentecost Sandstone	Ƥkpu	Upper: coarse-to medium-grained white quartz sandstone
PROTEROZOIC	CARPENTARIAN (LOW. MID. PROT.)	Kimberley Group: Pentecost Sandstone	Ƥkpm	Middle: buff to white fine-to medium-grained feldspathic sandstone and quartz sandstone, grey siltstone and glauconitic sandstone at base
PROTEROZOIC	CARPENTARIAN (LOW. MID. PROT.)	Kimberley Group: Pentecost Sandstone	Ƥkpl	Lower: white to pale brown medium-grained quartz sandstone
PROTEROZOIC	CARPENTARIAN (LOWER PROTEROZOIC)	Kimberley Group: Elgee Siltstone	Ƥke	Red-brown friable siltstone, flaggy brown to white quartz sandstone
PROTEROZOIC	CARPENTARIAN (LOWER PROTEROZOIC)	Kimberley Group: Teronis Member	Ƥkt	Grey micaceous siltstone, limestone, and dolomite with algal structures
PROTEROZOIC	CARPENTARIAN (LOWER PROTEROZOIC)	Kimberley Group: Warton Sandstone	Ƥkw	Pale purple to brown feldspathic sandstone, white cross-bedded quartz sandstone
PROTEROZOIC	CARPENTARIAN (LOWER PROTEROZOIC)	Kimberley Group: Carson Volcanics	Ƥkc	Tholeiitic basalt and minor spilite, amygdaloidal in part; rhyolitic tuff and agglomerate, feldspathic sandstone, siltstone, limestone, chert
PROTEROZOIC	CARPENTARIAN (LOWER PROTEROZOIC)	Kimberley Group: King Leopold Sandstone	Ƥkl	Massive white to pale purple cross-bedded poorly sorted quartz sandstone; minor siltstone. Localised pebble to boulder conglomerate, granule sandstone
PROTEROZOIC	CARPENTARIAN (LOWER PROTEROZOIC)	Speewah Group: Luman Siltstone	Ƥpl	Purple-grey and green-grey micaceous shale and siltstone
PROTEROZOIC	CARPENTARIAN (LOWER PROTEROZOIC)	Speewah Group: Lansdowne Arkose	Ƥpo	Buff to pale pink cross-bedded feldspathic sandstone, arkose, purple-grey quartz sandstone; purple, green, and grey micaceous siltstone and shale
PROTEROZOIC	CARPENTARIAN (LOWER PROTEROZOIC)	Speewah Group: Valentine Siltstone	Ƥpv	Chloritic siltstone, grey-green mudstone, feldspathic sandstone, rhyolitic tuff
PROTEROZOIC	CARPENTARIAN (LOWER PROTEROZOIC)	Speewah Group: Tunganary Formation	Ƥpt	Buff to pale grey feldspathic sandstone, quartz sandstone, pink arkose, granule sandstone, grey-green shale, micaceous siltstone and chert
PROTEROZOIC	CARPENTARIAN (LOWER PROTEROZOIC)	Speewah Group: O'Donnell Formation	Ƥpn	Khaki shale, siltstone, and greywacke; white, purple, and brown quartz sandstone, glauconitic sandstone, granule sandstone, conglomerate, localised feldspar porphyry
PROTEROZOIC	CARPENTARIAN (LOWER PROTEROZOIC)	Little Gold River Porphyry	Ƥwl	Dark grey orthopyroxene-feldspar porphyry with sporadic quartz phenocrysts; strongly xenolithic in places
PROTEROZOIC	CARPENTARIAN (LOWER PROTEROZOIC)	Whitewater Volcanics	Ƥw	Quartz-feldspar porphyry, feldspar-pyroxene porphyry, lapilli tuff, volcanic conglomerate; siltstone interbeds
PROTEROZOIC	(LOWER PROTEROZOIC)	Lamboo Complex: Bickleys Porphyry	Ƥbb	Grey quartz-feldspar porphyry and porphyritic microgranite. Phase with pink feldspar phenocrysts
PROTEROZOIC	(LOWER PROTEROZOIC)	Lamboo Complex: Mulkerins Granite	Ƥbu	White coarse and even-grained leucocratic granite, tourmaline-muscovite aplite, quartz-feldspar pegmatite
PROTEROZOIC	(LOWER PROTEROZOIC)	Lamboo Complex: Lerida Granite	Ƥbl	Grey porphyritic biotite granite with pale green feldspar phenocrysts
PROTEROZOIC	(LOWER PROTEROZOIC)	Lamboo Complex: Chaneys Granite	Ƥby	Coarse and even-grained biotite granite, foliated and locally sheared
PROTEROZOIC	(LOWER PROTEROZOIC)	Lamboo Complex: Long Hole Granite	Ƥbg	Grey coarse-grained porphyritic biotite granite, biotite gneiss, augen gneiss
PROTEROZOIC	(LOWER PROTEROZOIC)	Lamboo Complex: Violet Valley Tonalite	Ƥbv	Medium to coarse-grained tonalite
PROTEROZOIC	(LOWER PROTEROZOIC)	Lamboo Complex: Bow River Granite	Ƥbo	Grey coarse-grained biotite granite, pink coarse-grained porphyritic biotite granite, minor granodiorite
PROTEROZOIC	(LOWER PROTEROZOIC)	Lamboo Complex: Tickalara Metamorphics	Ƥbt	Biotite paragneiss with cordierite, sillimanite and staurolite
ARCHAEAN OR PROTEROZOIC	(ARCHAEAN OR LOW. PROT.)	Halls Creek Group: Olympio Formation	Aho	Phyllitic shale and siltstone with interbedded greywacke, minor quartzite and limestone

* Subdivisions of the Precambrian time-scale used by the Geological Survey of Western Australia, shown in grey

Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjunction with the Geological Survey of Western Australia. Issued under the authority of the Hon. David Fairbairn, Minister for National Development. Base map compiled by the Royal Australian Survey Corps. Aerial photography by the Royal Australian Air Force; complete vertical coverage at 1:50,000 scale. Transverse Mercator Projection.



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Showing Magnetic Declination

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NO ANNUAL CHANGE

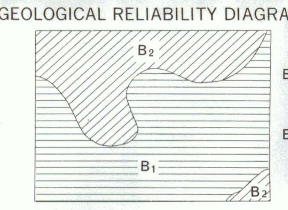
Scale 1:250,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

GREY NUMBERED LINES INDICATE THE 20,000 YARD TRANSVERSE MERCATOR GRID, ZONE 3 (AUSTRALIA SERIES)

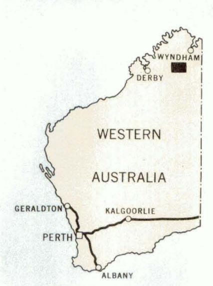
GEOLOGICAL RELIABILITY DIAGRAM



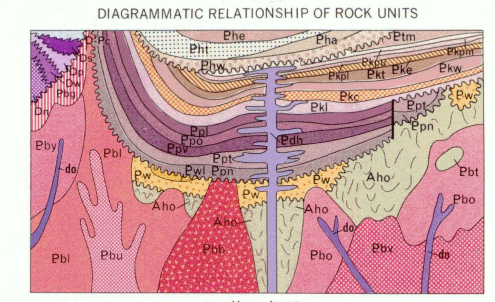
B_1 Detailed reconnaissance: numerous ground traverses and air-photo interpretation

B_2 Reconnaissance, some ground and helicopter traverses, and air-photo interpretation

Geology, 1964, by: K. A. Plumb, D. C. Gellatly, G. M. Derrick, J. F. Ivanac (B.M.R.), A. D. Allen, P. E. Playford, D. C. Lowry (G.S.W.A.)
Compiled, 1965, by: G. M. Derrick, D. C. Gellatly, A. S. Mikolajczak
Cartography by: Geological Branch, B.M.R.
Drawn by: Geodrafting Services Pty. Ltd.
Printed by: Mercury–Walch Pty Ltd., Hobart, Australia



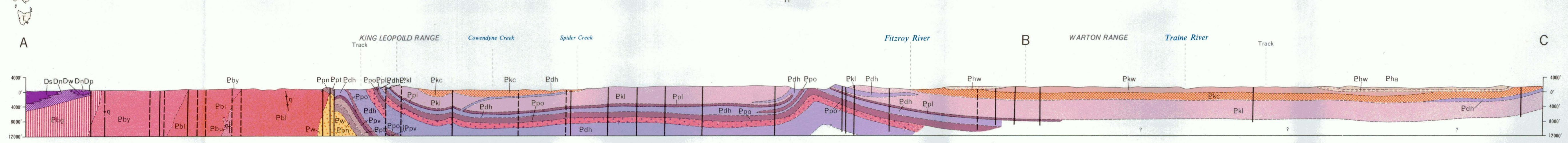
DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

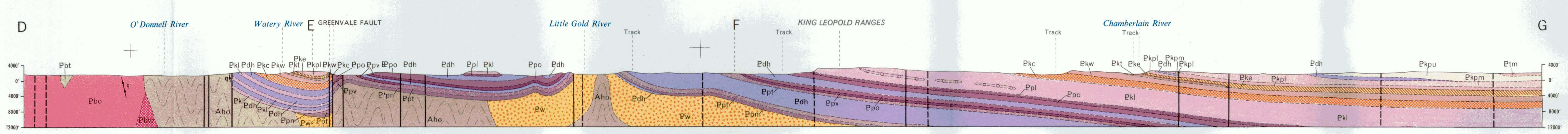


Unconformity
do Dolerite dykes

Sections

Cainozoic sediments omitted from section
Attitude of faults not known; Folding schematic
Scale: $\frac{V}{H} = 1$





LANSDOWNE
SHEET SE 52-5

Copies of this map may be obtained from the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T., or the Geological Survey of Western Australia, Perth.