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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

1966/55

GEOLOGY OF THE DRYSDALE - LONDONDERRY 1:250,000 SHEET AREAS SD52/5-9. WESTERN AUSTRALIA.

by

D.C. Gellatly and J. Sofoulis*
*(Geological Survey of Western Australia).

THE GEOLOGY OF THE DRYSDALE - LONDONDERRY 1:250,000 SHEET AREAS SD52/5-9, WESTERN AUSTRALIA

by

D.C. Gellatly and J. Sofoulis[1]

Records No. 1966/55.

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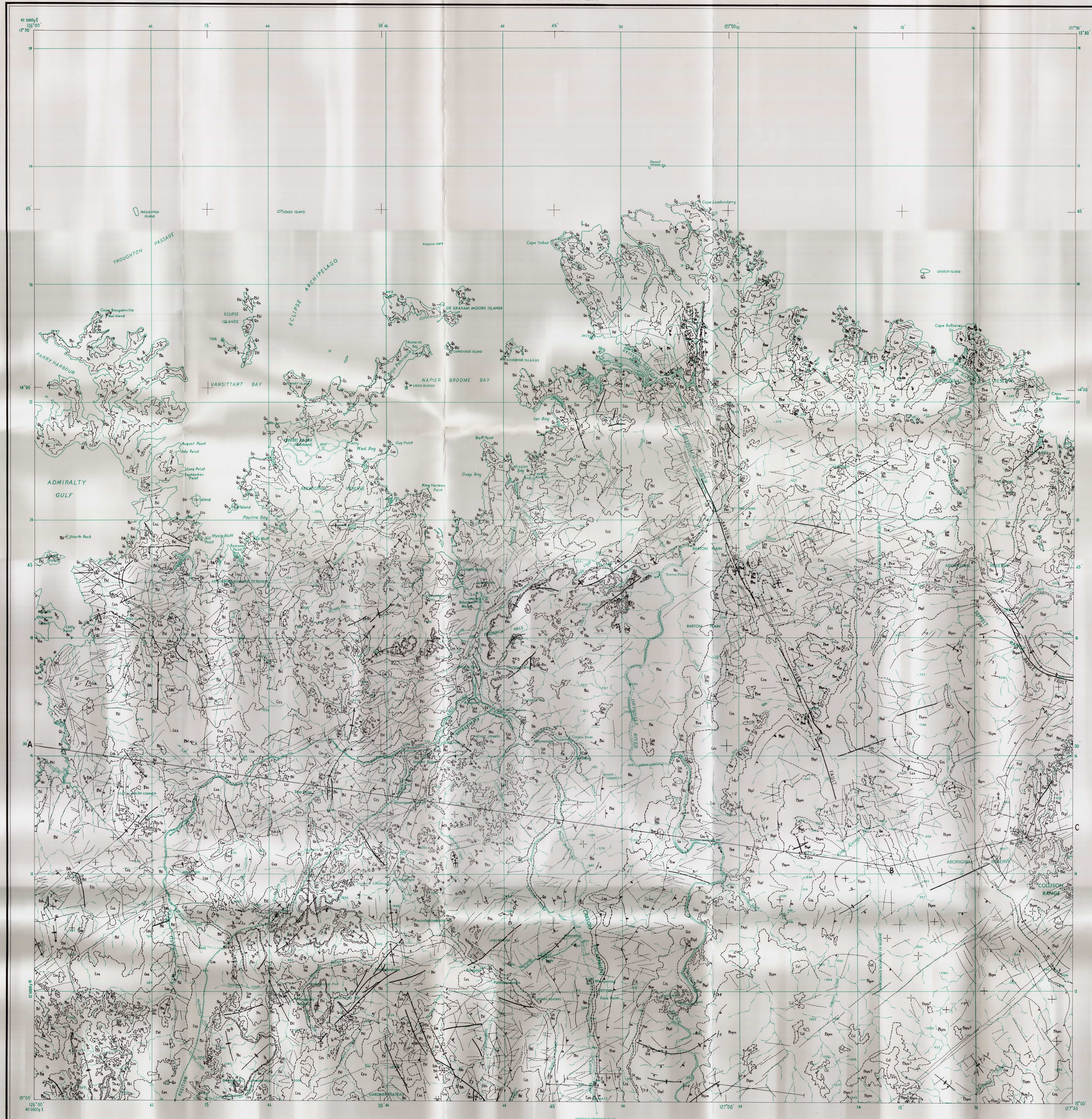
[1] Geological Survey of Western Australia

PLATE: GEOLOGICAL MAP OF THE DRYSDALE - LONDONDERRY 1:250,000 SHEET AREA.

+ Photograph

DRYSDALE - LONDONDERRY

WESTERN AUSTRALIA



PRELIMINARY EDITION, 1966

SUBJECT TO AMENDMENT

Reference

CAINOZOIC	QUATERNARY		Qa	Alluvium
			Qc	Coastal sand, silt and mud; thin salt crust locally
			Ql	Fragmental shelly limestone
			Qs	Beach sands; quartzose; locally pebbly and shell-bearing
	UNDIFFERENTIATED		Czs	Soil, sandy soil; eluvium
			Czs/Pkc	Grey and red basalt-derived soil
			Czb	Black soil
			Czl	Ferruginous, pisolitic, sandy soil
	TERTIARY		Tb	Bauxite, aluminous laterite
			Tp	Laterite, undifferentiated
PROTEROZOIC	ADELAIDEAN OR CARPENTARIAN	Hart Dolerite	Pdh	Dark grey medium-to coarse-grained dolerite.
	CARPENTARIAN	Kimberley Group: Pentecost Sandstone UPPER	Pkpu	White, medium- to coarse-grained quartz sandstone; minor granule sandstone; fine-to medium-grained clayey quartz sandstone.
		Pentecost Sandstone MIDDLE	Pkpm	White to buff, fine-to coarse-grained quartz sandstone, and minor feldspathic sandstone; glauconitic quartz sandstone at base
		Pentecost Sandstone LOWER	Pkpl	White to pale brown, medium-grained and minor coarse-grained quartz sandstone; prominent clay pellets
		Elgee Siltstone	Pke	Red brown siltstone, mudstone and shale, interbeds of fine-grained quartz sandstone and feldspathic sandstone
		Warton Sandstone	Pkw	White, cream, and pale purple-grey coarse- to medium-grained well-sorted quartz sandstone; minor feldspathic sandstone
		Carson Volcanics	Pkc	Grey to black locally amygdaloidal basalt; grey-green amygdoliodal spilite; minor feldspathic sandstone (stippled); stromatolitic chert and siltstone at top.
		King Leopold Sandstone	Pkl	White, buff, pale brown, and purple-grey coarse-grained, well-sorted quartz sandstone.

Geological boundary

Anticline, showing plunge

Syncline, showing plunge

Monocline, showing plunge

Fault, showing direction of throw.

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

Horizontal strata

Dip <5 | Dip 5°-15° | Dip 15°-45° | Horizontal strata | Trend line | Joint pattern — air-photo interpretation

Direction of movement of sediment-bearing currents from cross stratification.

Macrofossil locality

Sample locality for age determination

E 2 Measured section

• Cu Minor mineral occurrence

Cu Copper

Swamp

Windpump with tank

pe Pump engine

T Tank

Spring

Mangroves

Vehicle track

"Theda" Homestead

Landing ground

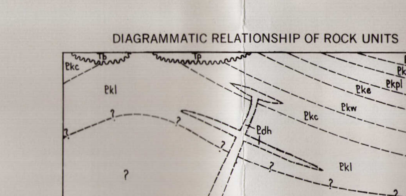
Yd Yard

KN6 Astronomical station

Trigonometrical station

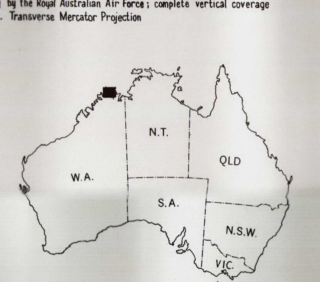
• 622 Height in feet, instrument levelled; datum; mean sea level.

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



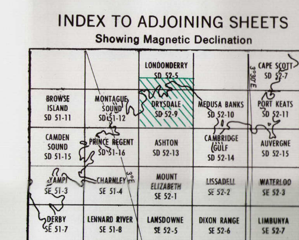
Unconformity

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjunction with the Geological Survey of Western Australia. Topographic base 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



INDEX TO ADJOINING SHEETS

Showing Magnetic Declination



ANNUAL CHANGE -0°30'W

Scale 1:250,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

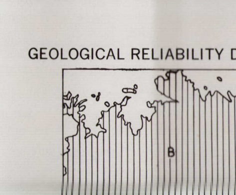
Section

Attitude of faults not known.

Cainozoic sediments, excepting Tertiary laterite omitted from section

Scale: $\frac{V}{H} = 2$

GEOLOGICAL RELIABILITY DIAGRAM

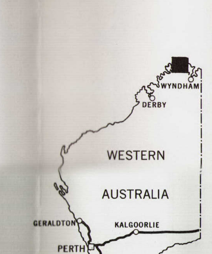


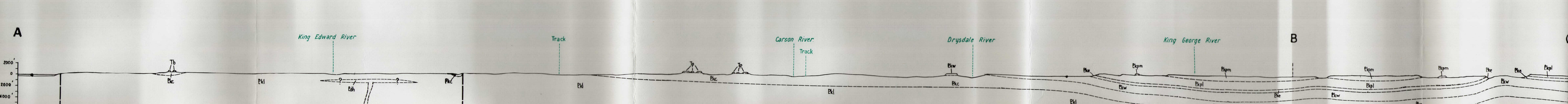
A Ground traverses

B Helicopter traverses and air-photo interpretation

C Air-photo interpretation.

Geological Photo Interpretation 1964 by: W. J. Perry. (B.M.R.)
Geology 1965 by: D.C. Gellatly (B.M.R.) J. Sofoulis (G.S.W.A.)
Compiled 1965 by: D.C. Gellatly, J. Sofoulis, J.L. McGovern
Cartography 1965 by: Geological Branch B.M.R.





DRYSDALE - LONDONDERRY

SHEET SD 52-9 & 5

ADDENDA - DRYSDALE-LONDONDERRY-RECORD 1966/55

When this report was written the analyses presented for the laterite and bauxite samples were incomplete. The following data complete the table of analyses given in Appendix 3.

Analysis	Reactive SiO_2	Available Al_2O_3
1	2.46	35.4
2	2.30	27.1
3	1.42	46.6
4	0.79	20.9
5	-	-
6	0.46	55.3
7	1.98	39.7
8	4.41	20.9
9	2.41	16.3
10	2.04	23.9
11	4.27	49.2
12	20.59	1.9
13	21.46	3.9

Analysis No5	
SiO_2	24.6
TiO_2	1.37
Al_2O_3	20.3
Fe_2O_3	43.6
FeO	0.16
MnO	0.01
MgO	0.04
CaO	0.03
Na_2O	0.07
K_2O	0.05
H_2O+	8.80
P_2O_5	0.09
CO_2	0.09
	99.94

Comments on bauxite and laterite analyses

Variations noted in the analyses depend partly on the grade of the material (i.e. the alumina content), and also apparently partly on locality and geological setting.

Total alumina values vary systematically with the content of Fe_2O_3 and silica in the rocks, but there is apparently no systematic variation between available alumina and the other constituents. The greatest proportional differences between total alumina and available alumina occur in specimens from laterite outcrops overlying sandstone, namely 12 and 13 which overlie the Warton Sandstone, and 10 which overlies the King Leopold Sandstone. Specimens 4, 7, 8, and 9 also show considerable proportional differences between total alumina and available alumina.

Titania shows no systematic variation with alumina content over the specimens as a complete group, but there are considerable variations in TiO_2 content from one locality to another. Within groups of specimens from individual localities, e.g. 1, 2, 3, and 7, 8, 9, TiO_2 decreases with increasing alumina, but this variation is not as marked as the variation between the average TiO_2 content at each locality.

Reactive silica contents of the two specimens from outcrops overlying the Warton Sandstone are much higher than in the other specimens and indicates a genetic difference between these specimens with high values of reactive silica and the others. The specimen from laterite overlying the King Leopold Sandstone comes from close to the contact with the Carson Volcanics and it is thought that the Volcanics have provided the source material for this laterite.

THE GEOLOGY OF THE DRYSDALE AND LONDONDERRY
1:250,000 SHEET AREAS 5052/5-9,
WESTERN AUSTRALIA

SUMMARY

The Drysdale-Londonderry 1:250,000 Sheet area in the extreme northern part of Western Australia has been mapped on a reconnaissance scale.

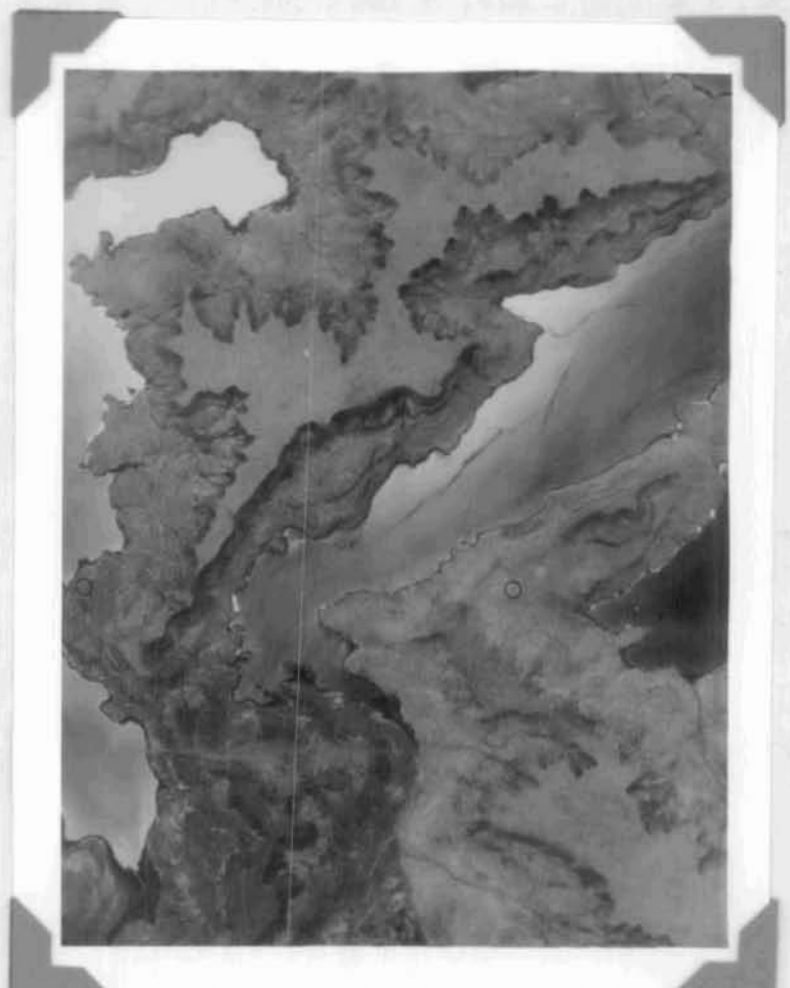
The area forms part of the dissected Kimberley Plateau, and has a drowned ria-type coastline. Within the area three physiographic divisions related to the type of bedrock are recognised - The Prince Regent Plateau, the Gibb Hills and the Karunjie Plateau.

Most of the rocks in the Sheet area are of Precambrian age, and are assigned to the Carpentarian System. The Carpentarian succession consists entirely of Kimberley Group rocks, which are sandstone and subordinate basic volcanics with minor siltstone. They are intruded by the Hart Dolerite of Carpentarian or Adelaidean age.

Superficial deposits include laterites, soils, coastal sands, and alluvium. The laterites occur as mesas which are remnants of a once more extensive laterite surface. They range from aluminous laterite to ferruginous laterite, and are being explored for commercial grade bauxite.

The rocks of the area are essentially flat-lying and have been gently folded along north-west and north-north-east axes into basins and domes. Joints, and rare faults have similar trends to the folds and are apparently related to them.

A study of palaeocurrent directions indicates that the source areas for the Precambrian sediments lay to the north and north-west.



Vertical air photograph showing laterite mesas (light coloured) overlying Carson Volcanics of Cape Bougainville Peninsula, and the deeply embayed nature of the (drowned) coastline of the area. Scale approximately 1½ miles to the inch.

INTRODUCTION

Location

The Drysdale and Londonderry 1:250,000 map Sheet areas are situated in the extreme northern part of Western Australia and lie between latitudes 13°00'S and 15°00'S, and longitudes 126°00'E and 127°30'E. The northern part of the Londonderry Sheet area is covered by the Timor Sea; for convenience the Drysdale Sheet area and the southern half of the Londonderry Sheet area have been combined in this record as the Drysdale-Londonderry Sheet area.

Object

The work described in this report is part of a programme of regional reconnaissance mapping on a scale of 1:250,000 being carried out jointly by the Geological Survey of Western Australia and the Bureau of Mineral Resources. This programme commenced in 1962 and since then Gordon Downs, Dixon Range, Lissadell, Cambridge Gulf, Mount Ramsay, and Lansdowne 1:250,000 Sheet areas have been mapped. In 1965, in addition to Drysdale and Londonderry, the Montague Sound (Allen, in prep.), Prince Regent-Camden Sound (Williams and Sofoulis, in prep.), Mount Elizabeth (Roberts, in prep), Ashton (Derrick, in prep.), and Medusa Banks (Plumb & Perry, in prep.) 1:250,000 Sheet areas and parts of Charnley and Lennard River areas were mapped.

The results of the present mapping programme will be published by the Bureau of Mineral Resources in three Bulletins describing the "Precambrian Geology of the Kimberley Region"; Part I, East Kimberley (Dow & Gemuts, in prep.); Part 2, Kimberley Basin (Plumb, in prep.); Part 3, West Kimberley.

The object of this report is to record all the geological information collected during the present survey. This and similar reports for adjoining areas will form the basis for the Bulletin on the Kimberley Basin.

Access

Access to the area by land is confined at present to a rough vehicle track leading from Gibb River Homestead in the Mount Elizabeth 1:250,000 Sheet area, branching at Drysdale Crossing, following the Carson and King Edward Rivers respectively, giving alternative access routes to Kalumburu Mission. These tracks have not been maintained since they were first made in 1954 and during the present survey it was possible to locate them in only a few places. Within the area, graded tracks lead from Kalumburu to Theda and Barton Plains Homesteads. Construction work on a new track from Gibb River Homestead to Kalumburu commenced in 1965.

A fortnightly air service connects Kalumburu Mission with Derby and Wyndham; Troughton Island has a less frequent air service. An airstrip at Theda Homestead is suitable only for light aircraft. A sealed airstrip at Truscott on the Anjo Peninsula, used during the second world war as a base for long-range bombers, is now unserviceable except for a short stretch at the south-eastern end, which is suitable for light aircraft.

The coastline and offshore islands are accessible by vessels of shallow draughts. Natural harbours which occur along the coast are backed mainly by tidal flats with precipitous cliffs that prevent access to the hinterland region.

Current shipping services include periodic visits by the State Shipping and Lighthouse Tender services to Troughton Island, and a twice yearly barge from Wyndham to Kalumburu Mission.

Population and Industry

The total population of the area is approximately 240, of which 220 are aboriginal and reside mainly at Kalumburu Mission. The only other permanently-inhabited settlement is the Radio Beacon Station on Troughton Island. Theda and Barton Plains Homesteads, the latter managed by Kalumburu Mission, are inhabited only periodically.

The sole industry of the area is the raising of beef cattle; at the time of writing only a small proportion of the potentially cattle-bearing parts of the area have been stocked.

Climate and Vegetation

The area has a monsoonal climate of tropical Savannah type with distinct wet and dry seasons.

Temperatures during the day are high throughout the year. Records for a 12 year period prior to December 1961 are given in the appendix. These indicate a narrow range in the mean monthly maxima (88°F-98°F) with the highest temperatures occurring during October and November. The mean monthly minima vary from 58°F to 77°F. Temperatures in the inland areas, are apparently slightly lower, with a greater range between maxima and minima. The coldest months are from June to August. Frosts have been recorded at Gibb River Homestead and Drysdale Crossing to the south of the area, and it is possible that rare frosts may occur in the southern part of the Drysdale-Londonderry Sheet area.

The area lies in the 30 to 40 inch rainfall belt. Over a 49 year period Kalumburu Mission has recorded an average annual rainfall of 39.6 inches (see Appendix I). The records show that 90% of this rain falls during the period from November to March. Light sporadic rains may occur during the rest of the year, and rainless months are not uncommon during the period July to September. Relative humidities rise at the onset of the "wet" season and humidities are generally higher on the coast than inland.

The typical vegetation of the area may be described as grassy eucalyptus woodlands and open forests (Speck, et al. 1960). The predominant associations are of E.tectifolia - E.grandifolia on volcanic soils and of E.tetrodonta - E.miniata, which covers about three-quarters of the area, on sandy soils. Cypress pine (Callitropsis intratropica) occurs in sandstone areas, but is gradually being destroyed by burning, moreso in soil covered areas than in rocky ones. Pandanus and paper barks fringe the water courses. Dense thickets of mangroves are found on tidal mud-flats, especially in the river estuaries.

Present Investigations

Maps and Photographs: At the time of the present survey the following air photographs and maps were available:-

(1) Vertical air photographs (approximate scale 1:50,000 flown by the Royal Australian Air Force in 1949.

(2) Air photograph mosaics (scale 1:63,360) produced by the Department of Lands and Surveys of Western Australia.

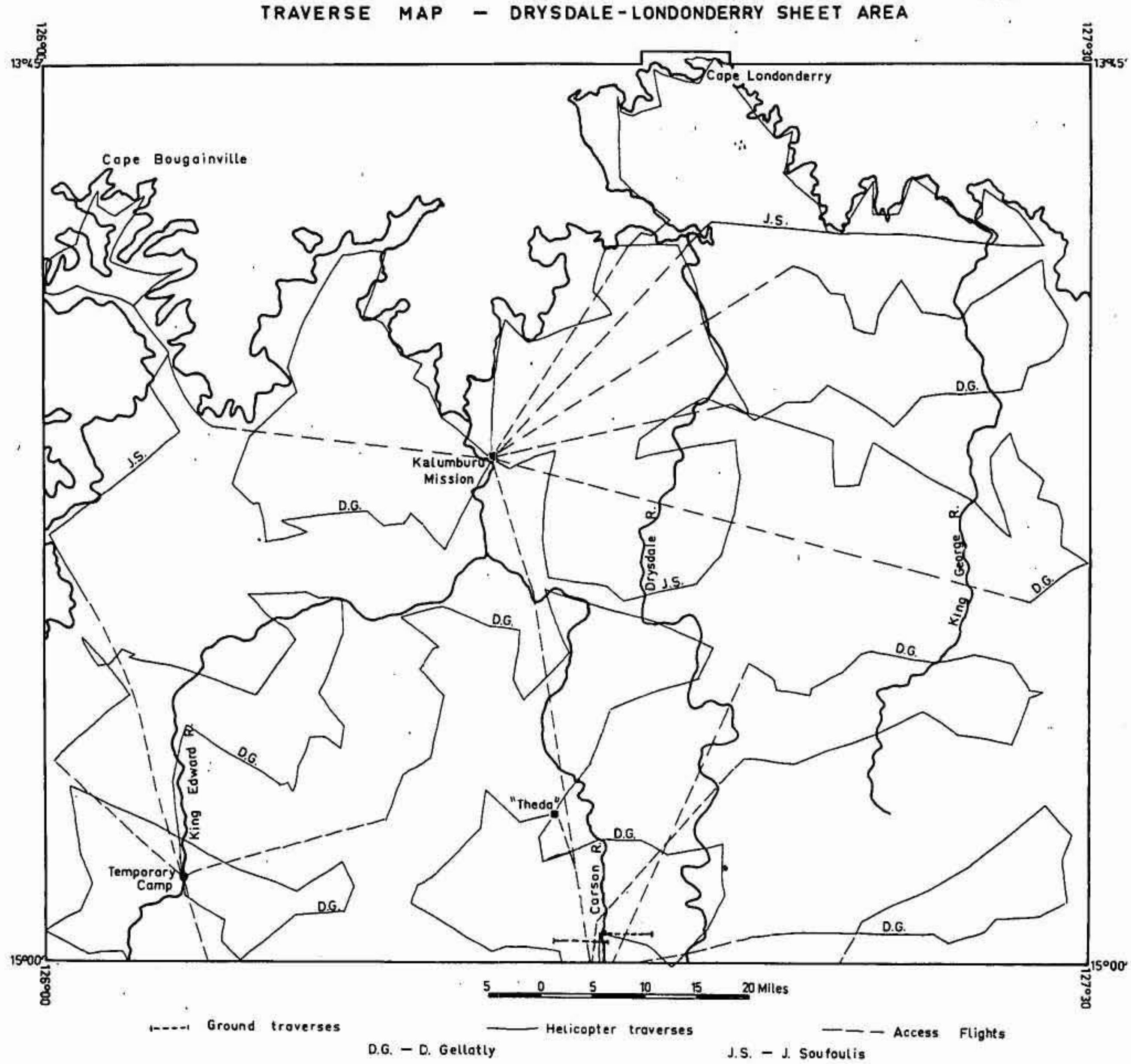
(3) Topographic maps (scale 1:250,000) prepared by the Royal Australian Survey Corps.

(4) Air photograph mosaics (scale 1:250,000) produced by the Commonwealth of Australia, Department of National Mapping.

(5) Topographic photo-compilation maps (scale 1:50,000) produced by the Lands and Survey Department of Western Australia.

FIG. 1

TRAVERSE MAP — DRYSDALE-LONDONDERRY SHEET AREA



To accompany Record No 1966/55

D52/A9/2

Methods: Mapping of the area was carried out in two stages, by preliminary photo-interpretation (Perry and Richard, 1965) and by field mapping using helicopters. In addition, two foot traverses were carried out in the southern part of the map Sheet area. Helicopter traverses were confined to 12 days flying with approximately 120 landings for ground observations. The traverse map (Figure I) indicates the parts of the area visited. In the course of field work, observations were plotted directly on to air photographs and these, and photo-interpreted information, were subsequently transferred to the 1:50,000 photo-compilation topographic base maps. These maps were then reduced to a scale of 1:250,000 and redrawn to produce the geological map accompanying this report.

Previous Work

The coastal parts of the Drysdale - Londonderry Sheet area were first visited by Tasman in 1644 (see chart in Sharp, 1963), and subsequently by King (in 1819-20) whose chart (Sharp, 1963) named several of the coastal features of the area. Geological specimens collected by King were described by Fitton (1825) who recorded that the coastal areas were almost entirely of sandstone, but also listed a specimen of "greenstone" (spilite or epidosite ?) from Vansittart Bay.

The first geological work in the interior of the area was carried out by Gibb Maitland and Gibson geologists attached to the Brockman expedition (Maitland, 1902; Brockman and Crossland, 1902). They collected specimens of basalt and dolerite subsequently described by Edwards (1943), who also produced a generalised geological map based on their observations. The area was visited by Easton (1922), a surveyor, in 1921. Jutson (1950)* described the geomorphology of the North Kimberley based on the observations of these earlier workers.

In 1954 the two tracks mentioned above, leading from Gibb River to Kalumburu were constructed by a survey party under Morgan (1955). Using these access tracks, Harms and Speck separately carried out geological work in the area. Traves (1955) produced a short report on the Geology of the King Edward-Drysdale area, based on photo-interpretation and this was used as a basis for the generalised geological map of the North Kimberley Area produced by Speck, et al. (1960). Harms (1959) revised the stratigraphic nomenclature of Traves (op. cit.) and produced a more detailed map of the Kimberley area which has been an extremely useful guide in the planning and preliminary photo-interpretation stages of the present survey.

PHYSIOGRAPHY

Three basic physiographic divisions are recognised in the Drysdale-Londonderry area. These are the Prince Regent Plateau, the Gibb Hills and the Karunjie Plateau Sub-Provinces of the Kimberley Plateau Province of Wright (1964) (= the North Kimberley Division of Jutson, 1950). These three divisions are part of a physiographic synthesis for the whole of the Kimberley Region which will be described in three Bulletins on the Precambrian Geology of the Kimberley Region (op. cit.). As elsewhere in the Kimberley there is a close correlation between physiography and bed-rock and the three physiographic divisions of the Drysdale-Londonderry Sheet area correspond to the areas of outcrop of (1) the King Leopold Sandstone, (2) the Carson Volcanics, and (3) the Warton Sandstone, Elgee Siltstone and Pentecost Sandstone.

The physiography of the Sheet area is essentially that of an irregular dissected plateau which dips gently seawards, and is drained by four major northward flowing rivers that have predominantly subsequent courses.

* First edition in 1934.

The maximum elevation of hills ranges from about 1300 feet in the inland areas to about 400 feet on the coast. The area has a drowned ria-type coast characterised by rocky promontories and high cliffs, with intervening shallow inlets and estuaries fringed by mangrove swamps.

Drainage

The principal rivers in the area are the King Edward River; the Carson River and its tributary the Morgan River, the Drysdale River; the King George River; and the Berkeley River. In the dry season the rivers are reduced to a string of isolated pools, although on the Drysdale and King Edward Rivers small permanent streams connect the more rocky pools. One pool on the Drysdale River is 12 miles long, and many pools on this, and on the other rivers, exceed 1 mile in length.

The rivers are mainly deeply incised into bedrock, but less deeply so than the rivers of the western part of the Plateau. Their courses are predominantly subsequent with obsequent reaches. Only the King George River and Morgan River have consequent parts. Subsequent parts of these rivers are controlled mainly by lithology, especially by soft beds and are bounded by escarpments of more resistant rock. Structural control of drainage is principally a response to faulting and jointing rather than to folding, and is more prominent as a controlling factor of the minor streams than of the major. Fault and/or joint control is prominent along parts of the King Edward and Drysdale Rivers. Apart from these examples there is a lack of correlation between geological structure and river development. For example the King Edward River in the south-western part of the Sheet area follows the trend of an anticlinal axis; the Morgan River cuts across a broad anticline of King Leopold Sandstone rather than following the easily eroded basal beds of the Carson Volcanics, and the Drysdale River, near the southern boundary of the Sheet area, meanders across the outcrop of the Penticost Sandstone rather than following the easily eroded Elgee Siltstone. This lack of structural control and the presence of broad meanders, e.g. on the Drysdale River, suggests that the major rivers are superimposed, and were developed before the present-day land-surface, possibly on an extensive laterite surface.

The pattern of the minor streams, on the other hand, is closely related to the lithology and structure of the bedrock and is described under each physiographic division.

Prince Regent Plateau

This physiographic division is underlain almost entirely by the King Leopold Sandstone which is mostly flat-lying and gives rise to typical rocky, butte topography. Deep valleys bounded by cliffs are found locally where dolerite sills are exposed. Elevations range from 1300 feet to sea level. Maximum relief is around 200 to 300 feet, and is most pronounced near the margins of the sub-province where 200 feet sandstone cliffs are common. Both major and minor streams are incised. The minor streams are largely controlled by faults and joints and have a rectilinear pattern, but small areas with dendritic drainage also occur.

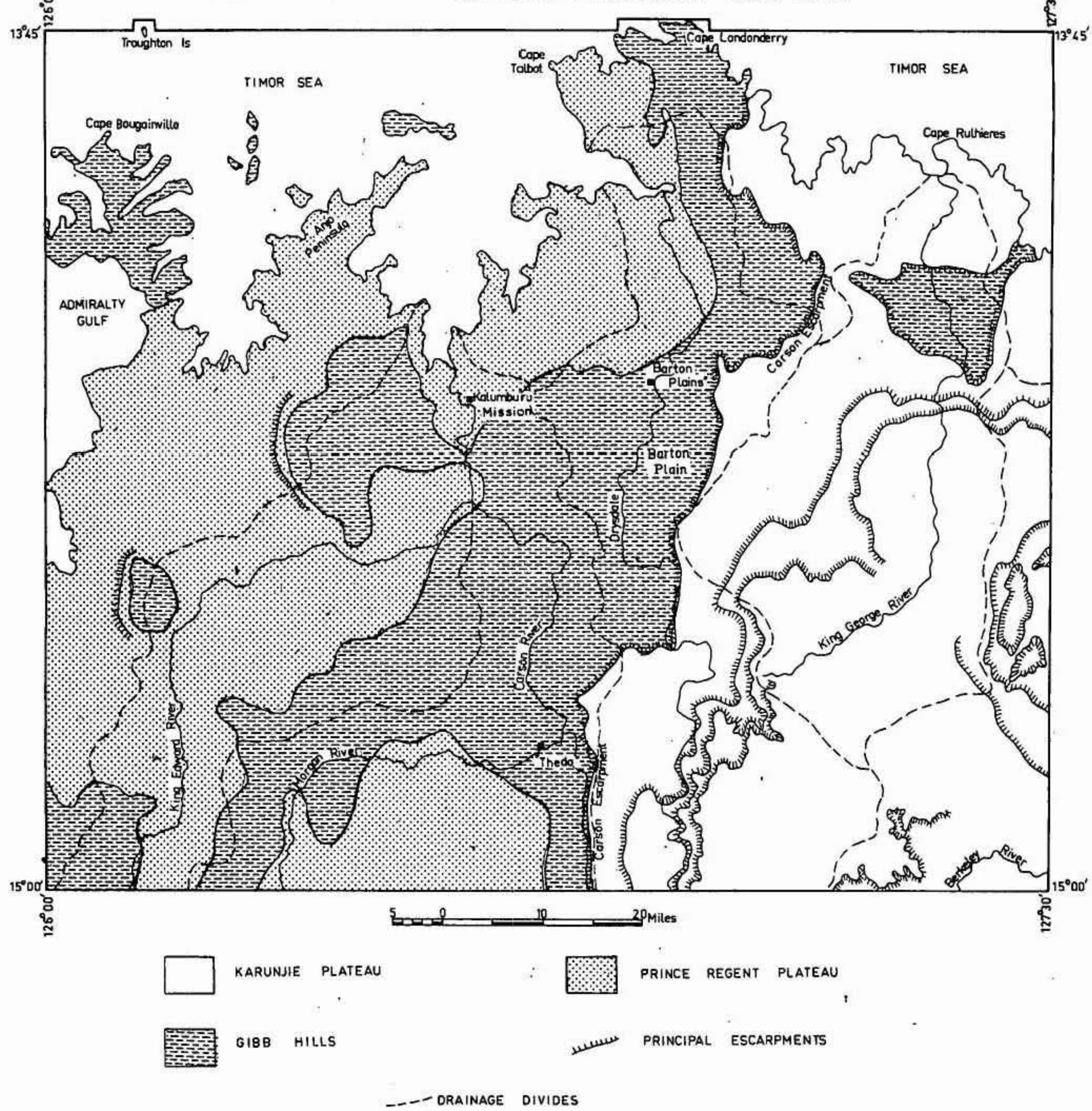
Gibb Hills

The distinctive appearance of the landforms of this physiographic division is a result of the basaltic bedrock. The hills are mainly smooth-sloped and rounded, and are commonly capped by small laterite mesas. Elevations range from 1300 feet to sea level, but even in the coastal areas the maximum elevation is commonly around 400 feet. Coastal cliffs are common especially in the Admiralty Gulf area. The maximum relief is about 400 feet., but locally, e.g. in the area south-south-east of Mount Leeming the relief is 700 to 800 feet. Part of this physiographic division is characterised by low rocky plain country e.g., Barton Plain.

Minor streams are deeply incised and most have a dendritic drainage pattern. The lineaments are preferentially eroded and exert a controlling influence on the drainage pattern in only a few localities.

FIG. 2

PHYSIOGRAPHIC MAP — DRYSDALE - LONDONDERRY SHEET AREA



To accompany Record No 1966/55

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Figure 3. The Carson Escarpment and Carson River near the southern boundary of the Sheet area. The top of the Carson Escarpment (Warton Sandstone) is about 400 feet above the river level (Carson Volcanics): further north its relief decreases to about 250 feet.

Figure 4. Mesa of laterite overlying Carson Volcanics of the Cape Bougainville peninsula; shows abrupt "break-away" at the edge of the mesa. (Photograph by G.M. Derrick)

Figure 5. Fault controlled course of the Drysdale River cutting the King Leopold Sandstone north of Barton Plain.

Figure 6. Coastal Lagoon, cut off from the sea by a sand bar. The sand bar is breached by an outlet channel which, together with a small part of the lagoon, is covered by a dense growth of mangroves.

Karunjie Plateau

The Karunjie Plateau is distinguished by numerous cuestas, mesas, and erosional escarpments. Bedrock is predominantly of beds of resistant sandstone, alternating with beds of easily-eroded sandstone and, in places, shale. Elevations range from 1300 feet to sea level. High cliffs of Warton Sandstone characterise the coastline and in these areas the maximum elevation is around 400 feet. The most prominent feature of this sub-province is the Carson Escarpment forming its western boundary. The Escarpment has a relief of up to 400 feet and runs from south to north across the area. Other excarpments have relief ranging from about 250 feet down to about 50 feet. In the southern part of this sub-province the escarpments are less prominent and the area is a true plateau.

The direction of minor streams is controlled partly by bedrock. In the northern part of this sub-province both dendritic and subsequent streams are common, whereas in the southern part they are partly subsequent and partly obsequent and form a rectinlinear pattern controlled by major lineaments and by the scarp-and dip-slope features.

Coastal Features

The Drysdale-Londonderry Sheet area has a drowned or ria coast, with large bays and inlets, long irregular promontories, and many islands. The coastline is rocky and cliffs are common, especially near Cape Bougainville and east of Cape Londonderry. Coastal plains are found only in the low lying area of the Anjo Peninsula.

Silting up of estuaries has given rise to flats of muddy sand. Parts of the mud flats are liable to occasional inundation and have a thin salt crust up to $\frac{1}{4}$ inch thick, whereas the seaward fringes, subjected to daily inundation, are thickly covered with mangroves.

The low-lying promontories and islands have numerous small intratidal lagoons. These consist of small bays which have been cut off from the sea by a sand-bar. (Fig. 6). In every example the sand bar has been breached, and the area immediately behind the breach is mangrove covered. The landward reaches of the lagoons are floored by silty sands with a thin salt crust.

The rocky areas of the Gibb Hills and Karunjie Plateau sub-provinces have spectacular cliffs and steep hill slopes leading directly to the sea. The rocky areas of the Prince Regent Plateau rarely have cliffs. Where they do, the cliffs are low and have numerous small geos (Holmes, 1945, p 287) due to preferential erosion of joints. The development of these geos may be regarded as the marine erosional equivalent of the sub-aerial butte topography. In areas of low relief the seaward margins of the Prince Regent Plateau are generally fringed by narrow sandy beaches, and sand spits are common on small promontories due to the influence of long shore drift.

Extensive coral reefs fringe many of the more northerly islands, and also the main peninsulas such as Cape Bougainville, Cape Talbot, and Cape Londonderry, with isolated reefs extending eastwards to Cape Rulhieres. These reefs are most extensive off the mainland coast between Cape Talbot and Cape Londonderry.

STRATIGRAPHY

A summary of the stratigraphy of the Sheet area is given in Table I. The nomenclature used is based essentially on that of Guppy et al (1958) and Harms (1959). The principal changes from that of Harms (op. cit.) is that the Elgee Shale has been renamed the Elgee Siltstone (Dow, et al 1964) and the Pentecost Sandstone is subdivided into lower, middle and upper members. The present nomenclature will be fully defined in Plumb (in prep.). The development of this nomenclature showing earlier superseded usage is given in Table 2.

Most of the rocks exposed in the Sheet area are of Precambrian age. The subdivision of the Proterozoic into Carpentarian, Adelaidean and Lower Proterozoic is based on preliminary radiometric dating carried out by the Bureau of Mineral Resources in conjunction with the Australian National University. This age determination work is still in progress and absolute ages cannot be given at present. The Carpentarian and Adelaidean systems, as used here have age ranges of 1800 to 1400 million years and 1400 to 600 million years respectively.

The Proterozoic rocks are mostly of Carpentarian age, except for the Hart Dolerite which is of Carpentarian or Adelaidean age. The laterites and other superficial deposits are of Tertiary and Quarternary age.

PROTEROZOIC

CARPENTARIAN

King Leopold Sandstone (Bkl)

The King Leopold Sandstone, the basal formation of the Kimberley Group, is the oldest formation exposed in the Sheet area. It is conformably 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 been restricted subsequently by Dow et al., (1964) to the sandstone overlying the Speewah Group and underlying the Carson Volcanics.

The King Leopold Sandstone crops out extensively in the western part of the Drysdale-Londonderry Sheet area. Except for some inextensive soil covered areas, mainly the Anjo Peninsula and the area to the north-east of Kalumburu, the King Leopold Sandstone is very well exposed. Being mostly flat lying, it forms rocky, dissected butte and mesa topography. Cuestas are developed locally where dips attain 5^{o} or more especially in the area to the south-west of Theda Homestead. Beds in the upper part of the formation commonly form cliffs up to 200 feet high. Joint and fault lineaments are preferentially eroded to form deep narrow valleys. Broad cliff-fringed valleys are prominent where intrusions of Hart Dolerite are exposed within the King Leopold Sandstone sequence.

Thickness estimates for the exposed part of the King Leopold Sandstone in this area range from 2,500 to 3,500 feet. Because of the relatively low angles of dip these values may be inaccurate, but nevertheless they provide an estimate of the order of thickness. The thickness estimates refer to only part of the full succession since the base of the formation is not exposed. It is thought that the thickness determined may represent only about half of the full succession. This suggestion is based on the following argument. In the Lansdowne Sheet area some 150 miles to the south, the King Leopold Sandstone is commonly intruded by the Hart Dolerite, for the most part at or near a stratigraphic horizon about half way up the sequence. Similarly the majority

TABLE 1

STRATIGRAPHIC TABLE - DRYSDALE - LONDONDERRY SHEET AREA

Era	Age	Rock Unit and Symbol	Thickness (in feet)	Lithology	Topography	Distribution	Remarks
CAINOZOIC	Quaternary	(Qa)		Alluvium: river sands and gravels.	Riverside flood-plains and low terraces.	Scattered areas along all major river-courses.	Sands predominate.
		(Qc)		Silty sand and mud, locally with thin salt crust.	Coastal flats and lagoons.	Estuaries: scattered lagoons around Vansittart and Napier Broome Bays.	Mostly mangrove covered in lower parts subject to daily tidal inundation.
		(Ql)		Coastal limestone: fragmental shelly limestone.	Small, low shoreline outcrops.	Small pockets along rocky stretches of present day shoreline.	Only one occurrence noted, but probably more extensive. Also found in Montague Sound Sheet area to west.
		(Qs)		Beach sands: quartzose, locally pebbly and shell-bearing.	Beaches and low scrub-covered sand bars.	Scattered areas all along coastline, mainly around Vansittart and Napier Broome Bays.	
	Undifferentiated	(Czs)		Undifferentiated sandy soils, coast eluvium.	Regional high plains, dissected marginally.	Mainly watershed areas on King Leopold Sandstone, and dip-slope of Warton Sandstone.	Podzols rare; occur only on Elgee Siltstone.
		(Czs/Pkc)		Grey and red fine textured basalt-derived soils.	Pediments and small plains.	Found overlying only Carson Volcanics.	Generally mixed with sand in areas close to Warton Sandstone escarpment. Small areas of similar grey soil locally overlie Hart Dolerite
		(Czb)		Black and grey heavy textured cracking soils.	Small plains and depressions: have gilgai micro-relief.	Principally in central part of map sheet area.	Found overlying only Carson Volcanics.
		(Czl)		Ferruginous pisolitic sandy lateritic soils.	Residual high plain; pediplains close to laterite mesas.	Mainly on south-eastern part of map Sheet area overlying Pentecost Sandstone. Also scattered areas on King Leopold Sandstone.	Have dark photo-pattern, but lack the typical mesa-forms of the laterites.
	Tertiary	(Tp)	450 feet	Ferruginous laterite, pisolitic, and locally rubbly.	Mesas; elevations from 300 - 1300.	Principally on Carson Volcanics; also locally on King Leopold Sandstone; on Warton Sandstone in coastal areas.	
		(Tb)	50 feet	Bauxite and bauxitic laterite; pisolitic and oolitic, locally pebbly.	Mesas; elevations mainly 500 to 1200 feet.	Almost entirely overlying Carson Volcanics mainly in south-western part of map Sheet area.	Variable in composition; grades into ferruginous laterite
				UNCONFORMITY			
	Adelaidean or Carpentarian	Hart Dolerite (Bdh)		Dark grey to black, medium- to coarse-grained dolerite.	Mostly forms low lying valleys flanked by cliffs of King Leopold Sandstone.	Confined to western part of Sheet area.	Found mainly near the base of the exposed King Leopold Sandstone sequence. One sill intrudes Carson Volcanics.

Era	Age		Rock Unit & Symbols	Thickness in feet	Lithology	Topography	Distribution	Remarks
PROTEROZOIC	Carpentarian	KIMBERLEY GROUP	Pentecost Sandstone upper (Bkpu)	50 - 100	White to pale rust-brown coarse-grained quartz sandstone.	Poorly defined mesas capping terraced hills.	Only in south-easter corner of Sheet area.	Mapped by photo-interpretation only. A prominent low escarpment occurs about 100 feet below the base of this member: only basal beds present
			Pentecost Sandstone middle (Bkpm)	1100	White to pale brown fine- to coarse-grained well sorted quartz sandstone; minor feldspathic sandstone; grey glauconitic sandstone at base.	Terraces, flat rocky plains, and gently dipping cuestas.	Eastern and south-eastern parts of Sheet areas.	Basal glauconitic sandstone occurs at foot of low escarpment.
			Pentecost Sandstone lower (Bkpl)	1300	Pale red-brown to white, fine- to medium-grained quartz sandstone; clay pellets prominent.	Terraces, mesas, gently-dipping cuestas.	Eastern and south-eastern parts of Sheet area.	Crops out mainly in two dip-slopes with an intervening 200 feet escarpment. Cross-beds indicate a current source direction from north.
			Elgee Siltstone (Bke)	440 to 235	Red-brown to chocolate-brown siltstone; thin interbeds of buff to pale brown fine-grained quartz sandstone and feldspathic sandstone.	Prominent scarp slopes.	Forms a narrow strip around eastern and south-eastern part of Sheet area; also in Collison Range.	Thins out towards west and becomes more arenaceous. Poorly exposed.
			Warton Sandstone (Bkw)	1100 to 1700	Creamy, white and pale purple-grey. Coarse- to medium-grained, well-sorted quartz sandstone minor feldspathic sandstone.	Forms a prominent escarpment and dip-slope.	Eastern part of Sheet area.	Strongly cross-bedded, cross-beds indicate a westerly to north-westerly current source direction.
			Carson Volcanics (Bkc)	1130 to 1950	Dark grey, and purple-grey, black, locally amygdaloidal basalt; grey-green amygdaloidal spilite at base; interbeds of feldspathic sandstone in lower part, stromatolitic chert and siltstone at top.	Prominent rounded hills, commonly capped by laterite; low undulating rocky plains.	Scattered throughout the Sheet area except the south-eastern corner, most abundant in central part of Sheet area.	Small specks of chalcopyrite characteristic of basal flows.
			King Leopold Sandstone (Bkl)	ca 2400 to 3400 (base not exposed)	White, buff, pale rust-brown and purple corase-grained, poorly-sorted quartz sandstone.	Deeply dissected rocky uplands, butte and mesa topography, topmost beds locally cliff-forming.	Western part of Sheet area.	Base of formation not exposed, strongly cross-bedded with dominant northerly current course direction.

TABLE 2 NOMENCLATURE OF THE KIMBERLEY BASIN SUCCESSION

Gellatly and Sofoulis			Dow, et al. (1964)		Harms (1959, 1965)	Speck, et al. (1960)	Guppy et al. (1958)	Edgell (1963)
Pentecost Sandstone	upper middle lower		Pentecost Sandstone		Pentecost Sandstone			
Elgee Siltstone			Elgee Siltstone		Elgee Shale	Mount House Beds	Warton Beds	
Warton Sandstone		KIMBERLEY GROUP	Warton Sandstone	KIMBERLEY GROUP	Warton Sandstone	Warton Beds		KING LEOPOLD GROUP
Carson Volcanics			Carson Volcanics		Mornington Volcanics	Mornington Volcanics	Mornington Volcanics	
King Leopold Sandstone			King Leopold Sandstone		King Leopold Sandstone	King Leopold Sandstone	King Leopold Sandstone	
Lower beds not represented			Speewah Group*					

* The Speewah Group nomenclature of Dow et al. (1964) has been modified by Gellatly, et al. (1965).

Where the nomenclature of other writers differs from that in this report it is either erroneous, or else has been superseded.

of occurrences of Hart Dolerite in the Drysdale-Londonderry Sheet area occur apparently at or near the one stratigraphic level, and it is suggested that this readily-intruded horizon may be the same one as that noted about half way up the sequence in the Lansdowne Sheet area.

The King Leopold Sandstone shows marked lithological uniformity throughout most of the sequence. It consists mainly of white, buff and pale rust-brown, coarse-grained, blocky to massive, thick-bedded quartz sandstone. The only exception to the general light colour of the sandstones is a purple-brown sandstone near the top of the succession. The colour of the rocks on the weathered surface is mainly buff to pale red-brown. Grain-size is not uniform; fine to medium-grained sandstones are found in places commonly low in the sequence, but are subordinate to the coarse-grained. Granule sandstones with an average grain-size of 3 to 4 mm were observed in one locality on Anjo peninsula. Sorting of the sandstones is good, although scattered quartz pebbles up to 1 cm in diameter are not uncommon and give the sandstones a poorly sorted appearance in hand specimen (see Appendix 4). The sand grains are mostly well-rounded except in the purple sandstones near the top of the succession which have angular grains. Granules in the coarser sediments range from rounded to sub-angular.

Conglomerates are rare, and are localised in their extent. A small lens of conglomerate noted near Monger Creek containing sandstone cobbles and clay pellet impressions up to 4 inches across was confined to 1 foot of vertical section.

Most of the rocks are pure quartz sandstones but some specimens contain minor amounts of white or pale cream opaque feldspar grains. Locally, e.g. immediately east of Wade Creek, feldspar may make up as much as 5% of the rock. Most of the sandstones, except the purple ones, are clean-washed rocks free from silt. They range from hard silica-cemented types to friable ones with little or no cementing material.

A generalised section compiled from a series of observation points in the Wade Creek area is given below:-

Estimated section of King Leopold Sandstone: Locality - near Wade Creek

(4327E, 31727N to 4445E, 31740N.)

Carson Volcanics (partly lateritised)

King Leopold Sandstone

15	Sandstone;*	dark purple-brown, fine- to medium-grained, thin- to thick-bedded, blocky to flaggy, silty quartz sandstone.
100	Sandstone;	white to very pale pink-brown, coarse-grained, well-sorted, thick-bedded, blocky to massive feldspar-bearing quartz sandstone; forms a prominent scarp, and a dip-slope with light toned photo-pattern; contains scattered 1 cm. pebbles.
1500	Sandstone;	buff to pale grey-brown coarse-grained, well-sorted, thick- to very thick-bedded, blocky to massive quartz sandstone; has rare grains of weathered feldspar; friable to hard and silica-cemented; cross-bedded.
175	Sandstone;	pale pink-brown to pale purple-pink, coarse-grained moderately well-sorted, thick-bedded, blocky quartz sandstone.
	Discontinuous dolerite sill	
600	Sandstone;	buff to pale pink, brown fine-grained, thin-bedded, flaggy, quartz sandstone; cross-bedded; wave ripple marks.
ca2390		

Lower beds not exposed

* In this and all other measured sections listed the lithologies underlined are the dominant ones.

Figure 7. Geo: a joint in the King Leopold Sandstone deeply eroded as a result of wave-action. West side of Anjo Peninsula. The joint is 3 feet wide.

Figure 8. Stromatolitic chert immediately overlying topmost lava-flows of the Carson Volcanics. Carson Escarpment, latitude 14°58'S.

Cross-bedding is ubiquitous. The cross-beds are mostly of the planar type (McKee & Weir, 1965), i.e. lower boundary surface of the set is a planar erosional surface, and are tabular. Trough cross-bedding with curved foreset laminae is also common. The thickness of the foreset units ranges from about 6 inches up to 3 feet with most foresets around 1 foot thick. The cross-bedding is repetitive rather than confined to individual beds. The original dips of the foreset laminae are steep; dip values of up to 27° have been recorded. Individual foreset laminae range from less than one inch in thickness to about 3 inches, and locally show graded bedding. Overturned or slumped cross-beds forming U-shaped recumbent folds occur locally in beds about 1 foot thick in an otherwise completely undeformed sequence.

Studies of the cross-bedding indicate a northerly current source direction. This aspect is discussed in Appendix 4, on Provenance of the Kimberley Basin Sediments.

Ripple marks are rare and have been noted from only one locality, near Wade Creek. Here fine- to medium-grained, thin-bedded sandstones have prominent symmetrical wave ripple marks with a wavelength of 1½ inches. The trend of these is north-south and indicates an east-west direction of wave propagation.

Carson Volcanics (Bkc)

Introduction: The Carson Volcanics overlie the King Leopold Sandstone conformably and are conformably overlain by the Warton Sandstone.

They were originally named the Mornington Volcanics by Guppy et al (1958), but this name was deemed to be invalid because of prior usage elsewhere, and they were renamed the Carson Volcanics by Dow et al (1964) from the Carson River which flows through extensive areas of the Volcanics.

The main outcrop of the Carson Volcanics forms an irregularly-shaped north-north-east trending belt. Numerous outliers occur to the west of this belt and one major inlier to the east of it.

The Volcanics crop out as rounded hills with deeply incised valleys, and to a lesser extent as low undulating rocky plains. Small mesas of laterite commonly cap the higher hills.

Thickness estimates for the Carson Volcanics range from about 1100 to 1900 feet. The greatest thickness is in the southern part of the Sheet area. The succession thins northwards to 1100 feet near the Barton River and apparently thickens again northwards to about 1600 feet 15 miles south of Cape Londonderry. These thicknesses are only approximate because of the low values of prevailing dips and the general absence of measurable dip surfaces within the Volcanics.

The Carson Volcanics consist predominantly of fine- to medium-grained, dark grey to purple-grey basalt, and of grey-green, fine- to coarse-grained spilite. Most of the basalts and spilites are amygdaloidal with small amygdules of chlorite and larger ones composed mainly of quartz and epidote. Small amygdules of chalcopyrite are also present, mainly in the spilites. Agglomerates are found locally, especially in the area immediately west of Kalumburu.

Sediments in the Volcanic sequence are less abundant than they are further south, e.g. in the Lansdowne area. A thin sandstone interbed is found throughout the area about 250 feet above the base. Two such beds are present in the south-western corner of the Sheet area. Thin discontinuous beds of epidosite found at various levels in the volcanics probably represent altered sandstones. The topmost part of the Carson Volcanics consists of a 75 feet thick shale and siltstone sequence overlying a thin bed of stromatolitic chert.

Volcanic Rocks. The basalts are fresh, and massive in outcrop. They make up about 75% of the total succession, and are particularly abundant as thick non-amygdaloidal flows in the middle and upper parts of the sequence (see section 1).

Carson Volcanics - Section 1

Localities:-

(a) Carson River, 2 miles north of map Sheet boundary - 4915E, 31023N.

(b) " " 24 miles north of map Sheet boundary - 4930E, 31348N.

(Distances paced; Abney level recordings)

Warton Sandstone

Feet		Carson Volcanics
13	(b)	Purple-brown, fissile, laminated, micaceous siltstone.
2	(b)	Grey-green, fine-grained, flaggy, micaceous, silty sandstone.
50	(b)	Crumbly, purple-brown and purple-grey shale and siltstone.
6	(b)	Dark grey, siliceous mudstone and siltstone; laminated, flaggy, micaceous in part.
3	(b)	Stromatolitic chert.
50	(b)	Coarse-grained, grey-brown amygdaloidal basalt; has 2-5mm. amygdules of chlorite and rare pale blue quartz.
509	(a)	Dark grey, coarse-grained basalt; mainly soil covered with scattered basalt pavements.
122	(a)	Dark grey, coarse-grained basalt with 6 in. to 8 in. beds of grey-brown chert.
525	(a)	Dark grey, medium-grained, massive, non-amygdaloidal basalt: topmost 96 feet mainly soil covered.
81	(a)	Pale grey-brown, finely-laminated, flaggy chert; locally green and epidotised: overlain by coarse-grained quartz epidosite.
10	(a)	Pale grey very fine-grained micro-amygdaloidal basalt.
171	(a)	Mottled grey-green and purple-grey massive coarse-grained highly amygdaloidal basalt.
135	(a)	Very fine-grained, grey-green, highly amygdaloidal spilite; amygdules, 1-2mm. in size, consist of chlorite: rare specks of chalcopyrite present.
40	(a)	Spotty epidosite.
17	(a)	Grey-green, very fine-grained micro-amygdaloidal spilite; has abundant chlorite amygdules to 1mm. and rare elongate quartz-calcite amygdules up to 5 cm.
18	(a)	Epidotised amygdaloidal basalt.
33	(a)	Grey, rotten, highly amygdaloidal spilite; has abundant chlorite amygdules 2 to 3 mm, and rare quartz amygdules up to 1 cm.

3	(a)	Green, massive, blocky-weathering, amygdaloidal epidosite; has quartz amygdules up to 2 cm.
21	(a)	Grey-green, very fine-grained, massive, slightly amygdaloidal spilite: 1 mm. chlorite amygdules and 5 cm quartz amygdules.
127	(a)	Dark grey, fine-grained, massive basalt; has localised planar flow surfaces.
38	(a)	No exposure.
20	(a)	No exposure: detritals of epidosite and quartz-epidote breccia.
37	(a)	Dark grey-green, fine-grained, massive, slightly amygdaloidal spilite; has 1-2 mm chlorite amygdules and rare specks of pyrite and chalcopyrite.
25	(a)	No exposure: black soil.

Total 1956

King Leópold Sandstone

Carson Volcanics - Section 2

Partial section measured by Abney Level; headwater area of Noolawayoo Creek 4415E 31312N.

Hart Dolerite

Carson Volcanics

18	Sandstone; white to pale buff and pale pink, coarse-grained, thick-bedded, blocky, well-sorted, feldspar-bearing quartz sandstone.
30	Basalt; purple-grey and highly amygdaloidal, with 5 mm amygdules of calcite and 1 to 2 mm amygdules of chlorite: contains 1 inch xenoliths of fine-grained red-brown sandstone.
50	Spilite; massive, dark grey-green, fine-grained and highly amygdaloidal with 1 to 5 mm amygdules of quartz, epidote, and calcite, with traces of chalcopyrite, and galena: contains rounded blocks of epidosite up to 10 inches surrounded by a 2 inch reaction border of limonitic altered basalt.
80	Spilite; massive coarse-grained, grey-green and micro-amygdaloidal with 1 to 2 mm amygdules of chlorite and specks of chalcopyrite.
2	Spilite; grey-green, highly amygdaloidal, with 1 cm. amygdules of quartz epidote, calcite, chlorite, feldspar, and rare chalcopyrite: top of flow.
25	Massive grey-green medium-grained partly epidotised amygdaloidal spilite with 1-2 mm chlorite amygdules and large (up to 20 cm) amygdules of pink potash feldspar, epidote, quartz, and calcite.
30	Massive, hard, green-grey spilite; micro-amygdaloidal with amygdules of chlorite (1-3 mm) and rarely of calcite (1 cm).
80	No exposure

TOTAL 305

King Leopold Sandstone

Carson Volcanics - Section 3

Generalised section ca 5 miles north-east of mouth of Drysdale River. 5114E 32263N to 5187E 32265N.

(Estimated from air photographs).

Warton Sandstone

Carson Volcanics

ca 1300	Basalt.
30	Sandstone; pale pink-maroon, thin-bedded, blocky, cross-bedded feldspathic sandstone.
250	Basalt; medium-grained, blocky to massive with traces of pyrite. Basalt; medium to coarse-grained amygdaloidal basalt with amygdules of quartz, epidote, feldspar, and chalcopyrite up to 6 mm across.
ca 1580	

King Leopold Sandstone

Spilites apparently predominate in the lowest part of the sequence, i.e. below the sandstone interbed, whereas basalts predominate above it. The spilites are characterised by their grey-green colour which is their only distinctive macroscopic feature. Despite a careful search, no definite pillow lavas have been found in the spilites, and it is not certain that they have been extruded under water. However, the close association between the epidosites (probably altered sediments) and the spilites suggests that the latter may have been extruded into shallow water. The following partial section measured in the middle part of the Carson Volcanic sequence 1 mile east of the Carson River about latitude 14°34'S illustrates this association.

20 ft.+	Basalt (full thickness not determined)
2 ft.	Epidosite
90 ft.	Basalt
140 ft.	Spilite; scattered epidosite debris
3 ft.	Epidosite
100 ft.	Spilite
2 ft.	Epidosite
20 ft.+	Spilite (full thickness not determined)

Epidosite occurs mainly as poorly exposed lenticular beds. Most commonly they are found only as detrital blocks strewn over extensive basalt pavements and locally as isolated blocks in basaltic agglomerate. The epidosite rock consists of olive-green elongate epidote crystals with irregular patches of white and pale purple-brown quartz. Locally spherical patches of quartz and of dark green epidote (more coarsely crystalline than the paler matrix) simulate amygdules.

Agglomerates are confined to a few scattered angular blocks of sandstone or epidosite in basalt or spilite. Cognate inclusions are unknown and no indications of close proximity to an eruptive centre have been found. Xenoliths about 1 inch long of unaltered red-brown, finer-grained, quartz sandstone occur in purple-grey basalt immediately underlying the sandstone interbed (section 2 locality); and large angular blocks of epidosite in basalts occur a few miles south of Mount Leeming. These epidosite xenoliths are surrounded by zones of epidotised basalt. In order to account for these reaction borders around epidotised xenoliths, and their absence round sandstone xenoliths, it is suggested that the epidosites represent incorporated blocks of unconsolidated sediment, and the sandstone xenoliths represent inclusions of older consolidated material.

Locally the amygdules decrease in abundance upwards in the sequence, but in only one case was it possible to delineate the boundary between two flows. The descriptions of the amygdules apply to both basalts and spilites, but the basalts are less commonly amygdaloidal than the spilites.

The amygdules range in size from 1mm or less, up to about 20 cm. Two distinct size ranges are present, less than 2mm and 0.5 to 20 cm. Those in the smaller size range consist exclusively of chlorite, or of chlorite with a quartz core, and are spherical. The larger ones, which are of irregular shape and include pipe amygdules, consist of quartz, epidote, calcite, pink feldspar and chlorite with traces of chalcopyrite and galena. These large amygdules have a zonal arrangement of their constituent minerals. From the margins to the core of the amygdules the sequence is feldspar, epidote, quartz, calcite. The quartz commonly forms euhedral prisms, some with well-formed pyramid terminations. Finely banded white quartz agates up to 5 cm across were found in one locality near the top of the sequence, about 12 miles north-north-east of the confluence of the Drysdale and Barton Rivers.

Sediments. The sandstone interbeds range in thickness from 10 feet up to about 30 feet. They consist of white buff and pale orange brown coarse-grained, well-sorted, thin-bedded, flaggy to blocky feldspathic sandstone, and feldspar-bearing quartz sandstone. Feldspar is not abundant in these sandstones and rarely exceeds 10% of the rock.

Chert is present locally low in the Volcanics (see section 1) and also near the top of the sequence where it is stromatolitic. The stromatolitic chert is found in a single bed 2 to 3 feet thick, that overlies the topmost volcanics and underlies the shale and siltstone sequence at the top of the formation. The upper part of this bed has well developed stromatolites which have been noted from two localities. The chert is finely laminated with $\frac{1}{4}$ to $\frac{1}{2}$ inch diameter cylindrical stromatolites each consisting of a pile of chert laminae 1 to 2 mm thick and convex upwards. This is in contrast to the calcareous stromatolites found further south (Gellatly et al 1965, Roberts et al 1965) in the Elgee Siltstone which are concave upwards. Siliceous stromatolites of a similar age have also been reported from the McDermott Formation in the Calvert Hills area, Northern Territory. (Roberts et al, 1963).

The uppermost beds, overlying the chert, consist of purple-grey and grey-green, fissile, laminated, micaceous shale and siltstone, and minor dark grey, laminated, siliceous mudstone. Interbeds of pale purple-grey, medium-grained blocky feldspathic sandstone are found locally. This sequence, some 75 feet thick in the southern part of the Sheet area, thins out northwards and is absent in the north-east, immediately south of Cape Bernier.

Warton Sandstone (Bkw)

The Warton Sandstone lies conformably on the Carson Volcanics and is overlain conformably by the Elgee Siltstone.

Guppy et al (1958) used the term "Warton Beds" to describe rocks lying conformably on the Carson Volcanics and unconformably overlain by the Walsh Tillite along the southern margin of the Kimberley Plateau. The name "Warton Sandstone" was first used by Harms (1959) for the basal unit of Guppy's Warton Beds from which Harms separated the Elgee Siltstone and the Pentecost Sandstone. The name is derived from the Warton Range (17°34'S 126°27'E) in the Lansdowne Sheet area.

The Warton Sandstone crops out as a north-north-east trending belt in the eastern part of the Sheet area, and also as a small inlier in the Collison Range in the extreme east. It forms a prominent 200 to 400 ft. escarpment (the Carson Escarpment) and a gentle dipslope. The more deeply dissected parts near the edge of the escarpment immediately east of Barton Plain, show a strong development of butte topography. Away from the escarpment exposures are poor due to a thin veneer of sandy soil which obscures much of the upper parts of the succession.

The thickness of the Warton Sandstone within the Sheet area ranges from 1125 feet to 1720 feet. The thickest succession is found in the north-eastern part of the area and the thinnest 40 miles to the south-west. The variations noted do not show a consistent trend and this may be partly due to difficulties of obtaining accurate thickness estimates in beds which, for the most part have dips of less than 5°. There is, however, a general regional increase in thickness westwards since the Warton Sandstone in the Cambridge Gulf Sheet area (to the east) is only 700 feet thick,[1] and in the Prince Regent - Camden Sound Sheet area (to the west) it is approximately 2800 feet.[2]

The Warton Sandstone consists mainly of white, pale buff, pale pink, and pale purple-grey, thick-bedded, blocky to massive quartz sandstone. The topmost 300 feet tends to be medium-grained rather than coarse-grained but no other significant variations are found. The basal 70 feet of the sequence consists of feldspar-bearing, slightly micaceous sandstone, generally slightly darker than others in the formation. Sorting is good throughout the sequence, although some of the coarser-grained sandstones have scattered quartz pebbles 1 to 2 cm in size. Clay pellets have been noted in the topmost beds. A thin purple-grey siltstone bed, occurs about 300 feet above the base of the succession, a few miles south of Cape Bernier. This siltstone is poorly exposed in a scree slope below the laterite profile and its thickness is unknown.

The sandstones are universally cross-bedded with the thickness of foreset units ranging from 2 to 5 feet in the lower beds and 4 inches to 12 inches in the uppermost ones. The cross-bedded units are mostly of the planar type and are tabular, or more rarely wedge-shaped. Overturned cross-beds have been noted in two places, in one of them associated with current scour striations. The source direction of the sediment-bearing currents was in the north-west. A small escarpment occurring about half way up the succession marks an abrupt change in source direction from south-south-west to the more dominant north-west.

1 Dow et al (1964)

2 Williams and Sofoulis (in prep.)

Warton Sandstone - Section W1

Measured Section east of Carson River, 3 miles north of map Sheet boundary. 4980E, 31063N. (Distances paced).

Elgee Siltstone (soil covered)(1)

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5 ft.(2)	Pure white, medium- to coarse-grained, silica-cemented feldspathic sandstone.
280	No exposure. Pale brown sandy soil.
2	Pale pink medium-grained, well-sorted, thick-bedded blocky quartz sandstone.
140	Pale cream to very pale purple-grey, coarse-grained thick-bedded, blocky, cross-bedded quartz sandstone; sorting good; grain size up to about 2 mm; scattered 1-2 cm quartz pebbles present.
314	White coarse-grained thin to thick-bedded, cross-bedded blocky silica-cemented quartz sandstone; forms a prominent low ridge at base.
425	No exposures. Grey-brown sandy soil with ferricrete pebbles.
30	Pale cream to pale purple-grey poorly-sorted, thick to thin-bedded, blocky to flaggy silica-cemented quartz sandstone.
150	Cream and pale purple-grey, medium to coarse-grained, thin-to thick-bedded, flaggy to massive, friable quartz sandstone; cross-bedded; some slumped cross-beds present; bedding thickens to 5 ft. near top of cliffs.
96	No exposures.
10(3)	Pale purple-grey to white, medium-grained, slightly micaceous, well-sorted, feldspar-bearing quartz sandstone.
Total 1450	

Carson Volcanics

(1) Warton Sandstone/Elgee Siltstone boundary is completely soil covered. The Elgee Siltstone/Pentecost Sandstone is taken as half way up the escarpment, and the position of the Warton Sandstone Elgee Siltstone boundary deduced by subtracting the interpolated thickness of the Elgee Siltstone (250 ft) from the combined thickness of this and the Warton Sandstone.

(2) Lithology observed at Wallis Peak - 5056E, 31195N.

(3) 4930E, 31355N.

Elgee Siltstone

The Elgee Siltstone overlies the Warton Sandstone conformably and is overlain conformably by 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 in the Lansdowne and Lissadell Sheet areas.

The Siltstone crops out in the eastern part of the Sheet area as a narrow arcuate belt concave to the south-east, and in a small north-trending inlier near the eastern margin of the Sheet area.

It is exposed in a prominent escarpment and also underlies flat, soil-covered areas at the foot of this escarpment. The lower part of the succession is rarely exposed but sporadic exposures of the upper part are found in small erosion gullies on the escarpment face.

The thickness of the Elgee Siltstone varies within the Sheet area from 440 feet in the Collison Range inlier to the east, to 230 feet in the south near the Drysdale River, and 340 feet in the north-east (Seppelt Range). These figures indicate a progressive thinning towards the north-west and are a continuation of the thickness trends found over the whole of the Kimberley Basin, e.g. the Elgee Siltstone is 610 feet thick in the Lissadell/Cambridge Gulf area to the south-east,[1] 700 feet thick in the Mount Elizabeth Sheet area to the south (Roberts, in prep.), and 1150 feet further south in the Mount Ramsay Sheet area (Roberts et al., 1965).

The Elgee Siltstone consists of red-brown shale, siltstone, and mudstone, and interbeds of sandstone. The lutites are mainly thin-bedded to laminated, blocky, and locally micaceous and fissile. Red-brown clay pellets noted in the siltstone, are difficult to distinguish from the matrix which is of similar colour and composition. Buff to pale grey-green, 1 to 2 inch spherical patches and 3 to 4 inch-thick irregular interbeds of siltstone with reduced iron oxide pigment, occur sporadically within the red-brown siltstone.

Elgee Siltstone - Section E1

Locality:- Wallis Peak 5056E, 31195N)

45 ft	Pentecost Sandstone
	Elgee Siltstone
60 ft.	Red-brown to pale purple-brown, thin-bedded, flaggy fine-grained quartz sandstone and feldspathic sandstone; thin partings of siltstone.
4	Buff to pale red-brown, fine-grained, feldspathic sandstone.
7	Red-brown siltstone, and fine-grained, flaggy, feldspathic sandstone.
5	Pale pink, fine- to medium-grained, laminated, blocky feldspathic sandstone.
10	Pale buff, micaceous, thick-bedded, blocky, fine-grained, slightly feldspathic quartz sandstone. Exhibits spotty weathered surface.
25	Red-brown, fine-grained, thin-bedded, flaggy, well-sorted feldspathic sandstone.
30	Dark red-brown, fractured siltstone and mudstone; thin-bedded and blocky.
3	White, pale buff, and purple-brown, fine-grained, blocky quartz sandstone; thin- to thick-bedded.

1 Dow et al (1964)

	3	Red-brown siltstone (as above).
	2	Pale red-brown, fine-grained, quartz sandstone.
	3	Red-brown siltstone (as above).
	7	Pale purple-grey to very pale orange-brown, fine-grained feldspathic sandstone thin- to thick-bedded, blocky to flaggy.
	21	Red-brown (terra cotta brown) laminated fissile micaceous shale and siltstone; contains clay pellets; has thin cream coloured laminae; thin partings of silty fine-grained chocolate-brown feldspathic sandstone near top.
	3½	White to pale cream, fine-grained, thin- to thick-bedded blocky to flaggy feldspathic sandstone.
	3	Purple-brown siltstone; poorly exposed.
	3	White to pale cream, fine-grained, thin- to thick-bedded, blocky to flaggy feldspathic sandstone.
	5	Pale purple-brown, laminated, fissile quartz sandstone.
	2	Pale buff fine-grained, thin-bedded, flaggy, well-sorted feldspathic sandstone.
	5	Purple-grey to purple-brown laminated fissile siltstone; has nodules of pale grey-green siltstone.
	25	Pale purple-grey to pale pink-brown, laminated to thick-bedded, fine-grained quartz sandstone and feldspathic sandstone; locally contains small chocolate brown clay pellets; thick beds are cross-bedded with 6 to 12 inch-thick foreset units; hard well-cemented beds alternate with friable beds; incompletely exposed and may contain thin partings of siltstone.
	2	Buff to pale pink, thin-bedded to laminated, flaggy feldspathic sandstone.
	5½	Very soft red-brown, micaceous shale, mudstone and siltstone; poorly exposed.
Total	234	

Warton Sandstone

Elgee Siltstone - Section E2

Section measured north of the Collison Range at 5680E, 31476N.

Pentecost Sandstone

Elgee Siltstone

67 ft.	Purple-brown to pale red-brown, fine-grained, well-sorted, flaggy, micaceous quartz sandstone; uppermost beds have clay pellets.
24	Chocolate-brown to purple-brown siltstone and mudstone with 2 in. to 8 in. interbeds of purple brown micaceous fine-grained, thin-bedded, flaggy to blocky feldspathic sandstone.
18	Chocolate-brown siltstone and mudstone.
7	Chocolate-brown to purple-brown siltstone and mudstone with 2 in. to 6 in. interbeds of buff very fine-grained micaceous ?feldspathic sandstone, and thin partings of pale green-grey mudstone.
7	Chocolate-brown to purple-brown siltstone and mudstone.
14	Cream and pale red-brown feldspathic sandstone; fine-grained, well-sorted; thin- to thick-bedded, blocky to flaggy.
1	Buff and purple-brown laminated, massive feldspathic quartz sandstone.
3	Red-brown, thin-bedded, fine-grained, quartz sandstone with interbeds of red-brown micaceous siltstone.
297	No exposures.
Total 440	

Warton Sandstone

Sandstones in the sequence vary from white, pale buff and pink to red-brown and purple-brown. They are fine to medium-grained, well sorted and include both quartz sandstone and feldspathic sandstone. They are laminated to thick bedded, and vary from flaggy to massive. They commonly contain purple-brown clay pellets, and are locally cross-bedded with 6 in. to 12 in. foreset units. Source direction indicated by the cross-beds is from the north-west.

In the central part of the Drysdale-Londonderry Sheet areas the formation is predominantly of sandstone rather than siltstone as elsewhere. The silt/sand ratio is 1/3.5 at Wallis Peak, but almost 6/1 in the north of the Lissadell Sheet area (Dow et al, 1964) and the formation is almost entirely of sandstone near Camden Sound in the west (Williams and Sofoulis, in prep.).

The boundary between the Elgee Siltstone and the overlying Pentecost Sandstone is gradational and is taken at the change from relatively dark red-brown sandstone with thin partings of siltstone, to pale red-brown and white sandstones, with clay pellets but without discrete siltstone beds. It is possible that the boundary between these two formations is diachronous and that sandstones (referred to the Pentecost Sandstone) were being deposited in the Drysdale-Londonderry area while siltstones (referred to the Elgee Siltstone) were still being deposited further to the south, and east.

Pentecost Sandstone

The Pentecost Sandstone overlies the Elgee Siltstone and is overlain unconformably by only a thin cover of superficial deposits of Cainozoic age. It is divisible into three members, lower, middle and upper. The upper member is incompletely preserved in this area.

The name Pentecost Sandstone, derived from the Pentecost Range in the north-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).

The Pentecost Sandstone crops out extensively in the eastern and south-eastern parts of the Drysdale-Londonderry Sheet area. The lower member forms a relatively narrow belt marginal to the outcrop area, while the middle member occurs extensively throughout it, and the upper one is confined to a few small mesa cappings near the southern boundary of the Sheet area.

Physiographically it forms a series of steep, locally terraced, escarpments and gently dipping cuestas. Flat upland plains with scattered mesas predominate in the central part of the outcrop area.

Dips throughout the area are low, rarely in excess of 5^{0} and exposures are good only around the margins of the outcrop area; hence information on thickness is sparse, and the section given below is a composite one.

The total thickness of the formation is about 2500 feet. Of this the lower and middle members make up 1300 and 1100 feet respectively. Only about 100 feet of the upper member is preserved in the area whereas further to the south-east, e.g. in the Lissadell Sheet area (Dunnet & Plumb, 1964) the full sequence of over 1000 feet is preserved. The total thickness of the formation varies little, but the individual members, particularly the lower member vary considerably. The thickness variations in the lower member are complementary to those in the Elgee Siltstone and also to those in the middle member of the Pentecost Sandstone. These illustrate the probable diachronous nature of (1) the lower boundary of the Pentecost Sandstone and (2) the lower boundary of the middle Pentecost Sandstone.

	Drysdale-Londonderry (This work)	Lissadell (Dunnet & Plumb 1964)	Lansdowne (Gellatly & Derrick 1966)
Pentecost Sandstone (Middle	1100	1300	2000
Pentecost Sandstone (Lower	1300	700	465
Elgee Siltstone	235	610	710

The <u>lower member</u> consists entirely of quartz sandstone and feldspathic sandstone. It crops out on two prominent dip slopes and an intervening escarpment of more easily eroded beds. The dip-slope forming sandstones of this member are white to pale buff, fine to medium-grained (and locally coarse-grained), well-sorted thin to thick-bedded, blocky to massive quartz sandstones. The cliff-forming sandstones are pale purple-grey to pale chocolate-brown, medium-grained, well-sorted, thin-bedded, flaggy and feldspathic, and characteristically contain abundant clay pellets. Cross-beds are common throughout the member and range in thickness from 1 foot up to 5 feet, but are only 2 in. to 6 in. thick in parts of the cliff forming sequence. Slumped cross beds are found locally. The source direction indicated by the cross-beds is from the north and north-west.

The <u>middle member</u> includes a bed of glauconitic sandstone which defines its base. The top, characterised by a change from medium-grained sandstone, to coarse-grained sandstone of the upper member, has been examined in the Ashton and Mount Elizabeth Sheet areas to the south, but has not been observed in the Drysdale-Londonderry Sheet area. The top of the middle member mapped in this area is a photo-interpreted extrapolation of the boundary mapped in the northern part of the Ashton Sheet area. The member forms three low escarpments with intervening gentle dipslopes.

The basal beds, crop out at the foot of a low escarpment and are generally poorly exposed. They consist of pale brown and dark purple-grey, fine to coarse-grained, thin-bedded flaggy to blocky, glauconitic quartz sandstone, and feldspathic sandstone. These are overlain by distinctive fine-grained pure white to pale pink, mainly thick-bedded, blocky, quartz sandstone. Overlying beds are mostly white, pale pink or cream fine- to medium-grained, thin- to thick-bedded, flaggy to blocky, well-sorted quartz sandstone and feldspathic sandstone. Coarse-grained sandstone noted in two widely separated localities caps a low escarpment near the top of the sequence. In the Seppelt Range a thin sequence of fine-grained feldspathic sandstone underlies this coarse-grained sandstone, but near the southern boundary of the map Sheet area only quartz sandstones are represented at this horizon. Clay pellets occur sporadically and are mainly confined to single beds.

Cross beds, abundant in this member, are principally of the trough or festoon type. They are wedge-shaped rather than tabular, and have foreset units from 8 inches to 3 feet thick. Irregular slump structures are present near a fault in the Seppelt Range, but no overturned cross-beds have been noted in this unit. The source direction indicated by the cross-beds is from north and north-west.

The <u>upper member</u> has been mapped in the Drysdale-Londonderry Sheet area only by photo-interpretation. The nearest beds of this member in the Ashton Sheet area a few miles to the south consist of white to buff medium-to coarse-grained quartz sandstone with a characteristic poorly sorted quartz granule sandstone at the base.

<u>Pentecost Sandstone - Section P1 (a,b,c,d)</u>

Composite section, partly measured in field with Abney Level, and partly estimated from air photographs.*

Localities (a) ca 5660 E 31470 N (Collison Range)

(b) 5395 E 31465 N (upper King George River)

(c) 5153 E 31035 N to 5310 E 31014 N (near southern boundary of map sheet area, from near Drysdale to upper Johnson Creek).

* National Army Grid Coordinates.

(d) 5484 E 31030 N (near southern boundary of map sheet area, north-west of Berkeley River) : lithological details from Ashton Sheet area.

	upper
ca 50-100 ft (d) (Higher beds not preserved)	Quartz sandstone; white to buff, coarse- to medium-grained, massive, thick-bedded; also poorly sorted, quartz granule sandstone, and fine- to medium-grained, clayey quartz sandstone.
	middle
ca 105 ft (c)	White to pale orange-brown medium- to coarse-grained thin- to thick-bedded, blocky to flaggy, well sorted quartz sandstone; resistant unit - basal beds form low escarpment.
20 ft (c)	Not exposed: detrital red-brown fine- to medium-grained well-sorted friable quartz sandstone, containing prominent black detrital grains.
120 ft (c)	Cream to white medium-grained, thick-bedded, blocky, well-sorted quartz sandstone; scattered clay pellets and spherical nodules.
200 ft (c)	Cream, pale pink, and pale rust-brown, fine- to medium-grained, thin-bedded, flaggy, well-sorted quartz-sandstone; festoon cross-beds; 1-2 feet thick soft beds present containing clay pellets: a resistant unit with basal beds forming a low escarpment.
ca 520 ft (c)	Pale cream-brown, pale purple-grey and white, medium-grained, thick-bedded, blocky, well-sorted quartz sandstone; strongly cross-bedded; ripple-marked.
150 ft (b,c)	Pale pink, fine-grained, well-sorted, thin-bedded flaggy to blocky, quartz sandstone; occurs at top of low escarpment.
16 ft (b)	No exposures.
10 ft (b)	Dark purple-grey, medium-grained, laminated, flaggy to blocky, glauconitic quartz sandstone.
11 ft (b)	Medium- to fine-grained, pale brown, friable, thin-bedded flaggy feldspathic sandstone.
25 ft (b)	Pale brown and grey, medium- to coarse-grained, thin-bedded, flaggy, feldspar- and glauconite-bearing quartz sandstone; locally micaceous.
Total 1097 ft	

lower

464 ft	(a)	White to pale buff, medium- to coarse-grained, thick-bedded, blocky, well-sorted, silica-cemented quartz sandstone.
431 ft	(a)	Purple-grey medium-grained thin-bedded, flaggy feldspathic sandstone; contains abundant clay pellets; escarpment forming.
25 ft	(a)	Pale purple-grey, medium-grained, well-sorted, thick-bedded, blocky feldspathic sandstone.
269 ft	(a)	White to pale buff, fine- to medium-grained, thick-bedded, blocky to massive, well-sorted quartz sandstone; strongly cross-bedded; forms dip slope.
40 ft	(a)	As above; cliff-forming.
50 ft	(a)	Pale buff, fine- to medium-grained, thin-bedded, blocky to massive, well-sorted, feldspar-bearing quartz sandstone; escarpment-forming.
Total 1279 ft		

Elgee Siltstone

ADELAIDEAN OR CARPENTARIAN

Hart Dolerite

Sills of dolerite, occurring in the Drysdale-Londonderry Sheet area are referred to the Hart Dolerite which crops out extensively around the periphery of the Kimberley Plateau. In this Sheet area it intrudes the King Leopold Sandstone, and the Carson Volcanics, but not the younger formations.

The name "Hart Basalt" derived from Mount Hart in the Charnley Sheet area was used by Guppy et al. (1958) for "basalt and dolerite" found mainly in valleys in the King Leopold and Lady Forrest Ranges. Harms (1959) established the intrusive nature of these rocks and renamed them the Hart Dolerite.

Topographically the dolerite sills form valleys, many of them flanked by steep-sided cliffs of sandstone. The valley floors are mostly soil covered, with scattered rounded, low, bouldery hills of dolerite. The sills are confined to the western part of the Sheet area and occur most extensively in the areas to the south-east of Admiralty Gulf and to the south-west of Theda Homestead.

Most of the sills intrude the King Leopold Sandstone apparently at the same, or similar horizons some 2,500 feet to 3000 feet below the upper boundary of the formation. Only one sill has been found in the Carson Volcanics, but Edwards (1943) has described a specimen of dolerite from the McDonald Creek area in the south-western part of the Sheet area and it is probable that a further occurrence of Hart Dolerite within the Carson Volcanics is to be found here.

The majority of dolerite sills in the Sheet area occur as inliers completely surrounded by sandstone and are the lowest rocks exposed in the sequence. One sill, with sandstone exposed at its base, was found to be 260 feet thick.

The Hart Dolerite is hard, dark grey in hand specimen, fine- to coarse-grained and contains traces of pyrite and chalcopyrite. It appears to be compositionally homogeneous and in general not differentiated. Veins of epidotised dolerite and schlieren of coarse-grained dolerite containing bladed pyroxenes up to 1 cm long are found locally. One sill examined had a 15 to 20 ft. thick layer containing abundant small quartz xenocrysts, parallel to and some 40 feet below the upper contact.

CAINOZOIC

TERTIARY

Laterite and Bauxitic Laterite

Small scattered mesas of ferruginous and bauxitic laterite, with a total area of about 180 square miles occur throughout the Drysdale-Londonderry Sheet area, except for the south-eastern part. They are remnants of a once more extensive Tertiary or pre-Tertiary plateau surface. The principal laterite occurrences in the area are in the south-western corner, and in the north near Capes Bougainville, Londonderry and Rulhieres respectively.

The laterites overlie the Carson Volcanics throughout the Sheet area, and overlie the Warton Sandstone in the north-eastern part. Scattered areas of laterite are also found locally overlying the King Leopold Sandstone close to its contact with the Carson Volcanics.

The laterites mostly occur as mesas with amoeboid outcrop plan, with small valley-fill deposits present locally. A thin veneer of sandy and lateritic soils commonly mantles the laterite and exposures are found only at the edges of the mesas where small cliff-faces are developed locally. Even here exposures may be poor, and commonly the only means of examining these deposits is by studying detrital boulders of laterite on the debris slope, below the escarpment edge of the mesas. The bauxitic laterite (Fig. 11) is restricted almost entirely to the south-western part of the Sheet area, and to a small area immediately south of Mount Leeming. Even within these areas where bauxitic laterite is found, it appears that there are rapid lateral variations to the more common ferruginous laterites which predominate over most of the Sheet area.

The thickness of the laterite profile is not constant, and in most places is uncertain due to lack of outcrop. In the area between the Morgan River and Loenjool Creek the tops of the mesas are 200 feet above the level of the surrounding basaltic pediplain, but not all of this is necessarily laterite. Elsewhere in the area the vertical interval between the top of the laterite mesas, and exposed fresh bedrock below is generally about 50 to 70 feet. Near Cape Rulhieres laterite overlying the Warton Sandstone is apparently 50 feet thick, but thins inland to about 10 to 15 feet within 3 to 4 miles.

The laterites are mainly red-brown to yellow-brown, hard, compact pisolitic rocks containing 2 mm to 2 cm iron-rich pisolites in a porcellanous pale yellow brown aluminous matrix. Oolitic types are also found. These include rocks (mainly bauxitic types) consisting entirely of oolites, and pisolitic rocks with an oolitic matrix. Some laterites are cavernous or cellular having irregular 0.6 to 3 cm vug-like cavities. In some localities, e.g. near Mount Leeming, pebbly laterites are common. These have probably been transported and redeposited during their formation. The laterites grade downwards into highly weathered, partly lateritised basalt, and finally into fresh basalt.

The pisolites* range in composition from dark grey ?haematite with a sub-metallic lustre to dark brown sub-vitreous goethite, and pale yellow-brown slightly ferruginous gibbsite. Two, or rarely all three, types may be found in the one rock. The change in composition from iron-rich to alumina-rich types is accompanied by a progressive increase in the degree of roundness of the pisolites, and in the development of concentric banding.

The bauxitic laterites, which vary from pale pink and pale nut-brown to buff and creamy white, grade into ferruginous types. The bauxite laterites include pisolitic oolitic and pebbly varieties. In hand specimen they differ mainly in colour and specific gravity from the ferruginous laterites.

Where bauxitic laterites are present they commonly have a thin covering of ferruginous laterite.

The origin of the laterites is complex, but it appears that the material has been derived by weathering mainly from the basalts and spilites of the Carson Volcanics. Another possible source suggested for the alumina, the feldspar in the sandstone interbeds, could not provide the necessary quantity of material, since these beds are 30 feet thick, contain 5-10% of feldspar and a maximum have Al_2O_3 content of 2½%. Derivation of the laterites from these feldspathic sandstones could not explain the high TiO_2 content of the laterites.

The laterites overlying the King Leopold Sandstone occur close to the contact with the Carson Volcanics. This fact, and the high TiO_2 content (3%) of these laterites (Appendix 3, analysis 10) suggests that they have been derived by weathering of laterites originally developed on the Carson Volcanics.

The source of the alumina for the laterites overlying the Warton Sandstone presents a more difficult problem. The most probable sources are (1) the siltstone bed within the Warton Sandstone (2) the Elgee Siltstone (3) the minor amounts of feldspar within the Warton and Pentecost Sandstones.

The irregular gradients of the laterite surface (which presumably covered either most or all of the area) apparent from the isohypses, suggest that the laterites were formed on an undulating surface. Such gradients could account for the presence of the pebbly laterites, which are thought to have been transported, though the distance of transport may have been small, and also for the titania-rich laterites overlying the King Leopold Sandstone. Mineralogical studies (Appendix 3) suggests that two periods of laterisation are involved and agree with this concept of movement of the laterites during their formation.

UNDIFFERENTIATED CAINOZOIC

Lateritic Soils (Czl)

Lateritic soils in the Drysdale-Londonderry Sheet area are found in two distinct settings, but the products are similar. They occur partly as high level cappings on sandstones, particularly on the Pentecost Sandstone, and as low level deposits derived by erosion of the laterites. These soils have a dark photo-pattern similar to that of the laterite, but being unconsolidated and easily weathered are not bounded by low escarpments as are the laterite mesas.

* The term pisolites is preferred to pisoliths, since the former term has priority (Lyell, 1833) and the latter includes the restriction of concentric banding in its definition; not all the pisolites in these laterites are concentrically banded.

Figure 9. Pebbly laterite. Aluminous laterite containing angular and sub-rounded pebbles of bauxite up to 1 inch across in a slightly more ferruginous matrix.

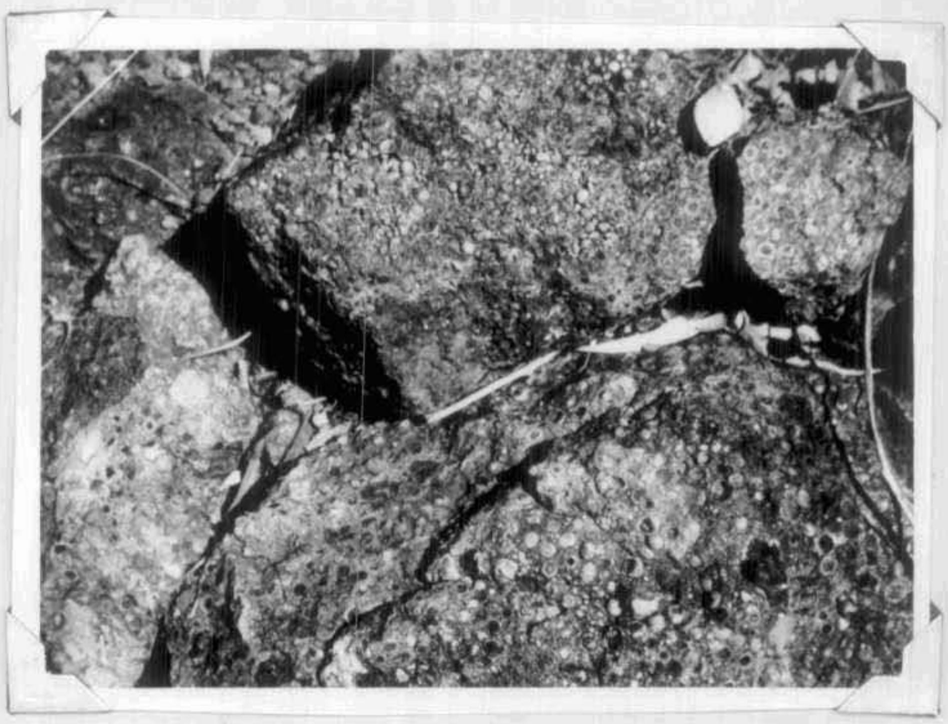
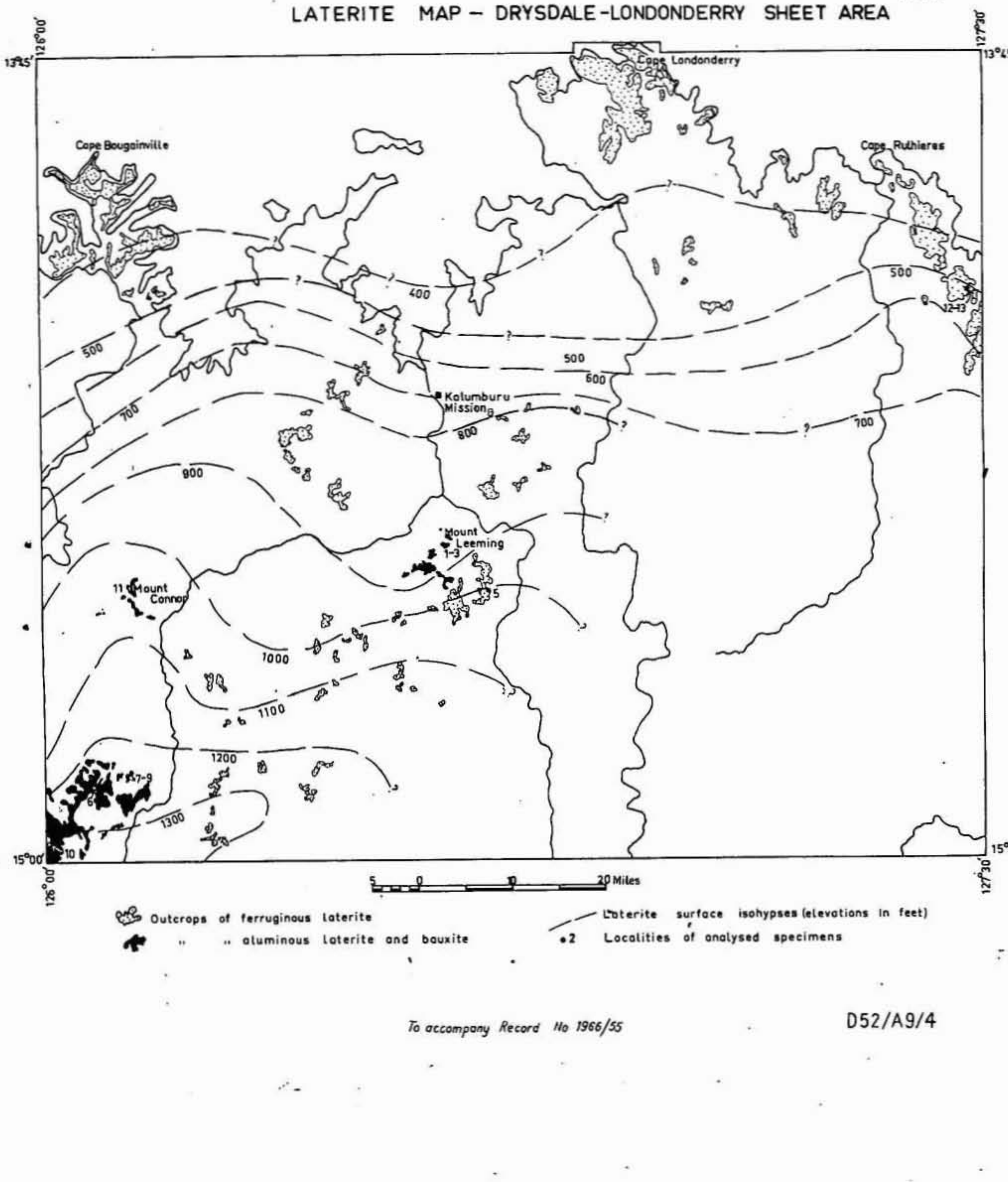


Figure 10. Pisolitic laterite. Concentrically banded pisolites up to ½-an-inch in a massive, aluminous laterite matrix.

FIG. 11

LATERITE MAP – DRYSDALE-LONDONDERRY SHEET AREA



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These lateritic soils consist of pebbly, locally pisolitic, ferruginous material, generally mixed with moderate amounts of sand.

Black Soils (Czb)

Black soils are developed locally on areas of the Carson Volcanics. They form distinctive low-lying treeless areas with an even photo-pattern. They are characterised by deep polygonal cracks. Elsewhere in the Kimberley Region these soils are commonly developed on Hart Dolerite, but they have not been observed overlying the Hart Dolerite in the Drysdale-Londonderry Sheet area. The reason for this, apparently, is that a small proportion of quartz sand effectively inhibits the development of black soil; since the outcrops of Hart Dolerite in this area occur in small, deep valleys fringed by sandstone cliffs, there has been a sufficient supply of sand to prevent the development of typical black soil.

Volcanic-derived Soils (Czs/Pkc)

Volcanic derived soils have been mapped separately because of their distinctive composition and texture, and because they are more important than the other types of soil (except black soil) for the fodder grasses which they support. They are mainly red and grey fine-textured silty loams and podzols forming on sediments and valley floors. They tend to grade into more sandy soils towards the Carson escarpment.

Undifferentiated Soils (Czs)

Within this heading are included miscellaneous sandy soils, podzols, and eluvium. Eluvium is comparatively rare except as thin veneers on the lower parts of escarpment slopes. Such deposits derived from the basal beds of the Pentecost Sandstone commonly obscure the upper beds of the Elgee Siltstone. Pale grey-brown podzols occur as a narrow strip overlying the lower beds of the Elgee Siltstone.

Light textured, pale grey-brown sandy soils which overlie sandstone are the most extensively developed in the Sheet area. They occur in several areas around Napier Broome Bay, around Mount Connor, and as a discontinuous strip overlying the higher beds of the Warton Sandstone. For the most part, the areas of soil overlying the King Leopold Sandstone form high level plains representing an earlier erosion surface now deeply dissected by the King Edward River and by minor streams.

QUATERNARY

Beach Sands (Qs)

Beach sands form narrow strips at many places round the coasts of the Sheet area, mainly bordering outcrops of King Leopold Sandstone. They occur as beaches backed by rocky outcrops and also as breached sand bars separating small lagoons from the sea. The sands are coarse to medium-grained and relatively well-sorted. They consist of clean-washed quartz sand with about 15% of calcareous grains derived from shell fragments. Scattered sandstone cobbles and large gastropod shells are found locally on the landward side of the sand-bars.

Coastal Limestone (Ql)

Small pockets of fragmental shelly limestone border the Carson Volcanics on the western side of the Cape Bougainville Peninsula, and at Cape Londonderry. They form low outcrops on the present day shoreline and buff-coloured rock consisting of well-cemented shell fragments ranging in size from about 0.5 mm to 1 cm, with scattered ellipsoidal 2 to 5 mm fragments of basalt. Similar small deposits have been noted in the Montague Sound area to the west (Allen, in prep.) and there may be several such occurrences in the Drysdale-Londonderry Sheet area.

Coastal Muds and Sands (Qc)

Estuarine coastal flats, and small, isolated lagoons, which are widely distributed in the Sheet area, are floored by silty sands and muds. The landward areas of these flats are subject to only occassional inundation and dry out superficially forming a thin crust of salt up to ¼-of-an-inch thick. The seaward areas of the flats and lagoons are subject to daily tidal inundation and support a dense growth of mangroves.

Alluvium (Qa)

River deposited alluvium occurs in scattered localities along all the major river courses of the Sheet area. It consists mainly of moderately well-sorted, coarse- to medium-grained sand derived from the sandstones of the area. Gravels are probably present locally in these deposits where there is a sudden reduction in stream velocities, e.g. where the Drysdale and King George Rivers flow out of gorges on to the relatively low-lying Carson Volcanics.

In places, rivers have eroded down to bedrock through small flood-plain deposits leaving the latter as relatively upraised terraces.

STRUCTURE

The Drysdale-Londonderry Sheet area forms part of the structurally stable Kimberley Block (Traves, 1955), in which the degree of deformation is low compared with that in the King Leopold and Halls Creek Mobile Zones to the south. The structural pattern is predominantly one of cross-folding producing basins and domes and is thus similar to that found further south in the Mobile Zones e.g. in the Lansdowne Sheet area (Gellatly, et al, 1965). The two main trends of folding and faulting, are similar to those found throughout the Kimberley Region. No definite evidence has been found concerning the relative ages of these two trends and they are regarded as being penecontemporaneous.

Folding

Folding in the Sheet area is gentle, with broad open folds, and dips of less than 10° predominating. Dips over 20° have been found only in the immediate vicinity of the Seppelt Range Fault. Over wide areas, particularly in the eastern part of the Sheet area, dips do not exceed 5°.

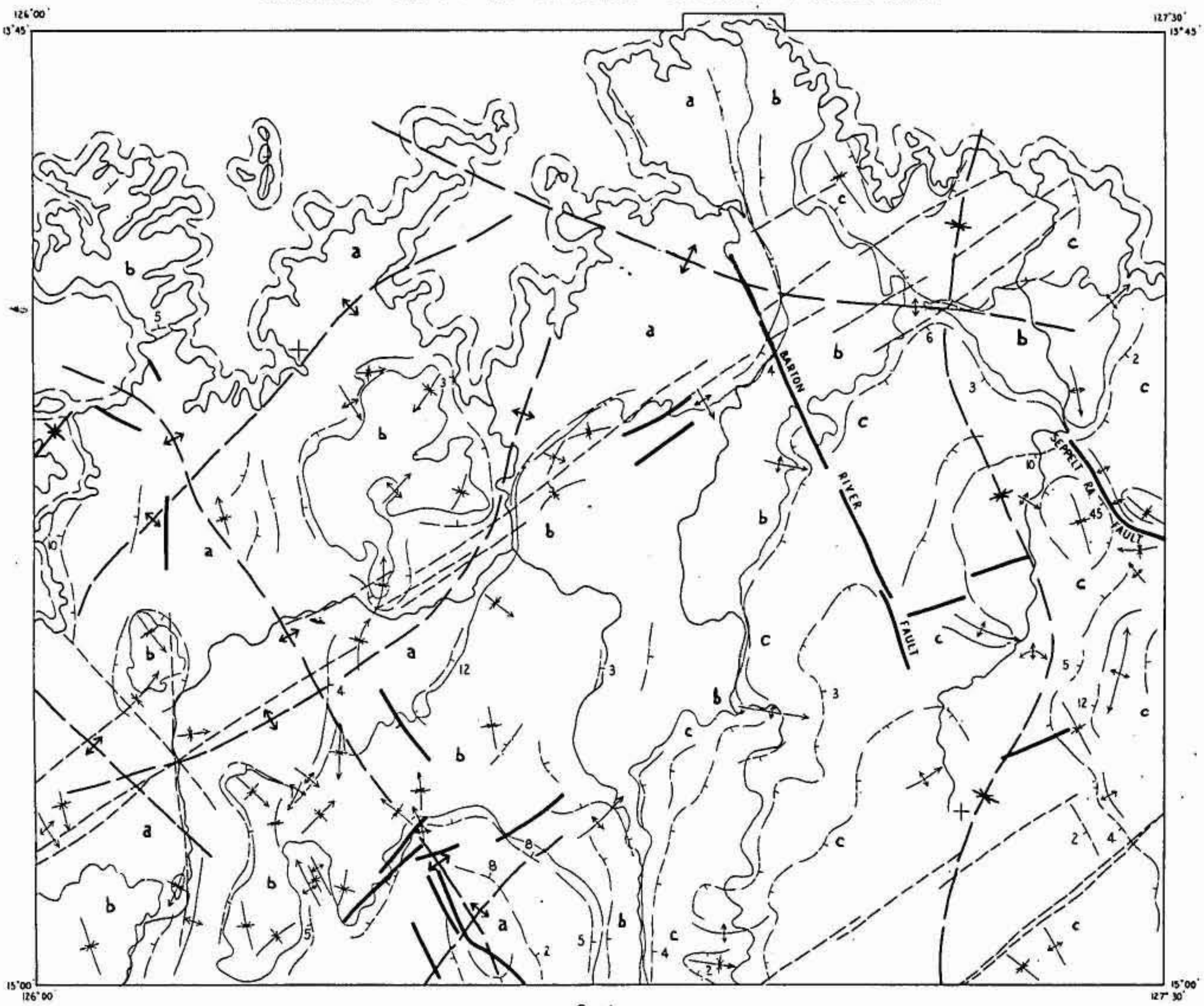
The folds may be divided into two classes, first order folds and second order folds. The first order folds are those that are defined essentially by the distribution of the various stratigraphic formations, and partly also be regional dips. The axes of these first order folds may be traced for 50 miles or more, and they have little, if any, plunge. The second order folds are those that are defined principally by dips observed in the field or from air photographs. Their fold axes can rarely be traced for more than 5 miles, and not uncommonly have discernible directions of plunge.

Two principal fold systems, trending 320° and 030° respectively, are recognised and are reflected in both the first order and second order folds. Intersection of the two trends of the first order folds has produced basins and domes. The dominant plunge directionsof the second order folds are less than 5° to north-east and south-east.

A few folds trend either north or east and apparently belong to neither of the main systems. In the case of the first order folds, this is partly due to local variations in the trend of axes with a dominant trend similar to the principal directions. Within the group of second order folds a distinct north-south trending fold system may be present.

FIG. 12

STRUCTURAL SKETCH MAP - DRYSDALE - LONDONDERRY SHEET AREA



Scale

5 0 5 10 15 MILES

Fault	Anticline / Syncline — First order folds	a King Leopold Sandstone
Major Lineaments	Anticline / Syncline / Monocline — Second order folds	b Carson Volcanics
Dip and strike of bedding		c Warton Sandstone, Elgee Siltstone Pentecost Sandstone
Bedding horizontal		
Trend of bedding showing dip		

To accompany Record No 1966/55

D52/A9/5

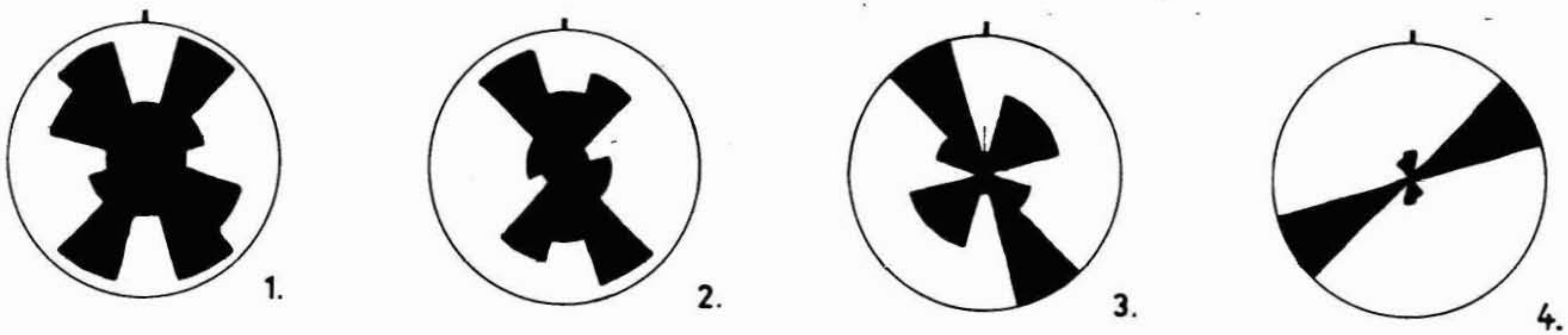


Fig. 13 Rosette diagrams of structural features

1. First order folds
2. Second " "
3. Faults
4. Major lineaments

To accompany Record No 1966/55 D52/A9/6

Faulting and Jointing

Faults and joints in the Sheet area may be classified into: (1) faults with recognisable displacement; (2) major lineaments which may be either joints or else faults along which displacement is too small to be recognised; and (3) joints.

Faults, which are rare in the Sheet area, show two principal trends 330° and 040°. The only major ones are the Barton River Fault, which, with offset portions, has a total length of 40 miles, but has only a comparatively small displacement; and the Seppelt Range Fault, some 15 miles long with a maximum displacement of over 600 feet. Where the direction of downthrow is known it is either to the south-east or to the south-west.

Major lineaments with a trend of 050° form a prominent belt crossing the area from the south-west corner to the north-east, and are also found in the south-east corner. They mostly form narrow clefts up to 30 miles in length which control the drainage (see Fig. 5) and locally contain highly brecciated sandstone.

Joints are abundant throughout the area and are particularly conspicuous where they cut the King Leopold and Warton Sandstones. They are generally closely spaced, especially in the Warton Sandstone. In any one locality, two or more trends may be recognised. Generally these trends are parallel to nearby faults or lineaments, but in places they are transverse to the major fractures.

Interpretation

The most important structural features of the area are (1) faults and lineaments of great extent, but small displacement; and (2) the close association in trend between the folding and the faulting (see fig. 13); (3) There is relationship in the amount of displacement, i.e., where the fault movement is greatest, dips are steepest and therefore the folding the most intense.

It appears that the folding and faulting have been caused by essentially the same set of movements and that the folding took place first and was followed by faulting once the elastic limit of the rocks was exceeded. It is suggested that these features are best explained as the response of the sedimentary cover to reactivation of old lines of weakness in the underlying "basement".

ECONOMIC GEOLOGY

MINERALS

Copper Minerals

Chalcopyrite amygdules up to 5 mm across have been noted in spilite of the Carson Volcanics a few miles north-east of the estuary of the Drysdale River (512800 E 3227100 N). Minor amounts of chalcopyrite have also been found elsewhere in the Carson Volcanics, mainly low in the sequence. This copper mineralisation is unlikely to be economic.

Malachite has been noted in a siltstone near the base of the middle Pentecost Sandstone in the Ashton and Mount Elizabeth Sheet areas to the south, but has not been found in the laterally equivalent sediments in the Drysdale-Londonderry area.

Bauxite

The field occurrences of the laterites and bauxites have been described in the section of stratigraphy. Little is as yet known about their economic potential particularly in the Drysdale-Londonderry Sheet area. More extensive information including analyses is available from the Montague Sound Sheet area to the west. Analyses of samples from the Drysdale-Londonderry Sheet area are included in Appendix 3. Further analyses of laterites and bauxites will be given in Derrick (in prep), and Sofoulis (in prep.).

The area was first examined for bauxite in 1958 by Reynolds Pacific Mines Pty. Ltd., who found only a low alumina content (20% to 40%) in the laterites of the Cape Bougainville Peninsula.

During the time of the present survey parts of the area were covered by Temporary Reserves held by United States Metals Refining Co., who found commercial grade bauxite in the Mitchell Plateau, lying to the south of Admiralty Gulf in the Montague Sound Sheet area (Allen, in prep.). The Mount Connor area and other parts of the south-western ocrner of the Drysdale-Londonderry Sheet area are included in Temporary Reserves at present held by this company.

Preliminary exploration work done to date indicates that in the areas with bauxitic laterites the bauxitic material persists to a depth of at least 1½ feet and the alumina content tends to increase slightly with depth. Four analyses from the Montague Sound Sheet area (Sofoulis, in prep.) average 50.5% available Al_2O_3, and 1.3% reactive SiO_2. The relatively high TiO_2 content, (ca 6%) apart from grade dilution, is not considered to be detrimental to the value of this material as a source of alumina. Mineralogically the bauxitic laterites consist mainly of gibbsite ($Al_2O_3.H_2O$), with minor boehmite ($Al_2O_3.H_2O$).

The deposits appear to be promising economically and exploration is at present being carried out by United States Metals Refining Company. From surface indications it is unlikely that the deposits in the Drysdale-Londonderry Sheet area will prove to be of as high grade as those in the Montague Sound Sheet area.

Iron Ore

Ferruginous laterites have been noted in many parts of the Sheet area including the south-western corner (where the most aluminous types are also found) and the north-eastern corner where they overlie the Warton Sandstone. They appear to be sufficiently rich in iron to warrant classification as possible iron ore. A sample of laterite from the north-eastern part of the Sheet area contains 37% Fe, and Harms (1959) records up to 45% Fe in laterites from the Drysdale area.

Beach Sands

The beach sands, particularly on the Anjo Peninsula, where they are well developed, have been examined for heavy mineral deposits but none were observed. The sands were found to contain small shell fragments (ca 15%).

Salt

Salt (Fig. 6) is found in coastal lagoons but harvesting would be uneconomic because the area is isolated and the lagoons are small and widely distributed.

CONSTRUCTIONAL MATERIALS

Sand and Gravel

Deposits of moderately well-sorted medium-grained sands suitable for building purposes are found locally along the courses of all the major rivers in the area, particularly those of the Drysdale River and Carson River. No gravels were observed during the course of the present survey, but are probably present locally, e.g. where the Drysdale River debouches from its gorge in the Carson Escarpment on to the plains.

Road Metal

Road metal available within the Sheet area may be classified into two types; those suitable for dirt roads, and those suitable for bituminised surfaces.

For dirt roads the most suitable materials are;- the laterites and the detritus derived from them; the shales and siltstones at the top of the Carson Volcanics; the shales and siltstones of the Elgee Siltstone.

For bituminised road surfaces the basalts of the Carson Volcanics, and the Hart Dolerite provide the best sources of road metal. The Carson Volcanics are the more valuable since they crop out more extensively and are found close to most routes of access within the area.

WATER SUPPLY

Information on water supply is based partly on the writers' own observations and partly on the work of Allen (1966).

Surface Water

As a result of the relatively high rainfall (35-40 inches per annum) surface water is plentiful in most parts of the area. Because of this, and because of the sparse population, no wells or bores exist in the area, and the groundwater potential can be estimated only by reference to other areas.

Within the Drysdale-Londonderry Sheet area these are four major catchments drained by sea-going rivers. These are the King Edward-Carson, Drysdale, King George, and Berkeley Rivers. In addition, there are areas along the coast drained by minor streams. These all lie within the "Drysdale Drainage Division" of Allen (op. cit.).

In the dry season the major rivers are reduced to a series of water holes some of them connected by small permanent surface streams maintained by groundwater depletion. Surface streams in the King Edward and Drysdale Rivers noted during the present survey were estimated to have flows of 1 cusec. Similar streams were noted in the lower reaches of the other rivers. Tributary streams also contain abundant water holes, but do not in general have permanent streams. Surface water is more common in the areas underlain by sandstone than in those underlain by volcanics. In particular the minor tributary streams in the volcanics contain little or no water.

The only water used in the area for domestic purposes, at Kalumburu Mission and at Barton River and Theda Homesteads, is pumped directly from pools in the King Edward, Drysdale and Morgan Rivers respectively.

Salinity of surface water with catchments in sandstone areas varies mostly within the range 20-40 p.p.m. of total dissolved solids (T.D.S.). The Carson River, which has a dominantly basaltic source area, has a salinity of 120 p.p.m. (Allen, 1966). This may be due to the different bedrock in the source area, or alternatively to evaporation.

Groundwater

Groundwater present in joints and fractures in the rocks throughout the area maintains the few permanent streams observed, as well as sporadic springs, mainly in the King Leopold Sandstone. The quality of the groundwater is indicated by the water from a running stream in the King Edward River in the south-western part of the Sheet area which contained only 20 p.p.m. T.D.S.

Groundwater is more likely to be sought, however, in the areas of volcanic rocks since surface water is less abundant in the volcanic areas, and because they include the best grazing land. By analogy with areas further south where several producing bores and wells are located in the Carson Volcanics, it is probable that these rocks in the Drysdale-Londonderry area could provide adequate supplies (up to about 2000 gallons/hr.) for stock watering.

PETROLEUM

Petroleum prospects in the landward parts of the Sheet area are negligible. The off-shore areas to the north, however, are leased for petroleum exploration to the Australian Aquitaine Petroleum Pty. Ltd., and Ario Ltd., and were under active investigation at the time of the present survey.

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APPENDIX I

Mean Temperatures and Rainfall Recordings
Kalumburu Mission, W.A.
(previously known as Drysdale Mission)

Month	Mean Max.	Mean Min.	Mean Rainfall
	12 year period to Dec. 1961		49 year period to Dec. 1961
Jan.	93.4°F	76.2°F	1011 points
Feb.	91.7	75.6	916
Mar.	94.1	74.5	741
Apr.	93.4	69.8	176
May	91.5	63.4	48
Jun.	88.3	59.6	39
Jul.	88.9	58.1	18
Aug.	91.3	59.1	2
Sept.	94.4	65.3	12
Oct.	97.3	72.4	74
Nov.	97.6	76.1	309
Dec.	95.1	76.7	614
Aver. Annual	93.1°F	69.0°F	Total 3960 points

Data supplied by Bureau of
Meteorology, Perth, W.A.

APPENDIX 2

List of measured and estimated thicknesses of stratigraphic units and details of measured sections.

Stratigraphic Unit		Thickness	Locality
Pentecost Sandstone	(upper)	50-100 ft. (2)	(1)
" "	(middle)	1100 ft.	(1)
" "	(lower)	1300 ft.	(1)
Elgee Siltstone	E1	234 ft.	(1)
" "	E2	440 ft.	(1)
" "	E3	340 ft.	Seppelt Range 5685E, 31850N.
Warton Sandstone	W1	1450 ft.	(1)
" "	W2	1125 ft.	Carson Escarpment 5145E, 31525N.
" "	W3	1720 ft.	Seppelt Range 5660E, 31880N.
Carson Volcanics	C1	1950 ft.	(1)
	C3	1580 ft.	(1)
" "	C4	1130 ft.	Barton Plain 5160E, 31960N.
King Leopold Sandstone	K1	2400 ft. (2)	(1)
" " "		3400 ft. (2)	Pangoor Creek 4685E, 31182N to 4740E, 31255N.

(1) For locality see measured section in text.

(2) Sequence incomplete; top eroded, or base not exposed.

APPENDIX 3 : BAUXITE AND LATERITE ANALYSES AND MINERALOGICAL DESCRIPTIONS

ANALYSES*

	H_2O-	H_2O+	Total SiO_2	Reactive SiO_2	Fe_2O_3	TiO_2	Al_2O_3	Available Al_2O_3
1	1.85	22.4	2.8		6.05	6.95	59.4	
2	1.27	18.6	2.6		31.7	6.85	38.9	
3	0.92	27.4	1.64		7.85	5.75	55.7	
4	0.89	18.4	0.93		34.5	2.30	42.5	
5								
6	0.54	29.9	0.66		2.50	4.45	60.8	
7	0.85	26.0	2.10		4.10	1.14	64.5	
8	1.04	18.8	4.50		26.7	1.93	46.7	
9	1.18	12.0	2.50		43.7	3.30	37.0	
10	0.76	20.6	2.10		5.20	3.10	67.5	
11	0.65	28.9	4.30		6.55	3.00	55.5	
12	0.95	7.30	20.7		54.5	0.91	14.9	
13	0.90	10.5	21.6		43.7	1.18	21.5	

* Numbers refer to localities on laterite sketch map, Fig. 11. The specimens analysed are surface samples purposely selected to show the range of compositions present and do not necessarily represent the average composition of the material present.

Analyses by A.M.D.L., Adelaide.

Mineralogical Descriptions * ø

(1) X-ray diffraction, mineral identification

The pisolites and oolitic aggregates in this rock consist essentially of gibbsite.

Gibbsite is also a major component of the matrix and massive parts of the specimen.

Description of the specimen

Most of this rock consists of extremely fine-grained indurated masses which contain porous aggregates of oolitic gibbsite and isolated pisolites. Several grains of detrital quartz are scattered through the oolitic aggregates.

ø By I.R. Pontifex (1966).

X-ray diffraction, mineral identification

An analysis of a whole rock sample revealed that gibbsite is the main component.

Description of the specimen. (No thin-section was cut).

This is a cream-light brown rock which consists of a compact aggregate of even-sized oolites of gibbsite. The average diameter of the oolites is 0.4mm. Although the rock is generally porous the intersticies in some parts are filled with secondary opaline-like silica, and minor hematite.

(3) Description of the specimen

The matrix of this rock is essentially the same as described for DY8a/28/1b. This contains isolated pisolites up to 6 mm. in diameter and irregular fragments which measure about 5 mm. across; both were identified by X-ray diffraction as gibbsite. The fragments are scattered at random through the oolitic matrix and under the binocular microscope they are seen to have a colloform, secretionary internal structure.

Comment on X-ray diffraction mineral identification

With the exception of two specimens (or selected parts of specimens) in which kaolinite and hematite were the essential constituents, all the samples analysed on the X-ray diffractometer were found to consist predominantly of gibbsite. In each of these samples the diffraction pattern also indicated the presence of one (or more) other minerals.

The 'd' spacings of the most prominant peaks recorded on each chart in addition to the gibbsite peaks are tabulated below.

The massive parts have a buff and light brown mottled appearance and they consist of closely packed aggregates of oolitic gibbsite which have been cemented by a cryptocrystalline siliceous matrix. Some areas have a porcellanous texture. The average diameter of the oolites in the massive and porous fractions is 0.3 mm.

The indurated masses grade imperceptibly into the relatively porous aggregates. Their relationships suggest that the entire rock was originally silicified and some parts have subsequently been leached with removal of silica, or alternatively, that the rock was originally porous and subsequently some parts were silicified.

Some pisolites are composed of several oolites which appear to have been welded together by some concretionary process, subsequent to the formation of most of the gibbsite oolites.

The relationships of the components in this specimen indicate that some parts of the rock have been subject to secondary silicification and reconstitution of the matrix. This suggests that probably more than one period of lateritisation is responsible for the present form of these bauxites.

Reference: Pontifex, I.R., 1966. An examination of seven bauxite samples from the Ashton 1:250,000 Sheet, Kimberley Area, W.A. Bur. Min. Resour. Aust., Ore mineralogy Rept No. 1, File 65-7074.

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5 - R65 - 16 - 1055	10 - R65 - 16 - 1060	

APPENDIX 4 : PROVENANCE OF THE KIMBERLEY BASIN SEDIMENTS

Introduction

During the mapping of the Kimberley Basin sediments in the Lansdowne 1:250,000 Sheet area to the south (Gellatly et al, op. cit.) it was noted that cross-beds indicated a current-direction from the north-east in the Speewah Group and the lower part of the King Leopold Sandstone and from the north-west in the remainder of the Kimberley Group. Observation of cross-bed directions and other sedimentary features, continued during mapping of the Drysdale-Londonderry 1:250,000 Sheet area has similarly produced evidence of derivation from a general northerly or north-westerly direction.

Details of current source directions and other sedimentary structures are presented here together with information on facies changes, and mineralogy and petrography of the sediments which may have a bearing on the provenance of these sediments and on the palaeogeography of the region in Carpentarian times.

Cross-beds

Cross-beds in the Kimberley Group sediments in the Drysdale-Londonderry 1:250,000 Sheet area are mostly of the planar type or of the trough or "festoon" type (according to the nomenclature of McKee and Weir, op. cit.). The later type are common (Fig. 15) and generally have gently curving traces on bedding plane surfaces. Tabular and wedge-shaped sets are present. The thickness of the foresets ranges from 2 to 3 inches up to about 5 feet; the majority are from 6 to 18 inches thick. The dip of the foresets ranges from about 2° to 3° in the gently wedging types to about 30° in the tabular ones.

Wherever possible 25 or more readings of cross-beds were made from each locality studied in order to obtain statistically valid results for the current source directions. In addition, a few scattered observations of up to 5 readings per locality have been made. The consistency of the directions is such that 25 readings from each locality is adequate to give a statistically valid mean. The plots of these sets of 25 measurements are shown on figure 16.

Most of the measurements were made on trough-type cross-beds which showed arcuate intersections with bedding-planes. The measurement was made on the direction of concavity of these arcs.

The source direction of the sediment-bearing currents (the "source direction") during deposition of the King Leopold Sandstone was from the north and north-west (Figs. 16, 17). The variation in source direction in the King Leopold Sandstone does not appear to be related to stratigraphic position. Within the Warton Sandstone a north-north-easterly source direction is found near the base but gives way upwards to a general north-westerly direction. About the middle of the Warton Sandstone succession there is an abrupt change from coarse-grained sandstone to medium-grained sandstone which takes place at the base of a low escarpment. This change in grain-size is accompanied by a change in source direction from westerly in the lower beds to the more general north-westerly in the upper beds. In the Elgee Siltstone cross-beds are uncommon, but the two examples found indicate a north-westerly source direction. The same north-westerly and northerly source directions apply in both the lower and middle Pentecost Sandstone, although in certain beds source directions from the north-east are indicated.

Overturned Cross-beds

Overturned or "slumped" cross-beds have been noted in several localities in the Sheet area. These take the form of an intraformational recumbent "U" shaped fold within otherwise undisturbed strata (Fig. 14). The beds below and above the overturned cross-beds generally show normal cross-bedding, although in one exposure two such overturned cross-beds were noted within a vertical thickness of about 2 feet of strata.

Where overturned cross-beds are found the direction of overturning is essentially the same as the direction of flow of the sediment-bearing current as indicated by the original foreset dip of the cross-beds. This observation agrees with the experimental formation of overturned cross-beds by McKee, Reynolds and Baker (1962) who found that they could be produced by dragging a bag of sand over freshly formed cross-beds and concluded that the traction effect of strong sediment-laden currents was probably the main agent in their formation in nature.

Ripple-marks are rare in the sediments of the Sheet area, and have been noted in only two localities, one from the King Leopold Sandstone and one from the Pentecost Sandstone. The former are symmetrical oscillation ripple-marks and the latter are asymmetrical ripple-marks with a wave length of 1½ inches. In both cases the trend of the ripple-marks is approximately north and the implied current and wave propagation directions are at right angles to the current directions indicated by the cross-beds.

Sorting, Grain Size and Roundness

Thirteen samples from the King Leopold Sandstone (4), the Warton Sandstone (4) and the Pentecost Sandstone (5) have been crushed and sieve analyses carried out. These indicate that the sandstones are very well sorted. The lowest value obtained for the Sorting Coefficient ($So = \frac{Q25}{Q75}$) is 1.24 and the highest 1.46 (the upper limit for well sorted sediments according to Pettijohn (1948) is 2.50). The mean sorting coefficients for the specimens from the various formations are as follows:-

Pentecost Sandstone	1.36
Warton Sandstone	1.42
King Leopold Sandstone	1.32

The value for specimens from the King Leopold Sandstone is surprisingly low, especially as many of them showed an extremely wide range in grain-size in hand specimen; in some, granules and pebbles up to 1 cm diameter are present. The large grains however make up only a very small percentage of the total rock and thus do not affect to any extent the value of the sorting coefficient.

No systematic variation has been noted in grain-size. Grain size varies both vertically and laterally throughout each formation. An increase in grain-size was however noted on the Anjo Peninsula where the sandstones of the King Leopold Sandstone are unusually coarse in grain and one bed was noted with an average grain-size of 3-4mm. A localised conglomerate has also been noted in this vicinity.

Of the sieve-analysed specimens, which may be regarded as being representative of the general grain size variations, the median diameter of the grains varies from 0.18 mm to 0.64 mm. The King Leopold Sandstone specimens have a higher average median diameter than those from the Warton Sandstone, which in turn have a higher median diameter than those from the Pentecost Sandstone. The variation in median diameter is greatest in the Pentecost Sandstone and least in the King Leopold Sandstone. No statistical study has been made of roundness of the grains, but microscopic examination of thin sections indicates that the quartz grains are mostly rounded to sub-rounded, except for the fine-grained sandstones where sub-angular grains may also be present.

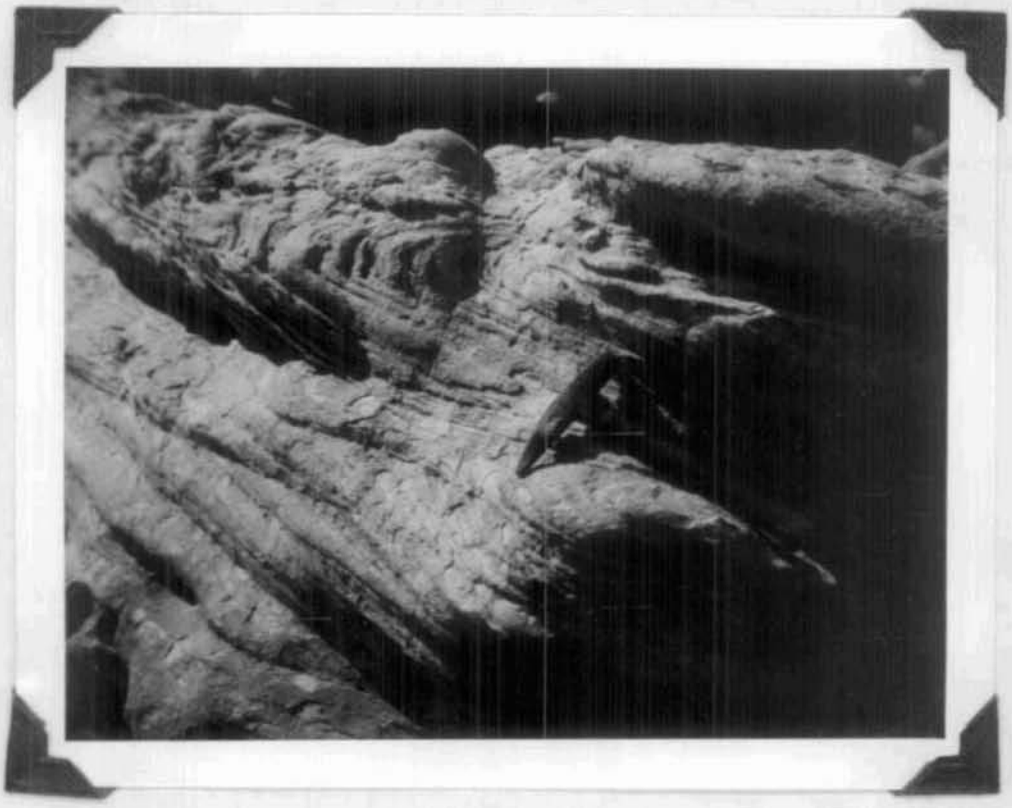


Figure 14. An overturned or slumped cross-bed forming an intraformational recumbent fold in King Leopold Sandstone. West side of Anjo Peninsula.

Figure 15. Trough or "festoon" cross-bedding in King Leopold Sandstone. West side of Anjo Peninsula.

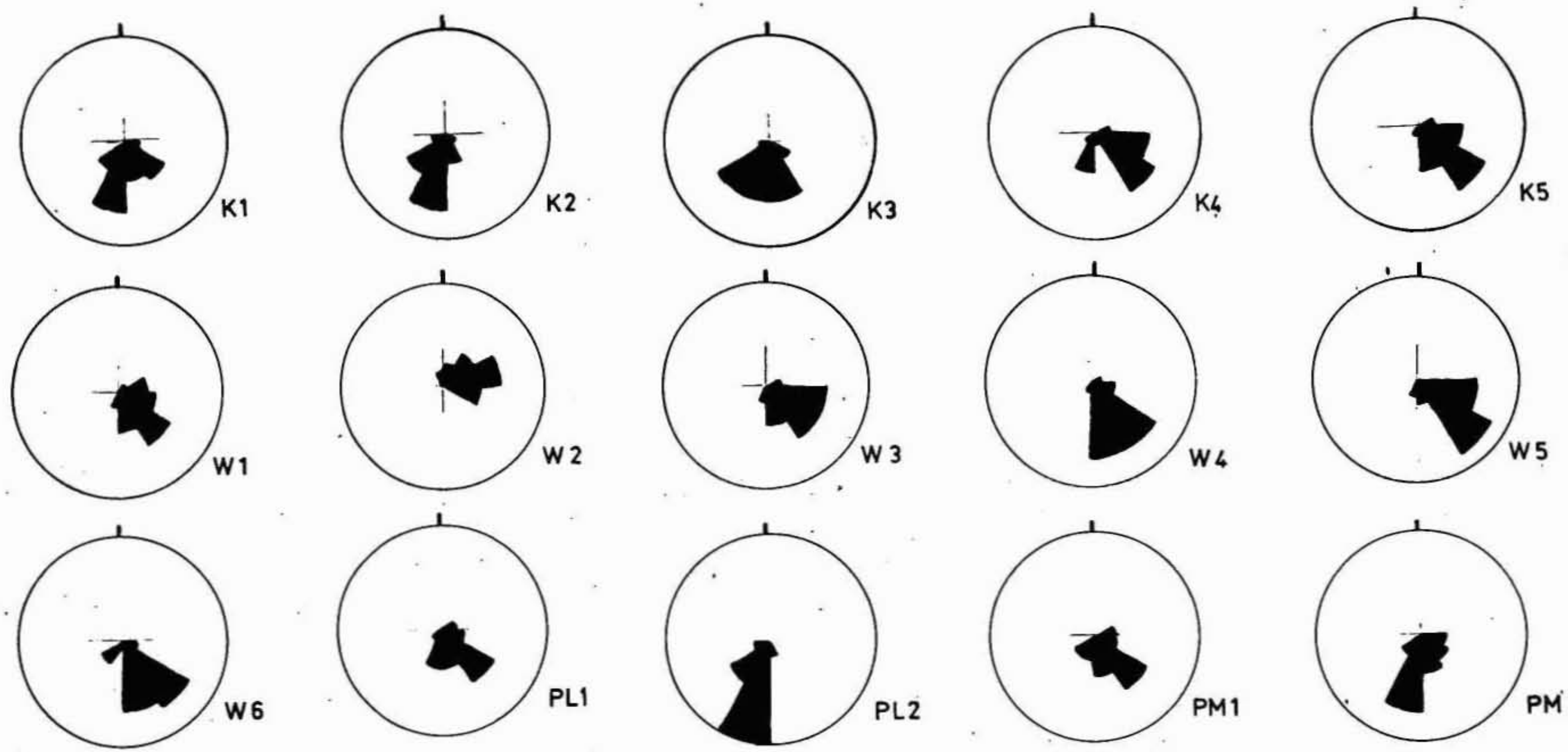


FIG. 16 Current directions from cross-beds (25 readings per diagram)
Numbers refer to localities on fig. 17

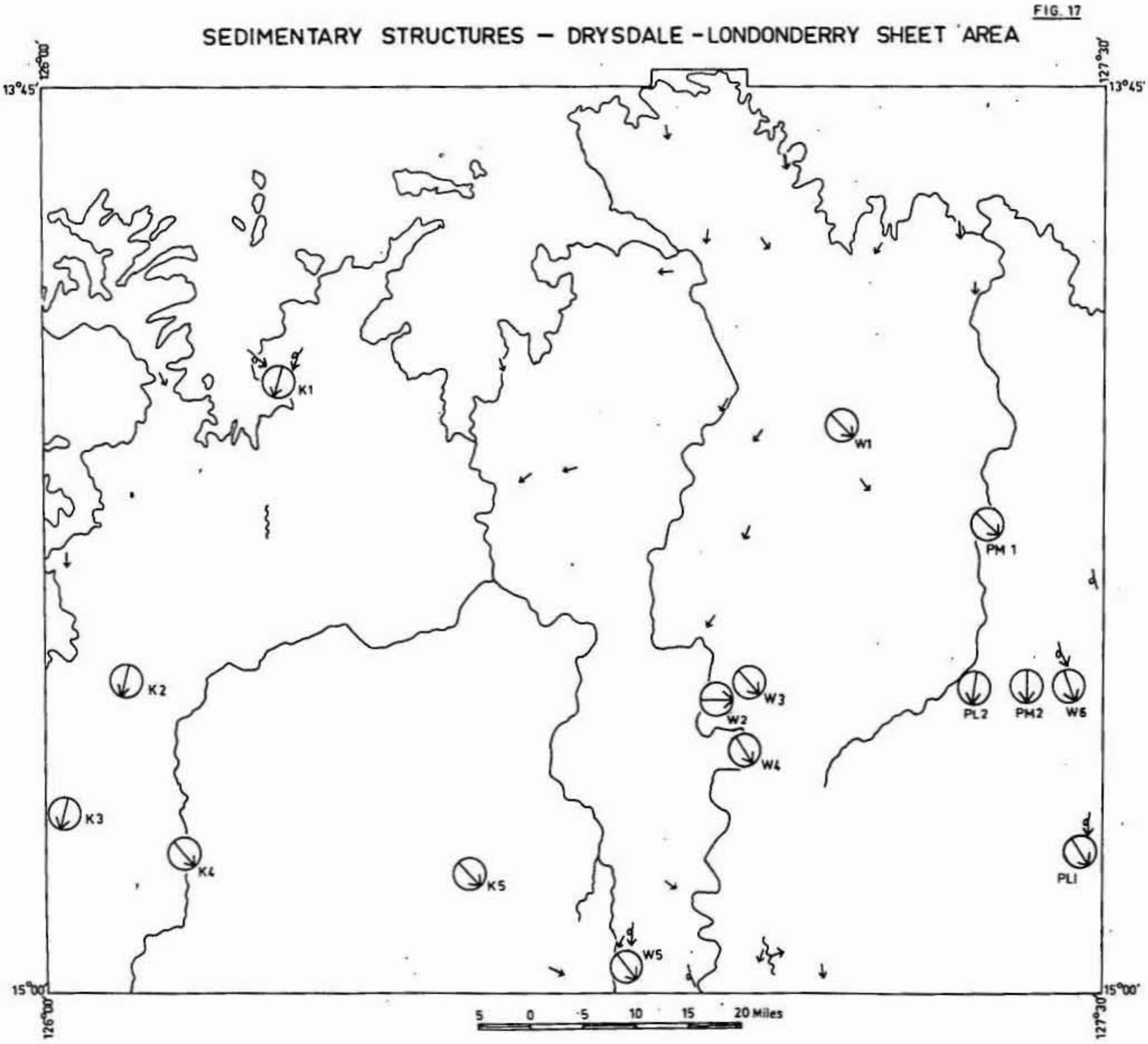
K - King Leopold Sandstone
W - Warton Sandstone
PL - Pentecost Sandstone (Lower)
PM - " " (Middle)

To accompany Record No 1966/55

D52/A9/7

FIG. 17

SEDIMENTARY STRUCTURES — DRYSDALE - LONDONDERRY SHEET AREA



Current source direction from cross-beds (25 readings)

" " " " " " (<5 ")

Trend of symmetrical ripple-marks

" " asymmetrical " " with current direction

Overturned cross-beds

" " " with direction of overturning

To accompany Record No 1966/55

D52/A9/8

Mineralogy

The sandstones consist of quartz, with trace amounts of heavy detrital minerals and locally with small amounts of feldspar or glauconite. Feldspar occurs in the King Leopold Sandstone in the northern part of the Sheet area, e.g. near Wade Creek; is common in the basal and topmost beds of the Warton Sandstone; in some of the sandstone beds in the Elgee Siltstone; and at certain horizons in the Pentecost Sandstone. The feldspar is mainly fresh and is found as well-rounded grains.

The heavy detrital mineral assemblage consists almost entirely of tourmaline and zircon. It reflects the maturity of the sediments, their good sorting, and also their age, since detrital minerals which are chemically more reactive tend to disappear with time. Epidote which is also present is not rounded and is probably of diagenetic origin.

Facies Changes

The principal facies changes found in the area have been described in the section on stratigraphy and are merely listed here as a basis for discussion.

(1) The Warton Sandstone increases markedly in thickness westwards.

(2) The Elgee Siltstone decreases in thickness north-westwards and the sand/silt ratio increases.

(3) The lower Pentecost Sandstone thickens northwards.

(4) The siltstone associated with the glauconitic sandstone at the base of the middle Pentecost Sandstone dies out northwards and is absent in the Sheet area.

(5) The middle Pentecost Sandstone thins northwards.

Provenance and Depositional Environment

As noted above the cross-bed directions indicate consistent currents from the north and north-west, but these may not have been the original sediment transporting currents. For example if the sediment had been redistributed by long-shore currents rather than estuarine, deltaic or shallow shelf sea currents normal to the coastline, the implied location of the source area would differ considerably from that suggested here.

Oscillation ripple-marks are rare in the Drysdale-Londonderry area but they nevertheless may be taken as indicating shallow water deposition, at least locally.

If ocean currents were responsible for redistribution of the sediment and for the cross-bedding observed, one would expect laterally persistent cross-beds to occur exclusively and trough types to be absent, and one would also expect uniformity of the original direction of dip of the foresets at least within a restricted area but this is not found. For example diagram K2 (of Fig. 16) shows cross-bed directions recorded from a single bed of King Leopold Sandstone all the measurements being made within an area of about 100 square yards. Although the plot of these measurements shows a well-defined maximum, there is a spread of about 120°, which cannot be explained by redistribution of the sediment by a long-shore current whose direction would be controlled by the shoreline and would be relatively constant, but is probably compatable with fluviatile or deltaic sedimentation, or with near-shore marine sedimentation in which the dominant sediment transporting currents were normal to the shoreline. Also the evidence of the overturned cross-beds implies strong current action which is not consistent with marine currents other than turbidity currents (e.g. the Gulf Stream current has a maximum velocity of ca 4 m.p.h.).

The facies changes noted, particularly the increase in the sand/silt ratio north-westwards, and the thickening of the arenites (except the Middle Pentecost Sandstone) northwards and westwards suggest that the shoreline and the source areas lay to the north and west of the basin.

The presence of feldspar in some of the sandstones is apparently anomalous when considered in conjunction with the high maturity implied by the good sorting and roundness and by the tourmaline- and zircon-rich heavy mineral assemblage. This can be resolved by postulating arid or semi-arid conditions in the source area, with a lack of chemical weathering but a high abrasion rate. Keunen (1960) for example found that abrasion of quartz grains in air transport was 100 to 1000 times greater than by water transport over the same distance.

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APPENDIX 5 : PETROGRAPHIC DESCRIPTIONS

(a) Drysdale (by D.C. Gellatly)

KING LEOPOLD SANDSTONE

R 65-16-1001 DY 5-18-1b

Hand Specimen : Pale buff coloured, coarse-grained, well-sorted quartz sandstone. Typical of most of King Leopold Sandstone.

Thin Section : This is a coarse-grained pure quartz sandstone. Minor accessory minerals are rare minute flakes of muscovite, well rounded 0-1 mm. grains of zircon and epidote and scattered grains of opaque altered feldspar. Quartz grains range in size from 2mm to 0.2 mm with most around 0.7 mm. They are well rounded and have optically continuous overgrowths of silica which forms the cement. Many quartz grains show lamellar structure; most show undulatory extinction; a few are mylonitic. Small inclusions of biotite and green tourmaline are present in quartz.

KING LEOPOLD SANDSTONE

R 65-16-1002 DY 5-28-1

Hand Specimen : White to pale cream, coarse-grained, poorly-sorted silica-cemented quartz sandstone.

Thin Section : A coarse-grained pure quartz sandstone. Contains minor accessory feldspar, muscovite and zircon and epidote. Cementing material is almost entirely silica, but minor amounts of sericite are also formed. Quartz grains range in size from 2 mm to 0.2 mm with the mean around 0.6 mm. They are moderately well rounded. Many of the grains are strongly deformed. A few show lamellar structure. Inclusions of sericite and goethite are present in a few grains, which are interpreted as being second cycle grains.

KING LEOPOLD SANDSTONE

R 65-16-1003 DY 15-27-1

Hand Specimen : Medium- to coarse-grained poorly-sorted purple-brown, silty quartz sandstone. About 200 feet below top of King Leopold Sandstone.

Thin Section : A coarse-grained limonitic quartz sandstone, consisting of quartz grains with limonite occurring as interstitial cement and as a thin coating on quartz grains; and minor accessory zircon, brown tourmaline and epidote. Quartz grains range from 1.0 mm to about 0.05 mm; and are sub-rounded to sub-angular. Most grains are deformed and show very irregular patchy extinction. Lamellar quartzes are absent.

KING LEOPOLD SANDSTONE

R 65-16-1004 DY 6-13-1

Hand Specimen : Pale grey-buff coloured, laminated, fine- to medium-grained well-sorted quartz sandstone. From upper part of sequence, near Pkc contact.

Thin Section : A medium-grained clayey quartz sandstone. In addition to quartz, contains abundant clay or sericite occurring interstitially, and minor accessory zircon, muscovite, tourmaline, rutile, epidote, and an opaque mineral (? magnetite). Quartz grains are sub-rounded and range in size from 0.5 mm to 0.1 mm. Many grains have overgrowths of silica cement which incorporates some of the earlier clay material. Most grains show undulatory extinction, but few polygonised grains are present. A few grains have lamellar structure.

WARTON SANDSTONE

R 65-16-1020 DY 13-25-1a

Hand Specimen : Medium-grained, well-sorted, pure white silica cemented feldspathic sandstone from topmost beds.

Thin Section : The rock is a medium-grained feldspathic sandstone. Consists of quartz ca 85% and feldspar ca 15% with rare zircon, tourmaline, epidote ?magnetite, and muscovite. Quartz grains are mainly 0.2 to 0.1 mm in size and are sub-rounded to sub-angular. They are mostly free from strain and from lamellar structure. Optically continuous silica surrounding the quartz grains forms the cementing material. Feldspar grains are partly turbid ? orthoclase but mainly fresh microcline.

WARTON SANDSTONE

R65-16-1021 DY 15-29-3

Hand Specimen : Coarse-grained well-sorted, well cemented, mottled pale purple-grey / pale orange brown quartz sandstone.

Thin Section : A coarse-grained quartz sandstone consisting almost entirely of quartz. Contains a few grains of chert, sericitized feldspar, muscovite and very rare minute zircons. Quartz grains range from 0.9 mm to 0.3 mm. The rock is very well sorted. They have optically continuous overgrowths of silica. Most grains show slight undulatory extinction, but a few strongly deformed ones are also present. Many show lamellar structure.

WARTON SANDSTONE

R 65-16-1022 DY 4-85-1b

Hand Specimen : Slightly feldspathic, pale purple-brown well-sorted coarse-grained quartz sandstone from basal beds.

Thin Section : A coarse-grained feldspathic sandstone. Contains slightly more than 10% of feldspar, and minor accessory zircon, tourmaline, epidote and turbid muscovite replacing biotite. The quartz grains have overgrowths of silica cement which in most cases is indistinguishable from the original grain. They range in size from 0.5 mm to 0.3 mm, and are mostly well-rounded. They show only slight undulatory extinction; embayed volcanic quartzes are present. Lamellar structure is rare. Feldspar grains are well rounded and mostly ca 0.4 mm. They are entirely of potash feldspar and apparently include microcline and partly inverted orthoclase.

CARSON VOLCANICS

R 65-16-1019 DY 2-15-1

Hand Specimen : Very pale orange-brown, coarse-grained, well-sorted feldspathic sandstone; from interbed about 280 feet above the base of the Carson Volcanics.

Thin Section : A coarse-grained feldspathic sandstone. Consists of quartz (ca 90%) and feldspar (ca 10%). Grain size ranges from 0.7 to 0.1 mm with the average around 0.5 to 0.4 mm. Grains are mostly sub-rounded to sub-angular, although some feldspars are well rounded. Quartz grains are mostly unstrained or only slightly strained; a few grains of quartz mylonite are present; some quartzes have dust trails; lamellar structure is absent. Feldspar grains include turbid orthoclase and orthoclase microperthite, and clear microcline. Trace amounts of tourmaline and zircon (as inclusions in quartz) and epidote are found.

CARSON VOLCANICS

R 65-16-1018 DY 11-57-1B

Hand Specimen : An amygdule of epidote bordered by a pink mineral occurring within a partly epidotised spilite.

Thin Section : The main item of interest is the pink mineral forming the outer zones of the amygdule. The amygdule has 3 zones. From the centre outwards these consist of epidote, plagioclase, and potash feldspar. The epidote occurs as elongate prisms up to 10 mm long, studded with numerous small inclusions of a poorly birefringent mineral. Plagioclase forms a 0.5 mm wide zone outside epidote; it has $X^{n}C = 14^{\circ}$ and -ve 2V. Therefore its composition is An_{30}. It is relatively clear and free from inclusions. It grades outwards into turbid potash feldspar through a zone of lamellar, plumose microperthite with which it is optically continuous.

CARSON VOLCANICS

R 65 -16-1019 DY 11-51-4

Hand Specimen : Purple grey medium grained amygdaloidal basalt (or ?spilite). Has amygdules of calcite; occurs immediately below sandstone bed; from measured section C2.

Thin Section : A fine grained amygdaloidal olivine-bearing tholeiitic spilite with an interstitial texture; consists of plagioclase (40%), secondary iron oxides (?25%), olivine (5%), potash feldspar (15%) and quartz with amygdules of chlorite, epidote and carbonate (amygdules ca 15%). Plagioclase occurs as very thin elongate laths showing finely developed albite twinning. It has +ve 2V and $X^{\wedge}C = 16^{\circ}$ and therefore its composition is about An_5. It has dust inclusions but is not sericitised. Potash feldspar is slightly cloudy and is locally micro perthitic; it is found mainly around a large carbonate amygdule. The interstitial iron oxides appear to be the result of replacement of iron-rich glass.

CARSON VOLCANICS

R 65-10-1015 DY 11-60-1a

Hand Specimen : A grey-brown coarse-grained spilite with 2 to 5 mm amygdules of chlorite, and rare pale blue quartz; topmost flow of Carson Volcanics.

Thin Section : A coarse-grained tholeiitic spilite; with a devitrified hyalinocrystalline texture. Consists of plagioclase (40%), chlorite pseudomorphs after pyrite (35%), amygdules (10%) and quartz (10%) with minor skeletal magnetite, carbonate and epidote. Plagioclase occurs as tabular crystals up to 1 mm long; they are turbid due to dust inclusions, and are replaced locally by carbonate; 2V is +ve and $\hat{XC} = 15^\circ$ and therefore its composition is An_5. Pyroxene pseudomorphs consist of a pale green slightly pleochroic length-slow chlorite similar to that found in the amygdules. The interstitial glass has recrystallised to form a fine-grained aggregate including iron oxide, quartz and epidote. Amydules consist of chlorite with minor amounts of quartz.

CARSON VOLCANICS

R65-16-1016 DY 11-60-1B

Hand Specimen : A very fine-grained dark grey siliceous siltstone or mud-stone.

Thin Section : Chloritic Siltstone. Consists of an extremely fine-grained (0.=1mm) aggregate of chlorite, detrital quartz, sericite, carbonate, interstitial cryptocrystalline silica with minor muscovite, sphene and iron oxides. Carbonate tends to be concentrated in thin laminae. The rock shows graded bedding.

CARSON VOLCANICS

R65-16-1005 DY15-27-3

Hand Specimen : Amygdaloidal coarse-grained spilite, dark grey-green. Specks of pyrite and chalcopyrite; from basal flow of Carson Volcanics. (Measured section C1).

Thin-Section : Coarse-grained spilite. Consists essentially of plagioclase, clinopyroxene, and magneto -ilmenite, with amygdules consisting of chlorite, carbonate and quartz and minor epidote and ?corundum. Plagioclase forms tabular grains up to 1.5 mm long; $\hat{XC} = 3^\circ$; composition is ca An20; it is highly sericitised. Pyroxene forms subhedral, subophitic grains up to 1mm consisting of pigeonite, locally partly altered to pale green chlorite. Magneto-ilmenite is partly skeletal and has been altered to magnetite plus leucoxene which is partly inverted to sphene. Amygdules have a zonal structure with fibrous green chlorite (?delessite) forming the outer zone; the carbonate (present only locally) and quartz; also minor penninite and ?corundum.

CARSON VOLCANICS

R65-16-1006 DY15-27-4

Hand Specimen : Dark grey, fine-grained non-amygdaloidal basalt; from measured section C1.

Thin Section : A fine to medium-grained spilite (or oligoclase basalt) with a hyalopilitic texture. It consists of plagioclase (35%), pyroxene (30%) and interstitial chlorite (10%) and glass (25%). Plagioclase occurs as 0.5 to 1.0mm sericitised laths of oligoclase and 0.2 to 0.3mm fresh laths of ?andesine with $\hat{XC} = 15^\circ$. Pyroxene occurs as slender 1 mm prisms of pigeonite. Chlorite is green, slightly pleochroic ?delessite. The interstitial glass is turbid and brown in colour, and contains small plagioclase microlites and exsolved needles of iron oxide. Minor amounts of calcite are also present.

CARSON VOLCANICS

R65-16-1007 DY15-27-5

Hand Specimen : Extremely fine-grained grey-green, slightly vesicular spilite; from measured section C1.

Thin Section : A fine-grained spilite with a sub-radiolitic, hyalopilitic texture. Consists of plagioclase, pyroxene, about 15% of partly recrystallised turbid brown interstitial glass, and minor chlorites (green, and orange-brown), and iron oxide. Small amygdules consist of green chlorite, sphene, quartz and epidote. Plagioclase occurs as slender 0.5 to 1mm grains having $X^\wedge C = 2^\circ$ and showing partial alteration to a pale green, highly birefringent chlorite. Pyroxene is pigeonite and occurs as very elongate prisms with very low 2V. Some pyroxenes are skeletal. They are present in the spherulites along with plagioclase.

CARSON VOLCANICS

R65-16-1008 DY15-27-6

Hand Specimen : Coarse-grained, spotted olive green epidosite.

Thin Section : A medium-grained quartz epidosite, consisting of epidote (50%), quartz (25%) and pyroxene (20%) with minor leucoxene and rare partly recrystallised skeletal magnetite. Epidote occurs partly in 2 to 3 mm clots which probably represent former amygdales, and partly as small euhedral crystals associated with quartz and pyroxene. Quartz forms hypantomorphic aggregates, with grains up to 1 mm long, and having straight interlocking crystal boundaries. Pyroxene is pigeonite which occurs as scattered elongate prismatic grains. Original magnetite still retains in part its skeletal form, but has been partly recrystallised and altered to hematite with consequent adjustment of crystal boundaries. The rock is an altered basic volcanics.

CARSON VOLCANICS

R65-15-1009 DY15-27-7

Hand Specimen : Very fine-grained, highly vesicular, grey-green spilite; has specks of chalcopyrite; from measured section C1.

Thin Section : A medium-grained olivine-bearing tholeiitic spilite. Consists of plagioclase (50%), pyroxene (15%), olivine (15%), interstitial glass (20%); minor skeletal magnetite, chlorite, and sphene with amygdules (10%) containing chlorite, quartz and carbonate. The rock has a hyalopilitic texture. Plagioclase which is partly altered to sericite and chlorite, as thin tabular crystals with $X^\wedge C = 016^\circ$ and +ve 2V; composition therefore about An_5. Pyroxene forms equidimensional grains and elongate prisms up to 0.3 mm. Both pigeonite and calcic augite are present. Olivine is completely pseudomorphed by a pale green chlorite or serpentine, and is rimmed by and cut by thin veinlets of orange-brown chlorite.

CARSON VOLCANICS

R65-16-1010 DY15-27-8

Hand Specimen : Coarse-grained vesicular, grey-green spilite; forms measured section C1 .

Thin Section : A coarse-grained two-pyroxene olivine-bearing spilite with a hyalinocrystalline texture. Consists of plagioclase (35%), pyroxene (10%), glass (45%), olivine (5%), and amygdales (10%). Plagioclase occurs as thin tabular and short prismatic crystals up to 2 mm long which are partly altered to chlorite and sericite; $X^\wedge C = 16^\circ$ and 2V is +ve. Pyroxene forms short euhedral prisms up to 0.5 mm long; both pigeonite and calcic augite are present. Olivine, forming scattered equant grains up to 1 mm is completely altered to a pale green serpentine cut by veinlets of orange brown chlorite or serpentine. Amygdules consist of chlorites (including a highly birefringent variety) and quartz. The glass contains numerous plagioclase microlites, and needles of iron ore.

CARSON VOLCANICS

R65-16-1011 DY15-27-9

Hand Specimen : Greasy brown finely laminated chert. Forms a 25 foot interbed in lower part of Carson Volcanics.

Thin Section : Chert with thin irregular laminae of fine grained epidote rich quartz sandstone. The chert layers consist of a cryptocrystalline silica mosaic with small scattered granules of epidote. The sandstone laminae consist of quartz ca 65%, epidote 30% and minor amounts of turbid potash feldspar; magnetite; and zircon. Zircon is much more abundant in the sandstone laminae in this rock than it is in the sandstones of the area.

CARSON VOLCANICS

R65-16-1012 DY15-27-10

Hand Specimen : Coarse-grained quartz epidosite; has traces of chalcopyrite.

Thin Section : A coarse-grained quartz epidosite consisting of quartz (65%), epidote (30%) and minor magnetite, potash feldspar, green and brown chlorites, and sphene. Quartz forms an equi-granular mosaic of grains with straight interlocking boundaries. Original boundaries of detrital quartzes are outlined locally by small turbid granules of sphene; the quartz contains abundant small blebs of alkali feldspar?, and small vermiform chlorites. Epidote occurs mainly as simple prismatic grains. Magnetites are euhedral to subhedral and non-skeletal. Sphene forms clouds of abundant minute granules. The rock is probably an altered sandstone.

CARSON VOLCANICS

R65-16-1013 DY15-27-11

Hand Specimen : Dark grey, medium-grained, non-amygdaloidal basalt; makes up much of upper part of sequence; from measured section C1.

Thin Section : A medium to coarse-grained two-pyroxene tholeiitic basalt with a hyalinocrystalline texture; consists of plagioclase (45%), pyroxene (20%), and glass (30%) with minor amounts of chlorite, skeletal magnetite, ?corundum, quartz and epidote. Plagioclase is almost completely altered to sericite; remaining fresh plagioclase has 2V +ve and $X \wedge C = 27^{\circ}$ and therefore has a composition An_{50}; it occurs mostly as tabular grains up to 1.5mm long; both pigeonite and calcic augite are present. The glass shows perlitic contraction cracks and contains microlites of plagioclase, iron oxide and skeletal pyroxene. Chlorite mostly fills small amygdules; a few patches may pseudomorph original olivine.

CARSON VOLCANICS

R65-16-1014 DY15-29-1

Hand Specimen : Pale grey brown, finely laminated chert with possible stromatolitic structures - $\frac{1}{4}$ to $\frac{1}{2}$ inch diameter cylindrical structures in which laminae are convex upwards. Comes from 3 foot thick chert bed overlying highest volcanics and underlying siltstone.

Thin Section : Consists of alternating layers of fine and cryptocrystalline silica. The fine-grained is relatively free from opaque inclusions and contains rare concentrically banded silica spherulites. The cryptocrystalline material contains abundant small specks of orange brown iron oxide and minute flakes of ?sericite, along with rare 0.01 grains of detrital quartz and muscovite. The ferruginous material is locally concentrated into 0.1 mm spots.

HART DOLERITE

R65-16-1030   DY14-67-1b

Hand Specimen : Medium-grained type with small spherical quartz xenocrysts. The thin section was cut in order to determine to what extent the siliceous material had been assimilated. c.f. 14-69-1a.

Thin Section : A coarse-grained dolerite with an ophitic texture. Consists of highly sericitised plagioclase and clinopyroxene with minor skeletal magnetite, chlorite, quartz and leucoxene. The quartz occurs as small scattered grains and as distinct xenocrysts up to 3 mm across. There is no micropegmatite. The larger quartz xenocrysts have localised turbid marginal zones, and a few show development of newly-grown pyramid terminations marginally. Most however are rounded or partly rounded and probably represent detrital quartz grains which have suffered very little recrystallisation or assimilation.

HART DOLERITE

R65-16-1028   DY15-23-1

Hand Specimen : Coarse-grained magnetite-rich dolerite with elongate bladed pyroxenes. c.f. similar types from Lansdowne.

Thin Section : A coarse-grained dolerite with a sub-ophitic texture, consisting of plagioclase (35%) and pyroxene (30%) with minor magnetite, chlorite and granophyric quartz/potash feldspar intergrowths (25%). Plagioclase occurs as euhedral to subhedral tabular crystals up to 4 mm long. It is partly altered to sericite and is strongly zoned from An_{60} cores to An_{35} margins. Pyroxene includes pigeonite (clear) and ?calcic augite (streaky); the former is colourless to very pale brown, and the latter pale green, it occurs as euhedral to subhedral prisms up to 4 mm long. Magnetites are up to 1.5 mm across and are skeletal. Chlorite is interstitial, and in part appears to have been derived through alteration of pyroxene; it is associated with minor amounts of ?sphene.

ELGEE SILTSTONE

R65-16-1024   DY13-25-1(s)

Hand Specimen : Pale cream fine-grained flaggy slightly feldspathic quartz sandstone. From measured section.

Thin Section : A fine-grained feldspathic sandstone consisting of quartz ca 90% and feldspar 10% with rare accessory muscovite, zircon, tourmaline and epidote, and scattered rounded grains of rhyolite. Cementing material is dominantly silica, but scattered patches and intergranular films of sericite. Quartz (and feldspar) grains range in size from 0.2 mm to 0.05 mm with a medium diameter of about 0.1 mm. Grains are sub-rounded to sub-angular. Quartzes are mostly unstrained and free from lamellar structure. Feldspar is apparently entirely of microcline (probably low to maximum varieties).

ELGEE SILTSTONE

R65-16-1025 DY-25-1(f)

Hand Specimen : Fine-grained, red-brown, silty quartz sandstone or siltstone. From measured section.

Thin Section : A coarse-grained feldspathic quartz siltstone. Consists of quartz and feldspar with minor amounts of interstitial sericite, muscovite, biotite, blue-green tourmaline, rare zircon, and opaque ?magnetite and limonite. Grains are mostly around 0.05 mm, i.e. less than the minimum for a sandstone (according to Pettijohn). Quartz grains are unstrained and free from lamellar structure. Feldspar is almost entirely microcline, with possibly a few grains of orthoclase.

PENTECOST SANDSTONE (L)

R65-16-1033 DY15-29-8

Hand Specimen : Medium-grained, white, wilica-cemented, quartz sandstone from base of Lower Pentecost Sandstone.

Thin Section : Medium-grained quartz sandstone consisting almost entirely (ca 98%) of quartz grains with scattered rounded mylonite and rhyolite rock fragments, and rare tourmaline, epidote (diagenetic) and zircon. The rock has a silica cement. Quartz grains range in size from 0.5 to 0.1 mm with a mean grain size of about 0.3 mm. About 30% of quartzes have marked undulose extinction, and many grains show lamellar structure (possibly vein quartz).

PENTECOST SANDSTONE (L)

R65-16-1034 DY7-50-1a

Hand Specimen : Pale purple brown mottled medium-grained slightly feldspathic quartz sandstone. Has chocolate brown clay pellets up to ½ inch across.

Thin Section : A coarse-grained feldspathic sandstone. Consists of quartz 85%, feldspar ca 13%. Clay pellets ca 2%, and minor sericite, tourmaline, zircon, epidote, muscovite, and altered biotite. Quartz and feldspar grains range from 0.6 to 0.1 mm with medium diameter ca 0.3 mm. A few quartzes are strongly deformed; most are unstrained or only slightly strained. Rare grains show lamellar structure. Feldspar grains are mainly microcline (probably high to low types) with a few grains of turbid orthoclase and highly sericitised feldspar (?possibly original plagioclase). Clay pellets, up to 1 mm across and 5 mm long, consist of dark brown opaque material.

PENTECOST SANDSTONE

R65-16-1035 DY15-31-1(c)

Hand Specimen : Buff to pale orange brown medium-grained quartz sandstone, well sorted: from upper part of Lower Pentecost Sandstone.

Thin Section : A medium-grained quartz sandstone consisting almost entirely of quartz with a few scattered grains of turbid feldspar, chert, blue-green tourmaline, epidote and very rare zircon. Quartz grains range from 0.1 to 0.4 mm with the median diameter about 0.25 mm. They are rounded to sub-rounded and have an optically continuous border of silica cement. The grains are mostly slightly strained or unstrained. A few have lamellar structure. Rare composite grains (?from metamorphic quartzite) are found.

PENTECOST SANDSTONE

R65-16-1036 DY12-79-1(b)

Hand Specimen : Creamy-white/pale purple-brown, coarse-grained poorly-sorted silica cemented quartz sandstone with well rounded quartz grains. From topmost beds of Lower Pentecost Sandstone. Most rocks of this horizon are finer in grain than this.

Thin Section : A coarse-grained quartz sandstone consisting almost entirely of quartz with trace amounts of limonite forming a film round quartz grains, rare fragments (grains of siliceous siltstone) and zircon, epidote and tourmaline. Quartz grains are well rounded and range in size from 1.5 to 0.1 mm. The rock is rather poorly sorted. Quartzes are only slightly strained. Highly deformed grains and ones with lamellar structure are rare. Some grains have abundant acicular birefringent inclusions. The rock has a silica cement.

PENTECOST SANDSTONE (M)

R65-16-1037 DY13-27-1

Hand Specimen : Dark purple-brown glauconite-bearing sandstone from the base of the Middle Pentecost Sandstone. Sample submitted for age determination.

Thin Section : A fine-grained ferruginous, glauconite-bearing quartz sandstone, consisting of quartz ca 90-95%, glauconite ca 3-4% and scattered grains of feldspar, tourmaline, epidote, iron oxide, and muscovite. The rock has a silica cement and each quartz grain has a thin film of iron oxide which pre-dates the cement. Quartz grains range from 0.3 to 0.07 mm with a mean grain size of about 0.1 mm. The grains are mostly sub-rounded and unstrained. Glauconite grains are well-rounded, consist of a fine-grained mosaic of glauconite crystals, and average 0.3 mm in size. The greater size of the glauconite grains relative to the quartz may be the result of winnowing action.

PENTECOST SANDSTONE (M)

R65-16-1038 DY11-67-1

Hand Specimen : Very pale pink fine-grained, well-sorted, feldspar-bearing quartz sandstone. From beds overlying glauconitic sandstone.

Thin Section : Medium-grained quartz sandstone. Consists of quartz ca 98-99% with minor accessory feldspar, limonite, muscovite tourmaline, epidote and zircon. Silica cement fills interstices, is in optical continuity with detrital quartzes and is difficult to distinguish from them. Grain size is 0.1 to 0.2 mm. The rock is very well sorted. Quartz grains are unstrained or slightly strained. Feldspar grains which are very rare are turbid potash feldspar and slightly sericitised.

PENTECOST SANDSTONE (M)

R65-16-1040 DY6-45-1b

Hand Specimen : Pale grey-buff, medium grained well sorted feldspathic sandstone, from near the top of the Middle Pentecost Sandstone. Underlies DY-45-1a.

Thin Section : Medium-grained feldspathic sandstone; consists of quartz ca 95% and feldspar 5% with trace amounts of muscovite, zircon, tourmaline and epidote and rare grains of chert. Quartz grains range in size from 0.1 to 0.3 mm and are mainly sub-rounded. Most quartzes are unstrained or only slightly strained. A few mylonitic grains are present. They have an optically continuous rim of silica cement. Feldspar is mainly microcline with subsidiary turbid ?orthoclase.

PENTECOST SANDSTONE (M)

R65-16-1039 DY6-45-1a

Hand Specimen : Coarse-grained, white, well-sorted, quartz sandstone with well-rounded grains. From topmost beds of Middle Pentecost Sandstone.

Thin Section : A coarse-grained quartz sandstone, consisting almost entirely of quartz with a few scattered grains of rhyolite (similar to matrix material of Whitewater Volcanics) and chert, and rare tourmaline and zircon. The rock has a silica cement and is well sorted. Quartz grains range in size from 1 mm to 0.4 mm. and are well-rounded. Most quartz grains are slightly strained. A few are highly deformed. Some show dust trails and a few show lamellar structure. Grain boundaries are outlined by a very thin film of limonite.

HART DOLERITE (?)

R65-16-1052 DY11-51-3

Hand Specimen : A medium-grained dark grey dolerite. It is intruded into Carson Volcanics.

Thin Section : A medium-grained dolerite with an interstitial texture; consists of plagioclase pyroxene magnetite (5%) olivine pseudomorphs (5%) interstitial glass (15%) and chlorite (5%). Plagioclase occurs as tabular grains up to 1.5 mm long; it is fresh and is strongly zoned with An_{50-55} cores and An_{35} margins. Pyroxene, which forms discrete euhedral and subhedral grains, is pigeonite. Olivines are completely replaced by green and orange brown chlorites or serpentine. Magnetites are small and mostly non-skeletal. The glass is pale red-brown in colour and probably consists mainly of potash feldspar. The presence of glass in a supposed dolerite intruded into basic volcanics may appear anomalous. A dolerite intruded into the King Leopold Sandstone (where there is no chance of mistaking it for a basalt) however also contains interstitial glass. The basic composition of the plagioclase, its lack of alteration, the absence of amygdules, and the generally non-skeletal nature of the magnetites all indicate closer affinities with other samples of dolerite from the area than with the Carson Volcanics.

HART DOLERITE

R65-16-1031 DY5-15-1.2

Hand Specimen : A fine-grained olive-green epidosite with feldspar pseudomorphs, from a vein within the Hart Dolerite near its contact with King Leopold Sandstone.

Thin Section : A fine-grained epidosite consisting mainly of a granoblastic aggregate of clouded quartz, and aggregates of epidote and pigeonitic pyroxene and highly birefringent uniaxial +ve ?scapolite, and minor ilmenite altered to leucoxene. There is no sign of plagioclase pseudomorphs in thin section. The altered ilmenite and the presence of pyroxene suggest that this rock has been formed by replacement of the dolerite.

HART DOLERITE

R65-16-1029 DY14-69-1a

Hand Specimen : Fine- to medium-grained dolerite from near base of outcrop. c.f. 14-69-1b.

Thin Section : A medium grained dolerite with an ophitic texture; consists of plagioclase (55%) pyroxene (25%) magnetite (5%) olivine pseudomorphs (5%) and interstitial glass (5%), with minor potash feldspar, quartz, and chlorite. Plagioclase occurs as thick tabular grains up to 1 mm long. It is zoned with cores of Au_{55} and margins of about An_{30-35}; it is mostly fresh but a few grains are partly replaced by sericite and chlorite. Pyroxene includes both pigeonite and calcic augite; it forms small subhedral grains and large ophitic ones up to 2 mm. Magnetites are small, euhedral and mostly non-skeletal. Olivine (up to 0.3 mm) is partly intergrown with plagioclase and is completely altered to pale green serpentine. Interstitial glass is turbid, pale brown in colour and probably consists mainly of potash feldspar.

LATERITE

R65-16-1041 DY13A-04-2

Hand Specimen : A pale cream coloured pisolitic aluminous laterite or bauxite; it locally has a pale pink-grey matrix between the pisolites.

Thin Section : Aluminous laterite. Consists almost entirely of opaque minerals ranging from pale cream to red brown. The only translucent mineral occurs as aggregates of colourless flaky material (ca 5%) with first order birefringence and straight extinction. The rest of the rock is composed of pisolites and oolites of cream to pale brown coloured material in a red-brown limonitic matrix. Many of the pisolites are composite having scattered oolites in a structureless, or concentrically banded matrix. Very rare quartz grains are also present.

LATERITE

R69-16-1043 DY1-82-2

Hand Specimen : A brown pisolitic rock consisting of dark brown and grey iron-rich pisolites in a fine-grained yellow-brown matrix.

Thin Section : The larger pisolites consist of opaque dark grey ?hematite. Smaller ones consist of opaque yellow-brown oolites cemented by structureless material of the same composition. The matrix consists of opaque yellow brown oolites cemented by aggregates of a flaky colourless, translucent, mineral with first order birefringence and $X \hat{} C + 20^{o}$.

(b) Londonderry (by A.F. Trendall)*

Report : B.M.R. Reg. Nos. 65160001-65160007 inclusive are from the Carson Volcanics. 65160008 is a sandstone within the Carson Volcanics, 65160009 and 65160015 are from the King Leopold Sandstone, and 65160010 - 65160014 inclusive 5 samples of the Warton Sandstone. All rocks are referred to by the final two figures of their B.M.R. Reg. Nos. in the report below:

01-07 fall clearly into 2 groups. 01, 02, 03, 06 and 07 are all dark green or grey aphanitic structureless lavas, although 03 has part of a large siliceous amygdale adhering, while 04 and 05 are speckled rocks, with dark green blotches in a pale matrix. The distinction between these two groups is equally valid beneath the microscope, although this seems almost coincidental, since although 04 and 05 are coarser rocks the dark blotches are amygdales, and the impression that the speckling gives of coarse grain is false. Although grain-size is locally variable both 04 and 05 have about 60% of their volume made up of subhedral plagioclase laths, of average length 0.5 - 1.0 mm and elongate about 5:1, arranged at random in a close-packed meshwork. The interstices are filled variously by no more than 10% of augite in smaller and stumpier laths, by epidote, by aggregates of finely radiate chlorite, or by one or other varieties of a wide textural range of originally glassy materials devitrified to fine feathery aggregates of feldspar, pyroxene and chlorite. The plagioclase is albite-oligoclase, and slightly cloudy. Evenly scattered irregular amygdales filled by fine chlorite aggregate with included euhedral epidotes form the dark blobs of the hand specimens.

01, 02, 03, 06 and 07 all differ from the two rocks just described in their relatively finer grain-size. Again, over half the volume of the rock consists of plagioclase, but the lath length rarely exceeds 0.5mm and each is elongate 10:1 or more. These more needle-like laths are usually arranged in radiate groups or rosettes. The augite has a similarly needle-like habit and is commonly arranged in parallel aggregates alternately with feldspar laths. The polygonal interstices are occupied by a dense devitrified aggregate of finer feathery feldspar and pyroxene, skeletal opaque plates often arranged in regular patterns, together with epidote and chlorite. The plagioclase is again albite-oligoclase, and this is commonly replaced by quartz. All five rocks have amygdales of some kind. 01 and 02 both have patches with abundant angular areas about 0.05 mm across filled by cherty quartz mosaic. Their shapes suggest replacement of coarse pyroxenes. 03 has abundant irregularly amoeboid amygdales up to about a millimetre across, strikingly zoned from rim to core with finely radiate chlorite, chalcedony, more chlorite, and more coarsely crystalline quartz. Epidote appears in this zonal sequence in various positions. 06 has angular chloritic areas pseudomorphous after some unknown mineral. In 07 some of the shapes and textural relics suggest derivation from olivine.

From these slides alone these lavas have a strong textural resemblance to some basalts, but the plagioclase is sodic throughout, and it is quite possible that they were andesites.

Among the sandstones there is an obvious difference in macroscopic appearance between the two groups. 08, 09 and 15 from the Carson Volcanics and the King Leopold Sandstone, are white tough quartzitic-looking rocks, whereas 10 - 14, the 5 Warton Sandstone samples, are, by contrast, all pale reddish-brown (often blotched or mottled), and slightly friable. These differences are less apparent beneath the microscope: here, all these sandstones have a mosaic of quartz grains almost entirely between 0.2 and 1.0mm in diameter. (Part of this range is of course due to small cross-sections of large grains, and the sorting is better than the impression given by it).

In all slides a minority of grains has an internal 'ghost' line marking the original grain boundary, but in all rocks subsequent overgrowth of quartz has reduced the porosity effectively to nil. Strain and distortion of the grains is variable: although strain extinction is general it is least obviously developed in 15 and most strongly in 10. In two features only can any sort of distinction be made between the Warton Sandstone group and the remainder: the Warton Sandstone samples often have a thin opaline layer between grains (quartz grains, not sand grains), and secondly in these rocks there is a very slight scattering of cherty quartz and micaceous grains, both of which are absent from the Carson Volcanics and King Leopold Sandstone.

From this collection it seems unlikely that if any petrographic difference exists between the various sandstones, it could only be detected by much closer sampling, and that the simple hand specimen criterion of colour is more sensitive than thin sectioning as an index for at least some sort of lithological differentiation.