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THE GEOLOGY OF THE LANSDOWNE 1:250,000 SHEET SE 52/5, WESTERN AUSTRALIA.

by

D.C.Gellatly, G.M.Derrick & K.A. Plumb

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SE 52/5 WESTERN AUSTRALIA

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THE GEOLOGY OF THE LANSDOWNE 1:250,000 SHEET SE 52/5 WESTERN AUSTRALIA

SUMMARY

The geology of the Lansdowne 1:250,000 Sheet in the East Kimberley Division, Western Australia is described, based on reconnaissance mapping. The topography over most of the area is rugged and exposures in general are good. The King Leopold and Durack ranges dominate the area physiographically.

Precambrian rocks cover the area entirely, except for rocks of Palaeozoic age which crop out in the south-western corner, and scattered areas of Cainozoic soils. The Precambrian formations are provisionally separated into Archaean, and Middle and Upper Proterozoic divisions. Most of the rocks in the area are assigned to the Middle Proterozoic.

The oldest rocks present in the area belong to the Halls Creek Group of ? Archaean age. It consists of shales and greywackes which have been tightly folded and metamorphosed to low Greenschist Facies. This Group is unconformably overlain by the Whitewater Volcanics which constitute the basal formation of the Middle Proterozoic succession. Granites of the Lamboo Complex, of uncertain age, intrude the Halls Creek Group and Whitewater Volcanics.

The Whitewater Volcanics are overlain with slight angular unconformity by the Middle Proterozoic Kimberley Basin Succession comprising the Speewah, Kimberley and Bastion Groups. These form part of a continuous sequence and consist respectively of feldspathic arenites and lutites; arenites and basic volcanics with minor lutites and carbonates; and lutites. This succession is extensively intruded by dolerite and minor associated granophyre.

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

The Palaeozoic rocks, consisting of Devonian reef limestones and Devonian to Permian conglomerates, lie unconformably on Lamboo Complex granites.

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

No mineral deposits of economic importance have been found in the area but traces of copper and lead have been found in quartz veins in the Whitewater Volcanics. Small veins of fluorite occur locally near faults. Surface water persists throughout the year in scattered rock holes and springs, and is supplemented for stock watering by wells and shallow bores.

This part of the Kimberley may be of future importance because of the proposed Fitzroy Irrigation Scheme with storage dams in the Lansdowne Sheet area.

INTRODUCTION

Present Investigation

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

Location and Access

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

Lansdowne Homestead, situated near the geographical centre of the Sheet area, is approximately 300 and 340 miles by road from Derby and Wyndham respectively. These towns are commected by way of Halls Creek by a regularly maintained gravel road from which spasmodically maintained station tracks give access to the Lansdowne Sheet area from Fitzroy Crossing, and from near Halls Creek. Access to the north-western part of the Lansdowne Sheet area from Derby is by way of Mount House. Within the area graded station tracks connect the homesteads, from which sparse subsidiary tracks radiate to bores and stockyards. All roads in the region are impassable at times during the wet season.

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

Population and Industry

The only centres of permanent habitation are the homesteads of Glenroy, Tableland, Mornington, Bedford Downs and Lansdowne. Elgee Cliffs, a small property 20 miles south-west of Bedford Downs is now abandoned. The population is estimated to be approximately 250, the majority being aboriginals employed as stockmen by the station owners. Cattle raising is the only industry of any importance, an extension to this being the Air-Beef meat-works at present based on Glenroy.

In view of the proposed irrigation scheme in the Fitzroy Basin with storage dams in the Lansdowne Sheet area at Diamond Gorge, Pyra Gorge, and on the Leopold River, the area may assume greater importance in the foreseeable future.

Climate and Vegetation

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

The Lansdowne sheet lies almost entirely between the 20" and 25" isohyets. The mean annual rainfall ranges from 18" to 20" at Lansdowne in the central south, to near 25" at Glenroy in the north-west, almost all of the rain falling between December and March.

Maximum temperatures during the day are uniformly high throughout most of the year, ranging between 90°F. and 100°F. for all months except June, July and August, when the mean maximum temperature is near 80°F. Mean minimum temperature for the same periods are 75°F. and 50°F. respectively, though homesteads such as Tableland, located on the Kimberley plateau, often record frosts during July, the coldest month. November is the hottest month with a mean maximum temperature of 100°F. Evaporation rates are high, approximately 100" to 110" per year, the highest rates occurring during September, October and November. The majority of waterholes are, as a result, only semi-permanent.

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

The northern plateaux of the Sheet area form open woodlands with scattered eucalypts, scrub and grasses, while to the south, scrub and spinifex are more common, and the eucalypts more stunted. Along most water-courses moderately dense stands of eucalypts occur, while many of the spring-fed gorges within the King Leopold and Durack Ranges contain abundant fern growth and pandanus palms. A common eucalypt type throughout the area is E. brevifolia, or snappy gum.

Basaltic country, in general, carries fine grasses, and supports box and coolibah (E. microtheca) and bloodwoods (E. pyrophora and E. terminalis). In areas of sandstone bedrock, woolly butt (E. miniata), messmate (E. tetra-donta) and the cypress pine (Callitris verrucosa) are common tree types. (Teakle, 1944; Jutson, 1950). The baobab or bottle tree is commonly well developed in limestone areas of the plateau region, and in open sandy water-courses in granite and sandstone.

Survey Methods

Geological investigations were carried out by means of Land-Rover and foot traverses, the more inaccessible areas being covered by helicopter reconnaissance, during which 25 flying hours were logged. Air photographs flown in 1949 at a scale of 1:50,000 and air photo mosaics covering the area were made available by the Royal Australian Air Force. Geological data were plotted initially on 1:50,000 scale Royal Australian Survey Corps topographic base maps prepared from air photographs. These maps were then photographically reduced to a scale of 1:250,000 and redrawn, using a Royal Australian Survey Corps topographic base map on this scale, compiled in 1961 from the 1949 air photographs.

Previous Work

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

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

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

PHYSIOGRAPHY

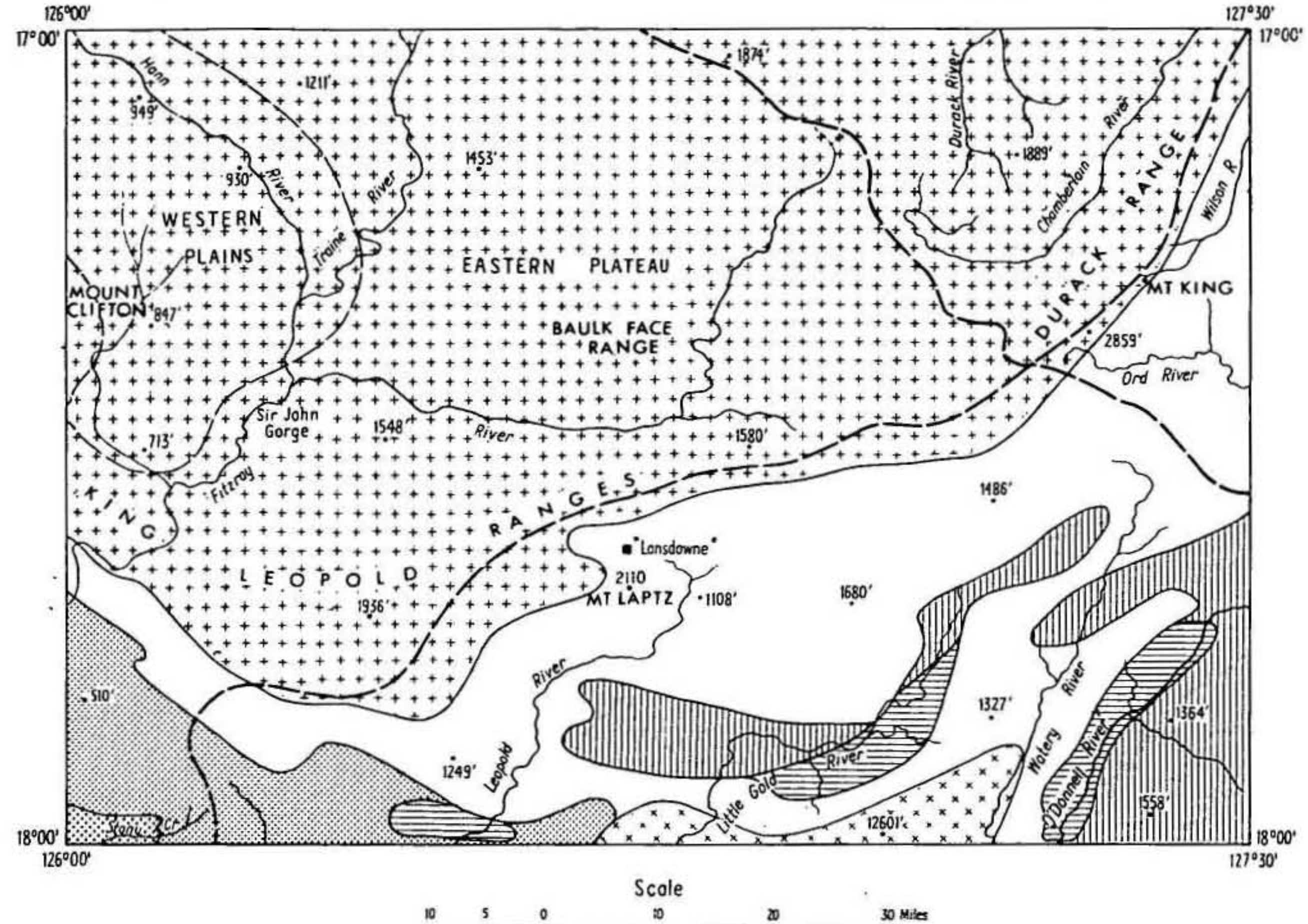
Observations in the Lansdowne Sheet area are in agreement with those of Dunnet and Plumb in the Lissadell Sheet area (1964), who found that physiography and rock types are closely related. The physiographic divisions of the Lansdowne Sheet are a natural continuation of those delineated in the East Kimberley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

Wright (1964) recognises two broad divisions - a <u>North Kimberley Division</u> and a <u>Fitzroyland Division</u>. Within the Lansdowne Sheet area they consist of the Kimberley Plateau Province and the Kimberley Foreland Province on the one hand, and the Fitzroy Upland Province and Fitzroy Plains Province on the other. The divisions recognised in the Lansdowne are are:

This report	Wright 1964
(a) Kimberley Plateau	Kimberley Plateau Province
(b) Mt. Cumming Plateau	Kimberley Foreland Province
(c) Kimberley Foothills	
(d) Bow River Hills	
(e) Onslow Hills	Fitzroy Uplands Province
(f) Halls Creek Ridges	
(g) Fitzroy Ranges	Fitzroy Plains Province

Fig. 1

PHYSIOGRAPHIC SKETCH MAP - LANSDOWNE 1:250 000 SHEET AREA



Reference

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(a) The Kimberley Plateau occupies more than half of the Sheet area, and is the most outstanding physiographic unit in the North Kimberley Division of Jutson (1950) and Wright (1964). The southern margin is a line of rugged cliffs with heights of up to 300 feet and elevations ranging from 1400 ft. to 2800 ft. above sea level, the average elevation of the plateau being between 1500 ft. and 2000 ft. The Kimberley Plateau is an uplifted peneplain which can be subdivided into the Eastern Plateau and the Western Plains (Wright, 1964). The former represents the High Kimberley Surface of Wright, and consists of structural benches, gently dipping cuestas, and plateaux bounded by scarps up to 300 ft. high, with bedrock predominantly of resistant sandstone.

These plateau areas are developed on Mount Clifton, Baulk Face Range and the Durack River headwaters, generally where shales and siltstones underlie resistant sandstones. The isolated nature of the plateaux distribution reflects the gentle warping of the Kimberley Plateau which took place during the Tertiary. Erosional remnants of the Eastern Plateau province occur in the south and south-east of the Sheet area. Wright also recognises a Low Kimberley Surface forming dissected plains (100 ft. to 1500 ft.) in the main headwater valleys of the eastern plateau, but this surface has generally been obscured by a further cycle of erosion which developed his Fitzroy Surface. In the Kimberley Plateau region this surface is represented by the subsequent valleys of the Chamberlain and Upper Fitzroy Rivers, and by the Western Plains which have an average elevation of 900 ft. and relief of approximately 100 ft. The Western Plains, lying west of the Hann River, have formed over the softer and weaker siltstones and shales of the Mount House Group, illustrating the close adjustment of erosional surface to lithology.

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

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

Figure (2). Physiography of the Halls Creek Group. K.A.P.

Typical physiography of the southern part of the Lansdowne Sheet area. Whitewater Volcanics and Hart Dolerite are present in the foreground, and are faulted against the Halls Creek Group in the middle distance, which shows typical "hummocky" topography; vertical Speewah Group in the distance. Locality 8 miles east-northeast of Pyra Gorge looking east.

Figure (3). Physiography of the Kimberley Plateau. K.A.P.

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

1200 feet. In the Lansdowne Sheet area the drainage is deeply incised, dendritic and essentially obsequent.

(c) Kimberley Foothills. These coincide with the Kimberley Foreland Province Division (Jutson, 1950 and Wright 1964) which extends from the King Leopold Ranges southwards and westwards into the Fitzroy Basin. The foothills range in elevation from 100 ft. to 1500 ft. above sea level, with an average elevation of 1300 ft. and form a complex system of hogbacks and cuestas interspersed with extensive tracts of undulating hills and broad valleys. These latter features are characteristically developed on outcrops of dolerite and show in places a strong development of black soil, which generally yields fair pastures. The foothills, according to Wright (1964) constitute a part of the Low Kimberley erosional surface, but mesas with relief of up to 500 ft. are erosional remnants of a previously more extensive Kimberley Plateau (or High Kimberley) surface.

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

(d, e) Bow River Hills, Onslow Hills. These two divisons, which are characteristically developed on granitic terrain, are similar in physiographic type, and differ only in areal distribution and in elevation.

They are natural subdivisions of the Fitzroy Uplands Province and coincide respectively with the Eastern Uplands and North-Eastern Mountain Ranges of Wright (1964). They are areas of relatively low relief forming on crystalline basement rocks cropping out in the south-eastern, southern and south-western parts of the Lansdowne Sheet area. Both divisions are characterised by low rounded bouldery hills and isolated tors, between which are narrow pediments and pockets of alluvium and sandy soil, supporting a poor and sparse vegetation. Drainage is markedly dendritic, but in the Onslow Hills is strongly joint-controlled in parts. The Bow River Hills have an average elevation of approximately 1400 ft., the Onslow Hills being lower, with an average elevation of 800 ft. Wright (1964) notes that both divisions represent the Low Kimberley erosion surface, and it seems probable that the lower elevation of the Onslow Hills is due to transgression of the Fitzroy erosion surface from the south, where it forms broad plains as a result of complete dissection of the Low Kimberley surface.

(f) Halls Creek Ridges. These are a further subdivision of Fitzroyland, and form part of the Eastern Uplands of Wright (1964). This physiographic unit is developed exclusively on rocks of the Halls Creek Group, which are isoclinally folded metasediments of low Greenschist Facies in the Lansdowne Sheet area.

The tightly folded nature of the rocks has produced a series of discontinuous ridges and sub-parallel subsequent valleys, in which the minor drainage is developed. Gully development on the sides of the subsequent valleys is common. As a result of headwater erosion in these gullies, the ridges are breached and downcutting at these points has produced a major drainage pattern at right angles to the structural grain of the sediments. These major streams locally show strong meander development and appear to be superimposed. Average elevation of the Halls Creek Ridges is 1000 ft., and relief of the low rounded hills is between 100 ft. and 300 ft. Soil cover is poor because of the steeply dipping nature of the bedrock, and supports only thick spinifex and rare stunted eucalypts.

(g) Fitzroy Ranges. This division is best developed on the Mount Ramsay Sheet area, and extends into the far south-western corner of the Lansdowne Sheet. It consists of broad sandy plains from which walls of massive Devonian reef limestone rise sharply to form relief of approximately 100 ft.

STRATIGRAPHY

A summary of the stratigraphy of the Sheet area is given in Table 1. The nomenclature used will be fully defined in Dow and Gemuts (in prep.) and Plumb (in prep.). The current usage is based essentially on that of Guppy et al (1958) and Harms (1959), but differs from these works in that certain of the units have been further subdivided on the basis of the present more detailed work.

The classification of the Precambrian formations into Archaean, Middle Proterozoic and Upper Proterozoic is based on preliminary radiometric dating carried out by the Bureau of Mineral Resources in conjunction with the Australian National University (Bofinger, pers. comm.). This age-determination work is still in progress, and absolute ages cannot be given at present. The upper limits of the Archaean, Lower Proterozoic and Middle Proterozoic in North Australia are provisionally taken at 2,500, 1,800, and 1,400 million years respectively.

Most of the rocks exposed in the Lansdowne Sheet area are of Precambrian age, but minor outcrops of Palaeozoic rocks are found in the south-western corner. All the Precambrian rocks present are assigned to the Middle Proterozoic with the exception of the Halls Creek Group and Tickalara Metamorphics which are tentatively regarded as being of Archaean age, and the Mount House Group which is of Upper Proterozoic age.

ARCHAEAN

HALLS CREEK GROUP.

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

The name Halls Creek Group was first used by Matheson and Guppy (1949) for rocks which had previously been included in the "Mosquito Creek Series" (Matheson and Teichert, 1946). The term "Olympio Creek Formation" was used by Smith (1963) and Dow et.at. (1964), who put forward a subdivision of the Halls Creek Group, including in it the McLintock Greenstones of Matheson and Guppy, (op. cit.). The name has now been changed to Olympio Formation, and is included in the revised stratigraphical succession of the Halls Creek Group. (Dow and Gemuts, 1964).

The formation crops out in the southern part of the Lansdowne Sheet area in the cores of several major anticlines, scattered over a 70-mile-long belt, and has a total area of outcrop of about 280 square miles. The rocks are strongly folded and no estimate of thickness can be made.

The Halls Creek Group rocks form irregular hummocky topography consisting of low rounded hills with densely spaced subsequent minor streams and meandering consequent major streams deeply incised into bedrock.

In most places in the area the Olympio Formation is overlain by the Whitewater Volcanics. In general the strike of the two formations is parallel at the contact but an unconformity is inferred from localised differences in dip and from the much greater degree of deformation exhibited by the underlying rocks. At a locality ten miles south-east of Torrens Yard however, a strong angular unconformity is present between the two formations. In certain places in the south-eastern part of the Sheet area the Olympio Formation is overlain with strong angular unconformity by the O'Donnell Formation and by the King Leopold Sandstone. The Olympio Formation is intruded by granites of the Lamboo Complex and by dykes of porphyry similar to those of the Whitewater Volcanics.

Rock types are principally grey, purple-grey, green-grey, and red-brown greywackes and shales. Subordinate rock types include dark-grey and finely banded purple limestone occuring as rare 1 to 3 feet thick beds near the top of the sequence, and banded siliceous siltstones and fine-grained sandstones. The shales and greywackes are mostly interbedded, with greywackes predominating near the top of the sequence, and shales becoming dominant lower down. Slight, mainly dynamic metamorphism has resulted in the production of slates and phyllites from the more argillaceous rocks. Intersection of cleavage and bedding has locally given rise to blade-shaped cleavage fragments. The greywackes are relatively unaffected, and maintain their original bedding with 6-inch to 18-inch thick beds even where the shales are strongly cleaved. The more massive greywackes are jointed with thin quartz veinlets infilling ac joints.

Petrographically the Olympio Formation sediments are predominantly siltstones composed mainly of quartz with interstitial patches of sericite and pale yellow-brown chlorite which in some specimens forms anastamosing films indicating an incipient cleavage or schistosity. Late muscovite flakes are present in certain samples and have poikiloblastic inclusions of quartz.

A lithic quartzose sub-greywacke examined consists mainly of poorly-sorted quartz grains, fragments of shale, and acid and basic volcanics, set in a very fine-grained quartz sericite-chlorite matrix.

The porphyritic dyke rocks cutting the Halls Creek Group have phenocrysts of quartz, feldspar, highly altered biotite, and pyroxene in a very fine-grained quartzo-feldspathic matrix.

An example of a thermally metamorphosed Halls Creek Group rock from the contact with Bow River Granite consists of large poikiloblasts of cummingtonite and glomeroporphyroblastic aggregates of phlogopitic biotite, and ? andalusite, chondrodite and quartz, with minor accessory magnetite.

ARCHAEAN TO PROTEROZOIC

LAMBOO COMPLEX.

The name Lamboo Complex, derived from the Lamboo Homestead, 30 miles south-west of Halls Creek, was used informally by Matheson and Guppy (1949), and defined by Guppy et al (1958), to include granite, granite gneiss and undigested remnants of metasediment.

In the Lansdowne Sheet area the Lamboo Complex crops out principally in the south-eastern and south-western corners, but small outcrops are also found near Pyra Gorge and near Mad Gap Yard. It consists almost entirely of intrusive granitic rocks and their associated dykes and veins. Metamorphic rocks are of minor importance, and are confined to narrow zones of hornfels in intruded sedimentary and igneous rocks though small areas of metamorphics - Tickalara Metamorphics - crop out as roof pendants in granites in the south-east corner of the Sheet. Low rounded hills, and residual tors with sandy pediments are characteristic topographic forms of the complex.

Granites of the Lamboo Complex cut rocks of the Halls Creek Group and Whitewater volcanics, and are overlain unconformably by rocks of the Speewah Group. Their age is Lower to Middle Proterozoic in part, but younger intrusives may be represented. Age relationships between the intrusives have been determined from field observations in most cases, though some relationships are uncertain and await age determination for confirmation.

Seven granitic types are recognised, all of them apparently of magmatic origin except for the Long Hole Granite which may also include metasomatic rocks. The nomenclature of the granites in the east follows the usage of Dow and Gemuts (in prep.). That for the western granites, which is used for the first time in this report, has been proposed because it is undesirable to continue the East Kimberley granite subdivisions indefinitely westwards, and because the western granites of the Lansdowne area are more varied in type and certain of the varieties present do not correspond lithologically to those of the East Kimberley. The five types recognised in the west, in order of decreasing age are Long Hole, Chaneys, and Lerida Granites, Bickleys Porphyry and Mulkerins Granite. Of these, Long Hole and Chaneys Granites may possibly be equivalent to the Bow River and Violet Valley Granites of the eastern part of the Sheet area. Bickleys Porphyry is similar to the Castlereagh Hill Porphyry of the Lissadell Sheet area but it is almost 100 miles from the nearest outcrop of Castlereagh Hill Porphyry.

Characteristic petrographic features of the Long Hole, Chaneys, and Bow River Granites which are all biotite granites, are the presence of perthitic feldspar, zoned plagioclase, myrmekite, intergranular albite, albite rims on microperthite, and the presence of minor accessory pink zircon.

Tickalara Metamorphics.

The Tickalara Metamorphics, named by Dow et al. (1964) from the Tickalara Bore in the Dixon Range Sheet area are found in the Lansdowne Sheet area only as two small outcrops in the south-east where they form roof pendants in the coarse-grained biotite granite (Bow River Granite). The most common rock types are foliated and compositionally banded cordierite-sillimanite- and sillimanite-staurolite-bearing paragneisses. Contacts between xenoliths and granitic host rocks are sharp with no obvious contact effects. Metamorphic minerals such as sillimanite, cordierite, and garnet predate a prominent secondary foliation, a feature which suggests that the metamorphism of these gneisses is earlier than, and not a result of the granite emplacement.

Bow River Granite (new name)

The name Bow River Granite is derived from Bow River, in the southern areas of Lissadell Sheet, which flows through typical outcrops of the granite.

It is the most widespread mass in the south-east corner of the Lansdowne Sheet area, and intrudes the Tickalara Metamorphics, Halls Creek Group and Whitewater Volcanics. It includes coarse-grained grey biotite granite, minor granodiorite, and pink porphyritic biotite granite, and is intruded by quartz reefs and dolerite and aplite dykes.

Lenticular xenoliths up to 9" in diameter of fine-grained biotite granite are common, while xenoliths of still recognisable sedimentary rock predominate near the contact with the Halls Creek Group. Towards the contact the granite, normally massive, becomes foliated locally and finer-grained. The irregular nature of the contact and the restricted foliation in the Bow River Granite suggests absence of major movement at the time of its intrusion.

In thin section the Bow River Granite shows a hypidiomorphic-granular texture, and consists of zoned plagioclase (An_{30-10}) which is sericitised, epidotised, and has myrmekitic rims. Perthitic potash feld-spar, chloritised biotite, and minor accessory zircon and apatite are also present. The narrow contact zone of the Bow River Granite shows a xeno-morphic-granular texture and contains large anhedral flakes of muscovite and scattered grains of tourmaline in addition to the mineral assemblage listed above. The development of muscovite may reflect contamination of the granite by pelites of the Halls Creek Group.

Violet Valley Granite (new name)

This granite is named after the Violet Valley Bore, latitude 17°14'S, Longitude 128°00'E, in the Dixon Range Sheet area, around which typical rock types crop out. It is a medium-grained biotite-hornblende granite or granodiorite of small areal extent found only in the south-eastern corner of the Sheet area, and has a distinctive dark grey air photo-graph pattern. It intrudes the Halls Creek Group, and is apparently later than the Bow River Granite. Dow et al (1964) tentatively consider the Violet Valley mass to be a finer-grained biotite-rich phase of the Bow River Granite.

Long Hole Granite (new name)

The name Long Hole Granite is derived from Long Hole Bore, latitude 17°58'S, longitude 126°04'E, about 6 miles west of the main outcrop of this rock type. The Long Hole Granite crops out in the south-western corner of the Sheet area where it is overlain unconformably by conglomerates of Devonian to Permian age.

In hand-specimen it is a coarse-grained grey biotite-bearing rock which locally contains equidimensional phenocrysts and possible augen of pink and white potash feldspar up to 4 centimetres across and quartz grains up to 1 centimetre. The quartz is characteristically slightly turbid and pale blue-grey in colour, and this together with the presence of pink potash feldspar, where present, distinguishes this mass in hand-specimen from others in the complex.

In thin section, the rock shows a hypidiomorphic-granular texture. Plagioclase crystals are zoned with cores of An_{35-40}, and outer margins of An_{8-12}. Calcic cores are generally highly altered to a fine-grained aggregate of sericite and epidote, much of which shows anomalous blue birefringence characteristic of clinozoisite and zoisite. Potash feldspar is microcline microperthite. Intergranular sodic plagioclase in optical and structural continuity with exsolved plagioclase in the perthite, and small areas of myrmekite (described in detail below) are developed locally.

Biotite characteristically contains oriented inclusions of rutile (?) arranged in a triangular pattern, as well as hyacynth-pink zircons which produce marked pleochroic haloes in the enclosing biotite. Kink folding in the biotite flakes deforms the rutile inclusions. Small amounts of granophyric material are present, and apatite is a common accessory.

Myrmekite and (?) albitic rims occur sporadically associated with altered plagioclase, set in potash feldspar as host. The myrmekitic intergrowths appear immediately outside the altered plagioclase core, and grade outwards into the albitic rims with the disappearance of the stems of intergrown quartz. The albitic rims are continuous around the plagioclase margins, but myrmekite generally occurs only in the direction of the a crystallographic axis of the plagioclase. These features are similar to those commented on by Phillips (1964). Where plagioclase grains are in contact with quartz or other plagioclase grains the untwinned sodic rims of plagioclase and/or zones of myrmekite, described above, are generally absent. This suggests that the rims are not a product of normal igneous zoning, and that the perthitic potash feldspar, with which the myrmekite is invariably associated has played a part in the development of the myrmekite.

Chaneys Granite (new name)

This granite crops out near Chaneys Yard, latitude 18°08'S, longitude 126°14'E, on the Mount Ramsay Sheet area, from which the name has been derived.

It is a coarse to medium-grained, even-grained grey biotite granite which crops out in the south-western part of the Lansdowne Sheet area. It is commonly foliated and appears gneissic in localised zones of shearing.

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

Lerida Granite (new name)

The name Lerida Granite, is derived from Lerida Gorge, latitude 17°54'S, longitude 126°15'E. It crops out in the south-west corner of the Sheet area where it is overlain by sedimentary rocks of the Speewah Group, and near Mad Gap Yard, where it is in contact with Whitewater Volcanics. Small fault-blocks of Lerida Granite are found a few miles west of Pyra Gorge. Relationships between the Lerida Granite and the Long Hole and Chaneys Granite are unknown. It is older than Bickleys Porphyry and Mulkerins Granite.

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

The invariable porphyritic nature of the Lerida Granite, the relatively small phenocryst size, the pale olive green colour of the plagioclase phenocrysts, the white colour of the potash feldspar and the relatively high biotite content distinguish it from the other granites of the Lamboo Complex.

Bickleys Porphyry. (new name)

The name is derived from Bickleys Creek, latitude 17°44'S, longitude 126°00'E, which crosses one of the main outcrops of this rock type. It consists of porphyry and porphyritic microgranite, and crops out as small discrete bodies within the Lerida Granite, south of Torrens Yard and near Bickleys Yard.

Bickleys Porphyry crops out mainly as upstanding rounded hills with only sparse soil development both on and between the hills. Large residual boulders which completely cover the hill slopes are locally devoid of vegetation, and produce characteristic small dark patches on air photographs.

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

No contacts with the enclosing Lerida Granite have been found, but xenoliths of this granite in the porphyry suggest an intrusive relationship. About 5 miles south of Torrens Yard highly sheared Whitewater Volcanics have been traced along strike almost to the margin of the Bickleys Porphyry which is completely undeformed and is thus later than the Volcanics.

However, broad shear zones up to half-a-mile wide have been found elsewhere within the porphyry, which becomes gneissic in character. Large phenocrysts of quartz and feldspar become strongly aligned and locally form augen. Along narrow shear zones up to 3 feet wide deformation is more intense and the porphyry becomes phyllonitic in character.

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

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

Mulkerins Granite

The name of this granite mass is derived from Mulkerins Gap, (Lat. 17°54'S, Long.126°17'E) about four miles north of the northern boundary of the mass. The Mulkerins Granite is a leucocratic coarse-grained non-porphyritic biotite granite. It is an intrusive mass, eliptical in outcrop form, which crops out to the south and south-west of Saddlers Yard in the south-western corner of the Lansdowne Sheet area and extends into the north-western part of the Mount Ramsay Sheet area. The rock is very friable and consequently crops out only as very low undulating hills and low isolated tors, separated by broad sandy pediments. These low outcrops are traversed by upstanding ridges consisting of erosion-resistant quartz veins.

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

The granite is white to very pale grey in colour, and consists of pale grey quartz, white potash feldspar, very pale yellow-green plagioclase and minor amounts of biotite. It is massive, unfoliated, and generally contains few xenoliths. A large roof pendant of Lerida Granite, more than $\frac{1}{4}$ of a mile in diameter, is present near the north-eastern margin. Where it is in contact with Lerida Granite, Mulkerins Granite has a contact zone from 3 feet to 6 feet in width, which is slightly coarser-grained and contains pegmatitic quartz-feldspar intergrowths and elongate bladed crystals of biotite. The outermost 2 inches of this contact zone are partly granophyric.

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

The quartz veins which cut the granite are up to 2 miles in length with an average thickness of about 10 feet. They are mostly barren, but traces of copper have been noted locally.

<u>Dykes and Veins</u>.

Minor intrusions which are found in the Lansdowne Sheet area include dolerite, dacite, granophyre, aplitic and pegmatitic dykes and quartz veins. With the exception of the quartz veins, most, but not all, are only found cutting rocks of the Lamboo Complex. Their age is uncertain. Some are almost certainly related to the Lamboo Complex granites while others may be related to the Carson Volcanics and the Hart Dolerite.

(a) Dolerite

Dolerite dykes up to 4 miles in length and 20 feet wide intrude the biotite granites of the south-eastern and south-western parts of the Sheet area. They are dark grey in colour, fine-grained and commonly show small-scale igneous banding in which magnetite-rich bands are prominent. In the south-east most of the dolerite dykes trend north-west and apparently fill joints of a conjugate fracture system in the Bow River Granite.

In thin section the dolerites show a sub-ophitic texture and consist of plagioclase (An_{60}) laths up to 1 mm. in length, augite, minor accessory magnetite and rare pyrite.

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

(b) Dacite

Dykes of dacitic composition are found intruding the Lerida Granite four miles east of Saddlers Yard, and intruding the Whitewater Volcanics 3 miles south of Six Mile Yard. They are grey-green in colour, vesicular and fine-grained. The dyke from the Six Mile Yard area is a composite body which includes a narrow selvedge of vesicular purple-grey calcite-bearing basalt along its northern margin.

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

(c) Granophyre

A dyke of granophyre intrudes Lerida Granite near Saddlers Yard. It is partly sheared and is associated with small veins of amethystine quartz. It is a fine-grained dark-grey porphyritic rock with tabular phenocrysts of pale green-grey plagioclase up to 5 mm. in length.

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

(d) Aplite and Pegmatite

Dykes and veins of aplite, pegmatite, and tourmaline granite are present in the south-western part of the Lansdowne Sheet area, mainly cutting Mulkerins Granite. A few aplite dykes also cut Chaneys Granite. These dykes, which are predominantly aplitic, contain tourmaline-rich segregations up to 3 inches in diameter, and have a typical saccharoidal texture with granular quartz, plagioclase, and microperthite constituting the bulk of the rock. Biotite and tourmaline are accessory minerals. The tourmaline, which locally forms a coarse symplectite with quartz and feldspar, is mainly orange-brown in colour but has localised blue-grey areas, and is strongly pleochroic from brown (or blue-grey) to very pale-brown.

An aplite dyke found cutting the Bow River Granite in the south-eastern part of the Sheet area is exceptional in that it contains minor amounts of pleochroic pale rose pink andalusite which is partly altered to (?)gibbsite.

(e) Quartz Veins

Quartz veins are found cutting most formations in the Lansdowne Sheet area; they are most common within parts of the Bow River Granite, Halls Creek Group, Mulkerins Granite, Whitewater Volcanics, and locally in the Hart Dolerite, and are also found extensively as fault fissure fillings in other formations.

The veins cutting the Mulkerins Granite are up to 2 miles in length with an average thickness of about 10 feet. They are mostly barren, but traces of copper have been noted locally. Quartz veins are particularly abundant in the pink porphyritic phase of the Bow River Granite near Tumagee Yard, where they are of similar dimensions and completely barren.

Quartz veins are also abundant in areas of the Whitewater Volcanics especially east of Goads Yard and west and south-west of Six Mile Yard. In these areas minute traces of chalcopyrite and galena have been noted and also some minor limonitic boxworks east of Goads Yard. They rarely exceed half-a-mile in length and 5 feet in thickness and are generally much smaller.

The quartz veins cutting the Hart Dolerite mostly extend for only 10 to 20 yards and have an average thickness of about 1 foot. Chalcopyrite and galena are widespread in these, but only in trace amounts.

Those quartz veins found as fault infillings are of greater linear extent and generally thicker than the other quartz veins in the area. For example in the Greenvale Fault north of Tumagee Yard, a prominent quartz reef, up to 75 feet thick, extends for about 6 miles. This reef is brecciated in parts and the breccia zones are cut by later undeformed veins.

An interesting example of a fault-fissure quartz reef has been noted cutting the Warton Sandstone 7 miles south-east of Reed Spring Yard. Here a complete gradation can be traced from unaltered quartz sandstone into quartz sandstone with randomly oriented quartz veinlets, and finally through an increase in the number and thickness of these veinlets and gradual silicification of the sandstone, into a reef of massive quartz.

Most of the quartz reefs found in fault-fissures occur within areas of acid rocks and may have been formed at least partly through in situ transformation of the host rock. These reefs are barren except for small amounts of malachite noted in the marginal brecciated phase of the above-described large vein in the Greenvale Fault, 3 to 4 miles north-west of Tumagee Yard.

MIDDLE PROTEROZOIC

Whitewater Volcanics.

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

The most abundant rock types, which range in composition from rhyodacitic to andesitic, are red-brown and grey-green quartz-feldspar porphyries which are apparently mainly ash-flow tuffs. Pyroxene-bearing feldspar porphyries, epidosite breccia (probably formed through secondary alteration of intermediate to basic agglomerate), Lapilli tuffs and volcanic conglomerates are also represented. Interbedded sediments of sparse occurrence include shales, siltstones, ferruginous sandstones and greywacke grits. Intrusive acid rocks have been found in the sequence, but are not readily recognisable in the field. These are probably rare.

The porphyries are mainly massive and structureless, but localised bedding or flow structures outlined by lenticles of fine-grained non-xenocrystic acid material ¼ to ½ inch thick and 3 to 4 inches in diameter have been noted which serve to outline the structure where they are present. These tend to be aligned parallel, or sub-parallel to the contact of the overlying O'Donnell Formation. In places the porphyries are highly sheared, especially in the western part of the area, and may resemble sheared granites in hand-specimen.

The relationship with the underlying Halls Creek Group rocks is one of unconformity. In the majority of places where the contact has been examined, there is a parallelism of strike trends of the Whitewater and Halls Creek rocks, but an unconformity may be inferred from the intense isoclinal folding in the Halls Creek Group rocks and the simple open folding of the Whitewater Volcanics. A strong discordance has been noted south-south-west of Gap Yard which confirms the presence of an unconformity.

The relationship with the overlying O'Donnell Formation is also an unconformity, particularly well displayed 8 miles west of Pyra Gorge, where a strong discordance is found. Elsewhere, however, the strike of the two formations is concordant or only slightly discordant, with transgressions of the O'Donnell Formation on to the Halls Creek Group being found in several places.

In certain places, e.g. near Dingo Well, and extending as far west as longitude $126^{\circ}40'$, a series of greywacke grits overlies the Whitewater Volcanics and overlaps on to the Halls Creek Group. These grits are composed of material derived from, and lithologically similar to the Whitewater Volcanics. They are overlain apparently conformably by rocks of the O'Donnell Formation and are thus included with this Formation on structural grounds, rather than with the Whitewater Volcanics on grounds of lithological similarity.

The maximum thickness of the Whitewater Volcanics is uncertain, principally because of lack of structural information. Where it has been possible to obtain dip values from bedding, from flow-structures, and from interbedded sediments, e.g. west of Carola Yard, a thickness of 6,000 to 7,000 feet has been calculated. A less reliable estimate of 9,000 feet, based on the dip of the overlying O'Donnell Formation, has been obtained south-west of Tunganary Gorge. Because of the unconformable relationship with the O'Donnell this thickness is probably also less than the true maximum.

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

These basal boulder beds, which overlie the Halls Creek Group rocks with strong angular unconformity, have been found in only one locality in the Lansdowne Sheet area, 6 miles south-south-west of Gap Yard, but similar deposits have been noted a few miles to the south-east in the Mount Ramsey Sheet area, and also 4 miles south of Melon Patch Creek in the Lansdowne Sheet area. The occurence near Gap Yard consists of rounded to elliptical cobbles and boulders of quartzite and feldspathic greywacke up to 12 inches in length, in a very fine-grained highly sheared quartzose sub-greywacke matrix. The presence of such large polymict boulders in a fine-grained matrix suggests that this deposit could be a tillite. At present insufficient evidence is available to comment further on this possibility.

Volcanic conglomerates, which overlie these basal boulder beds, form the lowest Whitewater beds locally elsewhere, e.g. near Pyra Gorge and west of Carola Yard. They consist of 1 to 2 inch fine-grained acid volcanic pebbles in a siliceous matrix. These conglomerates pass laterally into tuffaceous greywackes rich in rounded rhyolitic fragments. In other localities, especially in the eastern part of the area, the basal rocks consist of pyroxene-bearing feldspar porphyries and of quartz-feldspar porphyries.

In the Tumagee - Tunganary area a generalised gradation upwards in the sequence has been noted from basal feldspar-pyroxene porphyry, with an included volcanic conglomerate horizon which is well displayed half-a-mile north of Tumagee Yard, into quartz-bearing feldspar porphyry and through to quartz-feldspar porphyry which makes up most of the sequence. This generalised succession is interrupted by localised beds of siltstone, and tuff which locally contains scattered lapilli, occurring about half way up the exposed sequence; and by a reappearance of feldspar pyroxene porphyry near the top. Elsewhere the succession is remarkably uniform and shows little variation except for the presence of feldspar pyroxene porphyry near the base and also near the top. Lapilli tuffs and agglomerates occur locally near the top of the sequence in widely separated localities, such as 12 miles north-east of Old Bedford Homestead and 8 miles west-south-west of Pyra Gorge, where they are associated with rhyolites, rhyolitic tuffs and siltstones.

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

The phenocrysts in the quartz-feldspar porphyries are quartz, plagioclase, and potash feldspar, with rather rare altered pyroxene and biotite. In the feldspar porphyries, only plagioclase, altered pyroxene, and rare altered biotite occur as phenocrysts.

Quartz forms subhedral grains commonly up to 5 mm. across, and shows conspicuous resorption embayments. Plagioclase, which predominates greatly over potash feldspar, occurs as euhedral short prismatic grains up to 3 mm., which are mostly highly sericitised and locally replaced by carbonate. The composition of the plagioclase, where it is relatively unaltered, is around An_{25-30}. Potash Feldspar which occurs as subhedral grains up to 2 mm. is a slightly turbid variety of microperthite, probably orthoclase-microperthite, containing minute irregular shaped flecks of exsolved plagioclase. Alteration to sericite is absent but partial replacement by carbonate occurs in some specimens. Pyroxene pseudomorphs have prismatic habit and are up to 2 mm. in length. Original pyroxene is completely replaced by chlorites, especially a variety with low anomalous birefringence, and by minor amounts of associated secondary sphene, epidote, and carbonate. Biotite flakes up to 2 mm. across are completely replaced by interlayered chlorite and muscovite with small amounts of associated (?) sphene.

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

Apatite occurring as small equidimensional grains, mainly associated with altered pyroxene, and small scattered zircons are minor accessories.

The matrix is mainly a structureless crypto-crystalline mosaic, probably a devitrified glass, consisting of quartz, feldspar and chlorite, and commonly contains small splinters of quartz and feldspar. Traces of flow streaks around phenocrysts occur in several specimens, and cuspate glass shards in one specimen.

Because of the high percentage of matrix of indefinite mineralogy, the petrological classification of the Whitewater rocks is uncertain. Based on relative percentage of the various xenocrysts and phenocrysts they appear to range from rhyodacite to andesite. The majority are probably dacites.

Watery River Porphyry*

The Watery River Porphyry, is a discrete mass of apparently intrusive dark-grey Whitewater-type rock which crops out athwart the boundary of the Lansdowne and Mount Ramsay Sheet areas about longitude 126°37'E, latitude 18°00'S. It intrudes the Whitewater Volcanics and is overlain unconformably by the O'Donnell Formation. The Porphyry has a sharp contact with the Whitewater Volcanics and is darker-coloured and finer-grained at the contact. The name is derived from the Watery River (=Little Gold River) which crosses the outcrop of this porphyry. The intrusion is apparently a flat lying sill which has an elliptical outcrop and an extent of about 25 square miles. Because of the lack of structural features, the thickness cannot be estimated accurately, but it is probably at least 200 to 300 feet thick. It crops out as low rounded hills dissected by a joint-controlled rectilinear drainage pattern.

The Watery River Porphyry is a relatively homogeneous mass of fine-grained dark grey rock with sporadic phenocrysts of quartz, and locally contains abundant angular xenoliths of cognate material 1 to 2 inches across.

In thin section the rock consists mainly of enhedral phenocrysts up to 2 mm. long of slightly pleochroic very pale pink to colourless orthopyroxene, and equant grains of completely sericitised plagioclase up to 1 mm. across, which together make up about 40% of the rock, in a very fine-grained feldspathic matrix. Sporadic fresh 0.5 mm. phenocrysts of magnetite with coronas of small biotite flakes, euhedral embayed quartz and small flakes of red-brown biotite are the other phenocrysts present. Minor accessory minerals include apatite and pale pink zircon, together with secondary chlorite and fibrous amphibole derived by alteration of pyroxene.

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

Petrographically the intrusive rock is similar to the more basic members of the Whitewater Volcanics, except that pyroxene is very much more abundant and is fresh whereas in the extrusives pyroxene is completely chloritised.

KIMBERLEY BASIN SUCCESSION

The Kimberley Basin is a large structural basin covering the whole of the Kimberley Plateau. With it are included the areas of Speewah and Kimberley Group sediments exposed in the foothills of the Plateau. Rocks of the Kimberley Basin succession are strongly folded along the margins of the Plateau, but elsewhere are relatively undisturbed. They consist mainly of arenites with subordinate lutites, basic volcanics, and carbonates, and have a total thickness in this area of about 12,000 feet.

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

It has been found that the reported unconformity between the Liamma Beds and the O'Donnell Formation is in fact a reverse fault and that the Liamma Beds are the faulted equivalents of part of the O'Donnell Formation of Dow et al., (op. cit.). The O'Donnell succession described by them included beds now defined as the Tunganary Formation, the Valentine Siltstone and the basal member of their Looningnin Arkose, and is now redefined. The term O'Donnell is retained, but is now restricted to the lower 975 feet of the sequence listed by Dow et al., (op.cit.). The beds lying between the O'Donnell (as redefined) and the Valentine Siltstone have been removed from the original O'Donnell Formation and renamed the Tunganary Formation. The Valentine Siltstone has been redefined and is now restricted to the upper 263 feet of the original type section. The lower 75 feet of the type section are now included in the Tunganary Formation. The relationship of the Valentine Siltstone to the underlying beds is now recognised to be one of conformity.

Because of considerable variations in spelling the name of Looningnin and the fact that these deviate considerably from the pronunciation (Lonegan) this name has been changed in favour of Lansdowne. The Lansdowne Arkose now includes the lower 335 feet of the Luman Siltstone as originally defined. This change has been made because of lateral facies changes and the difficulty of recognising the original Luman-Lansdowne (Looningnin) boundary.

TABLE 2

NOMENCLATURE OF KIMBERLEY BASIN SUCCESSION

This Work		Dow et al. (1964)		Harms (1959)	Guppy et al. (1958)
Estaughs Formation Throssell Shale Traine Formation Walsh Tillite	Mount House Group			Mount House Beds (=Mendena Formation) Walsh Tillite	Mount House Beds Walsh Tillite
UNCONFORMITY					
Higher Beds not represented Mendena Formation	Bastion Group	Cockburn Sandstone Wyndham Shale Mendena Formation	Bastion Group		
				UNCONFORMITY	
Pentecost Sandstone Elgee Siltstone Warton Sandstone Carson Volcanics King Leopold Sandstone	Kimberley Group	Pentecost Sandstone Elgee Siltstone Warton Sandstone Carson Volcanics King Leopold Sandstone	Kimberley Group	Pentecost Sandstone Elgee Shale Warton Sandstone Mornington Volcanics	Warton Beds Mornington Volcanics
---(?) UNCONFORMITY ---					
Luman Siltstone Lansdowne Arkose Valentine Siltstone	Speewah Group	Luman Siltstone Looningnin Arkose Valentine Siltstone	Speewah Group	King Leopold Sandstone	
		--ANGULAR UNCONFORMITY--			
		Liamma Beds			King Leopold Beds
		--ANGULAR UNCONFORMITY--			
Tunganary Formation O'Donnell Formation		O'Donnell Formation			
U N C O N F O R M I T Y					

Whitewater Volcanics, Halls Creek Group & Lamboo Comples

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

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

SPEEWAH GROUP

The Speewah Group is a succession of quartzose and feldspathic arenites interbedded with chloritic lutites and minor acid volcanics. The Group crops out in a broad arc concave to the north in the north-eastern, south-eastern and southern parts of the Sheet area and contains approximately 3200 feet of sediments. The rocks are openly folded and are extensively intruded by dolerite. The Speewah Group lies unconformably on rocks of the Lamboo Complex, Halls Creek Group, and the Whitewater Volcanics with which it exhibits a slight angular discordance, and is conformably overlain by rocks of the Kimberley Group, except in the area west of Tumagee Yard where the relationship with the overlying Kimberley Group is unconformable.

The Speewah Group consists of the following formations:

5. Luman Siltstone
4. Lansdowne Arkose
3. Valentine Siltstone
2. Tunganary Formation
1. O'Donnell Formation

O'Donnell Formation (Old name redefined)

The O'Donnell Formation is the basal unit of the Speewah Group. The name is derived from the O'Donnell Range (Lat.16°24'S Long.128°12'E) in the Lissadell Sheet area. The reference section is in the Lissadell Sheet area Lat.16°32'S, Long.128°02'E. The O'Donnell Formation as redefined excludes the basal 110 feet of the original reference section (Dow et al, 1964) and includes the succeeding 865 feet. The overlying beds originally assigned to the O'Donnell now belong to the Tunganary Formation, the Valentine Siltstone and the Lansdowne Arkose.

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

The outcrop of the Formation is confined mainly to a narrow 130-mile-long strip extending from the western boundary of the map Sheet area to near the north-eastern corner. For the most part the outcrop of the O'Donnell Formation follows the southern margin of the broad arcuate belt of Speewah Group rocks. It consists essentially of two members, a lower quartz sandstone member, and an upper siltstone member. A thin discontinuous greywacke grit succession locally forms the basal part of the sequence especially in the eastern part of the area. A thin siltstone which occurs near the top of the quartz sandstone member occurs exclusively in the eastern part of the area (see Fig.5). The formation is locally intruded by the Hart Dolerite which forms a thin sill within the upper siltstone. In one locality near the eastern boundary of the Lansdowne Sheet area a thin sill of porphyritic rhyolite intrudes the upper siltstone member.

The thickness ranges from over 700 feet in the eastern and western parts of the Sheet area to around 300 feet in the central part. The lower part of the Formation crops out as prominent strike ridges and cuestas, while the upper siltstone forms valleys with subsequent drainage. In the axial regions of folds, where dips are shallow, this siltstone forms low rounded hillocks.

The arenites of the Formation consist of medium-grained, coarse grained, and granule quartz sandstones which are mainly white, pale brown or pale purple-grey in colour, and minor purple ferruginous and grey-green glauconitic quartz sandstone. They are mostly thick-bedded, massive to blocky, and are locally ripple-marked and cross-bedded. The siltstones are grey-green, khaki, grey-brown, and dark grey in colour, thin-bedded and fissile, and are commonly micaceous. They show load-casts, wave, current, and interference ripple marks and locally graded bedding. In the west of the area they are phyllitic due to low grade regional metamorphism.

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

O'Donnell Formation - Section 1

Generalised section measured $4\frac{1}{2}$ miles east-south-east of Dingo well (Lat. 17°41'30" S, Long.127°11' E). Measured by A.D. Allan.

Feet	Tunganary Formation
313	Siltstone; green-grey thin-bedded fissile siltstone, alternating with thin beds of micaceous green-grey very fine-grained quartz sandstone and subgreywacke. Upper 60 feet has numerous sandstone interbeds.

Feet	O'Donnell Formation (contd.)
21	Sandstone; white to red-brown thick-bedded medium to coarse-grained silica-cemented quartz sandstone, and quartz granule sandstone.
33	Siltstone; olive-green silicified siltstone, fine-grained sandstone and shale; contains thin glauconitic layers.
95	Sandstone; red-brown medium to coarse-grained moderately well sorted quartz sandstone; ripple-marked and cross-bedded; basal 20 feet contain thin conglomerates with well rounded $\frac{1}{8}$ inch to $\frac{1}{4}$ inch quartz pebbles.
	----------Unconformity----------
462 Total	Whitewater Volcanics

O'Donnell Formation - Section 2

Generalised section measured 1 mile south-west of Torrens Yard 17°41'S, 126°11'E. Measured by D.C. Gellatly.

Feet	Tunganary Formation
333	Siltstone and shale; thin-bedded grey-green to khaki thin-bedded, flaggy, micaceous siltstone and shale with load-casts and ripple-marks. Rare thin interbeds of fine-grained quartz sandstone present, becoming increasingly abundant towards the top of the section.
27	Quartz sandstone; pale grey medium-grained, thick-bedded slightly glauconitic silica-cemented quartz sandstone.
178	Quartz sandstone; pale brown to white coarse-grained, poorly-sorted, thick-bedded quartz sandstone.
224	Quartz sandstone; white, buff and pale grey, coarse- to fine-grained, thin- to thick-bedded silica-cemented quartz sandstone.
	---------- Unconformity ----------
762 Total	Lamboo Complex (Lerida Granite)

O'Donnell Formation - Section 3

Generalised section measured 4 miles east-south-east of Mad Gap Yard (Lat.17°48'30" S, Long.127°11'E) (Distances paced). Measured by D.C.Gellatly.

Feet	King Leopold Sandstone
	---------- Unconformity ----------
	Tunganary Formation (108 ft.)
273	Shale; grey-green and dark grey very thin bedded fissile micaceous siltstone, shale, and mudstone.
80	Quartz sandstone; white to pale grey coarse-grained, thick-bedded hard silica-cemented quartz sandstone.
83	Siltstone; grey-green thinly laminated to flaggy glauconitic siltstone, with thin interbeds of fine-grained grey-green quartz sandstone and shale.
11	Quartz sandstone; white, coarse-grained, thick-bedded silica-cemented quartz sandstone.

Feet	O'Donnell Formation (contd.)
77	Quartz sandstone; purple-grey, coarse-grained, thin- to thick-bedded silica-cemented quartz sandstone.
	---------- Angular Unconformity ----------
524 Total	Halls Creek Group

O'Donnell Formation - Section 4

Generalised section estimated from air photographs about 2½ miles north of Old Bedford Yard (Lat. 17°33'S, Long. 127°22'E). by G.M. Derrick.

Feet	Tunganary Formation
300	Siltstone; khaki, micaceous, thin-bedded siltstone with load-casts; blocky interbeds of fine-grained quartz sandstone near top of sequence.
50	Quartz sandstone; white to purple, coarse-grained, poorly-sorted quartz sandstone and quartz granule sandstone.
75	Siltstone; khaki, micaceous, thin-bedded siltstone with ripple marks and load casts.
270	Quartz sandstone; Ferruginous coarse-grained quartz sandstone and purple glauconitic sub-greywacke; rock fragments common; conglomerate.
30	Arkosic greywacke grits and conglomerate.
	---------- Unconformity ----------
725 Total	Whitewater Volcanics.

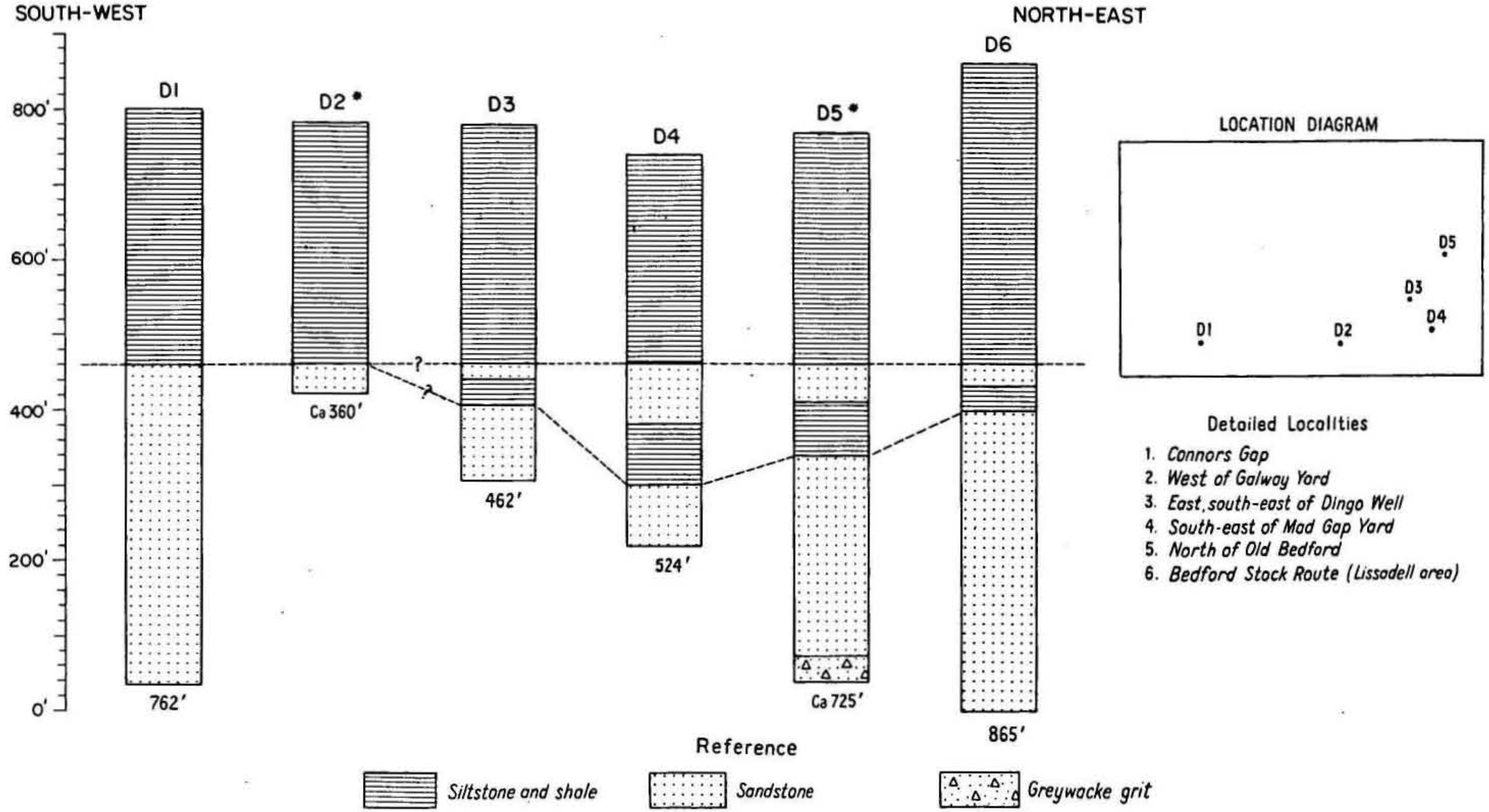
The thickness variations of these and two other sections are readily apparent from Fig.2. Although the Formation thins towards the central part of the Lansdowne Sheet area both from the north-east and south-west, almost all of the thickness variation can be accounted for by changes in the lower (arenite) part of the formation which varies from a maximum of 465 feet down to 38 feet. The lower siltstone is confined to the eastern part of the area, but an additional thin siltstone is present near the base of the succession at the Fitzroy River in the extreme West. The upper siltstone member becomes progressively more arenaceous westwards between Torrens Yard and the Fitzroy River where it is represented by poorly-sorted coarse-grained grey silty quartz sandstone. It has not been possible to estimate the thickness there because of complex folding in the Formation.

The variation in the lower part of the succession probably indicates that the base of the O'Donnell Formation is diachronous and that submergence in the central part of the Lansdowne Sheet area was later than elsewhere.

In certain areas, particularly in the eastern part of the Lansdowne Sheet area, in Dixon Range, and extending westwards to near Coolan Creek Yard, a variable greywacke, siltstone, sandstone, and

Fig.5

STRATIGRAPHIC COLUMNS-O'DONNELL FORMATION



* Thickness calculated partly from air photograph measurement

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A. M.

conglomerate sequence is present underlying the normal clean-washed basal O'Donnell sandstone. It overlaps from the Whitewater Volcanics on to the Olympio Formation near Dingo Well and is thus unconformable on the Whitewater Volcanics. Its relationship with the overlying beds of the O'Donnell Formation is uncertain. There is no apparent discordance between the two units but the arkosic grit is laterally discontinuous and this fact, together with the sudden change in lithology, suggests that there may be a paraconformity or possibly a slight unconformity between them.

The dominant lithologies of these basal beds are greywacke grit, occurring at the base of the sedimentary succession, purple ferruginous sandstone, flaggy purple-brown granule quartz sandstone, pebble and cobble conglomerate, and purple ferruginous silts. These sediments reach their maximum development in the Dixon Range Sheet area, and only the greywacke grit is represented in the Lansdowne area. These beds are only about 120 feet thick. Of this the greywacke grit varies from about 10 to 30 feet. It varies from purple and grey-green to red-brown in colour and consists of angular grains of quartz and feldspar up to 3 mm. across in a fine-grained, silty matrix. It closely resembles the Whitewater Volcanics themselves and has clearly been derived locally from them.

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

An example of a siltstone consists of 0.6 mm. sub-angular quartz grains and heavily kaolinised feldspar in a copious matrix of yellow-brown clay material. Minor accessories are muscovite and rare zircon, apatite and sphene. Where the siltstones are slightly metamorphosed, an axial plane cleavage is well developed in the more micaceous bands, the cleavage being outlined by recrystallised chlorite and muscovite which show preferred planar orientation.

<u>Tunganary Formation</u> (new name)

The Tunganary Formation is predominantly a feldspathic arenite sequence within the Speewah Group. The name is derived from Tunganary Gorge, Lat. 17°40'S, Long. 127°20'E, where a typical section of the formation crops out. The reference section is in the Lansdowne Sheet area at Lat. 17°41'30" S, Long. 127°11'15" E. It is overlain conformably by the Valentine Siltstone, and conformably underlain by the O'Donnell Formation. The formation crops out in a broad arcuate zone extending across the southern part of the map Sheet. Thicknesses of between 700 and 750 feet have been measured near Torrens Yard and Dingo Well. A thickness estimate from air photographs suggests that the Formation thickens near the eastern boundary of the Sheet area.

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

Generalised measured sections are as follows:

Tunganary Formation - Section T1

Measured near Torrens Yard, Lat. 17°15'30" S, Long. 126°19'30" E. Measured by D.C. Gellatly.

Feet		Valentine Siltstone
216		Pink to buff arkose, purple to pale grey blocky to flaggy feldspathic sandstone. Arkose dominant at top. Interbedded flaggy purple and grey micaceous shale.
160		Coarse- to medium-grained feldspathic sandstone; buff, grey and purple, thin-bedded and friable.
5	(A)	Pale grey coarse-grained blocky to massive feldspathic sandstone, grading into silica-cemented quartz sandstone.
130		Pink to buff feldspathic sandstone, blocky and thin-bedded, with interbeds of pale grey-green quartz sandstone.
75		Feldspathic sandstone, silica-cemented, pale purple-grey to pale pink, massive, blocky, locally flaggy.
5		White to pale grey silica-cemented quartz sandstone, medium-grained.
112		Alternating pale purple grey and pale pink feldspathic sandstone, thin-bedded and medium-grained.
42		Feldspathic sandstone, deep purple to buff and brown; blocky, clay pellets common.
745 Total		O'Donnell Formation

Tunganary Formation - Section T2 (Reference Section)

Measured 6 miles east-south-east of Dingo Well, Lat. 17°41'30" S, Long. 127°11'15" E. Measured by A.D. Allan.

Feet	Valentine Siltstone
165	Arkosic sandstone, pink and friable, upper horizons silicified.

Feet	Tunganary Formation - Section T2 (Contd.)
270	Friable feldspathic sandstone, irregularly bedded with arkosic interbeds; medium- to coarse-grained, ripple marks common.
40 (A)	Conglomerate ($\frac{1}{4}$" pebbles) with interbedded coarse-grained quartz sandstone, purple to white, cross-bedded.
5	Feldspathic sandstone, red-brown to grey, friable, cross-bedded.
50	Siltstone, dark grey and fine-grained, blocky and siliceous, with some sandstone interbeds.
50	Well-sorted feldspathic sandstone, red-brown on weathered surface, grey to pink when fresh. Friable, irregularly bedded, cross-bedded.
3	Quartz sandstone, white, silicified, medium- to coarse-grained, cross-bedded and ripple-marked. Marker bed locally.
130	Feldspathic sandstone, brown to dark grey, medium- to coarse-grained. Thin interbeds of coarse-grained quartz sandstone and quartzose sub-greywacke in basal 20'.
715 Total	O'Donnell Formation

Tunganary Formation - Section 3

Generalised section, estimated from aerial photographs, 6 miles south of Cattle Creek Well, Lat. 127°27'E, Long. 17°27'S. by G.M. Derrick.

Feet	Valentine Siltstone
140	Pink to purple arkosic sandstone, medium-grained, ferruginous. Purple flaggy siltstones.
240	Arkose, feldspathic sandstone, green-grey to light brown, medium- to coarse-grained. Beds 1' - 1½' thick, with thin interbeds of friable silty sandstone.
190 (A)	Medium- to coarse-grained quartz sandstone and granule quartz sandstone massively bedded, cross-bedded and strongly jointed. Overlain by coarse-grained ferruginous granule sandstone, purple in colour, friable. Grades downwards into fine- to medium-grained quartz sandstones, pink, massive, thick-bedded and blocky.
40	Silicified siltstone, khaki-green to white, poorly sorted, with lenses of granule sandstone. Characterised by abundant tree growth.
50	Granule quartz sandstone, coarse-grained feldspathic sandstone, arkose, flaggy to massive. Cross-bedded, clay pellets common.
220	Feldspathic sandstone, fine- to medium-grained, thin-bedded and flaggy, strongly cross-bedded, ripple marks common. Grades downwards into grey-green quartz sandstones with interbedded siltstone. Thin stringers of coarse-grained feldspathic quartz sandstone common.
880 Total	O'Donnell Formation

Three broad divisions of the Tunganary Formation can be recognised in the eastern part of the Sheet area. Both the upper and lower members are similar in lithology and outcrop form, though siltstones are more common in the upper part of the sequence. The arenites of both upper and lower members are predominantly feldspathic, buff, purple and white in colour, locally cross-bedded and ripple-marked, with ripple wavelengths varying from 3" to 18".

These two members are separated stratigraphically by a massive scarp-forming quartz sandstone (A). This latter unit is best developed in the eastern part of the sheet area near Bedford Downs, Cattle Creek Well and Motor Car Yard (see section 3), where it is expressed as a rugged dip slope. When traced westwards this member thins from 190 feet in the east to 40 feet on the northern margin of the Carola Syncline. In the western and central parts of the area it is represented by a 5-feet-thick prominent marker bed of white to pale grey quartz sandstone.

Other facies changes apparently take place laterally in the succession. For example, near Bluff Yard the Tunganary beds, which occur as inliers in the Hart Dolerite and have a total exposed thickness of 425', are predominantly fine-grained pink arkoses which grade upwards into a mixed sequence of buff to white medium to coarse-grained feldspathic sandstones. The beds at the base of this sequence are much more feldspathic and finer-grained than the Tunganary beds elsewhere.

Dolerite sills intrude the Tunganary Formation extensively. Contact metamorphism of the sandstone is restricted to some recrystallisation of grains and matrix at the contacts with the dolerite.

Petrographically the arenites vary from well-sorted to poorly sorted and have grain-size varying from 5 mm. to 0.06 mm., but most are less than 0.7 mm. Quartz, which is the predominant detrital mineral, varies from sub-angular to rounded, and grains commonly have optically continuous overgrowths of silica cement. Feldspar which is present in varying amounts up to 35% is principally turbid potash feldspar. Chlorite, hematite and clay minerals occur interstitially, and in a few specimens are sufficiently abundant for the rocks to be classified as subgreywacke (Appendix I). Minor accessory minerals include green tourmaline, zircon, sphene, epidote, rutile, anatase, glauconite and muscovite. Fragments of chert and other rock types are found but are comparatively rare.

A high degree of rounding of large quartz grains and slight pitting of grain boundaries noted in one specimen suggest possible aeolian abrasion in the source area, but the thin-bedded nature of the rocks and the type of cross-bedding displayed preclude aeolian deposition of the arenites.

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

Valentine Siltstone (old name redefined)

This formation was named from the Valentine Creek (Lat. 15°45'S, Long. 128°35'E) in the Lissadell Sheet area (Dow et al. 1964). The reference section in the Lissadell Sheet area is at Lat. 16°28'30" S, Long. 128°3'E. The original definition of the Valentine Siltstone included a basal sandstone member 70' in thickness, but in the redefinition of the constituent formations of the Speewah Group this member has been incorporated in the Tunganary Formation.

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

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

Sections of the Valentine Siltstone are as follows:

Valentine Siltstone - Section VI

Measured section 2 miles south-east of Coolan Creek Yard, Lat. 17°48'S, Long. 126°35'E. Measured by G.M. Derrick.

Feet.	Lansdowne Formation
24	Arkosic siltstone, buff to orange, green-pink on fresh surface, micaceous. Well-bedded, flaggy, beds 1 in. to 2 in., capped by more massive arkose, medium-grained, buff to pink.

Feet	Valentine Siltstone - Section V1 (Contd.)
12	Vesicular rhyolite, rhyolitic tuff, tuffaceous siltstone, massive, well-bedded in parts.
36	Green to black mudstone, regularly interbedded with finely banded arkosic siltstone, blue-green, purple and grey, siliceous; slumping present, current ripples characteristic.
4	Alternating bands of pink and green arkosic siltstone, 3 in. to 6 in. thick.
26	Mudstone, black, grey and purple, finely-laminated, locally conchoidal in fracture.
38	Mudstone, thin-bedded, grey to black, with flaggy 1 in. to 2 in. interbeds of arkosic siltstone, micaceous, buff-coloured and well-bedded.
140 Total	Tunganary Formation

Valentine Siltstone - Section V2

Composite section, with distances paced, 1 mile south-south-west of Lily Yard, Lat. 17°27'S, Long. 127°29'E. Measured by G.M. Derrick.

Feet.	Lansdowne Formation
25	Fine- to medium-grained arkose, with interbedded buff, flaggy and micaceous siltstone.
20	Rhyolite, rhyolitic tuff, rhyolitic agglomerate.
42	Micaceous shales and siltstone, dark brown to buff, strongly laminated.
12	Rhyolitic tuff, coarse-grained, well-bedded, with tuffaceous siltstone, micaceous, and closely jointed.
50	Khaki and purple slumped, micaceous, flaggy, siltstone, with thin interbeds of purple granular sandstone near base.
149 Total	Tunganary Formation

Valentine Siltstone - Section V3

Composite section 1½ miles west-south-west of Old Bedford Yard, Lat. 17°36'S, Long. 127°20'E. Measured by K.A. Plumb.

Feet	Lansdowne Formation
30	Black claystones, imperfectly laminated, interbedded with siltstone, flaggy, dark green in colour, micaceous and feldspathic, with load-casts and slump structures. Laminated siltstone contains blocky siltstone (6 in. to 8 in.) interbeds, khaki to buff, and highly siliceous.
5	Rhyolitic tuff, fine-grained, green-grey in colour, medium-grained, glassy, quartz fragments common.
	dolerite sill
100	Siltstone, well laminated and feldspathic: buff to khaki in colour some conchoidal fracturing in interbedded claystones, which are poorly bedded. Siltstone more blocky and siliceous towards base.
135 Total	Tunganary Formation

The Valentine Siltstone is consistently much thinner on the Lansdowne Sheet area than on the Lissadell Sheet area, where the average thickness is 235 feet, the differences being due to a lesser development of the siltstone-shale members on the Lansdowne sheet area. In the Lansdowne Sheet area the Valentine Siltstone is consistently about 140 feet thick except locally in the south, where it thins markedly, e.g. to about 35 feet west of Carola Yard.

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

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

Lansdowne Arkose (New name)

The Lansdowne Arkose overlies the Valentine Siltstone and underlies the Luman Siltstone. The name is derived from Lansdowne Station (Lat. 17°38'S, Long. 126°45'E) much of which is underlain by rocks of the Formation. The Lansdowne Arkose is the new name proposed for the Looningnin Arkose (Dow, et al., 1964) the latter name having been deemed unsuitable (vide supra), but the redefined formation includes beds previously assigned to the Luman Siltstone. The reference section is a composite one measured about 2 miles south-east of Lansdowne Homestead (lower part), 17°37'45"S, 126°45'24"E., and 2 miles north of Elba Hole Yard (upper part) 17°34'51"S, 127°53'00" E. Relations with the overlying and underlying formations are apparently conformable, but considerable thickness variations in the basal beds of the Lansdowne Arkose, which are locally conglomeratic, may possibly indicate a localised paraconformity between the Valentine Siltstone and the Lansdowne Arkose.

The Lansdowne Arkose crops out mainly in a continuous arcuate belt, concave to the north, which extends from the north-eastern corner of the Lansdowne Sheet area to the western margin at Diamond Gorge, and in a subsidiary belt trending east-north-eastwards from Pyra Gorge in the southern part of the map Sheet area. It is extensively intruded by the

Hart Dolerite which has rafted large blocks, several miles long, away from their original stratigraphical position. Within the Lansdowne Sheet area the thickness of the formation varies from over 2000 feet in the south at Pyra Gorge, to 1625 feet in the central part and 1330 feet in the south-west. The formation can be subdivided into six mappable members as follows:

Member No.	Lithology	Thickness*
6	Arkose and quartz sandstone	(350 feet)
5	Feldspathic sandstone	(480 feet)
4	Siltstone	(25 feet)
3	Feldspathic sandstone	(360 feet)
2	Siltstone	(170 feet)
1	Arkose and feldspathic sandstone	(240 feet)

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

The Lansdowne Arkose forms a series of low parallel escarpments and strike ridges with intervening valleys underlain by the more easily eroded siltstones. Member 5 mostly forms distinctive low cliffs, and the topmost unit forms rounded, gentle hill slopes with a smooth air photograph pattern. Locally, e.g. in the southern part of the area, the Lansdowne Arkose strike ridges increase in height and form prominent bluffs.

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

Cross-bedding is ubiquitous throughout the sequence, and slump structures, ripple marks and current striations are found locally. Concentrations of clay pellets are present in certain beds, and 1 in. to 2 in. ball structures, probably due to the effects of weathering, have been noted.

Considerable variations are found in the thickness of the foreset units. In the lower arenites foresets are mostly 4 in. to 16 in. thick, while in member 5 (above) they are characteristically 2 feet to 4 feet thick. Slump structures are principally single overturned cross-beds within individual beds. Ripple marks, some of them asymmetrical, have wavelengths of up to 18 inches and amplitudes up to 3 in..

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

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

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

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

The following two generalised measured sections are representative of the Lansdowne Arkose within the Lansdowne Sheet area and indicate some of the variations present within the formation.

<u>Lansdowne Arkose - Section L-1</u>

Composite section measured partly 2 miles south-east of Lansdowne Homestead (members 1, 2, 3, 4) (Lat. 17°38'S, Long. 126°45'30"E) and partly 2 miles north of Elba Hole Yard, (members 5, 6) (Lat. 17°35'S, Long. 126°54'E). Measured by D.C. Gellatly.

Luman Siltstone

<u>Feet</u>	Lansdowne Arkose (6)
197	Arkose; deep pink, coarse-grained, hard, silica-cemented arkose with thin feldspathic siltstone interbeds.
17	Siltstone; purple micaceous siltstone.
31	Feldspathic sandstone; white to pale grey and purple, medium-grained, thin-bedded clayey feldspathic sandstone and pink-brown arkose.

Lansdowne Arkose - Section L-1 (Contd.)

Feet.	
108	Quartz sandstone; purple to grey-brown, friable, coarse-grained thin-bedded, quartz sandstone with 1 to 2 mm. millet seed grains; cross-bedded with 3 in. to 6 in. foreset units.

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(5)

155	Feldspathic sandstone; buff-coloured medium- to coarse-grained, thick-bedded feldspathic sandstone; cross-bedded with 1 foot-thick foreset units.
306	Feldspathic sandstone; pale creamy-pink to buff and purple medium-grained feldspathic sandstone.
119	Feldspathic sandstone; cream and purple medium-grained very thick-bedded, well-sorted feldspathic sandstone; cross-bedded with 2 to 4 feet-thick foreset units.

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(4)

18	Siltstone; grey and purple highly micaceous siltstone with thin interbeds of grey-green quartz sandstone and pink arkose.
7	Sandstone; fine-grained grey-green cherty sandstone.

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(3)

176	Arkose; pink medium-grained, thick- to thin-bedded arkose and feldspathic sandstone.
185	Feldspathic sandstone; pale pink to cream, medium-grained, thick- to medium-bedded feldspathic sandstone and minor quartz sandstone. Cross-bedding with 1- to 2-feet-thick foreset units near the base; clay pellets present locally.

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(2)

42	Siltsone; flaggy grey to grey-green micaceous siltstone and shale with thin interbeds of fine-grained pink arkose and grey feldspathic sandstone.
10	Arkose; pink to brown, fine-grained arkose with 2 in. interbeds of grey fine-grained micaceous sandstone.
16	Feldspathic sandstone, dark grey, fine-grained feldspathic sandstone with interbeds of flaggy grey micaceous siltstone.
48	Shale; purple grey and grey-green shale with interbeds of flaggy grey micaceous feldspathic siltstone.
36	Mudstone; blocky to flaggy grey mudstone and shale.
2	Feldspathic sandstone; pale grey-green to pink-grey fine-grained feldspathic sandstone.
12	No exposure (? siltstone).
2	Quartz sandstone; pale grey-green fine-grained quartz sandstone.

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(1)

42	Feldspathic sandstone; buff to pale pink coarse- to medium-grained thin-bedded feldspathic sandstone.
119	Arkose; deep to pale pink medium-grained thin- to thick-bedded arkose.
32	Quartz sandstone; coarse-grained slightly feldspathic quartz sandstone with clay pellet impressions; granule quartz sandstone at base.

Feet.	Lansdowne Arkose - Section L-1 (Contd.)
44	Arkose; medium- to coarse-grained, medium- to thin-bedded pale pink arkose; cross-bedded with relatively thin foreset units.
1623 Total	Valentine Siltstone

Lansdowne Arkose - Section 2

Generalised section measured 2 miles north-east of Torrens Yard (Lat. 17°38'S, Long. 126°45'30"E). Measured by D.C. Gellatly.

Luman Siltstone

Lansdowne Arkose

Feet	(6)
93	Arkose; coarse- to fine-grained pink arkose and feldspathic sandstone.
69	Granule sandstone; quartz granule sandstone with minor pink feldspar in upper part.
2	Conglomerate; quartz pebble conglomerate: $\frac{1}{4}$ in. to $\frac{3}{4}$ in. pebbles of vein quartz in a buff to pale brown quartz granule sand matrix.
	(5)
48	Feldspathic sandstone; white to pale cream medium-grained, medium-bedded cross-bedded feldspathic sandstone.
86	Quartz sandstone; white, medium- to coarse-grained, slightly feldspathic quartz sandstone; hard silica-cemented beds alternate with friable ones.
340	Feldspathic sandstone; very friable, pale buff, medium-grained thick-bedded, strongly cross-bedded feldspathic sandstone; thick foreset units.
	(4)
91	Siltstone; grey-brown micaceous siltstone.
	(3)
275	Feldspathic sandstone; buff to cream, friable, flaggy, very strongly cross-bedded feldspathic sandstone.
	(2)
149	Siltstone; poorly exposed weathered red-brown micaceous siltstone and shale.
	(Dolerite - 83 feet)
	(1)
146	Feldspathic sandstone; white to pale pink and buff medium- to coarse-grained feldspathic sandstone and arkose.
31	Arkose; buff fine-grained flaggy arkose with thin grey siltstone interbeds.
1330 Total	Valentine Siltstone

The measured thickness of 1623 feet in the centre of the Lansdowne Sheet area is the maximum observed along the edge of the Kimberley Plateau. The section thins to 1330 feet in the south-west and to 1355 feet in the north-east on the Bedford Stock Route in the Lissadell area. Near Carola Yard and at Pyra Gorge in the southern part of the Lansdowne Sheet area approximate thicknesses of 1300 feet and over 2000 feet respectively have been noted. The thickening at Pyra Gorge is accompanied by a coarsening of the arenites with the appearance of pebble conglomerates and pebbly coarse-grained sandstones, and a reduction in feldspar content. Despite this general thickening at Pyra Gorge, there is a westward and southward thinning of member 6 from 350 feet east of Lansdowne to 164 feet north of Torrens Yard and only 25 feet at Pyra Gorge.

The principal lithological variations from the quoted sections are as follows. All the arenites become less feldspathic in the south of the area, e.g. in the southern part of the Carola syncline and westwards to Pyra Gorge, and also in the west between Torrens Yard and Diamond Gorge. Coarse granule sandstones and pebble conglomerates are characteristic of the Carola Syncline-Pyra Gorge area, but are not found in the extreme west. These pebble conglomerates occur principally in members 5 and 6. An isolated occurrence of boulder conglomerate has been noted in member 6 in the southern part of the Carola Syncline and probably reflects localised movements along the nearby Greenvale Fault. The 15-foot thick siltstone noted in member 6 in the reference section east of Lansdowne dies out to the south-west and thickens north-eastwards to about 50 feet north of Bedford Downs homestead and 170 feet in the Lissadell area (Dow, et al. 1964).

Luman Siltstone (old name redefined)

The Luman Siltstone which is the topmost formation of the Speewah Group is underlain by the Lansdowne Arkose and overlain by the King Leopold Sandstone. The name is derived from the Luman Land Division of the East Kimberley and was first used by Dow et al. (1964). The reference section is 1 mile east of Mt. Laptz in the Lansdowne Sheet area at Lat. 17°40'30"S, Long. 126°45'E. As defined by Dow et al., the unit consisted of two siltstone members separated by an arkose member and totalling 660 feet in thickness. Because of the discontinuity of the lower of these two siltstone members, the formation has been redefined as the 285-feet-thick upper siltstone. The arkose, and the underlying siltstone (where present) are now assigned to the Lansdowne Arkose.

The Luman Siltstone is found throughout the area as a narrow outcrop at the base of the King Leopold Sandstone cliffs, extending from the north-eastern corner of the Lansdowne Map Sheet area to Diamond Gorge in the west, and also in the southern part of the area in the Carola Syncline and around Pyra Gorge. Because of its ready weathering, the Luman Siltstone is poorly exposed and is commonly obscured by large detrital boulders of King Leopold Sandstone. It is commonly intruded by the Hart Dolerite. It consists essentially of one uniform siltstone unit varying from 235 feet to less than 165 feet in thickness. It lies conformably on the Lansdowne Arkose and is in general overlain conformably by the King Leopold Sandstone, which it grades into by an increase in sand content. The transitional beds, consisting of purple flaggy, fine- to medium-grained micaceous sandstones are assigned to the King Leopold Sandstone. In the southern part of the area, e.g. in the Carola Syncline and at Pyra Gorge, there is a sharp boundary between feldspathic sandstones forming the upper part of the Luman Siltstone and clean-washed quartz sandstone of the King Leopold Sandstone, and it is possible that this sharp junction may indicate a localised paraconformable relationship.

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

In thin section the Siltstones consist mainly of sub-angular quartz grains up to 0.05 mm., with a copious intergranular mosaic of sericite and pale green chlorite, minor muscovite, green biotite, zircon, sphene and goethite. The arenites consist of rounded second-cycle quartz, with scattered patches of completely kaolinised feldspar, and much interstitial chlorite and clay minerals.

A generalised section of the Luman Siltstone is given below. The principal variations from this section are that the sequence thins to 170 feet westwards, 4 miles west-north-west of Torrens Yard, and is apparently even thinner at Diamond Gorge. Also, in the Carola Syncline and at Pyra Gorge, thin beds of feldspathic sandstone are interbedded with the siltstone and increase in abundance upwards to the total exclusion of siltstone. The exposed thickness in the Carola Syncline is 120 feet of which feldspathic sandstones form the upper 40 feet.

Luman Siltstone (Reference Section)

Generalised measured section 1½ miles east of Mount Laptz (Lat.17°40'30"S, Long. 126°45'E.). Measured by D.C. Gellatly.

Feet.	King Leopold Sandstone.
156	Siltstone; pale grey-green and pale purple-grey micaceous siltstone.
25	Siltstone; grey, green-grey, and purple-grey micaceous siltstone with minor grey shale interbeds.
22	Shale; purple-grey shale with thin grey shale interbeds.
33	Shale; grey-brown and purple-grey shales with thin interbeds of flaggy micaceous siltstone.
236 Total	
	Lansdowne Arkose.

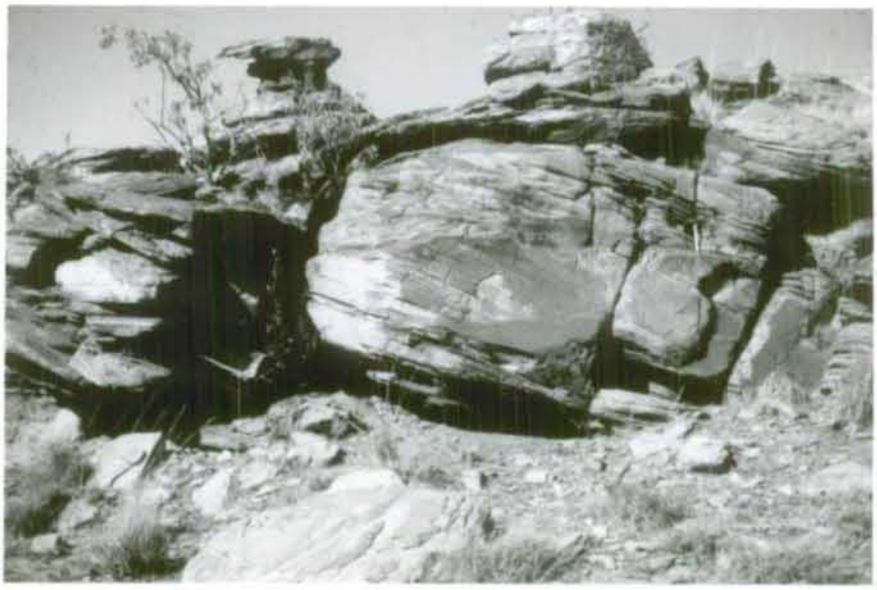

Figure (6). Cross-bedding in the Lansdowne Arkose D.C.G.

Strongly developed current-bedding in the Lansdowne Arkose near Lansdowne-Fitzroy track 4 miles due east of Mount Laptz summit. The 3 feet to 4 feet thick foreset units are typical of this member (No.5) of the Lansdowne Arkose and distinguish it from others in the Speewah Group.

Figure (7). King Leopold Sandstone. K.A.P.

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

KIMBERLEY GROUP

The Kimberley Group, of Middle Proterozoic age, lies conformably on the Speewah Group, except in the south-eastern part of the Sheet area, where it is transgressive and locally lies unconformably on the Speewah Group, the Halls Creek Group and Whitewater Volcanics. It is conformably overlain by the Bastion Group in the north-eastern part of the Lansdowne Sheet area and unconformably by the Mount House Group in the north-western part.

The Kimberley Group consists essentially of sandstone with subordinate basalt, siltstone, and carbonate rocks and is intruded locally by dolerite. The following formations are recognised within the Group:

5. Pentecost Sandstone
4. Elgee Siltstone
   Teronis Member
3. Warton Sandstone
2. Carson Volcanics
1. King Leopold Sandstone

The maximum thickness of the Group in the Lansdowne Sheet area is about 11,000 feet, of which arenites make up more than 8000 feet.

King Leopold Sandstone

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

The relationship of the King Leopold Sandstone to the Luman Siltstone, at one time thought to be "probably unconformable" (Dow et al. 1964), is now recognised as being generally conformable in the Lissadell and Lansdowne Sheets. However, an unconformity occurs at the base of the King Leopold Sandstone in the south-eastern part of the Lansdowne Sheet area, where it rests unconformably on the basal beds of the Tunganary Formation and overlaps on to the Halls Creek Group and the Whitewater Volcanics.

The King Leopold Sandstone crops out mainly in a broad belt extending from the western boundary of the Lansdowne Sheet area to the north-eastern corner, and forms the King Leopold and Durack Ranges. Minor outcrops are also found in the Pyra Gorge-Goanna Spring area in the south-east. The thickness is about 4000 feet.

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

The unit consists almost entirely of coarse-grained, commonly medium- to thick-bedded, poorly-sorted quartz sandstones ranging in colour from white, pale pink and buff to purple and pale brown. They range from poorly cemented friable varieties to hard silica-cemented ones. Strong cross-bedding is characteristic throughout the unit, with cross-bedded units mainly 1 to 1½ feet thick. Slump structures are developed locally.

Pebble conglomerates with ⅛" to 1" pebbles are present in the lower part of the sequence, and a marker bed of cobble to boulder conglomerate associated with quartz granule sandstone and localised siltstone is found about half way up the succession. Cobbles and boulders within the conglomerates consist of vein quartz, quartzite, white to purple quartz sandstone and minor shale.

No detailed section has been measured on the ground with tape and Abney Level, but the following composite stratigraphical section has been compiled from observations at several localities in the Elgee Homestead-Mount Laptz area. Thicknesses are partly from field observations and partly calculated from air photograph measurements.

<u>Section of King Leopold Sandstone - Kl</u>

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

(a) 12 to 14 miles south-west of Elgee Homestead (Lat. 17°31'S, Long. 127°08'E, to Lat. 17°24'S, Long. 127°08'E).

(b) 8 miles north-east of Elgee Homestead (Lat. 17°21'S, Long. 127°21'E).

(c) 4 miles north-north-west of Elba Hole Yard (Lat. 17°31'S, Long. 126°43'E).

(d) 1½ miles east of Mount Laptz (Lat. 17°40'30"S, Long. 126°45'E). Measured by G.M. Derrick and D.C. Gellatly.

Approximate Thickness Feet.		Carson Volcanics
(a,c)	125	Sandstone; pale rusty brown, medium-grained, medium- to thin-bedded quartz sandstone.
(a)	700	Sandstone; pale purple and pink to white, cross-bedded coarse-grained quartz sandstone, with ripple-marks and clay pellets.
(a)	200	Sandstone; red-brown to purple ferruginous thin-bedded fine- to medium-grained silty quartz sandstone.

Feet	Section of King Leopold Sandstone - Kl (Contd.)
(a,c) 1170	Sandstone; hard white, medium- to coarse-grained silica-cemented quartz sandstone; cross-bedded and massive, with minor quartz pebble beds.
(b) 70	Siltstone; dark grey siltstone and fine-grained fissile sandstone; poorly exposed; thins out to north-east and south-west.
(c) 20	Sandstone; hard white medium- to coarse-grained silica-cemented quartz sandstone.
(a,c) 10	Granule sandstone; coarse purple-grey quartz granule sandstone, with 2 to 4 mm. rounded grains; thickness up to 30 feet.
(a,c) 5	Conglomerate; pebble, cobble, and boulder conglomerate, purple-grey to red-brown in colour with inclusions of quartz sandstone, quartzite, slate and vein quartz; thickness variable from 2 in. to 25 feet.
(c) 1300	Sandstone; white, pale pink, and buff medium- to coarse-grained strongly cross-bedded, poorly-sorted quartz sandstone; rare pebble conglomerates with pebbles up to 1 in..
(c) 350	Sandstone; cliff-forming white to pale cream slightly micaceous fine- to medium-grained clayey quartz sandstone.
(d) 50	Sandstone; strongly cross-bedded pale purple-grey to pale brown micaceous fine-grained quartz sandstone with bleached spots in purple beds.
4000	

Luman Siltstone

Not all the minor lithological subdivisions given in this section can be recognised throughout the area. The most useful marker bed is the conglomerate unit. Although this thins down to as little as 2 inches in places west and south-west of the reference area, the association of conglomerate overlain by granule sandstone is distinctive and can be recognised over a total strike length of more than 80 miles.

Thickness estimates range from 4400 feet north of Elba Hole Yard and 3850 feet a few miles south-west of Elgee Homestead, to 3000 feet north of Lansdowne Homestead and 2300 feet at Diamond Gorge. These figures together with the estimate of 300 feet + (Dunnet and Plumb, 1964) for the Lissadell area indicate that the maximum thickness occurs in the central part of the Lansdowne Sheet area and that the unit thins to the north-east and to the west. The area of maximum thickness of the King Leopold Sandstone is also the area of maximum thickness of the Lansdowne Formation.

In the south-east of the Lansdowne Sheet area, a thickness of only 900 feet is present, lying unconformably on lower Speewah Group and Halls Creek Group rocks. The thin sequence present here, which includes a basal conglomerate, is probably equivalent to the topmost part of the full succession. At Pyra Gorge, however, further to the south-south-west on the same structure, a full section is present.

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

Carson Volcanics

The basic volcanics which crop out extensively around the Carson River (Lat. 14°30'S, Long. 126°45'E) in the north Kimberley Plateau have been renamed the Carson Volcanics by Dow et al. (1964). The original name, Mornington Volcanics, (Guppy et al., 1958, Harms, 1959) is invalid because of prior usage elsewhere. The reference section is in the Lissadell Sheet area at Lat. 16°17'30"S, Long. 127°42'E.

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

The Formation consists dominantly of altered basic lavas and subordinate pyroclastics, with numerous thin, discontinuous arenite interbeds which range in thickness from about 5 feet up to 80 feet. The basal flows which have a total thickness ranging from about 100 feet up to 500 feet, consist dominantly of altered, readily weathered dark grey and grey-green coarse-grained basalts and spilites including highly amygdaloidal types with amygdules of chlorite, epidote, quartz, calcite and chalcopyrite. In the area north and north-west of Elgee Homestead, beds of feldspathic sandstone and arkose up to 25 feet thick are interbedded with the basal flows, but are absent elsewhere. Above the basal, dominantly spilitic, part of the sequence, a massive medium-grained dark grey non-amygdaloidal basalt (A) up to almost 400 feet in thickness probably represents a single flow. Above this flow the section is more varied both in thickness and in lithology, and flows cannot be correlated readily from area to area. The dominant rock types in this part of the succession are coarse-grained basalt with arkose interbeds, and minor pale grey-green amygdaloidal rhyolite, tuff, agglomerate, chert, and limestone. The topmost part of the sequence consists of a uniform succession of siltstone and feldspathic sandstone, 200 to 300 feet thick, which forms a steep scarp slope underlying the more resistant Warton Sandstone.

The following generalised sections have been measured:

Carson Volcanics - Section C1

Fitzroy River Valley, 5 miles north of Colass Yard, Lat. 17°28'S, Long. 126°33'E. Measured by D.C. Gellatly.

Feet	Warton Sandstone
300	Scree slope; poor exposure of purple siltstone and micaceous arkose.
25	Thinly banded cherty limestone.
10	Pale grey amygdaloidal rhyolite.
50	Dark grey-green basaltic agglomerate with chert fragments.
285	Fine- to medium-grained non-amygdaloidal basalt, dark grey, with thin interbeds of arkose and chert.
90	Grey-pink medium- to fine-grained micaceous arkose and feldspathic sandstone.
255	Coarse-grained dark grey slightly amygdaloidal basalt.
210	Pink to brown feldspathic sandstone, arkose and flaggy micaceous siltstone.
130	Pale green-grey fine- to medium-grained slightly amygdaloidal ? andesite.
20	Pale pink flaggy, micaceous, medium-grained arkose.
55	Dark grey, fine-grained slightly amygdaloidal basalt.
80	Fine-grained, pale pink to dirty grey, thin- to medium-bedded arkose and feldspathic sandstone.
A 385	Massive, dark grey, mostly fine-grained non-amygdaloidal basalt.
20	Clean-washed feldspathic sandstone.
30	Green-grey non-amygdaloidal spilite, with traces of chalcopyrite.
55	Pale purple-grey amygdaloidal spilite. Amygdules of grey-green chlorite, calcite and quartz. Traces of specular hematite and chalcopyrite.
80	Non-amygdaloidal grey-green spilite with specks of chalcopyrite.
95	Potash feldspar bearing spilite; poorly exposed.
2175 Total	King Leopold Sandstone

Carson Volcanics - Section C2

Measured 4 miles east of Teronis Gorge. Measured by G.M. Derrick.

Feet.	Warton Sandstone
180	Arkosic siltstone and fine-grained sandstone; flaggy, micaceous cross-bedded and slumped.
30	Purple and green micaceous shales.
50	Silicified tuffaceous sandstones; coarse-grained to fine-grained, with abundant bands of grey-green chert and greywacke siltstone.
220	Altered basic lavas; highly amygdaloidal, with chlorite, calcite, epidote and chalcopyrite amygdules. Some tuff and agglomerate. Rare pillow structures.
A 285	Massive non-amygdaloidal basalt; grey to black, fine- to medium-grained.
50	Basaltic agglomerate, flow breccia, tuffaceous sandstone.
120	Fine even-grained basalt with interbedded orange-brown arkose.
20	Altered basalt; highly amygdaloidal, with chlorite, quartz, chalcopyrite and epidote amygdules. Interbeds of chert characteristic. Possibly spilitic.
175	Feldspathic sandstone, arkose and buff to purple-green quartz sandstone; pebbly at base, some slumping and cross-bedding at top. Thin interbedded basalt flows, fine- to medium-grained, slightly amygdaloidal.
90	Basalt; medium-grained, epidotised, with amygdules of chlorite, calcite, epidote, and more rarely chalcopyrite and galena.
60	Green-grey basalt; medium-grained, amygdaloidal, some quartz veins. Amygdules contain chalcopyrite traces. Potash feldspar present in amygdules in upper part of flow.
1280 Total	King Leopold Sandstone

The upper-most lavas described in Section 2, are extremely calcitised, with coarse calcite occupying pore spaces in basaltic "froth" and amygdules in altered basalt. Amygdule trails through otherwise non-amygdaloidal basalt and large amygdules containing chert and calcite indicate an irregular streaming of emanations charged with silica and carbonate. This is suggestive of local submarine extrusion, and is supported by the abundance of interbedded sediments, and the presence in one locality of possible pillow structures. Likewise the basal flows, which are dominantly spilitic and locally interbedded with sediments, may also have been extruded into water, but the majority of flows in the Carson Volcanics appear to have been extruded sub-aerially. A possible vent and fissure line are located in the vicinity of Lat. 17°20'S, Long. 127°17'E.

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

The Carson Volcanics show rapid variations in thickness throughout the Lansdowne Sheet area, particularly in the upper part of the Volcanic sequence. Measured thicknesses on the Lissadell Sheet area of 750 feet and 865 feet (Dow et al., 1964) and the measured thicknesses of 1280 feet and 2175 feet in the Lansdowne Sheet area indicate a general thickening of the Carson Volcanics south-westwards. This variation however is irregular; for example a thickness of 880 feet has been recorded south-east of Tullewah Hill equidistant from the two measured sections in the Lansdowne Sheet area. A thickness of 1700 feet is recorded in the Little Gold River valley immediately south of Pyra Gorge, where the section is similar to that in the Fitzroy Valley except that pyroclastics are more abundant towards the top, and the siltstones are apparently absent.

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

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

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

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

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

Warton Sandstone

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

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

The thickness, estimated from the width of outcrop on air photographs and dips measured in the field, is approximately 1200 feet 12 miles due south of Tableland Homestead, and 900 feet near Teronis Gorge.

With the exception of a slight increase in feldspar content upwards in the sequence, the rocks are uniform in appearance. The basal beds consist almost entirely of massive medium-grained white cliff-forming silica-cemented quartz sandstones with thin interbeds of thin-bedded pale purple-grey friable quartz sandstones. Locally the lower sandstones are pale rusty brown on weathered surfaces. The middle and upper parts of the succession are characterised by the appearance of grains of pale pink bands of chert locally ferruginous, and with feldspathic sandstone and arkose, which is locally slumped. This association has been commented upon by Turner & Verhoogen (1960, p.261) and others.

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The Warton Sandstone is strongly current-bedded throughout the sequence. Current-bedded units are mainly 2 to 3 feet thick in the lower part of the succession, but are mostly only 3 in. to 12 in. thick in the middle and upper parts. The current directions are dominantly from the north and north-west, with a spread from 240° to 75°. Ripple marks and clay pellets are found locally.

In thin section a specimen from the lower part of the Warton Succession is a moderately coarse-grained, well-sorted quartz sandstone consisting essentially of rounded to sub-rounded quartz grains with optically continuous overgrowths of silica cement and minor accessory turbid feldspar, muscovite, zircon, sphene, olive-green tourmaline, and interstitial sericite.

A specimen from near the top of the sequence is a fine-grained, well-sorted, silica-cemented arkose, consisting of quartz with silica-cement overgrowths, and about 35% of feldspar, mostly turbid potash feldspar, but including some clear plagioclase and microcline, along with minor accessory muscovite, zircon, and sphene.

<u>Elgee Siltstone</u>

The Elgee Siltstone overlies the Warton Sandstone and underlies the Pentecost Sandstone. Its relationship with each is conformable. The name "Elgee Shale" was used by Harms (1959) for the principal lutite member of the "Warton Beds" of Guppy et al. (1958); Dow et al. (1964) modified the name to Elgee Siltstone. The name is derived from the Elgee Cliffs which extend for a distance of about 100 miles from the north-eastern part of the Lansdowne Sheet area to the northern part of the Lissadell Sheet area.

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

Elgee Siltstone		(4)	Sandstone
		(3)	Red-brown Siltstone
	Teronis Member	(2)	Limestone and dolomite; with algal structures.
		(1)	Grey Siltstone

The thickness is about 700 feet, of which the Teronis member in most cases constitutes less than 100 feet.

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

Section of Elgee Siltstone

Generalised measured section; distances paced; at Boab Creek, east side of Baulk Face Range, 5 miles south of Tableland-Glenroy track. (Lat. 17°19'30"S, Long. 126°43'30"E). Measured by D.C. Gellatly.

Feet	
	Pentecost Sandstone (Hard white cliff-forming quartz sandstone)
210	Sandstone; pale brown quartz sandstone with rare interbeds of fissile silty sandstone.
50	Sandstone; thin-bedded, hard to friable pink-brown, purple-brown, and pale buff quartz sandstone, with minor brown silty feldspathic sandstone and thin red-brown siltstone interbeds.
375	Siltstone; poorly exposed soft friable red-brown siltstone with 1 in. to 2 in. interbeds and scattered spheroidal patches of green-grey siltstone; thin pink-grey fine-grained silty arkose at base.
685 Total	
	Dolerite - 97 ft.
	Teronis Member
10	Limestone; mottled pale grey-green and pink-brown siliceous limestone with algal structures; poorly exposed.
	Dolerite - 31 ft.
20	Siltstone with thin interbeds of pale brown feldspathic sandstone.
25	Shale; purple-grey fissile micaceous shale and siltstone.
20	Siltstone; purple-grey micaceous siltstone and shale with 2 in. to 6 in. interbeds of pale grey and pale brown ripple-marked micaceous feldspathic sandstone.
75 Total	
	Warton Sandstone
710 Feet Combined Total	

The lower part (unit 3) of the Elgee Siltstone proper, is a thick succession of siltstone which is only rarely exposed. It consists of soft red-brown siltstone and silty shale with 1 in. to 2 in. interbeds of pale green-grey siltstone and sporadic subspherical patches of green-grey siltstone, presumably derived from the red-brown siltstone by the chemical reduction of ferric oxide by small amounts of organic matter. This siltstone sequence is overlain by sandstone (unit 4). There is a moderately rapid transition from siltstone into deep pink-brown and buff-coloured sandstone with thin interbeds of red-brown and green-grey micaceous siltstone. Clay pellets are common on the sandstone bedding planes. These siltstones grade upwards into pale-brown sandstone through an increase in the sand/silt ratio, a decrease in colour intensity, and a thickening of the bedding. Thin cross-bedded units appear and become progressively thicker upwards.

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

The total thickness of the formation, which is 700 feet in the measured section, decreases to 600 feet to the north-east near Teronis Gorge, and thickens southwards to over 1,100 feet in the Mount Ramsay area, the increase being mainly due to an increase in the thickness of the Teronis Member.

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

Teronis Member (new name)

The Teronis member is defined as a succession consisting predominantly of grey siltstone and carbonate rocks, including algal limestone which overlies the Warton Sandstone and underlies the typical red-brown siltstone of the Elgee Siltstone escarpment sequence. The name is derived from Teronis Gorge (Lat. 17°18'15"S, Long. 127°15'30"E) in the Lansdowne Sheet area where the member is well developed.

The lower part (unit 1) of the Teronis Member consists mainly of purple-grey micaceous shale and siltstone with 2 in. to 6 in. interbeds of pale brown to buff coloured fine-grained feldspathic sandstone, and has a sharp contact with the underlying clean washed feldspathic sandstone and arkose of the Warton Sandstone.

The succession of limestone and dolomite (unit 2), which is very variable within the Lansdowne Sheet area, has been examined in detail only around the eastern margin of the Baulk Face Range, where it is mostly only 8 feet to 25 feet thick and consists of several thin carbonate beds with thin interbedded siltstones, e.g. in the following section measured on Boab Creek 1 mile south of the Tableland-Glenroy track:

2½ feet	Siliceous carbonate
1 foot	Siltstone
1 foot	Siliceous carbonate
1 foot	Siltstone
1 foot	Siliceous carbonate
12 feet	Flaggy siltstone and silty sandstone
8 feet	Carbonate

Several types of carbonate rock are present. One type, probably the most abundant, is dark brown on weathered surfaces and pale grey on fresh surfaces. Another type has a ¼ in. to ½ in. thick coating of powdery limonite on weathered surfaces and varies from pale grey to pale-pink-brown mottled with pale grey-green when fresh. Algal limestone occurs extensively throughout the area, but is locally absent; it is mainly grey to grey-brown on weathered surfaces and contains abundant cylindrical algal structures 3 in. to 8 in. high and about 1 in. in diameter. These structures have an erosion resistant central columella surrounded by a preferentially eroded intermediate zone and an outer erosion-resistant ring. They are generally found in continuous colonies with the individual algal structures only about 1½ inches apart.

The thickness of the Teronis member varies considerably within the Lansdowne and Mount Ramsay Sheet areas. Other areas where it may occur have yet to be mapped and the variations elsewhere are thus unknown. The Teronis Member decreases in thickness to the north-east and dies out in the Lissadell Sheet area. It increases southwards in the Lansdowne Sheet area from 75 feet in the measured section to around 150 feet in the south, about 8 miles south-south-west of Mad Gap Yard, where the limestone is massive and about 100 feet thick. Here the lower 30 feet contain algae and the topmost 20 feet are dark brown and limonitic. At Pyra Gorge, further west, it is about 300 feet thick. In the reference section in the Margaret River area, it is 240 feet thick, and farther to the north-east in the Mount Ramsay Sheet area it attains a thickness of 450 feet.

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

Figure (8). Algal structures in Teronis Member. K.A.P.

Plan view looking down vertically on to algae in limestone of Teronis Member of the Elgee Siltstone; note the upstanding central columella and readily eroded surrounding ring; length of scale = 6 in.; locality 20 miles east of Pyra Gorge. (Scale is 20 cm. long).

Figure (9). Metasomatic granophyre of Hart Dolerite. D.C.G.

Extremely elongate prismatic pyroxenes in upper part of granophyre below small circular outcrop of arkose 3 miles south-south-west of Lily Yard (Lansdowne Station). This upper part of the granophyre is probably metasomatic. It overlies Hart Dolerite and underlies Tunganary Arkose.

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

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

Pentecost Sandstone

The Pentecost Sandstone, which is the topmost formation of the Kimberley Group, overlies the Elgee Siltstone conformably and is conformably overlain by the Mendena Formation of the Bastion Group. The name Pentecost Sandstone, derived from the Pentecost Ranges (15°46'S, 127°48'E) in the western part of the Cambridge Gulf Sheet area, was first used by Harms (1959) for the uppermost division of the "Warton Beds" of Guppy et al. (1958).

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

The formation may be subdivided into three units, two sandstones and an interbedded siltstone. Of the total thickness of 2,500 feet, the lower sandstone and the siltstone make up 480 feet and 65 feet respectively.

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

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

The sandstones are strongly cross-bedded, particularly in the lower part of the sequence, with foreset units mostly 12 in. to 18 in. thick. The source direction indicated by the current bedding in the lower sandstone is dominantly from the west-north-west, like that of the Warton Sandstone.

The basal beds are white to very pale brown medium- to coarse-grained silica-cemented quartz sandstone. They are medium- to thick-bedded (4 inches to 2 feet) and are strongly cross-bedded with foreset units 12 in. to 18 in. thick. These basal beds crop out as low cliffs up to 50 feet high and form a resistant capping overlying the more easily weathered siltstones and sandstones of the Elgee Siltstone.

Above the first 50 feet, the sandstones become white, and are blocky weathering with conchoidally fractured blocks. These grade rapidly upwards into friable off-white to pale rusty brown, fine-grained quartz sandstone. These pale rusty-brown quartz sandstones persist throughout most of the sequence up to the siltstone unit.

The siltstone unit, which is poorly exposed, consists of purple-grey to green-grey ripple-marked micaceous shale and siltstone with interbedded pale grey, flaggy, feldspathic sub-greywacke. Towards the top of the siltstone sequence there is a thin bed of grey-green muscovite-bearing glauconitic quartz sandstone containing about 20% of fresh bright green glauconite. The siltstone unit forms a useful marker bed which has been noted in the southern part of the Baulk Face Range and in the drainage basin of the Durack River.

The upper sandstone unit consists of thin-bedded, locally flaggy fine- to medium-grained buff to pale pink feldspathic sandstone and arkose, and hard white silica-cemented quartz sandstone and feldspathic sandstone.

In the Lissadell area, three siltstone units are recognised in the Pentecost Sandstone. Of these only one, namely the lowest one, has been noted in the Lansdowne area. This may be due to lensing out of the upper two siltstones or possibly due to lack of exposure and lack of ground control in the inaccessible north-eastern part of the Lansdowne Sheet area.

In thin section, sandstones from the basal sandstone unit are well-sorted and fine-grained with grain-size about 0.1 mm. to 0.05 mm. They consist almost entirely of rounded to sub-angular quartz grains with optically continuous silica overgrowths, together with minor accessory feldspar, zircon, green tourmaline and black opaque ore.

A specimen from the siltstone unit is a silty quartz sandstone consisting of small (0.07 mm.) angular to sub-angular quartz grains in a matrix of pale green chlorite, minor accessory feldspar, glauconite, tourmaline, and green biotite.

The glauconitic sandstone consists of interlocking 0.2 mm. silica-cemented quartz grains; rounded 1 mm. grains of pale green glauconite, some partly replaced by chlorite; and minor accessory feldspar, muscovite, goethite and limonite.

BASTION GROUP

Mendena Formation

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

In the Mount Elizabeth Sheet area, the Formation consists predominantly of shale and siltstone with thin interbeds of sandstone. The shales and siltstones are purple-grey in colour, laminated and fissile, and make up about 90% of the sequence. Sandstone interbeds are up to 10 or 20 feet thick, and are separated by 50 to 100 feet of lutite. The sandstones become less abundant upwards and vary from green and purplish fine-grained micaceous laminated flaggy feldspathic sandstone to white fine- to medium-grained thin-bedded, blocky quartz sandstone.

In the Lansdowne Sheet area the thickness is difficult to estimate because of the low angles of dip but is probably not more than 100 feet.

HART DOLERITE

Introduction

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

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

This unit is one of the most extensively developed dolerites in the world, and is probably the most extensive Precambrian example. The total area of outcrop in the Kimberley area is about 1800 square miles, which is less than that of the Karroo Dolerite of South Africa, and the Tasmanian Dolerite, but is of the same order of magnitude as the latter. The total area underlain by dolerite in the Kimberley area is about 50,000 square miles, and the total volume is of the order of 30,000 cubic miles. As yet, however, there is little information on it, compared with that available on the South African and Tasmanian dolerites.

In the Lansdowne Sheet area, the Hart Dolerite crops out principally in a broad arc concave to north-north-west, following the outcrop of the Speewah Group, but minor occurrences are found outside this belt. The extent of outcrop in the Sheet area is about 850 square miles.

It forms low rounded boulder-covered hills which have an even grey tone on air photographs, and tree-less stony black-soil plains. The granophyre, which is slightly more resistant to weathering, forms mesas and strike ridges and is locally covered by red soil.

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

Field Occurrence.

The Hart Dolerite intrudes the majority of Middle Proterozoic and older formations found in the Lansdowne Sheet area. It is rare in rocks below the Speewah Group, but localised occurrences are present in the Halls Creek Group and Whitewater Volcanics immediately north of Pyra Gorge. A few basic dykes, possibly related to the Hart Dolerite, are found in the Lamboo Complex particularly in the south-eastern part of the Sheet area. The most extensive series of sills is found throughout the Speewah Group from the upper O'Donnell Formation up to the Luman Siltstone. Within this Group, the Dolerite shows a marked preference for the siltstone horizons, in which it forms anastamosing, dominantly concordant sills of considerable lateral extent, although a few small sills, some of them discordant, are found intruding arenites, e.g. 7 miles south-west of Coolan Creek Yard. Within the Kimberley Group, the Hart Dolerite is quite extensively developed along a thin conglomerate horizon about the middle of the King Leopold Sandstone, and is found locally within the Carson Volcanics, particularly in the south-eastern part of the Sheet area, where it is difficult to distinguish from the Carson basalts. Thin sills are commonly found in the lower part of the Elgee Formation, and a few sills, one of them traceable for more than 20 miles, are present within the Pentecost Sandstone. Discordant relationships are partly sinuous and uncontrolled, and partly the result of splitting of the host sediments along fault and joint planes. Locally, large blocks of sediment, several square miles in extent, have been rafted out of their original position by the dolerite. The dolerite elsewhere follows individual beds for distances of up to 30 miles, and a single complex outcrop of dolerite can be traced continuously for 145 miles within the Sheet area from near the Bedford Stock Route in the north-east to Diamond Gorge in the west.

The total area of the Hart Dolerite outcrop in the Lansdowne Sheet area is about 850 square miles, of which approximately 200 square miles occur within the Kimberley Group, 650 square miles within the Speewah Group, and only 10 square miles in older rocks. Of the total area of outcrop, 800 square miles are dolerite and 50 square miles are granophyre.

The thickness of the sills is variable, mostly from 50 feet up to 3000 feet, e.g. 12 miles south of Bedford Downs. The maximum thickness in the Lansdowne Sheet area, however, is apparently of the order of about 10,000 feet, found to the north-west of Galway Valley Yard.

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

Late-stage hydrothermal alteration has resulted in the formation of epidote veins within the dolerite and in localised occurrences of prehnitised dolerite. Sporadic veins of calcite, some with individual crystals up to 6 inches across, and minor quartz veins carrying traces of chalcopyrite, are also found.

Contact metamorphism of country rocks at the margin of the dolerite intrusions is slight. Siltstones are altered to hard blocky hornfelses, and arkoses are indurated for a distance of only two to three feet from the contact.

Igneous flow lamination has been noted in a number of places, but is not common. It is best developed about 3 miles east of Mud Spring and 4 miles south-east of Lily Yard. It is also well-developed relatively high in the dolerite sequence in the Speewah Valley. Such lamination infers the presence of a planar boundary to control the plane of flow, and could be the result of two-stage intrusion in which flow lamination in the later intrusion has developed along the upper contact of the earlier intrusion, or could be interpreted as the result of flow conditions developing within a partially settled magma.

Granophyre. In almost all known occurrences, the granophyre forms a flat-lying sheet either at, or near the top of a dolerite sill. A few exceptions to this are known; about 2 miles north-west of Lily Yard a plug of granophyre has apparently intruded dolerite; 3 miles south-south-west of Bedford Downs Homestead, granophyre, which is not in contact with dolerite, has intruded arenites of the Lansdowne Arkose; one mile east-south-east of Piantis Yard a thin dyke of granophyre cuts dolerite lying above a granophyre layer; and a short distance west of Piantis Yard a thin dyke of granophyre has been noted cutting dolerite.

The occurrence of granophyre is not directly dependant on the thickness of the associated dolerite sills, but is at least partly related to it. For example, the very thin dolerite sills, especially the transgressive ones, do not have any associated granophyre and most, but not all, of the thick ones do have granophyre. Sills 2,500 feet thick 12 miles south of Bedford Downs Homestead, and 4 miles north-west of Twenty Mile Yard, and 2000 feet thick 6 miles east of Lansdowne Homestead, show no development of granophyre. Similarly, the relative thickness of the dolerite and granophyre are very variable. North-west of Galway Valley Yard, only 100 to 200 feet of granophyre are present overlying dolerite estimated to be more than 10,000 feet thick, whereas in the Red Valley, a short distance to the west, 750 feet of dolerite are overlain by 500 feet of granophyre.

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

(6) Within the lower part of the King Leopold Sandstone Succession, e.g. 5 miles west-north-west of Lansdowne Homestead.

(5) Within the Luman Siltstone, e.g. 1 mile south-west of Melrod Yard.

(4) Between the middle and upper Lansdowne Arkose, (i.e. between units 5 and 6), e.g. east of Old Bedford Yard.

(3) Within the lower Siltstone horizon (unit 2) of the Lansdowne Arkose.

(2) At the lower contact of, or within the Valentine Siltstone.

(1) Within the Tunganary Formation, probably at different levels, e.g. about the top of the sequence near Lansdowne airstrip, and near the base six miles south-east of Goads Yard.

No granophyre has been found at horizons lower than the Tunganary Formation or at horizons higher than the King Leopold Sandstone. This is probably due to the fact that all the thickest sills are found within the Speewah Group. Granophyre is more commonly developed within the Tunganary Formation and at the Valentine Siltstone than at other horizons.

The granophyre is a red-brown to pale pink-brown rock which is mostly medium-grained and commonly mesocratic. Porphyritic phases with phenocrysts of pyroxene and off-white plagioclase in a pink granophyre matrix are found, but are uncommon. A peculiar type of granophyre with slender pyroxene up to 4 inches long and locally forming "comb" or "herring-bone" structure is developed sporadically overlying normal granophyre and underlying arkose.

Contact alteration of siltstone by the granophyre is restricted to slight induration, but arkose is strongly indurated for distances of 20 feet or more from the contact and generally has a spotted appearance due to the segregation of the feldspathic components of the arkose into ¼ inch spheroidal nodules surrounded by narrow siliceous borders. On a small scale the contact between arkose and granophyre is irregular and sinuous and is gradational over a ¼ inch wide zone. In places elongate crystals of pyroxene have grown into the arkose.

In the field a gradation has been found between dolerite and granophyre in one locality about 3 miles north of Mud Spring. Such gradations may be general, but the intermediate rocks are more readily weathered than either the dolerite or the granophyre and there is commonly an area of no outcrop between the two rock types.

About 1 mile east of Piantis Yard, a thin granophyre dyke which has been traced for over 100 yards, cuts coarse-grained dolerite and shows gradational contacts with it. The dolerite is considerably enriched in micropegmatite in a 6-inch wide contact zone adjacent to the dyke, and this, together with the gradational nature of the contact, suggests that the dyke was intruded into only partly consolidated dolerite, as otherwise no appreciable metasomatism of dolerite would be expected. This occurrence may be cited as evidence of the contemporaneity of dolerites and granophyre in at least one part of the area.

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

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

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

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

The contact metamorphosed arkoses adjacent to the granophyre are characterised by the development of small amounts of interstitial micropegmatite. These "meta-arkoses" which consist mainly of quartz, potash feldspar and minor chlorite show marginal recrystallisation of quartz grains resulting in the formation of a series of peripheral pyramidal terminations on each detrital quartz grain. These recrystallised quartz grain margins have been locally <u>penetrated</u> by potash feldspar to give small patches of finely crystalline micropegmatite which makes up around 5% of the rock.

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

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

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

(2) Contact metasomatism and/or assimilation of arkose in situ.

(3) Direct intrusion of two separate magmas accompanied by partial mixing.

(3) On a small scale the existence of a separate acid magma in the Lansdowne area is indicated by dykes of granophyre intruding dolerite, and by the porphyritic nature of certain of the granophyres, which suggests slow partial crystallisation at depth followed by more rapid crystallisation on intrusion. Such an origin would necessitate the derivation of intermediate rocks by partial mixing of acid and basic magma, a postulate which is not consistent with the known temperature differences between these two magmas and the fact that in other areas of the world where they have come in contact the effect has been one of chilling of the basic magma by the acid rather than of mixing (Blake et al. 1964). Because of this objection and the comparative paucity of intrusive granophyres, this possibility is not favoured, for the origin of the granophyre as a whole, but it is possible that minor amounts of acid magma were intruded independently.

(2) Assimilation also seems to have been relatively unimportant, since at dolerite-sediment junctions there are no contact effects, either thermal or metasomatic, other than slight induration. If assimilation of xenoliths had occurred, localised inhomogeneities might be expected, due to incomplete assimilation or incomplete dissipation of assimilated products,

but these are not found except in one locality in the Speewah Valley. Evidence for assimilation is generally lacking in most dolerites (Walker, 1958).

In this context, the possibility of assimilation or metasomatism caused by the granophyre itself must be considered. Although this possibility cannot provide an explanation for primary development of granophyre, it is possible ~~that the~~ amount of granophyre may have been increased by assimilation and metasomatism of arkose. The compositional changes required to convert arkose to a relatively leucocratic granophyre are comparatively minor. In one locality it has been noted that very elongate crystals of pyroxene have grown into the arkosic host rock from the intruding granophyre, and in several places the development of granophyric textures is found in the contact altered arkose. In several places a distinct variant of the granophyre containing slender elongate pyroxenes has been noted overlying normal granophyre and underlying arkose. The fact that elongate pyroxenes have been found growing in contact altered arkose, and the position at which this unusual type of granophyre is developed, strongly suggest that it may have originated in situ by metasomatism of arkose. It is of interest that a similar granophyre with elongate pyroxenes figured by Walker and Poldervaart (1949, Plate 10) is described by them as metasomatic.

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

In many places in the area the Hart Dolerite contains between 5% and 10% of micropegmatite and locally considerably more, so it appears that over these areas little or no differentiation can have taken place, if it is assumed that the original magma was similar in composition to the average tholeiite. The most abundant type of dolerite, however, contains only about 1-2% of interstitial quartz and potash feldspar; if the original magma was a normal tholeiitic one, it could therefore have differentiated to form granophyre, plus dolerite relatively impoverished in salic constituents.

The relationships in areas where the granophyre/dolerite ratio is much greater than 1/12, such as Red Valley, where it is 2/3, still require explanation. Perhaps the most likely explanation is that the Red Valley granophyre originated elsewhere, possibly to the east, in the area north of Mud Spring, probably as a result of crystallisation differentiation and was intruded into its present position by lateral injection along a pre-existing dolerite-sediment contact.

Age. The age of the Hart Dolerite is uncertain. In most places it is apparently earlier than the main folding and faulting of the area, but it probably post-dates the earliest faulting. The occurrence of uniformly thick dolerite sills with overlying granophyre which maintains a uniform thickness on both crest and limbs of fold structures, e.g. as in Red Valley, indicates that in general the dolerite pre-dates the folding. This is supported by the fact that the granophyre sheets, which presumably must have developed in a horizontal or sub-horizontal position, are now mostly inclined and are parallel to the adjacent dipping sediments.

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

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

UPPER PROTEROZOIC

MOUNT HOUSE GROUP (old name redefined)

The Mount House Group contains the youngest Precambrian rocks in the Lansdowne Sheet area and consists of the following formations:

(4) Estaughs Formation
(3) Throssell Shale
(2) Traine Formation
(1) Walsh Tillite.

The name is derived from Mount House (Lat.17°08'S, Long. 125°44'E), in the Lennard River Sheet area, to the west of the Lansdowne Sheet area. The rocks of the Group were originally named the "Mount House Beds" and

"Walsh Tillite" by Guppy et al. (1958); the Beds have now been raised to Group status and the Walsh Tillite included. The reference area for the Group is in the scarp at the south-eastern side of the Mount Clifton plateau, about Lat. 17°24'S, Long. 126°02'E.

In the Lansdowne Sheet area the Mount House Group overlies the Kimberley Group with a slight angular unconformity. It is overlain only by Cainozoic soil cover. The Group is considered to be a stratigraphic equivalent of the Ord Group in the Dixon Range Sheet area (Dow et al., 1964) and the Kuniandi Group in the Mount Ramsay Sheet area (Roberts et al., 1965).

Outcrops are confined to the north-west corner of the Lansdowne Sheet area, bounded roughly by the Traine River in the east, and from there by a line extending south-westwards through Glenroy Homestead to the western Sheet boundary immediately south of the Mount Clifton plateau. The topmost beds of the Group have been removed by erosion and the maximum preserved thickness in the Lansdowne Sheet area is estimated to be about 900 feet.

Rocks of the Group, which are mostly flat-lying and essentially undeformed, consist mainly of flaggy micaceous green shale. Massive tillite occurs at the base of the Group and is overlain by dolomite and sandstone. Within the overlying shale succession, interbeds of flaggy sandstone are found near the base and blocky quartz greywacke at the top. Most of the rocks in the Group are very easily eroded, so that most of the area underlain by these rocks consists of wide low-lying plains with only very scattered outcrops amongst the soil cover. The blocky quartz greywackes at the top of the succession crop out strongly to cap a prominent scarp, about 500 feet high, which borders the Mount Clifton plateau.

The sequence of tillite at the base, overlain by dolomite and green shales, is diagnostic of the Group.

Preliminary radiometric dating of rocks from the Ord Group and Kuniandi Group indicates a late Upper Proterozoic age (Bofinger, pers. comm.). Since the Mount House Group is correlated with these Groups, it is also considered to be of Upper Proterozoic age.

The following composite section was measured in the vicinity of Mount Clifton and contains the reference sections for all the constituent formations.

Composite Section at Mount House Group - H1

Name of Unit		Thickness	Description
ESTAUGHS FORMATION	(1)	50 feet +	Top of unit eroded. Flaggy, cross-bedded, purple micaceous siltstone with interbeds of blocky, fine-grained sub-greywacke.

Composite Section at Mount House Group - H1 (Contd.)

Name of Unit	Thickness	Description
	40 feet	Blocky to massive purple, hematitic sub-greywacke and purple-brown flaggy feldspathic-micaceous-quartz siltsone. Clay pellets and ripple-marks present. Bed forms a prominent scarp.
	165 feet	Flaggy to blocky, laminated, grey-green fine-grained micaceous subgreywacke alternating with flaggy grey-green micaceous siltstone. Arenites occur in beds five to ten feet thick, while the siltstones occur in beds twenty to thirty feet thick. Some ripple-marks. Probable slump structures in the lower beds. This bed is transitional into the under-lying unit.
Total	255 feet	
THROSSELL (2) SHALE	490 feet	Uniform flaggy, grey-green to blue-grey, chloritic and micaceous shale with lenticular flaggy interbeds of laminated, micro-cross-bedded, fine-grained grey-green micaceous sandstone.
	85 feet	Very poorly outcropping flaggy green siltstone and fine-grained sandstone with flaggy brown sandstone interbeds near the base.
Total	575 feet	
TRAINE (3) FORMATION	12 feet	Blocky blue-grey dolomitic, chloritic sandstone.
	5 feet	Dolomite breccia.
	3 feet	Massive green-brown, medium-grained, dolomitic, chloritic sandstone with large scattered pyrite pseudomorphs.
Total	20 feet	
WALSH (4) TILLITE	14 feet	Flaggy to blocky, pink to yellow, fine-grained thin-bedded dolomite. Abundant pyrite in bedding planes.
	2 feet	Algal dolomite.
	45 feet	Massive tillite.
Total	61 feet	

Carson Volcanics.

(1) Eastern side of Mount Clifton (Lat.17°18'15"S, Long.126°1'45"E)

(2) Near Mount Clifton (Lat. 17°24'15"S, Long.126°2'15"E)

(3) South-eastern corner of Mount Clifton (Lat.17°24'15"S, Long.126°2'40"E).

(4) Throssell River (Lat. 17°24'00"S, Long.128°2'50"E)

Sections measured by K.A. Plumb and A.D. Allan.

Walsh Tillite (old name)

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

The Tillite is the basal unit of the Group. It is conformably overlain by the Traine Formation and unconformably overlies rocks of the Warton Sandstone, and transgresses on to the Carson Volcanics.

The Walsh Tillite consists of massive tillite, flaggy, thinly bedded, pink to yellow fine-grained dolomite, and algal dolomite. In the extreme north-east on part of the outcrop area, a greenish-white quartz sandstone occurs. A typical section of the Tillite is described in the measured section (above). Within the Lansdowne Sheet area the Walsh Tillite varies in thickness from less than 15 feet to about 200 feet.

Within the Lansdowne Sheet area the Walsh Tillite is exposed in a line of scattered outcrops which in general follow the western side of the Traine River to its confluence with the Hann River, and then trend westwards past Glenroy Homestead to meet the western Sheet boundary to the south of Mount Clifton. A line of outcrops also occurs along the northern Sheet boundary west of the Traine River and an outlier of Tillite occurs in the Warton Range area. The Tillite is poorly exposed and is generally observed only in scarps beneath the more resistant Traine Formation or in stream sections.

Good exposures of tillite have been observed in only a few localities, e.g. south of Mount Clifton; on the track to Mornington No.1 Bore at the Station Creek Crossing; on the Glenroy-Tableland road ½ mile north-east of the Hann River Crossing; and in the scarp below the Traine Formation west of the Traine River. Elsewhere, the presence of tillite is indicated only by areas of glacial boulders within soil cover. The pink dolomite at the top of the unit generally crops out quite well and provides a very useful marker bed.

The tillite consists of very poorly sorted particles, ranging from grit size up to boulders 3 feet in diameter, set in a matrix of distinctive green clay or fine greywacke. The boulders are sub-angular to sub-rounded, the corners generally being rounded, and the larger specimens are polished. Faint striae are visible on certain specimens. The boulders consist almost entirely of pink fine-grained quartz sandstone, similar to the Pentecost Sandstone, and white fine-grained sandstone, similar to the Warton Sandstone. Other rock types include basalt (Carson Volcanics?), dolomite, black dolomitic sandstone, ferruginous grit, green chert, quartz, and flaggy, laminated green siltstone (Bastion Group?). Most, if not all, of the boulders are apparently derived from the Kimberley and Bastion Groups. Granitic and metamorphic rocks are absent.

The best exposure of the tillite occurs in the measured section in the bank of the Throssell River, south of Mount Clifton. Here the matrix consists of a massive green very fine-grained greywacke or clay. Towards the top of the tillite, bedding develops, and the tillite grades into 2 feet of overlying purple shale. Accompanying this gradation is a decrease in the size and number of boulders.

The matrix of the tillite includes numerous lenses of reddish fine-grained sandstone. These are very irregular in shape and difficult to identify as lenses rather than erratics; proof of their origin as lenses is found in the presence of glacial erratics within them and even lying across the sandstone green clay contact. They vary in size from lenses two or three feet in diameter to elongate bodies several yards in length and up to 4 feet thick.

Near the base of the tillite in the Station Creek exposure, the matrix is disposed in large "bedding-rolls" or folds with an amplitude of about 18 inches and wave-length of two feet. They are symmetrical in cross-section and apparently are cross-folded. A short distance away the same beds show a complex rectangular "bedding-roll" pattern, reminiscent of interference ripple-marks. Here the amplitude is of the order of 3 or 4 inches. The origin of these structures is obscure, but it is thought that they may possibly be the result of folding of the plastic matrix material due to compression caused by the advance of ice.

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

To the north of the Glenroy-Tableland track a white quartz sandstone overlies the tillite and underlies the pink dolomite. This sandstone persists to the northern boundary of the Sheet area, but the overlying dolomite dies out north-eastwards.

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

(1) Area south-east of Mount Clifton	45 feet.
(2) 4 miles north-east of (1)	Nil
(3) Station Creek	20 feet.
(4) Traine River area north of Tableland-Glenroy track	10-20 feet.
(5) Warton Range	200 feet.

Figure (10). Walsh Tillite. K.A.P.

Sandstone lenses within green siltstone matrix; sandstone erratics throughout the matrix; sandstone lens in centre of photograph. Locality on the Throssell River 5 miles south-west of Glenroy Homestead.

Figure (11). Algal dolomite overlying Walsh Tillite. K.A.P.

Vertical section of dolomite bed showing irregular dome-shaped algae with silicified laminae; these algal structures are intensely brecciated in places. Locality on the Throssell River 5 miles south-west of Glenroy Homestead.

The variations in lithology along the northern boundary of the Sheet area are shown in the following sections:

Macnamara Creek area — West	Macnamara Creek area — East	Traine River area
Traine Formation	Traine Formation	Traine Formation
Feet	Feet.	Feet.
15 - Flaggy pink dolomite. Algae at base.		
10 - Thin, flaggy, green white quartz sandstone.	30 - Massive white quartz sandstone.	10 - Blocky quartz sandstone.
10 - Tillite.		20 - Tillite.
Carson Volcanics	Carson Volcanics	Warton Sandstone

The dolomite at the top of the formation is readily recognised by its pink colour, very fine grain-size, and regular very thin to laminated bedding. In thin section the rock consists of a very fine-grained (0.01 mm.) aggregate of carbonate crystals with rare patches of quartz. In the Throssell River exposure the dolomite shows scattered bedding laminae containing abundant goethite pseudomorphs after euhedral pyrite. The crystals are about $\frac{1}{8}$ inch in size and cover up to 50% of the area of some bedding planes. The dolomite is generally uniform in thickness, but in the extreme north-eastern part of the Mount House Group outcrop it dies out.

The dolomite is immediately underlain by 2 feet of algal dolomite. The algal structures consist of irregularly folded siliceous laminae, apparently forming moderately spaced hemispherical domes. No cross-sections have been observed, however. In many places the laminae are dislocated and brecciated. The upper and lower contacts of the algal beds are planar and extremely sharp.

Traine Formation (new name)

The Traine Formation conformably overlies the basal unit of the Group, the Walsh Tillite and is in turn conformably overlain by the Throssell Shale. It crops out on a low plateau immediately to the north-west of the Traine River, from where the name is derived, and from there a narrow line of outcrops extends south-westwards, through Glenroy Homestead, to the south-eastern corner of the Mount Clifton plateau. In the latter locality it is about 20 feet thick (reference section), and in the Traine River area it exceeds 50 feet, and may be as great as 200 feet, but the full thickness cannot be determined accurately. In the west, the rocks of the Formation are poorly exposed, but in the Traine River area a prominent sandstone is developed which forms a low plateau, with a bordering scarp up to about 150 feet high.

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

In the north-east, between the Hann and Traine Rivers, the Formation consists of massive, fine- to medium-grained, purple-brown ferruginous sandstone, which characteristically weathers into large rounded boulders five to ten feet in diameter. The thickness cannot be accurately estimated, as the sandstone forms a wide plateau area with a very low angle between the dip of bedding and the land surface. More than 50 feet of sandstone is exposed in the bordering scarps and the total thickness of sandstone may be as great as 200 feet.

Between the Hann River and Glenroy Homestead, the Formation is poorly exposed. Here the dominant lithology is purple shale. It is interbedded with flaggy to blocky buff dolomite, purple-brown dolomitic sandstone, and sporadic dolomite breccias. The sandstones show load-casts and bedding rolls. The thickness is probably less than fifty feet.

In the measured reference section on the south-eastern edge of the Mount Clifton Plateau, the base of the unit is characterised by a massive green-brown medium-grained chloritic dolomitic sandstone with scattered pyrite pseudomorphs up to $\frac{1}{4}$ inch in size. Small fragments of dolomite occur within the sandstone, which grades upwards into a dolomite breccia consisting of abundant angular dolomite fragments up to 2 inches in size set in a sandstone matrix. When weathered, the dolomite is leached out to leave a boxwork framework of sandstone.

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

Adjacent to Glenroy Homestead the only outcrops of the Traine Formation consist of about 20 feet of massive, white, fine-grained quartz sandstone with numerous limonite-filled holes, probably resulting from the weathering of pyrite.

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

Throssell Shale (new name)

The Throssell Shale is the most characteristic unit of the Mount House Group. It lies conformably on the Traine Formation and is conformably overlain by the Estaughs Formation. The Throssell Shale is poorly exposed within the soil covered plains around the headwaters of the Throssell River, from where the name is derived, and in the scarp bordering the Mount Clifton plateau. Except for a few outcrops immediately to the east, outcrops of the Shale are confined to the area west of the Hann River. In the reference section near Mount Clifton it is 575 feet thick.

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

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

A measured section of the Throssell Shale is given above. There are no significant lateral variations within the Lansdowne Sheet area.

The green shales of the formation are distinctive, but both the upper and lower contacts of the Throssell Shale are gradational. The base is marked by the appearance of green shale as the dominant lithology, while the top is marked by the development of the blocky subgreywacke interbeds of the Estaughs Formation. The upper contact coincides with a conspicuous physiographic change.

Estaughs Formation (new name)

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

Within the Lansdowne Sheet area, outcrops of the Estaughs Formation are confined to the top of the Mount Clifton Plateau on the western edge of the Sheet area. Massive siltstone and subgreywacke beds crop out boldly to form small cliffs at the top of the bordering scarp. In the reference section on the eastern side of Mount Clifton, the Formation is about 255 feet thick, but since the top has been eroded the original thickness of the Formation is not known.

The Formation consists of interbedded flaggy purple to green micaceous siltstone and fine-grained subgreywacke alternating with prominent interbeds of blocky to massive purple hematitic subgreywacke.

Beds of flaggy fine-grained subgreywacke near the base of the Formation contain complex intraformational folds, are intensely contorted, and lens out rapidly. These folds may be slump structures or sedimentary structures, such as large flow-casts or scour-and-fill structures which have been subjected to later compaction and flowage.

In thin section a specimen of the feldspathic-micaceous quartz siltstone consists mainly of sub-rounded quartz grains about 0.04 mm., partly cemented by silica. Scattered grains of sericitised feldspar occur. Minor accessories are fine-grained goethite, tourmaline, sphene, black iron oxide, and mica and chlorite which lie parallel to the bedding.

The Formation is characterised by the occurrence of the blocky subgreywacke interbeds. The lower contact is gradational and is marked by the first bed of blocky subgreywacke. This basal bed is distinctive due to the intraformational folding described above.

PALAEOZOIC

The Palaeozoic units represented in the Lansdowne Sheet area are the Windjana Limestone, Pillara Limestone and Napier Formation, which together constitute a Devonian reef complex; the Stony Creek Conglomerate of Devonian age; and undifferentiated conglomerates of Devonian and ?Permian age. The reef complex in this area has not been dated accurately but it is regarded as being of Frasnian and/or Famennian (Upper Devonian) age. No Middle Devonian is believed to be present. The total thickness of the various facies of the reef complex in this area is not known precisely, but it is unlikely to exceed 500 feet.

Windjana Limestone.

This formation is the reef facies. It consists of massive limestone which is commonly dolomitized. The limestone is built up of a framework of colonial organisms, especially algae and stromatoporoids, the interstices between the organisms being filled with calcarenite or calcilutite. The Windjana limestone occurs as a discontinuous band between the

Pillara Limestone and the Napier Formation and interfingers with each. It also interfingers with the Stony Creek Conglomerate.

Pillara Limestone

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

Napier Formation

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

The fore-reef facies is crudely bedded to well bedded and shows depositional dips of 30 degrees or more away from the reef. The inter-reef facies contains relatively little material derived from the reef and is made up of silty limestone and calcareous siltstones, shales, and sandstones. The inter-reef deposits are largely red in colour, in contrast to the light grey and yellow limestones and dolomites of the other parts of the reef complex. The Napier Limestone interfingers with the Stony Creek Conglomerate and the Windjana Limestone. In those areas where the reef (Windjana Limestone) is absent it interfingers directly with the Pillara Limestone.

Stony Creek Conglomerate

The Stony Creek Conglomerate is composed of angular to subangular boulders, cobbles, and pebbles of granite with lesser amounts of quartz, quartzite, and sheared acid volcanic rocks. They are set in a matrix of very coarse arkose and are believed to have been transported only a short distance from the adjacent Precambrian rocks. The thickness of the formation is not known precisely, but it is estimated to be of the order of 500 feet. The conglomerate interfingers with the reef complex and is overlain by conglomerate of possible Permian age.

Undifferentiated Conglomerates

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

CAINOZOIC

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

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

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

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

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

STRUCTURE

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

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

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

Folding

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

Three principal fold trends may be recognised, especially in the south-eastern part of the Sheet area where three sets of minor fold axes (Fig. 15.1) plunge respectively to north-east at about 35°, to south-south-west at about 30°, and approximately vertically. Of these three trends evidence of the post-Whitewater structures indicates that the near vertical folds are apparently the latest. The relative ages of the other two is uncertain.

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

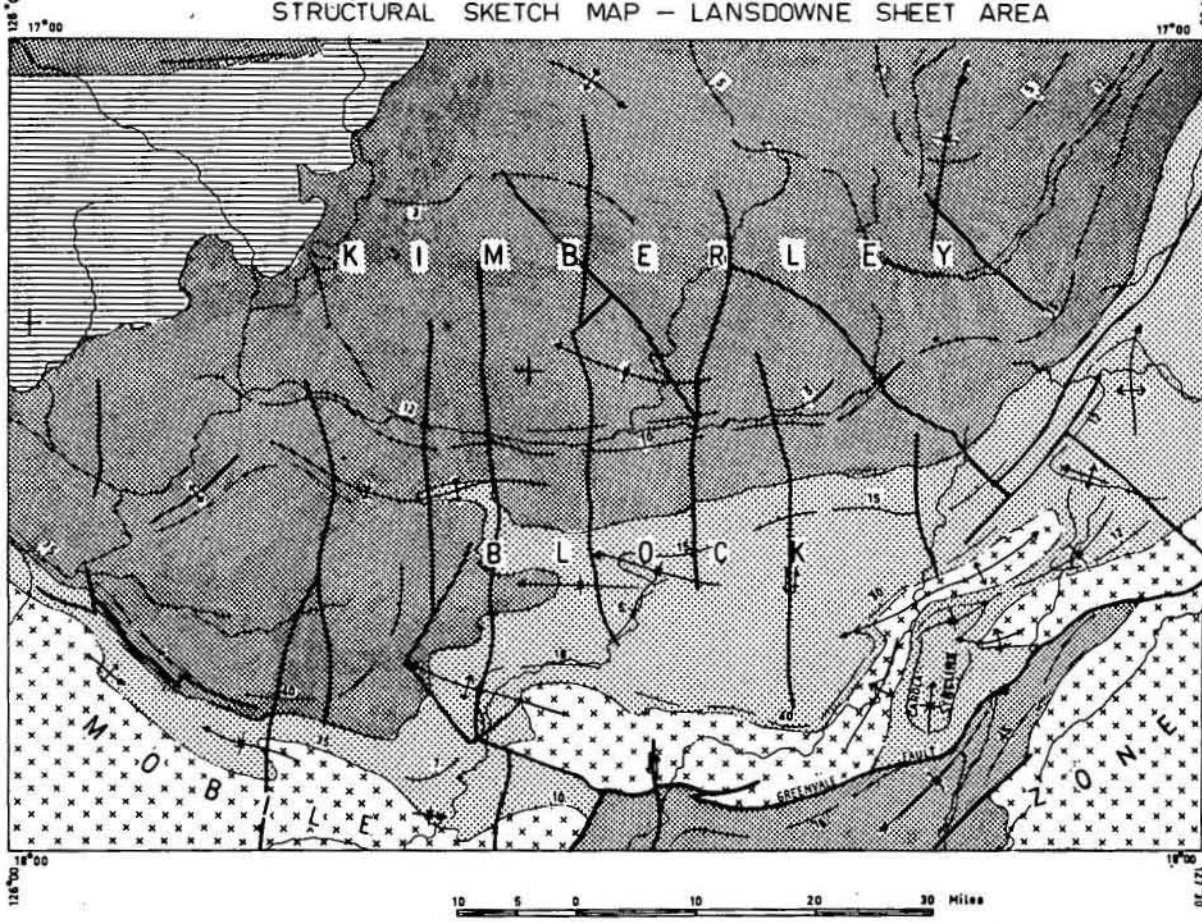
Fold styles vary from moderately open to tight, similar and concentric types, to asymmetrical drag-folds, isoclinal folds, and chevron-type similar folds. The only correlation of trend and style that has been noted is that the chevron folds generally have steeply plunging axes, and tend to be associated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

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

Problems of structural interpretation exist because the fold axes, though varying in degree of plunge, are almost coplanar in places, and because the various folds are not found deforming each other in the field. The variations in trend may be due to deformation of a single early fold system by a later one with differing trend, or the three fold phases may exist in their own right. Because of this, interpretation of the structure of the Halls Creek rocks is best deferred until the post-Whitewater Volcanics structures have been described.

Fig. 12

STRUCTURAL SKETCH MAP – LANSDOWNE SHEET AREA



Upper Proterozoic	
Kimberley Group	Middle Proterozoic
Speewah Group	Middle Proterozoic
Archaean to Middle Proterozoic	

- Trend and dip of bedding, angle in degrees
- Bedding horizontal
- Fault
- Fault with horizontal movement sense
- Synclinal axis with plunge direction
- Anticlinal axis with plunge direction
- Monoclinal axis

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

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

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

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

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

The main plunge directions in Post-Whitewater rocks are north-east and west-north-west in the eastern part of the area, and west-north-west and east-south-east in the western part. In each of these two area, two separate trends are recognised, and local interference of these is found, e.g. about 2 miles north-east of Six Mile Yard, where eastward-plunging minor folds are found on the flank of a west-north-west-plunging major fold.

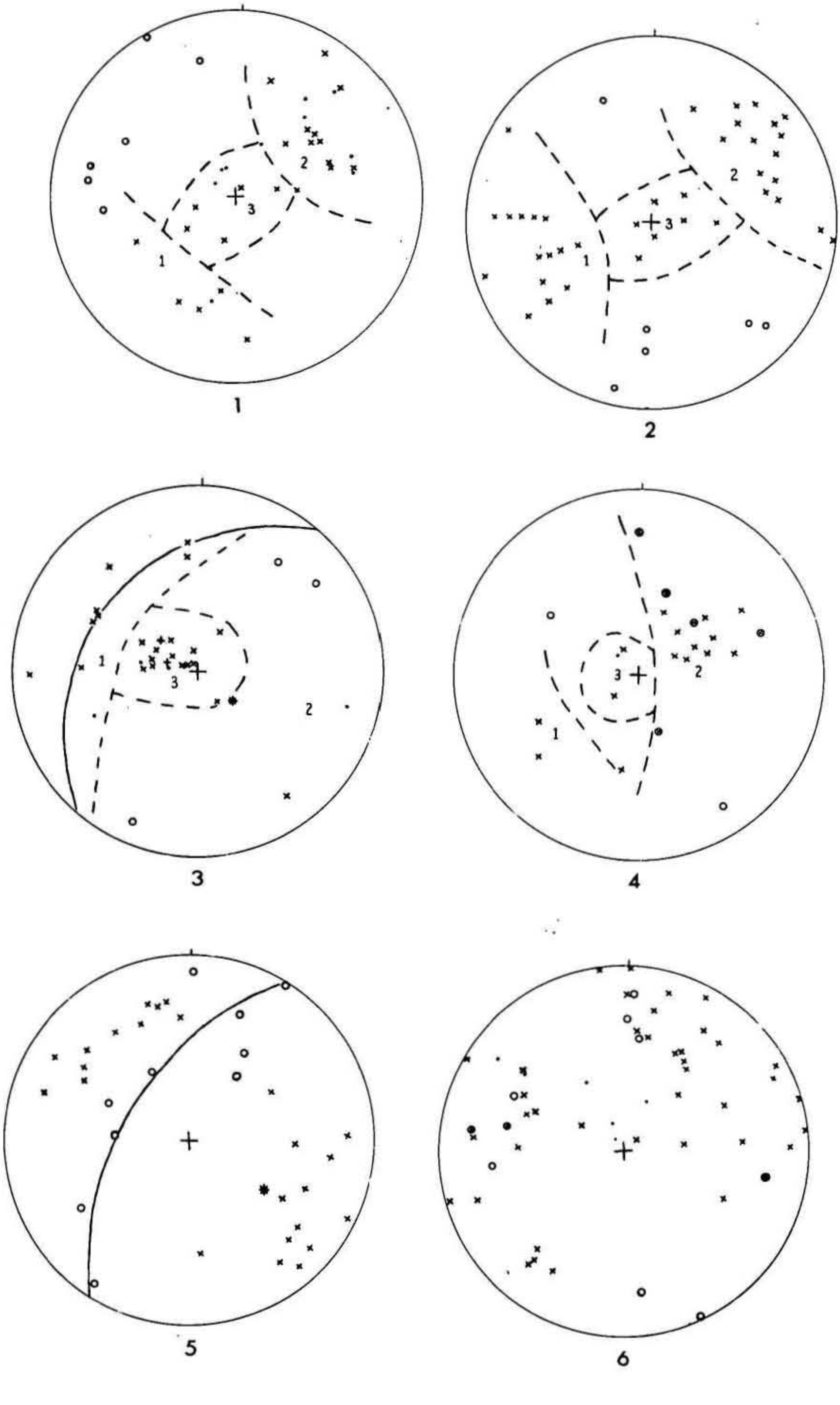
Figure (13). Major drag fold. D.C.G.

Major drag fold in King Leopold Sandstone. Fold axes plunge gently to north-west (left) and axial planes dip steeply to north-east (away from camera). Locality about 10 miles north-west of Torrens Yard. This style of folding is typical of the Middle Proterozoic rocks in the western part of the Lansdowne Sheet area.

Figure (14). Minor chevron folds. K.A.P.

Chevron-type minor similar folds in siltstone of O'Donnell Formation. These folds are associated with a reverse-fault zone; their axial planes dip north-west and are parallel to the fault plane in this vicinity. Locality 5 miles east-north-east of Pyra Gorge.

Fig.15



STRUCTURAL ELEMENTS OF THE LANSDOWNE SHEET AREA

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The style of these folds varies from concentric to similar. The majority of minor folds of the north-east-plunging group have well developed a lineations due to bedding plane slip during folding and are probably similar folds of the "bending type". This type of folding is particularly well displayed in siltstones of the O'Donnell Formation, e.g. near Dingo Well, and 2 miles west of Carola Yard. In the western part of the Sheet area, minor folds of the similar variety predominate. Major structures include monoclinal folds which are present on the fringe of the fold belt and have axial planes dipping to the north-east.

In the Upper Proterozoic rocks, folding is very gentle, with dips apparently nowhere greater than 10^o. The principal folding noted in these rocks is in the extreme north-western part of the area, i.e. north of the Hann River, where the strike of the Upper Proterozoic rocks is parallel to that of the underlying Kimberley Group rocks. It appears that this post-Upper Proterozoic period of folding has been caused by further tightening of the earlier post-Kimberley Group anticline on the flanks of which the folded Upper Proterozoic rocks lie.

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

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

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

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

Faulting.

Faulting along three main trends is recognised in the Lansdowne Map Sheet area. These are north-east, west-north-west and north-south.

North-east trend. The main fault of the north-east trending system is the Greenvale Fault which cuts across the south-eastern part of the area. The trend at the eastern boundary is north-east, but further west it gradually changes to east-west, and finally to west-north-west near Goads Yard where it loses its identity and is replaced by several minor faults of diverse trend. In most places the Greenvale Fault is not a single fault, but forms a complex zone of two or more faults. It is apparently partly a transcurrent fault with sinistral displacement, especially in the east. Further west it has an essentially vertical displacement and is variously a normal fault, or a reverse fault. The direction of downthrow is to the south-east or south. The maximum vertical displacement in the Lansdowne Sheet area is apparently at least 15,000 feet, 6 miles north-east of Mad Gap Yard, but diminishes rapidly westwards. Prominent quartz reefs and infaulted lenses of basal O'Donnell sandstone occur throughout its length. West of Pyra Gorge, it is displaced by a north-east trending reverse fault with a throw to south-east of about 4000 feet. Throughout part of its length in the Lansdowne Sheet area it is a faulted asymmetrical anticline, and much of the movement has been taken up by folding prior to the faulting, so that the throw of the fault in places is comparatively small. This is particularly true of the area between Pyra Gorge and the southern end of the Carola syncline.

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

North-west trend. Faults of this trend are of moderately common occurrence throughout the area, except in the north-west corner. Their lateral extent varies from 1 mile up to more than 20 miles. The direction of downthrow is to the south-west and they are associated locally with monoclinal folds, such as the complex monoclinal fold-and-fault system which passes south of Colass Yard. These monoclines have axial planes dipping to north-east and show a sense of vertical movement similar to that of the associated faults indicating compression from north or north-east.

The throw of these north-west trending faults is mostly small, but in the King Leopold Ranges north-west trending faults, which have caused repetition of part of the succession, have throws of up to 6000 feet (see map section ABC).

North-south trend. Faults of the north-south trend are prominent, especially in the central and south-western parts of the area. Some extend for over 30 miles but displacements are apparently small. Sinistral transcurrent movement has been noted on two examples and may be present in others. The displacement on the majority of north-south faults however may be interpreted as indicating either a sinistral transcurrent movement or a normal movement with downthrow to the west.

Age of Faulting

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

From the evidence of the unconformity between the Tunganary Formation and King Leopold Sandstone south-west of Goanna Spring, and the boulder conglomerates in the Upper Lansdowne beds at the southern end of the Carola Basin, it appears that movements connected with the Greenvale Fault were in operation in Middle Proterozoic times when the direction of downthrow was to north-west, in contrast to the later movements which took place in the opposite sense.

Faults of all trends cut the Hart Dolerite. The Hart Dolerite was apparently intruded in part along pre-existing north-south faults, and is also cut by these faults, so that both pre- and post-dolerite movements are recognised. Both pre- and post-dolerite movement is also inferred for the other fault systems, but is less well substantiated. The latest fault movements appear to be of post-Devonian age.

TECTONIC HISTORY

A summary of the tectonic history of the area is given in Table 2.

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

After a period of gentle folding, strong shearing, and erosion, sedimentation was resumed in early Middle Proterozoic times. With the exception of minor earth movements in the south-eastern part of the Sheet area, probably associated with movements on the Greenvale Fault, sedimentation was then apparently continuous throughout the early Middle Proterozoic, when the Speewah, Kimberley and Bastion Groups were deposited. These sediments are mainly shallow water arenites and lutites. There appears to have been little if any interruption of sedimentation during the extrusion of the Carson Volcanics, since no unconformity is recognised and some of the lavas were submarine.

Strong folding, faulting, and dolerite intrusion, and uplift and erosion followed the Middle Proterozoic sedimentation and preceded deposition in Upper Proterozoic times of the Walsh Tillite and subsequent shallow water arenites and lutites of the Mount House Group.

Following Upper Proterozoic sedimentation, uplift occurred, and erosion has apparently persisted since then over the whole of the area except the south-western corner where a short period of limestone reef formation and conglomerate deposition occurred in Middle Palaeozoic times.

ECONOMIC GEOLOGY

No economic metalliferous mineral deposits have been found so far in the Lansdowne Sheet area, but several small showings of economic minerals have been noted, mainly associated with igneous rocks. None of these occurrences is sufficiently promising to warrant specific investigation, but further work in the area might possibly be justified. Geochemical prospecting for base metals is at present being carried out in the southern part of the Sheet area by Pickands Mather International Co. Ltd.

Groundwater is one of the principal mineral resources of the area and is being actively exploited for stock watering by means of bores and wells. Constructional materials may be of future importance in connection with the proposed Fitzroy Irrigation Scheme, for which damsites have been selected within the Lansdowne Sheet area, at Diamond Gorge, Pyra Gorge, and on the Leopold River.

Minerals

Copper: Traces of chalcopyrite and malachite have been noted in quartz veins cutting the Whitewater Volcanics and the Hart Dolerite, mainly in the area south and south-west of Mount Laptz. Chrysocolla, malachite, bornite, and chalcopyrite occur in veins in the Lamboo Complex granites of the south-western corner of the Sheet area.

Some quartz veins cutting porphyry of the Whitewater Volcanics about 4½ miles east of Goads Yard contain boxworks of powdery earthy brown limonite with associated specks of malachite. These veins are up to 4 feet thick and half a mile long, but boxworks make up only a small proportion of each vein.

In the Carson Volcanics small grains and vesicle fillings of chalcopyrite occur extensively. Such traces are particularly abundant in the lowest flows in the northern outcrop of the Carsons, east of Longitude 126°30'E, and have also been noted in the basal flows in the south-eastern part of the area about 4 miles east-south-east of Mad Gap Yard.

Small amounts of malachite have been found as fracture infillings in vein quartz associated with the Greenvale Fault about 2 miles east-north-east of Goanna Spring.

Several minor occurrences of copper minerals have been found associated with the Hart Dolerite. These are mainly traces of chalcopyrite and malachite in small quartz veins within dolerite, especially near Coolan Creek Yard. Malachite, occurring as a surface coating, has also been noted by Harms (per. comm.) on a dolerite dyke intruding shales of the Elgee Siltstone about 15 miles east of Tableland Homestead.

Lead: Minor amounts of galena, mostly associated with chalcopyrite, have been recorded from quartz veins cutting the Whitewater Volcanics in the south-west on part of the area. Similar occurrences have also been noted in the Hart Dolerite, particularly in a calcite vein near Coolan Creek Yard. Traces of galena have been noted in the Carson Volcanics in the north-eastern part of the Sheet area where they form rare vesicle infillings.

Fluorite: Two small occurrences of fluorite are known from the Lansdowne Sheet area. One of these occurs two miles east-north-east of Goanna Spring, where ½in. to 1 in. thick veins of fluorite cut weathered porphyry of the Whitewater Volcanics adjacent to the Greenvale Fault. The other occurrence consists of fluorite veins 3 in. to 4 in. thick, in a quartz-feldspar-muscovite dyke rock cutting the Long Hole Granite. This occurrence is situated about ¼ mile north of a fault separating the granite from Devonian limestone.

Iron: A thin veneer of magnetite sand is found in the beds of minor creeks in parts of the Lansdowne Sheet area where dolerite is the predominant source rock. These deposits are of no foreseeable economic value.

Constructional Materials, etc.

Building Stone: Rocks suitable for use as building stone are abundant throughout the area. The most suitable for this purpose are the relatively thin-bedded feldspathic sandstones of the Tunganary Formation and the Lansdowne Arkose, and the upper part of the Warton Sandstone. Most other rocks in the area are too massive to be worked conveniently.

Roadmetal: The Hart Dolerite, which crops out extensively in the Lansdowne Sheet area, is suitable for use as road-metal, as are also the porphyries of the Whitewater Volcanics. Some of the Lamboo Complex Granites and Carson Volcanics basalts might also be utilised. With the exception of the north-western corner of the Sheet area, no place within the area is more than about 15 miles from an outcrop of igneous rock, and therefore from a potential source of road-metal.

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

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

Limestone: Lime for agricultural purposes may be required in future in connection with the proposed Fitzroy Irrigation scheme. Adequate supplies are present in the Devonian rocks in the south-western corner of the Lansdowne Sheet area and in contiguous areas, especially in the Lennard River area.

Water Supply.*

The area covered by the Lansdowne Sheet has an average annual rainfall decreasing from 27 inches in the north to 20 inches in the southern part of the area. The rainfall is received mainly during the wet season from November to April, and the rest of the year is relatively dry. Annual potential evaporation is 100 to 110 inches.

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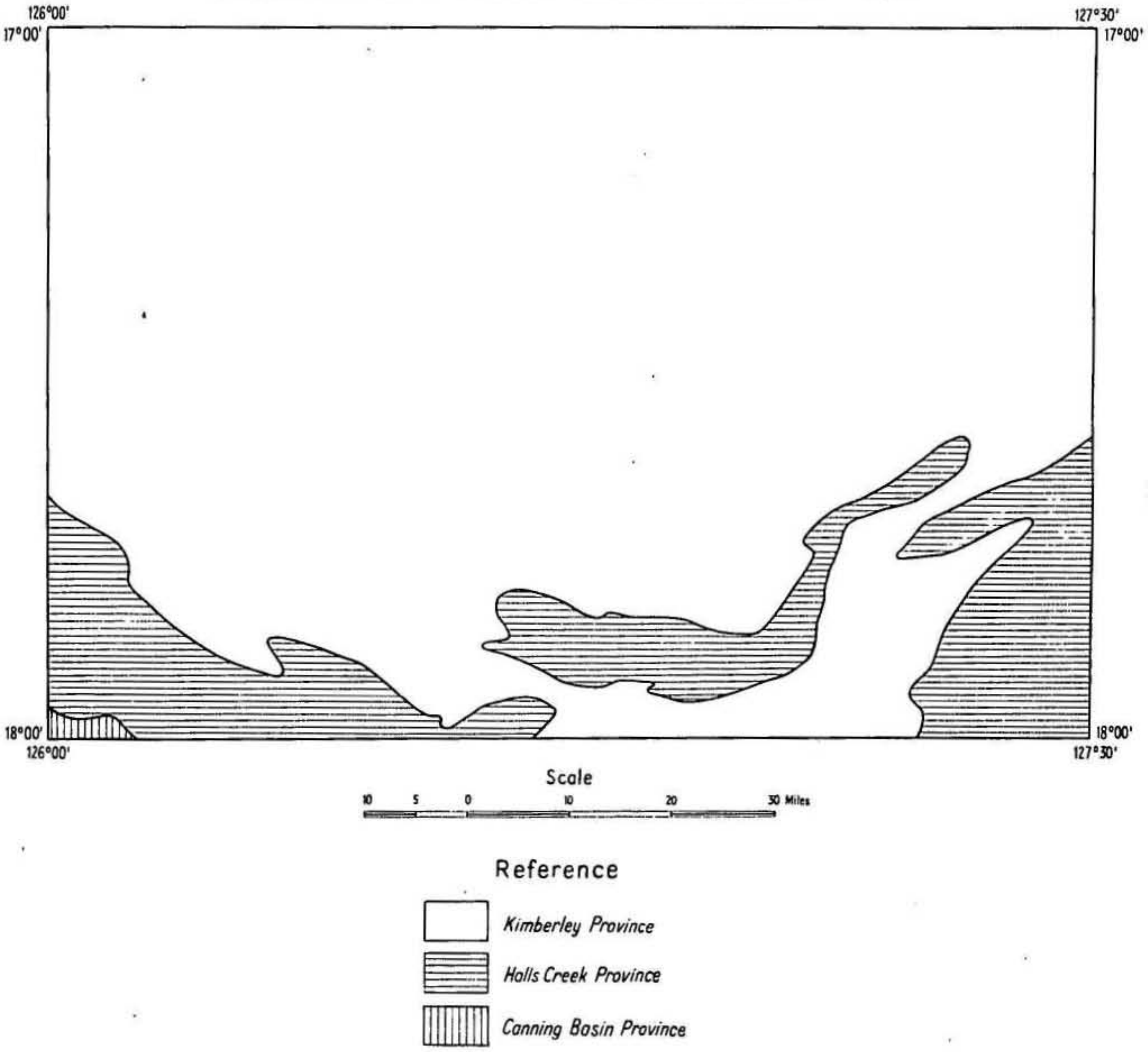
* By A.D. Allan, Geological Survey of West Australia.

Fig. 16

GROUNDWATER DIVISIONS - LANSDOWNE SHEET AREA



To accompany Record 1965/210

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A. M.

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

There are 29 operating bores or wells in the area. Their relative scarcity is due mainly to the unsuitability of a large part of the area for pastoral purposes and to the relative abundance of natural water. Three distinct groundwater provinces can be recognised.

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

These three divisions, which are shown on Fig.3, correspond to (1) Middle and Upper Proterozoic rocks of the Kimberley Basin succession; (2) the Archaean to Lower Middle Proterozoic (pre-Speewah Group) rocks, and (3) the Palaeozoic rocks respectively.

1. KIMBERLEY PROVINCE.

The Province is underlain by sedimentary and basic igneous rocks which range from Middle to Upper Proterozoic in age and make up the Speewah, Kimberley, Bastion and Mount House Groups. The sedimentary rocks are dominantly feldspathic and quartzose sandstones with minor siltstones. They are hard and silicified in outcrop and in general appear to have a low primary porosity and permeability, although this may not be so at depth. The basic igneous rocks, comprising dolerites and volcanics, are well jointed and less resistant to weathering, and commonly have residual black soil plains developed over them.

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

There are 27 bores or wells within the province. They are mostly 40 to 60 feet deep, with static water levels 20 to 30 feet below the surface. The groundwater is usually non-pressure water, but locally pressure water may be obtained from confined joints or bedding planes; salinity on the average is 450 p.p.m. total dissolved solids. Supplies vary from a few gallons to 2000 gallons per hour, with average yields of about 750 gallons per hour.

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

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

2. HALLS CREEK PROVINCE

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

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

There is one well in the Province. However, bores and wells within the same Province in the adjacent Mt. Ramsay Sheet area range in depth from 30 to 50 feet and yield non-pressure, and rarely pressure water. The groundwater occurs at a depth of 20 to 30 feet below the surface, except in alluvium along creeks, where groundwater (underflow) may occur at very shallow depth. Groundwater salinity varies between 150 and 4500 p.p.m. total dissolved solids, with an average salinity of about 450 p.p.m. Supplies of up to 2000 gallons per hour have been obtained from the fractured rocks, but 250 to 500 gallons per hour is more usual. Bores or wells in alluvium may give higher yields.

Alluvial deposits along drainage channels, which are usually aligned along master joints, are probably the most important sources of water in this Province. If there is a depth of about 30 feet of alluvium and weathered granite, groundwater is usually present. However, hard rock is generally intersected at shallow depth and even if hard rock drilling plants are used, it is a matter of chance whether water-bearing exfoliation joints or cross joints are intersected. In areas underlain by the Halls Creek Group, greywackes are potential sources of supply.

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

3. CANNING BASIN PROVINCE

The Canning Basin Province occurs only in the extreme southwest corner of the Lansdowne Sheet area, where it is represented by limestone and conglomerates of Devonian to Permian age.

Only one bore exists in this Province in the Lansdowne Sheet area, but several, ranging in depth from 50 to 250 feet with yields of up to 5000 gallons per hour and low but variable salinity, are present in the Mount Ramsay Sheet area to the south.

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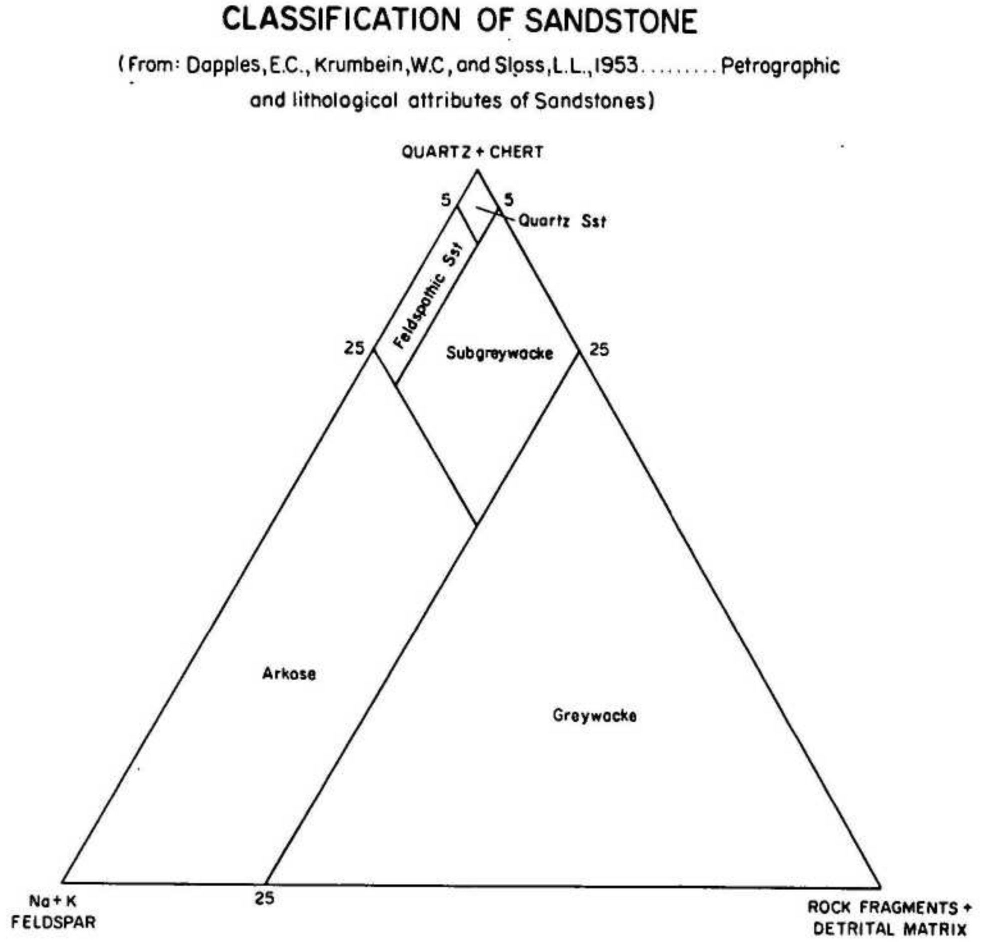
APPENDIX I

Classification and Description of Sandstones



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

Standard Terms for the thickness of stratification and parting units.

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

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

Terms to describe stratification	Thickness cm.	Thickness ins.	Terms to describe parting units
Very thick bedded	100	36	Massive
Thick bedded	15 - 100	6 - 36	Blocky
Thin bedded	1 - 15	0.4 - 6	Flaggy
Laminated	1	0.4	Fissile

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TABLE 1.

STRATIGRAPHIC TABLE - LANSDOWNE SHEET AREA

ERA	Age	Rock unit and Symbol	Thickness in feet	Lithology	Topography	Distribution	Remarks
CAINOZOIC	Quaternary	Qa	-	Alluvium, boulder gravel and fluviatile sand.	Narrow riverside flats	Mainly along Fitzroy, Hann, and Chamberlain Rivers and small creeks in granite country in south-east and south-west.	
	Tertiary to Quaternary	Czs	-	Residual soil (undifferentiated) red and grey soils, sands and ferricrete.	Pediments and featureless plains.	Throughout the area but predominantly on Kimberley Plateau.	Mainly red-brown soils associated with basalt, dolerite and granophyre; grey soils with granitic terrain, sandy soils and underlying ferricrete with arenites.
		Czb	-	Residual black soil	Pitted stony plains	Occurs sporadically throughout the area.	Confined mainly to outcrops of dolerite and basalt. Also found locally on limestone outcrops.
				UNCONFORMITY			
PALAEOZOIC	Devonian - ?Permian	(Undifferentiated conglomerates) D/Pc	-	Conglomerate: rounded pebbles, cobbles and boulders of quartzite set in an arkosic matrix.	Prominent rounded hills with dendritic drainage.	Confined to extreme south-western corner of Sheet area.	In part Upper Devonian; in part ?Permian and lie unconformably on Devonian rocks.
	?Devonian	Stony Creek Conglomerate (Ds)	500	Conglomerate; cobbles and pebbles of granite, and minor quartz, quartzite, and sheared acid volcanics.	Prominent rounded hills with dendritic drainage.	"	Interfingers with reef complex. Overlain by conglomerates of ?Permian age.
		Winjana Limestone (Dw)	"	Limestone: Reef facies; colonial organisms with interstitial calcareous sediments; partly dolomitised.	Prominent massive outcrops sparse vegetation cover.	"	Occurs as a discontinuous band between the Pillara Limestone and the Napier Formation.
		Pillara Limestone (Dp)	"	Limestone: Back reef facies; well-bedded stromatoporoid limestone; partly dolomitised.	"	"	Interfingers with Winjana Limestone, Stony Creek, Conglomerate and locally with Napier Formation.
	Devonian	Napier Formation (Dn)	"	Limestone: Fore-reef to inter-reef facies: calcarenite and calcirudite; partly dolomitised.	"	"	Essentially a talus deposit; interfingers with Stony Creek Conglomerate and the Winjana Limestone.
				UNCONFORMITY			
UPPER PROTEROZOIC	Adelaidean	MOUNT HOUSE GROUP: Estaughs Formation (Ehe)	255	Hematitic quartz sandstone and siltstone; purple to green micaceous siltstone and fine-grained sub-greywacke.	Caps Mount Clifton Plateau and forms marginal scarp.	Confined to top of the Mount Clifton Plateau at western boundary of Sheet area.	Distinctive beds with complex intraformational folding at base.
		Throssell Shale (Eht)	575	Uniform flaggy grey-green chloritic-micaceous shale. Lenticular interbeds of flaggy, fine-grained, grey-green micaceous sandstone.	Scattered outcrops within soil covered plain and on scree slope beneath Estaughs Formation scarp.	Around the headwaters of the Throssell River.	Green shales are distinctive, upper and lower contacts gradational.
		Traine Formation (Eha)	20 to 50	Blocky grey to buff chloritic dolomitic sandstone; dolomite breccia: massive ferruginous sandstone, purple shale; flaggy buff dolomite.	Forms scarp in Traine River area; crops out poorly in soil covered plains in west.	North-west corner of Sheet area between Traine River and Mount Clifton Plateau.	Marked facies changes. Prominent sandstone developed in the north-east. Pyrite pseudomorphs in basal beds.
		Walsh Tillite	15 to 200	Tillite; flaggy pink to yellow fine-grained dolomite; quartz sandstone lenses.	Crops out poorly in creeks or soil covered plains and in scarp beneath Traine Formation		Marked lateral variations in thickness. Pink dolomite is excellent marker bed. Outcrops are rare. Pyrite pseudomorphs in dolomite.

Table I. (2)

Era	Age	Group	Rock unit and Symbol	Thickness in feet	Lithology	Topography	Distribution	Remarks
					UNCONFORMITY			
MIDDLE PROTEROZOIC			Hart Dolerite (Ꝑdh)	Up to ca 10,000	Dark grey to black tholeiitic dolerite and gabbro: pink to pale red-brown pyroxene-bearing granophyre.	Low rounded boulder-strewn hills with minor black soil plains. Granophyre forms slightly more resistant outcrops and is associated with red-brown soils.	Throughout the Sheet area except the north-western part.	Dolerite outcrops have a uniform grey tone on air photographs. Granophyre locally forms a capping overlying dolerite and occurs at several different horizons. Intrudes formations up to Pentecost Sandstone, but is found principally intruding Speewah Group.
		BASTION GROUP	Mendena Formation (Ꝑtm)	?100	Purple siltstone, quartz sandstone, dolomitic siltstone, micaceous feldspathic sandstone.	Gently undulating plains; partly soil covered.	Northern margin of sheet, north-east of Tableland Homestead.	Mapped from photo-interpretation only. Only lowest beds present.
		KIMBERLEY GROUP	Pentecost Sandstone (Ꝑkp)	Ca, 2,800	Cross-bedded white quartz sandstone; grey siltstone and glauconitic sandstone; white to pale brown feldspathic sandstone.	Undulating and hilly plateau country with rounded mesas and cuestas. Basal beds form low cliffs.	North-eastern part of area; Baulk Face Range; south-east of Pyra Gorge.	Not completely measured on ground due to inaccessability.
			Elgee Siltstone (Ꝑke)	700* (including Teronia Member).	Red-brown friable siltstones with grey green reduced zones; brown to white quartz sandstones.	Steep easily eroded escarpments preserved by hard capping of Pentecost Sandstone.	Occurs only as narrow outcrops peripheral to the areas of Pentecost Sandstone noted above.	Siltstones grade upward into sandstones.
			Teronia Member (Ꝑkt)	70* - 300	Grey micaceous siltstone with thin feldspathic sandstone interbeds; limestone and dolomite, with algal structures.	Poorly exposed gently dipping pediments with low limestone outcrops.	As Elgee Siltstone above.	Forms basal beds of Elgee, much intruded by Hart Dolerite in northern part of the area.
			Warton Sandstone (Ꝑkw)	900-c1200	Cross-bedded white to pale purple and pale brown quartz sandstone; pink and pale brown feldspathic sandstone forms upper part of unit.	Forms gentle cuestas. Basal beds are scarp forming.	North-central and north-eastern parts of the area: narrow outcrop south-east of Pyra Gorge.	Thickness calculated from air photo-measurement. Upper beds have darker photo pattern. Cross-bedding indicates transportation from north-east.
			Carson Volcanics (Ꝑko)	1300* to 2300*.	Tholeiitic basalt and spilite, amygdaloidal in part; andesine basalt; agglomerate; and lapilli tuff with several thin interbeds of clean-washed and silty feldspathic sandstone; upper 200 feet consist of thin limestone, chert and siltstone grading upwards into silty sandstone.	Crops out poorly; forms very low cuestas, largely soil covered, within major valleys with subsequent drainage. Upper beds form a steep scarp slope preserved by a hard capping of overlying Warton Sandstone.	Valleys of Chamberlain and Fitzroy Rivers; Paddy's Paddock; Goanna Spring-Pyra Gorge area; also small scattered outcrops to north of Baulk Face Range.	Charcteristic highly amygdaloidal flow near base of sequence contains sporadic small vesicle infillings of chalcopyrite. Upper 200 feet are very poorly exposed. The unit is only 750 feet in Lissadell area, but thickens westward to 1300 feet north-west to 1300 feet north-west of Bedford Downs homestead and 2300 feet north of Colass Yard.
			King Leopold Sandstone (Ꝑkl)	3500 to 4000	Massive cross-bedded pale purple, white, and pale brown poorly sorted quartz sandstone; localised pebble and cobble conglomerate, granule sandstone and siltstone.	Forms rugged mountainous terrain; is cliff-forming where dips are gentle. Residual vertical sided mesas occur in flat lying areas. Drainage mainly consequent and controlled by north-south faults and joints.	King Leopold and Durack Ranges; Goanna Spring-Pyra Gorge area, and small outcrops in Carola Syncline.	Poor sorting of lower part is characteristic. Cross-bedding indicates transportation from the north-east and north-west.
		SPEEWAH GROUP	Luman Siltstone (Ꝑpl)	240"	Purple-grey and green-grey micaceous shale and siltstone with thin sandstone interbeds, especially near top of sequence.	Forms steep scarp-slopes below the King Leopold Sandstone cliffs.	Forms a broad complex arcuate belt concave to north in southern and eastern parts of the Sheet area.	In Carola Syncline and at Pyra Gorge the upper part of the unit consists of feldspathic sandstone.

Table 1 (3)

Era	Age		Rock unit and Symbol	Thickness in feet.	Lithology	Topography	Distribution	Remarks
MIDDLE PROTEROZOIC		SPEEWAH GROUP	Lansdowne Arkose (Bpo)	1300* to 1600	Buff to pale pink cross-bedded feldspathic sandstone and arkose; deep pink arkose; purple-grey quartz sandstone; purple-grey and green-grey micaceous siltstone and shale.	Forms a series of paeallel ridges with dip and scarp slope features; low cliffs present locally. Topmost member has smooth rounded topography.	Forms a broad complex arcuate belt concave to north in southern and eastern parts of the Sheet area.	Consists of two siltstone units and four arenite ones. Third arenite (from base) has distinctive cross-bedding with thick cross bedded units and forms low cliffs. It is a useful marker horizon. Cross-bedding indicates transportation from the north-east.
			Valentine Siltstone (Bpv)	140*	Dark grey and grey green blocky mudstone and chertitic siltstone; minor rhyolitic tuff and feldspathic sandstone.	Forms a low gentle scarp slope preserved by a capping of harder basal Lansdowne Arkose.	"	The occurrence of tuffs in this formation is characteristic. Over most of the area they differ from other siltstones in being non-micaceous. It is much intruded by Hart Dolerite.
			Tunganary Formation (Bpt)	740-* 940	Buff to pale grey feldspathic sandstone, and quartz sandstone; pale pink arkose; minor interbeds of brown granule sandstone, grey to purple-grey shale, and flaggy purple micaceous sandstone and siltstone.	Gently dipping rounded cuestas and strike ridges with both consequent and subsequent drainage.	"	Lithologies are similar to those of Landsdowne Formation. Upper beds are locally ripple marked, e.g. near Bluff Yard.
			O'Donnell Formation (Bpn)	480* 760*	Upper O'Donnell: Grey-green to khaki shales and siltstones, with minor interbeds of sandstone and greywacke (320"). Lower O'Donnell: White to pale purple and pale brown coarse-grained silica-cemented quartz sandstone, with localised interbeds of green-grey silt and glauconitic sandstone. In extreme eastern part of area also localised feldspar porphyry, granule sandstone, and conglomerate (28' - 430').	Lower part forms an erosion resistant ridge, and upper part mainly forms a narrow valley.	"	The two parts are distinctive readily mappable units. Thickness of Lower O'Donnell varies greatly but that of Upper is relatively constant. Upper O'Donnell becomes more arenaceous in extreme west of the area. Lies unconformably on Whitwater Volcanics. Strong angular discordance is rare, but overlap of O'Donnell on to Halls Creek Group is found in several places.
			UNCONFORMITY					
	INTRUSIVE INTO WHITEWATER VOLCANICS		Watery River Porphyry (Bww)		Dark grey coloured orthopyroxene feldspar porphyry with sporadic phenocrysts of quartz. In places is strongly xenolithic.	Low rounded hills forming a dissected peneplain. Water courses are controlled by faults and joints.	Southern boundary of Map Sheet area about longitude 126°38'E.	The dark grey colour and paucity of quartz phenocrysts are diagnostic features.
			Whitewater Volcanics (Bw)	?6000-9000	Quartz-feldspar porphyry, feldspar-pyroxene porphyry; minor lapelli tuff, volcanic conglomerate and siltstone interbeds.	Low rugged hill country, and sandy pediments with isolated low residual hills; minor drainage is predominantly reticulate.	Arcuate belt in southern and south-eastern parts of area.	Probably mainly ash-flow tuffs. Quartz veins are common along major joints.
			UNCONFORMITY					

Table I. (4)

Era	Age	Rock unit and Symbol	TThickness in feet	Lithology	Topography	Distribution	Remarks
PROTEROZOIC	LAMBOO COMPLEX	Bickleys Porphyry (Ebb)		Grey acid porphyry and porphyritic microgranite with quartz and feldspar phenocrysts.	Low rounded hills consisting of large residual blocks.	Small outcrops in south-western part of area, south of Torrens Yard, and south of Diamond Gorge.	Similar to Whitewater porphyry but intrusive into it. Post-dates shear zones which affect Whitewater Volcanics.
		Mulkerins Granites (Ebu)		Coarse-grained, white, non-porphyritic biotite-bearing granite.	Very low rounded hills with sandy pediments.	South of Saddlers Yard.	Forms a discrete elliptical outcrop. Dykes of tourmaline-bearing aplite and pegmatite, and quartz veins are common throughout the mass.
		Lerida Granite (Ebl)		Grey to pink-grey porphyritic biotite granite with euhedral phenocrysts of pale green feldspar and quartz. Phenocrysts of pale pink feldspar present locally.	Low rugged hills with rectilinear drainage pattern. Sandy pediments developed locally.	In south-eastern part of Sheet area immediately underlying O'Donnell Formation.	Overlain unconformably by O'Donnell Formation intruded by Bickleys Porphyry. Possibly intrudes Whitewater Volcanics.
		Chaneys Granite (Eby)		Coarse-grained grey biotite granite, commonly foliated and locally sheared. Essentially even-grained.	Low rounded "whale-back" outcrops, with isolated residual tors.	Mainly north and north-west of Long Hole Bore.	Even grained nature and pale grey quartz are characteristic.
		Long Hole Granite (Ebg)		Coarse-grained porhpyritic grey biotite granite, pink-grey biotite gneiss and augen gneiss. Quartz tends to be blue-grey in colour and slightly cloudy.	Forms very low easily weathered outcrops with broad sandy pediments.	Forms an elongate outcrop in south-west, mainly underlying Devonian conglomerates.	Blue-grey quartz is characteristic. Pink feldspar, where present, also serves to distinguish it from other gneissic biotite granites. Appears to be a deeper level type of granite than others in the Sheet area.
		Violet Valley Granite (Ebv)		Dark-grey medium-grained biotite granite and granodiorite.	Low residual bouldery hills.	Small outcrops in south-eastern part of Sheet area.	Distinctive dark grey photo pattern. Probably younger than Bow River Granite.
		Bow River Granite (Ebo)		Coarse-grained grey biotite granite, and coarse-grained pink porphyritic biotite granite.	Low tors with sandy pediments.	Forms almost entire south-eastern corner of Sheet area.	Grey granite is xenolithic. Pink porphyritic type is found mainly near Tumagee.
		Tickalara Metamorphics (Ebt)		Biotite paragneisses with cordierite, sillimanite and staurolite.	Low residual bouldery hills.	Two small inliers in south-eastern part of Sheet area.	Have dark-grey tone on air photographs. Occur only within granites.
?ARCHAEAN	HALLS CREEK GROUP	Olympio Formation (Aho)		Phyllitic shale and siltstone with interbedded greywacke; minor quartzite and limestone.	Forms very distinctive rounded hills - hummocky topography. Meandering water courses predominate.	Southern and south-eastern part of area.	Isoclinally folded. Intruded by minor quartz veins. Unconformity with overlying Whitewater is locally anglular, but in most places is inferred from differing intensities of folding.

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

TABLE 3. TECTONIC HISTORY – LANSDOWNE SHEET AREA

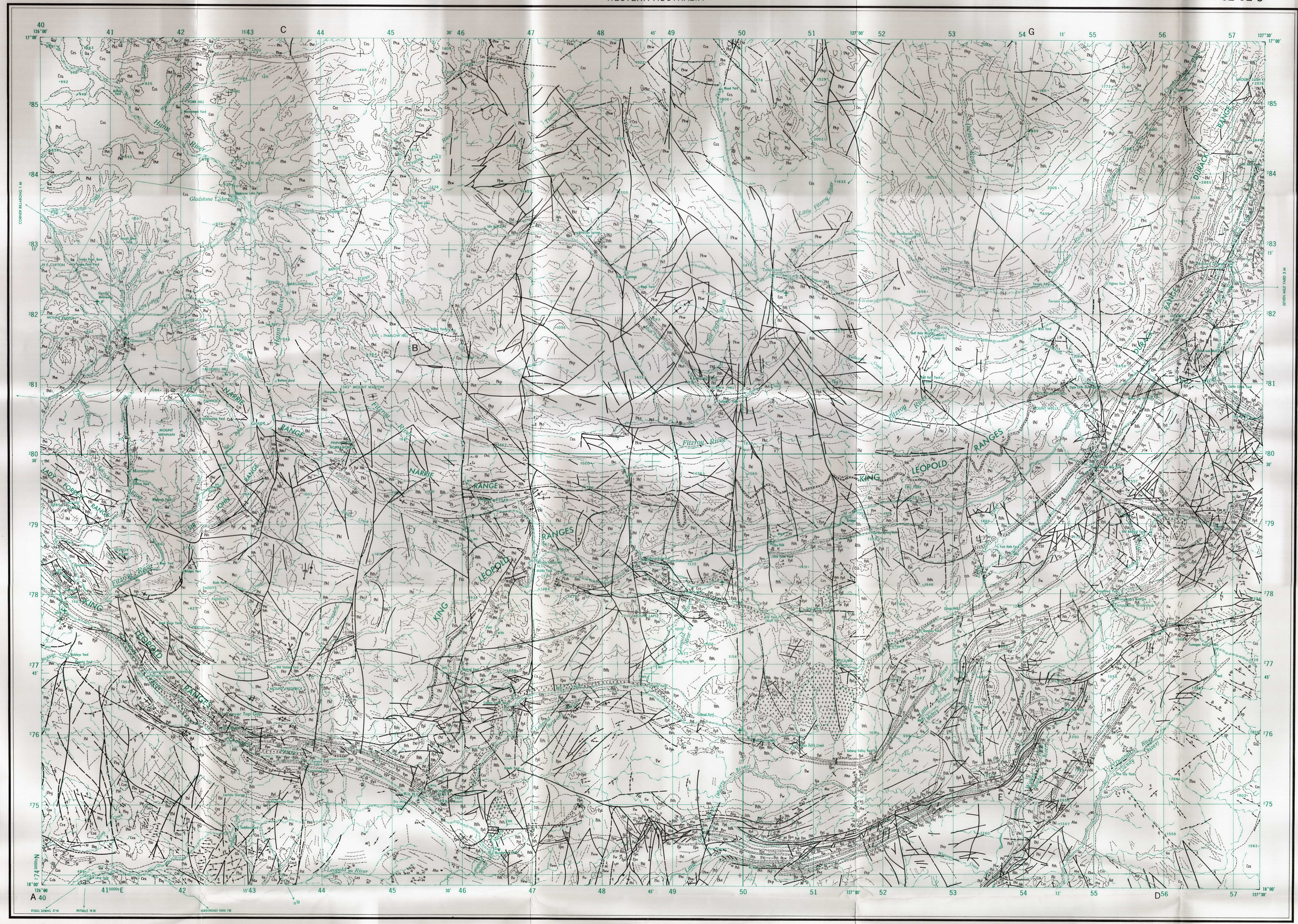
CAINOZOIC		EROSION – Development of Soils and Alluvium	
PALAEOZOIC		EPEIROGENIC UPLIFT LIMESTONE REEF COMPLEX AND CONGLOMERATE DEPOSITION IN SOUTH-WESTERN PART OF AREA ONLY — EROSION OF OTHER PARTS OF AREA	
		SUBSIDENCE AND MARINE TRANSGRESSION IN SOUTH-WESTERN PART OF AREA	
		EROSION	
UPPER PROTEROZOIC	MOUNT HOUSE GROUP	FOLDING AND EPEIROGENIC UPLIFT	
		SHALE, SANDSTONE, AND DOLIMITE DEPOSITION	Upper part of Walsh Tillite; Estaughs, Throssell and Traine Formation.
		SUBSIDENCE	
		TILLITE DEPOSITION	Walsh Tillite
		EROSION	
MIDDLE PROTEROZOIC		STRONG FOLDING AND FAULTING	
		INTRUSION OF DOLERITE AND DEVELOPMENT OF GRANOPHYRE	
	KIMBERLEY GROUP — BASTION GROUP	LUTITE DEPOSITION	Mendena Formation
		ARENITE, LUTITE, AND CARBONATE DEPOSITION VULCANISM : BASIC LAVAS ARENITE DEPOSITION	Warton, Elgee and Pentecost Formations Carson Volcanics King Leopold Sandstone
	KIMBERLEY GROUP	Minor UPLIFT AND EROSION : Probably in south-eastern part of area only	
		ARENITE DEPOSITION LUTITE DEPOSITION ARENITE DEPOSITION	King Leopold Sandstone Luman Siltstone Upper Landsdowne Arkose
		Minor UPLIFT AND EROSION: Probably in south-eastern part of area only	
	SPEEWAH GROUP	ARENITE AND LUTITE DEPOSITION Minor VULCANISM AND LUTITE DEPOSITION ARENITE AND LUTITE DEPOSITION	Lower and Middle Lansdowne Arkose Valentine Siltstone Tunganary and O'Donnell Formations
		SUBSIDENCE AND MARINE TRANSGRESSION	
		EROSION	
		GRANITE EMPLACEMENT	Granites in south-western part of area.
		FOLDING AND SHEAR BELT DEVELOPMENT	
		GRANITE EMPLACEMENT and localised METAMORPHISM	Bow River Granite
		Major VULCANISM – ACID PORPHYRIES	Granites in south-western part of area Whitewater Volcanics
		EROSION	
ARCHAEAN		FOLDING and REGIONAL METAMORPHICS: ?GRANITE EMPLACEMENT	Folding and metamorphics of Halls Creek Group; Tickalara Metamorphics.
		DEPOSITION OF GEOSYNCLINAL SEDIMENTS	Olympio Formation ? Part of Bow River Granite

AUSTRALIA 1:250,000

LANSDOWNE

WESTERN AUSTRALIA

1:250,000 GEOLOGICAL SERIES SHEET SE 52-5



PRELIMINARY EDITION, 1965

SUBJECT TO AMENDMENT

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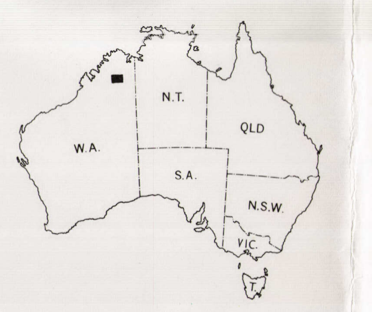
Reference

CAINOZOIC	UNDIFFERENTIATED			Qa	Alluvium: boulder gravels, fluviatile sand
				Czs	Residual red and grey soils, sand, and ferricrete
				Czb	Residual black soil
PALAEOZOIC	DEVONIAN OR PERMIAN			D/Pc	Conglomerate: mainly pebbles, cobbles, and boulders of quartz sandstone
	DEVONIAN		Stony Creek Conglomerate	Ds	Conglomerate: pebbles, cobbles, and boulders of granite, quartz sandstone, and sheared volcanics
			Windjana Limestone	Dw	Limestone: reef facies
			Pillara Limestone	Dp	Limestone: platform facies
			Napier Formation	Dn	Limestone: fore-reef to inter-reef facies
PRECAMBRIAN	UPPER PROTEROZOIC	Mount House Group	Estaughs Formation	Ehe	Quartz-hematite greywacke, purple-green micaceous siltstone
			Throssel Shale	Eht	Green micaceous sandstone, chloritic micaceous shale
			Traine Formation	Eha	Purple and green shale, dolomitic sandstone, ferruginous quartz sandstone, dolomite breccia
			Walsh Tillite	Ehw	Tillite, pink dolomite and quartz sandstone
	MIDDLE PROTEROZOIC		Hart Dolerite	Edh	Pyroxen-bearing granophyre; Tholeiitic dolerite and gabbro
		Bastian Group	Mendena Formation	Etm	Purple siltstone, quartz siltstone, dolomitic siltstone
		Kimberley Group	Pentecost Sandstone	Ekp	White cross-bedded quartz sandstone, grey siltstone and glauconitic sandstone, feldspathic sandstone
			Elgee Siltstone	Eke	Red-brown friable siltstone, flaggy brown to white quartz sandstone
			Teronis Member	Ekt	Grey micaceous siltstone, limestone, and dolomite with algal structures
			Warton Sandstone	Ekw	Pale purple to brown feldspathic sandstone, white cross-bedded quartz sandstone
			Carson Volcanics	Ekc	Tholeiitic basalt, vesicular in part, rholitic tuff and agglomerate, feldspathic sandstone, siltstone, and limestone
			King Leopold Sandstone	Ekl	Massive white to purple quartz sandstone, pebbly sandstone, grit, ferruginous sandstone. Boulder and cobble conglomerate
		Speewah Group	Luman Siltstone	Epl	Purple-grey and green-grey micaceous shale and siltstone
			Lansdowne Formation	Epo	Buff to pale pink cross-bedded feldspathic sandstone and arkose, purple-grey quartz sandstone, purple, green, and grey micaceous siltstone and shale
			Valentine Siltstone	Epv	Chloritic siltstone, siliceous siltstone, grey-green mudstone, feldspathic sandstone, rhyolitic tuff
			Tunganary Formation	Ept	Buff to pale grey feldspathic sandstone, quartz sandstone, pink arkose, granule sandstone, grey-green shale, micaceous siltstone and chert
			O'Donnell Formation	Epn	Khaki shale, siltstone, and greywacke, white, purple, and brown quartz sandstone, glauconitic sandstone, grit, conglomerate, localised feldspar porphyry
			Watery River Porphyry	Eww	Dark grey orthopyroxene-feldspar porphyry with sporadic quartz phenocrysts, strongly xenolithic in places
			Whitewater Volcanics	Ew	Quartz-feldspar porphyry, feldspar pyroxene porphyry, lapilli tuff, volcanic conglomerate, siltstone
	PROTEROZOIC	Lamboo Complex	Bickleys Porphyry	Ebb	Grey porphyry and porphyritic microgranite with quartz and feldspar phenocrysts
			Mulkerrins Granite	Ebu	White coarse and even grained leucocratic granite, tourmaline-muscovite aplite, quartz-feldspar pegmatite
			Lerida Granite	Ebl	Grey-green porphyritic biotite granite with pale green feldspar
			Chaneys Granite	Eby	Coarse and even-grained biotite granite, foliated and locally sheared
			Long Hole Granite	Ebg	Grey coarse grained porphyritic biotite granite, biotite gneiss, augen gneiss, cloudy blue quartz common
			Violet Valley Granite	Ebv	Dark grey medium-grained biotite granite
			Bow River Granite	Ebo	Grey coarse-grained biotite granite, pink coarse-grained porphyritic biotite granite
	ARCHAEAN(?)	Halls Creek Group	Tickalara Metamophics	Abt	Granulite
			Olympio Formation	Aho	Phyllitic shale and siltstone with interbedded greywacke, minor quartzite and marble

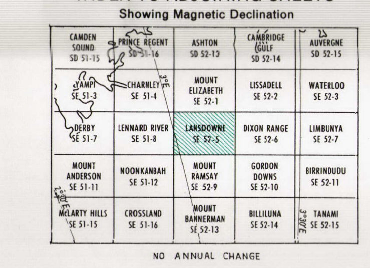
Geological boundary
Anticline, showing plunge
Syncline, showing plunge
Monocline, showing plunge
Plunge of minor anticline
Plunge of minor syncline
Plunge of drag fold
Fault, showing relative horizontal movement
Vertical fault
Inclined fault
High-angle reverse fault
Shear zone
Where location of boundaries, folds, and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes
Strike and dip of strata
Unmeasured strike and dip of strata
Vertical strata
Horizontal strata
Overturned strata
Trend lines, Joint pattern — air-photo interpretation
Strike and dip of foliation
Vertical foliation
Inclined platy flow
Strike and dip of joints
Strike and dip of cleavage
Plunge of lineation
Lineation on bedding

Macrofossil locality
Measured section
Dyke: q-quartz, di-dolerite, rh-rhyodacite, to-gr-tourmaline granite, ap-aplite
Minor mineral occurrence
Cu Copper
F Fluorine
Pb Lead
Bore with windpump
Well with windpump
Tank
Earth tank
Spring
Waterhole
Road
Vehicle track
Fence
Homestead
Landing ground
Yard
Astronomical station
Trigonometrical station
Height in feet, instrument levelled; datum: mean sea level

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



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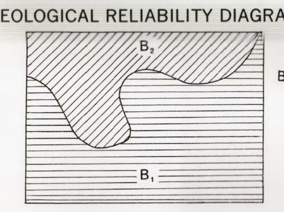
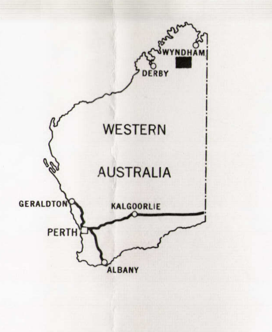
Compiled: 1965, by: G.M.Derrick, D.C.Gellatly, A.S.Mikolajczak
Drawn by: A.S. Mikolajczak

GEOLOGICAL RELIABILITY DIAGRAM



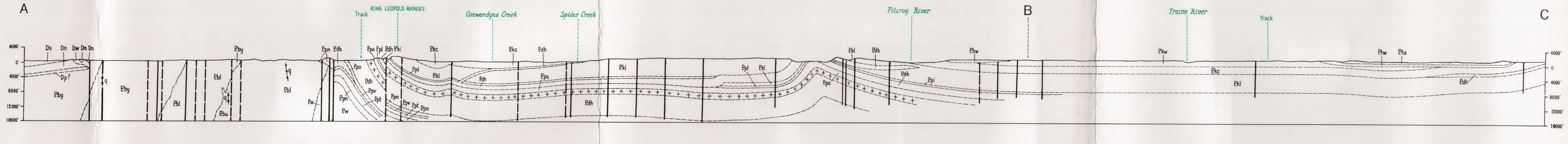
B1 Detailed reconnaissance: numerous ground traverses and air-photo interpretation

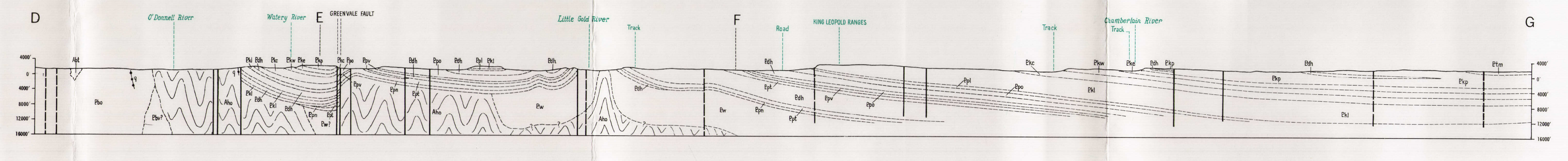
Reconnaissance, scattered ground and helicopter traverses, and air-photo interpretation



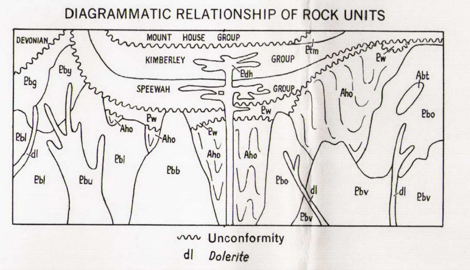
Sections

Cainozoic sediments omitted from sections
Attitude of faults not known
Scale $\frac{V}{H} = 1$





DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



LANSDOWNE

SHEET SE 52-5