Report Bk. 66/74
G.S. 3936

DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY
REGIONAL SURVEY DIVISION

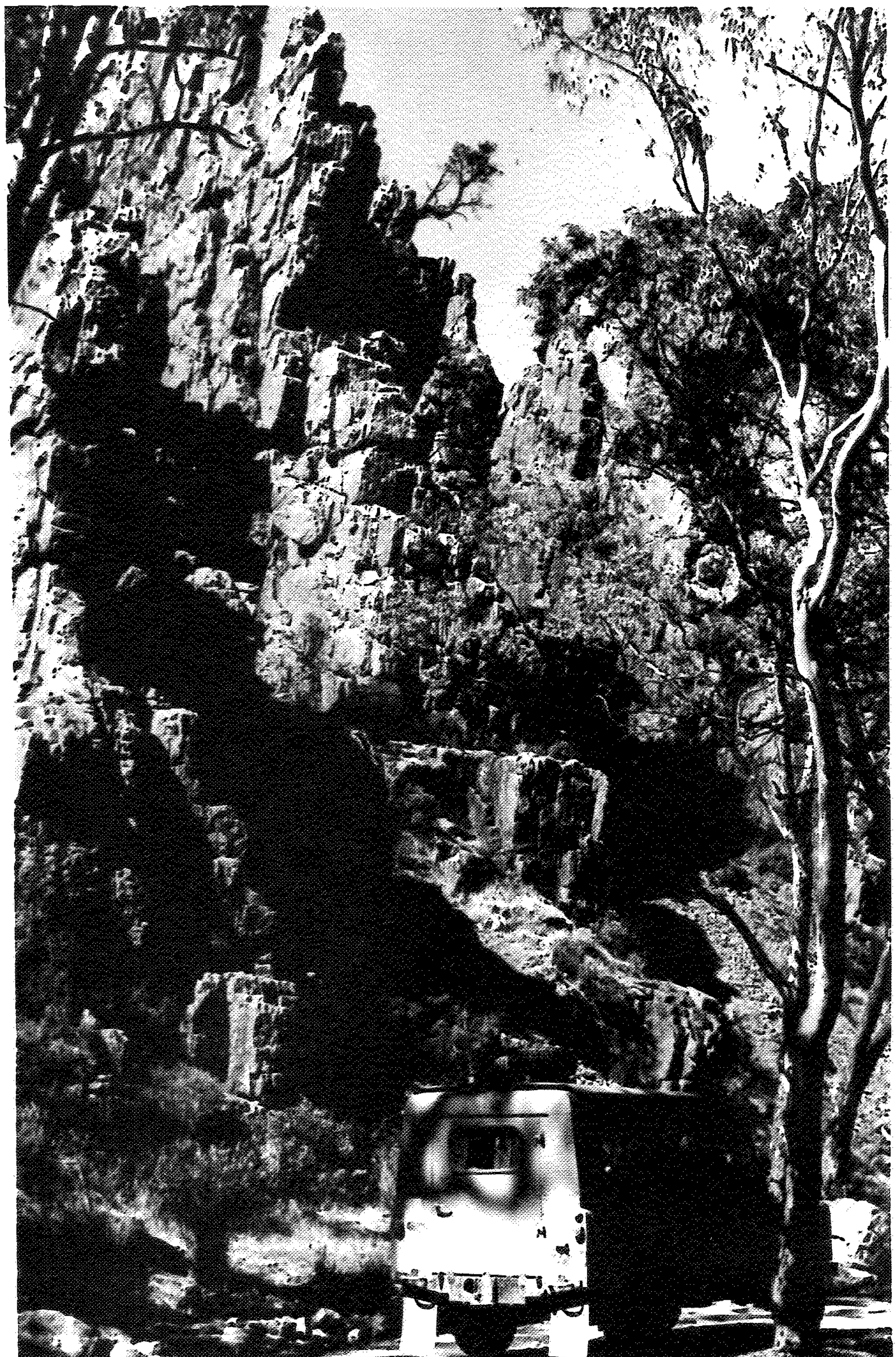
GEOLOGY OF THE ORROROO 1:250,000 MAP AREA

by

P.J. Binks
Geologist

DM.380/59

19th March, 1968



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Frontispiece: Steeply dipping ABC Range Quartzite in Warren Gorge, Willochra 1:63,360 area.

DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGY OF THE ORROROO

1:250,000 MAP AREA

by

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Sections on the River Wakefield and Burra Groups

by

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SENIOR GEOLOGIST
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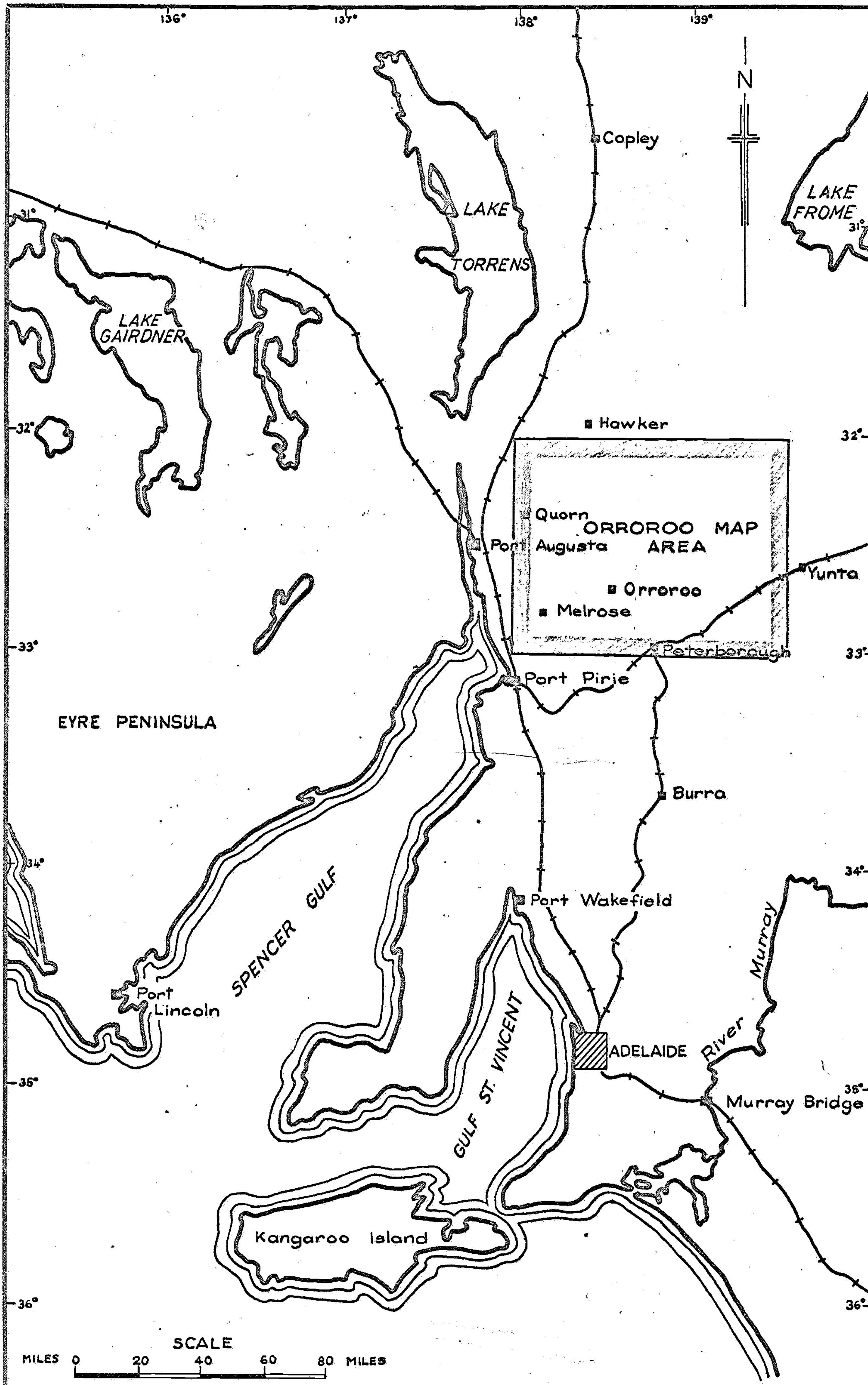

FIGURE 1

DEPARTMENT OF MINES — SOUTH AUSTRALIA

	Drn. P.B.	ORROROO 1:250,000 GEOLOGICAL MAP LOCALITY PLAN	SCALE: 1 Inch = 40 Miles
	Tcd. RAJ		S5564 Fef + hj
	Ckd. L.V.W.		
	Exd.		DATE: 1 Nov. 1966

DEPARTMENT OF MINES
SOUTH AUSTRALIA

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GEOLOGY OF THE ORROROO 1:250,000 MAP AREA

ABSTRACT

An essentially unmetamorphosed sequence of Upper Proterozoic Adelaide System rocks has been folded into a parallel series of north and northeast trending folds in the Orroroo map area. Rocks of the Adelaide System are upto 50,000ft. thick and include sediments of Willouran to Marinoan age. Marked facies changes occur from west to east in the Lower Marinoan. Lower Cambrian rocks occur in the keels of tightly folded synclines in the northwest of the survey area and Triassic beds are preserved in two small basins southwest of Cradock. Lacustrine Tertiary sediments occur at depth in the Willochra and Walloway Basins.

Willouran rocks have been forcefully emplaced into upper Adelaidean sediments in several places in the survey area. Some of these piercement structures were contemporaneous with sedimentation while others were intruded after the main Lower Palaeozoic orogeny. Copper mineralisation in the vicinity of these structures is probably associated with basic igneous rocks which have intruded the piercement breccias.

Mineral production from the area has been small and mainly limited to iron flux, copper and gold, mined towards the end of the 19th Century.

INTRODUCTION

The ORROROO (i.e. Orroroo 1:250,000 Sheet) area is situated in the upper north of the settled part of South Australia, partly in the Flinders Range Province and partly in the Mt. Lofty-Olary Province. Longitudes 138°00' and 139°30' east and latitudes 32°00' and 33°00' south bound the area, which covers approximately 6,000 square miles.

Up to 50,000ft. of strata belonging to the Adelaide System and ranging from the Willouran to Marinoan Series have been mapped in the area. Rocks belonging to the Cambrian System and two small basins of strata belonging to the Triassic System occur in the northwest. About 50 to 60 per cent of the total area is occupied by outcrop of these rocks.

Mapping of ORROROO was started by R.C. Mirams in 1963 as part of the Geological Survey programme of mapping the Adelaide Geosyncline on 1:250,000 scale. Two 1:63,360 sheets, Willochra and Quorn, had been mapped previously. W.B. Robinson spent three months mapping on the Koonamore, Waukaringa and Paratoo sheets late in 1963. In May 1964, P.J. Binks commenced mapping on the Paratoo sheet. Mirams completed the majority of the Nackara, Peterborough, Melrose and Wilmington sheets in 1963-1965.

B. Leeson mapped part of the central area of the Waukaringa 1:63,360 Sheet during one month's field work in 1964. K. Yong spent six months during 1965 mapping in the mid-north of ORROROO, two months of which were spent mapping the eastern half of the Carrieton sheet at a standard suitable for publication at a scale of 1:63,360. A provisional one mile Carrieton sheet and a report (Yong 1965) was prepared by Yong in October, 1965.

In November 1965, B.G. Forbes began re-examining the Burra Group on ORROROO in order to correlate rock units in the area with units in the type section on BURRA. In 1966, B.P. Thomson, who has visited the area on several occasions, recognized rocks of the River Wakefield Group on the eastern limb of the Pekina Syncline and in the core of the Carrieton Anticline. Forbes (1966b) has since sub-divided the River Wakefield and Burra Groups on ORROROO and is responsible for describing these sequences in this report. Compilation of the map was by P.J. Binks. B.P. Thomson was responsible for overall supervision of the mapping programme.

Representative rock specimens of rock units in the Umberatana, Wilpena and Hawker Groups have been described by A.B. Simpson (1967). Selected descriptions are included in Appendix I of this report together with other descriptions by petrologists of the Australian Mineral Development Laboratories.

The Broken Hill-Port Pirie narrow-gauge railway line crosses the southeastern quadrant of the sheet, and the former main north line to Leigh Creek and Alice Springs (narrow-gauge) runs north through Peterborough, Orroroo and Quorn. The Port Pirie-Broken Hill line is currently being replaced with standard-gauge to complete the transcontinental standard-gauge linkage. Several diversions from the old line are being made; the standardisation is expected to be finished by late 1968.

With the opening of the standard-gauge line from Port Augusta to Alice Springs in 1956, the Peterborough-Quorn line was only used for local traffic, and the line from Port Augusta to Quorn through the Pichi Richi Pass was closed. The Quorn-Hawker narrow-gauge line is kept open for the transport of barytes to the S.A. Barytes works in Quorn. A narrow-gauge branch line from Gladstone to Wilmington via Booleroo Centre and Melrose is still in use.

Two north roads, one via Melrose, Wilmington and Quorn, the other via Orroroo and Carrieton, and the northeast road to Broken Hill are the main roads through the area. The north road via Quorn is bituminised as far as Wilmington and a current programme of sealing the road from Quorn to Hawker, to provide a sealed road between Adelaide and Hawker, is in progress. The north road via Orroroo and Carrieton is sealed as far as Orroroo, no further bituminisation of this road is envisaged for some years. The Broken Hill road will be completely sealed by 1968, and only a few stretches of dirt road remain.

Other roads in the area, particularly in the west and central areas, are nearly all well graded dirt tracks and access is good. Eastern areas are not so readily accessible, especially in the northeast, though good station-tracks enable a two wheel drive vehicle to get to most places. A four wheel drive vehicle is necessary for some of the tracks in the hilly areas and also for some of the country not served by station tracks in the northeast.

Peterborough is the largest town in the area with a population of about 3,500. Orroroo and Quorn are similar in size with approximately 1,000 inhabitants, though Quorn's population was larger before the diversion of the main railway line in 1956 (in 1954 the population was 1,806; in 1961 it had decreased to 1,163). Booleroo Centre, with a population around 700, is next in importance followed by Melrose, Wilmington and Carrieton. Other townships with very small populations include Pekina, Black Rock, Tarcowie, Hammond, Cradock, Morchard, Murray Town and Oodlawirra.

Sheep raising is the main industry in the area, though wheat production is important in the southwest. South Australian Railways employ a considerable number of men in the railway yards and workshops at Peterborough and a few others at Quorn, Wilmington, Melrose and Carrieton. S.A. Barytes Ltd. employ about a dozen men at Quorn. Local councils employ men, particularly for the maintenance of roads.

PREVIOUS WORK

The first recorded visit of a geologist to the area was in 1860 when A.R.C. Selwyn, the Government Geologist of Victoria, passed through the area in the company of G.A. Goyder, the Surveyor General of South Australia. Selwyn noted basic intrusives at Melrose and suggested the possibility of artesian water in the Willochra Basin (Selwyn, 1860).

Howchin was the first geologist to study the area and the first to correlate strata with the Adelaide region. He recognised tillitic beds, which he thought were of Cambrian age, at Mt. Grainger and Peterborough (Howchin, 1901) and compared them with similar deposits in Sturt Creek near Adelaide. In 1916 he mapped the Mt. Remarkable-Spring Creek area (Howchin, 1916) and described the sequence in detail. He correlated the quartzite forming the Mt. Remarkable Range with a quartzite underlying the tillite at Adelaide (the upper quartzite in the Belair "group"). Above this quartzite he recognized the tillite, Tapley's Hill Slates, Brighton Limestone and "purple slates series". Howchin proposed a series of strike faults to increase the thickness of the quartzite as he did not conceive that a quartzite of this thickness (approximately 4,000ft.) occurred in the area. Mawson (1947) later equated the Mt. Remarkable Quartzite with the Emeroo Range Quartzite thus eliminating the need for the rather artificial strike-faults suggested by Howchin. Howchin mapped many small, plug-like basic masses intruding a highly crushed slate at the southeastern foot of the Mt. Remarkable Range. In a later paper (Howchin, 1920) he refers to these slates as a shatter zone probably resulting from a vertical "thrust" movement. This "shatter-zone" is now believed to be a diapiric structure.

Howchin gives further descriptions of the Adelaide Series in the Southern Flinders Ranges in a later paper (Howchin, 1928). He includes in this account cross-sections and descriptions of the geology in the Pichi Richi Pass and Dutchman's Stern area, Spear Creek and Deep Creek, Baroota Creek, Mt. Remarkable and Back Creek Gorge (Port Germein Gorge). Another paper (Howchin, 1930) gives an account of several features of the geology in the vicinity of Orroroo township. Howchin refers to the Brighton Limestone south of Orroroo but does not indicate that there are many limestones which lens rapidly making it difficult to recognise this horizon further south in the same structure. In a north-south cross-section, through the Black Rock Range he shows several strike faults to explain prominent scarp faces; no evidence of these faults was found in the course of recent mapping.

The Mount Grainger, Pichi Richi Pass and Horrocks Pass areas have been mapped in detail by Segnit (1939). The Mount Grainger area is of particular interest as Jack (1913) had previously mapped the area in the vicinity of the Mount Grainger Goldfield and recognised two tillitic horizons. Segnit did not accept this concept and proposed a complex series of dip faults and concentric strike faults to duplicate the tillite. Recent work has proved beyond doubt the validity of Jack's work; a more detailed account of the area is given in a later section.

In the Pichi Richi Pass area Segnit correlated the quartzite forming the Emeroo Range with the "Flinders Range Quartzite Series" (Pound Quartzite). Mawson (1947) disagreed with Segnit as he found magnesitic beds immediately overlying the quartzite, thusmaking a conformable sequence underlying the Sturtian tillite. Mawson called this unit the Emeroo Range Basal Rudaceous and Arenaceous Formation and correlated it with the quartzites of Mt. Remarkable and the Bluff Range, east of Port Pirie.

Segnit's work in the Horrocks Pass area is supported by the present mapping. Among several of his observations that have since proved important are:- thin dolomitic bands within the Tindelpina Shale Member of the Tapley Hill Formation; massive siltstones with thin interbeds of brecciola limestone in the upper part of the Tapley Hill Formation, and thin bands of dolomite above the Brighton Limestone forming a passage into the "Purple Shale Series".

A small area in the mid-north of the Yednalue Sheet was mapped by Spry (1951 a) in the course of examining small basic intrusives in the Worumba region. Spry regarded an area of crushed and folded phyllites and dolomites intruded by small dolerite bodies as an upfaulted block, probably equivalent to the Castambul Dolomite horizon. Dalgarno and Johnson (1966) show this crushed zone as a diapir on PARACHILNA; the southern extension of this structure has been mapped on ORROROO. Spry regarded an oolitic limestone above a blue-grey quartzite siltstone unit to be the Brighton Limestone. This is not accepted, as abundant red shales occur at the base of this quartzite siltstone unit to the southwest of the flanks of the Uroonda Syncline. The petrology of the basic intrusives, which Spry described as uralitised and saussuritised dolerites and basalts, was discussed by Spry in another paper (Spry, 1951 b).

Fossiliferous Cambrian beds were recognized by Daily (1956) 18 miles north of Quorn. Daily considered these beds to be extensions of the Cambrian rocks found by Howchin (1925) 20 miles to the north in the Wilson-Kanyaka area.

In 1957 a party of students from the University of Adelaide, mapping under the direction of Kleeman, discovered a small basin of Triassic sediments 8½ miles east of Gordon. Subsequent mapping and drilling by the S.A. Mines Department (Johnson, 1960) proved a thickness of 1,000-3,000ft. of conglomerate, argillite, sandstone and coal-measures. A water-bore revealed another small Triassic basin about seven miles south-southwest of the latter area (Von der Borch, 1958).

Members of the Geology Department of the University of Adelaide have carried out detailed mapping in an area to the west and northwest of Quorn.

Two 1:63,360 sheets, Willochra and Quorn, have been mapped by the Geological Survey in the northwest of ORROROO. The Quorn Sheet was mapped by Shepherd and Thatcher (1956) and a Report of Investigation on the area published in 1959 (Shepherd and Thatcher, 1959). The Willochra Sheet was mapped by Webb and Von der Borch (1962); unfortunately no report was published. Some alterations have been made to the Quorn Sheet, particularly to the east of the Willochra Plain where large sheets of

Tertiary silcreted gravels and minor diapiric structures have been recognised. Tertiary gravels and another minor diapiric structure were found southeast of Quorn township. The Willochra Sheet, included on ORROROO with little modification, was the first in the Geological Atlas of South Australia to show diapiric structures.

Brook (1962) mapped an area in the central part of ORROROO, from Tarcowie to Belton, for Consolidated Zinc Proprietory Ltd. in their search for phosphate rock during 1962. He mapped the known phosphate horizons in detail but large areas were covered by photo-interpretation and some alterations have been made, particularly in the Walloway area where a complicated area of faulting has been reinterpretated as a diapiric zone.

Much has been written on the mines and mineral prospects of the area. Brown (1908) in his "Record of Mines" gives the only comprehensive account of the known mineral deposits. Since Brown's work reports have been confined to individual areas. Many reports by Mining Inspectors on the progress of development at individual mines, especially at the gold workings of the Waukaringa and Mt. Grainger areas, appear in the Mining Reviews of the S.A. Mines Department.

Fairburn and Nixon (1966) have recently mapped in detail the workings and surface geology of the Mt. Grainger Mine for Grainger Gold Pty. Ltd. Wright (1966) mapped the Mt. Grainger Goldfield and surrounding area, and discussed the mineralisation and mineral resources of the area for his Honours Thesis at the University of Adelaide in 1966.

A report on the Prince Alfred Copper Mine, 29 miles northeast of Carrieton, was prepared by Wade and Wegener (1954). Nixon (1960) revisited the area to site a bore recommended by Wade and Wegener in 1960.

In the course of a radiometric survey of old mines, Summers (1953) gave a general appraisal of the Spring Creek Copper Mine, situated seven miles south of Wilmington.

Whitten (1961) supervised drilling and prepared a report on the Devil's Chimney Ironstone Deposit (located three miles east of Yalpara Station), after a recommendation for a diamond drill-hole by Crawford (1955).

A report on the Paratoo Copper Deposit was prepared by Nixon (1965) after a request for geological advice by Electro Winning Prop. Ltd.

A more recent classified report has been prepared by Blissett (1966).

Much investigation for non-metallic minerals has been carried out in the area. Johns (1963) has fully outlined the magnesite deposits occurring in Torrensian rocks at Saltia and Port Germein Gorge in the Flinders Range. Phosphate deposits on the Orroroo Sheet have been summarised by Jack (1919) and Brook (op. cit.).

Hiern has prepared a number of reports on road-metal and ballast deposits for the Highways Department and South Australian Railways. Hiern (1966) has prepared a reconnaissance map of the Peterborough district showing various stratigraphic horizons with potential interest as ballast deposits. An earlier report (Hiern, 1964) also approaches the problem of finding ballast and road metal from stratigraphic and structural principles.

Many reports have been written on individual groundwater prospects in the region but only two areas, the Willochra Basin (O'Driscoll 1956) and Walloway Basin (Sprigg, 1950), have been assessed on a regional scale.

A recent paper by Twidale (1966) discusses the geomorphology and denudation chronology in and around the northern part of the Willochra Basin in the northwest of the survey area. Twidale has established units in the Cainozoic sediments of the area, the status and use of these units will be discussed in a later section on stratigraphy.

An airborne magnetic and radiometric survey of ORROROO was carried out in 1965 by the Bureau of Mineral Resources. Tipper and Finney (1965) prepared a report on the survey which includes plans showing total magnetic intensity profiles and radiometric profiles.

PHYSIOGRAPHY AND CLIMATE

Relief of the ORROROO area is subdued compared to that of the Northern Flinders Ranges and consists essentially of rounded hills and ranges separated by broad, alluviated valleys. Somewhat higher and starker relief occurs in the Flinders Range along the western margin of the survey area, particularly north of Quorn, where resistant quartzites dominate the topography with high ridges and cuestas. In the west the ranges are orientated in a north-south fashion, while in the east they swing round to the northeast and east reflecting the pattern of the major structures. Generally, relief varies between 1000 and 2000ft. Mt. Brown is the highest point in the area at 3166ft. above sea level.

Low lying alluviated areas separating the ranges are shown on Fig. 2. The Willochra and Walloway valleys are commonly referred to as intermontane basins as they are enclosed by comparatively high ranges of hills. To the north and east the Siccus, Koonamore the Nackara drainage systems form large areas of flood plain.

All the creeks except a few in the southwest are ephemeral. Seasonal lakes are located west of Koonamore Station, these are usually dry, though the western lake often contains fresh water after heavy rains. Gypseous deposits (kopi) derived from evaporating waters, and blown by prevailing westerly winds along the eastern margins of the lakes, suggest that considerable quantities of water have reached these lakes. Watersheds dividing the major drainage systems are shown on Fig. 3.

The Willochra Creek system forms the largest drainage basin, draining the western part of the area northwards to Lake Torrens. Apart from the Siccus River which drains a small area in the north to Lake Frome, and drainage southeastwards to the Murray Plains from the southeastern area, the rest of the drainage of the area is internal. The Koonamore system drains most of the eastern half of the area north to the Koonamore Lakes. Large creeks including the Nackara, Buttamuck and Mukra Creeks in the south of the basin, flow north before diverging into many separate water courses, which finally reach the lakes. The Siccus River may have drained the Koonamore Basin at some time in the past as the terrain separating the river bed from the lakes is quite flat and consists of gravels and sands of possible fluviatile origin.

Drainage within the Walloway Basin collects in a flat depression about twelve miles northeast of Orroroo, from where it drains via Hillpara Creek into the Koonamore drainage basin. Hillpara Creek has cut back through prominent ridges of quartzites and tillites of the Torrensian and Sturtian Series, to capture the drainage of the Walloway Basin. The creek has taken advantage of a small fault to cut through a very hard ridge of quartzite, and probably linked up with creeks cutting back from the Walloway side of the ridge, to produce quite a deep gorge through the ridge.

The highest rainfall occurs in the southwest, where high winter rainfall in the Flinders Range gives averages of over 20 inches per year. (Melrose 22.80 inches p.a.). Rainfall drops off sharply to the east, Booleroo Centre, 12 miles east of Melrose, has only 15.15 inches per annum. In the northeast of the area average rainfall is only 8 inches per annum. (Koonamore 7.61 inches p.a.). The pronounced winter maximum of the southwest becomes less evident to the northeast and has no influence on the annual rainfall at Koonamore. Fig. 3 shows isohyets and average annual and monthly rainfall for fourteen recording stations on the area.

Average maximum temperature for January varies between 85°F and 90°F, while the average minimum temperature for July varies between 35°F and 40°F. Maximum temperature increases to the north and east but the minimum temperatures are higher in the west due to the moderating effect of Spencer Gulf.

STRATIGRAPHY

The ORROROO area lies in the central part of the Adelaide Geosyncline and consists almost entirely of rocks belonging to the upper Proterozoic Adelaide System. Upto 50,000ft. of strata belonging to this system have been mapped in the area. Lower Cambrian rocks, outcropping in the keels of synclinal structures in the northwest of the survey area, overlie the Adelaidean with apparent conformity. After the Lower Cambrian the next record of sedimentation on ORROROO occurs in the Triassic when lacustrine sediments were deposited in intermontane basins southwest of Cradock (Springfield and Boolcunda Basins). Lacustrine deposits of Tertiary age are present in the Willochra Basin and probably at depth in the Walloway Basin. Dissected Pleistocene gravels, frequently calcreted and underlain by mottled clays, cover large areas in the north of the Willochra Plain and in the southeast of the survey area. Large areas of Recent alluvium in drainage channels and on flood plains, and colluvial deposits flanking outcrops, occur in the area. All these rocks are essentially unaffected by metamorphism, though low grade regional metamorphism (biotite, chlorite, sericite) has taken place in the Adelaidean rocks in the east of ORROROO adjacent to the Olary Region.

Thicknesses of rock units used in the following sections have been calculated from aerial photographs. Names of structures are shown on Fig. 4.

Adelaide System

The Adelaide System was divided into the following ascending time-rock units by Mawson and Sprigg (1950):- Torrensian Series, Sturtian Series, and Marinoan Series. Later Sprigg (1952) included the Willouran Series as the lowest unit of the Adelaide Sytem.

Daily (1963) proposed that the time-rock terms of the Adelaide System and accompanying Series should be replaced by the following rock-stratigraphic terms:- Adelaide Supergroup; Torrens Group; Sturt Group and Marino Group. Members of the Geological Survey of South Australia (Thomson et al 1964) established another rock-stratigraphic subdivision of the Adelaide System. Rock groups set up were, in ascending order:- Callanna Beds; Burra Group; Umberatana Group, and Wilpena Group. Time-rock terms of Mawson and Sprigg were retained for descriptive purposes and a correlation chart was compiled showing relationships of time-rock and rock stratigraphic units. Rock groups conformed to the Series terms except for the Umberatana Group which extended into the Marinoan to avoid the difficult mapping boundary between the Sturtian and Marinoan Series over the large areas covered by 1:250,000 scale sheets.

Forbes (1967a) has recently pointed out the anomaly of including an angular unconformity at the base of the Appila Tillite within the Umberatana Group and suggested that the base of the tillite should be taken as the base of the Umberatana Group. Because of this anticipated revision of the Umberatana Groups, units below the Appila Tillite which were included in the Umberatana Group on BURRA are placed in the Burra Group on ORROROO.

Callanna Beds

No rocks of the Willouran Callanna Beds outcrop in sequence on the greater part of ORROROO, though they do occur in sequence below the basal quartzite of the Burra Group (Rhynie Sandstone) in an anticlinal structure immediately west of Gladstone in the northwest of BURRA and at Depot Creek on AUGUSTA. In the extreme northwest corner of the ORROROO area there is a faulted sequence of ?Callanna Beds (sandstone and shale), too thin to be represented on the map. Highly brecciated and crushed rocks, believed to be Callanna Beds, have been forcefully emplaced into younger rocks of the Adelaide System in diapiric structures at several places on ORROROO. Rock types occurring in these structures will be discussed in the section on diapirs.

The Nelshaby Sandstone and Wirrabara Formation have been previously defined as units in the Callanna Beds (Mirams in Thomson et al 1964). Mirams established these formations in the Bluff Range east of Port Pirie and classified them as Willouran age on BURRA (Mirams, 1964). Forbes (1967b and this report) has revised this correlation and now believes these "formations" to be local members of the Rhynie Sandstone and has not differentiated them on ORROROO.

River Wakefield Group

This term is used for siltstone-carbonate-quartzite sequences below the Rhynie Sandstone equivalent; such sequences are exposed west of Yatina, southwest and north of Carrieton and northeast of Belton. The term Callanna Beds is not used mainly because of the presence of carbonate rocks in the upper part of the succession. In the Orroroo region the River Wakefield Group presents a much less metamorphosed appearance, and a greater thickness is exposed, than in its type area in the Clare district (Wilson, 1952; Forbes, 1964).

These rocks often occur in low, bare hills or in hills with malle-type eucalypts where carbonate-rich.

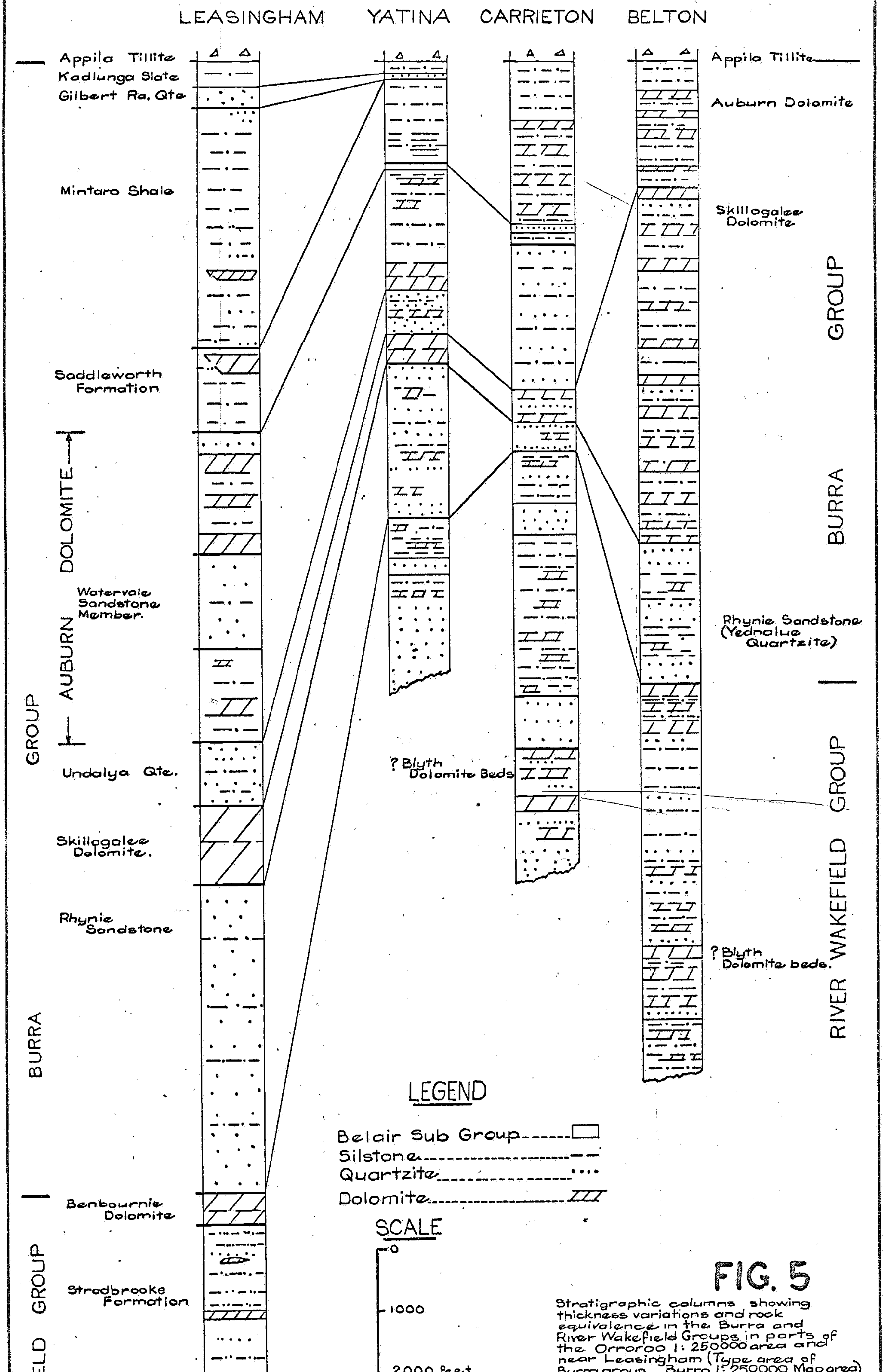

FIG. 5

Stratigraphic columns showing thickness variations and rock equivalence in the Burra and River Wakefield Groups in parts of the Orroroo 1:250000 area and near Leasingham (Type area of Burra group, Burra 1:250,000 Map area)

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Drn. B.F.	ORROROO 1:250000 SHEET STRATIGRAPHIC COLUMNS OF THE BURRA AND RIVER WAKEFIELD GPS.	SCALE: As shown
Tcd. NE		S.6058 Fef+hj
Ckd. L.V.W.		
Exd.		DATE: 14 Sept 67.

A sequence comprising about 2,400ft. of siltstone, dolomite and quartzite are exposed in the eastern edge of the hills west of Yatina. The lower half of the sequence, the base of which is not exposed, is mainly quartzite, partly laminated and feldspathic, with minor siltstone and dolomite interbeds. The overlying interbedded grey siltstone and dolomite is capped in one place by a grey laminated dolomite, containing dark cherty blebs, resembling the Benbournie Dolomite (top of the River Wakefield Group west of Clare).

A thicker sequence of about 7,000ft. may be seen southwest of Carrieton in the Carrieton anticline. Lowermost rocks exposed are dolomitic arkose overlain by dark grey cherty dolomites and quartzites strongly resembling the Skillogalee Dolomite of the Burra Group. The dolomites also resemble the Blyth Dolomite Beds, to which they may be equivalent. The overlying sequence is composed mainly of grey siltstone and dolomite. The uppermost 1,300ft. is more quartzitic and includes a prominent feldspathic quartzite, possibly equivalent to the Ingomar Quartzite.

A broadly similar succession of about the same thickness (6,100ft.) may be seen in the Yednalue anticline northeast of Belton. It is difficult to make close correlations with other areas, but there is again near the base of the sequence dark cherty dolomite possibly equivalent to the Blyth Dolomite Beds.

About four miles southwest of Johnburgh and southeast of "Oladdie", there are grey laminated siltstones and dolomite tentatively equated with the River Wakefield Group. Some quartzite associated with these beds have also been shown on the map as units of the River Wakefield Group, but they could be included in the Rhynie Sandstone of the Burra Group.

Burra Group

The Burra Group, originally defined in the Leasingham area north of Auburn by Mirams and Forbes (Thomson et al, 1964, pp. 5-7) has been mapped most extensively by R.C. Mirams (1964) on BURRA. As shown on BURRA, the Burra Group extends from the base of the Rhynie Sandstone to the top of the Saddleworth Formation. However, because of an anticipated revision of the Burra Group to correspond to the sequence from the base of the Rhynie Sandstone to the base of the Appila Tillite, ORROROO portrays this revised version of the Group. The revised top of the Burra Group is in places an angular unconformity and probably corresponds to the base of the Umberatana Group as defined by R.P. Coats (Thomson et al, 1964, pp.7, 8).

An average value of exposed thickness of the Group is about 15,000ft., but there are considerable variations in thickness through lenticularity of units and erosion prior to deposition of the Appila Tillite.

The lower units in the Burra Group, Rhynie Sandstone to Undalya Quartzite, are generally more readily recognized than the upper part of the sequence as perhaps may be inferred from the uncertainties expressed in the reference column of the map.

Some typical sequences are shown in Figure 5.

Rhynie Sandstone

The Rhynie Sandstone (Wilson, 1952, pp. 135-136) commonly forms prominent rough, wooded ridges of feldspathic quartzite (sp. 1 and 2)* with shales and, in places, minor dolomite rock. It overlies siltstone and sandstone of the Callanna Beds or siltstone and dolomite of the River Wakefield Group, and is overlain by the usually distinctive Skillogalee Dolomite.

Formations considered to be equivalent to the Rhynie Sandstone are the Emeroo Quartzite or its upper part and the Yednalue Quartzite (Spry, 1952, p. 170). The Nelshaby Sandstone and Wirrabara Formation, defined by Mirams (Thomson et al, 1964, pp. 18, 19) as units in the Callanna Beds are now thought to be members of the Rhynie Sandstone. This revision results mainly from the re-mapping of the area between Laura and Hughes Gap (northwest BURRA) where siltstones and sandstones considered to be equivalent to the Callanna Beds are overlain by the full sequence of Nelshaby Sandstone, Wirrabara Formation and the upper part of the Rhynie Sandstone.

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* Numbers in brackets refer to descriptions of thin-sections contained in Appendix I. Locations of samples are shown on Fig. 10.

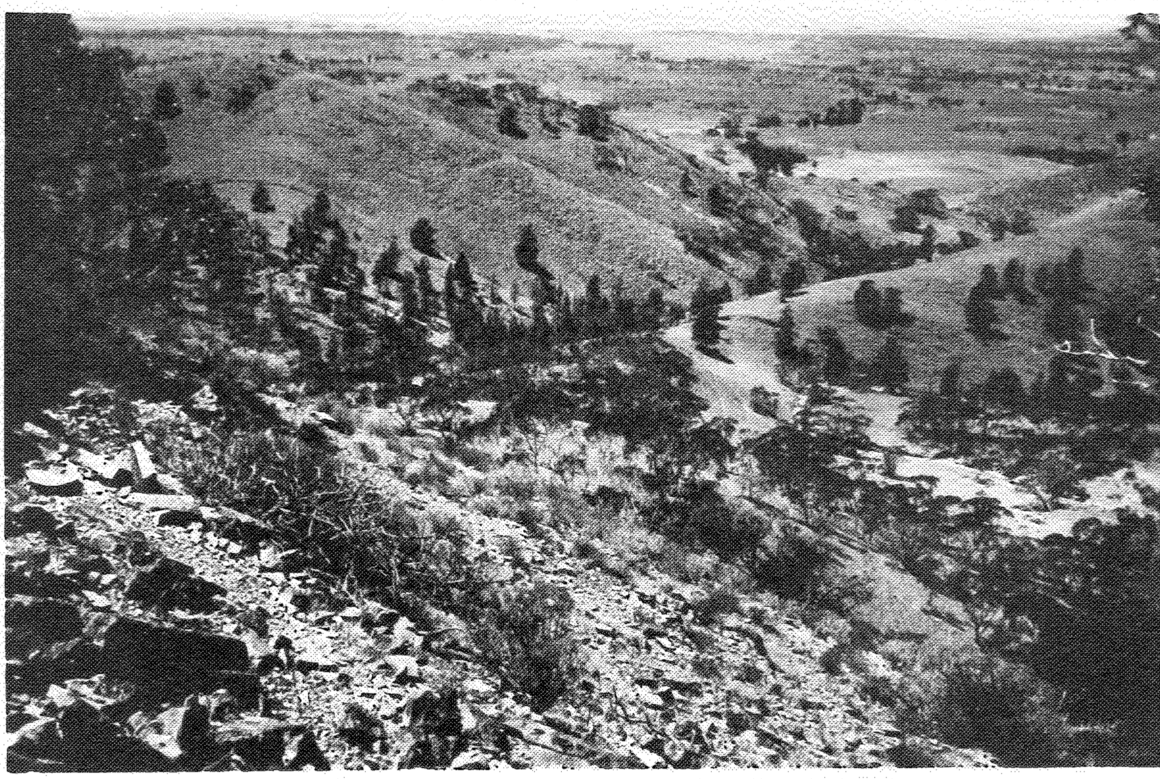

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Plate 1 - Yednalue Quartzite (Rhynie Sandstone equivalent), in left foreground, about ten miles NNE of Belton, Yednalue 1:63,360 area, looking north-east. Down slope to the east of the high quartzite ridge, are steeply dipping grey dolomite and siltstone (in area of mallee eucalypts near centre of photograph) and quartzite (among pines) underlain to the east by further siltstone, quartzite and dolomite. The dolomitic sequence is part of the River Wakefield Group and is on the north-west limb of the Yednalue anticline.

The term Emeroo Quartzite appears to be a contraction for Mawson's (1947, p. 270) "Emeroo Range basal rudaceous and arenaceous formation", and has been used by Spry (1952, p. 169) and on the published geological sheets Willochra (Webb and von der Borch, 1962) and PARACHILNA (Dalgarno and Johnson, 1966).

Approximately 2,400ft. of Rhynie Sandstone, coextensive with the Emeroo Range beds of Mawson's type-section, are exposed northwest of Buckaringa Hill in the northwestern corner of the map area. The uppermost 1,200ft. of quartzite are mainly pale grey, flaggy, laminated, medium-grained and feldspathic; there are minor grey siltstone interbeds and in places, at the base, some pink quartzite typical of the Nelshaby Sandstone. Ripple marks and cross-bedding are displayed. Below this, to the west, are valley-forming softer grey and reddish laminated micaceous sandy siltstones and quartzites. Further west, as far as the western edge of the ranges, pink and pale grey quartzites are repeated by strike faults.

In Port Germein Gorge the Rhynie Sandstone is composed almost entirely of the pink Nelshaby Sandstone rock-type, which is overlain by about 200ft. of interbedded shale, red chert and quartzite equivalent to the Wirrabara Formation and/or upper Rhynie Sandstone. Southeast of the gorge, on the eastern limb of the Nelshaby anticline, the red chert ends in the lower part of the overlying Skillogalee Dolomite and appears to be a local silicification accompanying some brecciation of the upper quartzites. Brown or grey chert is present just below the top of the underlying pink quartzites - this is a silicified laminated siltstone. Black heavy-mineral lamination has been seen near the top and about 1,200ft. below the top of the pink quartzites. Lamination and cross-bedding are frequent throughout; some cross-bedding is on a large scale. Laboratory terms for these rocks (Smale, 1966) are argillaceous orthoquartzite, feldspathic quartzite and arkose. Orthoquartzites contain numerous white argillaceous specks at least in part resulting from alteration of microcline and grains of igneous rock. Maximum grain size is commonly about 0.5mm.

Mawson (1947, p. 284) considered the thick quartzite sequence of the Mount Remarkable range to be part of his Emeroo Range sequence. As in Port Germein Gorge, there is a lower, mainly pink, quartzite sequence (at least 2,600ft. thick) with minor grey laminated siltstone, which strongly resembles the Nelshaby Sandstone. This grades upward to the west into flaggy pink and pale grey feldspathic quartzite (1,200ft.) without any significant intervening silty beds similar to the Rhynie Sandstone or Wirrabara Formation of the Wirrabara area. Heavy mineral lamination is apparent at intervals in the pink quartzites.

Feldspathic sandstone in the core of the anticline south of Booleroo Centre is tentatively correlated with the Rhynie Sandstone; it has a minimum thickness of 800ft.

Northwest of Quorn the Rhynie Sandstone is at least 3,200ft. thick in the faulted Quorn anticline. About 500ft. of poorly outcropping laminated siltstone, pale grey feldspathic quartzite and pink quartzite (very like the Nelshaby Sandstone) is underlain by at least 2,700ft. of pale grey feldspathic quartzite.

The sandy sequence named Yednalue Quartzite (Fig. 5) is considered to be equivalent to the Rhynie Sandstone and was first described by Spry (1952, p. 170) from near the northern edge of the map area about seven miles northeast of Cradock. Here it is recorded as being 750ft. thick and composed of interbedded quartzite and shale. The shale contains interbedded carbonate rocks, and this fact together with the position of the Yednalue Quartzite immediately below the Skillogalee Dolomite, facilitates lithologic correlation with other similar quartzite-siltstone-dolomite formations.

Southeast of the type section, the Yednalue Quartzite is well displayed around the Yednalue anticline. Here it is composed of two to three main ridge-forming clayey or feldspathic quartzite beds with intervening grey laminated siltstone and dolomite. The quartzites are pale grey or reddish and have a maximum grain size of about 0.8mm. Thickness of the formation varies from about 1,200 to 2,300ft.

In the Carrieton anticline, the Rhynie Sandstone is about 500ft. thick and is composed of feldspathic quartzite with minor grey dolomite and siltstone. To the east, west of Johnburgh, it is about 2,000ft. thick.

West of Yatina, the Rhynie Sandstone is 2,500ft. thick and composed of feldspathic and clayey quartzites, with interbedded grey dolomite, dolomite breccia and siltstone.

Skillogalee Dolomite

The Skillogalee Dolomite (Wilson, 1952, pp. 136-139) only outcrops in the western half of the map area, where it is generally characterized by a lower silty, quartzitic, sequence containing light grey or cream dolomite beds overlain by a more dolomitic sequence containing dark grey dolomite and magnesite conglomerate beds. The formation usually occupies hilly, partly mallee-covered country.

Near Port Germein (Back Creek) Gorge, southwest of Melrose, the lower part of the Skillogalee Dolomite is about 1,000ft. thick and overlies the Rhynie Sandstone. It is composed of grey siltstone and very light grey to cream dolomite with minor darker grey dolomite and quartzite. The overlying sequence comprises about 2,300ft. of dark grey dolomite, brown-weathering pale grey dolomitic arkose, siltstone and pale grey magnesite conglomerate.

South of Booleroo Centre the Skillogalee Dolomite is possibly present in the form of 300ft. of cherty grey dolomite near the core of the anticline.

West of Yatina the formation is represented by pale grey dolomite overlain by darker dolomite and dolomite breccia; thickness is about 450ft.

In the Carrieton anticline there are about 500ft. of grey dolomite, siltstone and quartzite which may be equivalentto the Skillogalee Dolomite.

In the southwestern part of the Quorn anticline there are 800ft. of poorly-outcropping grey dolomite, chert and siltstone, and, near the northwest corner of the map area, about 1,500ft. of dolomite, chert, magnesite conglomerate, siltstone and sandstone, correlated with the Skillogalee Dolomite.

The formation reaches its greatest thickness (about 5,400ft.) in the Yednalue anticline. Here the greatest concentration of magnesite conglomerate beds is present above a prominent central ridge-forming feldspathic quartzite member. Magnesite is also present in the Skillogalee Dolomite in the Oladdie anticline and east of Cradock (described by Spry, 1952). There are old workings in the magnesitic beds 2½ miles northwest of Johnburgh (Segnit, 1940) and in Port Germein Gorge.

Undalya Quartzite

The Undalya Quartzite (Wilson, 1952, p. 140) is recognized as a sandy unit overlying the Skillogalee Dolomite.

In the type section of the Burra Group the Woolshed Flat Shale intervenes between the Skillogalee Dolomite and the Undalya Quartzite, but has not been recognized in the Orroroo region. It is very thin or absent over much of the Burra 1:250,000 area to the south. The Undalya Quartzite is thus present near Port Germein Gorge as 600ft. of interbedded light grey laminated feldspathic sandstone and minor grey siltstone; a similar thickness of possible Undalya Quartzite also occurs south of Boolerco Centre. West of Yatina it contains arkose and minor dolomite and is about 750ft. thick. Near Quorn about 800ft. of coarse- to medium-grained feldspathic quartzites, and in the northwest corner of the map area at least 600ft. of laminated dolomitic and medium- to coarse-grained feldspathic quartzite, are overlain unconformably by tillite and are correlated with the Undalya Quartzite. It is possibly represented by about 30ft. of siltstone and feldspathic quartzite above the Skillogalee Dolomite in the Oladdie anticline, but seems to be generally absent from the central and northeastern part of the map area.

Auburn Dolomite

The Auburn Dolomite (Wilson, 1952, pp. 140-141) is a thick and multifarious sequence containing dark and pale grey partly cherty dolomite, greenish and grey siltstone (sp. 5) and quartzite. It is distinguishable from the overlying dark, fine-grained calcareous siltstones of the Saddleworth Formation by the presence of quartzite and coarse-grained siltstones. However, it has been found difficult to make lithological correlations within this part of the sequence either within the Orroroo region or with the type section of the Auburn Dolomite. Further work may justify a different nomenclature or raising of the Auburn Dolomite to the rank of subgroup. Because of these uncertainties only two new formal units have been named here (Cradock Quartzite and Minburra Quartzite) and these are named as formations rather than as members of the Auburn Dolomite equivalent.

Within the equivalent sequence in part of the Orroroo map area one can draw parallels with the type Auburn Dolomite - there is a lower siltstone-dolomite succession, an intermediate sandy unit probably equivalent to the Watervale Sandstone and an uppermost sandy unit.

The Auburn Dolomite equivalent is well displayed near Cradock in the northern part of the map area and corresponds to Spry's calcareous siltstone (1952, p. 174). Since the Undalya Quartzite has not been recognized in the area, the sequence extends southwest from the top of the Skillogalee Dolomite northwest of "Yednalue". The lower part occupies the bare hills northeast of Cradock, and is composed of interbedded grey laminated fine-grained dolomitic feldspathic quartzite, laminated cross-bedded grey and green-grey siltstone and silty dolomite. Uncertainties of equivalence are illustrated by the fact that B.P. Thomson (personal communication) would correlate most of this silty sequence with the Saddleworth Formation (Thomson in Thomson et al, 1964, p. 18).

About 3½ miles northeast of Cradock, the silty, dolomitic sequence, which is about 6,800ft. thick, is overlain by light grey medium- to coarse-grained laminated feldspathic and clayey quartzite (sp. 3) with interbedded siltstone and silty dolomite. This is named here the Cradock Quartzite after the town of Cradock (lat. 32°4'S., long 138°29'E.) and is about 1,500ft. thick (460 metres). The type section is shown on the map and runs from 3½ to 3 miles northeast of Cradock. It is possibly equivalent to the Watervale Sandstone Member of the Auburn Dolomite.

The Cradock Quartzite is overlain by about 800ft. of grey and green-grey laminated siltstone, grey dolomite, dolomite breccia, sandy dolomite and quartzite. A little northeast of Cradock there succeeds the uppermost unit locally in the Burra Group, a hard, pale grey, medium-grained clayey quartzite about 50ft. thick. This quartzite is depicted on the map with the same symbol as the Minburra Quartzite, defined below, but equivalence is by no means certain.

The upper part of the Auburn Dolomite equivalent is well displayed east and northeast of Orroroo. The Cradock Quartzite outcrops west of "Treehaven" and "Yalpara" and is overlain by grey siltstone and dolomite and then a prominent ridge-forming quartzite (sp. 4) named here the Minburra Quartzite.

The type-section of the Minburra Quartzite, named after "Minburra" (lat. 32°26'S. long. 138°54'E.), is ten miles southwest of "Minburra" on the north side of a track four miles west of "Yalpara". Here it is a hard, siliceous brown-weathering cross-bedded quartzite approximately 100ft. thick. It occurs to the south at Granite Top and east of there, where it is about 100ft. thick. West of Minburra it is about 300ft. thick and overlain and underlain by laminated grey dolomitic siltstone and dolomite. Siltstones are coarse-grained and cross-bedded in part.

The Minburra Quartzite has been tentatively correlated with the uppermost quartzite member of the Auburn Dolomite as mapped on BURRA because of its prominence and because of the general absence of any obviously coarse, sandy siltstone of the Mintaro Shale immediately above or below it. However, it differs from the usual feldspathic, medium-grained quartzite members of the Auburn Dolomite and west of Minburra is overlain by siltstones not greatly unlike those of the Mintaro Shale. It could thus be correlated with the Leasingham Quartzite as depicted on BURRA.

Thin quartzite beds repeated by folding near the centre of the Waukaringa anticline are tentatively correlated with the Minburra Quartzite.

In the anticline east of Oodlawirra the lowermost grey dolomite-siltstone sequence has been named Nackara Dolomite by Mirams (in Thomson et al. 1964, p. 18). Within the silty sequence above this there is a thin siliceous quartzite here correlated with the Minburra Quartzite.

The Booleroo Centre region displays a thick sequence (possibly 9,000ft.) of interbedded feldspathic or clayey quartzite and siltstone probably equivalent to the Cradock Quartzite. This may be seen west of Yandiah and northwest of Booleroo Centre where quartzites extend up to a bed equated with the Minburra Quartzite. Northeast of Booleroo Centre the bed shown as Minburra Quartzite is a pale grey medium-grained, feldspathic quartzite about 30ft. thick which is separated from the underlying Cradock Quartzite by about 4,000ft. of grey laminated siltstone and dolomite. These correlations with the Minburra Quartzite are again uncertain.

West of Yatina there are 450ft. of dark grey cherty dolomite at the base of the Auburn Dolomite equivalent. This is overlain by 1,500ft. of grey laminated siltstone and minor dolomite, then 50ft. of pale grey laminated

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Plate 2 - The Burra Group near Yatina, looking southerly from the main dividing ridge west of Yatina. In the foreground is quartzite, possibly equivalent to the Gilbert Range Quartzite, of the Belair Sub-Group. The base of the Appila Tillite, Umberatana Group, not far above the quartzite, is near the edge of ploughed paddocks, upper right. The next ridge left of centre contains medium-grained feldspathic cross-bedded quartzite with Saddleworth Formation to the right of it and Auburn Dolomite to the left. Wooded hills, upper left, contain the Undalya Quartzite and Rhynie Sandstone, lowermost formation of the Burra Group.

cross-bedded medium-grained feldspathic quartzite. This quartzite (see Fig. 5) is shown as Minburra Quartzite on the map and is the same as a quartzite shown as Leasingham Quartzite on BURRA near Mannanarie. As has been suggested by B.P. Thomson (personal communication) it is more likely that this quartzite is equivalent to the uppermost member of the Auburn Dolomite because of its prominence and composition and because it is not accompanied by sandy siltstone typical of the Mintaro Shale, which normally flanks the Leasingham Quartzite.

Saddleworth Formation

The Saddleworth Formation (Thomson, in Thomson et al. 1964, p. 18) is characterised by dark, fine-grained laminated pyritic slate and calcareous siltstone with minor dolomite and with the absence of quartzite or boldly-outcropping coarse-grained siltstone which are typical of the overlying Mintaro Shale. It thus appears in many areas as an intermediate siltstone-dolomite sequence between the Minburra Quartzite and Mintaro Shale. If one viewed the Minburra Quartzite as a lens, the Saddleworth Formation could be extended down to include at least the upper part of the Auburn Dolomite equivalent in areas where this is appropriately fine-grained. One such area is west of Yatina.

About six miles southeast of "Yalpara" there are very dark grey siltstones reminiscent of a carbonaceous member of the Saddleworth Formation in its type section near Riverton.

A sandstone dyke not shown on ORROROO cuts grey laminated siltstones referred to the Saddleworth Formation just to the northwest of Chewing Knob (northeast of Paratoo R.S.). This dyke is about 1200ft. long and up to 6ft. wide and trends in a northeasterly direction. It ends in or near laminated sandy siltstone about 100ft. below the base of the Appila Tillite.

Belair Sub-Group

This term refers to coarse-grained and sandy siltstone and quartzite of the Mintaro Shale, Gilbert Range Quartzite and lesser quartzites previously referred to the Umberatana Group on BURRA. It is used on ORROROO in anticipation of formal usage later on ADELAIDE (in preparation).

The Mintaro Shale and quartzites possibly equivalent to the Leasingham Quartzite of Mirams (op. cit.) and Gilbert Range Quartzite may be seen underlying the Appila Tillite west of Tarcowie. The Mintaro Shale is a boldly-outcropping grey, laminated, partly dolomitic siltstone which contains a thin, siliceous fine to medium-grained quartzite 800ft. above its base. This is succeeded by brownish-weathering, boldly outcropping coarse siltstone and fine sandstone about 1,500ft. thick. Just below the Appila Tillite are 400ft. of pale grey quartzite possibly equivalent to the Gilbert Range Quartzite. This sequence is progressively eliminated to the north along an angular unconformity at the base of the tillite.

Some other areas where the Mintaro Shale is inferred are east of Nackara, southwest of Carrieton and north of Waukaringa.

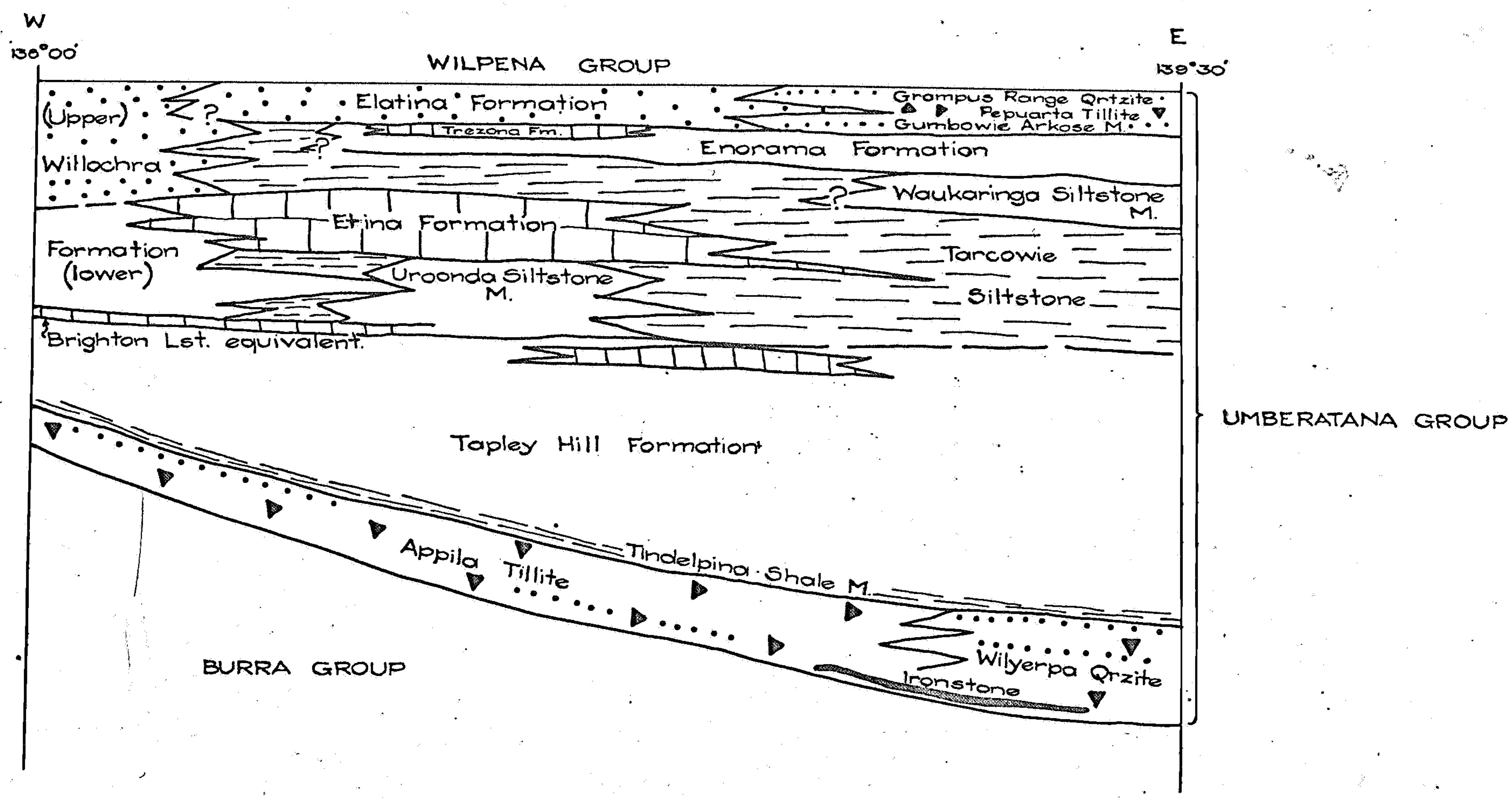
Umberatana Group

The Umberatana Group was defined by Coats (in Thomson et al 1964) in the Mt. Painter area of the Northern Flinders Ranges. The group includes all the glacigene deposits of the Adelaide System thus giving it a unifying lithogenitic significance. In some areas, particularly along the western margin of the Adelaide Geosyncline, definite glacial beds are confined to the basal part of the group,

Coats (op. cit.) pointed out that further mapping was required to clarify the lower limit of the Yudnamutana Sub-Group in the Sturtian type area. Recently Coats (1967) has carried out this mapping and now suggests that in this area the base of the "Lower Glacial Sequence" (Yudnamutana Sub-Group) is best defined by the base of the Sturt Tillite. Thus the base of the Umberatana Group would not coincide with the base of the Sturtian Series.

Coats (in Thomson et al 1964) indicated that in many areas the base of the Umberatana Group is defined by an unconformity with the Burra Group. This situation is common on <u>ORROROO</u> and Forbes (1967a) has suggested that there the base of the Appila Tillite should be taken as the lower limit of the Umberatana Group. This suggestion has been followed on <u>ORROROO</u> assuming an expected redefinition of the Burra Group.

The Umberatana Group on <u>ORROROO</u> consists of up to 12,000ft. of tillites, siltstones and minor dolomites and limestones which outcrop exten-



Vertical Scale approx. 3,000 feet to 1 inch.

FIG. 6

DEPARTMENT OF MINES — SOUTH AUSTRALIA

ORROROO 1:250,000 SHEET
ROCK RELATIONSHIP DIAGRAM
OF UMBERATANA GROUP

Drn. P.B.
Tcd.
Ckd.
Exd.

SCALE: 1" = 3,000 feet.

S 6114

DATE: 12-9-67

sively in the area. Ideally the group consists of tillites of the "lower glacial" (Yudnamutana Sub-Group) separated from tillites of the "upper glacial" (Pepuarta Tillite) by a thick sequence of siltstones. This situation exists in the east of the survey area but in the west no tillites occur above the "lower glacial" and the sequence is generally more clastic. A rock relationship diagram (Fig. 6) of the Umberatana Group illustrates this and shows the complex intertonguing of units in the upper part of the group. The relatively uniform lower part of the group with throughgoing rock units is also apparent on this diagram.

Rock units used in the Umberatana Group on ORROROO were established by Survey geologists on BURRA to the south and PARACHILNA to the north. North-south intertonguing of these units occurs, particularly between the Tarcowie Siltstone and Etina Formation. Two new units, the Uroonda Siltstone Member and the Waukaringa Siltstone Member were established and will be defined in this report. Both are members of the Tarcowie Siltstone.

For descriptive purposes it is proposed to discuss the Umberatana Group under two main headings, the Yudnamutana Sub-Group and the upper Umberatana Group.

Yudnamutana Sub-Group

This sub-group was defined by Goats (op.cit.) to include all the glacigene beds below the Tindelpina Shale Member. In many places on ORROROO this unit lies unconformably on the Burra group thus making an excellent group boundary and, at the same time, a readily mappable boundary. Early Sturtian diapirism with subsequent erosion prior to deposition of the tillite has produced local high angle unconformities, as for example on the flanks of the Yednalue Anticline and the eastern flank of the Carrieton Anticline. Early Sturtian beds were probably not deposited over much of ORROROO, or were deposited and subsequently eroded, though Forbes (1967a and this report) has recognised early Sturtian rocks overlain unconformably by the tillite on the east facing limb of the Pekina Syncline.

Glacial beds of the Yudnamutana Sub-Group are generally between 1000 and 2000ft. thick on ORROROO and probably represent only the upper part of this unit due to transgression onto positive areas. To the northeast and east (Bibli-

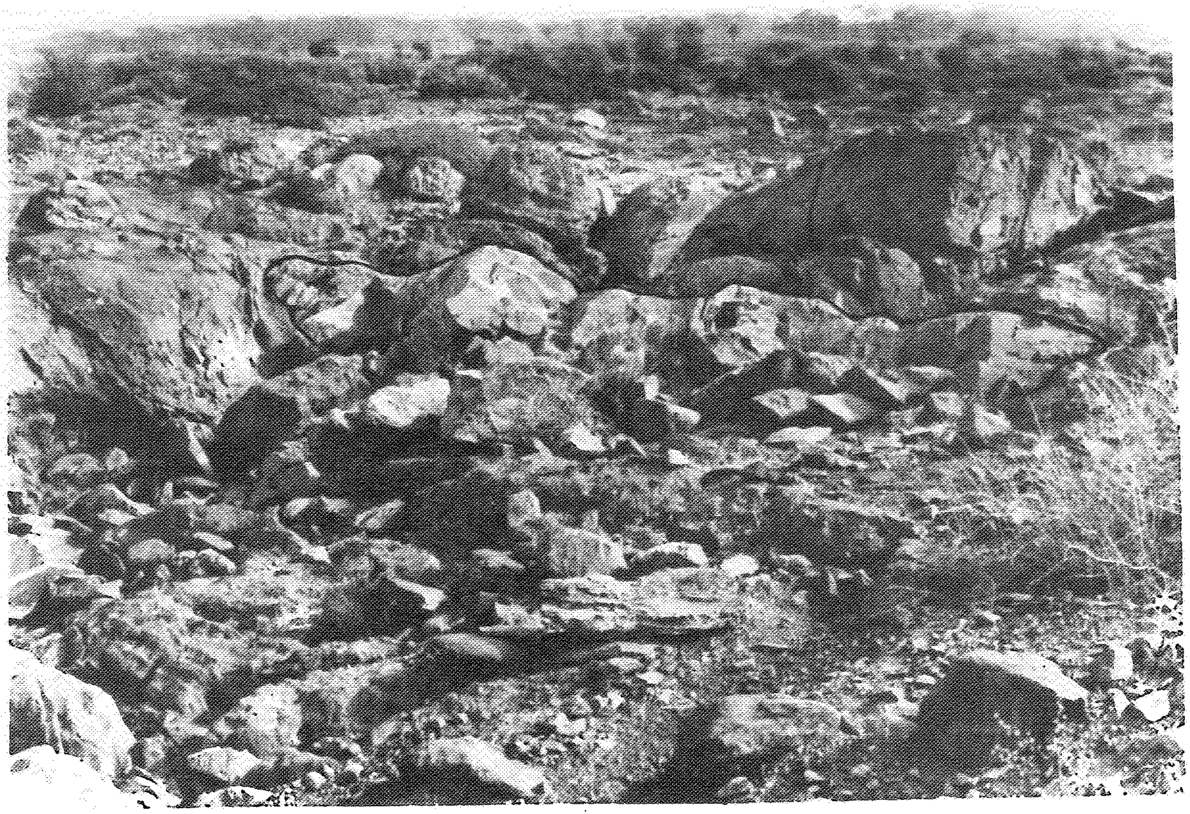


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Plate 3 - Large erratic (outlined) in the Appila Tillite exposed in Hillpara Creek, Orroroo 1:63,360 area. The erratic is 25 feet long and consists of white, fine-grained quartzite.

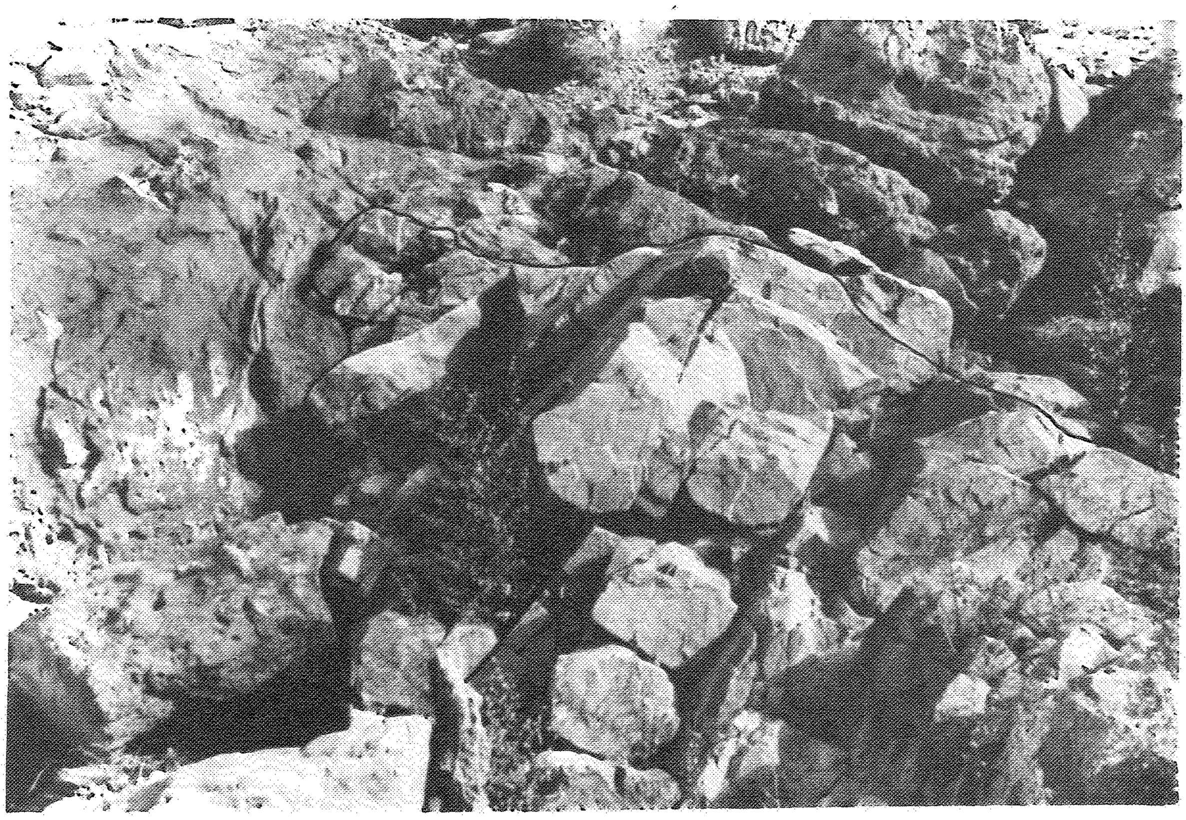

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Plate 4 - Close-up of the quartzite erratic in Hillpara Creek.

ando Dome area and Olary region respectively) the Sub-group rapidly increases in thickness to many thousands of feet and it is suggested that these areas were basins undergoing rapid sedimentation while much of the ORROROO area, especially the north-central areas, were being eroded, presumably by glacial action.

Appila Tillite

This formation was defined by Mirams (in Thomson et al 1964) in Appila Gorge on BURRA and consists of boulder tillite, quartzite and siltstone. On ORROROO it is the only unit differentiated in the Yudnamutana Sub-Group apart from the Wilyerpa Formation which forms limited areas of outcrop in the northeastern corner of the area. The unit has a very varied lithology and many members could be mapped but lack of time made this impossible. However in places a thin ironstone member has been differentiated and prominent quartzites shown.

The Appila Tillite outcrops widely on ORROROO and is usually between 1000 and 2000ft. thick. In the Flinders Range, west of the Willochra Plain, it is only a few hundred feet thick and in places along the flanks of the Yednalue Anticline it is only a few feet thick. This formation usually forms areas of rugged outcrop, often emphasized by more subdued relief developed on the softer siltstones and shales which frequently underlie and overlie it.

The formation generally consists of beds of boulder tillite (sp. 6; sp. 7) separated by lithic sandstone (sp. 8) and siltstones frequently containing erratics. The tillite contains facetted and striated erratics of diverse rock types which are usually cobble sized but often reach 3 to 4ft. in diameter. Very large quartzite erratics, up to 25ft. long by 10ft. high (the third dimension was obscured) and conservatively estimated at 100 tons in weight were found in Hillpara Creek 15 miles northeast of Orroroo (Plates 3 and 4). Rock types of the erratics include quartzite, granite, gneiss, volcanics, porphyry, jaspilite, conglomerate, schist, siltstone and dolomite. Many of these rock types are completely alien to the survey area but are similar to rock types occurring in crystalline basement areas west of the Torrens Lineament and consequently suggest a western provenance for the glacigene deposits. Quartzite erratics are the most abundant, many (including the large erratics in Hillpara Creek) consist of fine-grained white quartzite similar to quartzites in the upper part of the Burra Group.

A thin bed of hematitic siltstone occurs at the base of the Appila Tillite in the nose of the Waukaringa Anticline and on the eastern limb of the Yednalue Anticline. This ironstone unit reaches a maximum thickness of about 200ft. but is very lenticular. Dalgarno and Johnson (in Thomson et al 1964; 1965a) mapped a similar hematitic siltstone (Holowilena Ironstone) in the Yudnamutana Sub-Group on PARACHILNA. The ironstone on ORROROO is tentatively correlated with the Holowilena Ironstone and also with an ironstone in the Olary Region (Campana 1958) and the Braemar Ironstone in the Manunda area (Mirams 1962). In the latter areas the ironstone is underlain by massive boulder tillite thus if the correlation of the ironstones is correct it would indicate that the Appila Tillite is equivalent only to the upper part of the Yudnamutana Sub-Group.

In the central area of ORROROO a fine-grained flaggy siltstone unit occurs at the top of the Appila Tillite. This unit, which reaches 1,400ft. in thickness on the western limb of the Yalpara Anticline is a well-bedded grey siltstone containing no erratics. This siltstone has not been differentiated on ORROROO. The top of the unit is marked by the Tindelpina Shale Member; if this shale were absent the siltstone could easily be confused with the Tapley Hill Formation. The siltstone occurs on limbs of other structures in the central part of the survey area and could well be a useful unit if further mapping is undertaken. It is suggested that the best locality for a type-section would be at Hillpara Creek 14 miles northeast of Orroroo.

Wilyerpa Quartzite

Dalgarno and Johnson (in Thomson et al 1964) defined this formation, which represents Mawson's (1949) interglacial arenites, in the Bibliando Dome area in the southeast of PARACHILNA. This unit occurs only in the extreme northeast of ORROROO in the Orama Range. Here it consists predominantly of well-bedded grey siltstone with interbeds of medium-grained off-white feldspathic sandstone which form prominent ridges. Erratics occur in thin bands interbedded occasionally in the siltstones. Dalgarno and Johnson (1965a, 1960) place the Holowilena Ironstone below the Wilyerpa Formation, thus if the ironstone at the base of the Appila Tillite on ORROROO is correlated with the

Holowilena Ironstone the Appila Tillite would be equivalent to the Wilyerpa Formation.

Upper Umberatana Group

In this report the term upper Umberatana Group refers to the sequence between the base of the Tindelpina Shale Member and the base of the Nuccaleena Formation. Boulder tillite occurs at the top of this sequence in the southeast of the survey area but is not present in the central and western areas. Above the Tapley Hill Formation marked changes in rock types occur from west to east. In the west the sequence is red-brown in colour with grit bands and sandstones; ripple-marks and mud-cracks indicate shallow water conditions. In the east the sequence is green-grey in colour and consists essentially of siltstones. Intertonguing of these beds indicates at least partial contemporaneity and it is suggested that the red-beds in the west are a shallow-water facies of the green, finer-grained beds in the east. This facies relationship in the lower Marinoan was first recognized by Horwitz (1961) who divided a typical east-west section of the area (and other parts of the Adelaide Geosyncline), into three zones: a western zone characterized by purple and green beds with no boulder tillite; an eastern zone characterized by grey beds with boulder tillite and a central passage zone intermediate between the east and west zones. A rock relationship diagram of the Umberatana Group (Fig. 6) illustrates the east-west intertonguing of rock units in the area.

Tapley Hill Formation

This formation was originally established by Howchin (1904) as the "Tapley Hill Slates" in the Adelaide area, subsequently Mawson and Sprigg (1950) defined the formation as "laminated slates, becoming increasingly calcareous above". Coats (in Thomson et al 1964) defined a subsidiary type section in the Northern Flinders Ranges and split off the upper calcareous sequence as a separate formation; the Yankaninna Formation. Recently Coats (1967) has revised the status of this formation and it is now regarded as a member of the Tapley Hill Formation.

The Tapley Hill Formation is a remarkably uniform unit throughout the survey area and consists typically of well-laminated blue-grey, flaggy siltstones (sp. 9; sp. 10). Thickness is usually between 2000 and 4000ft.

though in the Flinders Range west of the Willochra Plain it is only in the order of 500 to 1000ft. The base of the formation is usually marked on ORRORO0 by the black shales of the Tindelpina Shale Member.

Conglomerate bands of reworked erratics occur in the basal part of the formation on the limbs of the Yednalue Anticline. This basal unit may be equivalent to the Serle Conglomerate Member of the Umberatana Group type area (Coats, in Thomson et al 1964). Much difficulty was experienced in differentiating between the tillites of the Yudnamutana Sub-Group and these conglomerates, though the conglomerates are interbedded in dark, well laminated shales typical of the lower part of the Tapley Hill Formation. In places the conglomerate rests directly on the Burra Group and thus, if the interpretation is correct, the tillite has been completely eroded in these localities. Erosion of the tillite with associated accumulation of conglomerate bands was probably due to positive uplift of the Yednalue Diapir.

Bands of conglomerate with associated slump structures occur near the base of the Tapley Hill Formation north of "Yednalue" on the eastern limb of the Worumba Diapir. These conglomerates, which consist essentially of reworked erratics, were first observed by C.R. Dalgarno (pers.comm.) and are taken as evidence of early Sturtian movement of the Worumba Diapir.

Intraformational limestone conglomerate occurs in the Tapley Hill Formation in many areas but is particularly well developed northwest of "Melton" in the Waukaringa Syncline and west of "Milang" in the nose of the Orama Anticline (Plate 5). West of "Milang" sandy limestone with granule size grains is interbedded with the limestone conglomerate and may indicate a period of erosion associated with uplift of the Baratta Diapir situated six miles northwest of this locality.

Tindelpina Shale Member

This unit is the best marker bed on ORROROO and probably the best in the Adelaide Geosyncline. It consists of carbonaceous, pyritic, finely laminated black shales with thin interbeds of buff-weathering dolomite (sp.11; sp.12). The shale grades upwards, over a few hundred feet, into siltstones of the Tapley Formation. It usually forms areas of poor outcrop and low relief next to prominent outcrops of the Appila Tillite.

K7 17624

Plate 5 - Intraformational limestone conglomerate in the Tapley Hill Formation near "Milang", Koonamore 1:63,360 area.

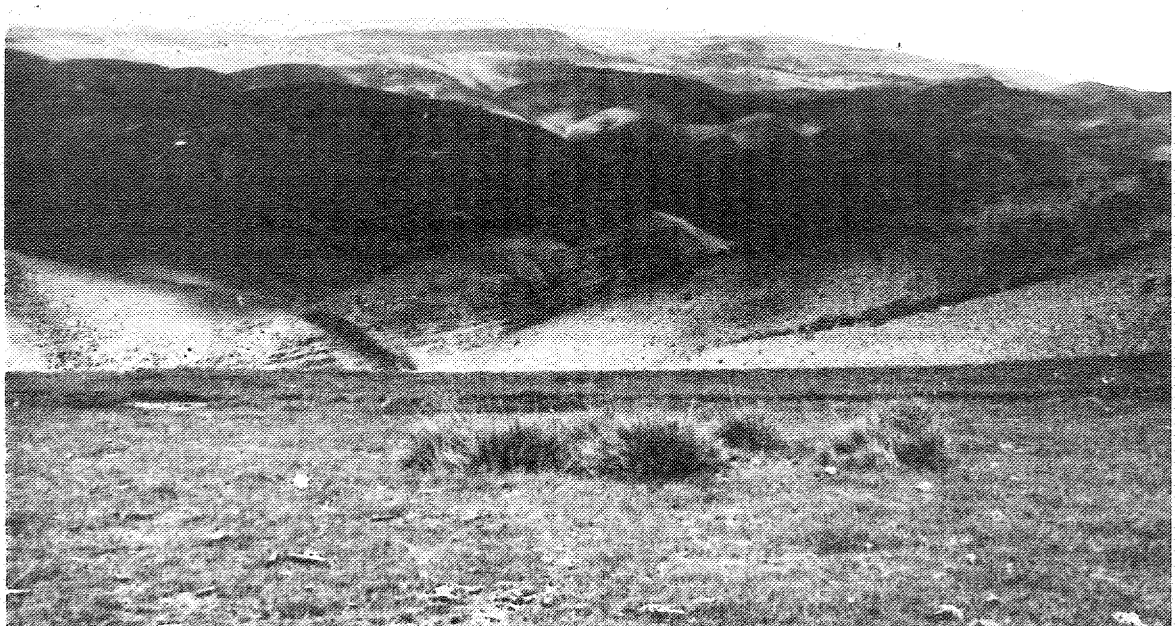

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Plate 6 - View from north of Horrocks Pass looking southeast to Mt. Remarkable (on horizon), Wilmington 1:63,360 area. The Brighton Limestone equivalent overlies the prominently outcropping Yankaninna Member in the foreground. This unit is overlain by the unnamed lower member of the Willochra Formation.

Yankaninna Siltstone Member

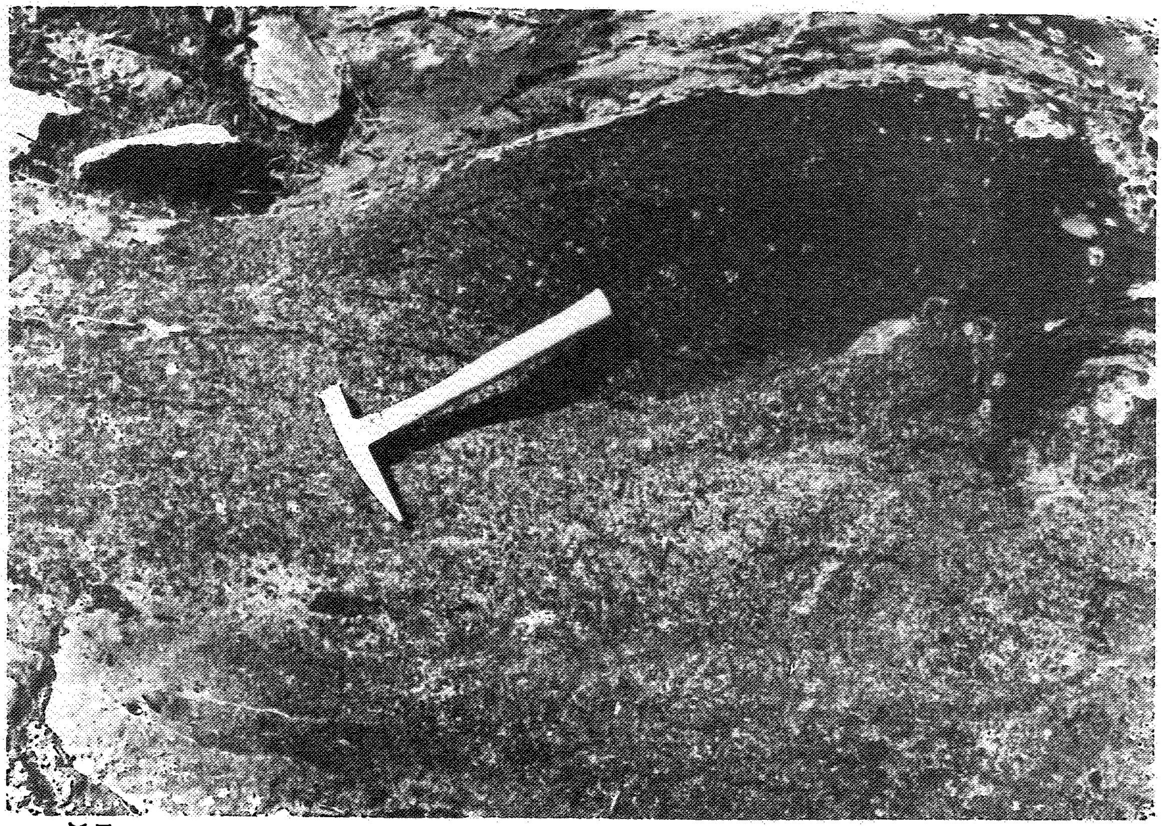
This unit has not been differentiated on ORROROO but has been mapped on the Yednalue 1:63,360 sheet. In its type-section in the Northern Flinders Ranges (Coats in Thomson et al 1964) it consists of well-bedded, calcareous or dolomitic green siltstone. Thin bands of limestone interbedded near the top of the Tapley Hill Formation occur in places on ORROROO and are probably equivalent to the Yankaninna Member. On the Yednalue sheet the Yankaninna Member consists of well-bedded grey siltstones with thin bands of calcareous siltstone and limestone. The unit is not as flaggy as the Tapley Hill Formation and usually forms prominent ridges. This prominent outcrop can be seen on Plate 6 which is a view taken north of Horrocks Pass looking southeast to Mt. Remarkable. The unit has not been mapped in this area.

The Pekina Formation, defined by Mirams (in Thomson et al 1964) near Tarcowie, is in part equivalent to the Yankaninna Member but also includes sandy limestones of the Brighton Limestone equivalent. This unit has not been used on ORROROO.

Brighton Limestone equivalent

This unit consists of grey to pink limestone and dolomite (sp. 13, sp. 14). It often contains Collenia and is frequently sandy. This limestone is essentially confined to the Flinders Range west of the Willochra Plain but also occurs in the north of the Pekina Syncline (Plate 7) and on the western limb of the Yednalue Anticline. The unit is usually between 20 to 100ft. thick but lenses rapidly along strike.

In the Flinders Range the limestone is underlain by the Tapley Hill Formation and overlain by the red beds of the Willochra Formation (Plate 6). This sequence is very similar to the type area of the Brighton Limestone near Adelaide and the limestones are considered to be equivalent. Howchin (1916, 1928) first correlated these units while working in the area in the early part of this century. The top of this unit is taken as the boundary between the Sturtian and Marinoan Series (Mawson and Sprigg 1950) and in this area forms an excellent mapping boundary. However in areas to the east of the Willochra Plain this limestone is usually absent and the overlying beds are green, not unlike the underlying Tapley Hill Formation thus making it practically impossible to locate the Sturtian Marinoan boundary.



J7 17626

Plate 7 - Sandy, cross-bedded limestone of the Brighton Limestone equivalent near Orroroo. Orroroo 1:63,360 area.

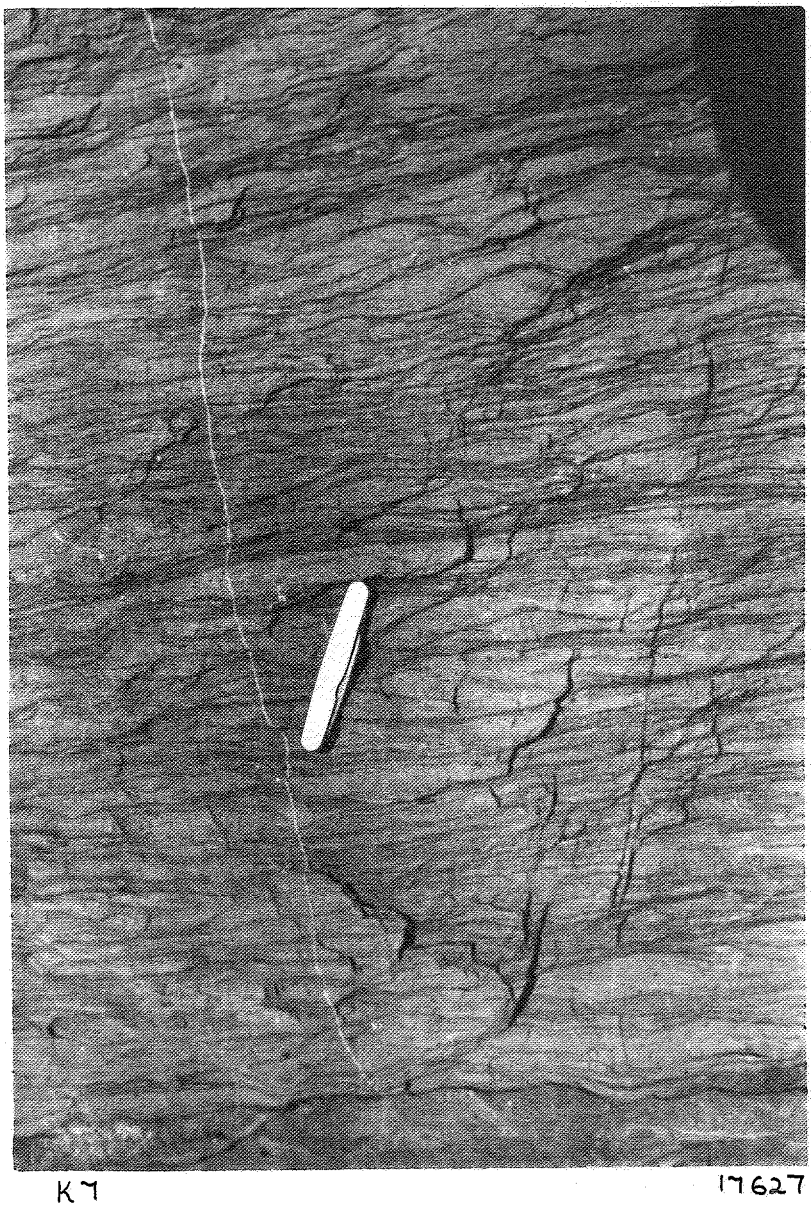


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Plate 8 - Tarcowie Siltstone near Waukaringa, Waukaringa 1:63,360 area. "Wavey" bedding reflects ripple-marked bedding planes.

Willochra Formation

The type-section of this formation is in Willochra Creek in the west of the Willochra 1:63,360 Sheet (Thomson et al 1964) and constitutes units 21 to 23 defined in the area by Mawson (1947). Dalgarno (pers.comm.) suggested that the unit could be divided into two members. This suggestion has been followed and two unnamed members have been mapped on ORROROO. Essentially the formation consists of 2000-4000ft. of red-brown siltstone and sandstone between the top of the Brighton Limestone and the base of the Nuccaleena Formation. These beds form the lower part of Howchin's "purple slates series" (Howchin 1928).

The lower unnamed member of the Willochra Formation consists of flaggy red-brown siltstones with mud-cracked and ripple-marked shale partings (sp. 15; sp. 16). Thin bands (1-3ft.) of sandstone and limestone with sand grains and pink granules are interbedded with the siltstones. This unit, which is between 700 and 1500ft. thick, forms areas of low relief next to the prominently outcropping upper member of the Willochra Formation.

The upper member comprises grey to red-brown sandstones (sp. 17; sp. 18), siltstones and granule limestones. The boundary between this member and the lower unit is gradational and has been shown as an approximate boundary on ORROROO. Limestones with sand and pink granule grains possibly represent intertonguing with the Etina Formation. A massive siltstone near the top of the sequence (possibly equivalent to the Reynella Siltstone Member) is similar to the siltstone occurring in the Elatina Formation. No erratics or other positive evidence supporting glacial origin were found in these beds, though Webb and Horwitz (1959) thought that the larger granules were of glacial origin.

Tarcowie Siltstone

This formation consists of up to 3000ft. of green-grey siltstones and sandy siltstones (sp. 19; sp. 20) lying between the top of the Tapley Hill Formation and the base of the Enorama Formation. Ideally it is banded and has a characteristic "wavy" bedding reflecting ripple-marked bedding planes (the rock usually breaks along cleavage planes). The bands are due to bedding layers of different grain size (Plate 8).

The unit was defined by Mirams (in Thomson et al 1964) near

Tarcowie in the southern part of the Pekina Syncline and was presumed (pers. comm.) to extend to the base of the Gumbowie Arkose Member. Recent mapping has shown that the Enorama Shale occurs throughout the central and eastern parts of ORROROO and the base of this formation is now taken as the upper limit of the Tarcowie Siltstone. Two new units, the Uroonda Siltstone Member and the Waukaringa Siltstone Member, both members of the Tarcowie Siltstone, have been defined (this report) and mapped on ORROROO.

The boundary between the Tapley Hill Formation and Tarcowie Siltstone is gradational and in some areas doubt exists about the position of the boundary due to the similarity of the two units. This problem arises on the southern limb of the Marchant Hill Syncline but in most areas the boundary is readily mappable.

The Tarcowie Siltstone and Uroonda Siltstone Member intertongue with the Willochra and Etina Formations in the central and west-central parts of the survey area. This relationship is shown on Fig. 6. Red-brown flaggy siltstones of the lower member of the Willochra Formation intertongue with the Tarcowie Siltstone on the western limbs of the Horseshoe Syncline and Yednalue Anticline. These red-beds intertongue with the Uroonda Siltstone Member on the limbs of the Uroonda Syncline. Intertonguing of the Tarcowie Siltstone and Etina Formation occurs in the Pekina Syncline and on the limbs of the Horseshoe, Uroonda and Price Hill Synclines.

Uroonda Siltstone Member

Approximately 1,700ft. of green-grey siltstone (sp. 21) outcropping on the flanks of the Uroonda Syncline are here named the Uroonda Siltstone Member of the Tarcowie Siltstone. The name is taken from Uroonda Hill (Lat 32°12' south and Long. 138°28' east) and the type section, which is shown on the published map, starts about ¼ of a mile south of "Slatey Cliff" (Lat. 32°08' south, Long. 138°28' east). The base of the unit is taken at the top of the laminated grey siltstone of the Tapley Hill Formation and the top at the base of the sandy limestone of the Etina Formation.

The siltstone is bedded but outcrop is of a massive nature as the rock does not break along bedding planes like the underlying Tapley Hill Formation. Bands of coarse siltstone, practically a quartzite, are interbedded with the siltstone and in places the unit intertongues with the lower member of the Willochra Formation. The unit thins out rapidly to the south on the limbs of the Horseshoe Syncline and to the east lenses out on the northern limb of the Marchant Hill Syncline.

Waukaringa Siltstone Member

About 1600ft. of well laminated blue-grey siltstones (sp. 22) outcropping in the Waukaringa area are here named the Waukaringa Siltstone Member of the Tarcowie Siltstone. The type section is one mile west of "Old Wabricoola" (Lat. 32°27' south, Long. 139°21' east) and is shown on the published map. The unit is named after the deserted township of Waukaringa (Lat. 32°17' south, Long. 139°27' east). The base of the unit is taken at the top of the "wavey-bedded" sandy siltstone of the Tarcowie Siltstone and the top at the base of the laminated green shales and silty shales of the Enorama Shale.

Thin bands of limestone and calcareous siltstone are interbedded with the unit and are well exposed around Chinaman's Hat and Euro Hill in the keel of the Waukaringa Syncline. This siltstone member is very similar to the flaggy Tapley Hill Formation but is separated from it by the Tarcowie Siltstone. The unit has only been recognised in the Waukaringa Syncline and on the northern limb of the Waroonee Syncline; it probably occurs to the east on the Winnininnie 1:63,360 Sheet.

Etina Formation

This formation, which consists of limestone and shale, was defined by Dalgarno and Johnson (in Thomson et al 1964) in the Central Flinders Ranges. On ORROROO the formation has been restricted to limestone beds and, in general, the unit is much thinner than on PARACHILNA. This thinning is ideally shown in the north of the Price Hill Syncline where the formation is up to 2000 to 3000ft. thick. Further south on the limbs of this syncline the unit thins to less than 200ft. Intertonguing with the Tarcowie Siltstone occurs west of Heaslip Well on the western limb of the Yednalue Anticline and in the north of the Pekina Syncline about 2 miles south of Orroroo township.

This formation is restricted to the central and north-central parts of ORROROO and consists typically of limestones (sp. 23) which are sandy and contain abundant granule grains; oolites are common. Frequently this unit consists of nearly pure dolomite (sp. 24). Sandy limestones in the

Willochra Formation are believed to be tongues of this formation interdigitating with the latter formation.

Enorama Shale

This unit is widespread on ORROROO and occurs in all areas except the Flinders Range west of the Willochra Plain. Generally it is between 500 and 1500ft. thick and consists of green, well laminated calcareous shale and silty shale (sp. 25). This formation was defined in the Central Flinders Ranges (Dalgarno and Johnson in Thomson et al 1964) where it is 1200 to 1400 ft. thick.

Thin limestone bands, frequently containing red shale flake fragments are interbedded near the top of the unit in the north of the Price Hill Syncline. These limestones are very similar to the Trezona Formation and probably represent intertonguing between the formations. In the southeastern part of the survey area the formation is generally more silty and less calcareous than in the north central and central areas.

Trezona Formation

This formation only occurs on the limbs of the Marchant Hill Syncline and on the western limb of the Uroonda Hill Syncline. The unit is very lenticular on the flanks of the former syncline, thinning from a maximum thickness of almost 800ft. southwest of "Milang" to a few feet in Buckalowie Creek. Typically the formation consists of grey limestone with fragments of red-brown shale forming "hieroglyphic limestone". In the type-section in the Central Flinders Ranges (Dalgarno and Johnson in Thomson et al 1964) grey shales are interbedded in the limestone; these shales are not present in the unit on ORROROO.

Elatina Formation

The Elatina Formation was defined by Dalgarno and Johnson (in Thomson et al 1964) in the Central Flinders Ranges as a "pink pebbly sandstone with local glacigene lenses". In a later paper these authors (Dalgarno and Johnson 1964) described striated and facetted cobbles and pebbles embedded in a reddish mudstone in Brachina Creek. Previously Mawson (1949) had identified glacial features at this horizon in the Central Flinders. On ORROROO no evidence of glacial origin was found in this unit though a mudstone with small granules is interbedded with the sandstone in most places. This mudstone may be equivalent to the Reynella Siltstone Member described by Thomson (1966) in the Adelaide area.

The Elatina Formation outcrops extensively in the north-central and central parts of the survey area and is usually between 500 and 800ft. thick. It consists of cross-bedded, red-brown feldspathic sandstone (sp.26) with interbeds of red-brown massive siltstone. Granule grains up to 2 to 4mm. are common. The formation usually forms areas of prominent relief accentuated by the subdued relief of the underlying Enorama Formation.

Pepuarta Tillite

This tillitic unit is confined to the southeastern part of the survey area east of a line between Peterborough and Waukaringa. Unfortunately no direct relationship can be established between this unit and the Elatina Formation as this part of the column has been eroded in the critical zone between the Marchant Hill Syncline where the Elatina Formation outcrops and the Waroonee and Dawson Syncline where the Pepuarta Tillite outcrops. However as the Enorama Shale underlies both the Elatina Formation and the Pepuarta Tillite and as the Nuccaleena Formation and Ulupa Siltstone overlie both formations they are equated with some confidence. Jack (1913) first recognised this tillite in the Mt. Grainger area in the early part of this century.

Mirams (in Thomson et al 1964) established the type section of this unit at Pepuarta Bluff on OLARY. Here the formation is 5000ft. thick and consists principally of feldspathic sandstone and shale. On ORROROO the unit is generally between 400 and 600ft. thick and consists of massive, grey siltstone (sp. 27) and greywacke containing erratics. These erratics reach 8ft. in diameter and some show facetting and striations. In places erratics are sparse, particularly on the flanks of the Dawson Syncline, but in general are readily found. Good exposure of this tillite occurs immediately east of The Cone about 4 miles north-northeast of Nantabibbie Railway Siding and 5 miles north-northeast of Chewing Knob on the southern limb of the Waroonee Syncline.

Gumbowie Arkose Member

Mirams (in Thomson et al 1964) established this unit in the southern part of ORROROO as a member of the Pepuarta Tillite (pers. comm.). The unit usually consists of coarse-grained feldspathic sandstone (sp. 28) between 150 and 300ft. thick. Small erratics have been found in shales interbedded with thin bands of arkose near the base of this member on the northern limb of the Waroonee Syncline. The base of the "upper glacial" sequence is placed immediately beneath these erratics. This unit thins out to the south along the western limb of the Uroonda Syncline and the Pepuarta Tillite lies directly on the Enorama Formation.

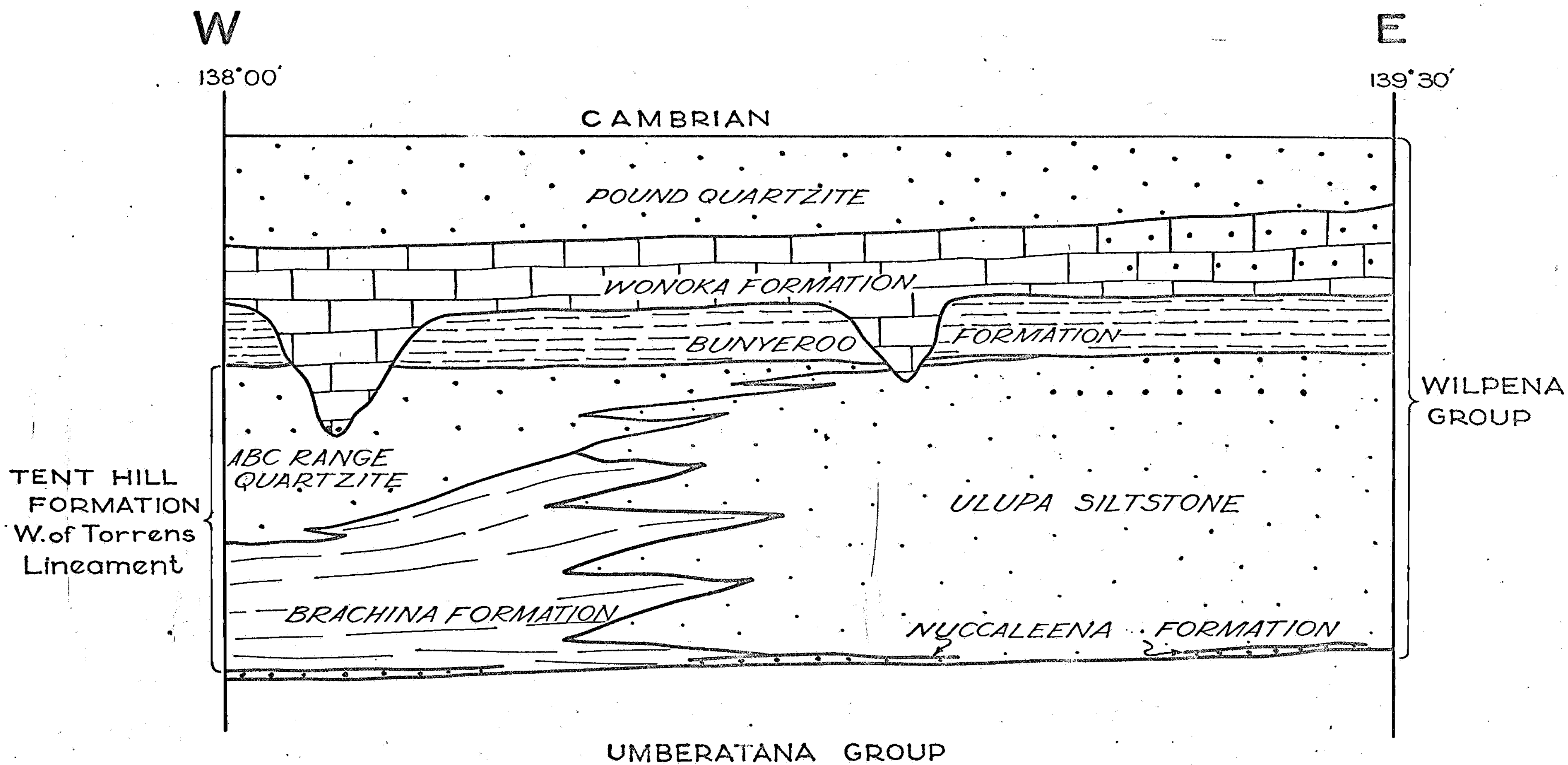
Grampus Quartzite

This formation was defined by Mirams (in Thomson et al 1964) in the Grampus Range as a "silicifial angular quartz sandstone". On ORROROO however it is a complex unit consisting of medium grained, grey to brown quartzite (sp. 29), grey siltstone with occasional erratics, off-white arkose and minor thin dolomite bands. On the published map the formation symbol has been confined to the prominent quartzite within the unit.

The quartzite in the formation is resistant to weathering and forms prominent ridges in the southeast of the area, particularly along the flanks of the Ulupa Syncline.

Wilpena Group

This group consists of up to 10,000ft. of siltstones, shales, quartzites and minor limestones. Dalgarno and Johnson (in Thomson et al 1964) subdivided the Wilpena Group on PARACHILNA into the following ascending formations:- Nuccaleena Formation; Brachina Formation; A.B.C. Range Quartzite; Bunyeroo Formation; Wonoka Formation and Pound Quartzite. All these formations have been recognised and mapped on ORROROO. In addition a green siltstone unit, the Ulupa Siltstone, established on BURRA by Mirams (in Thomson et al 1964) has been differentiated in the central and south-eastern area. This formation is believed to be equivalent to the Brachina Formation and is differentiated by colour and lithology from the characteristically red-brown and finer grained Brachina Formation. Apart from the Waroonee Syncline region in the east outcrop of upper units of the Wilpena Group is confined to the central and northwestern parts of the survey area. The ABC Range Quartzite thins out rapidly to the east from a maximum of about 2000ft. in western areas. A rock relationship diagram of the Wilpena Group is shown on Fig. 7a.



VERTICAL SCALE: 2,000 ft to 1 in.

FIG. 7a

DEPARTMENT OF MINES — SOUTH AUSTRALIA

ROCK RELATIONSHIP DIAGRAM OF WILPENA GROUP — ORROROO 1:250,000 SHEET

Drn. P.B.
Tcd. G.M.
Ckd. L.W.
Exd.

SCALE: 2000 ft. to 1 inch

S5953

fef+hj

DATE: 17.7.67

Nuccaleena Formation

This formation was established by Dalgarno (in Thomson et al 1964) on COPLEY and consists typically of a cream, well bedded dolomite overlain by purple shales with occasional dolomite bands. The unit is remarkably widespread on PARACHILNA and COPLEY and forms an excellent marker horizon and good base to the Wilpena Group. On ORROROO however the formation thins out and in many places is missing. It is usually present in the western areas and occurs sporadically over the rest of the area. On the published map the overprint has been restricted to areas where the characteristic basal cream dolomite outcrops. Purple shales of the formation occur in areas where the dolomite is absent, as for example on the northwestern limb of the Marchant Hill Syncline. In these areas the formation has not been differentiated.

The Nuccaleena Formation is particularly important in the west of the area where, in its absence, it would be practically impossible to locate the base of the Wilpena Group due to the similarity of the lower part of the Brachina Formation to the underlying Willochra Formation. The Nuccaleena Formation has not been found on the eastern limb of the Alligator Syncline. Here the base of the Wilpena Group has been placed below sandstones in the lower part of the Brachina Formation, at a presumed similar horizon to that at which the Nuccaleena Formation occurs on the western limb.

Generally the characteristic basal dolomite of the Nuccaleena Formation varies between 2 to 20ft. on ORROROO, though it has been differentiated in places (Buckalowie Creek area, and north of Mt. Grainger) where it is less than a foot thick. The dolomite rock of the Nuccaleena Formation consists of over 90% of the mineral dolomite (sp. 30; sp. 31).

Brachina Formation - Ulupa Siltstone

The Brachina Formation is confined to the west and northwest of the survey area and consists typically of well bedded, red-brown, ripple-marked siltstones (sp. 32). Thickness of the unit is in the order of 1,200ft. in the Flinders Range west of the Willochra Basin. The bottom few hundred feet consist of fine-grained, thick-bedded to massive, red-brown sandstone (sp. 33) very similar to sandstones in the underlying unnamed upper member of the Willochra Formation. This sandstone is apparently the equivalent of the

Seacliff Sandstone Member near Adelaide and the Whyalla Sandstone Member (Thomson and Johnson 1968) of the Tent Hill Formation of the western shelf area.

The Brachina Formation forms an area of subdued relief between the boldly outcropping Willochra Formation and the very prominent outcrop of the ABC Range Quartzite. This characteristic topographic expression of the formation is ideally developed immediately west of Buckaringa Gorge and Warren Gorge where a valley, flanked by a steep ridge of ABC Range Quartzite to the east and by hills of the Willochra Formation to the west, has been cut in the comparatively soft siltstones of this formation.

East of the Willochra Plain red siltstones of the Brachina Formation give way to grey-green, slightly coarser siltstones of the Ulupa Siltstone. Intertonguing of the red, flaggy siltstones of the Brachina Formation with the grey-green siltstones of the Ulupa Siltstone occurs on the flanks of the Uroonda and Horseshoe Synclines. No attempt has been made to show this intertonguing on the published map and siltstones in these areas are shown as the Brachina Formation as they are predominantly red-brown in colour. As the Ulupa Siltstone occurs between the same units as the Brachina Formation (i.e. Nuccaleena Formation and ABC Range Quartzite) and as it intertongues with this formation it is considered to be equivalent to it. Further, as the Ulupa Siltstone does not have shallow-water characteristics (sun-cracks, ripple-marks) it is considered to be an eastern, deeper water facies of the Brachina Formation.

The Ulupa Siltstone forms extensive areas of outcrop in the central and southeastern parts of the survey area. Typically it weathers to give a red soil supporting few trees and forms bold hills. Thickness varies between 4,000 and 5,000ft., though a marked thinning occurs on the northwestern limb of the Paratoo Anticline, possibly due to contemporaneous movement of the Paratoo Diapir. Grey-green siltstones are the dominant rock type (sp. 34; sp. 35) but fine-grained sandstones are common, particularly in the upper part of the formation. Thin, off-white sandstones interbedded with siltstones are very common in the upper part of the Ulupa Siltstone in the Dawson Syncline and may, in part, be equivalent to the ABC Quartzite (see next section).

Quartz is the dominant mineral of the siltstones (over 70%) but phyllosilicates (biotite, chlorite, muscovite, sericite) usually make up over 10% of the rock; Plagioclase feldspar is usually less than 2%.

ABC Range Quartzite

This formation is a white orthoquartzite consisting usually of over 95% quartz with little feldspar and clay minerals (sp. 36; sp. 37). Thickness west of the Willcohra Basin is between 2,000 and 2,500ft. but to the east it thins rapidly to 600ft. on the flanks of the Horseshoe Range Syncline and to a few feet thick further east. The quartzite is absent on the flanks of the Waroonee and Ulupa Synclines. Around the Price Hill Syncline grey-green siltstones, similar to the Ulupa Siltstones are interbedded with the quartzite; these siltstones have been included within the ABC Range Quartzite on the published map due to the difficulty of showing the relationship at this scale. Thin bands of white quartzite are interbedded near the top of the Ulupa Siltstone on the limbs of the Marchant Hill and Dawson Synclines and probably represent intertonguing of the ABC Range Quartzite with the Ulupa Siltstone.

Intertonguing of the Brachina Formation and ABC Range Quartzite with the Ulupa Siltstone suggest that the latter formation may be equivalent to both these formations. Fig. 7 illustrates this relationship; thicknesses are shown approximately to scale on this diagram and it is apparent that the combined thickness of the Brachina Formation and ABC Range Quartzite is equal to the thickness of the Ulupa Siltstone. To the west (west of the Torrens Lineament) the Brachina Formation and ABC Range Quartzite have been correlated with the Tent Hill Formation by Coats (1965a).

The ABC Range Quartzite is very resistant to weathering and forms prominent ridges and cuestas, particularly in the northwest of the survey area where dips are steep and the quartzite frequently forms vertical outcrops, as for example in Warren Gorge and Buckaringa Gorge (Plate 1). The quartzite forms the ridge encircling the "pound" of the Horseshoe Range Syncline and forms the landmark of Moockra Tower, visible on the skyline west of Carrieton. Extensive outcrop of the quartzite occurs in the keel of the Alligator Syncline, where flat dips and steeply incised creeks provide excellent exposures.

Bunyeroo Formation

The prominently outcropping ABC Range Quartzite is overlain by the shales of the Bunyeroo Formation which give rise to subdued topography with poor outcrop. In the east of the survey area the Bunyeroo Formation rests directly on the Ulupa Siltstone (see Fig. 7). The formation is widespread and quite constant both in thickness and lithology and forms a readily recognisable mapping unit. Thickness of the formation is usually between 500 and 1000ft. It consists predominantly of red-brown to purple, well-laminated shales. Quartz, with a grain size less than 0.01mm, is the dominant mineral (over 60%) followed by phyllosilicates (chlorite and sericite) and feldspar (around 2%); varying amounts of hematite (4% to 18%) produce the red-brown colour (sp. 38; sp. 39).

In the keel of the Marchant Hill Syncline, where the Bunyeroo Formation outcrops extensively, green shales are interbedded with the red-brown shales. In the eastern part of this structure two bands of green shale are interbedded near the base of the formation. The lower band, approximately 50ft. thick, forms the basal member of the formation and rests directly on the Ulupa Siltstone, 30ft. of purple shale separate this band from the other green shale which is approximately 250ft. thick. Similar green shale units are found to the west in the same structure.

Wonoka Formation

This formation does not outcrop extensively on ORROROO as, together with higher units in the column, it has been eroded from most part of the area. Outcrop is confined to synclinal areas in the northwest and to the keel of the Waroonee Syncline in the east-central area. However, outcrops of this formation occur out of stratigraphic sequence in the keels of Mt. Brown, White Valley and Ulupa Synclines.

In the northwest the Wonoka Formation consists of flaggy, calcareous shales and dolomitic limestones (sp. 40) forming subdued outcrops beneath the Pound Quartzite. On the flanks of the Waroonee Syncline typical flaggy, calcareous shales and limestones of the Wonoka Formation (sp. 41) outcrop, but unusually two bands (approximately 50ft. thick) of white quartzite (sp. 42) are interbedded with the carbonates near the top of the formation. These sandstone units form readily mappable members of the Wonoka Formation in this structure. They have been differentiated on the map but have not been named.

The Wonoka Formation rests with strong unconformity on the Bunyeroo Formation, ABC Range Quartzite and Ulupa Siltstone in the keel of the White Valley Syncline, northeast of Carrieton. Breccia bands interbedded with the calcareous siltstones of the Wonoka Formation occur at the base and at higher levels in the formation. The breccia consists predominantly of subrounded fragments of green siltstone and limestone set in a matrix of calcareous siltstone. It is suggested that slumping removed the Bunyeroo Formation, ABC Range Quartzite, and upper part of the Ulupa Siltstone prior to deposition of the Wonoka Formation. This mechanism was suggested by Coats (1964) to explain similar relationships at Patsy Springs in the Northern Flinders (Angepena 1:63,360 Sheet). The breccia bands interbedded in the Wonoka Formation were probably formed by contemporaneous slumping.

The Wonoka Formation rests unconformably on underlying units in the Mt. Brown Syncline and Ulupa Syncline. Both unconformities are believed to have been formed by slumping prior to deposition of the Wonoka Formation. In the Mt. Brown structure calcareous siltstones and limestones of the Wonoka Formation lie unconformably on the Bunyeroo Formation and ABC Range Quartzite in the south of the syncline. No breccias have been found within the Wonoka Formation in this structure. Almost a mile to the west of this area the Wonoka Formation occurs in another slump structure which has cut through the Bunyeroo Formation and upper part of the ABC Range Quartzite. An axial plane fault has eliminated the eastern limb of the syncline in which this slump structure occurs. Contemporaneous slumping is indicated by breccias interbedded in the Wonoka Formation. Fragments of the Bunyeroo Formation occur in these breccias. The Wonoka Formation rests unconformably on the Ulupa Siltstone in the eastern part of the Ulupa Syncline but no breccia bands have been found in this area.

Pound Quartzite

Outcrop of this formation is confined to the northwest of the survey area and to the Wareenee Range. Like the ABC Range Quartzite it dominates the topography in the northwest with imposing ranges; in the east it forms the prominent hills of the Waroonee Range. The Pound Quartzite can be divided into two units: a lower predominantly red coloured sandstone and an upper white quartzite. These units have not been differentiated on ORROROO. In the northwest the formation varies between 1000 and 3000ft. in thickness while in the Waroonee Syncline it is approximately 800ft. thick. In this latter area the top of this formation and overlying units have been eroded, consequently total thickness is not known.

In the northwest the upper part of the Pound Quartzite is a white orthoquartzite consisting of over 90% well rounded quartz grains with interstitial specks of clay minerals, possibly after feldspar. Accessory grains of tourmaline occur (sp. 43). The lower part consists of a red arkose with 70% sub-angular quartz grains and 25% feldspar (sp. 44). The upper part of the Pound Quartzite in the Waroonee Range is a feldspathic sandstone with about 10% feldspar and 80% rounded to sub-rounded quartz grains. Accessory minerals include tourmaline and zircon (sp. 45). The lower part of the formation in this area is quite different from that in the northwest, here it is a well-bedded, dark-grey to red-grey siltstone consisting of 85% quartz with a little feldspar (2%) and phyllosilicates (chlorite and muscovite). No fossils have been found in the Pound Quartzite on ORROROO.

([illegible]).

Cambrian System

Only rocks of the Lower Cambrian Series are present on ORROROO. These rocks are confined entirely to the northwest of the survey area and only outcrop on the Willochra 1:63,360 Sheet. Howchin (1925) proposed the term "Wilson Series" for Cambrian beds exposed near Wilson but did not define this series. Later work by Dalgarno and Johnson (Dalgarno 1964) invalidated the sequence established by Howchin. Daily (1956), with members of the Geology Department, University of Adelaide, found Cambrian rocks 18 miles north of Quorn. Daily proposed the informal name "Yarrah Beds" for these Cambrian rocks, which contained fossils characteristic of his faunal assemblages 1, 2 and 4 (archaeocyathids in 1; brachipods *Kutorgina peculiaris* (Tate), and *"Micromitra (Paterina)" etheridgei* (Tate) in 2; trilobites of *Pararaia*-like forms in 4). In this paper Daily tentatively included the underlying "Pound Sandstone" in the Cambrian.

Dalgarno (op. cit.) included formations established in the Lower Cambrian in the Lake Frome area by Daily (op.cit.) and two new formations in the Hawker Group. This group is suggested by Dalgarno to represent a phase of marine transgression following the deltaic and shallow marine conditions in which the Pound Quartzite was deposited.

Webb and Von der Borch (1962) mapped the Cambrian rocks in the Wilson and "Yarrah" areas on the Willochra 1:63,360 Sheet and established rock units (unnamed) which they recognised in both areas. In the Wilson area these units are coextensive with formations in the Hawker Group mapped on PARACHILNA by Dalgarno and Johnson (1966). These formations have been extended onto ORROROO in the Wilson area; they have also been used in the "Yarrah" area on the basis of Webb and Von der Borch's mapping. Formations of the Hawker Group mapped on ORROROO include, from the base up: Parachilna Formation, Wilkawillina Limestone, Parara Limestone and Oraparinna Shale.

Parachilna Formation

This, the lowest unit in the Hawker Group, rests with structural conformity on the Pound Quartzite. The lower part of the formation consists of white argillaceous sandstones and siltstones and is overlain by sandy and oolitic limestones and grey algal limestones. Vertical burrows are found typically in the lower part of this unit but poor outcrop of this horizon makes it difficult to find these burrows on ORROROO. The Parachilna Formation and overlying units are not present in the Waroonee Range in the east of the survey area, thus indicating probable erosion of the upper part of the Pound Quartzite in this area.

Wilkawillina Limestone

On PARACHILNA Dalgarno included in this unit the Lower Cambrian limestones stratigraphically below the Parara Limestone or beds representing continued deposition of the thick-bedded *Archaeocyatha* limestone. Following this outline the Wilkawillina Limestone on ORROROO consists of massive grey limestone (sp. 46), between 500 and 1000ft. thick, containing *Archaeocyatha*. The limestone is almost pure, consisting of over 95% $CaCO_3$.

Parara Limestone

On ORROROO this unit comprises thin limestone bands interbedded with dark-green shales. The limestone bands, like the Wilkawillina limestone are remarkably pure with about 98% $CaCO_3$ (sp. 47).

Oraparinna Shale

This formation consists of laminated, grey-green shales with thin interbeds of limestone. The shales are frequently calcareous and silty (sp. 48). The formation outcrops extensively in the Kanyaka Valley where it is between 500 and 1000ft. thick.

Triassic System

Triassic beds in the northwest of ORROROO are preserved in two small structural basins in the east of the Willochra 1:63,360 Sheet. The largest basin, the Springfield Basin, is about 3½ sq.mls. in area and is situated approximately 5 miles southwest of Cradock. About 9 miles south-southwest of this basin is situated the smaller Boolcunda Basin. Coal was found in the Boolcunda area in 1956 while drilling for water, but at the time was thought to be a lignite of Tertiary age. Later palynological examination by Balme (Univ. of W. Australia) in 1957 proved the sediments of the Boolcunda Basin to be of Triassic age; subsequently Von der Borch (1958) mapped the area and prepared a report.

The Springfield Triassic deposits were discovered in 1957 by students of the University of Adelaide mapping under the direction of Kleeman. The possible Triassic age was suggested by leaf impressions and Kleeman informed the Department of Mines of their possible similarity to coal bearing strata at Leigh Creek. Johnson and Von der Borch (Johnson 1960) mapped the area and supervised a drilling programme to test for economic coal during 1958 and 1959. Coal deposits in both basins proved to be uneconomic and no further work has been carried out in either basin. The following notes on the geology of the basins have been taken from the work of Johnson and Von der Borch.

The deposits are believed to have been formed in intermontane basins, possibly similar to the present nearby intermontane valleys of the Willochra and Walloway Basins. The presence of fresh-water lakes in the Triassic basins is indicated by fresh-water molluscs in the upper beds of the Springfield Basin.

Deposits are similar to Triassic rocks at Leigh Creek some 130 miles to the north. Preservation of these deposits is believed by Johnson (op. cit.) to be due to a combination of post Triassic faulting and folding. Folding of the Springfield Basin along a northeast trending synclinal axis (this axis is parallel to earlier Lower Palaeozoic folding in the area) has produced dips of up to 25 degrees near the centre of the basin.

The sediments rest unconformably on the underlying Proterozoic Adelaide System. In the Springfield Basin, Triassic rocks rest on diapiric Callanna Beds, the Yudnamutana Sub-Group and the Tapley Hill Formation. Deposits of the Springfield Basin are between 1100 and 2800ft. thick and consist of conglomerates, sandstones, argillites and coal measures. Along the eastern and southeastern parts of the basin the lowest unit of the Triassic consists of grey to yellow shales and argillites with carbonaceous bands. Conglomerates with interbedded grey and purple arkosic sandstones and soft red argillite overlie the basal shales. Boulders in the conglomerate consist principally of quartzite; cut and fill structures and strong current bedding occurs in this unit. Red argillite and sandstones overlie the conglomerate; these are in turn overlain by coal measures which have been divided into upper and lower series, separated by fine grained sandstone. The coal measures contain a number of impure coal seams. The top unit is an argillite containing abundant leaf impressions and casts of fresh-water molluscs. This unit has been baked by burning coal seams to a pink porcellanite (Johnson and Bucknell 1959). Johnson discusses the environment of deposition of these Triassic beds at some length in his report on the Springfield Basin (Johnson op. cit.).

Triassic deposits in the Boolcunda Basin reach a maximum thickness in the order of 1000ft. A basal conglomerate occurs in the southern part of the basin; in other areas basal beds consist of sandstone and shale. Overlying the basal beds is a carbonaceous shale-coal sequence which is in turn overlain by gypsiferous clays and siltstones forming the youngest beds of the basin.

Fossil fresh-water mollusca which were found in the upper unit of the Triassic beds in the Springfield Basin by Johnson and Von der Borch were described by Ludbrook (Ludbrook in Johnson 1960) as species of Unio and Protovirgus. Impressions of plant remains are common in this upper unit; "Thinnfeldia" feistmanteli, redescribed by Townrow as Dicroidium feistmanteli is the commonest. In a later paper Ludbrook (1960) described two new species (Unio springfieldensis and Protovirgus jaeenschi) and redescribed another species (Unio eyrensis) of fresh-water mollusca of the family Unionidae occurring in the Springfield and Leigh Creek Basins.

Spores and pollen grains from impure coal seams in the Springfield Basin were examined by B.E. Balme in 1957. Genera represented include Pityosporites sp., Entylissa sp., Acanthotriletes and Microreticulatisporites n.sp. This microflora indicates a Middle or Upper Triassic age and shows affinities with the microflora of the Leigh Creek coal.

Tertiary

Outcrop of Tertiary rocks on ORROROO is extremely limited and practically confined to a few areas of silcreted and ferricreted sands and conglomerates. However lacustrine sediments of this age occur at depth in the Willochra and Walloway Basins. These sediments were intersected in three stratigraphical bores drilled in the Willochra Basin by the Department of Mines (O'Driscoll 1956). The sediments consist of sandy silts and silty clays. Lignitic sands containing Nothofagus pollen dated as post Eocene but pre-Pliocene (ibid. O'Driscoll 1956) occur near the bottom of Stratigraphical Test Bore No. 3 (between 486 and 502ft.). Pollen and spores from between 78 and 88ft. and 96 and 101ft. in Stratigraphical Test Bore No. 2 were dated by Harris (1966) as middle-upper Eocene.

Small areas of ferruginised and silicified white sands and silts were mapped around the northern margins of the Willochra Basin by Webb and Von der Borch (1962) and shown on the Willochra 1:63,360 Sheet. Later Twidale (1966) named these marginal Tertiary sediments the Langwarren Formation and tentatively correlated them with the Tertiary sediments at depth in the Basin. The Langwarren Formation has not been used on ORROROO as it is not a valid rock unit as no type-section was nominated and it includes several diverse rock types.

Southeast of Quorn and northeast of Bruce flat-lying silcreted gravel and boulder beds mantle Adelaide System rocks (Plate 9). These beds have been tentatively assigned to the Tertiary as they occur higher (topographically) than calcreted gravel beds, thought to be of Pleistocene age, which occur immediately northeast of Bruce. The silcrete horizons of these gravel beds are possibly of Plio-Pleistocene age and may be equivalent to the Boston Bay Silcrete (Firman 1967).

A small isolated butte (about 100 yards in diameter) of silcreted conglomerate occurs about 2 miles northeast of the Two Sisters in the northeast of the Orroroo 1:63,360 area. The butte is about 50ft. high and rises prominently above the flat, alluviated plain of the Nackara drainage system. This silcreted conglomerate is believed to be a remnant of a once extensive Tertiary surface. Sheets of calcreted gravels, probably of Pleistocene age occur at a lower level (topographic) than the silcreted gravels in the Nackara Plain and probably, in part, consist of reworked Tertiary gravels.

Remnants of ferruginous laterite, coextensive with similar deposits mapped by Mirams (1960, 1962) on the Manunda 1:63,360 area, occur in the southeastern corner of the Nackara 1:63,360 area. The laterites are probably remnants of a more extensive laterite which covered the present flood plains associated with the Manunda Creek.

Quaternary

Pleistocene

Calcreted gravels overlying mottled clays are widespread around the margins of the Willochra Plain and in the eastern areas of ORROROO. Both units are believed to be of Pleistocene age. Firman, (1967) has described two units in the Northern Flinders Ranges, the Telford Gravel and the Avondale Clay, which are similar to the gravels and clays on ORROROO. These names have been used on ORROROO. At a scale of 1:250,000 it was only possible to portray the Telford Gravel, the Avondale Clay being usually exposed in creek banks under the gravel capping. This situation is ideally shown in the southern bank of the Siccus River about 2 miles north of "Milang" on the Koonamore 1:63,360 area. Here grey clays at least 15ft. thick (the base is not exposed) are overlain by about 10-20ft. of calcreted gravels.

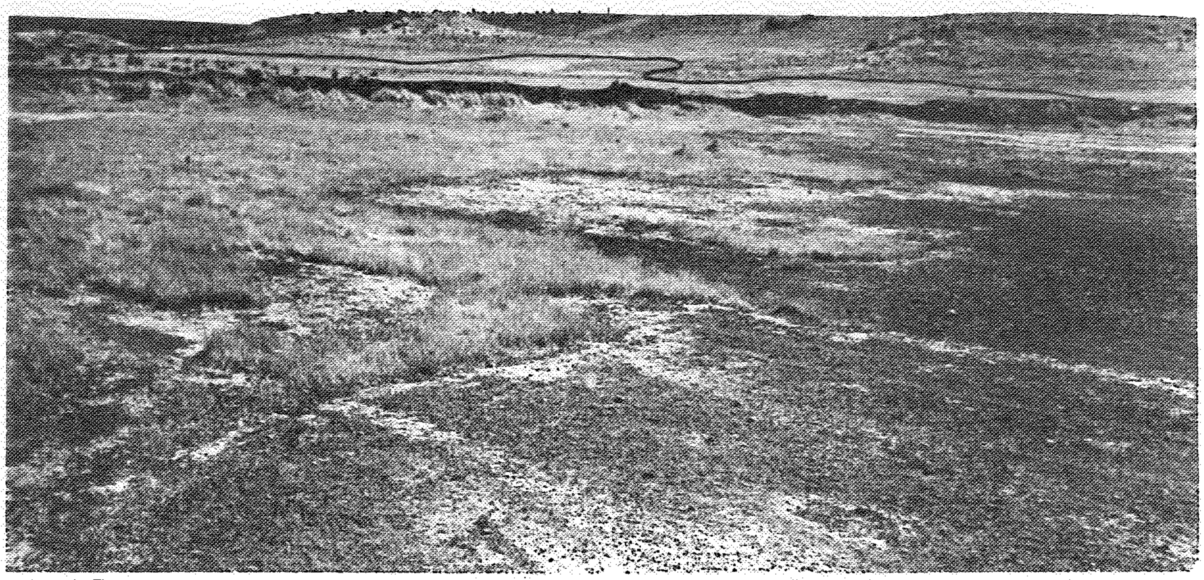


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Plate 9 - Silcreted gravels northeast of Bruce, Quorn 1:63,360 area. The marked boundary separates gravels from weathered silt-stones and shales of the Tapley Hill Formation.

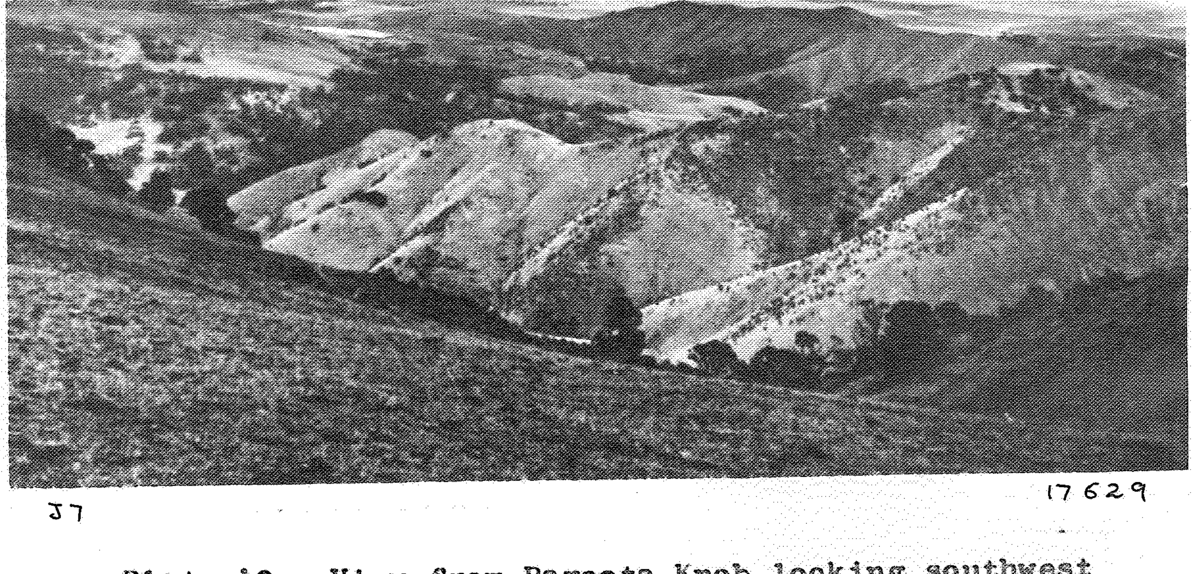

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Plate 10 - View from Baroota Knob looking southwest to Baroota Reservoir and Spencer Gulf.

Twidale (1966) included red clays and sands occurring at the surface and at depth in the Willochra Basin together with marginal gravels in the Bruce Formation. This unit includes both the Avondale Clay and the Telford Gravel and for regional mapping purposes is of little practical use as the gravels, which form a prominent unit easily recognisable on aerial photographs, would not be differentiated. Twidale (op. cit.) proposed another unit, the Coonatto Member, in the Quaternary sediments of the Willochra Basin. This unit consists of any calcreted Quaternary deposit, thus it includes the calcreted marginal gravels together with calcrete and travertine forming in present creeks. It has not been used on ORROROO as it is not considered to be a lithostratigraphic unit.

Recent Deposits

Five types of Recent deposits have been differentiated on ORROROO:- alluvium of drainage channels and flood plains; slope deposits; sand dunes and sand spreads; gypseous sands; lake deposits.

Slope deposits consist of colluvial material derived from local outcrop and transported downslope by gravity and slope wash. Unfortunately this simple situation is rarely encountered and usually the slope deposit consists partly of alluvial deposits. The boundaries between the local colluvial material of the slopes and the water transported alluvial material of the drainage channels and flood plains are often very difficult to map and in places are arbitrary.

Sand dunes occur east of the lakes on the Koonamore 1:63,360 area. The axes of these dunes are somewhat haphazard but a general northeasterly trend is evident. Gypseous sands and silts are widespread around the eastern margins of the Koonamore lakes and indicate evaporation of large volumes of water. Prevailing westerly winds are indicated by the restriction of sand dunes and gypseous sands and silts to the eastern margins of the lakes. Fine gypseous silts and clays occur on the dry lake floors of the Koonamore lakes and also east and southeast of Ucolta R.S. on the Nackara and Peterborough 1:63,360 areas.

TECTONICS AND STRUCTURE

The ORROROO area is situated in the central part of the Adelaide Geosyncline between the Gawler Platform and Stuart Stable Shelf to the west and the Willyama Block to the east. Here the geosyncline is thought to be of a miogeosynclinal type (Sprigg 1952) though Thomson (1965) regards it as a mobile shelf rather than a linear geosyncline.

The Upper Proterozoic and Lower Cambrian sediments of the geosyncline suffered a major orogeny sometime in the Lower Palaeozoic. From evidence elsewhere in the State (collated by B.G. Forbes 1966) this orogeny is placed between the Lower Cambrian and Middle Ordovician. Earlier, milder tectonism occurred during the Adelaide System, particularly between the Burra and Umberatana Groups when a major phase of diapirism was initiated (Coats 1965b). Coats (op. cit.) suggested that the fold pattern of the Lower Palaeozoic orogeny substantially followed the same axial trends originated by this earlier movement. Ample evidence of this early Sturtian movement is found on ORROROO where, in places, a strong angular unconformity exists between the Burra and Umberatana Groups. In some areas (Carrieton Anticline and the southwest limb of the Worumba Diapir) the Burra Group has been pushed aside by diapiric intrusion and eroded, so that the Umberatana Group lies unconformably on successively lower units in the Burra Group, and finally on the diapiric Callanna Beds. Other areas (Yednalue Anticline, Mt. Remarkable and the western limb of the Yalpara Anticline) show pre-Umberatana Group faulting. This is particularly marked in the core of the Yednalue Anticline where the River Wakefield group and Burra Group are highly faulted and fractured in complete contrast to the overlying Umberatana Group which is practically undisturbed.

Later tectonism is evidenced by further diapirism and contemporaneous faulting during the Sturtian and Marinoan (also in the Lower Cambrian on PARACHILNA). These movements, with associated effects on sedimentation, have been discussed elsewhere by Coats (1964, 1965b) and Dalgarno and Johnson (1965b). On ORROROO there is limited evidence of diapiric movement in the Marinoan and most post early Sturtian piercement structures are believed to have formed during the main Lower Palaeozoic Orogeny.

The next major phase of movement after Lower Palaeozoic times took place in the Late Tertiary when the old fold belt was raised by block-faulting. Evidence of earlier, probably minor, tectonism is supplied by the Triassic deposits of the Springfield and Boolcunda Basins which are folded and faulted (Johnson 1960). Campana (1958) regards these movements as a probable continuation or periodic renewal of the major Lower Palaeozoic Orogeny.

Campana (1955) suggested that the folding of sediments in the Adelaide Geosyncline was due to horizontal compression between the rigid blocks of the "Gawler nucleus" to the west, and the "Willyama nucleus" to the east, and by a presumed "cratonic element" under the Murray Basin. Thomson (1965) on the other hand suggested that the fold types ("block" and "injection" type of Beloussov) and other features of tectonism were produced by vertical movements of the earth's crust; thus Thomson emphasizes the importance of pre-Adelaidean faults and shears in the floor of the geosyncline. Evidence on ORRORCO appears to favour the compressive theory as the folds are typically elongate and parallel; also a series of anticlines arranged in right-hand en echelon fashion (Oladdie, Bendleby Hill and Waukargina. See Fig. 7b) are located in the convex part of the arcuate system of the Mt. Lofty-Olary arc. This pattern would be expected assuming compressive forces against the curved basin border (De Sitter, 1956 ch.23). Other evidence to support the compression theory are the probable high angle reverse faults in the northwest and southeast of the survey area. Evidence to support vertical tectonics rather than horizontal compression is the presence of major fault systems which were active in at least the Torrensian (e.g. Mt. Remarkable Fault), and continued throughout the Sturtian and Marinoan. These fault systems probably reflect important fault and shear zones within the basement.

Folding

The style of folding on ORRORCO is mainly of the concentric or parallel type (Webb, 1962). Units on the limbs of folds are probably near their original thickness, as suggested in the series of cross-sections across the survey area shown in Fig. 8a. Folding of a "similar" type occurs in the

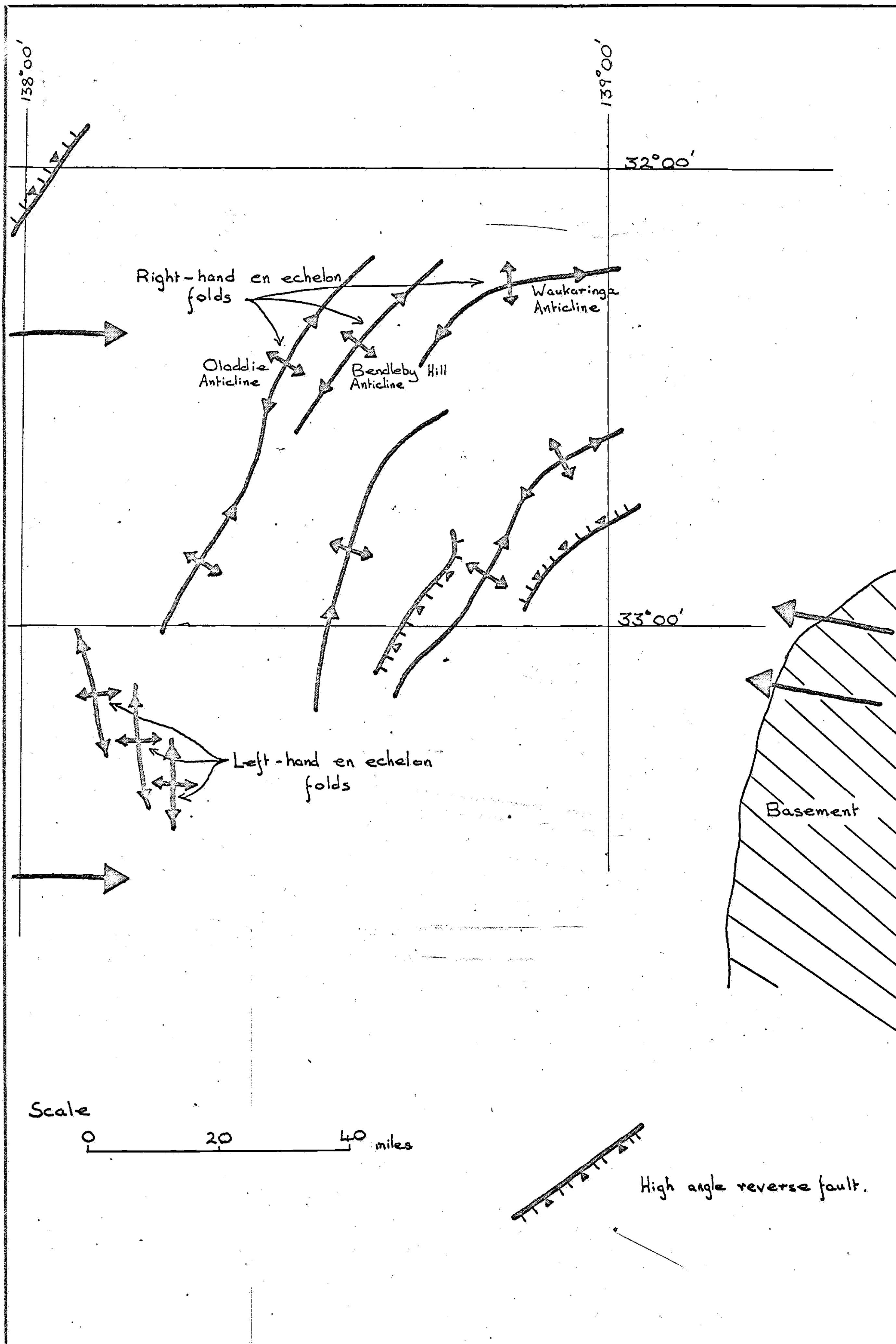

Fig 7b

S.A. DEPARTMENT OF MINES

Approved	Passed	Drn.	EN ECHELON FOLDING. ORROROO and BURRA 1:250,000 SHEETS.	D.M.	Scale As Shown.
		Tcd.		Req.	S 6431 FG
		Ckd.			
Director		Exd.			Date

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Marchant Hill, White Valley Syncline. In this structure the Ulupa Siltstone and Bunyeroo Shale are strongly cleaved and drag of individual laminae in the rock is clearly visible (Plates 11 and 12). Rapid plunge reversals are also common in this structure. The underlying Elatina Formation, a sandstone, is not highly cleaved and it is suggested that this structure is probably of a fracture-cleavage type producing a disharmonic fold as shown on Latitude 32°15' south on Fig. 8a. Probably fracture-cleavage folding is common in other parts of the survey area, particularly where an incompetent, argillaceous unit is sandwiched between competent arenaceous units.

Folds in the survey area are typically symmetrical, elongate and parallel; axial flexures produce a series of elongate domes along the major anticlinal axes. Individual folds are up to 20 to 30 miles in length; the Ulupa Syncline in the southeast of the area extends onto OLARY and BURRA and attains a length of about 130 miles.

Axial trends in the west are approximately north-south but swing round to the northeast and east in the central and eastern areas. Folding is much tighter in the northwest, possibly reflecting greater compressive forces against the stable basement to the west. Generally anticlines are tight, steep-limbed structures whereas the synclines are more open with shallow dips. Flat-lying beds occur along the axial portions of the Waukaringa and Pekina Synclines. Concentric folding, with consequent lack of space in the core of anticlinal folds, probably accounts for some diapiric intrusions with associated steepening of anticlinal structures.

Right hand and left hand en echelon folding is common. Right hand structures are dominant and have been mentioned previously. Left hand structures are located in the southwest of ORROROO and northwest of BURRA (see Fig. 7b). The dominant right-hand pattern is believed to be due to compression against a curved basin border, though O'Driscoll (1961) has demonstrated that similar patterns can be produced by vertical shear movements and their mutual interference. In this area, however, a strong slaty cleavage, necessary to produce such movements, does not exist.

Asymmetric anticlines with overturned axial planes occur in the southeast of the survey area. The southern part of the Paratoo Anticline and the northern part of the Nackara Anticline are overturned to the west,

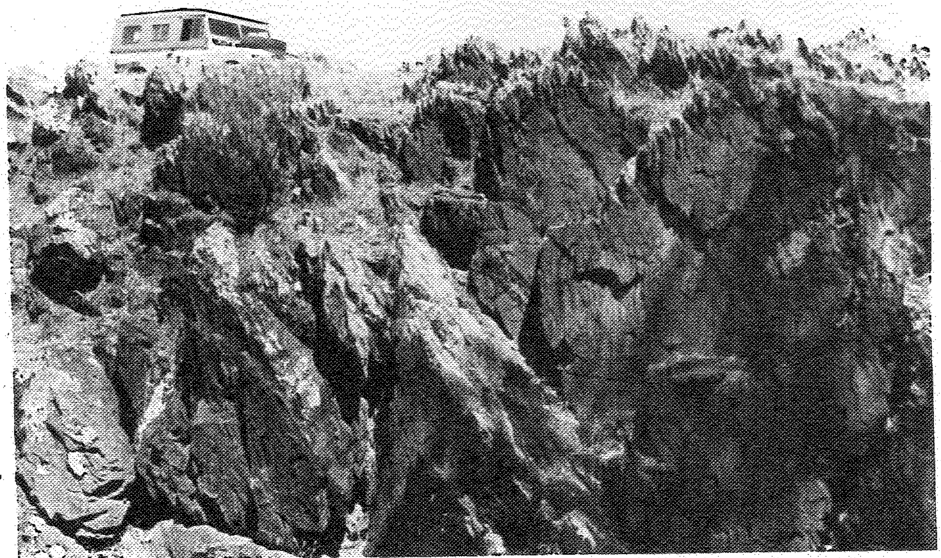

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Plate 11 - Highly cleaved Ulupa Siltstone north of Marchant Hill, Yednalue 1:63,360 Sheet.

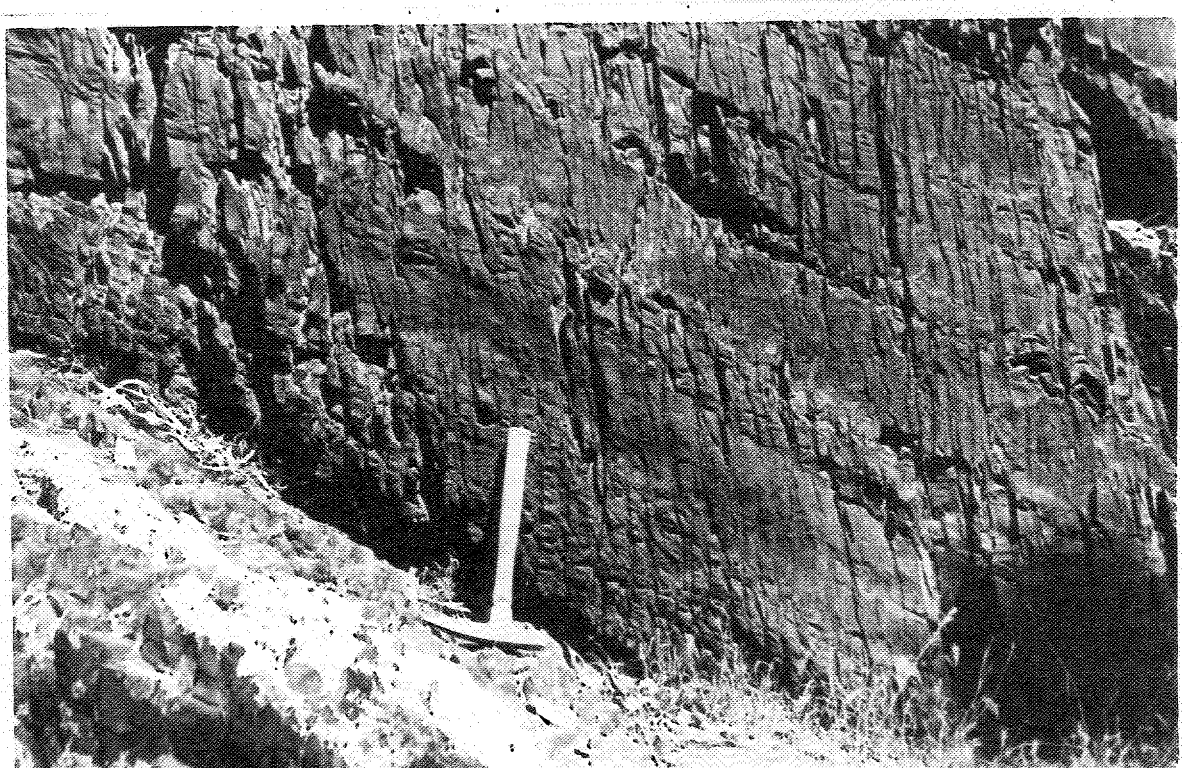

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Plate 12 - Close up of the Ulupa Siltstone north of Marchant Hill showing drag of bedding by movement on near vertical cleavage planes.

probably reflecting overthrusting from the southeast. The Mt. Grainger Anticline is overturned to the east, possibly due to overthrusting from the west along the Oodlawirra Fault. Fairburn (Fairburn and Nixon 1966) found that the statistical fold axis of dips and strikes in the vicinity of the Mt. Grainger Mine plunged at 40°, in a direction of 243°. This indicates considerable buckling of the northern part of this fold and is probably due to the emplacement of the Mt. Grainger Diapir.

A broad anticlinal structure in the southwest around Booleroo Centre plunges north producing a series of diverging, and quite distinct structures. Individual anticlinal axes can be traced from the Booleroo area northwards onto PARACHILNA. To the south the anticline continues as far as Brinkworth on BURRA. This structure forms an important tectonic unit on the BURRA and ORROROO areas.

Faulting

Three periods of faulting can be recognised on ORROROO. These are:- a/ Early Sturtian; b/ Sturtian-Marinoan; c/ Post Lower Palaeozoic.

a/ Early Sturtian

Faulting of this age is particularly evident in the Yednalue Anticline where a series of radial faults, emmanating from a probable diapiric core (there are only limited outcrops of diapiric material), disrupts units of the River Wakefield and Burra Groups (See Fig. 8b). Much fracturing and brecciation of the country rock is associated with this faulting indicating compaction and induration prior to faulting. The early Sturtian age is indicated by the unconformity at the base of the Umberatana Group on the flanks of the structure. Units in the Burra Group (particularly the Skillogalee Dolomite) are repeatedly cut off by the Umberatana Group northwards along the western flank of the anticline; on the eastern limb the Umberatana Group lies directly on the River Wakefield group indicating a period of strong erosion in this area.

The Mt. Remarkable Fault was also active in the early Sturtian. The cross-section drawn on Latitude 32°45' south on Fig. 8a, and also the cross-section on the published map show a section normal to the plane of the

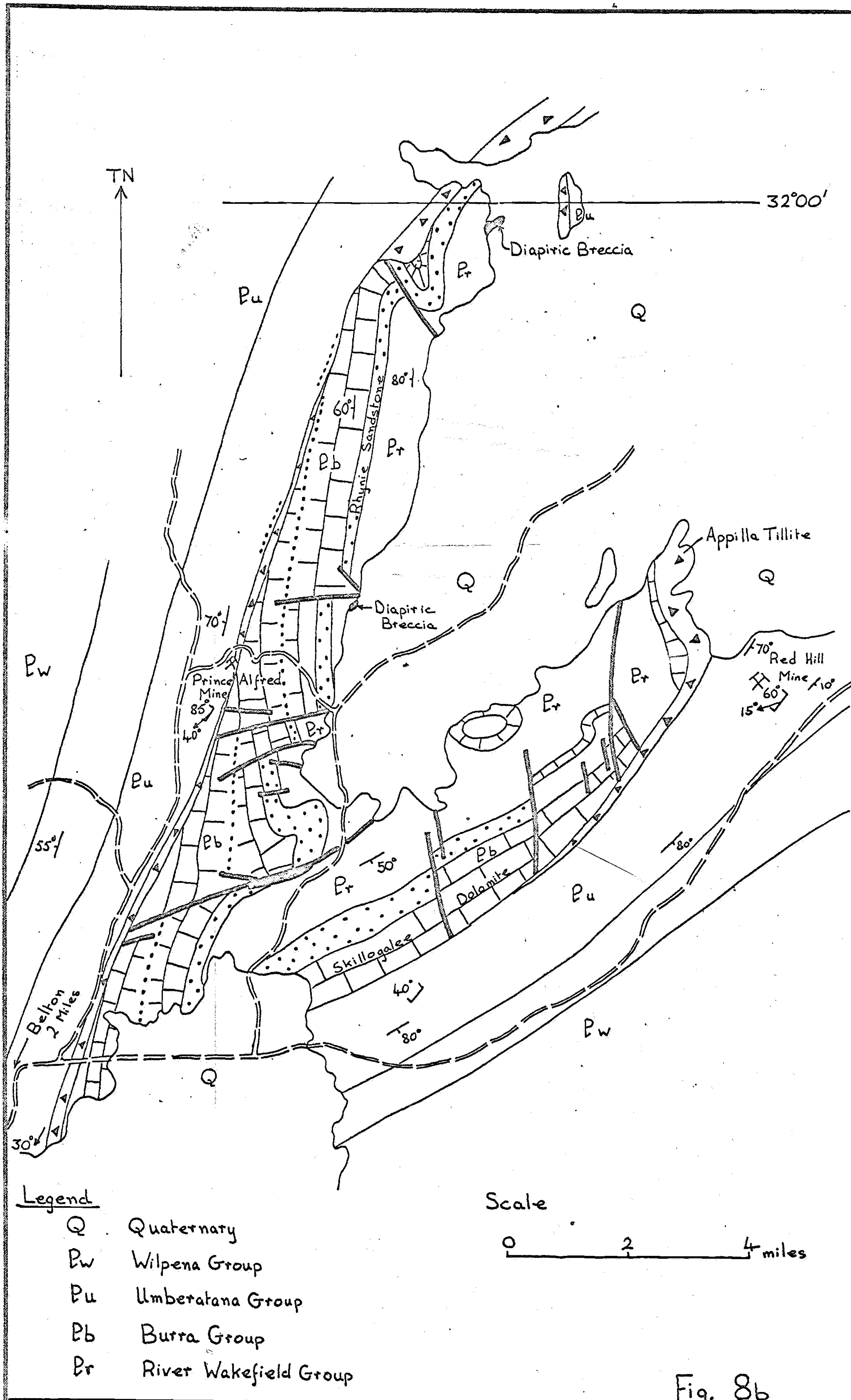

Fig. 8b

DEPARTMENT OF MINES — SOUTH AUSTRALIA

Drn.	ORROROO 1:250,000 SHEET.	SCALE: As Shown
Tcd.	GEOLOGICAL SKETCH MAP	S 6429 FG
Ckd.	YEDNALUE ANTICLINE	
Exd.		DATE:

fault. It is apparent from these sections that the base of the Burra Group is downthrown more than the base of the Umberatana Group thus indicating pre-Umberatana faulting in the order of 10,000-15,000ft. The Burra Group is much thicker east of the fault; approximately 15,000ft. of strata between the Rhynie Sandstone and the Umberatana Group is missing west of the fault and the Appila Tillite lies directly on the Rhynie Sandstone. This is a remarkable disconformity, especially as the strike of the Rhynie Sandstone and the overlying Umberatana Group is parallel and appears quite conformable on the aerial photographs. The cause of this disparity of thickness in the Burra Group is probably related to complex movements on the fault associated with contemporaneous diapirism. Two explanations based solely on faulting are suggested here. One is that the Mt. Remarkable Fault was contemporaneous with Torrensian sedimentation and formed a hingeline with a basin of thick sediments to the east and a positive shelf area to the west with little sedimentation. The other is that Torrensian sedimentation was uniform on both sides of the present fault and that early Sturtian faulting downfaulted the eastern block protecting it from subsequent erosion (?glaciation) which removed the middle and upper Burra Group units from the western block.

Early Sturtian faulting occurs on the western limb of the Yalpara Anticline. Here a resistant white quartzite (Minburra Quartzite), which forms a pronounced ridge about $\frac{1}{4}$ mile east of the Appila Tillite, is offset by faults in two places (see Fig. 8c). West of "Treehaven" one of these faults offsets the southern portion of the ridge about $\frac{1}{2}$ mile to the east but does not affect the base of the tillite. Approximately 10 miles north-northeast of "Yalpara" the other fault eliminates the northern portion of the quartzite ridge; again the fault does not affect the overlying Appila Tillite.

On the southeastern limb of the Pekina Syncline, about four miles southwest of Yatina, two parallel faults trending northwest dislocate the Burra Group but do not affect the Umberatana Group.

b/ Sturtian-Marinoan

Evidence of fault movement during these epochs is limited on <u>ORROROO</u>. Several faults were active however and these will be outlined below.

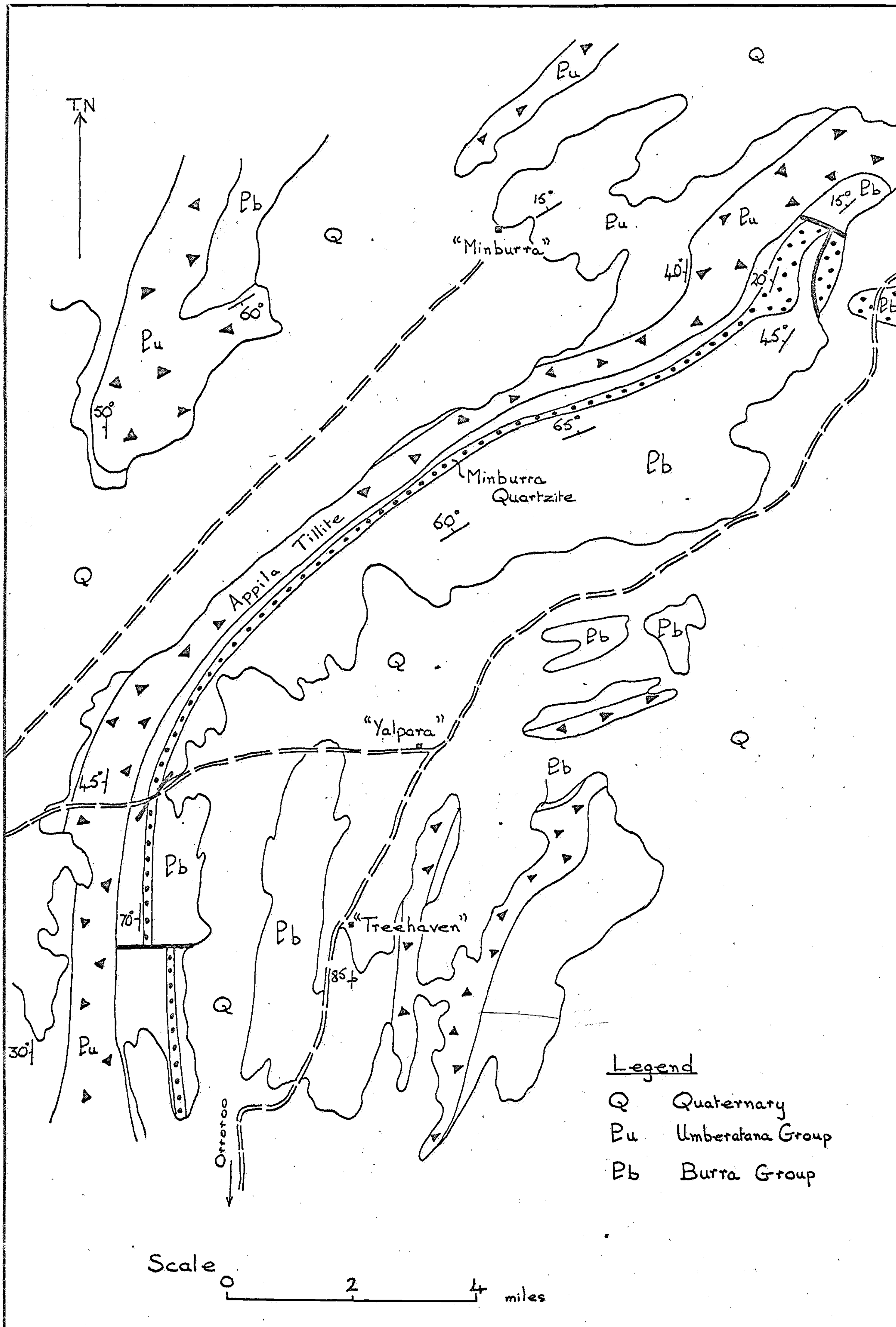

Fig 8c

S.A. DEPARTMENT OF MINES

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		Tcd.	GEOLOGICAL SKETCH MAP	Req.	S 6430 FG
		Ckd.	"YALPARA" AREA		
Director		Exd.			Date

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Movement of a fault on the northwestern limb of the Yednalue Anticline (seven miles north-northeast of the Prince Alfred Mine. See Fig.8b) was contemporaneous with deposition of the Sturtian tillite (Dalgarno and Johnson 1965a). A thick sequence of massive boulder tillite occurs to the north of the fault while to the south the tillite rapidly thins out and the overlying Tindelpina Shale Member lies unconformably on the Burra Group. The fault does not affect the Tapley Hill Formation. Earlier faulting in the Torrensian along the same fault plane severely dragged and crumpled the Rhynie Sandstone. Other evidence of Sturtian movement occurs elsewhere on the flanks of the Yednalue Anticline where, in places, the Tindelpina Shale Member lies directly on the Burra Group and conglomerate bands with reworked erratics occur near the base of the shale. These movements with consequent erosion of some of the tillite from the flanks of the structure are probably related to positive movements of the diapir in the core of the present anticline.

The Cradock Fault, east of the township of Cradock, trends approximately east-west and affects Torrensian, Sturtian and early Marinoan sediments. Final movement of the fault occurred in early Marinoan times as the fault does not affect the Enorama Shale and Elatina Formation in the upper part of the Umberatana Group, but has dragged lower units in the northern block to the west. Contemporaneous movement of the fault is indicated by the thicker deposits of the Etina and Tarcowie Siltstone Formations north of the fault. The precise course of this fault is hidden by recent deposits of the Wirreanda and Pendowaga Crreks.

Another east-west fault affecting Sturtian and early Marinoan rocks occurs on the western limb of the Yanyarrie Diapir about six miles north of Carrieton. The fault downthrows the northern block about 700ft. but does not affect units above the Elatina Formation thus dating final movement of the fault in the early Marinoan. A slight angular unconformity between the Tarcowie Siltstone and overlying Elatina Formation occurs immediately south of this fault.

A north-trending fault southeast of Mt. Brown (approximately five miles north-northwest of Wilmington) dislocates units in the Umberatana and

Wilpena Groups. This fault is overlapped by basal units of the ABC Range Quartzite dating movement as late Marinoan in age.

c/ Post Lower Palaeozoic

Most of the faulting on ORROROO took place after the Lower Palaeozoic orogeny. This is evident on Fig. 4 which reveals that most faults disorientate and offset the parallel and symmetrical folding which characterises the area. Some faults were probably contemporaneous with folding, as for example the Bookunda and Ballarata Faults in the southern axial parts of the Uroonda and Horseshoe Synclines (Webb 1962), while others were later, possibly associated with Tertiary uplifting. These later movements were probably along pre-existing lines of movement. Some of the faults must reflect basement fractures, particularly those reviving earlier Adelaidean faults (e.g. Mt. Remarkable Fault) and those which show some degree of alignment, possibly signifying zones of fundamental "weakness" in the basement. As these post Lower Palaeozoic faults are numerous only the more important ones are discussed below.

The Mt. Remarkable Fault was reactivated after folding and the eastern block downthrown about 5000ft. As mentioned previously the eastern block had been downthrown 10,000-15,000ft. in the early Sturtian and the later movement on the same fault plane indicates a probable zone of weakness in the basement.

The Yatina Fault, inferred under the alluvium of the Walloway Plain on the basis of surrounding structures, can be linked with other structures, including diapirs, northwards through Walloway and Carrieton to the Worumba Diapir on PARACHILNA. Individual faults and structures do not actually link up as areas of country rock between structures are undisturbed. This trend is probably another zone of basement weakness. Cross-folding on the Pine Grove Anticline, southeast of Cradock, may be due to transcurrent movements along this basement lineament. Another inferred fault immediately east of Boolerco Centre can be linked northwards with the same zone. The epicentres of the main shock and after-shock of an earthquake which took place in the mid-north of the State on August 28th 1965 (Sutton and White 1966) plot just to the west of the Carrieton Anticline, quite near this probable basement lineament.

The Paratoo Fault trends west-northwest from the Paratoo Diapir offsetting the southern part of the Waroonee Syncline and probably continuing to "Yalpara". The "Devils Chimney", an ironstone outcrop on a conformable vein of specular hematite, lies along the inferred trend of this fault. The Oladdie Fault, west of Johnburgh, has a similar trend and is more or less in line with the Paratoo Fault probably indicating another basement lineament. Drag on the Oladdie fault suggests that the northern block was downfaulted, possibly prior to folding, then later uplifted after folding to produce a fault with the downthrow drag on the upthrown block. The Oladdie Diapir has been intruded along this structure.

The Arden Vale Fault downthrows the Pound Quartzite against the Rhynie Sandstone about one mile northwest of Quorn. This is a throw in the order of 15,000ft., yet only four miles to the north the displacement is zero. To the south the fault bifurcates and a remnant of the Pound Quartzite is preserved at the "Devils Peak" on AUGUSTA in a downfaulted block. The Horrocks' Pass Fault, which is probably a continuation of the Arden Vale Fault, offsets the northern part of the Alligator Syncline to the west.

Probable high angle reverse faults occur in the southeast (Oodlawirra and Bulyninnie Faults) and northwest (Wyacca Fault) of the survey area. Cross-sections through the Oodlawirra and Bulyninnie Faults on Latitude 32°57½'S on Fig. 8a and also on the cross-section on the published map show the relatively downthrown block between the two faults. The east facing limb of the Mt. Grainger Anticline has been truncated by the Oodlawirra Fault, which thrust the Tindelpina Shale Member against the Ulupa Siltstone, a movement in the order of 10,000ft. The north limb of the Bulyninnie Anticline has been truncated by the Bulyninnie Fault, which thrusts the Burra Group against upper units of the Umberatana Group, a throw between 5-10,000ft. Another reverse fault in the axial portion of the Nackara Anticline eliminates the eastern flank of this structure further south on BURRA. In the northwest the Tapley Hill Formation is faulted against the Pound Quartzite along the Wyacca Fault, a throw in the order of 10,12,000ft. as shown in cross-section on Latitude 32°00'S on Fig. 8. Approximately one half mile southwest of Mt. Brown the Brachina Formation is thrust onto near vertical ABC Range Quartzite

J7 17632

Plate 13 - Brachina Formation thrust onto steeply dipping ABC Range Quartzite west of Mt. Brown, Wilmington 1:63,360 area.

J7 17633

Plate 14 - Diapiric breccia containing small blocks enclosing a larger block in the Walloway Diapir, Orroroo 1:63,360 area.

along a low angle fault plane dipping to the east at about 45°. (Plate 13).

Uplift on faults along the western scarp of the Flinders Range flanking Spencer Gulf on AUGUSTA and the southwest of ORRORO0 probably occurred during the Tertiary. O'Driscoll (1956) suggested that the Simmonston Fault in the north of the Willochra Basin is truncated by the Arden Vale Fault. As he believed the Simmonston Fault was active during the Tertiary he argued that the Arden Vale Fault is also of Tertiary age and formed a part of the "strong orogenic movements" which resulted in the ranges flanking the Willochra Basin. Mapping of the Willochra 1:63,360 Sheet by Webb and Von der Borch showed that the Arden Vale Fault dies out well south of the Simmonston Fault thus invalidating O'Driscoll's conclusion. Twidale (1966) established that Tertiary beds have been downfaulted 98ft. (north block down) by the Simmonston Fault proving Tertiary or Post-Tertiary movement on this fault.

DIAPIRIC STRUCTURES

Diapiric or piercement structures were recognised by Webb and Von der Borch in the course of mapping the Willochra 1:63,360 Sheet in 1958. In the same year Webb (1960) proposed a similar origin for the Blinman Dome. Webb recognised that these structures consisted essentially of brecciated and crumpled rocks lithologically similar to rocks of Willouran age forcefully emplaced into younger rocks of the Adelaide System. Summaries of the geology and possible mechanics of intrusion of diapirs in the Flinders Ranges have been outlined by Coats (1964b, 1965b) and Dalgarno and Johnson (1965b).

There are fewer and smaller diapiric structures on ORROROO than on PARACHILNA and COPLEY to the north. Dalgarno and Johnson (op. cit.) imply that this is due to the tighter and more regular folding characteristic of ORROROO and areas to the south. Alternatively the Willouran source beds may be thinner or of a different, more competent, facies in this area. Nevertheless typical Willouran rocks occur in diapirs over much of ORROROO.

Movement of diapirs on ORROROO is confined mainly to the early Sturtian and Lower Palaeozoic. The comparative lack of Sturtian-Marinoan movement stands in complete contrast to PARACHILNA where there is well documented evidence of this period of diapirism (Dalgarno and Johnson 1965b). Evidence of early Sturtian movement on PARACHILNA is lacking as there is practically no outcrop of rocks of this age. Early Sturtian positive movement of diapirs caused erosion of the intruded Burra Group - evidence for this is seen on the southwestern limb of the Worumba Diapir where the Appila Tillite lies with sedimentary contact on the diapiric material.

Callanna Beds

Rock types found in the diapirs on ORROROO are similar to those found in piercement structures to the north and are lithologically similar to the Callanna Beds of Willouran age and include:- grey siltstones and sandstones with shale partings showing ripple-marks, suncracks and occasional casts of halite; purple shales and siltstones; phyllites; dolomites, and dolomitic breccia. These rocks occur as blocks set in a breccia consisting of small fragments of the latter rocks in a matrix of finer fragments cemented with carbonate material (Plate 14). Halite casts have been found in the Worumba, Wirreanda, Mt. Remarkable and Depot Hill diapirs but not in the other diapirs on ORROROO. No definite volcanics have been found in diapirs on the survey area, though Wright (1966) recently found float of amygdaloidal andesite in the Mt. Grainger Diapir. Only one example of a foundered block of the overlying country rock has been found within a diapir on ORROROO. This consists of a small block, $\frac{1}{4}$ sq. mile in area, of Tindelpina Shale Member with a few feet of Sturtian tillite underlying it in the southern part of the Melrose Diapir.

The Baratta, Paratoo and Bulyninnie piercement structures, located in the east of the area, consist predominantly of crumpled and brecciated dolomite with no characteristic sediments of Willouran age. It is feasible that these structures could be formed of Torrensian rather than Willouran rocks, especially the Paratoo Diapir, which is situated in the core of a tight anticlinal structure with thick Torrensian dolomites exposed on its flanks. However if they are formed of Willouran rocks this may indicate an eastern zone of carbonate deposition in the Willouran "trough".

Basic Intrusives

Numerous small plugs and dykes of basic igneous rock have been intruded into the diapiric breccia in some of the diapirs. Howchin (1916) found small basic plugs in the "crush zone" at the foot of Mt. Remarkable (Melrose Diapir), and Thiele (same reference) described them as fine to coarse grained dolerites (sp. 49) similar to the basic rocks at Blinman. Plugs of quartz porphyrites and aplites also occur in the Melrose Diapir.

Spry (1952) described basic intrusives twenty miles east of Hawker in a "fault block" (Worumba Diapir) in the centre of the Worumba Anticline. These intrusives, which Spry describes as dolerites and basalts are typically uralitised and saussuritised. The dolerites originally consisted of augite and labradorite with accessory hornblende, ilmenite, apatite and quartz. The basalts usually consist of a groundmass of albite, actinolite, chlorite, calcite, epidote and iron ore with amygdales filled primarily with calcite and less often with siderite, epidote, quartz, chlorite or biotite. Spry noted the lack of contact metamorphism around the intrusives in the area. Another small plug of basic rock (sp. 50) intruding diapiric material was found just to the south of the intrusive described by Spry.

Wright (op. cit.) has mapped basic dykes intruding the Mt. Grainger Diapir. These dykes, which Wright described as consisting typically of large phenocrysts of andesine in a groundmass of fine andesine crystals and secondary chlorite, have been altered by deuteric action to give knots of chlorite and biotite after an earlier mineral (? hornblende). Wright also described amygdaloidal and trachytic andesites, which, he suggests, may be rafted blocks brought up in the diapir.

Basic plugs and dykes intrude the Paratoo Diapir. A group of these plugs, represented as a single intrusion on ORROROO, have been mapped by Hiern (1965) as a source of ballast for the Highways Department. Hiern recognised three varieties of basic rock based on grain size (sp. 51; sp. 52; sp. 53); all three variants are hornblende diorites consisting of amphibole, intermediate plagioclase, sphene and opaques. The diorites have been altered, possibly by deuteric action, and the laths of plagioclase replaced by epidote and chlorite. Similar basic plugs intrude the Bulyninnie piercement structure in the northwest of the Manunda 1:63,360 Sheet. On the published Manunda Sheet Mirams (1960) shows one plug of dolerite intruding Marinoan sediments in the area; in fact there are several small plugs intruding brecciated and crumpled dolomites of this probable piercement structure.

Chloritized porphyritic microdiorite (sp. 54) outcrops on the western flank of the Great Gladstone Diapir, and a small dyke of altered porphyritic quartz microdiorite (sp. 55) intrudes the lower Marinoan country rock just to the north of the diapir.

Phases of Diapirism

Early Sturtian

This phase of movement is important and affects the following diapirs in the north-central parts of the survey area:- Carrieton Diapir, Uroonda Diapir, Worumba Diapir, Yednalue Diapir, diapir south of Round Hill, and diapirs just to the north and west of the Wirreanda Diapir. In some of these structures the Burra Group has been forced aside and eroded so that the Umberatana Group lies directly on the diapiric Callanna Beds.

The Carrieton Diapir, which is situated in the north plunging axial region of the Carrieton Anticline, has pushed aside rock units of the River Wakefield and Burra Groups on the eastern limb of the structure. Appila Tillite lies on successively lower units of these groups, and finally rests directly on the brecciated Callanna Beds of the diapir in the north of the structure. This strong unconformity at the base of the Umberatana Group dates the movement of the Carrieton Diapir as early Sturtian; the diapir does not intrude the Umberatana Group thus limiting movement of the diapir to this latter phase. A possible earlier period of movement is indicated by upturning of River Wakefield group beds against the diapir on the western limb of the structure, about two miles south of Carrieton Railway Station. The Burra Group is not affected by the diapir at this point indicating possible late Willouran movement. Upturning of the River Wakefield group units is not strong and no units are actually cut off by the Burra Group, thus some doubt exists about the validity of this period of movement.

The Uroonda Diapir intrudes the southern axial portion of the tightly folded Pine Grove Anticline; the main road between Carrieton and Cradock cuts through the diapir in a creek-crossing about 16 miles north of Carrieton. Like the Carrieton Diapir, units of the River Wakefield and Burra Groups have been pushed aside by the diapir, and the Appila Tillite lies with strong unconformity on these sequences and on the diapiric Callanna Beds. On the western limb of the structure the diapir has cut through the tillite and intruded the Tapley Hill Formation, indicating a later phase of diapirism.

Evidence of early Sturtian movement of the Worumba Diapir is found southwest of Cradock, where the Burra Group has been forced aside by the diapir and the Appila Tillite rests directly on the diapir. (The Worumba Diapir has been extended to the south from PARACHILNA to join up with rocks of Willouran age, originally mapped on the Willochra 1:63,360 Sheet southwest of Cradock (see tectonic sketch on published map). Later mid Sturtian movement of this diapir is indicated by slump structures and boulder-trains in the lower part of the Tapley Hill Formation on the eastern flank of the structure.

Outcrop of the Yednalue Diapir is extremely limited but is assumed to occupy much of the core of the Yednalue Anticline, as shown on the tectonic sketch of the published 1:250,000 Sheet. Pre-Umberatana Group radial faulting with associated erosion of the Burra Group and much of the River Wakefield Group along the eastern flank of the structure, is thought to be due to positive early Sturtian movement of this diapir. No later movement of this diapir has occurred.

The Appila Tillite rests directly on diapiric Callanna Beds south of Round Hill. Again the Burra Group has been forced aside and eroded due to positive movement of these diapirs.

Marinoan

The only documented evidence of diapiric movement during the Marinoan on ORROROO occurs on the western flank of the Great Gladstone Diapir. Here conglomerate bands within the unnamed upper member of the Willochra Formation contains pebble and cobble sized fragments of the porphyritic micro-diorite which outcrops on the western limb of the diapir (Plates 15 and 16). This indicates that the diapir was undergoing erosion in early Marinoan times, probably as a result of positive movement.

J7 17634

Plate 15 - Thin band of breccia containing fragments of basic rock, interbedded in the upper member of the Willochra Formation on the flank of the Great Gladstone diapir, Quorn 1:63,360 Sheet.

J7 17635

Plate 16 - Close up of the breccia band on the flank of Great Gladstone diapir showing angular fragments of basic rock.

Movement of the fault on the western flank of the Yanyarrie Diapir and thinning of the Umberatana Group rock units against the diapir on this flank are indicative of contemporaneous positive movement of this structure. Early Marinoan movement of the Cradock Fault with associated facies changes may be due to contemporaneous movement of the Worumba Diapir.

Possible evidence of Marinoan movement of the Paratoo Diapir is indicated by thinning of the Ulupa Siltstone on the northwestern limb of the Paratoo Anticline. This diapir, which consists mainly of crumpled and brecciated dolomite (Plate 17), intrudes the Burra Group in the southern axial part of the Paratoo Anticline and units in the Umberatana Group on the western limb of this structure.

Lower Palaeozoic

Diapirs intruded during or after the Lower Palaeozoic orogeny disrupt regional structures formed during this period of folding. These diapirs probably owe their origin to lack of space in the cores of anticlines folded in a concentric (parallel) style. As mentioned before this is the style of folding typical of the central and southern Flinders Ranges. Some of these diapirs were injected along major faults. The following diapirs were emplaced in this phase of diapirism:- Mt. Grainger Diapir; Walloway Diapir; Coonooroo Diapir; Mt. Remarkable Diapir; Oladdie Diapir, and the diapir in the southern axial portion of the Urroonda Syncline. Some of the diapirs may have been in existence prior to this phase but were remobilised by the Lower Palaeozoic orogeny.

The Mt. Grainger Diapir is situated in the overturned eastern part of the Mt. Grainger Anticline. The eastern limb of this anticline has been truncated by the Oodlawirra Fault which thrust this structure against the Oodlawirra Syncline. It is suggested that the latest movement of the diapir was along this fault plane, during, or after folding. Marked facies changes in rock units of the upper part of the Umberatana Group on the eastern limb of the structure and slump structures in a limestone unit a few miles north of the diapir indicate a possible earlier (early Marinoan) phase of movement.

The Walloway Diapir (Plate 18) consists of a zone of diapiric breccia along a north-south fault which affects regional structures. Beds of

K 7 17636

Plate 17 - Contorted and crushed carbonate breccia in the Paratoo Diapir, Paratoo 1:63,360 Sheet.

J 7 17637

Plate 18 - Diapiric breccia exposed in the banks of a creek in the Walloway Diapir, Orroroo 1:63,360 Sheet.

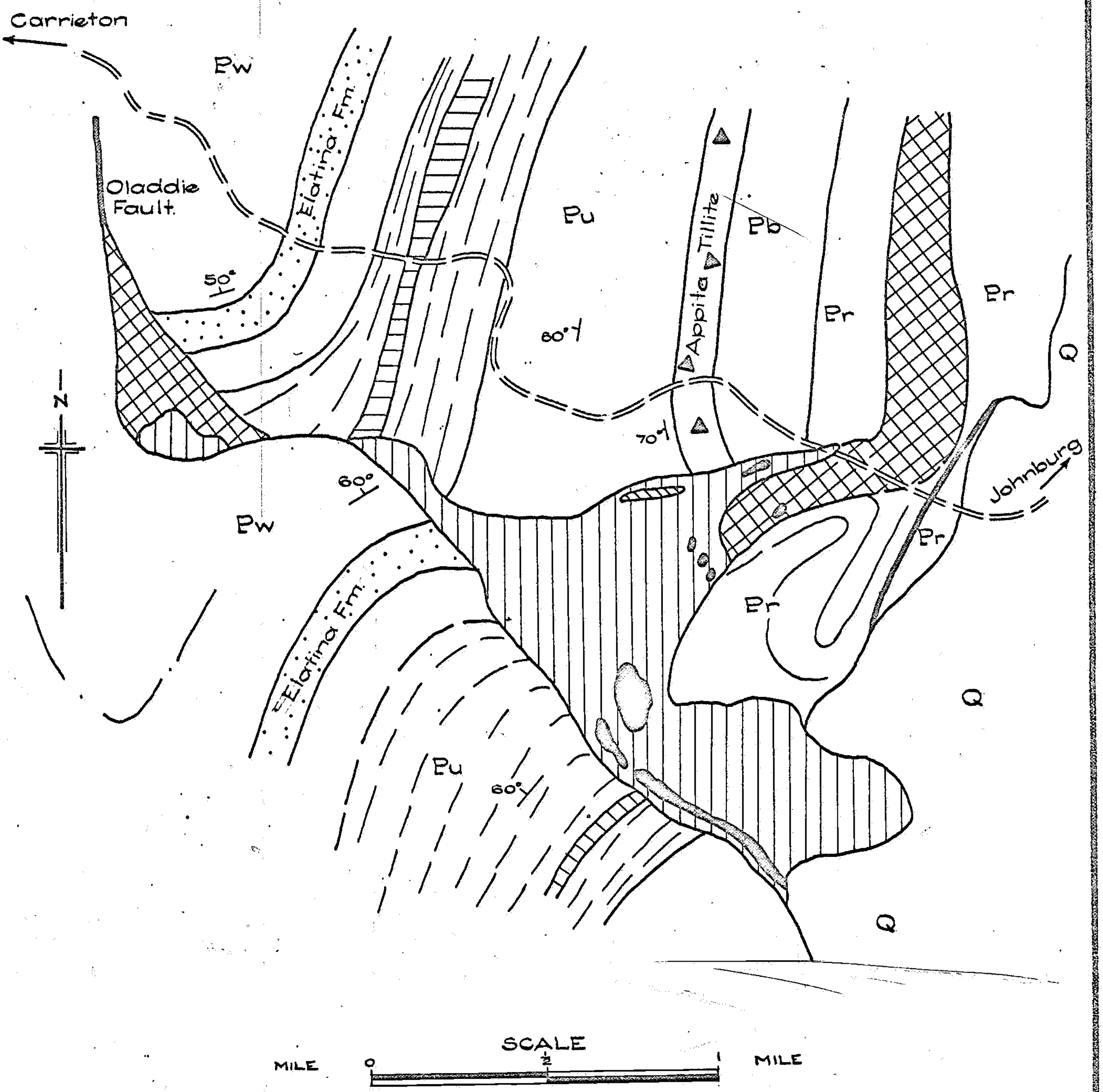
the country rock have not been upturned by the intrusion of this diapir; in fact beds on the eastern flank dip in towards the diapir. The Coomooroo Diapir, which disrupts regional structures, intrudes Sturtian and Marinoan rocks a few miles to the west of the Walloway Diapir.

The Mt. Remarkable Diapir is situated at the foot of Mt. Remarkable: a smaller zone of possible diapiric breccia occurs less than a mile to the southwest. Typical Willouran rocks have not been found in this latter zone and the area may be a crush breccia associated with faulting. The Mt. Remarkable Diapir cuts through regional structures and is believed to have been injected along the Mt. Remarkable Fault during, or after folding. The Mt. Remarkable Range has been forced up from the east, possibly by the rising diapir, and disrupts structures southwest of Melrose. It is difficult to reconstruct the structure before this uplifting as the whole of the range consists of a west facing limb of one large anticline which cannot be matched with a corresponding structure to the south.

The Oladdie Diapir has been intruded along the Oladdie Fault about 4 miles west-southwest of Johnburgh. Crush breccia of the River Wakefield Group occurs in a north-south fault zone immediately north of the diapir in the core of the Oladdie Anticline and breccia of the Umberatana and Wilpena Groups occurs in the western part of the Oladdie Fault.

A large block of siliceous banded jasper (sp. 56), about 600ft. by 200ft. has been brought up by the diapir in the north of the structure (see Fig. 9). Other blocks of metasomatised "granite arkose" (sp. 57) have also been rafted-up by the intrusive breccia. Field evidence suggests that some of the "arkose blocks" may be intrusive igneous rocks, but further field and petrological work is required to verify this. The jasper and metasomatised arkose blocks are believed to be fragments torn from the basement during diapirism.

A small diapir is located about four miles east of the Boolcunda Basin on an important fault. The diapir has been injected along this fault, which affects the axial region of the Uroonda Syncline.



LEGEND

Q Quaternary
Pw Wilpena Group
Pu Umberatana Group
Pb Burra Group
Pr River Wakefield Group

Fault Breccia
Diapiric Breccia
Metasomatised Granite Arkose
Banded Silicified Jasper

FIG. 9

DEPARTMENT OF MINES — SOUTH AUSTRALIA

Drn. P.B
Tcd. AMFD
Ckd. L.Y.W.
Exd.

ORROROO 1:250,000 SHEET
BASEMENT BLOCKS IN
OLADDIE DIAPIR

SCALE: As shown
S6113
Fef+hj
DATE: 12-9-67

ECONOMIC GEOLOGY

Mineral production in the ORRCROO area has never been large but many minerals have been mined, including gold, copper, manganese, iron flux, phosphate, magnesite and barytes. Only a few areas, the Prince Alfred Copper Mine, the Waukaringa Gold Field, the Oodlawirra Flux Quarries and Donnelly's Ironstone Quarries have been worked on a large scale; all were worked in the latter part of the 19th century and early part of this century.

Many small copper mines and prospects occur throughout the area but production from them has been insignificant. Small gold mines and prospects occur in the Mt. Grainger and Waukaringa areas. Manganese has been worked spasmodically at the Boolcunda and Muttabee Mines; limited amounts were extracted from these mines during the last World War.

Non-metallic minerals and constructional materials which have been mined and quarried in the survey area include rock phosphate, magnesite, clay, barite, quartzite and diorite. The diorite and quartzite are used for road metal and rail ballast. Only limited amounts of clay and barite have been extracted and total phosphate production was small: however, current exploration for clay and phosphate may alter this situation.

At the present time the only minerals being extracted on ORRCROO are quartzite for rail ballast from Nackara and Black Rock and pottery clay from Booleroo Centre. Concrete aggregate and rubble for road works are extracted in limited amounts by local councils. Copper ore has recently been mined at Paratoo but is lying in dumps at the mine.

The following sections deal more fully with mineral deposits on ORRCROO. Locations of deposits are shown on Fig. 10. An excellent resumé of all mines in the area up to 1908 is given in the fourth edition of The Mines of South Australia by H.Y.L. Brown.

Metallic Mineral Deposits

Copper

Over 50 copper mines and prospects are located in the area but the only mine which produced significant amounts of copper was the Prince Alfred. Production from other mines amounted to little more than bulk assay samples, though some of the workings are quite extensive. A short summary of some of the more important mines is given below.

Prince Alfred Mine:

This copper mine is situated nine miles north of Belton on the west facing limb of the Yednalue Anticline. The deposit was discovered in 1866 and worked until 1908. Most of the production, believed to be about 40,000 tons of over 5% ore, was extracted prior to 1900. The ore was jigged to a 20% concentrate at the mine and before 1900 was smelted at the mine. Wade and Wegener (1954) mapped the mine and surface geology and prepared a report which recommended a drill hole to cut the lode below water level. Nixon (1960) reported the drilling of three holes at the mine. No ore was located but low grade primary sulphides were found in thin grit bands.

The main lode is parallel to bedding and is situated in the lower part of the Tapley Hill Formation in blue-grey well laminated siltstones. Thin bands of coarse grit are interbedded with the siltstones near the mine: these are believed to have been formed by erosion and slumping due to contemporaneous positive movement of the diapir in the core of the present anticline. Finely laminated black shales occur immediately east of the mine and are underlain by a few feet of tillite. The tillite rests with marked angular unconformity (20°) on the underlying rocks of the Burra Group.

Wade and Wegener (op. cit.) suggested that the lode has been deposited along a transcurrent fault; the hanging wall is broken and crushed and broken slate occurs in the lode material. The lode consists of sideritic copper ore with minor amounts of calcite and quartz. Chalcopyrite is the primary copper sulphide. Wade and Wegener (op. cit.) suggested that secondary enrichment would have been restricted by the lack of pyrite and abundance of calcium carbonate, but if this was so the deposit should have persisted below the water table. It appears more likely that the ore body was a product of secondary enrichment of primary low grade sulphides; this comparatively rich body has apparently been completely worked out.

Mine workings consist of two underground workings separated by an open-cut 220ft. long and approximately 20ft. deep. The southern shaft (main

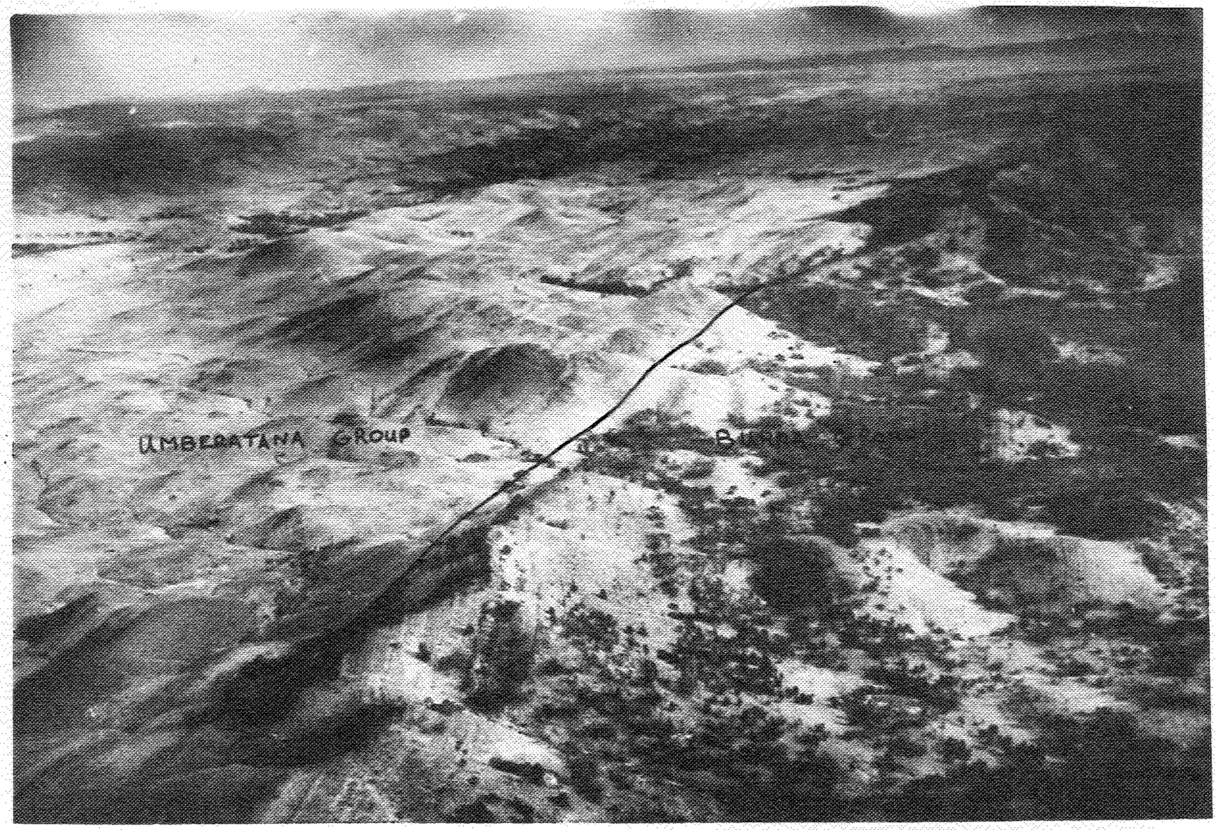


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Plate 19 - View from the air over the Prince Alfred Mine looking northwards and showing the unconformity at the base of the Umberatana Group. (Photograph by B.P. Thomson)

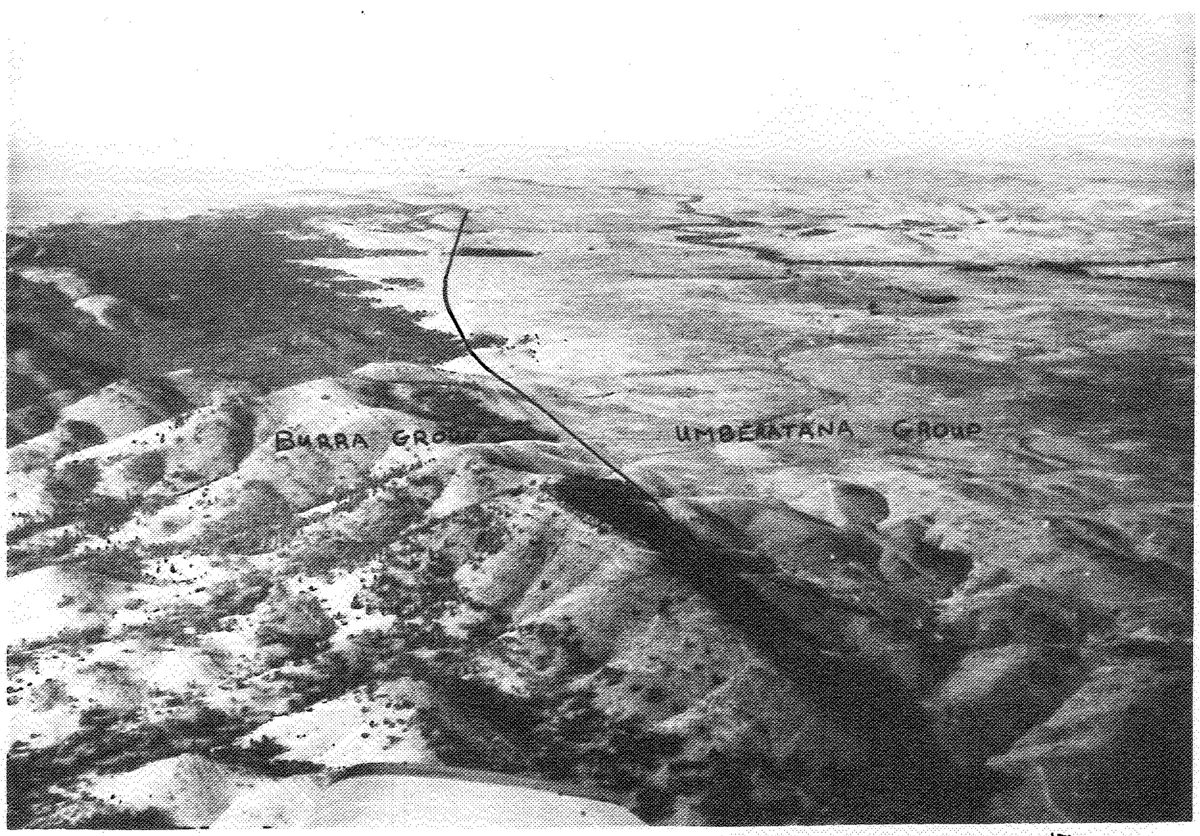

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Plate 20 - View from the air over the Prince Alfred Mine looking southwards. The mine is visible near the bottom right hand corner. (Photograph by B.P. Thomson)

shaft) was reported to be 270ft. deep with levels at 34, 58 and 170ft. and the northern shaft (engine shaft) was reported to be 80ft. deep with levels at 18 and 45ft. A considerable amount of stoping was carried out but most of this has now been filled with tailings. Plates 19 and 20 are aerial views of the mine showing the ruins of the crushing plant and smelter. The unconformity at the base of the Umberatana Group is clearly visible.

Spring Creek Mine:

This copper mine is situated about five miles south of Wilmington on the eastern limb of the Alligator Syncline. It is located in the Tindelpina Shale Member which here rests disconformably on the thick Rhynie Sandstone. (This sandstone forms the bold ridge of the Mt. Remarkable Range). Immediately north of the mine an important east-west fault downthrows rocks of the lower part of the Umberatana Group against the sandstone.

The mine was worked between 1860 and 1874 and again in the early part of this century. Workings are quite extensive and a crushing plant and smelter were erected indicating that a fair amount of ore was probably mined. Production figures for the mine are not available. In 1917 the Hydraulic Engineers Department commenced pumping of water from the mine into the mains for the surrounding district and the area was reserved from the Mining Act. In 1953 Summers (1955) visited the mine to test for radioactive mineralisation. In his report Summers gave a resumé of the history and geology of the mine and concluded that the mine is in the zone of secondary enrichment and that primary sulphides had not been reached; radioactivity was not significant. A zone of enrichment occurs at the intersection of two lodes. The ore consists of malachite, azurite, native copper and pyrite associated with limonite. The workings consist of an adit driven east to cut the lode and a 132ft. shaft with a crosscut to intersect the adit level. An open-cut in the mineralised zone and underground stoping in this zone constitute the main workings.

Paratoo Copper Mine:

The Paratoo Mine is situated 3 miles northwest of Paratoo R.S. in the core of the Paratoo Anticline. Mineralisation is of a stratiform type in well laminated, dark-grey siltstones of the Burra Group and consists chiefly of malachite with minor cuprite. Contorted and brecciated diapiric rock, mainly carbonates, has intruded the Paratoo Anticline just to the north of the mine. Plugs and dykes of diorite intrude the diapiric material.

The original mine consisted of two 70ft. shafts connected by a drive. This work was carried out in the early part of this century but very little ore was extracted. Recently this area has been the scene of intensive exploration by Kennecott Explorations (Australia) Pty. Ltd. Geophysical, geochemical, diamond drilling and rotary percussion drilling programmes were carried out but grades were too low and Kennecott subsequently relinquished the area. The highest grades proved by Kennecott were 25ft. of 0.69% copper between 175 and 200ft. and 19.6ft. of 0.57% copper at 600ft. in two drill holes just to the south of the old workings.

Electro Winning Prop. Ltd. hold four mining leases in the area including the site of the original mine. This company has opened up the old mine with two 20ft. deep open-cuts and proved thin bands of rich malachite and cuprite carrying up to 8% copper interbedded in the siltstones. Some of this hand picked richer ore (believed to be a few hundred tons) has been sent to Port Kembla for processing. The low grade ore removed from the open cuts to expose the richer ore has been left in dumps near the mine.

Nixon (1965) mapped the surface geology and sampled the area for the Electro Winning Company. He concluded from surface sampling that an average grade of 1% copper could be expected in the mineralized zone. Nixon (op. cit.) discussed the genesis of the deposit at some length and infers that the deposit is of epigenetic type with some grains of malachite of allogenetic origin.

A classified report by A.H. Blissett (1966) points out that much of the copper is stratiform and that the deposit is generally of relatively low grade, containing bands, lenses and pods of richer ore.

Other copper mines in the survey area which have produced small quantities of copper (no production figures are available) include: Rhonda Mine 4 miles north-northeast of Carrieton; Slatey Rock Mine 7 miles southwest of Cradock; Boolcunda Copper Mine about 1 mile due east of the Boolcunda Triassic Basin; Great Gladstone Mine 10 miles southeast of Quorn; Penn Mine 3 miles north of Oodlawirra; Medina Mine 7 miles north of Oodlawirra, and the Red Hill Mine 14 miles northeast of Belton.

Gold

Gold from structurally controlled vein type deposits has been mined in the Waukaringa and Mt. Grainger areas of ORROROO. Placer deposits of gold associated with gold bearing quartz veins in the Waukaringa area occur to the east of the survey area at Teetulpa. Both areas were worked during the latter part of the nineteenth century and both worked at an overall financial loss.

Waukaringa Goldfield:

The deserted township of Waukaringa lies about 20 miles north-northeast of Yunta in the east of the survey area. Several gold mines occur just to the north of the town along an east-west ridge of fine-grained feldspathic sandstone which dips southwards at 30° into the shallow, west plunging Waukaringa Syncline. This sandstone is an unnamed member of the Tapley Hill Formation and occurs at the top of the formation immediately underlying the Tarcowie Siltstone. Gold bearing quartz veins follow the strike and dip of this sandstone which thins to the east and west from a maximum of approximately 50ft. in the town area. Quartz veins die out to the west corresponding with the the thinning of the sandstone. At the Ajax Mine, 7 miles south-southwest of the Waukaringa mines, similar gold bearing quartz veins are associated with the same sandstone unit, which here dips north on the southern limb of the Waukaringa Syncline. The intimate association and similar orientation of the quartz veins and sandstone unit indicate probable structural control of mineralisation.

The Waukaringa Goldfield includes two large mines, the Alma and Victoria and the Alma Extended (later "Glenunga Mine"), and several smaller mines and prospects. At its peak the Alma and Victoria Mine employed 140 men and treated 300 tons of ore per week. Gold occurs with pyrite, arsenopyrite and calcite in quartz veins upto 5ft. wide; rich pockets of ore occur throughout the veins probably in oblong patches. Approximately 23,000oz. of gold with an average grade of 16dwt. 20grs. per ton were obtained from the Alma and Victoria Mine. Unfortunately no production figures are readily available for the Alma Extended Mine but production was probably considerably less than the Alma and Victoria.

Workings at the Alma and Victoria Mine are extensive with 12 shafts and 6000ft. of drives. Five of the shafts are underlie shafts following the dip of the vein (approximately 30° south), the deepest of these being 1180ft. A 995ft. deep shaft with various levels from which some driving, crosscutting and stoping were carried out forms the main workings of the Alma Extended Mine. The shaft was vertical for the first 470ft. and then turned to 32° from the horizontal to become an underlie shaft following the dip of the vein. The ore was crushed, roasted and amalgamated at the mines.

The workings at the Ajax Mine comprise several small shafts and drives; the main shaft is 355ft. deep and underlies the lode. The primary sulphides occur at the 240ft. level in the main shaft, approximately 110ft. below the surface.

Mt. Grainger Goldfield:

The Mt. Grainger Goldfield is situated north of Oodlawirra in the nose of the Mt. Grainger Anticline. The field consists of one large mine, the Mt. Grainger Mine, and several smaller mines including the Medora, Golden Junction, Heather Bell, Aureous Line and the Dustholes. Most of the mines and prospects occur in the Appila Tillite but the Aureous Line is located in the Tarcowie Siltstone and the Dustholes at the base of the Gumbowie Arkose Member. The Mt. Grainger Mine is 6½ miles north of Oodlawirra and the Dustholes 2 miles north-northwest of the latter mine. The field was worked between 1894 and 1916 and total production was approximately 3,600oz. of gold averaging 9.9dwt. per ton, of which the Mt. Grainger Mine produced approximately 2,400oz.

This goldfield has been the subject of reports by Jack (1913), Segnit (1938, 1939), Hiern (1963a), Fairburn and Nixon (1966) and Wright (1966). Jack mapped the geology of the area and examined all accessible workings; he concluded that mineralisation had been controlled by structure and that veins along bedding-slip planes were the most likely to persist at depth. Segnit suggested that the Golden Morn Mine (near the Dustholes Mine) was located in a crush zone of an important fault, this fault is one of a complex series that Segnit proposed to duplicate the tillite, and its validity is doubtful. Fairburn and Nixon concluded that most of the gold production in the Mt. Grainger Mine was from a zone of hydrothermal wall rock alteration which was structurally controlled by local directions of folding and shear jointing and stratigraphically controlled by an arkosic tillite unit. Wright emphasized that the strongest mineralisation in the area occurs at the base of the tillite in a fractured sandstone-quartzite overlying impervious siltstones and shales. He also suggested that the source of hydrothermal mineralisation was the andesite dykes in the Mt. Grainger Diapir southeast of the goldfield.

Manganese

Several small manganese deposits occur on ORROROO centred mainly in the Carrieton area. Some of these deposits were worked towards the end of the last century and have been summarised in Brown's Record of Mines. A few of the deposits were reworked in the early part of the Second World War but production was only in the order of a few thousand tons of ore. Total production of manganese ore, primarily pyrolusite associated with manganite and psilomelane probably with a grade between 30 and 50% manganese, was in the order of 10,000 to 20,000 tons. A short summary of the Boolcunda and Muttabee manganese mines is given below.

Boolcunda Manganese Mine:

This mine, formerly known as the South Australia Mine, is situated 12½ miles north-northwest of Carrieton on the eastern limb of the Urconda Syncline. The mine consists of several open cuts along four manganiferous lodes which are parallel to the strike of the red brown siltstones and sandstones of the Elatina Formation in which the deposit occurs. The lodes are between 2 and 9ft. wide and consist of pyrolusite, manganite and psilomelane. When the mine was first opened up (1832-3) it was worked by five vertical shafts, a 140ft. long tunnel and drives totalling 280ft. Production was reported to be 3000 to 4000 tons per annum in 1890. The mine was worked again in a small way between 1938 and 1940 and produced a little ore averaging 44% manganese, though samples taken in 1938 by the Inspector of Mines (A.T. Armstrong in the Mining Review No. 69) showed grades between 18% and 35% manganese.

Muttabee Manganese Mine:

This mine is located 9 miles west-southwest of Carrieton on the eastern limb of the Horseshoe Syncline. The mine was probably first worked in the latter part of the 19th century and was again worked spasmodically between

1940 and 1949 when 2,015 tons of ore averaging 50% manganese were produced. Mansfield (1949) and Ridgway (1950) inspected the mine; Ridgway produced a map of the surface geology and mine workings. Both concluded that the manganese ore had replaced "marl and earthy lime" filling solution cavities within a sandy dolomite (Etina Formation) and, in places, also replaced the dolomite itself. No further reserves were found. The dolomite thins out rapidly to the north and south thus limiting the area of possible cavity filling and dolomite replacement which has produced this deposit.

Iron Flux

Iron flux has been mined at several localities on ORROROO, the most important deposits are Donnelly's Ironstone Quarries and the Oodlawirra Flux Quarries. Total production amounted to approximately 38,000 tons, all of which was used for fluxing lead ore from Broken Hill at the Port Pirie smelters of the B.H.P. Company. The quarries were worked in the latter part of the 19th century and the first few years of this century until the richer deposits at Iron Knob were opened up in 1903. Jack (1962) and Whitten (1964, 1966) have discussed these areas in comprehensive accounts of the iron ores of South Australia. Whitten has prepared detailed maps of Donnelly's Ironstone Quarries and the Oodlawirra Flux Quarries.

Oodlawirra Flux Quarries:

These quarries are situated 4 miles north-northeast of Oodlawirra in the southern part of the Mt. Grainger Diapir. The ore is predominantly limonite with minor hematite; in places the limonite is siliceous and forms prominently outcropping "blows". The workings consist of a series of open cuts and pits from which 18,000 tons of + 51% iron ore was extracted. A little ochre (?50 tons) was later extracted from one of the southern quarries. A tramway connected the quarries with the Broken Hill-Port Pirie narrow gauge line. Whitten (1964) estimated reserves at 20,000-50,000 tons at approximately 51% iron.

Whitten (op. cit.) believes that the deposit is a surficial replacement of favourable brecciated beds related to Tertiary and Recent weathering of the existing land surface. Approximately 1½ miles south of the southern quarry an old surface (shown as Tertiary on ORROROO) stands isolated above the present alluvial flat at a similar height to the limonite of the quarries. It is suggested that the replacement at the quarries took place during the formation of this surface and is of probable Tertiary age.

Donnelly's Ironstone Quarries - Comstock Mine:

These quarries are located 12 miles north of Quorn in the keel of the Mt. Arden Syncline. The ore consists of scattered outcrops of limonite and hematite which has replaced shales and siltstones of Lower Cambrian age. Whitten (1964) suggested that the deposit was related to a former land surface. Production was 17,500 tons of ore with a grade probably around 50%. Jack (op. cit.) estimated reserves in the order of 300,000 tons, later Whitten (1964) agreed with this figure and gave a possible upper limit of 350,000 tons with a probable grade of 50% iron.

Pekina:

Limonite deposits cap a few small hills in the Pekina Syncline just to the south of Pekina Township. These deposits are believed to be related to an old Tertiary surface and are shown as Tertiary outcrop on ORROROO. Jack (1922) stated that several thousand tons of iron flux were sent to Port Pirie from a limonite capping 3 miles south of Pekina. The grade was very variable.

Devils Chimney:

This deposit, which consists predominantly of micaceous hematite with minor limonite is situated 3 miles east of "Yalpara" on the possible extension of the Paratoo Fault (Fig. 4). Crawford mapped the deposit in 1955 and laid out a diamond drill hole. Whitten (1961) supervised the drilling of two holes totalling 558ft. 6 ins. which proved not more than 5,000 tons of specular hematite (approximately 55% iron) per 100ft. strike length per 100ft. depth. Strike length is only in the order of a few hundred feet, consequently the deposit was considered too small for further interest. Whitten (1966) thought the deposit was situated within a diapir. Recent mapping has neither proved nor disproved this theory as outcrop is poor and the area is shown as surficial deposits on ORROROO.

Non-Metallic Mineral Deposits

Rock Phosphate

Phosphorite has been mined at several localities in the south-central and central parts of ORROROO. The most important deposits are situated 2 miles south of Orroroo, 2½ miles southeast of Tarcowie, 1 mile south-southeast of Pekina and 5 miles north-northeast of Johnburgh. The deposits were worked in the early part of this century; production figures are not readily available but total production must have amounted to only a few thousand tons of phosphorite with a grade of possibly 15-25% P_2O_5.

Jack (1919) discussed these rock phosphate deposits and pointed out that they are usually associated with limestones and that they are irregular in shape with little strike length. Such features, he suggested are inconsistent with a primary bedded deposit. Jack believed the deposits were formed by replacement of limestone at favourable localities by percolating groundwater containing phosphoric acid. He suggested that favourable conditions would exist when drainage, possibly associated with a Tertiary surface, was concentrated in areas of fractured limestone.

Brook (1962) mapped the geology of the phosphorite deposits on ORROROO and also produced a map of the regional geology in which these deposits are located. Brook thought the phosphorite was a primary bedded deposit (up to 9ft. wide with 20-30% P_2O_5) associated with the Brighton Limestone. Breccias are commonly associated with the phosphorite and Brook suggested that they may have resulted from infilling of cavities which formed by removal of the phosphorite by solution. Brook suggested that economic grades of phosphorite would exist below the zone of solution cavities and laid out two drill holes to test this hypothesis. Later drilling at the Orroroo deposit did not confirm Brook's suggestion as grades were low.

Forbes (1960) sampled the phosphate deposits at Tarcowie, Orroroo and Pekina and found average grades in the quarry faces to be 16% P_2O_5 at Tarcowie and 12% P_2O_5 at Orroroo. Forbes also prepared a geological map of the Pekina area showing results of surface sampling of the Pekina phosphate deposit.

A recent survey by the Exploration Services Section of the Department of Mines with a sensitive, vehicle-mounted scintillometer in the Tarcowie, Pekina, Orroroo area has shown localities with radioactivity higher than background (possibly associated with uranium phosphate) at several horizons in the Umberatana Group.

Deposits of guano in caves in the Etina Formation along Buckalowie Creek, 9 miles east-northeast of Belton, were worked in the last century. No production figures are available. Speleologists from the University of Adelaide report that the caves are quite extensive but little guano is left.

Magnesite

Thin bands of sedimentary magnesite (generally a conglomerate) occur within the Skillogallee Dolomite throughout the Adelaide Geosyncline and occur within this unit on ORROROO. Magnesite has been worked in the Port Germein Gorge and at Johnburgh on ORROROO and at Saltia on AUGUSTA. The Port Germein Gorge deposit was worked spasmodically from 1947 to 1956 by the B.H.P. Co. Ltd. and produced 1255 tons which was used between 1940 and 1953 as a refractory lining in steel furnaces. Production from Saltia totalled 2423 tons, the bulk of which was used by manufacturing chemists in Adelaide. King (1953) mapped these two areas for the Port Pirie Chemical Plant and concluded that their requirements of pure magnesite could be met from either deposit. Sampling of the workings carried out by King gave an average MgO content of approximately 45%. The magnesite deposit at Johnburgh is 2½ miles northwest of the town in the core of the Oladdie Anticline. Segnit (1940) mapped this deposit and estimated proved reserves to be only 1840 tons of magnesite. R.K. Johns summarized these deposits in Bulletin 38 (Johns 1963).

Forbes (1961, p. 218) suggested that the magnesite beds were deposited in a paralic environment. During periodic regression of the sea the magnesite was eroded and redeposited as bands of conglomerate in deeper water.

Coal

Triassic coal occurs in two small basins, the Springfield and Boolcunda Basins, in the east of the Willochra 1:63,360 Sheet. The combined area of the basins is only in the order of 4½ square miles and maximum thickness of Triassic sediments in the basins is less than 3,000ft. (The stratigraphy of the Triassic sediments has been discussed in a previous section). A stratigraphic bore drilled during 1958 in the Springfield Basin (Johnson 1960) revealed seams of high ash coal; subsequently a series of shallow holes were drilled to test for an economic open-cut coal deposit. This drilling revealed a number of thin seams (1 to 2ft. thick) and one seam 12ft. thick which has 30% ash and only a limited areal extent. W. Johnson (op. cit.) concluded that no economic coal deposits were present.

Clay

Booleroo Centre:

This clay deposit is situated 3 miles east of Booleroo Centre in siltstones and sandstones of mid-Torrensian age. The deposit was first worked in the early part of this century by the B.H.P. Co. Ltd. for use as a refractory bonding clay. In recent years the deposit has been worked for pottery clay. The clay has been described (Gaskin and Samson 1951) as a plastic fine-grained kaolinite associated with fine quartz.

Wade (1952) inspected this deposit in 1951 and estimated reserves at 37,000 tons of white clay. Gibson (1954) recalculated reserves at approximately 32,000 tons after the deposit had been drilled in 1953. Physical and chemical examination of the clay (Ellerton, 1953) indicated that the salt content was too high for high-grade refractory use but after removal of the salt the clay might be incorporated in whiteware pottery. Hiern (1957) has more recently visited the deposit and considers that further drilling is required to establish the measured reserves.

Simmonston:

This deposit is located on the east bank of the Willochra Creek approximately 1½ miles north-northwest of Simmonston. Miles (1954) inspected the deposit and recommended further investigation including systematic sampling. This was carried out by Shepherd (1954) who calculated reserves of clay at "7200 cu.yds. per horizontal yard over 1200yds. along the creek bank". The clay, which consists of decomposed Lower Cambrian shale, is not suitable for whiteware pottery or refractories but could be used for brick manufacture.

Other clay deposits on ORROROO listed by Gaskin and Samson in Bulletin No. 28 (1951) are located near Willowie, Kanyaka, Paratoo, Oodlawirra and Peterborough. Clay also occurs northwest of Yatina (Hiern, 1957).

Barite

Veins of barite have been worked in the north bank of Oladdie Creek approximately 3½ miles west-southwest of Johnburgh. The deposit is located in a crush zone in the core of the Oladdie Anticline. A diapir has been intruded along an important east-west fault just to the south of the deposit. The deposit was worked about 40 years ago but the barite was only of low grade due to pink and brown colouration and little ore was produced.

Constructional Materials

Diorite

In the course of geological mapping of the Paratoo 1:63,360 Sheet plugs of diorite intruding diapiric breccia in the core of the Paratoo Anticline were recognised. This diorite was mapped by Hiern (1965) and drilled by the Department of Mines as a source of ballast for the S.A. Railways. The Highways Department contracted with the S.A. Railways to extract the diorite for road metal and during 1966 large quantities of the rock were quarried and crushed. Unfortunately the diorite decomposed rapidly on exposure to the atmosphere and it was not entirely suitable for its intended use; large quantities of the crushed material are still standing near the quarry.

Quartzite

Hiern (1963, 1965, 1966) has investigated several quartzite deposits on ORROROO as sources of ballast for the S.A. Railways. One investigation (1966) approached the problem of locating suitable ballast sites on stratigraphical principles and a reconnaissance map showing outcrops of suitable quartzites was compiled. One of these quartzites (probably the Minburra Quartzite) is being worked for ballast for the S.A. Railways about 3½ miles south of Nackara. Another quartzite deposit, situated about 2 miles northeast of Black Rock (again probably the Minburra Quartzite), was investigated by P.J. Russ (1966) and is also being worked as ballast for the S.A. Railways.

Road Metal and Rubble

Little geological advice has been given on locating materials for graded road construction on ORROROO, however, Hiern (1964) mapped the geology of the Orroroo and Tarcowie area and suggested sites for potential road metal quarries.

Calcreted gravels (kunkar) and partly weathered shales and siltstones are commonly used as road rubble on ORROROO. In the west of the survey area siltstones from the lower part of the Willochra Formation have been used extensively for this purpose.

HYDROGEOLOGY

As the rainfall of the ORROROO area is low (see Fig. 3) the supply of groundwater for stock is of considerable importance. Groundwater salinity is fairly high in the area and usually increases to the north and east with decreasing rainfall. Salinity of shallow groundwater usually varies between 1,000 and 10,000 p.p.m. depending on the position of the bore in relation to intake of fresh water. Pressure water occurs in the Willochra and Walloway Basins; salinity of this water is less variable and usually lower than shallow non-pressure groundwater.

The ORROROO area can be divided into several broad hydrogeological entities: the Willochra Basin, the Walloway Basin, the Koonamore Plain and basement outcrop. These divisions are shown on Fig. 2.

Willochra Basin

The Willochra Basin is situated in the west of the survey area and forms a north-south valley approximately 50 miles long with a maximum width of ten miles. Up to 600ft. of Cainozoic sediments have been deposited on folded and faulted Adelaide System rocks which form the floor of this basin. Pressure water occurs in Tertiary silty sands at depth in the basin. Bores near the centre of the basin which have penetrated these sands yield a small flowing supply. Shallow non-pressure groundwater occurs throughout the area but supply is variable and is often saline.

E.P.D. O'Driscoll (1956) carried out a hydrogeological survey of this basin in 1953-4 and concluded that pressure water suitable for stock occurs practically throughout the area. The salinity of this water increases from south to north and is lowest at the foot of the Mt. Remarkable Range where the salinity is just over 1,000 p.p.m. To the north the salinity increases to about 7,000 p.p.m. The lower salinity in the south is due to recharge from the Mt. Remarkable Range which receives an average rainfall of 22 inches per annum. Rainfall to the north and east falls rapidly to less than 12 inches per annum and the aquifer achieves little recharge away from the Melrose Wilmington area.

The aquifer is thickest in the southern part of the basin and thins to the north over a basement high. Permeability of the aquifer is low and movement of recharge water is slow; O'Driscoll estimated maximum yield to be about 150,000 to 250,000 gallons per day. As the recharge is chiefly in the south of the basin and as the aquifer is thickest here and has low permeability it is apparent that the pressure water will only be of importance in the south.

Walloway Basin

This basin is situated in the central and south-central parts of ORROROO and forms a narrow north-south valley approximately 40 miles long and up to 8 miles wide. Pressure water occurs in Tertiary silty sands at depth between Orroroo and Johnburgh, but has not been fully exploited owing to blockage of the bores by the fine silts of the aquifer. Average salinity of this water is 1,800 to 2,000 p.p.m. Shallow non-pressure groundwater occurs throughout the basin but supply is variable and salinity often high; average salinity of 110 samples (Sprigg 1950) was 3,800 p.p.m. but salinity reaches 12,000 p.p.m. in some bores.

Sprigg (op. cit.) carried out a hydrogeological survey of the area in 1949 and concluded that the pressure waters of the basin are probably fossil and may be connate thus limiting the amount of water available. A gravity survey of the basin was undertaken by the Bureau of Mineral Resources in 1950 (Plan Ref. 50-449) from which Sprigg postulated that the western side of the basin was delineated by faulting. Sprigg suggested that the basin was a "graben" structure which may or may not have post-dated Tertiary sedimentation in the basin. Absence of gravels in these sediments was taken by Sprigg to indicate probable post-depositional block-faulting of the basin. No evidence of Tertiary faulting was found in this area during recent fieldwork for the Orroroo 1:250,000 Sheet.

Hillwood (1964) has recently carried out further hydrogeological investigations in the area and has supervised drilling of a bore to tap pressure water about 2 miles northwest of Orroroo. This bore has been successfully screened to prevent blockage by fine-grained sand and silt.

Koonamore Plain

This plain is located in the northeast of the survey area on the Koonamore 1:63,360 Sheet and is about 20 miles long by 10 miles wide elongated in an east-west direction. Pressure water has not been found in the area, probably because very few bores have been drilled and also because existing bores are shallow. This locality could well have been an area of Tertiary deposition in an intermontane basin similar to the Willochra and Walloway Basins. If this was the case the area must be considered as a possible source of pressure water.

It has been pointed out in a previous section on physiography that surface drainage from a large area reaches the Koonamore Lakes. This drainage collects in the southernmost lake and in a season of average rainfall provides good stockwater. In a season of high rainfall surface water collects in other lakes in the area but soon deteriorates due to lack of recharge.

Shallow non-pressure water probably occurs throughout the area, but owing to the lack of bores has not been proved. Bores that have been drilled have a salinity of about 5,000 p.p.m. but like other shallow water the salinity of future bores in the area could vary enormously.

Basement

Shallow non-pressure water occurs in areas of basement outcrop but supply and quality are very variable. Supply depends on the permeability of the rock and quality usually depends on the position of the bore in relation to local freshwater intake.

AIRBORNE MAGNETIC AND RADIOMETRIC SURVEY

An airborne magnetic and radiometric survey of ORROROO was carried out by the Bureau of Mineral Resources in 1965. Total magnetic intensity profiles, radiometric profiles and a magnetic interpretation map of the area were prepared by Tipper and Finney (1965). A series of 1:63,360 and a 1:250,000 total magnetic intensity contour maps have been prepared by staff of the Department of Mines from the results of the survey.

Over much of the ORROROO area, especially the southeast, the magnetic expression of the deep basement is masked by near surface rocks. This masking effect increases towards the southeast and Tipper and Finney (op. cit.) suggested that it was due to either magnetic disturbance from metamorphised rocks, possibly associated with a subsurface igneous body, or to a regional increase in sedimentary iron. Field work supports regional metamorphism as the masking effect. Tipper and Finney divided the area into six zones of specific magnetic character and analysed individual zones.

In the northwest of the survey area magnetic disturbance from surface rocks is low and it is possible to calculate depth to magnetic basement (pre-Adelaidean basement). The value obtained by Tipper and Finney was about 25,000 to 30,000ft. which fits quite well with expected thickness of the Adelaidean in this area. Tipper and Finney postulated a rise in basement towards the southwest but this has not been supported by a recent gravity survey carried out by the Department of Mines which revealed a substantial thickening of the Adelaidean in this area. Apart from a value of 14,000ft. to magnetic basement in the extreme northeastern corner of the survey area no further depth calculations could be carried out.

One of the zones established by Tipper and Finney is characterised by a negative anomaly which is associated with the Tindelpina Shale Member in the southeast of ORROROO. It was found that the negative values were only obtained on east-dipping beds of this shale member and it was suggested that the shales (which contain minor pyrrhotite) were remnantly magnetised prior to folding, such that the polarity of the present magnetic field from the shales is a function of geological dip.

A zone of high positive anomaly, mainly over 600 gammas, is associated with a ferruginous siltstone at the base of the Appila Tillite in the nose of the Waukaringa Anticline. Another zone with positive anomaly mainly less than 100 to 200 gammas is centred around the nose of the Waukaringa Anticline. This zone was suggested by Tipper and Finney to be due to local metamorphism associated with an intrusive igneous body, possibly a granite. If a granite exists at depth in this area the gold bearing quartz veins in the Waukaringa region are probably related to it.

Profiles of radioactive intensity recorded by an "inboard" scintillometer were prepared by Tipper and Finney (op. cit.). Difficulty was experienced during recording as it was found impracticable to maintain a constant ground clearance necessary for accurate results. Contours of radioactive intensity tend to cut across stratigraphic boundaries on ORROROO. The general level of radioactive intensity was 40 counts per second but was higher in the east of the survey area in the zone postulated from magnetic evidence to be underlain by a granite. The Burra Group generally has a slightly lower radioactive content than the Umberatana And Wilpena Groups.

GRAVITY SURVEY

A gravity survey of BURRA and the southern part of ORROROO has recently been carried out by the Department of Mines and a contour plan of the Bouguer anomalies drawn. This survey has revealed an elongate north-south trough along the western part of the map area. The deepest part of the trough is located in the Gladstone region. This trough coincides with a proved thickening of the Burra Group in the area (see cross-section on the published map) and indicates a probable thickening of Willouran rocks.

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APPENDIX I

Petrological descriptions of samples representative of rock units on ORROROO by staff of the Australian Mineral Development Laboratories. Locations of samples are shown on Fig. 10.

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1. (TS.17293, P82/66) Rhynie Sandstone
(Description by D. Smale)

This is a massive feldspathic quartzite in which secondary overgrowths have caused the formation of a complete mozaic. The specimen is somewhat mottled, but generally has a colour of 1 OR 6/2 (pale red). The grain size is 0.08 to 0.4 mm. Feldspar forms about 15% of the rock, and is mostly microcline; some is string-microperthitic. Both quartz and feldspar grains have secondary overgrowths; rarely the original well rounded shape of the grains can be discerned. Rare small ferruginous grains having octagonal cross-sections are scattered irregularly through the rock; their presence causes the mottling of the hand specimen.

2. (TS.17627, P470/66) Rhynie Sandstone
(Description by D. Smale)

This is a fairly massive, yet distinctly stratified, poorly sorted argillaceous orthoquartzite with a colour of 1 OR 7/2 (very pale red). The rock consists of a mozaic, about 20% of which consists of argillaceous or empty units; the rest is quartz, and the grain size is 0.06 to 1.1 mm. A few grains are altered microcline that has been completely sericitized. Muscovite flakes are rare. Rounded opaques are fairly common accessories, rounded rutile, subrounded clear zircon and brown zircon are less common accessories. Much of the rock is somewhat dirty and stained, especially in the regions of greater concentration of heavy minerals.

3. (TS.17376, P137/66) Cradock Quartzite
(Description by D. Smale)

This is a massive, fairly coarse feldspathic quartzite (nearly arkose) in which secondary overgrowths on the grains have been sufficient to form a complete mozaic. The overgrowths on the quartz are more pronounced than those on the feldspar, though both are present. The grains are well-rounded. The colour of the hand specimen is 10YR7/3 (greyish-orange). The grain size is 0.15 mm to 1.0 mm. Feldspar forms 10 to 15% of the rock, and most is potassic, but some is sodic plagioclase. Numerous cavities are present, the size of several individual grains, and are partly filled with slightly ferruginous clay.

4. (TS.17632, P475/66) Minburra Quartzite
(Description by D. Smale)

This is a massive, well-sorted orthoquartzite with a colour of SY5/0.5 (olive-grey) and a grain size of 0.1 to 0.3 mm. The rock is a mozaic, and considerable recrystallization has taken place at intergranular boundaries. The quartz is weakly stained. The original grain shapes are not detectable, but the present mozaic units are fairly equant. Rhombs and irregular masses of dolomite somewhat smaller than the grain size of the rock form 3 to 5%. A little clay is present in aggregates. Irregular opaques and rounded tourmaline are accessory. The tourmaline is blue or brown, and though the grains are rounded, very small projections of uncertain origin are present.

5. (TS.17298, P87/66) Auburn Dolomite
(Description by D. Smale)

This is an olive-grey (5Y4/1) siltstone with a grain size of 0.01 to 0.1 mm. It is slightly bedded, but the hand specimen has generally a fairly massive appearance. The framework forms about 50% of the rock, and has the composition of an arkose. Most of the feldspar is potassic, but a little is Plagioclase. A few muscovite flakes are present, and opaque grains form about 2% of the framework. The matrix is virtually unidentifiable optically, and appears only as a cloudy mass; clay (with low birefringence) and cryptocrystalline silica are probably the main constituents.

6. (TS.18176, P682/66) Tillite
(Description by A.B. Simpson)

This rock is obviously clastic in origin, for it consists of sub-angular fragments of various sizes and compositions set in a very fine-grained matrix which is pinkish-brown in colour. No bedding is descernible in the hand specimen.

In thin section, the fragments in the rock are seen to consist mainly of quartz. They range from 0.01 mm to about 1 mm in size, the smaller fragments being clearly angular while the larger have sub-rounded outlines. Feldspars are present also, but do not show such variability in size. Twinned plagioclase is the most commonly occurring variety, but micorcline fragments were also noted. Fragments of carbonate mineral, and of rock entirely composed of carbonate, are distributed throughout the rock, but the amount is relatively minor. X-ray examination showed that dolomite alone is represented. Some of the fragments are of chert, others are of chlorite, while still others appear to have been igneous types originally. The largest fragment in the section (18 mm across) is composed of feldspathic sandstone.

The matrix in which these coarse constituents occur in random orientation is very fine-grained (less than 0.01 mm) and appears to consist of chlorite, abundant granules of hematite, scattered shreds of muscovite, and tiny grains of a carbonate (dolomite). Some grains of green pleochroic tourmaline occur in very minor amount.

Estimation of mineral composition is not particularly significant in the case of a sediment showing such a wide range of grain sizes, but was made as follows:

	Vol %
Quartz	50
Feldspar	5
Dolomite	5
Chlorite	35
Hematite	5

The rock appears, from its unsorted and unstratified nature, together with the variety of composition of its clastic constituents and the fineness of its matrix, to be a tillite.

7. (TS.18211, P717/66) Tillite
(Description by A.B. Simpson)

This is a gritty grey rock containing a variety of poorly sorted fragments, the largest of which exceeds 14 mm in length. The fragments are of varied composition. No bedding is obvious in the rock, but a very poorly developed fabric is to be seen in hand specimen.

Under the microscope, the rock is seen to consist of fragments of various sizes and compositions set without marked orientation in a very fine-grained matrix. These fragments vary in shape from rounded to angular, and in size there is a continuous gradation from that of the matrix constituents (average about 0.02 mm) up to the maximum noted in hand specimen. Some of the fragments are monomineralic (quartz, plagioclase and microcline feldspar, calcite) while others are of lithic character (quartzite, limestone, sericitized rock, and feldspathic igneous rock). The matrix consists mainly of quartz, with calcite the next most important mineral. Sericite is also present in lesser amount, and the sub-parallel arrangement of its flakes and of a few of the more elongate quartz and calcite grains in the matrix impart a rudimentary fabric to the rock. A few grains of an opaque mineral occur in the matrix together with a very small number of zircon and tourmaline grains.

The mineral composition of this clastic sediment is estimated to be:

	Vol %
Quartz	75
Calcite	10
Feldspars	5
Sericite	7
Opaque mineral	2
Accessories	1

The rock appears to be a ?tillite the matrix of which has been recrystallized. Its calcareous content is presumably an original feature.

8. (TS.18212, P718/66) Sandstone in Appila Tillite
(Description by A.B. Simpson)

This is a medium-grained, porous arenaceous sediment, yellow in colour and rather friable. It is distinctly bedded, there being slight colour variations from one bed to the next. Some whiter bands react with acid, but the bulk of the rock does not.

Essentially this rock is composed of a mosaic of quartz grains, but a distinct mineralogical banding is superimposed on this mosaic texture. The chief constituent, quartz, occurs as grains of approximately polygonal outline in close contact with one another, there being virtually no cement visible in most parts of the mosaic. The average size of the grains lies in the region of 0.25 mm. Two feldspars are represented in the rock - microcline and plagioclase - and appear to be approximately equal, though minor, in amount. Lithic fragments also were observed. They consist of chert and a rock completely replaced by a fine-grained aggregate of sericite. Like the feldspar grains, they are not confined to any particular part of the rock. This is not true of the calcite present, which occurs interstitially to the fragments only in certain bands. In some places ?limonite is associated with this carbonate, but occurs also in rather variable amount throughout the rock. Some of the bands are defined by somewhat higher concentrations of this mineral. A few shreds of muscovite, possibly clastic in origin, are scattered through the mosaic. Tourmaline, zircon and an opaque mineral occur as accessories in the sediment.

The proportions of the various minerals present are approximately:

	Vol %
Quartz	65
Feldspars	3
Calcite	5
?Limonite	8
Lithic fragments	7
Muscovite and accessories	2
Voids	10

The rock may be named a calcareous quartzite. There is no evidence of the rock having suffered any metamorphism.

9. (TS.18178, P684/66) Tapley Hill Formation
(Description by A.B. Simpson)

Dark blue-grey in hand specimen, this rock is very finely bedded or varved. It is very fine-grained throughout.

In thin section, the main mineral in the rock is seen to be quartz, which occurs in most cases as angular grains, with sub-angular in lesser amounts. There is some size variation but the average falls about 0.02 mm. Feldspar grains are present also, and as previously noted are almost entirely composed of twinned plagioclase, with minor amounts of microcline in evidence. Grains of carbonate which failed to respond to staining tests are scattered in fair amount through the rock. This was shown by X-ray methods to be calcite and dolomite, with calcite the more abundant of the two.

Shreds of muscovite are fairly common and tend in places to lie parallel to the banding in the rock, whereas in others their orientation appears to be random. Chlorite occurs intergrown with this mineral, and may be present also in the very finely divided and abundant cementing material, along with ?clay minerals. Opaque minerals are present in small amounts, some of the grains showing euhedral crystal outlines. Zircon, ?sphene and tourmaline are the accessories.

The fine banding in this sediment indicates some sort of rythmic deposition. The dark bands are characterized by a greater proportion of clay minerals in very fine form, but throughout all of these bands quartz and feldspar grains of the normal dimensions occur without disruption of the bedding. There is also a complete absence of grading. These observations indicate that the banding is not due to a straightforward process of varve formation.

The approximate mineralogical composition of the sediment is as follows:

	Vol %
Quartz	60
Feldspar	2
Calcite and dolomite	5
Muscovite	6
Chlorite	5
?Clay minerals	20
Opaques and accessories	

The rock may be termed a carbonate-bearing siltstone.

10. (TS.18236, P742/66) Tapley Hill Formation
(Description by A.B. Simpson)

In hand specimen, this rock is very fine-grained and has a very distinct fine fabric. It is almost black in colour. Vigorous effervescence is produced by application of dilute acid.

Microscopically, the specimen bears a certain similarity to P745/66, but is texturally different from that rock. Sub-angular grains of quartz and very minor associated plagioclase feldspar are set with some degree of orientation in matrix of phyllosilicate and carbonate minerals. All of the minerals are of similar dimensions, the average size being about 0.02 mm. Sericite and chlorite are fairly prominently represented, and have a moderate degree of parallelism of orientation. Brownish-yellow ?hydrobiotite also occurs in some quantity in association with the other phyllosilicates. Calcite is readily distinguishable by its staining. The dolomite in the rock has a similar occurrence as fairly equidimensional grains, and is stained and rimmed by ferruginous material. Scattered irregular grains of hematite and an opaque mineral were observed in the rock.

The sediment is therefore mineralogically similar to P745/66, but appears to have suffered a slight amount of shearing or similar dynamic metamorphism. This is shown by the fine dark crush lines running through the rock in a common direction parallel to the preferred orientation displayed by the platy minerals.

The rock's composition is estimated to be:

	Vol %
Quartz	60
Plagioclase	1
Calcite	8
Dolomite	10
Sericite	7
Chlorite	5
?Hydrobiotite	8
Hematite and opaques	1

This sample may be considered as a slightly metamorphosed dolomitic siltstone.

11. (TS.18177, P683/66) Tindelpina Shale Member
(Description by A.B. Simpson)

In hand specimen, this rock is a very fine-grained, dark grey shaly variety. It is finely banded, and has a marked lamination which coincides with this banding. Thin veinlets of white carbonate traverse the rock.

Under the microscope, the rock is seen to be composed of angular and sub-angular grains of quartz with sizes sizes ranging from 0.01 mm to 0.04 mm. Similarly sized fragments of plagioclase feldspar occur, but in very minor amount. Grains of carbonate are distributed throughout the rock, and were shown by X-ray analysis to consist of both calcite and dolomite, with the former predominating slightly. The veinlets are of calcite. Plates of muscovite, in places in parallel intergrowth with chlorite, occur in random orientation in the rock. The main cementing medium appears to be very fine-grained ?clay minerals, but in some of the bands iron-staining indicates some of the cement may be ferruginous. Opaque minerals occur in the rock. They tend to be concentrated in some bands, and are almost absent from others. Hematite granules are present in fair amount.

The banding in the rock is due to variations in the proportions of the minerals present rather than actual mineralogical differences, in most cases. The individual bands are of widely varying thicknesses and do not show any discernible grading. The rock cannot therefore be described as varved.

The approximate mineralogical constitution of this rock is:

	Vol %
Quartz	60
Feldspar	2
Calcite and dolomite	3
Muscovite and chlorite	5
?Clay minerals	25
Opaques	5

The sediment is therefore classified as a banded calcareous shale.

12. (TS.18235, P741/66) Tindelpina Shale Member (Description by A.B. Simpson)

Macroscopically, this specimen is a dense, almost black rock with a very fine bedding or lamination. It contains scattered rusty specks, presumably of an iron mineral.

Under the microscope, the rock is seen to be exceptionally fine-grained. All the constituents are less than 0.01 mm in their maximum dimensions. The main mineral is again quartz, sub-angular grains of which are surrounded by orientated flakes of sericite and chlorite. Feldspar was searched for, but was not definitely observed. A greenish ?biotite occurs in association with the other platy minerals, but in lesser amount. Hematite is relatively abundant in the rock. It is present as small irregular grains and stringers which follow the direction of parallelism of the phyllosilicates in the sediment. A few larger individuals occur, and in places accompany, or possibly have been partially replaced by, recrystallized secondary quartz mosaic. The hematite itself appears to have been produced by alteration of a pre-existing iron mineral. A few grains of tourmaline were noted in the rock.

The mineralogical composition of the sample was estimated to be:

	Vol %
Quartz	75
Sericite	8
Chlorite	7
?Biotite	3
Hematite	7

The rock is classed as a ferruginous shale. Some recrystallization has taken place, but is probably ascribable to diagenesis, there being nothing to suggest metamorphic action.

13. (TS.18180, P686/66) Brighton Limestone Equivalent (Description by A.B. Simpson)

In hand specimen, this is a pale blue-grey rock of calcareous appearance. It is extremely fine-grained. Streaks of a pale brown material delineate what appears to be a type of contorted bedding in the rock.

Microscopic examination reveals that this rock is composed mainly of interlocking grains of calcite which are almost all only about 0.01 mm across. Scattered larger plates of this mineral attaining sizes up to 0.07 mm appear to have resulted from recrystallization, and coarser-grained veins of the same carbonate traverse the rock. A minor amount of another carbonate mineral, identified by X-ray methods as dolomite, occurs as scattered grains throughout the rock. Traces of rhodochrosite and ?strontianite were detected also. Sub-angular grains of quartz and twinned plagioclase feldspar have a patchy distribution in the sediment. These range in size from 0.02 mm to 0.07 mm. A few shreds of a colourless micaceous mineral which may be muscovite or talc were also noted. Some ?hematite occurs in small irregularly-shaped grains, and the brownish material which was noted as following the bedding in the hand specimen appears to be merely iron-stained.

The mineralogical composition of the rock may be estimated as:

	Vol %
Calcite	85
Dolomite	5
Quartz and feldspar	7
Other minerals	3

The rock appears to be a limestone of clastic derivation, since fragmental remnants of pre-existing carbonate rock may be distinguished in places in the rock. A certain amount of recrystallization of calcite may have taken place in association with the crumpling of the bedding planes, for some of the coarser patches of that mineral follow the bedding closely in places.

14. (TS.18216, P722/66) Brighton Limestone Equivalent
(Description by A.B. Simpson)

This specimen is a fairly fine-grained dark grey rock of calcareous appearance. It effervesces vigoursly on application of dilute acid. No fabric is discernible in hand specimen.

Under the microscope, calcite is seen to be virtually the only constituent of the rock. Its grains have been recrystallized under pressure, and now lie with their greatest dimension in a common direction. They average about 0.03 to 0.05 mm in size. Coarser plates occur in bands. These, and narrow zones of minutely crystalline calcite possibly representing crush zones, follow the common orientation of carbonate crystals in the rock. A minor amount of quartz and a very few grains of plagioclase feldspar, both of dimensions similar to the average in the rock, are to be seen. They are also elongate in shape and are parallel to the other constituent grains. Some plates of ?dolomite occur in the coarsely crystalline bands in the rock. These, together with ill-defined irregular areas of similar carbonate, may represent incipient dolomitization of the rock. A few grains of an opaque mineral are present.

The composition of the rock is approximately as follows:

	Vol %
Calcite	97
Quartz and feldspar	2
?Dolomite	1

The rock is a limestone which appears to have suffered some recyrystallization under stress, with consequent development of a strong fabric on a microscopic seale.

15. (TS.18182, P688/66) Willochra Formation, lower Unnamed member (Description by A.B. Simpson)

This rock is a pale grey-brown colour. It is very fine-grained and exhibits no fabric of any sort. The weathered surfaces of the specimen give no indication of the nature of the rock.

Under the microscope, the rock proves to be made up mainly of quartz and a carbonate mineral. The quartz occurs as sub-angular grains with an average size of 0.03 mm approximately, which appears to be the average for all the rock's constituents, as it is texturally uniform throughout. Since virtually none of the carbonate in the rock responded to staining tests, X-ray analysis had to be resorted to for identification. This showed it to be almost entirely dolomite. A few calcite grains were detected by staining Minor amounts of detrital muscovite and chlorite were observed randomly scattered throughout the rock, and very fine-grained sericitic material occurs along grain boundaries. A small amount of twinned albite-oligoclase is associated with the quartz in the rock. Irregular to subhedral grains of an opaque mineral, possibly iron-bearing, are fairly abundant, and tiny zircon and tourmaline crystal grains occur as accessories.

The mineralogical composition of the rock is estimated as follows:

	Vol %
Quartz	50
Dolomite and calcite	40
Feldspar	2
Muscovite/sericite and chlorite	2
Opaques	5
Accessories	1

This rock may therefore be classified as a dolomitic siltstone.

16. (TS.18181, P687/66) Willochra Formation, lower Unnamed member (Description by A.B. Simpson)

In colour and grain size, this rock resembles the previous specimen, but differs markedly from it in having a well developed fine bedding which is almost a lamination. Red streaking follows the main bedding planes in places, and fine cross-bedding is clearly observable.

Examination of the thin section reveals that the rock is less rich in carbonate than P688/66. The main mineral is quartz, with a fair degree of uniformity of grain size, the average again falling in the region of 0.03 mm. The grains are angular to sub-angular. They show a tendency to lie with their greatest dimension parallel to the fine bedding in the sediment. A very minor amount of feldspar also occurs in subhedral grains of a size similar to that of the quartz. Twinned plagioclase is the dominant variety present, but some microcline was also observed. Somewhat larger plates of a carbonate mineral occur in moderate amount throughout the rock. X-ray analysis was required to confirm that this is dolomite, but minor calcite was also detected. In the interstices between the clastic components of this sediment is to be found chlorite in very tiny flakes. Some of the larger flakes show anomalous blue birefringence. Sericite is associated with the chlorite. Larger plates of clear muscovite are common and lie in a parallel arrangement, apparently resting on bedding planes. Irregular grains of an opaque mineral, possibly an iron oxide, are distributed throughout the rock but also show a tendency towards concentration on bedding planes. Present in accessory amounts are grains of green pleochroic tourmaline, and rounded grains of zircon and possibly sphene.

The proportions of the various minerals present were estimated as follows:

	Vol %
Quartz	55
Dolomite and calcite	10
Chlorite and sericite	25
Muscovite	3
Opaque mineral	5
Feldspar	1
Accessories	1

No metamorphic effects were observed in the rock, the alignment of some constituents being attributed to sedimentary processes only. The rock may be termed a finely cross-bedded dolomitic siltstone.

17. (TS.18185, P691/66) Willochra Formation, upper unnamed member (Description by A.B. Simpson)

This specimen is a massive, fine-grained sediment which is of a brownish-purple colour. It is very uniform throughout, and possesses no special characteristics observable by the naked eye.

Under the microscope, the rock is seen to be dominantly arenaceous in character. Quartz predominates in the form of angular and sub-angular grains. The sorting of these clastic grains is not perfect. They range in size from 0.01 mm to 0.5 mm., with an average in the region of 0.07 mm. Sub-angular grains of feldspar also occur. These are mainly of twinned plagioclase whose composition was determined as lying on the albite-oligoclase boundary, but a few grains of microcline were observed, and some highly sericitized particles may also belong to the potash feldspar group. Other clastic constituents occurring in minor amounts are muscovite, in colourless detrital flakes, and angular detrital carbonate grains. Opaque minerals, possibly iron-rich, were noted, and a few grains of colourless zircon and greenish pleochroic tourmaline occur in accessory amounts.

The cementing medium in this sediment appears to be composed partly of ?iron oxide or hydroxide minerals, but it may contain also ?clay minerals. This cement is present in fair quantity in the rock.

The mineralogical constitution of this sediment was estimated as follows:

	Vol %
Quartz	70
Feldspar	5
Carbonate	2
Cementing material	20
Muscovite	1
Opaques and accessories	2

The rock may therefore be termed a feldspathic sandstone with a ferruginous cement.

18. (TS.18184, P690/66) Willochra Formation, upper unnamed member (Description by A.B. Simpson)

This specimen is a finely bedded arenacous sediment of coarser grain than P691/66. The bedding planes are defined by faint dark lines which may be concentrations of heavy minerals. In colour, the rock is a pale buff with a slight tint of pink.

Microscopic examination confirms its highly arenaceous character. In this case, the abundant rather angular quartz grains form a well compacted and well sorted mosaic with an average grain size of about 0.1 mm. Within this quartz mosaic occur various types of feldspars. Some are turbid and sericitized, and are presumed to ?potash feldspars. Microcline is plentiful, and twinned plagioclase was also observed in fair quantity. Some of the feldspars contain numerous tiny granular inclusions of hematite, but apart from this occurrence, the mineral is not common in this sample, in contrast to P691/66. Some shreds of muscovite occur interstitially in the mosaic of quartz and feldspar grains, and a very few clastic flakes of brown biotite were noted in a similar mode of occurrence. ?Clay minerals provide the scarce cement for the rock.

Opaque mineral(s) showing subhedral outlines delineate the bedding planes in the sediment. They are present in greater quantity than in the previous specimen. Bluish-green pleochroic tourmaline and partially rounded zircon grains are the only accessories in the rock.

The approximate mineralogical composition of this sediment is estimated to be:

	Vol %
Quartz	60
Feldspars	25
Micas	2
Opaques and hematite	7
Accessories	1
?Clay minerals	5

This rock is markedly different from P691/66. Its texture indicates a moderate degree of recrystallization (most probably only diagenetic), and its content of feldspar minerals is much higher than in the previous samples. This sediment contains sufficient feldspar to be termed an arkose (Pettijohn, 1957, p. 291).

19. (TS.18205, P711/65) Tarcowie Siltstone (Description by A.B. Simpson)

This grey rock is fairly fine-grained and exhibits a finely banded structure due to variations in grain size between successive bedding layers. The sediment appears to be rich in quartz.

In thin section quartz is the main mineral, as suspected from hand specimen. It occurs as angular and sub-angular grains with an average size of about 0.06 mm. A very minor amount of plagioclase feldspar accompanies the quartz. These clastic grains are set in a fairly abundant matrix composed of a fine-grained aggregate of chlorite and sericite flakes. Both minerals occur also as larger plates, possibly of authigenic origin, particularly in the coarser bands in the rock. A very few grains of calcite, distinguished by staining, are present. Opaque mineral grains of small dimensions and sub-rounded outline are scattered throughout the sediment. The usual accessories - tourmaline and zircon - were noted.

The fine banding in the rock is due to a slight variation in grain size, together with an increase in the proportion of phyllosilicate minerals in the fine-grained bands. No grading was seen.

The mineralogical composition of the sediment was estimated as:

	Vol %
Quartz	60
Feldspar	1
Chlorite	20
Sericite	15
Opaques	3
Others	1

The rock is classed as a siltstone. The presence of authigenic chlorite flakes is not interpreted as evidence of metamorphism.

20. (TS.18230, P736/66) Tarcowie Siltstone
(Description by A.B. Simpson)

In hand specimen, this is medium grey in colour and is banded in darker shades of grey. It is fine-grained in both types of bands. Weathered surfaces show that the darker bands are the more resistant. Neither type effervesces with dilute acid.

The thin section reveals that the basis of this rock is a recrystallized quartz mosaic. This mosaic is equigranular within the two different types of rock represented within this specimen, but the average grain sizes are different. In the dark grey bands quartz predominates, and has an average size of approximately 0.1 mm. The other bands are very rich in tiny rhombs of iron-stained dolomite, and in these the quartzes of the mosaic are of similar size to these rhombs viz. about 0.03 mm. The quartzose dark bands contain a minor amount of dolomite in the form of larger rhombs. A few crystals of twinned plagioclase feldspar occur in association with the quartz of the mosaic. Small flakes of muscovite are distributed throughout the rock. They show no preferred orientation and are present in only minor amount. Fairly large euhedral cubic crystals of an opaque mineral were observed. It is presumably an iron mineral, as it appears to be altering to hematite. Rounded prismatic grains of blue-green tourmaline and rounded yellow-brown zircon grains are present in accessory amounts. Thin veinlets of calcite traverse the sediment.

These minerals are estimated to occur in the rock in the following proportions:

	Vol %
Quartz	55
Dolomite	38
Plagioclase	1
Muscovite	3
Opaques and hematite	2
Accessories	1

This specimen may be classified as a banded quartzose dolomite. The rock has been recrystallized, as may be seen from the quartz mosaic and the euhedral form of the dolomite crystals, dolomite standing higher in the crystalloblastic series than does quartz (Turner and Verhoogen, 1960, p. 594).

21. (TS.18206, P706/66) Uroonda Siltstone Member
(Description by A.B. Simpson)

This specimen is a very fine-grained grey rock without any obvious fabric. A very faint undulating banding of a darker colour is discernible. Fairly brisk effervescence was produced by application of dilute HCl.

The thin section shows a very fine-grained texture in this dominantly arenaceous rock. The sorting is good, the average size of the quartz grains being approximately 0.08 mm. Their shape is mainly sub-angular, as is the case also with the accompanying minor plagioclase feldspar. A carbonate mineral is prominent in the rock. X-ray analysis indicated that the mineral is calcite, and that other carbonates are absent. Very fine-grained chlorite and sericite occupy the interstices between the clastic grains in the rock, but show no parallelism of orientation. Larger plates of chlorite and muscovite, also in a random arrangement, have crystallized in situ throughout the sediment. Small irregular grains of an opaque mineral are sparsely scattered among the other constituents, but the amount is small. The only accessory heavy mineral noted is zircon, in the form of tiny rounded grains.

No fabric is discernible in the section. The faint banding observed in hand specimen is presumably due to slight mineralogical variations, such as changes in the amount of calcite present.

The estimated composition of the rock is:

	Vol %
Quartz	60
Feldspar	1
Calcite	20
Chlorite	9
Muscovite/sericite	9
Opaque mineral	1

It may be termed a calcareous siltstone.

22. (TS.18237, P743/66) Wankaringa Siltstone Member
(Description by A.B. Simpson)

This dark grey, fine-grained sediment is very finely bedded. Weathering shows that some of the very fine bands are more resistant than others. Vigorous effervescence was produced by the application of dilute acid, showing the rock is calcareous.

Under the microscope, the rock may be seen to consist essentially of a very fine-grained calcite mosaic in which the average grain size is in the region of 0.02 mm. Throughout this mosaic are distributed angular and sub-angular detrital quartz grains averaging about 0.05 mm in their maximum dimension. These show a distinct tendency towards aggregation into bands which presumably define the bedding and form the resistant bands noted in hand specimen. A few clastic fragments of plagioclase feldspar occur in association with these quartzes. Phyllosilicate minerals are represented in the rock. Of these, muscovite and chlorite are the most common, and appear to have, in part at least, a detrital origin, as they lie parallel to the bedding planes. A greenish-brown biotite also occurs, however, and is apparently authigenic, as it is in many cases euhedral. Irregularly shaped grains of an opaque mineral showing alteration to hematite are distributed throughout the rock, but appear to be associated with the quartz stringers in particular. Zircon, occurring as small rounded brownish grains, was the only accessory mineral observed. Later veining of the rock by calcite is also present.

23. (TS.18199, P705/66) Etina Formation
(Description by A.B. Simpson)

In hand specimen, this is a massive crystalline carbonate rock of medium grain. It is greyish-buff in colour. Its reaction with dilute acid is vigorous.

Thin section examination shows calcite to be the major, and virtually the only, mineral in the rock. It forms an interlocking equigranular mosaic of grains with an average size of approximately 0.08 mm. In this as matrix occur elongated fragments composed of extremely fine-grained calcite. These have a very well defined parallel orientation which is followed also by some of the larger matrix mosaic crystals. These fragments are generally about 0.8 mm in length. Quartz grains occurring in the rock attain a maximum size of approximately 0.6 mm. They are sub-angular to sub-rounded in shape and in places show "pressure shadows" of elongated calcite crystals between adjacent grains. Feldspar fragments occur also. They appear to be mainly plagioclase, and have in some cases been extensively replaced by calcite. A few grains of opaque mineral were seen in the section.

The proportions of the minerals present were estimated as follows:

	Vol %
Calcite	93
Quartz	5
Feldspar	2

The mineralogical constitution of the rock points to its classification as a detrital limestone. It has, however, suffered deformation and recrystallization, as indicated by the elongated fragments, the preferred orientation of the matrix, and the development of "pressure shadows" between quartz grains.

24. (TS.18219, P725/66) Etina Formation
(Description by A.B. Simpson)

This rock appears to be medium-grained and is obviously crystalline. In colour, it is variegated pale blue and pale pinkish-brown. Both the rock itself and its weathered surfaces suggest that it is composed mainly of carbonate, and application of dilute acid produces some effervescence. No fabric is discernible in the rock.

Microscopic examination reveals that the rock is almost monomineralic, being composed mainly of a carbonate mosaic which is of finer grain than the hand specimen would suggest; the average lies in the region of 0.02 mm. Distributed through this fine-grained mosaic are larger plates of carbonate, including some euhedral rhomb-like crystals. X-ray analysis showed the dominant carbonate mineral present to be dolomite, with calcite playing a very minor role. Some grains of quartz occur in places in the mosaic. In some instances this mineral appears as patches of recyrstallized mosaic. Twinned plagioclase feldspar occurs in the same manner, but in smaller amount. A few irregular grains of an opaque mineral were noted in the section. The rock is traversed by thin quartz veinlets.

Texturally this sample is interesting. The bulk of the rock consists of the fine-grained material just described and this forms a matrix in which are set rounded carbonate fragments, generally consisting of only one crystal, or at most a few crystals. In places these fragments, which average about 0.5 mm, are rimmed by an exceptionally fine carbonate mosaic. They are regarded as clastic fragments derived from a pre-existing coarse-grained carbonate rock.

The mineralogy of this rock is estimated as follows:

	Vol %
Dolomite	90
Calcite	?5
Quartz	4
Feldspar	1

The rock is a dolomite which is partly of detrital origin.

25. (TS.18206, P712/66) Enorama Shale
(Description by A.B. Simpson)

This specimen is an extremely fine-grained and uniform grey rock with a poorly developed bedding. This fabric is revealed by the presence of faint, approximately parallel dark lines on the rock's sawn surface.

In thin section the rock proves to be composed of a variety of clastic fragments, none of which exceeds 0.01 mm in size. The main minerals present are quartz, in tiny angular fragments, chlorite and sericite. These platy minerals are present in considerable amount, and occur interstitially to the quartz grains. The sericite flakes in particular show a parallel orientation which contributes to the rock's poorly developed fabric. Larger plates of sericite and chlorite are present in the sediment. These appear to be authigenic, as they have developed with their greatest dimension (in section) lying across the fabric. In some of the larger chlorite plates, the white mica occurs in parallel intergrowth, while in others, there is incipient development of biotite, recognisable by reason of its higher birefringence. A few grains of plagioclase feldspar showing characteristic twinning were observed. Scattered irregular grains of an opaque mineral occur in the rock in small quantities. Some of them follow the fabric, which is presumably the original bedding.

The mineral proportions in this rock were estimated to be:

	Vol %
Quartz	55
Chlorite	20
Sericite	20
Feldspar	1
Opaque mineral	4

The rock may be classified as a siltstone. The development of authigenic phyllosilicate minerals, including biotite, may be attributable to processes of diagenesis rather than metamorphism, as there is no other evidence of recrystallization of the rock's components.

26. (TS.18208, P714/66) Elatina Formation
(Description by A.B. Simpson)

In hand specimen, this rock is fairly fine-grained and slightly gritty to the touch. It is strongly cross-bedded. The colour of the rock is light brownish-red.

The microscope reveals that quartz is by far the most abundant mineral in this sediment. It occurs singly and also in scarce chert fragments. The grains are sub-angular and are well sorted. They have an average size in the region of 0.07 mm, and appear to have a coating of ?clay minerals and sericite, minerals which form the scarce cement in this sediment and which are in many places discoloured by iron staining. Some larger flakes of sericite are present throughout the rock, but the total amount is not great. Feldspar is fairly abundant in grains of comparable size to that of the quartz. Microcline and a plagioclase feldspar were observed, the latter showing quite extensive alteration to sericite in many cases. Opaque minerals occur mainly as small rounded grains lying on bedding and cross-bedding planes, where they are accompanied by a few rounded prismatic tourmaline grains and a smaller number of colourless zircons. The only other constituent observed takes the form of small ferruginous shells of rhombic outline the cores of which are occupied by a yellow-brown aggregate of ?chloritic or other layered structure minerals. Their original composition is unknown, but they may have been iron carbonate rhombs.

The approximate percentages of the various minerals in the sediment are as follows:

	Vol %
Quartz	80
Feldspar	10
Sericite and ?clay minerals	6
Opaques	3
Others	1

The rock may be termed an arkosic sandstone.

27. (TS.18241, P747/66) Pepuarta Tillite
(Description by A.B. Simpson)

A fine-grained grey rock, this specimen has a poorly developed fabric. Weathered surfaces are rust-coloured. Effervescence with dilute acid is vigorous.

Under microscopic examination, the rock may be seen to consist of a fine-grained matrix which contains sub-angular fragments of quartz, quartzite, calcite, dolomite and plagioclase feldspar. These fragments attain a maximum size of approximately 0.3 mm, and show a tendency towards alignment along bedding planes. There is a continuous gradation in grain size down to the average of the matrix, in the region of 0.02 mm. Quartz is prominent also in the matrix, but feldspar was not observed there. Small grains of calcite and unstained dolomite are present in the matrix. The identification of the latter was confirmed by X-ray analysis. Phyllosilicate minerals are abundant. Chlorite and sericite are present in approximately equal amounts. They show a fairly well developed parallelism of orientation in the bedding planes, but this orientation may be due at least in part to metamorphic action producing recrystallization. A greenish biotite also is to be seen in significant amounts in the rock. It is associated with and appears to be developing from the chlorite. Irregular grains of opaque mineral are distributed haphazardly through the matrix, but are not of major importance. The accessory minerals are tourmaline and small rounded grains of zircon, mainly colourless.

The relative proportions of minerals present are estimated as follows:

	Vol %
Quartz	60
Feldspar	2
Calcite	6
Dolomite	4
Chlorite	10
Sericite	10
Biotite	5
Opaques	2
Accessories	1

From its heterogeneous composition and grain size range, this sediment is considered to be a ?metamorphosed tillite. The degree of metamorphism has not been extreme, but has been sufficient to cause recrystallization of the original clay components of the matrix.

28. (TS.18240, P746/66) Gumbowie Arkose
(Description by A.B. Simpson)

This sample is a pale yellow arenaceous sediment showing a few very faint traces of bedding. The rock is extremely porous. Reddish-brown flecks are probably iron oxide.

The thin section shows that the rock is composed mainly of quartz grains forming a sutured mosaic. These grains range in size from 0.06 mm up to about 0.35 mm. Associated with them are a few similarly sized grains of twinned plagioclase feldspar. A minor amount of sericite, in the form of tiny flakes, occurs in places interstitially to the grains in the mosaic. Some rhombs now consisting of iron oxides indicate the previous presence of dolomite, and a few grains of opaque mineral were also noted. Voids are abundant in the section, but there is no indication of the identity of any mineral previously occupying them.

The composition of this rock is estimated to be:

	Vol %
Quartz	65
Feldspar	2
Sericite	5
Opaques, hematite, etc.	3
Voids	25

The sediment is a feldspathic quartzite. Metamorphism appears to have been responsible for the recrystallization of the rock to its present mosaic form. The porous nature of the specimen is unusual for a metamorphic, and it is suggested that a soluble carbonate may have originally been a component of the recrystallized mosaic.

29. (TS.18242, P748/66) Grampus Range Quartzite
(Description of A.B. Simpson)

A fairly fine-grained grey rock, this specimen shows no bedding or other fabric. It is traversed by a network of white quartz veinlets, the thickest of which measures about 5 mm across.

In thin section, quartz can be seen to be the dominant mineral present. It forms a recrystallized mosaic in which the size of the grains ranges from about 0.03 mm up to 0.14 mm, with a modal value in the region of 0.05 mm. There is a perceptible preferred orientation in some of the larger quartz grains in this mosaic, but this is regarded as an original sedimentary feature which has survived the recrystallization. The grains making up the mosaic have sutured boundaries, and in places along the boundaries there are patches of very fine-grained mosaic such as may be formed by the recrystallization of the very fine material produced by later crushing. Feldspar is prominent in the mosaic. Plagioclase occurs in fair amount but the majority of the feldspar grains are composed of perthite which is easily distinguishable on account of its turboid appearance. A minor quantity of muscovite is present as small crystals distributed without orientation throughout the rock. Sub-rounded and irregular grains of an opaque mineral are moderately plentiful. In places, rhombic outlines now occupied by iron-stained ?clay minerals suggest the former presence of authigenic dolomite crystals which have been replaced after the completion of the rock's recrystallization.

Accessory minerals noted are apatite and zircon, some of which is of a distinctly yellow coloration.

The mineralogical composition of the rock is estimated as:

	Vol %
Quartz	75
Feldspar	19
Muscovite	1
Opaques	3
?Clay mineral pseudomorphs	1
Accessories	1

This specimen may be described as an arkosic quartzite. It has been produced by metamorphism, but no index mineral is present to show the degree of metamorphism which has operated.

30. (TS.18209, P715/66) Nuccaleena Formation
(Description by A.B. Simpson)

This is an extremely fine-grained pink rock whose weathered surfaces suggest the main constituent to be a carbonate. Cavities within the rock contain small white crystals which appear to be calcite, as they effervesce with dilute HCl, which the remainder of the rock fails to do. Bedding in the rock is shown by a faint colour banding.

In thin section, the rock is seen to consist almost entirely of an exceptionally finely crystalline equigranular mosaic of a carbonate identified by X-ray analysis as dolomite. A very minor amount of calcite (shown by staining) is present in this mosaic. The average size of the grains in the mosaic is less than 0.01 mm. Patches of recrystallized quartz mosaic occur in places throughout the section. This mineral was observed as isolated grains as well, and in both cases the grains are only a slightly larger than those of the carbonate. Twinned plagioclase feldspar is present in small amounts; its crystals are in the region of 0.05 mm. The only other constituents of the rock are a few shreds of ?talc and some irregular grains of an opaque mineral.

The proportions of thess minerals in the rock are as follows:

	Vol %
Dolomite	96
Quartz	2
Plagioclase	1
Others	1

The rock is a dolomite, and appears to have suffered some recrystallization.

31. (TS.18231, P737/66) Nuccaleena Formation
(Description by A.B. Simpson)

In hand specimen, this sample is an ochrous yellow. Its appearance suggests a dolomite, an impression strengthened by the type of weathering it exhibits and by its lack of reaction with dilute acid. No bedding is apparent to macroscopic examination.

Under the microscope, the rock may be seen to consist basically of a very fine-grained equigranular mosaic of dolomite. The average grain size in this mosaic is approximately 0.01 mm. Sub-angular detrital grains of quartz occur, and by their alignment define a very poorly developed bedding. Their size is in general larger than that of the carbonate mineral, the average arrived at in this case being in the region of 0.02 mm. Feldspar was searched for but was not detected. Flakes of colourless ?muscovite and ?talc are fairly plentiful, and are aligned in a sub-parallel arrangement in a direction approximately at right angles to the bedding traces. This points to a later origin for this mineral, an idea which gains some support from the way in which the mica has formed in close proximity to quartz grains, and in some cases appears to have formed at the expense of the marginal material of these grains. A very small amount of opaque mineral occurs in the rock also.

The rock is estimated to contain these minerals in the following proportions:

	Vol %
Dolomite	95
Quartz	2
?Muscovite or ?talc	3

The sample may be termed a dolomite. It is apparently of detrital origin, and appears also to have suffered some degree of metamorphism leading to the development of authigeni crystals of phyllosilicate mineral aligned perpendicula to the maximum stress operating at that time.

32. (TS.18188, P694/66) Brachina Formation
(Description by A.B. Simpson)

This specimen is identical to 33 in colour, but differs from it is being finer-grained, banded, and very distinctly bedded. The bedding is very fine, almost approaching a lamination in its nature.

Examination of the thin section shows the rock to be exceptionally fine-grained. There are variations in grain size from one band to another, but the great majority of the rock s constituents appear to have dimensions of the order of 0.01 mm. The main mineral is again quartz, occurring as sub-angular grains which in a few cases reach a size of about 0.06 mm. As in P693/66, twinned plagioclase feldspar grains are present, through possibly in smaller amount than in that sample. The banding in the rock is produced very largely by variations in the concentration of fine, dust-like particles of hematite which are scattered throughout the entire rock, but are very abundant in the darker bands. Laths of clear muscovite are fairly plentiful in all parts of the specimen, and show a rough parallelism to the bedding as revealed by the banding. Some chlorite also occurs, in places intergrown with the muscovite. Opaques are present as subhedral grains in moderate quantities, and appear to be preferentially located in the lighter, hematite-poor areas. A few grains of zircon and tourmaline are present also.

The approximate composition of this sediment is as follows:

	Vol %
Quartz	75
Plagioclase	2
Hematite	8
Muscovite and chlorite	10
Opaques	5
Accessories	-

This rock may be classified as a feldspathic siltstone.

33. (TS.18187, P693/66) Brachia Formation
(Description by A.B. Simpson)

This rock is fine-grained and purplish-brown in hand specimen. A faint suggestion of bedding is discernible, and on one of the poorly-developed planes a sedimentary structure occurs which consists of parallel narrow ridges separated from one another by distances varying from about 2 to 5 mm. This bedding plane irregularity may have formed part of the structure described as "rib-and.furrow" in Pettijohn, 1957. Small flakes of a white micaceous mineral are clearly visible on the plane on which this sedimentary structure occurs.

In thin section there is no indication of bedding other than a certain degree of parallelism of the platy minerals present. The main constituent of the sediment is quartz, occurring as sub-angular grains with an average size of approximately 0.03 mm. Interspersed among these quartz grains are similarly sized grains of polysynthetically twinned plagioclase feldspar whose exact composition could not be determined. These two constituent minerals are closely packed together in what is almost a mosaic arrangement. Cementing material is scarce, and appears to consist of tiny ?clay mineral flakes and minutely granular hematite. Larger grains and films of hematite occur throughout the sediment in fair abundance. Colourless muscovite is common, and the plates of this mineral show the imperfect orientation referred to above. A lesser amount of a yellowish biotite is present, but the form of this mica is less regular than that of the muscovite.

Zircon occurs in minor amount in the form of subhedral grains which are brownish and turbid in their appearance. Subhedral to euhedral crystals of opaque mineral are moderately plentiful. A few grains of tourmaline, pleochroic in shades of blue and green, were also noted.

The mineralogical composition of the rock was estimated to be:

	Vol %
Quartz	75
Plagioclase	5
Hematite	5
Muscovite	3
Biotite	2
?Clay mineral	2
Opaques	5
Accessories	3

The sediment may be termed a feldspathic siltstone. It shows no sign of metamorphic action.

34. (TS.18202, P708/66) Ulupa Siltstone
(Description by A.B. Simpson)

This is a light yellow-brown rock of fairly fine grain size. It posses a very poorly developed lamination, and is traversed by a number of narrow leached veinlets and lenses containing a pale whitish mineral.

Microscopic examination shows that the main mineral in the rock is quartz, occurring as sub-angular grains with a size range of 0.02 to 0.05 mm, the great majority falling in the lower part of this range. Twinned plagioclase fledspar was observed in association with the quartz, but the total amount of feldspar was difficult to gauge on account of the smallness of the grains. Phyllosilicate minerals are fairly abundant in the rock. The most noteworthy is a greenish biotite which appears to be developing from chlorite, and is in many places in parallel intergrowth with it. The biotite occurs mainly as book-like aggregates with their prominent basal cleavages lying at approximately right angles to the weak fabric developed in the rock. The pale green chlorite, in addition to its association with biotite, occurs throughout the rock as very tiny flakes in a roughly parallel arrangement. Sericite is fairly abundant in the same mode of occurrence as chlorite. Muscovite was noted intergrown with biotite, and also as large plates lying in the plane of the fabric in the rock.

Opaque minerals are moderately abundant in this sediment. They occur mainly as small irregular grains, but some are subhedral. These in particular are associated with hematite, which may be an alteration product, as well as occurring independently throughout the rock. A few tiny grains of zircon were also observed.

The mineralogical composition of the specimen was estimated as follows:

	Vol%
Quartz	70
Felspar	? 2
Biotite	15
Chlorite	5
Muscovite/sericite	5
Hematite	1
Opaques	2

The most suitable name for this sediment is siltstone, but it appears to have suffered some slight metamorphism, possibly of a local nature. The development of biotite is a pointer towards this. That some slight shearing may have taken place is indicated by dark lines running through the rock. These possible planes of weakness, and the slight degree of orientation of the sericite and chlorite flakes, give the rock its poorly developed fabric.

35. (TS.18229, P735/66) Ulupa Siltstone
(Described by A.B. Simpson)

This very fine-grained pale grey-green rock has a very flaggy appearance due to its marked fabric. Parallel to this schistosity run narrow bands of a brownish colour which appear to be iron-stained. The schistosity planes are slightly lustrous.

The microscope reveals that this rock is somewhat similar to P729/66. The major constituent is quartz which forms an equigranular mosaic. The average grain size in this mosaic varies from band to band in the rock, the observed limits being from 0.02 mm to 0.04 mm. A little plagioclase feldspar is again associated with the quartz. A green pleochroic chlorite is the next most important mineral. It occurs as isolated flakes which have crystallized parallel to one another distributed throughout the rock. A minor quantity of colourless sericite is associated with this mineral. Of more importance is the occurrence of the yellowish mica identified as ?hydrobiotite. It occurs in close association with the chlorite, and appears to be developing from it. It is present in moderate amount. Irregular grains of an opaque mineral are scattered throughout the rock, but are less plentiful than in the previous specimen. Zircon and tourmaline occur in accessory amounts.

The mineralogical composition of this sample is estimated to be:

	Vol%
Quartz	65
Plagioclase	1
Chlorite	20
Sericite	5
?Hydrobiotite	5
Opaques	3
Accessories	1

This rock is termed a quartz-chlorite schist.

3 . (TS18189, P695/66) ABC Range Quartzite
(Description by A.B. Simpson)

The hand specimen of this rock-unit in a whitish arenaceous sediment of medium to coarse grain. It is completely lacking in fabric, and has a saccharoidal texture.

Under the microscope, this rock is seen to consist almost entirely of quartz in the form of a well sorted and tightly compacted mosaic in which the grains are sub-polygonal in outline. The average grain size is approximately 0.35 mm. Feldspar was not detected in the sediment. Cementing material is almost entirely absent. Interstices are sparse, but appear to be filled with an aggregate of minutely crystalline ?clay minerals. A very few grains of zircon and tourmaline are to be found along inter-grain boundaries.

The mineralogical composition of this rock is estimated as being:

	Vol%
Quartz	97
?Clay minerals	3

The sediment is classified as an orthoquartzite. There is no indication of metamorphism having played a part in its formation.

37. (TS 18222, P728/66) ABC Range Quartzite
(description by A.B. Simpson)

In hand specimen, this rock is moderately coarse-grained and gritty. It possesses no noticeable fabric, and contains numerous small rusty specks. Small leach cavities are abundant.

Under the microscope, the rock is seen to consist almost entirely of quartz. The main constituents are rounded grits composed of single crystals of this mineral, or of mosaics of several crystals. These grits are fairly well sorted, and average approximately 1.15 mm. That recrystallization has taken place is shown by the presence of quartz overgrowths on these grits, and by the fine-grained quartz mosaic occurring in the interstices between the grits. The polygonal quartz crystals in these mosaic patches average about 0.03 mm in size. Muscovite laths are of common occurrence in the recrystallized patches. Iron-staining and small irregular masses of hematite occur in the mosaic also. Large concentrations of hematite form the rusty specks sporadically distributed throughout the rock as noted in hand specimen. Some feldspar was observed, and was determined as perthitic orthoclase. Very minor plagioclase occurs also. No accessory minerals were seen.

The minerals in this rock are estimated to occur in the following proportions:

	Vol %
Quartz	95
Muscovite	2
Feldspar	1
Hematite	2

The rock is termed an orthoquartzite. It has been subjected to recrystallization and silification, processes which may have resulted from metamorphic action of low grade.

38. (TS18204, P710/66) Bunyeroo Formation
(Description by A.B. Simpson)

This rock is exceptionally fine-grained and is a dark reddish-brown colour. It is very well laminated, and may have a trace of a cleavage running obliquely to the lamination planes.

Under the microscope, the great majority of the clastic grains which make up this rock prove to be under 0.01 mm in size. Tiny angular grains of quartz form a major part of the rock, and a few fragments of plagioclase showing its characteristic twinning are also discernible, though with difficulty. Very finely divided chlorite is abundant in the interstices between these grains and those of the other abundant constituent of the rock, viz. hematite. This mineral is distributed throughout the sediment in the form of tiny irregular granules and dust-like particles, and is in places situated along the planes of lamination. The fabric is otherwise not clearly defined in thin section, and there is no trace of any cleavage to be seen. Tiny flakes of sericite are present in fair abundance in association with the chlorite, but neither of these minerals show any high degree of orientation in all parts of the rock. Carbonate minerals were searched for but were not detected.

The proportions of the various minerals present were estimated as follows:

	Vol %
Quartz	65
Feldspar	2
Hematite	18
Chlorite	10
Sericite	5

The sediment may be classified as a ferruginous shale.

39. (TS18228, P734/66) Bunyeroo Formation
(Description by A.B. Simpson)

This is an exceptionally fine-grained rock which has a marked lamination or schistosity. In hand specimen there appears to be a second fabric which crosses the more prominent schistosity at a very low angle. The rock is grey, with a very definite purplish tint.

Thin section examination shows all the components of the rock to be less than 0.01 mm in size. The main constituent is quartz, which forms a finely crystalline mosaic in which the other major mineral, sericite, occurs as flakes with a strictly parallel orientation. Some pale green chlorite is associated with the sericite, and was observed in places in parallel intergrowth with it. A minor proportion of twinned plagioclase feldspar is present in the quartz mosaic, and in lens-like areas where the grain is somewhat coarser than normal. These lenses, and also some thin films of an opaque mineral, are aligned parallel to the main direction of mineral orientation in the rock. Small granules of opaque minerals are distributed haphazardly throughout the section studied, and some hematite was also observed. Tourmaline was the only accessory noted, and is present as a few tiny grains only.

The mineralogical composition of this rock is estimated to be;

	Vol %
Quartz	65
Sericite	25
Chlorite	?5
Plagioclase	1
Opaques and hematite	4

The rock appears to have been subjected to a very low grade of regional metamorphism, and is classed as a quartz-sericite schist. There are no signs in thin section of the faint fabric traces lying oblique to the main schistosity.

40. (TS 18191, P697/66) Wanoka Formation
(Description by A.B. Simpson)

Macroscopically, this specimen is a very fine-grained grey rock with a very well developed fine lamination. The surfaces of the laminae are dull, with only a few specks of a platy mineral to be seen. There is no obvious banding in the rock; its composition appears to be uniform throughout.

In thin section, the rock is seen to be very fine-grained, and with a very pronounced parallelism of orientation of its constituents. Angular grains of quartz, with an average size of about 0.01 mm, are set in an orientated matrix of fine greenish chlorite and sericite. A few angular fragments of twinned plagioclase feldspar also occur with the quartz grains between the grains of phyllosilicate minerals. They are of similar size to the grains of quartz. Calcite, easily distinguishable on account of its having been stained, is one of the major constituents of the sediment, and occurs as small crystals and aggregates uniformly distributed throughout the rock.

Opaque minerals are virtually absent, but a few tiny grains were noted. Disseminated minute grains of a mineral with high relief which may be ?sphene occur in very minor amounts in the rock.

The mineralogical composition of the sediment is estimated as follows:

	Vol %
Calcite	35
Quartz	22
Plagioclase	2
Chlorite } Muscovite }	40
Accessories	1

Some authigenic crystallization of crystals of chlorite and muscovite which are larger than the average and which lie across the fabric planes has taken place, but this is not interpreted as an indication of metamorphic action. The rock is regarded merely as a calcareous shale.

41. (TS 18224, P730/66) Wonoka Formation
(Description by A.B. Simpson)

Macroscopically, this specimen is an extremely fine-grained buff rock containing closely spaced dark streaks which lie in an approximately parallel arrangement and which probably define the bedding. A high content of calcite is indicated by the brisk effervescence produced by application of dilute hydrochloric acid.

The thin section of the rock shows it to be made up of a fine-grained equigranular mosaic of quartz and carbonate minerals. The constituents of this mosaic have an average grain size of about 0.03 mm. No variation is visible in the mosaic other than the parallel short dark lenses referred to above; these consist of an opaque mineral, possibly an iron oxide, further grains of which are scattered throughout the sediment. The quartzes of the mosaic show a tendency towards polygonal outlines, a phenomenon suggesting some recrystallization. The majority of the carbonate grains have responded to staining, showing calcite to be the dominant carbonate. X-ray examination of the sample indicated that the unstained constituent is also calcite, not dolomite as was suspected. A very minor amount of plagioclase feldspar is associated with the quartz of the mosaic. Flakes of muscovite occur throughout the rock in random orientation. Minor amounts of a greenish biotite were also observed; this mineral appears to be in the process of development, and may be a hydrobiotite. Also present are minute quantities of ?clay mineral forming the very scarce cementing medium in the mosaic. The accessory minerals in the rock are tourmaline grains, dichroic from colourless to greenish-yellow, and tiny rounded colourless zircon grains.

The proportion of these minerals occurring in the rock were estimated as follows:

	Vol %
Quartz	55
Calcite	30
Muscovite	6
Plagioclase	1
?Clay minerals	2
?Hydrobiotite	3
Opaques	2
Accessories	1

The sediment is classified as calcareous siltstone. It does not appear to have suffered any significant degree of metamorphism.

42. (TS 18225, P731/66) Wonoka Formation
(description by A.B. Simpson)

This rock is a massive, fairly fine-grained quartzitic variety. It is of a pinkish-white colour, with rusty weathered surfaces.

The microscope reveals it to consist basically of a mosaic of recrystallized quartz grains of fairly uniform size lying in the region of 0.25 mm. Within this recrystallized mosaic lie rounded grains of feldspar of similar size. These are mainly of microcline, but plagioclase is also represented. The latter appears to be of sodic composition, and is partially sericitized in some cases. A few small chert fragments are incorporated into the recrystallized quartz mosaic. Cement is very sparse in this sediment, but where present consists of very fine aggregates of ?clay minerals. Large grains of green pleochroic tourmaline and tiny rounded zircon crystals occur in accessory amounts.

The approximate mineralogical composition of the rock is:

	Vol%
Quartz	90
Feldspar	5
?Clay Minerals	4
Accessories	1

It is classified as a feldspathic sandstone. The rock has suffered recrystallization of its quartz content, but the feldspars have not been affected, as may be seen from the rounded grains still present in the mosaic.

43. (TS 18193, P699/66) Pound Quartzite
(Description by A.B. Simpson)

In hand specimen, this rock is nearly white. A slight trace of bedding is visible. Abundant tiny white specks, apparently a weathered mineral, are distributed throughout the rock.

The main part of the thin section is composed of well sorted and well rounded grains of quartz compacted in such a way as to leave little or no interstitial space. The average grain size met with in this part of the sediment is approximately 0.45 mm. A zone in which the texture is completely different traverses the section. In this part of the quartz grains are generally smaller and slightly more angular, and are set in a matrix of fine, very angular quartzes averaging about 0.03 mm. in size. The appearance of this interstitial material suggests that it has been formed by partial crushing and recrystallization of the normal sediment. The quartz grains in the main part of the rock themselves show the effects of strain, and are in many cases biaxial as a result.

Chert fragments are fairly numerous in this sediment. Feldspar was searched for, but was not found. Even staining with sodium cobaltinitrite failed to detect the presence of potash felspar. The whitish material seen in hand specimen was absent from the section, having disintegrated during sectioning. When studied in an oil mount, however, it proved to be composed entirely of clay minerals. The only other constituent of the rock is zircon, a few scattered grains of which were observed.

The composition of the rock is estimated as being:

	Vol%
Quartz	94
Chert grains	1
Clay minerals	5

This sediment may be classified as an orthoquartzite. It has evidently suffered a moderate amount of mechanical deformation.

44. (TS 18192, P698/66) Pound Quartzite, lower unnamed member
(Description by A.B. Simpson)

This rock is a medium-grained arenaceous sediment of a purplish colour. It possesses only a very poorly defined bedding. In hand specimen, the degree of sorting appears to be high.

Thin section examination proves that the main mineral in the rock is quartz, in the form of a mosaic of well sorted sub-angular grains in which the average grain size is approximately 0.2 mm. Some chert fragments occur also. A considerable amount of feldspar is present, also in sub-angular grains of similar size to that of the quartz. Turbid, partially sericitized potash feldspar is the more abundant, but a fair amount of twinned microcline also occurs. This latter mineral differs from the other feldspar in being in a very fresh condition. A few shreds of muscovite and a very minor amount of chlorite (detrital)were also observed. Along the boundaries of the grains, and in the interstices, occur very fine-grained aggregates of ?clay minerals and ?iron ores, but in very small quantities. Green tourmaline grains may be seen in some parts of the rock, but are not abundant.

The approximately mineralogical composition of this sediment is as follows:

	Vol %
Quartz	70
Potash feldspar	17
Microcline	8
Muscovite, chlorite and clay minerals	4
Tourmaline and iron minerals	1

The rock may therefore be classified as an arkose (Pettijohn, 1957, p 291).

45. (TS 18227, P733/66) Pound Quartzite
(Description by A.B. Simpson)

This quartzitic rock is fairly fine-grained and is greyish-white in colour, tinged with pink in places from the presence of iron oxides. A poorly defined bedding is shown by the alignment of these iron-stained areas.

Microscopic examination shows that the rock is almost entirely made up of quartz, the grains of which are mainly sub-rounded to rounded. They range in size from 0.08 mm to 0.44 mm, with an average in the region of 0.2 mm. In parts of the section, cement is virtually absent, and the grains combine to form a mosaic. Elsewhere, a very fine-grained aggregate of ?clay minerals forms a filling in the interstices between the grains. Feldspar is common in the rock. Fresh microcline is conspicuous, but grains of another alkali feldspar (?orthoclase) which shows no twinning and is turbid are present also in fair quantity. A few small flakes of muscovite were noted, and tourmaline and tiny rounded zircon grains occur in accessory amounts. Some small grains of an opaque mineral are scattered throughout the rock, but their numbers are insufficient to account for the pink coloration of the hand specimen. This is probably due to iron staining of the clay mineral cement in the bands where this cement is abundant.

The approximate percentages of minerals present are:

	Vol %
Quartz	80
Microcline	5
?Orthoclase	5
?Clay minerals	8
Other minerals	2

The rock may be termed a feldspathic sandstone.

46. (TS 18195, P701/66) Wilkawillina Limestone
(Description by A.B. Simpson)

The hand specimen of this rock is medium-grey and finely crystalline. It shows no fabric, but is traversed haphazardly by poorly-defined yellowish-buff zones of staining. It is clearly calcareous.

Under the microscope, this rock proves to be composed almost entirely of calcite. This takes the form of a mosaic of fairly uniform crystal size (about 0.02 mm), but with scattered larger individuals up to 0.13 mm. A few small angular grains of quartz were noted, but feldspar was not seen. The only other constituent of the rock is the ?iron oxide staining which gives the irregular "veining" referred to above.

The composition of this specimen is estimated as being:

	Vol%
Calcite	98
Quartz	2

It may be classified as a limestone of high purity.

47. (TS18197, P703/66) Parara Limestone
(Description by A.B. Simpson)

In hand specimen, this is a very fine-grained grey calcareous rock, the colour of which is appreciably darker than P701/66. It also displays no fabric. Thin veinlets of a white carbonate (proved to be calcite) traverse the rock.

Microscopically, the rock is seen to consist almost entirely of calcite in the form of crystal plates of various sizes. These range from about 0.02 mm to 0.13 mm, with the great majority of the crystals falling in the smallest sizes. The calcite of the veinlets is coarser in grain. No other carbonate was observed, but X-rays revealed the presence of minor rhodochrosite. A few scattered angular grains of quartz occur in the calcite mosaic, but no feldspar was visible. Chalcedony of a fibrous form fills some cavities and cracks in the rock. It is 'dusty' in appearance and is associated in places with ?opaline silica. Some muscovite is present, but in very small quantity. Small concentrations of ?hematite occur, apparently as a replacement of pre-existing rounded bodies. This mineral is also to be seen as a filling material in some of the thin cracks running through the rock.

An interesting feature of this rock is the presence of darker patches in the recrystallized carbonate mosaic. Some of these are rounded or sub-rounded, while others are of a more elongate outline. It is suggested that these are the remnants of carbonate fragments of a detrital nature which have been partially obliterated during recrystallization of the interstitial carbonates.

An estimate of the mineralogical composition of the rock is as follows:

	Vol%
Calcite and rhodochrosite	98
Quartz and chalcedony	1
Hematite	1

The rock may be classed as a limestone, possibly of detrital origin.

48. (TS 18198, P704/66) Oraparinna Shale
(Description by A.B. Simpson)

In hand specimen, this rock is pale greyish-buff and of very fine grain. It is finely laminated, the individual laminae in places showing alternations of lighter and darker colour. Slight flexuring of the laminae is observable, especially in the vicinity of aggregations of a fine-grained white mineral which is possibly a carbonate.

Thin section examination shows the sediment to be composed mainly of an extremely fine-grained carbonate mosaic throughout which are scattered abundant detrital materials; the distribution of these detrital minerals is responsible for the laminated texture of the rock. Staining indicates that virtually all the carbonate is calcite, but a very minor amount of unstained carbonate occurs. This is probably dolomite (see below). The average grain size of these minerals lies in the range 0.01 to 0.02 mm. Angular grains of quartz are common in the rock. Where they occur in the carbonate mosaic they have maximum dimensions of the order of 0.2 to 0.3 mm, but in those parts of the rock less rich in carbonate minerals they attain an average size of about 0.06 mm. Small flakes of partially chloritized biotite of a yellowish-green colour are the main constituents of the darker bands in which these coarser quartz grains occur. Scattered larger plates also of this mineral may be seen in these impure laminae. Some shreds of colourless muscovite are also present, but in fairly minor amount. Also present as a minor constituent is plagioclase feldspar, occurring as twinned grains of a size similar to that of most of the quartz. Small granules of hematite, rounded prismatic crystals of greenish-yellow tourmaline, and euhedral cubic crystals of an opaque mineral (?pyrite) are present in accessory amounts.

X-ray examination showed that calcite is the only carbonate detectable, but it is possible that the very small amount of unstained carbonate is ?dolomite.

The percentage composition of this rock is estimated as follows:

	Vol%
Calcite and ?dolomite	75
Quartz	10
Chloritized biotite	10
Muscovite	3
Others	2

The sediment may therefore be classified as a silty limestone.

49. Altered Dolerite from Melrose Diapir
(Description by E.O. Thiele)

Macroscopic characters - This example is a medium-grained holocrystalline rock, with a prevailing greenish-grey colour. Ferromagnesian minerals are dominant and the structure is granular.

Microscopic Features - Considerable mineral rearrangement has taken place, but in general a definite ophitic structure is recognisable though as a rule the breaking up of the original minerals has developed a granular character. The ferromagnesian minerals are the most abundant, and the unaltered forms are chiefly pyroxene, but uralitization has proceeded to some extent A little granular material of high relief is probably olivene.

The feldspars, where definitely determinable, are triclinic, giving extinction angles on the albite lamellae up to 25°, representing probably labradorite. They generally show considerable alteration, passing into epidote and calcite. Iron oxides are present, but are not very abundant.

50. (TS 16941, P535/65) Altered Microdiorite from Worumba Diapir (Description by R. Townend)

These three specimens appear to belong to one igneous suite; i.e., they are all members of the diorite clan, and differ chiefly in grain size. Specimen 1 is an altered porphyritic andesite, although its plagioclase is too altered to allow compositional determinations. The dominant matrix has a grain size below 0.03 mm, and is composed of plagioclase, pale green hornblende, epidote and opaque granules (10 to 15%). Coarser patches occur with secondary epidote and amphibole. The sporadic phenocrysts are chloritised plagioclase typically 0.3 by 0.05 mm. There are a few narrow epidote veins.

Specimens 2 and 3 are both plutonic, i.e. diorites, with 2 of similar composition to 1, but probably more mafic, with hornblende forming 60 to 70% of the rock. This rock is also altered with chlorite and epidote the main products. Opaques form less than 5%, and are mostly gone to leucoxenic sphene, indicating the original presence of ilmenite. Specimen 3 has a grain size averaging between 1.0 and 2.0 mm. It is slightly fresher than the other two and is likewise hornblendic, but also contains a certain quantity of augite mostly as cores to the amphibole. The texture of this rock is unusuol in that the feldspar (andesine) and mafics are intergrown in a graphic rather than ophitic sense. Alteration is intense locally, particularly in the plagioclase, apparently to clay material, and epidote, while extensive veining of the feldspar has occurred with the formation of (?)riebeckite and chlorite. Opaques are prominent and have the skeletal habit of ilmenite. Recrystallization of the amphibole has resulted in patches of fine microlite amphibole needles.

These rocks have certain features, such as their density, lack of voids, interlocking texture etc., which are desirable in ballast, but they are somewhat altered, and where this alteration is low temperature, such as clay formation, then this is probably rather detrimental.

54. (TS17610, P478/66) Microdiorite from Great Gladstone Diapir (Description by I.F. Scott)

This is a very heavily chloritized porphyritic microdiorite. Very occasional plagioclase feldspar phenocrysts are present in a medium grained groundmass of plagioclase laths, opaques and chlorite alteration products.

Phenocrysts are partly clouded with chlorite, sericite and fine, dusty opaques

Approximate mineral proportions are now:

	Vol%
Plagioclase feldspar	55
Chlorite	20
Opaques	25

Chlorite alteration is scattered throughout the rock and is also present as small segregations. Many of the opaque grains are haematitic in nature because of alteration.

55. (TS17609, P477/66) Dyke near Great Gladstone Diapir (Description by I.F. Scott)

This rock is an extremely altered porphyritic quartz microdiorite.

Approximate mineral proportions are:

	Vol%
Muscovite (?sericite)	40
Chlorite	20
Opaques	25
Quartz	5
Plagioclase feldspar	5
Biotite	5
Apatite, carbonate accessories	

The rock was a medium grained plagioclase-rich material which has been severely sericitized (developed into muscovite-sized areas) and chloritized so that very few remnants of the original feldspar crystals are now visible. Opaques have always been an important constituent and the "herring-bone" needle-like growths resemble ilmenite. Where these opaques have been altered a red, semi-opaque iron oxide is now present.

Quartz occurs in small segregations but is not a common constituent. Biotite is similarly relatively uncommon but is apparently of a primary nature. Traces of apatite and secondary carbonate (alteration) were also observed.

56. (TS19740, P374/67(Siliceous Jasper)
(Description by G. Williams)

Rock Name; Siliceous jasper.

Hand Specimen:

A microcrystalline rock with thin wavy banding (up to 2mm wide) in tones of grey with fine, dull red streaks following the banding.

Thin Section:

A visual estimate of the constituents gives the following:

	Vol%
Quartz	94
Opaques	5
Muscovite, carbonate	1

This is a banded siliceous jasper in which the quartz grains range in size from 0.65 to microcrystalline aggregates. The larger quartz grains are anhedral, and grade into the surrounding fine-grained groundmass. They contain numerous minute specks of opaque material, and rounded carbonate inclusions are common. An inclusion-free core may be present. In some areas silica has crystallized in cavities and along fractures. The banding is due to concentrations of disseminated opaque material (?magnetite). These layers are wavy and irregular. Secondary muscovite flakes are aligned parallel to these bands. Rare zircon grains are rounded and some are cored.

History:

It is suggested that this rock represents a siliceous sediment (chert) of chemical origin, which has been recrystallized. The fluctuations in the banding of the opaque material have probably resulted from the recrystallization.

57. (TS19700, P360/67) Metasomatisal Granite Arkose
(Description by G. Williams)

Rock Name:

Granitic arkose.

Hand Specimen:

A pink, medium-to coarse-grained, massive rock. Pink feldspars, and quartz grains are set in a pinkish matrix.

Thin Section:

A visual estimate of the constituents gives the following:

	%
Quartz	40
Microcline	30
Orthoclase	25
Secondary rutile	3
Biotite	2
Fluorite, tourmaline, zircon	acc

This is a medium- to coarse-grained rock, the median grain diameter being 1 mm; grain-size is moderately uniform. Sub-angular to sub-rounded quartz and feldspar grains are cemented by secondary silica and feldspar. Intergrowths between the two are common. Commonly quartz grains have a narrow rim of very small alkali feldspar euhedra which have been overgrown by silica. Some areas between grains consist of very finely recrystallized quartz and feldspar. Voids have been lined by fluorite. Orthoclase has been altered to a greater extent than microcline biotite is pale brown, and occurs as wavy flakes, sometimes pinched between grains; clusters of rutile granules are numerous. Many grains have been fractured and the cracks filled by quartz or feldspar.

History:

Detrital cores visible in many grains indicate this rock to be of sedimentary origin. There has been limited deformation of the grains and extensive metasomatism, particularly by potassium, and also by silica. This has resulted in many micrographic intergrowths between alkali feldspar and quartz, and very small crystals of alkali feldspar commonly surround quartz grains, and have been overgrown by silica.

To determine whether the metasomatism caused mobilisation of the arkose, it would be advisable to know if the surrounding fault breccia has or has not been metasomatised.

58. (TS19792, P413/67) Metasomatised Granite Arkose
(Description by G. Williams)

Rock Name;

Granitic arkose.

Hand Specimen:

A pale pink to buff-coloured rock composed of grains ranging from fine sand sized up to 3 mm in diameter (granule size). It is firmly cemented and porous.

Thin Section:

A visual estimate of the constituents gives the following:

	%
Alkali feldspar	55
Quartz	35
Lithics	6
Muscovite	2
Plagioclase	2
Opaques, rutile, tourmaline	acc

This rock is generally similar to P360/67. It differs from it by containing lithic fragments of rhyolitic/microsyenitic composition, quartzite and granite. There is also some recrystallized muscovite. Sorting has not been as good as in P360/67, and coarser grains are present, some up to 3mm in diameter. The overgrown fringes of alkali feldspar are not as obvious, though feldspathisation in the interstitial areas es extensive. Many grains are strained or fractured.

History:

This is an arkose which has been derived wholly from a granitic terrain, and been subjected to metasomatism.

APPENDIX II - 119

Spectrographic analysis for metallic elements in samples representative of rock units in the Umberatana, Wilpena and Hawker Groups on ORROROO. Analysis by N.V. Johnston of the Australian Mineral Development Laboratories.

Sample No.	Rock Unit	Locality	Cu	Pb	Zn	Co	Ni	Cr	V	Ag	Ba	Mn	Fe%	Ca%	Mg%
A3356/66	Oraparinna Shale	5½m NNE Gordon	50	50	40	25	60	150	400	0.8	1,500	300	73	H	H
A3355/66	Parara Lst	4m NNE Gordon	6	3	<20	<1	3	5	<1	0.2	200	300	0.03	H	M
A3354/66	" "	" " "	15	8	30	2	5	25	4	0.4	200	3,000	0.5	H	M
A3353/66	Wilkawillina Lst	6m NE Warrens Gorge	12	10	30	1	5	50	<1	0.3	40	6,000	0.61	H	M
A3352/66	Parachilna Fm	2½m NE Warrens Gorge	20	4	<20	2	5	500	5	0.2	5	30	0.6	L	L
A3385/66	Pound Quartzite	9m N Paratoo	7	6	<20	1	2	200	4	<0.1	600	10	0.3	L	L
A3351/66	" "	1m N Warrens Gorge	10	8	<20	<1	1	200	1	0.2	5	5	0.3	L	L
A3350/66	" "	" " "	15	20	<20	<1	3	700	6	<0.1	20	10	0.8	L	L
A3382/66	Wonoka Formation	9m NW Paratoo	30	15	<20	7	25	300	150	0.4	50	800	0.5	H	M
A3379/66	" "	4m W Bendleby	20	20	40	5	20	150	6	0.1	30	1,000	0.5	H	M
A3349/66	" "	1m N Warrens Gorge	100	15	20	7	15	150	8	0.2	1,000	2,000	0.8	H	M
A3386/66	Bunyeroo Formation	8m N Paratoo	15	20	60	12	25	120	100	<0.1	3,000	600	>3	M	M
A3362/66	" "	[illegible]m W Belton	10	150	80	15	50	200	250	<0.1	>10,000	2,000	>3	L	M
A3348/66	" "	Warrens Gorge	30	50	80	30	120	400	300	<0.1	1,000	50	>3	L	M
A3380/66	ABC Range Quartzite	¼m S Dawson	40	50	30	15	10	500	10	0.1	30	1,000	3	L	L
A3361/66	" " "	6m W Belton	120	25	20	15	25	300	300	0.2	50	1,000	>3	L	L
A3347/66	" " "	Warrens Gorge	20	2	<20	<1	1	600	1	<0.1	3	15	0.2	L	L

Sample No.	Rock Unit	Locality	Cu	Pb	Zn	Co	Ni	Cr	V	Ag	Ba	Mn	Fe%	Ca%	Mg%
A3387/66	Ulupa Siltstone	8m N Paratoo	25	10	70	15	25	120	100	<0.1	600	500	>3	L	M
A3360/66	" "	6m W Belton	20	20	40	7	15	115	300	<0.1	2,000	200	3	L	L
A3359/66	" "	" "	200	50	30	40	40	300	400	<0.1	2,000	5,000	3	L	L
A3346/66	Brachina Formation	¼m W Warrens Gorge	20	50	70	20	50	400	300	0.1	2,000	300	>3	M	M
A3345/66	" "	" " "	50	15	30	20	50	500	300	0.3	3,000	150	>3	L	L
A3389/66	Nuccaleena Formation	3m S Yunta	3	6	<20	<1	1	8	2	0.2	600	150	0.5	H	M
A3367/66	" "	4m ENE Carrieton	10	12	20	2	4	50	1	<0.1	700	2,500	0.4	H	H
A3344/66	" "	¼m W Warrens Gorge	10	2	<20	4	2	5	1	0.2	20	5,000	0.08	H	M
A3366/66	Elatina Formation	4m ENE Carrieton	8	8	<20	4	8	150	25	0.1	1,000	300	2	L	L
A3366/66	" "	" " "	20	10	<20	10	20	300	60	0.8	1,200	2,000	0.6	M	M
A3364/66	Enorama Shale	4m ENE Carrieton	40	50	60	12	30	150	250	0.1	2,000	250	>3	L	M
A3388/66	Tarcowie Siltstone	7m NE Paratoo	20	8	<20	8	15	500	50	0.7	2,000	1,000	3	H	H
A3378/66	" "	1½m SE Pekina	10	15	40	15	30	500	300	<0.1	3,000	300	3	M	M
A3376/66	" "	¼m SW Orroroo	60	70	25	10	30	250	300	0.2	1,000	[illegible]	3	M	M
A3363/66	" "	4m ENE Carrieton	12	30	60	10	20	300	250	0.1	1,200	300	3	L	M
A3377/66	Etina Formation	¼m S Orroroo	8	6	<20	3	1	8	4	0.2	80	200	0.5	H	H
A3357/66	" "	om ENE Gordon	8	3	<20	1	1	8	1	0.3	800	300	0.03	H	M
A3358/66	Uroonda Siltstone M	6m W Cradock	20	50	20	7	30	300	300	0.8	3,000	300	3	H	H
A3343/66	Unnamed u member Willochra Fm.	4m NW Quorn	50	20	40	15	50	500	250	0.1	1,500	600	3	L	L
A3342/66	" u " " "	" " "	15	12	20	4	8	500	120	<0.1	300	50	2	L	L
A3341/66	" u " " "	" " "	10	10	25	8	20	500	250	0.2	500	50	>3	L	L
A3340/66	Unnamed L member Willochra Fm.	3m W Quorn	30	12	20	15	80	500	250	0.2	500	200	2	H	H
A3339/66	" L " " "	" "	25	15	30	10	70	300	250	<0.1	500	100	>3	L	L

Sample No.	Rock Unit	Locality	Cu	Pb	Zn	Co	Ni	Cr	V	Ag	Ra	Mn	Fe%	Ca%	Mg%
A3374/66	Brighton Limestone	¼m SW Orroroo	6	6	<20	<1	5	8	<1	0.1	80	120	0.05	H	M
A3338/66	" "	3m W Quorn	20	5	<20	<1	6	40	4	0.1	500	600	0.4	H	M
A3373/66	Yankaninna Formation	¼m SW Orroroo	50	150	40	50	40	400	400	0.1	1,500	700	>3	M	M
A3337/66	" "	3m W Quorn	20	8	40	6	25	200	200	<0.1	3,000	100	3	L	L
A3394/66	Tapley Hill Formation	2½m WNW Melton	40	20	30	12	30	200	200	0.7	1,500	250	>3	H	H
A3372/66	" " "	2¼m W Orroroo	20	3	30	15	40	200	300	0.1	1,200	400	3	H	H
A3336d/66	" " "	2½m W Quorn	50	40	40	10	50	300	250	0.1	1,200	500	3	H	M
A3393/66	Tindelpina Sh. Member	4m NNW Melton Hstd.	40	15	30	3	15	150	200	0.2	1,500	25	3	L	L
A3371/66	" " "	3m W Orroroo	25	6	20	10	12	600	25	0.1	500	30	3	L	M
A3336c/66	" " "	2m W Quorn	50	15	40	12	70	300	400	0.4	2,000	500	>3	H	H
A3392/66	Siltstone in Yudnamutana Sub Group	4m NNW Melton Hmstd.	40	5	<20	12	10	500	40	0.2	3,000	1,200	2	H	M
A3391/66	Dol. Tillite " " "	" " " "	5	5	<20	3	4	10	4	0.1	150	1,200	0.8	H	H
A3390/66	Tillite " " "	" " " "	120	25	25	12	20	700	120	0.7	1,000	600	2	H	H
A3370/66	Siltstone " " "	3m W Orroroo	25	6	20	10	12	600	25	<0.1	300	500	3	L	L
A3369/66	Tillite " " "	" "	25	8	20	8	10	400	300	0.1	2,500	250	3	H	H
A3368/66	Lithic Siltstone " " "	5m W Orroroo	80	50	30	8	10	200	300	0.3	4,000	150	>3	M	M
A3336/66	Tillite " " "	4m ESE Quorn	70	15	30	5	40	500	400	0.4	3,000	200	>3	H	H
A3336a/66	Lithic Siltstone " " "	" " "	70	60	20	3	10	600	120	1.0	100	150	1	L	L

Results in p.p.m. Fe in %

Mg and Ca H = more than 10%

M = 1% - 10%

L = 0% - 1%

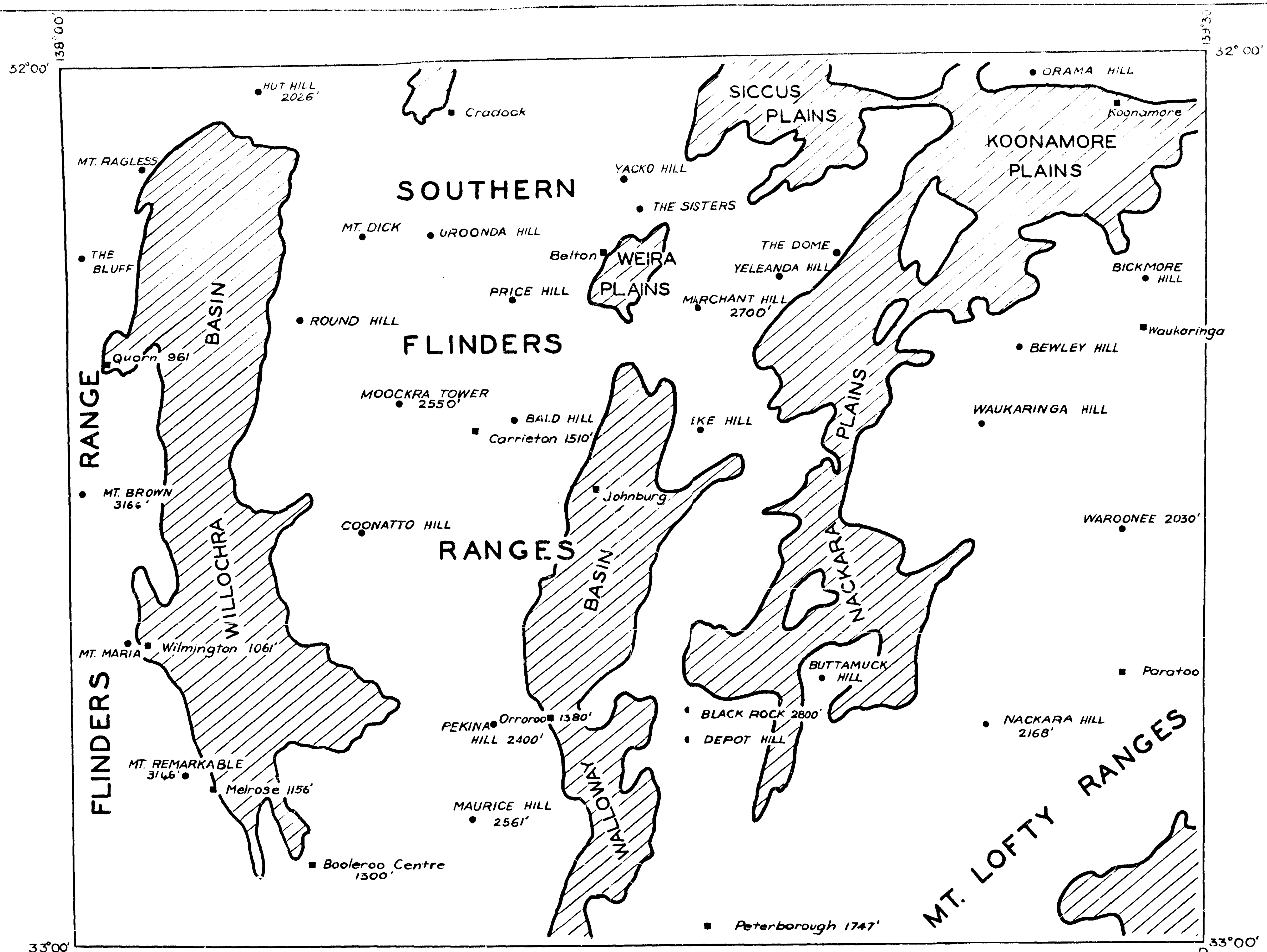
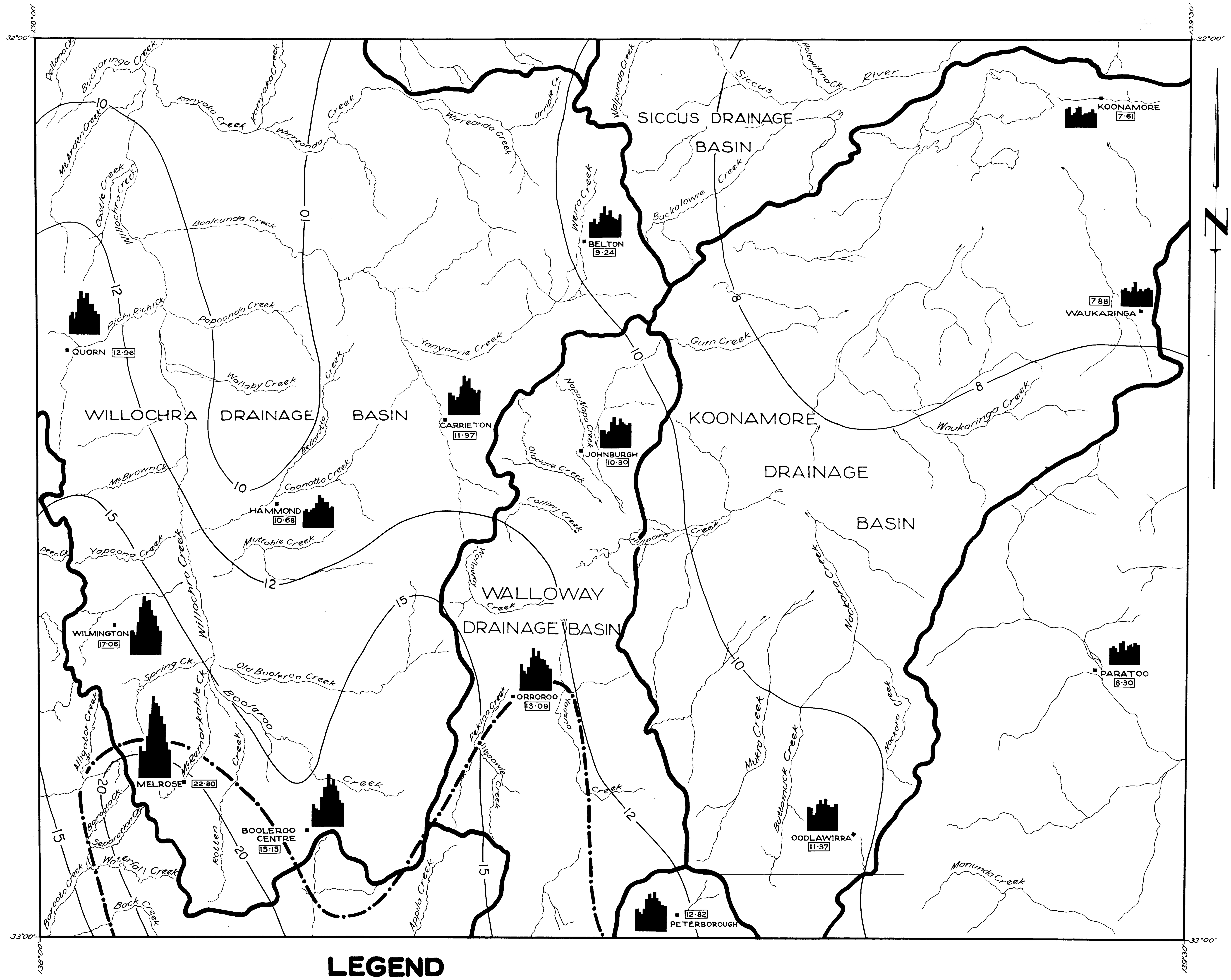


FIG. 2

DEPARTMENT OF MINES — SOUTH AUSTRALIA			
ORROROO 1:250000 SHEET PHYSIOGRAPHIC SUBDIVISIONS			
		Drn. P.B.	SCALE: 1 Inch = 8 Miles (approx)
		Tcd. R.A.J.	66-1001 Fef + hj
		Ckd. L.V.W.	
Director of Mines		Exd.	DATE: 17th. Nov. 1966



LEGEND

—12— —10— Isohyets in inches

Goyder's Line

Watershed

11·37 Average Annual Rainfall in inches

0 50 100 150 200 Average Monthly Rainfall in points

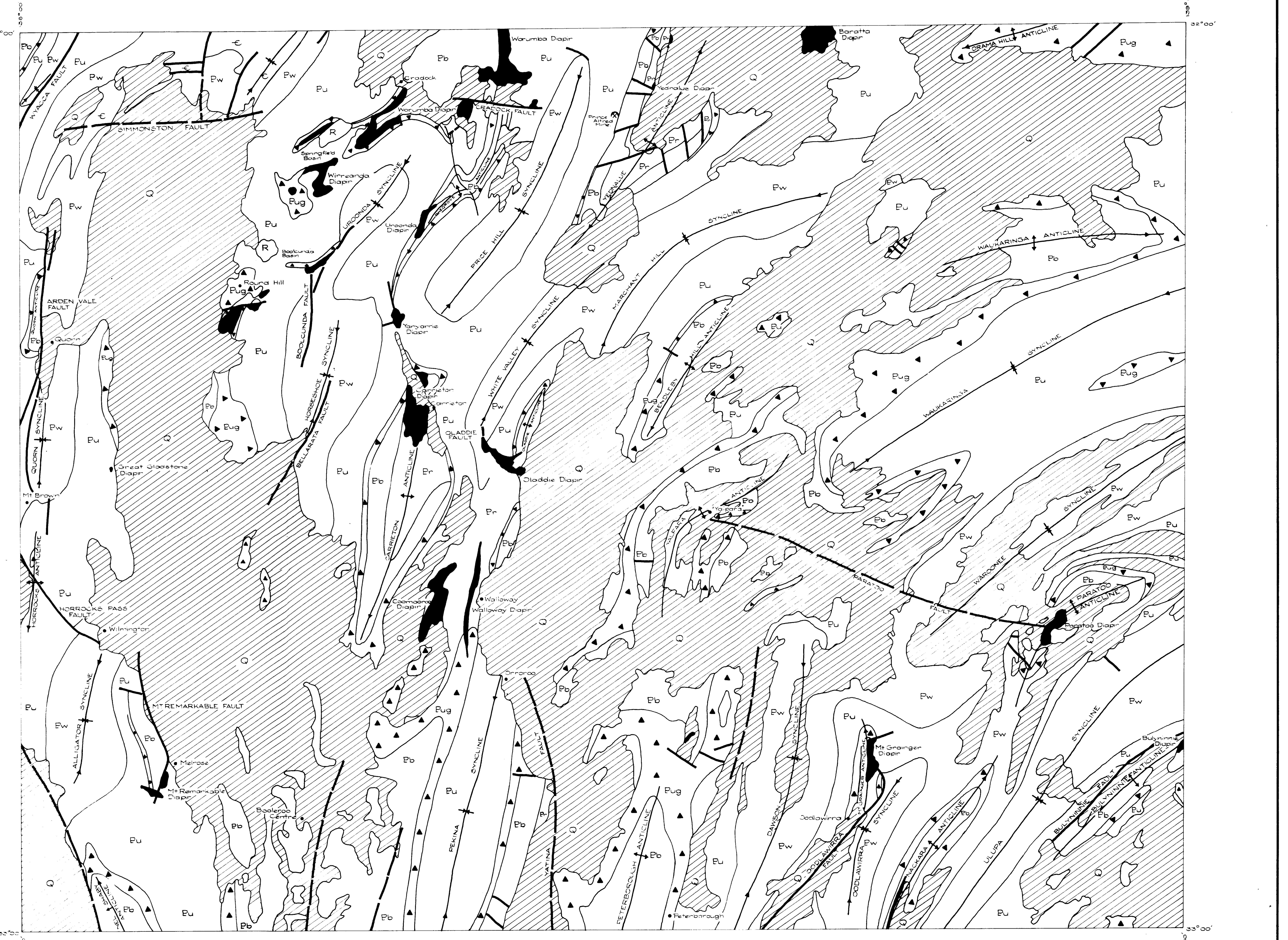
SCALE

4 0 4 8 12 16

MILES

FIG. 3

DEPARTMENT OF MINES — SOUTH AUSTRALIA			
ORROROO 1:250,000 SHEET			
RAINFALL AND DRAINAGE			
	Drn. P.J.B.	SCALE: 4 miles to 1 inch	
	Tcd. G.M.	66-977	
	Ckd. L.V.W.	Fef +hj	
Director of Mines	Exd.	DATE: 8·11·66	



LEGEND

QUATERNARY	Q	
TRIASSIC	R	
CAMBRIAN	€	
MARINOAN	Pw	WILPENA GROUP
	Pu	UMBERATANA GROUP
STURTIAN	Pug	YUDNAMUTANA SUB-GROUP
TORRENSIAN	Pb	BURRA GROUP
WILLOURAN	Pr	RIVER WAKEFIELD GROUP
		DIAPIRIC ROCKS (Callanna Beds)

FIG: 4.

DEPARTMENT OF MINES — SOUTH AUSTRALIA

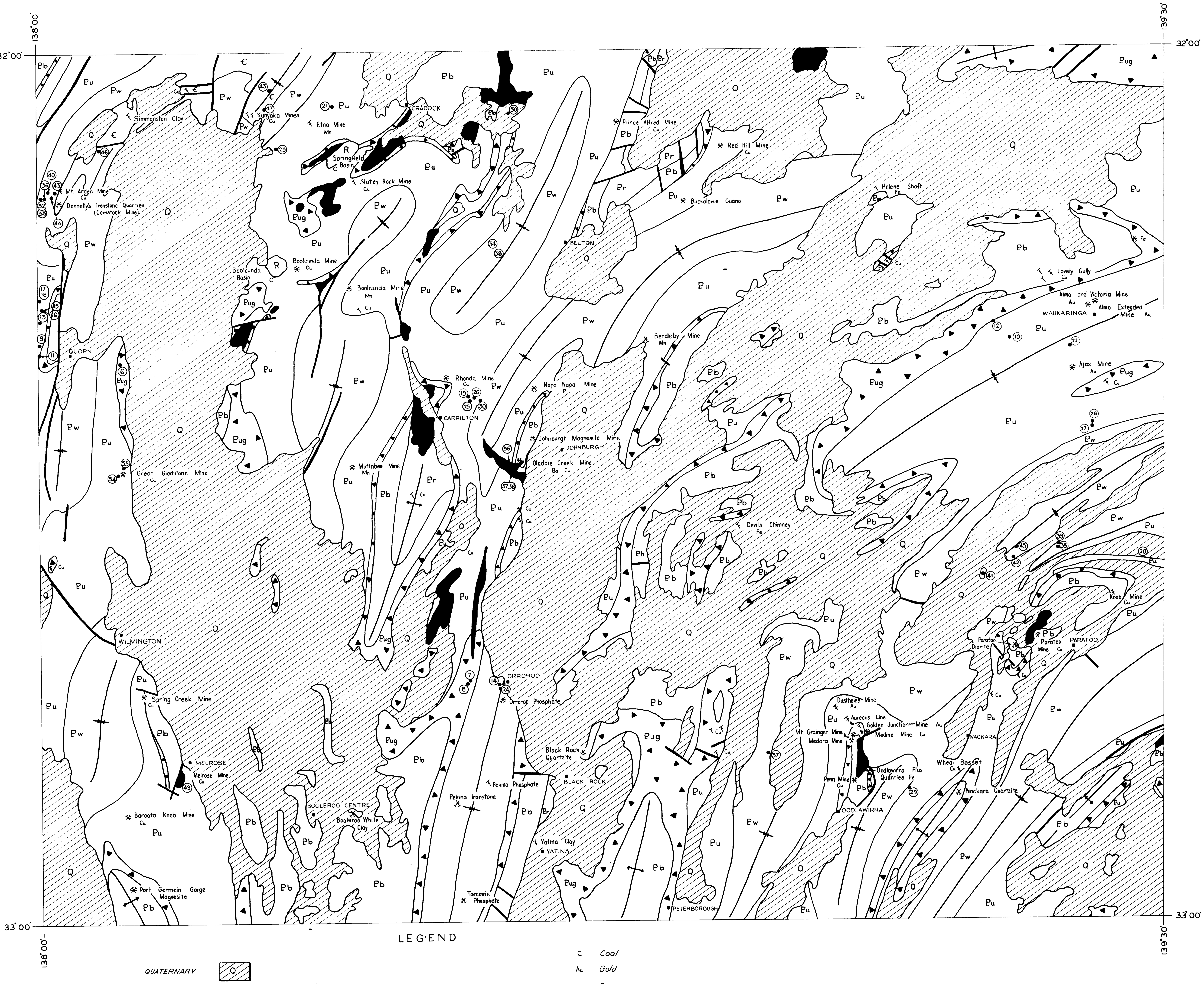
ORROROO 1:250 000 SHEET

GEOLOGICAL SKETCH MAP : REGIONAL STRUCTURE

Drn. PB	SCALE: 1" = 4 miles	
Tcd.	67-595	
Ckd.		
Director of Mines	Exd.	DATE: 21-8-67

FIG. 8

L 67-91 Fe



LEGEND

QUATERNARY	Q	
TRIASSIC	R	
L. CAMBRIAN	€	Hawker Group
Adelaide System	Pw	Wilpena Group
	Pu	Umberatana Group
	▲▲▲ Pb	Burra Group
	Pr	River Wakefield Group
	(black)	Diapiric ? Callanna Beds

- C — Coal
- Au — Gold
- Cu — Copper
- Fe — Iron
- P — Phosphorite
- Mine
- Abandoned mine
- Prospect: little or no production
- Open cut or quarry
- Abandoned open cut or quarry
- (9) — Petrological sample localities

FIG. 10

DEPARTMENT OF MINES — SOUTH AUSTRALIA			
ORROROO 1:250 000 SHEET			
MINERAL DEPOSITS AND SAMPLE LOCALITIES			
	Drn. P.B.	SCALE: 1" = 4 Miles	
	Tcd. R.A.J.	67-649 Fef + hj	
	Ckd. L.V.W.		
Director of Mines	Exd.	DATE: 19th. Sept '67	