THE STRATIGRAPHY OF THE STURTIAN GLACIGENE AND FERRUGINOUS SEDIMENTS, SOUTHEAST OF MATTAWARRANGALA STATION, CENTRAL FLINDERS RANGES, SOUTH AUSTRALIA.

by

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Frontispiece: Jaspilite showing the jasper lenses and secondary enrichment of hematite controlled by fractures.


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ABSTRACT

Detailed stratigraphic mapping of sediments of the Sturtian Glacial Sequence was carried out in an area in the Central Flinders Ranges. These sediments are unconformable on the Burra Group and are represented by the Pualco Tillite, the Holowilena Ironstone and the Wilyerpa Formation. The Pualco Tillite consists of lenticular diamictites, siltstones and sandstones and passes conformably into the Holowilena Ironstone which is composed of a mixture of chemical and detrital components. Minor erosion after the deposition of the Holowilena Ironstone is explained to be a result of post-Holowilena Ironstone faulting, which is responsible for a deepening of the basin of deposition. Evidence for ice-rafting in sediments of the Wilyerpa Formation is provided by the common occurrence of dropstones. The time gap between the Pualco Tillite, the Holowilena Ironstone and the Wilyerpa Formation is insignificant, based on the presence of a sandstone dyke which cuts the boundary between the Pualco Tillite and the Wilyerpa Formation (in absence of the Holowilena Ironstone).

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1. INTRODUCTION

General

The thesis area is located on Mattawarrangala Station 50km east of Hawker in the Central Flinders Ranges. The map area, which lies 2km south of the homestead, occupies an area of about 30 sq. km. Outcrop is, in general, quite good with excellent exposure occurring in several creeks which cross-cut the regional strike. Field work was carried out for a period of six and a half weeks between late May and late July, 1978.

Regional Setting

The map area is situated on the northern extremity of the Yednalue Anticline in the central part of the Adelaide Geosyncline. Fig. 1 shows the location and regional geology. Sediments of the Adelaide Geosyncline are of Late Precambrian to Cambrian age and extend from the Mt. Lofty Ranges in the south to the Peake and Denison Ranges 1100km to the north. These sediments have been divided into four groups; the Wilpena Group, the Umberatana Group, the Burra Group and the Callana Beds. Sediments of the Adelaide Geosyncline are not true geosynclinal sediments in that most are shallow marine. Pre-Sturtian to early Sturtian tectonism has been responsible for creating fault bound basins in which very thick local accumulations of sediment were deposited.

Previous Investigations

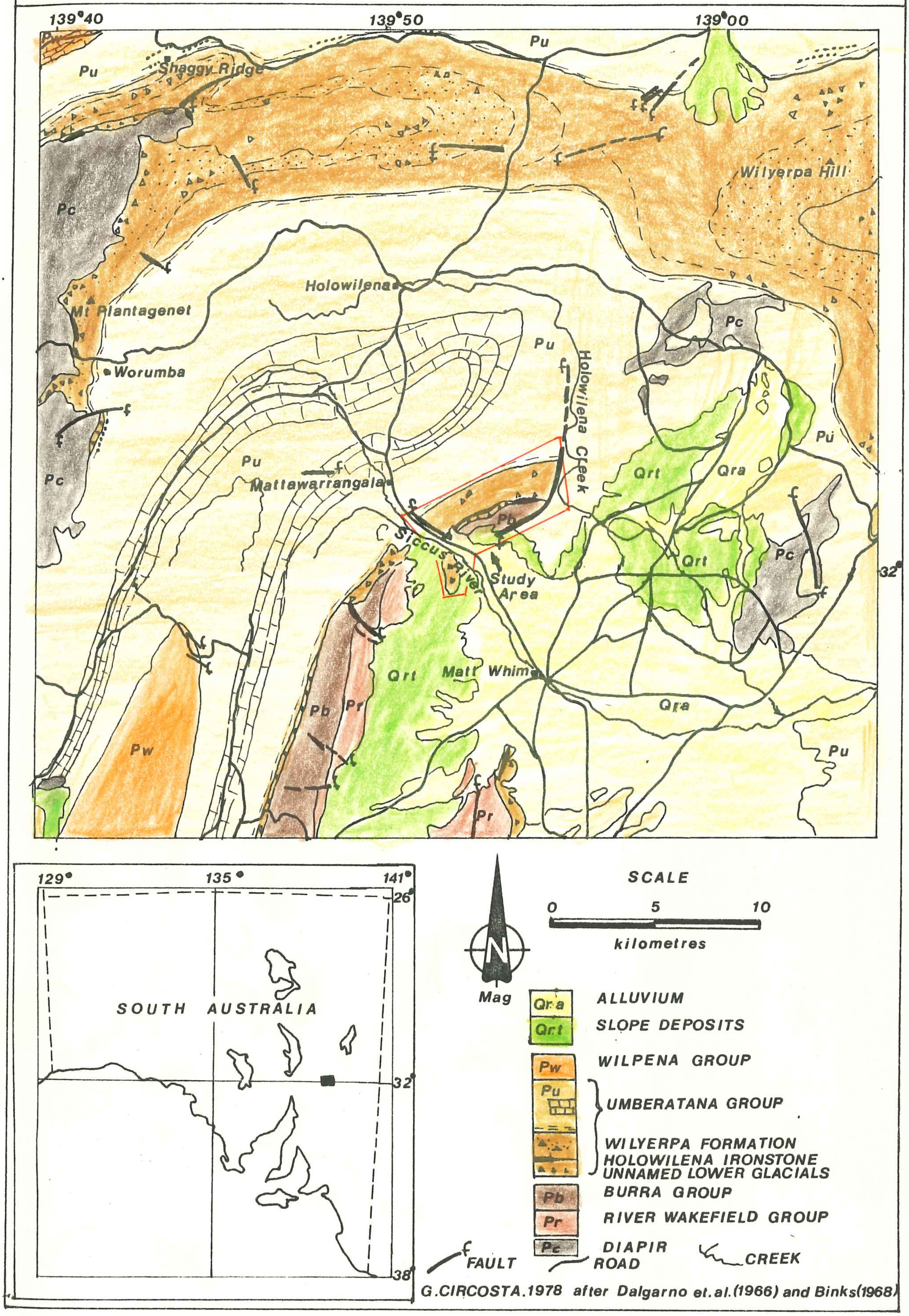
Much of the early work on the geology of the Flinders Ranges was carried out by Mawson, who in a series of papers between 1938 and 1949 described much of the Adelaidean Sequence. Mawson (1949) described the glacial sequence at Bibliando Dome, some 20km to the east of the map area. The Geological Survey of South Australia have published the 1:250,000 PARACHILNA sheet (Dalgarno and Johnson, 1966) with explanatory notes (Forbes, 1972). Dalgarno and Johnson (1965) have published a small article defining the Holowilena Ironstone and its overall stratigraphic position in the type section, which is the thesis area. Spry (1951a, 1951b) has described the geology of the Worumba Diapir and the surrounding Adelaidean sediments.

Nomenclature

Due to the controversy over the terminology of sediments containing dispersed megaclasts (Schermerhorn and Stanton, 1963, Harland, Herod and Krinsley, 1966, Flint, 1971, Schermerhorn, 1966, 1974, Jago, 1974, 1976) non genetic names are to be used in the terminology of such sediments. Several synonomous names have been proposed including diamictite (Flint, et. al. 1960) and mixtite (Schermerhorn, 1974). A diamictite is defined as a non calcareous sediment with a wide variation in particle size. The author will in this study include any calcareous clastic rocks under the classification of diamictite. Names with genetic connotation, such as tillite, can be used once the glacial origin of the sediments is proven.

FIGURE 1

Location and Regional Geology Map



G.CIRCOSTA.1978 after Dalgarno et.al.(1966) and Binks(1968)

2. STRATIGRAPHY

General

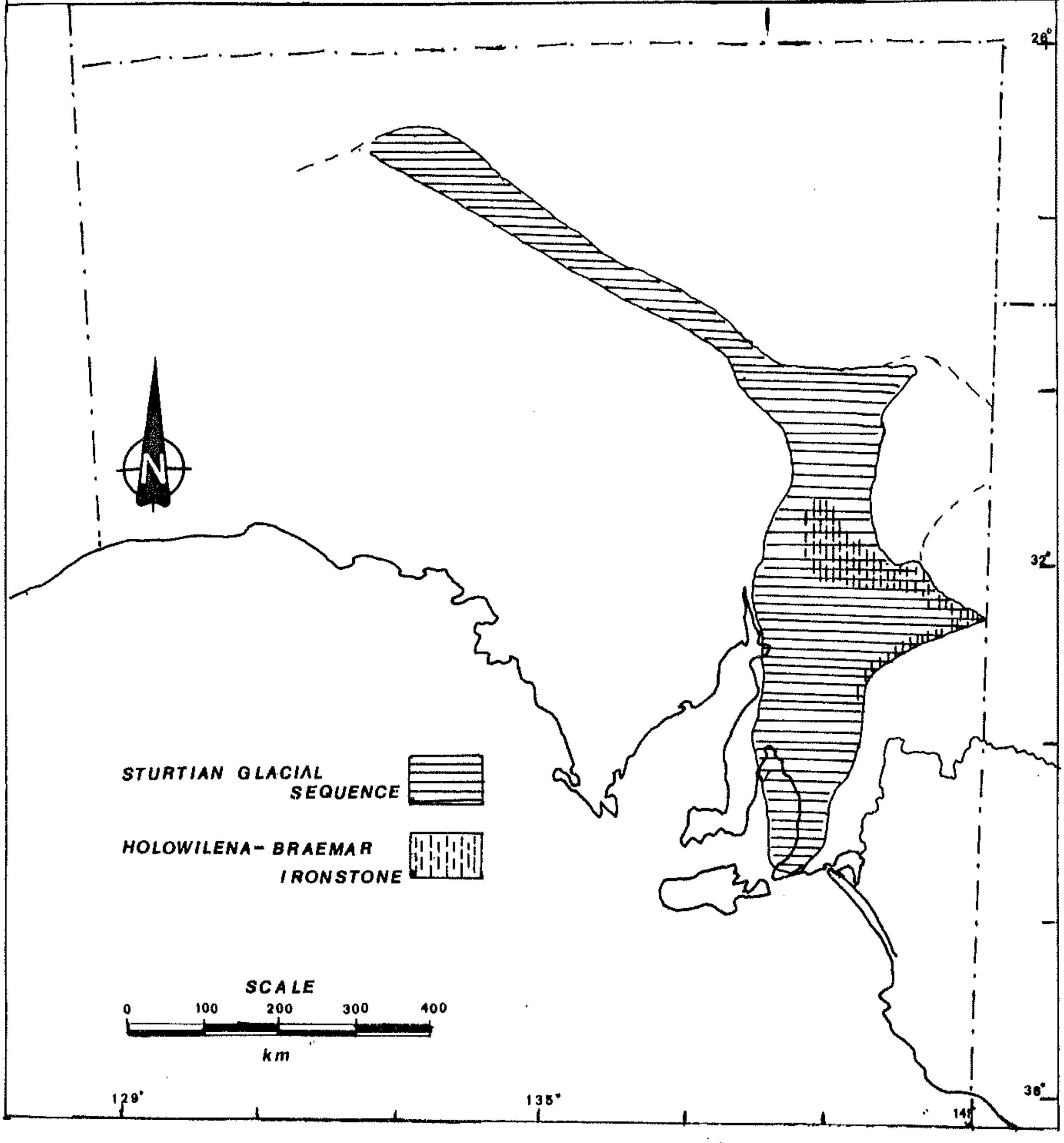
Sediments examined are part of the Adelaidean Burra and Umberatana Groups defined by Mirams and Forbes (1964) and Coats (1964) respectively. The Umberatana Group is defined as the sediments between the top of the upper glacial sequence (Marinoan) and the base of the lower glacial sequence (Sturtian). The lower glacial sequence was defined by Coats (1964) as all the Sturtian Glacial Sequence in the Mount Painter area and called the Yudnamutana Subgroup. It was, however, redefined by Coats (1973) and Coats et. al. (1973) to exclude the upper most portion of this sequence. Forbes and Coats (in Thompson et. al., 1976) tentatively subdivide the Sturtian Glacial Sequence into three groups. The lowermost of these includes thick tillites such as the Pualco Tillite in the Olary region and the Bolla Bollana Formation in the Mount Painter area. The middle unit contains the Braemar Iron Formation, the Holowilena Ironstone and the Benda Siltstone. These iron rich sediments have been mapped and interpretted by Forbes and Coats (in Thompson et. al. 1976) as representing a time stratigraphic unit and base the stratigraphic correlation of the Sturtian Glacial Sequence on this. The upper-most unit includes the tillite of Mount Jacob, the Merinjina Formation (Link, 1977), the Wilyerpa Formation, the Apilla Tillite and the Sturt Tillite, and is said to be characterized by the presence of reddish quartzites and porphyry boulders probably derived from the Gawler Craton (Forbes and Coats in Thompson et. al. 1976). This unit is not a part of the Yudnamutana Subgroup and is said to unconformably overlie the older glacial sediments. Correlation of the Umberatana Group in the Adelaide Geosyncline is shown on Table 1. The distribution of the Sturtian Glacial Sequence is shown in Fig. 3.

This study examines representatives of all three units. The Pualco Tillite Equivalents, which were mapped as unnamed lower glacials by Dalgarno and Johnson (1966), for the purpose of this study are referred to as the Pualco Tillite Equivalents, based on its stratigraphic position with respect to the Holowilena Ironstone. The upper unit is represented by the Wilyerpa Formation.

TABLE 1

TIME UNITS	CORRELATION OF THE UMBERATANA GROUP IN THE ADELAIDE GEOSYNCLINE			ROCK UNITS
MARINOAN	NUCCALEENA FORMATION			WILPENA GROUP
	ELATINA FORMATION		YERILINA SUBGROUP	UMBERATANA GROUP
	BRIGHTON LIMESTONE TAPLEY HILL FORMATION TINDALPINA SHALE MEMBER		FARINA SUBGROUP	
STURTIAN	STURT AND APILLA TILLITES WILYERPA AND MERINJINA FORMATIONS		Upper phase of Sturtian Glaciation	
	HOLOWILENA IRONSTONE, BRAEMAR IRON FORMATION BENDA SILTSTONE		YUDNAMUTANA SUBGROUP	
	OLARY PROVINCE PUALCO TILLITE	MT. PAINTER REGION LYNDHURST FORMATION BOLLA BOLLANA FORMATION FITTON FORMATION		
			BELAIR SUBGROUP	
TORRENSIAN	G. Circosta, 1978 modified from Thompson *et. al.* 1976.			BURRA GROUP

FIGURE 3 KNOWN AREAS OF STURTIAN SEDIMENTS



G. CIRCOSTA 1978 after PARKIN 1969

THE BURRA GROUP

The Burra Group is represented by poorly outcropping dolomites green shales and quartzites. For mapping purposes, subdivision into individual formations has not been made because of the lack of outcrop and the highly variable nature of the Burra Group sediments due to pre-Sturtian faulting.

Dolomites are represented by two main types. The first of these is dark grey well laminated dolomite which is commonly associated with dolomitic siltstones. This type of dolomite is seen to outcrop only in the eastern half of the map area where it is the oldest outcropping Burra Group. Older sediments are not present because of the large fault which cuts off the eastern limb of the Yednalue Anticline. Dalgarno and Johnson (1966) have mapped this unit as the Skillogalee Dolomite. The second type of dolomite is a bright yellow weathering, pale grey dolomite which can be both bedded and massive. Associated with this dolomite is diagenetic black chert which forms nodules 5mm in diameter, elongate replacements parallel to bedding, and larger irregular bodies. This type of dolomite typically occurs near the top of the Burra Group.

The siltstones are green and fissile, tending to be massive but can be well laminated and cross bedded when sandy. Common within these shales are limonite nodules after pyrite, up to 1cm in diameter. Near the top of the Burra Group a well laminated slightly sandy shale contains synaresis cracks, indicating shrinkage in a subaqueous environment. These siltstones are associated with quartzites and dolomites, especially dolomites of the second type.

Quartzites have a variety of different characteristics, some are massive, others are bedded and can show large scale tabular cross-beds. Grain size varies from fine to coarse and can contain small well rounded granules. Some have a calcareous matrix, others have a slightly hematitic matrix giving a red colouration. Limonite after pyrite is common and clay galls are rare. These quartzites are sometimes lensoidal, having a maximum thickness of about 10 metres and are commonly interbedded with siltstones and dolomites.

The Burra Group - Umberatana Group Contact

There is evidence to suggest that this boundary constitutes a major time gap. This evidence includes an excellent angular unconformity observed at several localities, the angle difference being up to 20^{o}. Evidence for an unconformity is also seen when one examines the clast lithologies of the glacials which are dominantly intrabasinal from the Burra Group. Evidence of pre-Sturtian faulting is seen by faults which cut Burra Group sediments but do not cut Umberatana Group sediments. This results in a varied sequence within the Burra Group. Evidence also suggests a basin high at the time of deposition of the Pualco Tillite. These sediments are seen to thin rapidly to the east due to non-deposition on the eastern flank of this basin high, while sediment was filling the main part of the basin to the west. These relationships are seen in Figure 2 (back pocket).

THE UMBERATANA GROUP

The Pualco Tillite Equivalent

The basal Umberatana Group is represented by the Pualco Tillite Equivalent. This unit consists mainly of interbedded and lenticular diamictite, siliceous siltstone, fine sandstone and dolomite. Its maximum thickness is about 250m, thinning out to the east onto a basement high.

Diamictites

These are strongly lenticular units containing mainly intrabasinal clasts but locally they possess abundant exotics which are mainly granitic (Plate 1(a)). Dominant clast lithologies are dolomites, grey siltstones, quartzites, black chert, sandstone and rare oolitic limestone. Grey siltstone clasts, and less commonly quartzite clasts are commonly striated (Plate 1(c)). Some clasts are faceted. Erratic clasts are generally small, rarely reaching cobble size, but can attain a maximum size of 80x50cm. The diamictite matrix is silty, dolomitic or sandy, and most diamictites contain rounded, medium sand sized grains of quartz. Diamictites are generally massive although some show a clast orientation parallel to bedding and in one, a subvertical clast orientation was observed. A bright yellow dolomitic diamictite about 5-6 metres thick (Appendix I, 125m mark of Section 5) occupies a channel cut into a sandstone. It lenses out in an east-west direction and has a total strike length of about 100 m. At the top of several diamictites are thin gritty beds which represent winnowed diamictites. Clast types in these sandy and gritty beds include quartzite, siltstone, dolomite and quartz.

Siltstones

These are siliceous, usually pale green, and vary from massive to fissile, containing rare convolute bedding. They may contain rare small clasts and at times are quite sandy. Apart from bedding, no other sedimentary structures have been observed. Towards the top of the Pualco Tillite in the transition to the Holowilena Ironstone these siltstones may be iron-rich. Like the diamictites the outcrop pattern of these sediments is lenticular.

Sandstones

The sandstones tend to be massive but are occasionally cross-stratified. They are usually lenticular, pale grey, and fine grained. Although clasts are rare some sandstones have small clasts of quartz and siltstone, with rare thin gritty beds which probably represent winnowed sands. These sandstones are quite common in the transitional zone to the Holowilena Ironstone. They occur as both iron-rich and iron-poor fine to medium grained and are generally devoid of clasts.

The glacial origin of the diamictites is supported by the presence of striated clasts. The very lenticular nature of the diamictites and their association with generally clast-poor shales and sandstones makes environmental interpretations difficult. These may be interpreted as terrestrial glacials but the fine grained clast-poor shales would be difficult to explain.

The Pualco Tillite - Holowilena Ironstone Boundary

The relationship between the Pualco Tillite and the overlying Holowilena Ironstone seems, for the main part, to be a conformable transistion. This results in a poorly defined boundary between these two units. This transitional zone seems to consist mainly of fine to medium grained generally massive iron-rich and iron-poor sandstones, thin dolomites containing layers rich in hematite, and thin gritty beds. The nature of the thinning out and eventual disappearance of the Holowilena Ironstone may be the result of non deposition to the east due to the infilling of a basin. In the eastern edge of the main development of the Holowilena Ironstone, iron-rich sediments seem to overlie and overlap a possible eroded surface of the Pualco Tillite. At one locality near the base of the ironstone it was observed that a hematitic silty-sand occupied a 1.25m deep erosional channel into non-hematitic siltstones. Other minor erosive channels have been observed elsewhere.

THE HOLOWILENA IRONSTONE

General

The map area includes the type section of the Holowilena Ironstone which was defined and first described by Dalgarno and Johnson (1965). They considered that the environment of deposition illustrates a transition between a transgressive morainic phase at the margin of a half graben which lies to the south-west of the map area. The glacial origin of the Holowilena Ironstone appears likely as in some areas, such as east of Oraparina asbestos mine, as striated quartzite dropstones occur in laminated siltstones within the Holowilena Ironstone (Daily and Forbes, 1969, p 27). In the Olary region the Braemar Iron Formation which is said to be the equivalent of the Holowilena Ironstone occurs near the top of the Yudnamutana Subgroup. The type section at Razorback Ridge was defined and described by Mirams (1962) and studied in much greater detail by Whitten (1970). The Braemar Iron Formation is described as a hematitic and magnetitic siltstone and ferruginous tillite interbedded with thin dolomites, graphitic slates and tillites, the sequence attaining a maximum thickness of 760 metres with all units being lenticular in nature. This is underlain by the Pualco Tillite and overlain by the Wilyerpa Formation. The Holowilena-Braemar Iron Formations are shown in Fig. 3 to occupy an area of 10,000 sq. km.

The Type Section

The lower boundary is difficult to locate due to the lenticular nature of the underlying Pualco Tillite and the probable lenticular nature of the iron-rich sediments. This boundary has already been discussed and was suggested to be a conformable transistion representing a change in the chemistry of the waters so as to favour the precipitation of hematite. The basal iron-rich sediments are usually interbedded hematite-rich and hematite-poor carbonate-rich sandstones. Clasts are rare and small in the sandy beds. Thin sandy beds in laminated siltstones are commonly lenticular and contain a variety of sedimentary structures which include cross-laminae, ripple bedding, flute clasts, soft sediment slumping, load casts and very rare long-wavelength, shallow-amplitude ripples.

Characteristic of the ironstone are beds of jaspilite which are usually about 30cm thick. These are interpreted as chemical sediments rich in silica. There appear to be two main types of jaspilite present, the first being the well bedded variety which commonly contains small jasper lenses whose origin is problematical (Frontispiece, Plate 2(b)). These lenses are 1-3mm long and always flattened parallel to bedding, giving a streaked appearance in hand-specimen. These lenses have a distinct zoning pattern which starts with a core made up of gangue and hematite which is usually surrounded by hematite poor microcrystalline jasper. This is in turn surrounded by a very hematite-rich zone. Some of these lenses are made up of white chert and others may show replacement by hematite.

This replacement of jasper by hematite is controlled by fractures and is easily seen in the Frontispiece. These jasper lenses are very similar to those observed in the Late Precambrian Rapitan Group of Canada which contains glaciogenic iron deposits. These lenses are interpreted as early diagenetic alteration of bedded iron ore. The jasper is associated with some thin beds of detrital material. Small ghosts of rhombs, probably after dolomite, are seen within the jasper and consist of silica. Their shape is outlined by a zone of iron-rich silica (Plate 2(a)). These rhombs are very common in some layers and are interpreted as representing early diagenetic crystals of dolomite which seem to cross-cut the very fine laminations observed in the rock. The second type of jaspilite appears as large lensoid to irregular bodies commonly parallel to bedding. This type of jasper is not as common as the first and is interpreted as secondary growth of jasper.

The typical laminated hematitic siltstone (Plate 3(c)) contains as much as 66% Fe_2O_3 as very fine hematite flakes generally about 0.01mm long. This is the dominant facies near the top of the ironstone. Laminae in this rock are very fine and consist of alternations of hematite-rich silt and hematite deficient silt. Carbonate apatite occurs in some of the hematitic siltstones, commonly as distinct bodies up to 1mm long and parallel to bedding (Plate 2(c)). These bodies are not detrital, and are composed of microcrystalline apatite with some hematite. At times they are seen to push bedding aside. This can be due to compaction or later growth of apatite within the sediment. The apatite is probably original but how it formed these concentrations is a problem. They may be some original sedimentary feature, possibly being some sort of concretion, or they may form by the secondary replacement of another mineral. Pettijohn (1975, pg 432) states that the high concentrations of P_2O_5 in iron rich sediments suggests that the environment of phosphorite and ironstone deposition have many factors in common.

The sandy-carbonate facies is very common especially in the east of the ironstone outcrop where it is seen to consist of very finely laminated sands, commonly graded on a scale of 0.5 - 1mm. This sand consists of quartz, dolomite and rare plagioclase, supported by a fine silt containing dolomite and hematite. These sandy units commonly have loaded bases and are generally associated with most of the sedimentary structures seen.

Throughout the ironstone are lenticular units of small clast-rich hematitic diamictite, which have a maximum thickness of 20m and are continuous for up to 2-300m. The clasts, which are generally less than 5mm in diameter with a maximum of 3-4cm, occur in a hematitic siltstone matrix. These are mainly hematitic siltstone, siltstone, dolomite, sandstone, and common rounded quartz grains. Examination in thin section reveals the clasts to be parallel to bedding. These diamictites are most probably mud flow deposits which have ripped up fragments of the underlying hematitic siltstone and have been observed to be draped by overlying units.

Towards the east the ironstone lenses out, its dominant facies being the sandy-carbonate facies with minor hematitic siltstone and jasper beds. These sediments are usually overlain by a clast-rich hematitic diamictite containing abundant jasper clasts. This represents an erosional interval at the top of the ironstone. Evidence of a brief erosional period is seen within the ironstone on the extreme east of the ironstone outcrop where a jasper clast is seen within bedded sands and hematitic siltstones. The reappearance of the ironstone to the east is represented by 15m of the sandy-carbonate facies overlain by a thick jaspilite unit which contains abundant martitized magnetite euhedra (Plate 3(a)). These euhedra are randomly oriented, not concentrated along bedding planes, and are all perfectly shaped, so a secondary origin is favoured. Whitten (1970), in describing the Braemar Iron Formation, interprets magnetite euhedra as representing chemical precipitates which have undergone very little transportation after formation. The grade of metamorphism of the Braemar Iron Formation is higher than that of the Holowilena Ironstone so a metamorphic origin for the magnetite is more probable. Whitten's interpretation of the fine grained Holowilena Ironstone as being deposited further from the source than tillitic ore is rejected.

The environment of deposition for the Holowilena Ironstone is a shallow basin, probably lacustrine. Sedimentary structures include cross laminae, starved ripples, flute casts, small slumps and shallow amplitude long-wavelength ripples. These structures are always associated with sandier beds indicating that the deposition of sandier material occurred under slightly higher energy conditions. The sandy-carbonate facies has common small-scale graded beds which are interpreted as the product of sediment from suspension, probably in a shallow water environment. Although conditions were generally very quiet, sandstones near the base can contain soft sediment clasts of hematitic siltstone (Plate 3(b)). Hematitic diamictites represent mass flow deposits which, from available palaeocurrent data (shown in Fig. 2), moved down a palaeoslope from the west to north-west. The source of the iron is problematical. A chemical origin for the hematite and jasper is favoured. These chemical components are mixed with fine detrital material including quartz, dolomite and rare feldspar.

GEOCHEMISTRY OF THE HOLOWILENA IRONSTONE

Whole rock and trace element analyses were carried out to determine the characteristics of the different facies of the Holowilena Ironstone. The four main facies analysed were the hematitic siltstones, the sandy carbonate facies, the jaspilites and the hematitic diamictites. Much of the trace element analyses were carried out with the idea that information about the provenance of the detrital component of the ironstone could be obtained. The results for whole rock and trace element analyses are shown in Tables 2 and 3.

Hematitic siltstones

These are characterised by very high Fe_2O_3 concentrations of up to 66%, with a bulk of the remainder being silica. The calcium content of these hematitic siltstones is generally less than 2%, although sample 548-363 has a high value of 4.98% which can be explained by the presence of 10% carbonate apatite in the sample (determined by X-Ray Diffraction, Appendix IIID). This is reflected in the presence of 3.66% P_2O_5. Of the trace elements, the most variable are strontium and barium. Strontium favours the replacement of calcium in the carbonates increasing with the calcium content. Rubidium shows a good correlation with potassium which is present in detrital feldspars.

Sandy-carbonate facies

These sediments have less iron-oxide and more silica than the hematitic siltstones. They are characterised by much higher calcium and magnesium values, due to the presence of fine sand sized detrital dolomite grains. The higher values for potassium and sodium are due to the presence of more detrital feldspars. This results in higher rubidium concentrations. Both zirconium and titanium have a higher concentration than in the hematitic siltstones which would indicate a detrital origin for the minerals containing them.

Jaspilites

Iron and silica make up a large portion of these samples. From the few analyses of these rocks, the iron shows significant variation, this being due to secondary enrichment of hematite. Some calcium and magnesium are present - probably as dolomite. Detrital material is rare and is reflected in the low potassium and sodium values which are normally found in detrital feldspars. Trace elements, as expected, are depleted, the only exception being barium, which is possibly associated with barite in the sample. Sample 548-297 is not a typical jaspilite, containing abundant white chert and magnetite.

Hematitic diamictites

These show a dilution in Fe_2O_3 by detrital components which include silica in quartz, calcium and magnesium in dolomites, and potassium and sodium in feldspars. These detrital components were observed under the microscope (TS 548-225).

The association of Late Precambrian glacial deposits with iron formations appears to be quite significant, also occurring in Canada, South America and Africa. Young (1976) suggests that a world wide glaciation on a global scale may provide an explanation for the ironstones which are associated with the glacial deposits. In Canada, the Rapitan Group (Gross, 1965, Gabrielse, 1972, Gabrielse et. al. 1973, Yeo, 1976, Young, 1976, Delaney et. al. 1977, Yeo, 1977, and Young, 1977) forms the youngest Proterozoic of the northern cordillera. The glacial origin of the group is based on widespread presence of diamictites, the presence of deeply striated and faceted clasts, and the presence of dropstones. The mineralogy of the ironformation is jasper and hematite with minor carbonate, apatite, chlorite and greenalite.

TABLE 2. MAJOR AND TRACE ELEMENT ANALYSES

	HEMATITIC SILTSTONES						CHEMICAL JASPILITES			HEMATITIC DIAMICTITES*	
	342	343	344	362	363	390	159	339	297	225	422
SiO_2	27.00	25.64	36.70	25.92	40.31	32.03	68.15	50.74	62.68	57.33	61.79
Al_2O_3	2.24	2.77	2.93	2.89	3.34	3.74	0.09	0.29	1.90	4.53	4.84
Fe_2O_3	63.34	66.49	52.22	64.29	43.75	54.32	28.36	47.33	31.40	14.18	15.37
MgO	2.48	1.97	1.59	1.40	1.24	2.73	0.73	0.41	0.51	3.23	3.47
CaO	1.48	0.64	2.48	1.96	4.98	2.21	1.04	0.63	0.19	4.24	4.61
Na_2O	0.08	0.17	0.23	0.12	0.46	0.43	0.06	0.07	0.05	0.90	0.89
K_2O	0.20	0.46	0.54	0.52	0.65	0.72	0.03	0.07	0.61	1.40	1.49
TiO_2	0.16	0.22	0.24	0.21	0.22	0.28	0.01	0.04	0.11	0.28	0.30
P_2O_5	0.45	0.47	1.88	1.41	3.66	1.08	0.14	0.41	0.22	0.48	0.51
MnO	0.06	0.05	0.07	0.06	0.05	0.06	0.04	0.03	0.08	0.03	0.05
Loss	2.41	1.29	1.40	1.39	1.09	2.47	1.32	0.20	2.06	13.13	6.58
Total	99.90	100.17	100.28	100.17	99.75	100.07	99.97	100.21	99.81	99.73	99.90
Zr	26	46	39	46	35	46	1	10	37		
Nb	4	7	4	10	7	7	4	0	1		
Ce	22	42	40	35	44	40	11	12	12		
Nd	1	10	16	22	22	18	4	0	3		
Ba	52	236	404	86	112	120	513	184	113		
Ti	987	1366	1496	1351	1379	1780	72	238	720		
Ni	7	11	2	16	15	15	10	16	8		
Zn	27	30	31	24	21	17	4	5	7		
Rb	8	14	16	21	17	27	3	7	17		
Sr	52	75	282	155	397	120	86	62	8		
Y	27	37	30	36	35	30	10	19	12		

Major element concentrations are in wt %. Trace element concentrations are in ppm.
* Only whole rock analyses done.

TABLE 3. MAJOR AND TRACE ELEMENT ANALYSES

	SANDY-CARBONATE ROCKS										
	321	322	324	353	360	370	388	389	391	404	417
SiO_2	36.55	35.71	38.97	35.52	36.77	41.41	41.41	47.35	42.69	39.44	37.39
Al_2O_3	4.23	4.90	3.53	4.27	4.36	4.05	4.67	4.43	4.71	4.36	4.96
Fe_2O_3	33.82	33.82	38.47	32.38	28.80	16.93	33.62	30.95	41.92	27.28	31.37
MgO	7.26	6.47	3.57	6.46	6.12	8.59	4.70	3.52	1.34	5.87	4.90
CaO	8.30	6.46	6.01	7.48	8.11	10.15	4.84	4.04	2.91	8.48	8.02
Na_2O	0.49	0.48	0.42	0.65	0.94	0.66	0.86	0.89	1.12	1.44	0.77
K_2O	0.82	0.85	0.79	1.25	1.02	0.87	1.11	1.08	1.30	0.53	1.16
TiO_2	0.29	0.35	0.25	0.33	0.30	0.26	0.36	0.29	0.36	0.28	0.34
P_2O_5	0.44	0.48	1.31	0.68	0.35	0.19	0.46	0.73	2.12	0.50	0.45
MnO	0.10	0.08	0.07	0.15	0.09	0.18	0.09	0.06	0.03	0.14	0.09
Loss	13.09	10.32	6.58	11.01	12.69	16.73	7.61	6.58	2.12	11.90	10.46
Total	100.01	99.92	99.97	100.18	99.55	100.02	99.73	99.92	99.60	100.22	99.91
Zr	63	73	44	115	64	68	78	72	88	68	81
Nb	2	9	7	8	8	6	4	8	9	9	5
Ce	34	38	44	32	36	18	32	26	44	26	30
Nd	11	10	11	10	5	10	13	11	19	13	12
Ba	134	141	144	176	165	141	164	194	524	104	215
Ti	1828	2246	1547	1998	1909	1603	2216	1855	2290	1778	2252
Ni	17	14	13	13	11	13	13	9	20	10	17
Zn	31	46	26	23	20	39	14	12	12	11	37
Rb	21	21	25	36	23	36	28	25	28	17	37
Sr	187	159	229	195	178	158	63	124	263	232	138
Y	19	22	28	28	20	18	20	28	35	24	20

Major element concentrations are in weight %. Trace element concentrations are in ppm.

Jasper and hematite are thought to be the primary minerals. The chemistry of the iron formation, when compared to normal Rapitan Group sediments, shows a depletion in all major oxides except for SiO_2, Fe_2O_3 and P_2O_5 (Yeo, 1977). P_2O_5 and Fe_2O_3 show an enrichment of four times. This compares favourably with the Holowilena Ironstone which have high Fe_2O_3 and P_2O_5.

THE WILYERPA FORMATION

Most of the Sturtian Glacial Sequence exposed in the study area consists of the Wilyerpa Formation. The Wilyerpa Formation has its type section at Wilyerpa Hill, 20km to the east. Dalgarno and Johnson (1965) correlate it to the interglacial arenites of Mawson (1949) who described the sequence in detail. In the study area the Wilyerpa Formation is found to be greater than 1500m thick, but decreases in thickness in the far west of the map area because of post-Holowilena Ironstone faults which are clearly seen to displace the ironstone. The thickness of the Wilyerpa Formation decreases even more to the south west to a thickness of 3-400m (D. New, pers. comm.).

The Holowilena Ironstone - Wilyerpa Formation boundary

The basal sediments of the Wilyerpa Formation are usually diamictites with a hematitic matrix and commonly contain clasts of jasper and rarer hematitic siltstone. One quite distinct diamictite unit is a bright yellow weathering dolomitic unit which occurs at the contact, or very close to it, and shows signs of deposition on a slightly irregular surface of the Holowilena Ironstone. These observations may lead one to believe that an unconformable relationship exists between the two formations. This is assuming that the ironstone clasts were derived from the Holowilena Ironstone, as a possibility exists that ironstones are not time equivalent units and that these clasts were derived from elsewhere. The most probable source to these ironstone clasts is erosion related to uplift associated with the post-Holowilena Ironstone faults. The contact may be erosional but does not have to represent any significant time break. The most conclusive evidence suggesting an insignificant time gap is based on evidence provided by a sandstone dyke in the eastern part of the map area (shown in Fig. 4, location in Fig. 2, Plate 1(b)). The dyke is about 90m long, averaging 40cm in thickness, dipping 80^{o} to the east and cuts the boundary between the Pualco Tillite Equivalents and the Wilyerpa Formation (in absence of the Holowilena Ironstone which was not deposited here). The source rock for the dyke is a fine to medium grained massive quartzite within the Pualco Tillite, hence the dyke intrudes younger sediments. The significance of this dyke is that sediments must have been soft at the time of intrusion, this includes sediments on both sides of the Boundary. Sediments stratigraphically above the source rock do show some signs of consolidation, being incorporated as clasts within the dyke at a higher stratigraphic level (e.g. in Fig. 4 clasts of Ps were observed in the dyke at the level of Wsl).

Sediments of the Wilyerpa Formation can be divided into three main facies, namely

a) Massive diamictite facies
b) massive sandstone facies
c) laminated siltstone facies.

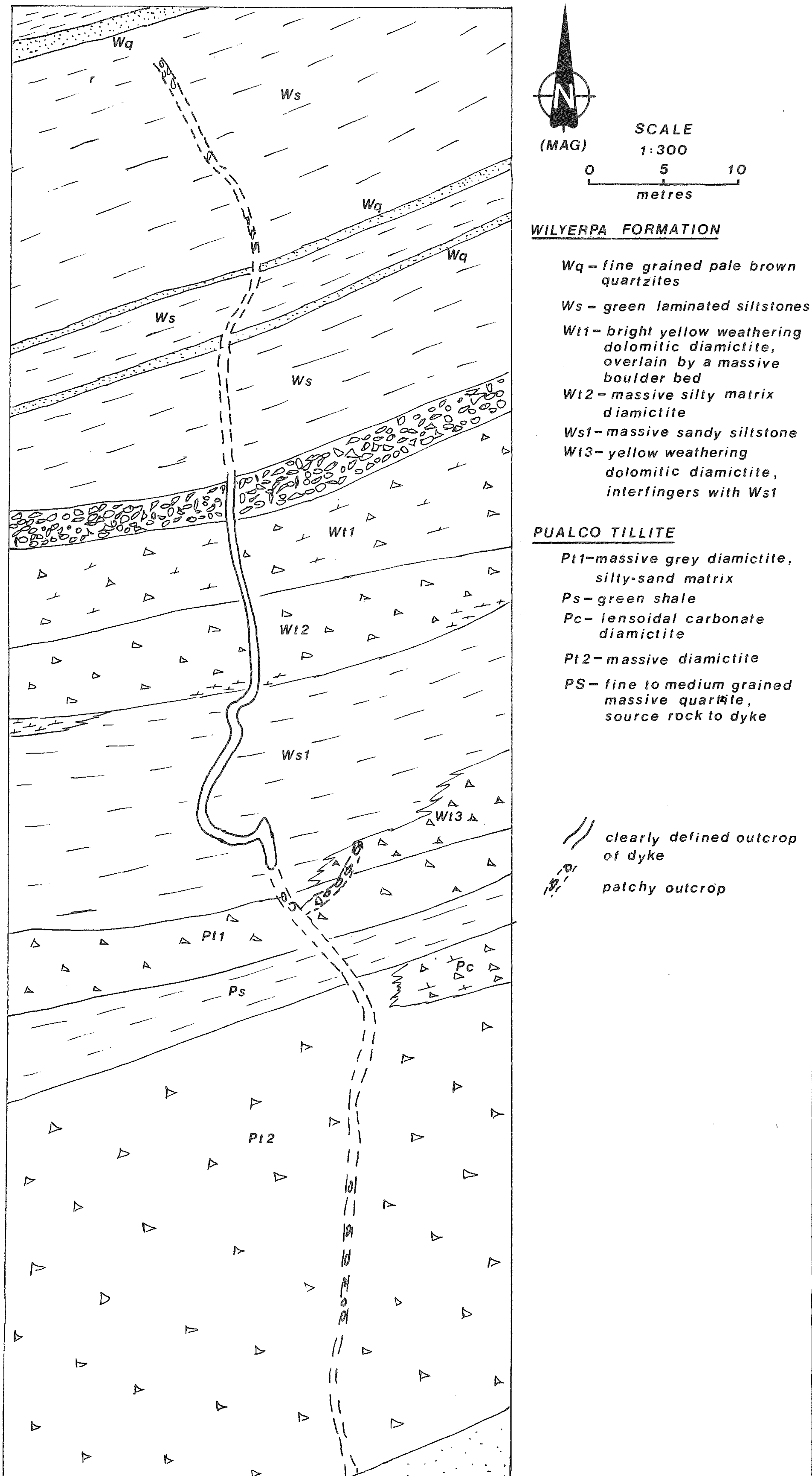
Of these the most common is the laminated siltstone facies. Each is described below:

Massive diamictite facies

Diamictites are more common near the base of the Wilyerpa Formation, especially to the western part of the map area. They are very lenticular, thinning out to the east, thus a westerly source is postulated. This is seen from a comparison of sections 1 and 2 (Appendix I). The diamictites overlying the Holowilena Ironstone are variable in character. To the extreme west of the map area is a diamictite with a hematitic matrix, containing small intrabasinal clasts including siltstone, sandstone, quartzite and dolomite (Appendix I, Section 3, 140-170m). This diamictite contains rare boulder-sized clasts of hematitic siltstone and jasper similar to that found in the Holowilena Ironstone. Others include non-hematitic diamictites with a green silty matrix containing clasts which include intrabasinal rock types such as dolomites, siltstones, chert, quartzite and jasper, and extrabasinal clasts including granites, volcanics and schists. Some have a dolomitic matrix, and are quite variable in both clast lithologies and matrix composition. These diamictites are generally less than 10m thick.

A massive, non-hematitic, bright yellow weathering dolomitic diamictite generally occurs within 10m of the top of the Holowilena Ironstone and is commonly in contact with it. Clasts within this diamictite are generally small angular intrabasinal clasts consisting mainly of siltstone, chert and quartzite, with rare granitic clasts. The dolomitic matrix may be a chemical precipitate. This unit is always overlain by a 10m thick boulder bed containing clasts up to 75 x 50cm. Clast types include quartzite, siltstone, chert, rare dolomite,granite, acid and basic volcanics, gneiss and schist.

FIGURE 4 SANDSTONE DYKE



This unit shows stratification and possible imbrication, and represents a winnowed deposit. Evidence of erosion after the deposition of these two units is seen in the east of the map area, 100m west of the sandstone dyke, where they are truncated and overlain by laminated siltstones and thin sandy beds. A similar boulder bed is seen higher in the sequence to the west (240m mark of Section 1, Appendix I) (Plate 4(a)). This has a wide variety of clast lithologies including common exotics. The matrix is sandy and the unit shows stratification (Plate 4(b)) representing a winnowed deposit. Above this unit are the laminated siltstone and massive sandstone facies of the Wilyerpa Formation. To the west are several hematitic diamictites which can contain jasper clasts. These may represent deposits formed upon erosion of the Holowilena Ironstone.

The diamictites are dominantly unstratified but can have clasts aligned parallel to bedding, and so are water laid. They are lenticular, being associated with laminated siltstones, sandstones and rare bedded dolomite units. The clast size is variable, the maximum being 1.25m, but averaging 5cm. The most probable origin for these diamictites is mass flow deposits related to a wet base glacier (Carey and Ahmad, 1961).

Massive Sandstone Facies

Quartzite bands up to 20m thick characterise the middle part of the section. These are usually pale brown and are generally massive. They possess well rounded poorly sorted, fine to medium sands having, at times, a calcareous matrix. Their poorly sorted nature is seen in Plate 5(c) . Microscope examination has shown that quartz grains have straight to undulose extinction and can have a composite texture indicating a metamorphic origin to some of the quartz. Feldspar and siltstone grains, although not common, can be present, hence using the classification of Folk (1974, p 129), most of these are quartz-arenites with some subarkoses and sublithic arenites.

In the field they are massive, containing soft sediment clasts of underlying siltstones near their bases. Most have a very sharp base with an indistinct upper surface which commonly appears to pass upward into laminated siltstones, being graded on a scale of a few metres. Most of the thick quartzite beds are composed of several of these graded beds and at times have a granule rich base. Clay galls are rare and are seen to define bedding planes when present. The overall environment of deposition is basinal, where turbidites of sandy, sometimes granule-rich sediment are deposited rapidly. This results in the massive appearance, the overall graded nature of these sediments and soft sediment clasts of siltstone ripped up from the underlying siltstones at the time of transport and deposition. At the top of one quartzite unit were vertical water escape structures (Plate 5(a)) similar to those described by Corbett (1972), consisting of vertical veins of lighter coloured sandstone a few millimetres in diameter and extending for at least 20cm. These represent elutriation columns attributed to localized upward movement of water through the bed during deposition. The quartzite units are ridge forming and can be traced for several kilometres along strike, but are on a large scale lenticular.

The thick beds of quartzite are interbedded with green laminated siltstones similar to those contained within the quartzite units. These siltstones are associated with slightly sandier beds with slump structures, and cross laminae, and are commonly loaded into the siltstones. Clasts are rare within these siltstones, with rare dropstones present, hence glacial influence is limited during the deposition of these sediments.

Laminated siltstone facies

These sediments consist of well laminated green to grey coloured siltstones. Their most important feature is the presence of dropstones (Plate 4(c), 6(b)) which indicate the presence of free floating ice, hence the sediments are sub-aqueous glacials. Dropstones have been observed in sediments of the Sturtian Glacial Sequence by others including Daily and Forbes (1969), Belperio (1973), Mortimer (1973) and Link (1977), and are considered by most as conclusive evidence for ice rafting. No till-clasts, till-pellets (Ovenshine 1970) or striated clasts were observed in sediments of the Wilyerpa Formation although some clasts were possibly faceted. Dropstones include granite, porphyries, gneiss, schist, dolomite, siltstone, quartz, chert and marble and range up to 2.5m in diameter, this boulder being a granite. Sediments with clast concentrations representing the overturning of sediment-laden icebergs (Ovenshine, 1970) may also be present. While these sediments represent periods where ice was transporting clastic material, long periods where no evidence of ice rafting occurred, are observed.

A characteristic of the laminated siltstones are graded beds which occur on a scale ranging from 0.5mm to 2cm (Plate 5(b), 6(a)). They contain within the coarse fraction, very fine sand to a maximum grain size of 0.1mm. TS 548-94 is an example which contains 33.7% by weight of ferroan dolomite. Examination in thin section revealed common angular detrital grains of dolomite and quartz which sit in a matrix of carbonate silt (Plate 5(b)). The larger scale graded beds in the field give the appearance of rhythmic alternation of fine sand and silt. However, microscope examination reveals most of these to be graded. The possibility exists that these represent varve-like deposits with the coarser fraction representing deposits formed when a greater amount of melt water was produced. Rare large scale slumping and soft sediment faulting have been observed (Plate 6(c)). Rare convolute bedding is also seen.

Thin lensoidal sand beds are commonly associated with the laminated siltstones. These are usually a carbonate-rich sand and are commonly cross-laminated and ripple cross-laminated with starved ripples, and show slumping, indicating deposition in a higher energy environment. These sediments may represent the winnowed remains of normal siltstone. Thicker sandy beds can have bedding in them. These are more common to the east of the map area where they consist of beds 30-50cm thick of fine to coarse sand. These typically show grading and are interpreted as turbidite deposits showing T_A - T_D of the Bouma Sequence (Selley, 1970, p 185).

Gritty beds are usually only a few centimetres thick containing small granules of dominantly quartz, siltstone, dolomite and granitic clasts. Rare gritty beds up to 1-2m have been seen to contain clasts up to 10cm in diameter. These deposits show evidence of subaqueous reworking, being stratified, and probably represent winnowed dropstone facies in which the silt and a great deal of the sand size fraction have been removed by bottom currents. One sandy matrix boulder bed, although never greater than 1m thick,was followed from one end of the map area to the other for a distance of 8km. This unit contained common white quartzite boulders and rare granitic boulders to 50cm diameter.

Thin bedded pale grey dolomites generally about 30cm thick, although not common, are found within sediments of the Wilyerpa Formation. Observation under the microscope revealed the presence of graded beds in which the coarse fraction was fine sand sized and composed dominantly of quartz with plagioclase and microcline. A 1m thick creamy weathering brown ferroan dolomite, near the top of the section, was traced for 5km. Authors in the past (e.g. Schermerhorn,1974) use the presence of carbonates in Late Precambrian diamictites to argue a non-glacial origin for the diamictites because carbonates today form, generally, in warmer waters. The association of the dropstone facies in the thesis area with carbonate sediments is fairly conclusive evidence for the presence of ice. These carbonates could have formed from cold waters saturated with respect to carbonate. This is quite reasonable as sediments of the underlying Burra Group were being eroded and most probably dissolved. Hanshaw (1978) has observed calcite precipitated beneath modern temperate glaciers which pass over a carbonate-rich bedrock dissolving carbonate and reprecipitating it elsewhere. Thus carbonate precipitation in cold climates is possible.

Environment of deposition of the Wilyerpa Formation

The environment of deposition envisaged for the Wilyerpa Formation is that of a floating wet base glacier (Carey and Ahmad, 1961). The diamictites represent flow tills and turbidites, some of which are stratified but are generally massive. These mud flows originated from the steep foreset slope of the distal edge of the grounded shelf zone. These diamictites are observed to pass into a dropstone facies which is more distal. The concentration of these units to the west of the map area and the lack of diamictites in the upper portion of the Wilyerpa Formation may indicate that the ice sheet retreated in time, with the more distal dropstone facies becoming the dominant rock type. The graded beds of the siltstones may represent varve-like sediments possibly produced by the seasonal variation in the amount of meltwater produced. Ice rafted clasts were carried into the basin and deposited as dropstones. The massive sandstones represent turbidite deposits which seem to form at a time when very little ice rafting was taking place.

THE TAPLEY HILL FORMATION

The basal Tapley Hill Formation consists of poorly outcropping, pink weathering, highly cleaved, black pyritic shales which are apparently conformable over the Wilyerpa Formation. It was observed at one locality that a slight angular unconformity of 2^0 may occur between the Tapley Hill and Wilyerpa Formation. Coats (1962) observed the Yudnamutana Subgroup to be overlain with angular unconformity by the Tapley Hill Formation along the western flank of the Yednalue Anticline.

The basal Tapley Hill Formation does not show the characteristic very fine lamination typical of the Tapley Hill Formation throughout the Adelaide Geosyncline. They are well laminated at times, but in general are not. The black shales contain abundant silt, ferroan dolomite and pyrite as the dominant mineralogy. Further up in the sequence, the shales are still black, containing fresh pyrite along bedding planes and are very well laminated. Within the basal Tapley Hill Formation are thin beds, usually less than 30cm, of bedded to well laminated yellow weathering dolomite (Plate 7(a)). Staining fcr carbonates (Appendix IIIB) has revealed the dolomite to be ferroan. The colour of these dolomites is grey to black and they are quite silty and sandy. Sedimentary structures associated with these carbonates are rare ripple cross-laminae and loaded bases.

Within 150 and 200 metres of the base of the Tapley Hill Formation are massive clast-rich black shales (Plate 7(b)). The clasts are dominantly dolomite, grey limestone, quartzites, black shales and calcareous sandstones. All clasts are well rounded and are seen to occupy broad shallow channels cutting into the black shales and are interpreted as submarine channels. Clasts are supported by a matrix of black shale. One quartzite clast is seen to contain garnets, so its source area is metamorphic. The provenance of the clasts can either be the Burra Group or from the underlying glacial sequence. Either of these is possible because further to the south, on the western limb of the Yednalue Anticline, an angular unconformity is seen between the Burra Group and the Tapley Hill Formation, with the glacials being thin or absent due either to non deposition or erosion. Binks (1971) observed these conglomerates on the western limb of the Yednalue Anticline to be resting directly on the Burra Group and favours erosion of the tillite and accumulation of conglomerate bands due to positive uplift of the Yednalue Diapir. Similar conglomerates on the eastern limb of the Worumba Diapir are thought to represent reworked erratics from the Wilyerpa Formation (Binks, 1971).

Within the black shales are rare cross-laminations and starved ripples which give a palaeocurrent direction from west to east.

3. FAULTING

Several phases of faulting have been recognised within the map area. These being

1. Pre-Yudnamutana Subgroup, affecting only Burra Group sediments.
2. Post Holowilena Ironstone faulting, which is the most significant phase as it does not appear to affect the Wilyerpa Formation.
3. Small faults affecting sediments of the Wilyerpa Formation and characterised by small displacements of around 10 metres.
4. Post Tapley Hill Formation faulting represented by the large fault to the east of the map area which cuts off the east limb of the Yednalue Anticline.

The Post Holowilena Ironstone faulting is the most significant faulting in the area, occurring prior to the deposition of much of the Wilyerpa Formation and being responsible for a thickening of the Wilyerpa Formation along a line which follows the Siccus River. This period of faulting is represented by two faults which are seen to displace the Holowilena Ironstone (Figure 2). The apparent erosional interval at the top of the Holowilena Ironstone may be explained by erosion after uplift of the west portion of the ironstone because of the faulting. Sprigg (1946) claims that early Sturtian tectonism in the Adelaide region elevated basement source areas, for coarse arkosic debris of the Belair Subgroup may have caused injection of sandstone dykes of Sturtian Mitcham Arkose into Torrensian Glen Osmond slates along the Sturtian-Torrensian contact. The presence of the sandstone dyke to the east of the map area may be related to this period of faulting, and if so, a possible control to the time of faulting is early in Wilyerpa time.

The eastern limb of the Yednalue Anticline is cut off by a large fault. This fault can explain the presence of the block of sediment to the south of the map area as the eastern limb of the Anticline. The sediments within this block do have some glacial influence, but this is limited to a small part of the section. These sediments have within them dropstones and are underlain by quartzites interbedded with well laminated siltstones and eventually dolomites, which may be equivalents of the Burra Group. The sediments overlying the dropstone facies are laminated siltstones, and eventually fine green quartzites which have been interpreted as the Tapley Hill Formation by Dalgarno and Johnson (1966) and, if so, it is of different character to the Tapley Hill Formation overlying the Wilyerpa Formation.

Associated with this fault are dolomite and siltstone breccias which have been interpreted by Dalgarno and Johnson (1966) as diapirs, but are reinterpreted by the author as fault breccias. These breccias are composed of angular dolomite and siltstone fragments commonly iron enriched along joints, and associated with quartz, siderite and calcite veins. These dolomites and siltstones are a part of the Burra Group stratigraphy. Further to the north the fault breccia contains fragments of black shale and the green quartzite with which it is in fault contact.

4. PALAEOGEOGRAPHY

Based on several lines of evidence the author favours a north-west to westerly source for the Wilyerpa Formation and Holowilena Ironstone. This evidence includes

1) Palaeocurrent data.
2) The overall thinning of the Wilyerpa Formation to the west and lensing out of coarser conglomeratic units towards the east.
3) The overall volcanic clast assemblage which contains both acid and basic volcanics.

Palaeocurrent data comes mainly from the measurement of cross-laminae in the laminated siltstones of the Wilyerpa Formation and both cross-laminae and scour marks in the Holowilena Ironstone. This data shows a marked dominance of readings from the west, with accurate readings giving a north-west direction.

The overall thinning of the Wilyerpa Formation further south-west along the western limb of the Yednalue Anticline also suggests a westerly source region. This thinning out is seen from the PARACHILNA 1:250,000 Sheet (Dalgarno and Johnson, 1966) and the ORROROO 1:250,000 Sheet (Binks, 1968). The Wilyerpa Formation thins from in excess of 1500 metres in the mapped area to 300-400 metres south of the Siccus River (D. New, pers. comm.). Further along the anticline the Wilyerpa Formation is not present due to a combination of an unconformity (Coats, 1962) and a shallowing in the basin of deposition. Dalgarno and Johnson (1965) suggest that sedimentation occurred in a glaciomarine environment with a transgressive morainic phase at the margin of a half graben to the east. New (pers. comm.) favours a glacio-fluvial environment to the diamictites because of clast orientation. The author has observed that diamictites near the base of the Wilyerpa Formation lens out quickly to the east, an observation also made by Dalgarno and Johnson (1965). This suggests a westerly source region. The main reason for a deepening of the basin to the east is the Sturtian faulting already described.

The dominant clast lithologies of the Wilyerpa Formation are intrabasinal sedimentary clasts including dolomites, siltstones, quartzites and black cherts derived from the Burra Group which unconformably underly the Sturtian sediments. Exotic lithologies include granites, gneisses, schists and volcanic clasts. The volcanic clast assemblage is significant in that it includes clasts which can be grouped as typical Gawler Range Volcanics and others which are basic and not related to the Gawler Range Volcanics (Giles, pers. comm.). The acid volcanics include porphyries (TS 548-305, TS 548-06), rhyodacites (TS 548-83), and crystal tuffs (548-419). The basic volcanics include porphyritic basalts (548-71) and vesicular basalts (548-258). The most likely source area for both acid and basic volcanics is to the west, the acid volcanics being part of the Gawler Range Volcanics and the basic volcanics possibly being related to the Roopena Volcanics or Beda Volcanics of Mason et. al. (1978). While evidence from the volcanic clast assemblages by themselves is not really conclusive evidence of a westerly source, when it is looked at with respect to other evidence, namely palaeocurrent and the overall shape of the basin, a westerly source is suggested. Mawson (1949), in his examination of Bibliando Dome, to the east of the map area, concludes an easterly source for the glacigene rocks based on the presence of granite and chiastolite schist corresponding closely with similar rocks occurring in situ in the older Precambrian complex of the Olary-Outalpa region. Unlike Mawson the author sees no chiastolite schist, in fact schists are quite rare. Binks (1971) suggests a westerly source to the Apilla Tillite, which is stratigraphically equivalent to the Wilyerpa Formation on the ORROROO 1:250,000 sheet. He states that clast types are completely alien to the survey area, but similar rock types occur in the crystalline basement areas west of the Torrens Lineament. While evidence supports a westerly source, an easterly component cannot be ruled out.

5. SUMMARY AND CONCLUSIONS

This study has discussed the relationships between various units of the Sturtian Glacial Sequence which are underlain, unconformably, by the Burra Group. The Pualco Tillite makes up the basal Sturtian and passes conformably into the Holowilena Ironstone which mainly represents a chemical sediment deposited during an interglacial period.

Post-Holowilena Ironstone faulting is significant as it occurs prior to the deposition of much of the Wilyerpa Formation. This faulting is responsible for a deepening in the basin of deposition, resulting in thicker sediments east of the Siccus River. The apparent unconformity at the top of the Holowilena Ironstone is interpreted as an erosional interval associated with this phase of faulting. Evidence suggesting an insignificant time gap between the deposition of the Pualco Tillite, the Holowilena Ironstone, and the Wilyerpa Formation is based on the presence of a sandstone dyke which cuts across the boundary of the Pualco Tillite and the Wilyerpa Formation (in absence of the Holowilena Ironstone). This dyke has a source from within the Pualco Tillite and intrudes younger sediments of the Wilyerpa Formation.

Evidence of ice-rafting during the deposition of the Wilyerpa Formation is well established by the presence of dropstones. Sedimentary facies of the Wilyerpa Formation are best explained as sediments deposited from a wet base glacier which floated as an ice shelf grounded in the west. A westerly source to this formation is postulated on the basis of palaeocurrents, the volcanic clast assemblage, and the overall thinning of coarse conglomeratic units, within the formation, to the east.

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PLATE 1

THE PUALCO TILLITE

a. Typical massive diamictite from the Pualco Tillite containing abundant angular clasts including granite. Bedding is near vertical and perpendicular to the main joint. Near loc. 374, Fig. 5.

b. Sandstone dyke, seen to cross-cut the stratigraphy. Location on Fig. 2.

c. Striated grey siltstone cobble from the Pualco Tillite showing several different sets of deep striations. Near loc. 374, Fig. 5.

a

b

c

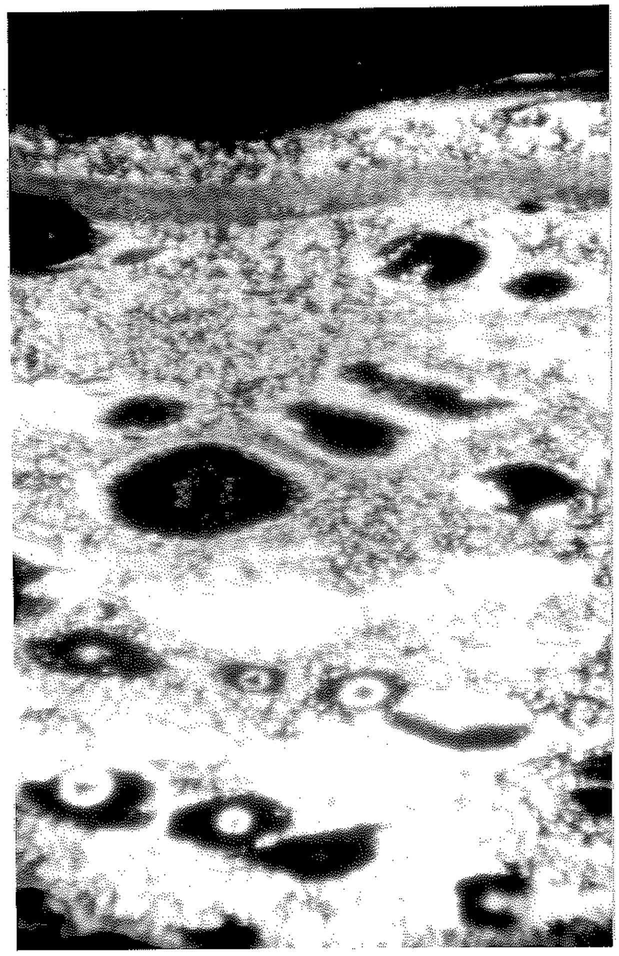
PLATE 2

THE HOLOWILENA IRONSTONE

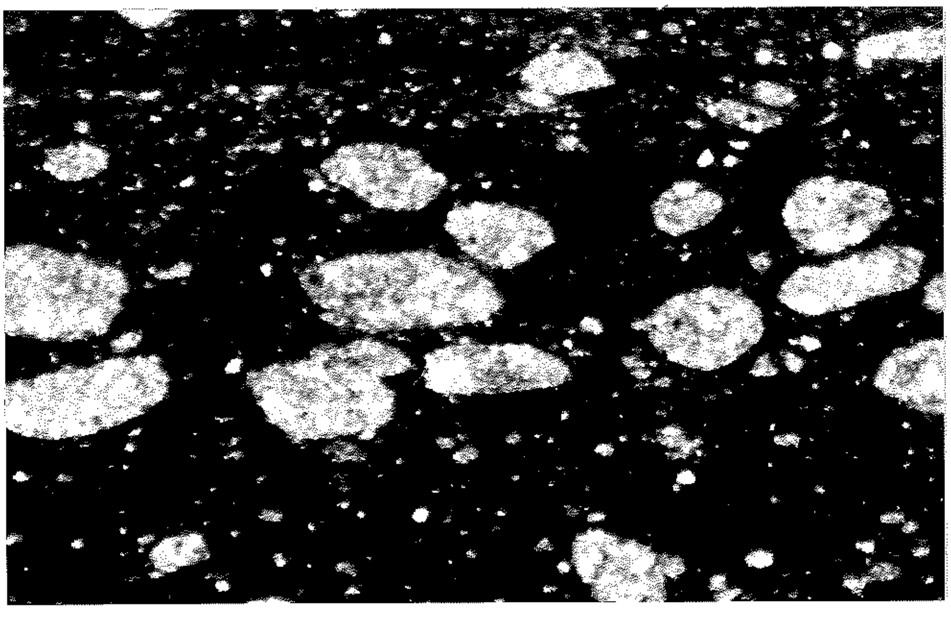
a. Rhombs after dolomite now replaced by silica and preserved by a rim of iron rich silica. TS 548-160. 100 x in plane light.

b. Jasper lenses (dark grains) in a white cherty matrix containing some hematite. TS 548-160. 10 x in plane light.

c. Apatite bodies in hematitic siltstone lying parallel to the bedding. 40 x in plane light. (Sample 548-363).



a b



c

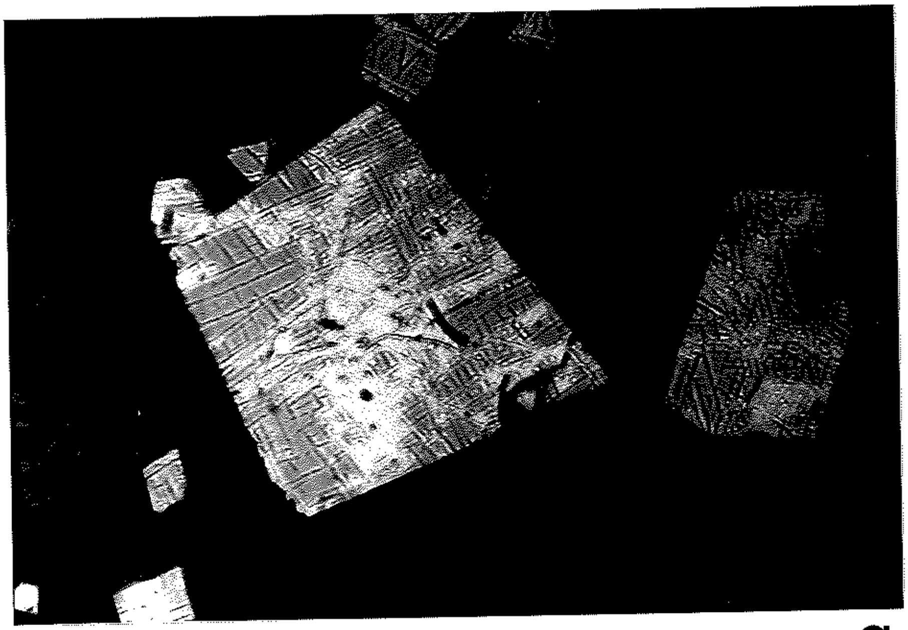
PLATE 3

THE HOLOWILENA IRONSTONE

a. Magnetite euhedra showing martitization sitting in white chert gangue. x 125. (Sample 548-273, near loc. 272. Fig. 5)

b. Small clast rich sandy hematite rock containing abundant soft sediment clasts of hematitic siltstone. (190m mark of Section 5)

c. Outcrop pattern of the typical laminated hematitic siltstone showing the very good jointing of the ironstone. Near loc. 334 (Fig. 5)



a

b

c

PLATE 4

WILYERPA FORMATION

a) Massive clast rich boulder bed (240 m mark of Section 1) showing the very clast rich nature and the abundant exotic rich nature of the boulder bed.

b) The same boulder bed showing some stratification consisting of alternation of clast-rich and clast-poor zones.

c) Dropstones in the laminated siltstone facies of the Wilyerpa Formation. (Loc. 88, Fig. 5)

a

b

c

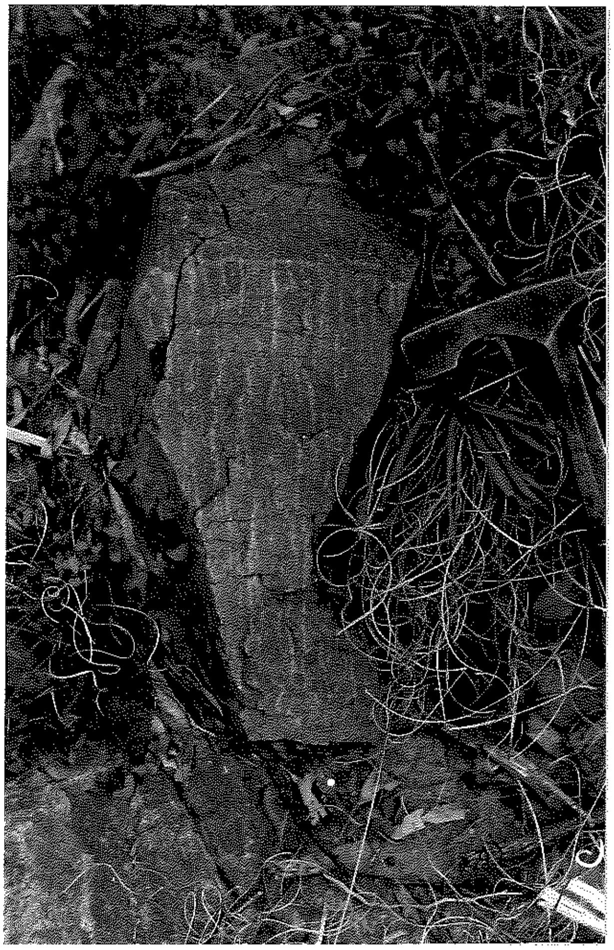
PLATE 5

WILYERPA FORMATION

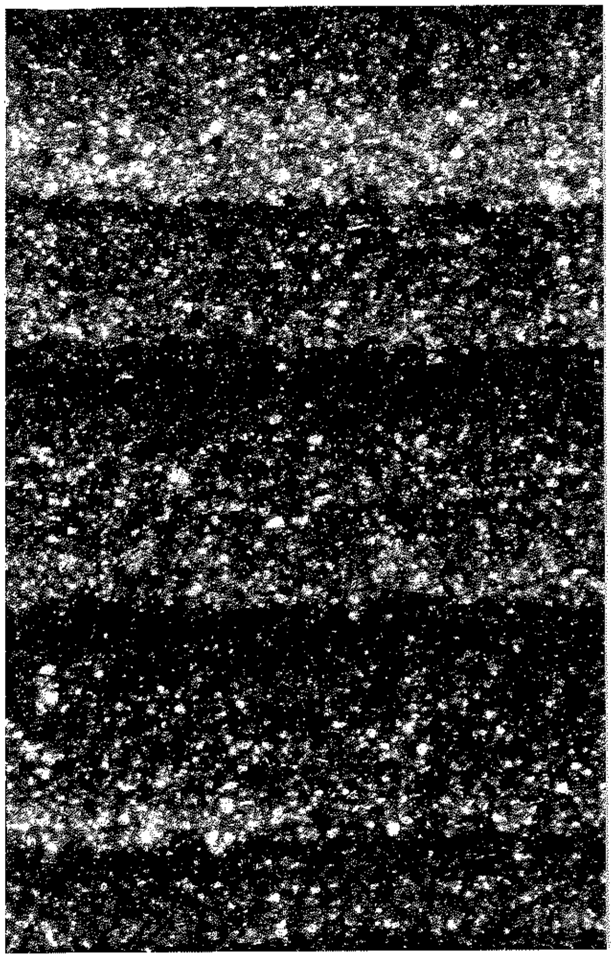
a) Massive sandstone facies (600 m mark of Section 1) showing vertical water escape structures resulting from rapid deposition of the unit.

b) Graded beds in the laminated siltstone facies. The sandy material consists of ferroan dolomite and quartz and silt in a carbonate-silt matrix (TS 548-96). 25 x in plane light.

c) Sandstone from the Wilyerpa Formation showing the unsorted nature of the sediments. Grains are supported by the fine silty matrix. (Sample 548-96). 25 x in plane light.



a



b

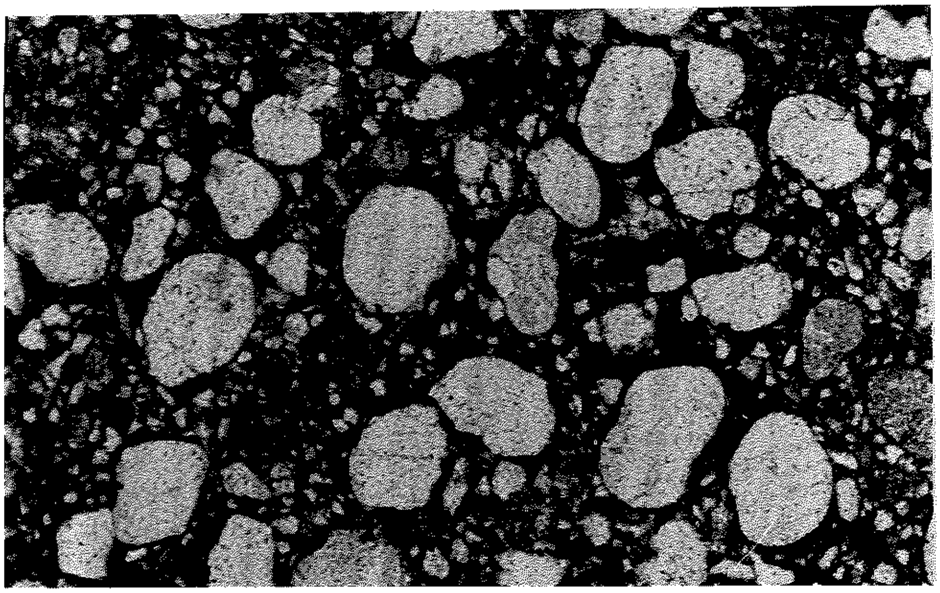


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PLATE 6

WILYERPA FORMATION - Laminated siltstone facies

a) Laminated siltstone which consists of graded beds on the scale of centimetres. (900 m mark of Section 1).

b) Dropstone in laminated siltstones piercing the underlying siltstones thus providing good evidence for it being a dropstone. Thin Gritty beds are also present in the photo. (loc. 88, Fig. 5.)

c) Soft sediment slumping and faulting of a clastless laminated siltstone. (340 m mark of Section 2).

a

b

c

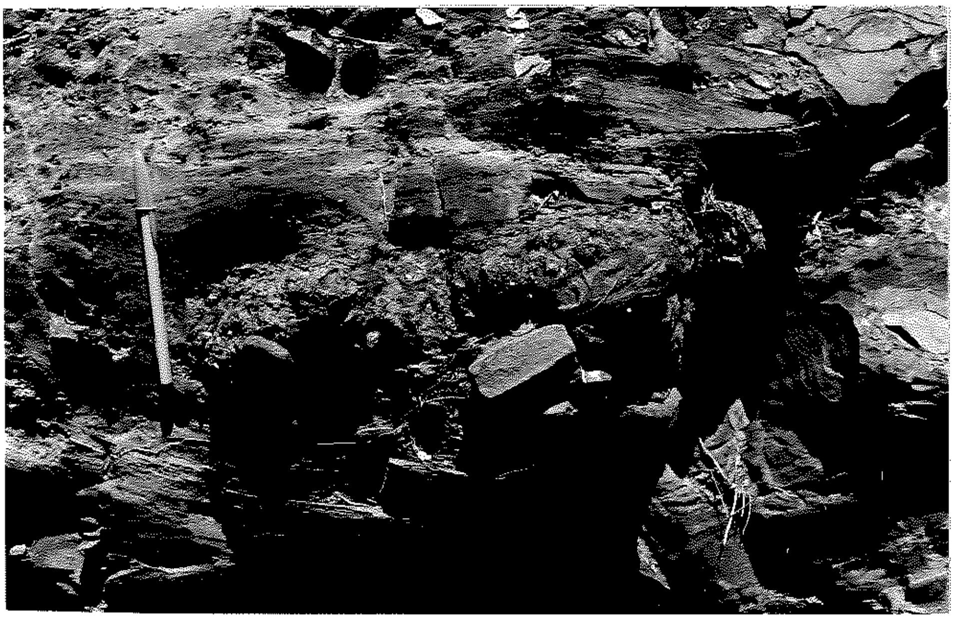
PLATE 7

TAPLEY HILL FORMATION

a) Thin dolomite beds in a typical laminated black shale of the basal Tapley Hill Formation. (near location 421, Fig. 5).

b) Thin conglomerate bed within the basal Tapley Hill Formation. (near location 421, Fig. 5).

a



b

A P P E N D I C E S

APPENDIX I

DETAILED STRATIGRAPHIC SECTIONS

These sections were accurately measured in the field. Thickness is not corrected but is very close to the true thickness as the average dip of the strata is 80^{0}. Locations of the sections are shown on Figure 5.

SECTION 1:	Wilyerpa Formation up Back Creek 1234 metres	Pages A2-A7
SECTION 2:	Wilyerpa Formation 1450 metres	Pages A8-A14
SECTION 3:	Holowilena Ironstone 180 metres	Pages A15-A16
SECTION 4:	Pualco Tillite and Holowilena Ironstone 400 metres	Pages A17-A20
SECTION 5:	Pualco Tillite and Holowilena Ironstone 270 metres.	Pages A21-A23

SYMBOLS USED

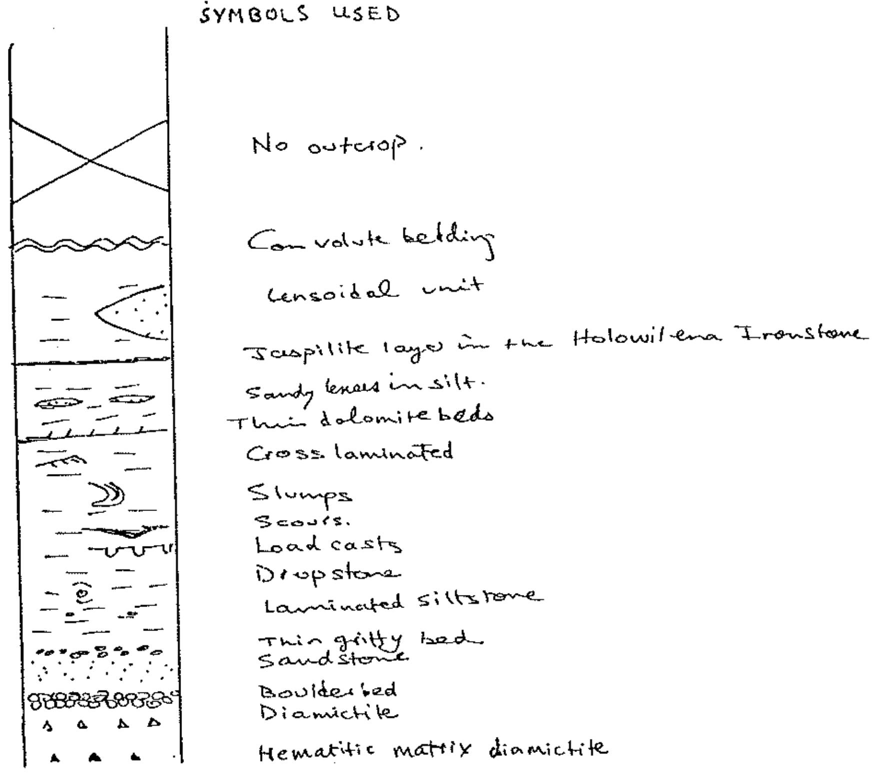
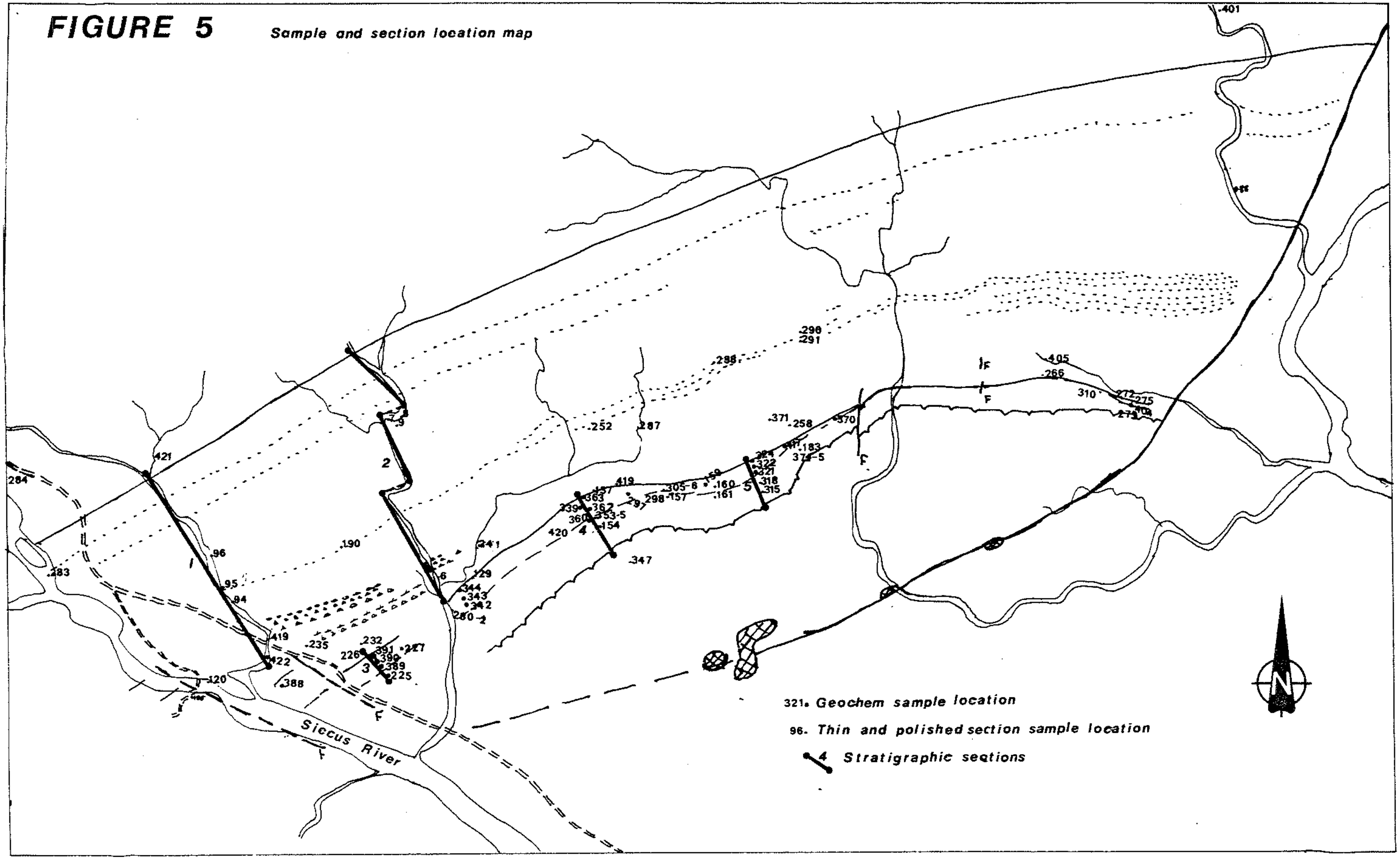


FIGURE 5

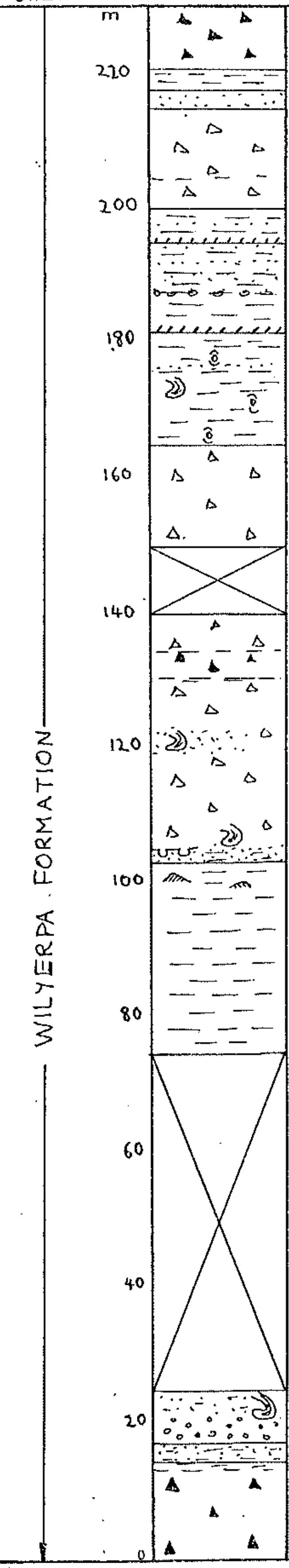
Sample and section location map



SECTION 1

WILYERPA FORMATION

UNIT



LITHOLOGIC DESCRIPTIONS

Black hematitic diamic with clasts of dolomite, jasper, quartz and siltstone also quartzite. Max 15x20cm. Silty matrix. Clasts parallel to bedding. Sub angular to well rounded.

laminated silt with clasts near top where it becomes massive.

medium grained clastless sandstone.

A green silt matrix diamictite with clasts of random orientation. These include granitic, dolomite (grey and yellow), silt and quartzite. Mainly subangular. Max is 25x15cm. Grades into a dark grey matrix till. Similar clasts but with jasper, volcanics(?). Dol to 35cm. Subrounded to rounded with possible flat orientation.

A 50cm thick bedded dolomite unit.
Green sandy silt with some clasts near the base. No dropstones. Does have coarse sandy layers in it and laminated silt beds.

35cm bedded dolomite unit, Grey (pale when fresh). Very finely laminated.
Laminated silts with dropstones including 7cm granite dropstone. Does have sandy layers in it.

Massive diamic with clasts of dolomite, sandstone, siltstone and quartzite and rare jasper. Less than 4-5cm but seem to be getting larger to the top. Dolomite very common towards the top. Rare granitic and oolitic limestone clasts. Clasts are angular to rounded.

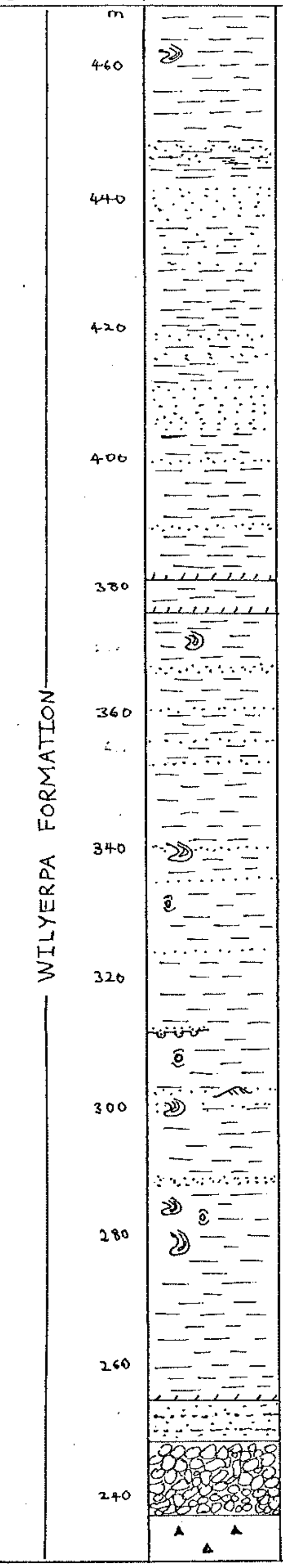
Massive diamictite silty matrix with dolomite, silt, sandstone and chert clasts to 15cm.
Slightly hematitic till. Clasts dominantly dolomite, with qtzite, siltstone (to 20cm) and schist. Alternation of clast rich clast poor layers.
Massive till. Clasts to 50cm occur in it. They include dolomites, quartzites, sandstones. Some dolomite clasts have clasts in them. Weak fabric can be seen but difficult and poorly developed.
Interbedded silty sand is slumped.

Coarse sandstone with gritty layers av size ~3mm. Very good load casts on scale of 15cm as coarse sand sinks into silt. Silty units slumped.

Laminated sandy-silt. No clasts. Has some thin rare sandy beds. Outcrop is badly weathered to a yellow/green but is grey when fresh. Well jointed. More sandy (fine sand) towards the top with X-laminae giving a dominantly E→W palaeocurrent but does have a W→E component.

Bedded sand, lacks clasts and is slumped.
Very clast rich gritty bed. Silt clasts to 40cm. Also qtzite, quartz, sandstone clasts. Dolomite near top. Waterdeposited. Sand matrix.
Slightly hematitic sand, small clasts near base. Slumped
Hematitic diamictite Clasts less than 8cm include dolomite, quartzite siltstone, sandstone, chert and jasper. Smaller ones dominantly dolomite. Clasts both angular and rounded. Top 2m are bedded and clastless.

UNIT		LITHOLOGIC DESCRIPTIONS



Clastless laminated silt with slumped sandier beds

A well rounded, poorly sorted, slightly calcareous quartzite. May be slightly arkosic and is massive.

Slightly more massive Siltstone

Thinner bands of massive quartzite with interbedded laminated silts.

A slightly calcareous poorly sorted quartzite. Has silt clasts in it and quartz grains larger than the average size. Towards the top becomes better sorted and nonarkosic. Grains tend to be well rounded. Massive

A laminated to bedded clastless silty sand.

A very fine thin bed of calcareous silt.
Silts get more massive with larger scale slumps

2m thick bedded sandy unit.

Dominantly green siltstones, These tend to be very well laminated but a times give the appearance of being massive. Thin sandy beds associated with these are usually slumped and cross laminated. Very few clasts are seen.

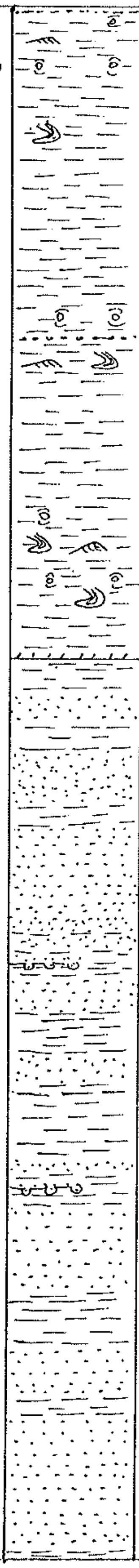
Get alternation of sand and silt on scale of centimeters - this is grading.

Load casts
Dropstones, rare but seen to 5cm in a thin band.

Sandy bands to 30cm. X-laminae are unidirectional W->E
These are also slumped.

Thin quartzite.
Laminated but sometimes massive siltstone. Very few clasts although a 1m dropstone is seen.
Sandy units are thin and often slumped and cross laminated.

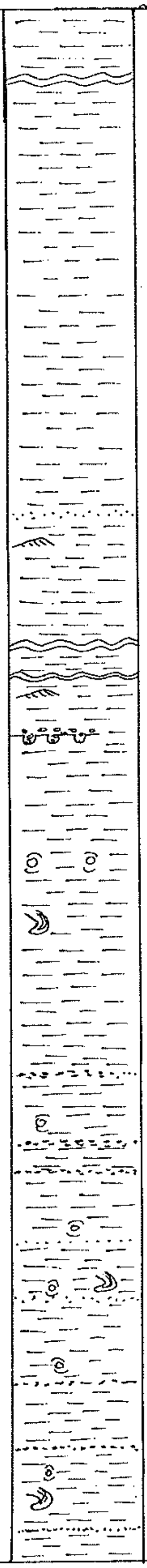
Thin bedded dolomite.
A poorly sorted sandstone with gritty layers containing exotics - continuation of rock type below.
Boulder bed with many exotic clasts including a variety of granitic clasts, gniesses, volcanics, quartz, quartzite, shale and rare dolomites and cherts. Rounded to angular. Not much matrix present. Water laid -> winnowed. Max size about 35cm

UNIT	m		LITHOLOGIC DESCRIPTIONS
WILYERPA FORMATION			W→E Palaeocurrent
	700		Granite and qtzite dropstones to 25 cm diam.
			Sandy beds slumped.
	680		Sometimes more massive silt.
			Dropstones to 35cm in silty-sand.
	660		Thin gritty band. Qtz, Quartzite and schist clasts to 6cm
			Slumping and cross bedding in laminated silt - get a west to east palaeocurrent direction
			Rare clasts in grey-green laminated silt.
	640		
			Grey laminated silts with thin sandy beds. These are X-laminated showing a W→E palaeocurrent or can be slumped. Dropstones to max size of 10cm occur and include granites.
	620		
			Thin bed of bedded dolomite - 25cm thick
			laminated silt with some rare small quartz clasts
			Medium grained, poorly sorted, well rounded, calcareous, massive quartzite
	600		A medium grained sand. Massive, poorly sorted, well rounded, calcareous and slightly arkosic. Grains to 2mm present.
	580		A massive quartzite. not well sorted, has calc matrix and is rounded. Basal 1m consists of a graded gritty sand with clasts averaging ½cm but up to 1cm in it.
			Massive Gritty sand unit, silt clast to 10cm also dolomite and quartzite. Non calcareous silty matrix.
	560		A massive, well rounded, poorly sorted, slightly calcareous quartzite. Does have some angular grains.
			silts are interbedded with massive sandy units to 30cm thick. No clasts.
	540		
			Sandy layer in silt is loaded at the base.
	520		A massive, well rounded, poorly sorted, slightly calcareous quartzite Grains to 2mm seen.
	500		A greenish, well rounded, massive, calcareous quartzite.
			laminated silt interbed.
			A massive, well rounded, slightly calcareous siltstone
	480		

LITHOLOGIC DESCRIPTIONS

WILYERPA FORMATION

m



940 — Soft sediment deformation seen by the wavy bedding

920

Alternation of silty layers with fine sand layers. The silty layers are about 1cm thick and the sandy layers up to 1cm thick. Silts are grey in colour

900

Not all that well laminated but still bedded.

880

X-laminae give an W to E direction. Have very rare sandy beds in a silty unit.

860

Wavy bedding surfaces, amplitude on scale of 10's of cm's. This is some sort of soft sediment deformation.

X laminae give a accurate reading of W → E.

840 — Loading of a sandy-gritty layer into laminated silts.

Alternation of fine sand and silt.

820 — A layer rich in marble dropstones. These are angular, may be faceted and pierce the bedding. Common in this thin layer.

Slumped sandy unit in otherwise well laminated green silts.

800 — Alternation of coarser and finer grained material → graded?

780 — 15cm quartzite dropstone

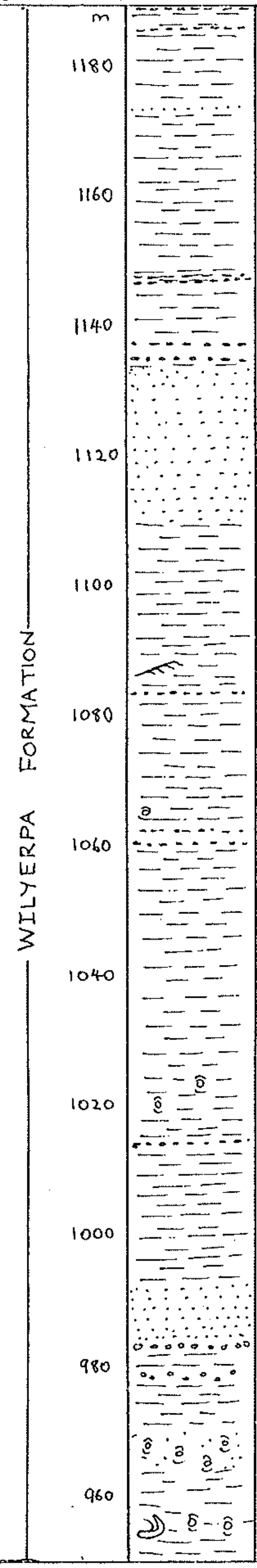
760

740

Grey green silt, laminated but gives a massive appearance at times. Has thin gritty bands. Dropstones to 35cm. Also slumped. Large dropstone is a quartzite.

720

UNIT	LITHOLOGIC DESCRIPTIONS



Clasts in gritty bandaise dominantly quartzites.

Very finely laminated silts with few clasts and thin sandy beds

Gritty lays with clasts to 10cm.

Gritty beds containing quatzites and masbles.

Massive, well rounded, non calcareous, fine, quatzite.

Bedded to laminated silt with the odd coarse layes.

Sandy silt beds with climbing ripples.
Gritty unit showing grading about 15cm thick.

Doget the odd clast in sandies beds, but are rare.

Good 10cm Granitic dropstone

Slightly brownish well bedded more massive silty sand.

Rare small dropstones can be seen

Laminated silts with thin sandies beds

A green, massive, fine, non calcareous quartzite
Underlain by a gritty bed.

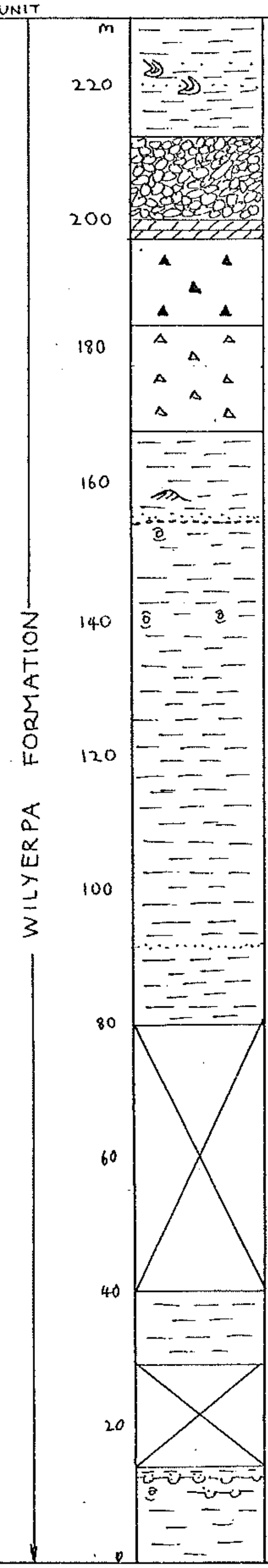
Laminated silts with no clasts but have occasional pebble rich beds.

Sandy, very clast rich dropstone facies. Clasts include chert, granite, quartzite and sandstone. Some angular to 20x10cm. Largest clasts alligned parallel to bedding. Not as well bedded near the top.

laminated greenish silt with some sand. Is slumped. Dropstones to 4cm's include granite, schist, quartz and quartzite.

UNIT	m		LITHOLOGIC DESCRIPTIONS
TAPLEY HILL FORMATION			Basal Tapley Hill Formation consists of poor outcropping black and pink weathering black shales with thin (~30cm) bands of black carbonate (dolomites). These shales do not seem to be very well laminated. X-laminae give a W→E direction. Carbonate beds do have loaded bases some times. Signs of conglomerate occur in the visinity but not up this branch of stream.
	1234		
WILYERPA FORMATION			W→E Palaeocurrent
	1220		Sandy silts with thin gritty bands.
			Palaeocurrent W→E from x-laminae in sandy bed.
			laminated silts with some sandy layers
	1200		

SECTION 2 WILYERPA FORMATION



LITHOLOGIC DESCRIPTIONS

Slumped sandy units in laminated siltstones.

A winnowed boulder bed with angular to subrounded clasts, oriented parallel to bedding. Little matrix - sandy near top. Cobbles and boulders of dolomite, quartzite, quartz and chert near base with schist, granite and quartz dominant to top.

Poor outcrop of a bedded dolomite unit.

A grey to black matrix diamict (due to hematite). Small clasts seem to be subvertical in orientation. Clasts include jasper, dolomite, quartzite, silt and granite. Rounded to subangular. Maximum is a 20cm dolomite. Matrix is silty.

A massive green coloured diamictite. Matrix is a fine sandy-silt. Maximum clast size is 15cm with most being about 1-2cm. Clasts include common dolomite, silt, chert, quartz and jasper (especially near the top). Also have rare granitic and volcanic clasts.

Cross-laminae give a E→W palaeocurrent.

A 30cm thick gritty unit with angular clasts to 5cm including quartz, quartzite, chert and granitic clasts. Overlain by a 50cm thick massive sand.

Excellent dropstones in a green laminated siltstone. Max size of dropstones is about 30cm (A quartzite). Also get a rounded porphyry dropstone about 10cm across. These are clearly seen to deform and penetrate underlying beds.

Laminated greensiltstone with no clasts. Does contain interbeds of sandy and silty material - probably graded beds.

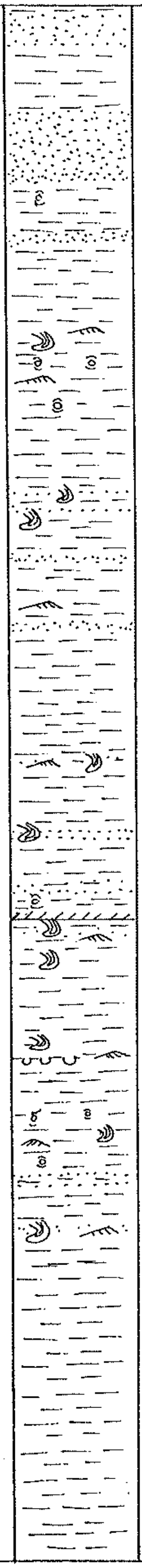
A very thin granule bearing bed in well laminated green siltstones.

A similar sediment with no clasts.

A green laminated siltstone with thin sandy beds which are loaded. Also get dropstones to 2 cm (chert)

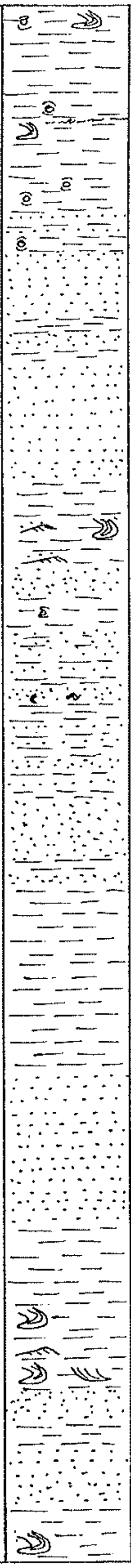
Basal 50m of the Wilyerpa Formation do not outcrop.

UNIT: W.ILYERPA FORMATION



m	LITHOLOGIC DESCRIPTIONS
	Massive quartzite. Poorly sorted well rounded grains. Calcareous matrix.
460	
	Massive fine creamy coloured quartzite.
440	
	Massive quartzite. Well sorted. Well rounded. Calcareous matrix
420	X-laminae give a W → E palaeocurrent direction
	75cm quartzite dropstone in laminated silts
400	
	Thin quartzite bands.
	75cm bedded creamy quartzite. Very fine grained and slightly calcareous
380	X-laminations giving both a E → W and a W → E palaeocurrent
360	
	Green laminated siltstones with cross bedded and slumped sandier beds.
340	Large scale soft sediment faulting in laminated silt. 
	Small 3-4cm dropstones
	30cm thick well laminated dolomite unit.
	Slumped and cross laminated sandy unit showing W → E direction.
320	
300	Dropstones common in laminated silt. Clasts include granitic, schist, quartzites and siltstones. Get very thin clast rich beds. Possible graded beds. X-laminae give a E → W direction.
	Thicker more massive sandy units.
280	Thin sandy beds are cross-laminated and slumped
260	Very well laminated green siltstones. Have no clasts and have only rare thin sandy beds.
240	

UNIT — WILYERPA FORMATION



Depth (m): 700, 680, 660, 640, 620, 600, 580, 560, 540, 520, 500, 480

LITHOLOGIC DESCRIPTIONS

Dropstones in green silt include granitic clasts, to 7cm. Slumping does occur in sandy layers.

Grey, possibly graded siltstone with dropstones and gritty layers. Sandy layers tend to be slumped.

Dropstones to 5cm diameter.

Graded silts. Has dropstones in it.

Very well rounded quartzite. Poorly sorted and has a calcareous matrix.

Quartzite with clasts of silt near base. Has a calcareous matrix and is well rounded. Near base it is a yellowish colour but gets greener near the top.

X-laminated sandier units giving a W→E direction. Fine grained non-calcareous quartzite.

Silts are graded and have the odd dropstone. Up to 10x20cm.

Quartzite with interbeds of well laminated grey-green siltstone.

Quartzite containing soft sediment clasts of siltstone. Probably ripped up at the time of deposition of the sand.

Quartzite. Well rounded with a calcareous matrix.

Fine grained quartzite. Poorly sorted.

A medium grained, honey coloured, calcareous quartzite. Grains well rounded. Massive.

Fine grained quartzite.

Very well laminated siltstone.

Thick massive quartzite.

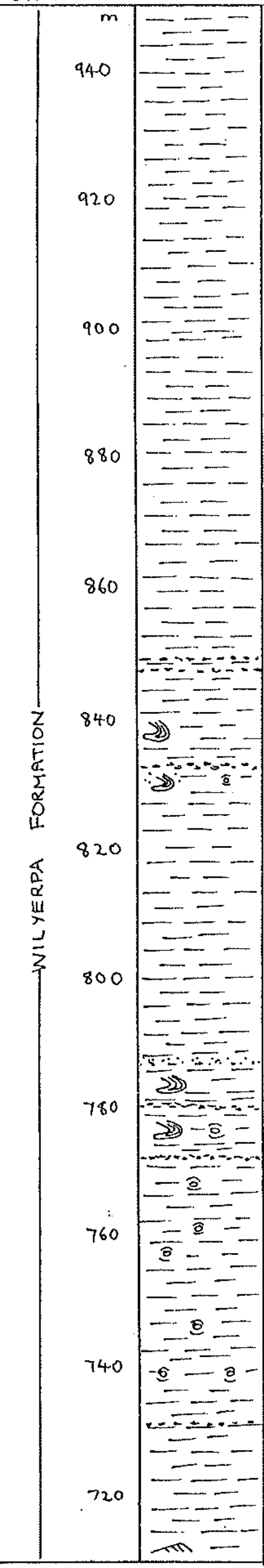
Silt is generally well laminated but can be more massive.

X-laminae giving a dominantly W→E direction but a E→W component is also present. Trough X-beds also give a W→E direction.

Massive quartzite. Not well sorted. Medium grained with grains to 1mm. Slightly calcareous.

Laminated siltstone with slumped sandier units.

UNIT | LITHOLOGIC DESCRIPTIONS



Similar lithologies to that just described below

Not all that well laminated but still bedded siltstones.

Grey-green laminated siltstone with no clasts. On the scale of cm's get alternation of silt and fine sand — most probably graded beds.

Get alternation of coarser material and fine silts. The coarser beds have small clasts of dolomite, quartz and silt generally <1cm but up to 2cm.

Slumping of a carbonate sand unit

Gritty beds, rare dropstones

Slumping of a carbonate rich sandy unit.

Slightly more massive but still well bedded siltstones

Series of gritty beds in laminated silt, to 50cm thick. Also have some large dropstones, one gniess is 75x50cm also granitic dropstone 30cm diameter. Sandy units slumped.

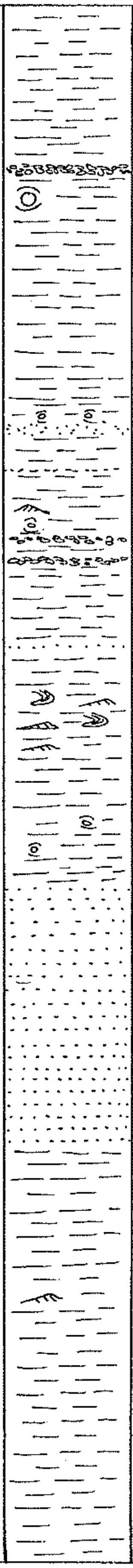
Good dropstones up to 20cm diameter.

Rare pebbly layers (winnowed) in laminated siltstones.

Very well laminated silts. Do have X-laminated sandy beds give a W→E palaeocurrent.

UNIT	m		LITHOLOGIC DESCRIPTIONS
WILYERPA FORMATION	1180		Very clast poor, laminated siltstone
	1160		
	1140		15cm diameter sandstone dropstone in well laminated siltstones. Have the odd gritty layer.
	1120		Very well laminated, clastless siltstone.
			A massive quartzite
	1100		A 1m thick quartzite bearing boulder bed - does not outcrop in creek but has been mapped.
			Normal laminated siltstones with some massive sandy layers.
	1080		Small dropstones to 5cm seen. Thin gritty layers
	1060		Small dropstone (4cm chest) present in laminated siltstone, many other smaller ones also present.
	1040		
	1020		Similar rocks. Give the appearance of being varved but are graded. Coarser zones have grains to 3mm diameter.
	1000		
	980		Possibly graded. green siltstones. No clasts.
	960		

UNIT: WILYERPA FORMATION

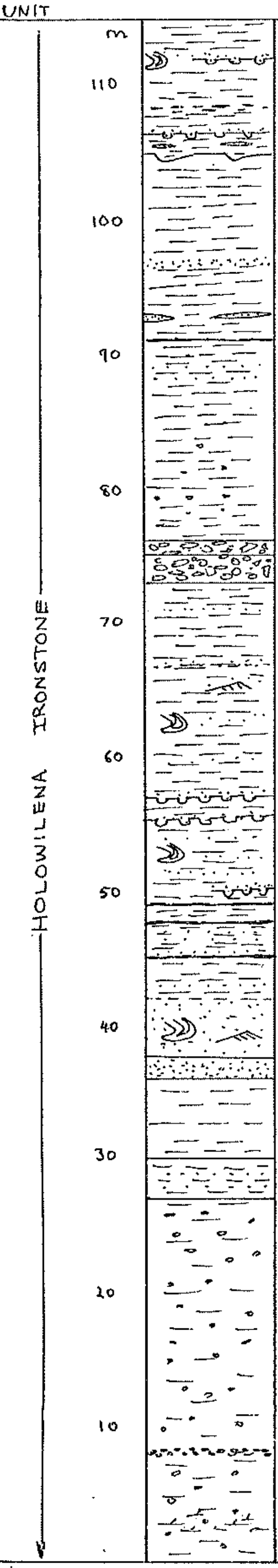


m	LITHOLOGIC DESCRIPTIONS
1420	Laminated, possibly graded, siltstone
	A 2m thick gritty bed. Clasts to 7cm include chert, quartz, quartzite, dolomite, silt, granite, schist. Waterlaid as clasts ⇈ to bedding
1400	A very large 2½ metre granite dropstone. Can be seen to deform bedding around it in the laminated siltstones.
1380	
	Laminated siltstones with thin gritty beds, rare thin sandy beds and sparse small clasts.
1360	
	X-laminae giving a E→W palaeocurrent.
	Another gritty bed. Can see stratification in it.
	A 1m thick gritty bed. Clasts to 7cm Has a bed of laminated silt in the middle. Most clasts are flatlying and include granites, schists, silt, quartz, quartzite and rare dolomite. Winnowed.
1340	Pale green-grey silt. No clasts
1320	Starved ripples giving a direction of 280°→100°. All unidirectional X-laminae in sands W→E, Also slumped. Possibly graded silts.
	Very well laminated siltstone. Grey colour. Has dropstones in it to 5cm. Clasts are quartzite, quartz and chert.
1300	
1280	Quartzite. Massive
1260	
1240	
	X-laminations showing a W→E palaeocurrent direction although a E→W component may be present.
1220	
	Dark grey well bedded siltstones.
1200	

UNIT	m		LITHOLOGIC DESCRIPTIONS
TAPLEY HILL FORMATION	1460		The Tapley Hill Formation consists of thin (<30cm) yellow weathering bedded dolomites. Pink and black weathering non laminated shales. Pink near contact with glacials. Outcrop is very poor due to weathering.
WILYERPA FORMATION	1440		laminated siltstones, can be sandier near the top.

SECTION 3 HOLOWILENA IRONSTONE

UNIT | LITHOLOGIC DESCRIPTIONS



Very well laminated hematitic siltstone

Sandy units are loaded and slumped.

sand lenses.

Scour marks giving a W→E palaeocurrent direction

laminated hematitic siltstones.

laminated sands

Thin sandstone lenses <1cm wide

Thin sandy beds in laminated hematitic silt.

hematitic siltstone, gives appearance of being massive but is well laminated.

Hematitic siltstone with rare small clasts.

1m clastic, nonhematitic rock. Dolomite matrix. gritty. rounded qtz grains. Clasts include quartzite, quartz, siltstone and hematitic siltstone.

Massive clast rich hematitic silt. clasts < $\frac{1}{2}$ cm and include silt, sandstone rounded quartz grains. Possible schistose clasts. Subangular to well rounded.

Very well laminated hematitic silt, little or no sand.

Do get laminated coarse sand layers in hematitic silt

Thin sandy layers are X-laminated giving a W→E direction.

Slumping occurs in a much sandier band.

Loaded on the scale of a few cm's.

Bedded not really laminated.

More sandy, loaded, slumped. Slightly more massive. Interbeds of hematite rich sand and hematite poor sand.

Dominantly hematitic silt with thin sandy layers

Interbedded hematitic silt and sandy layers.

Jasper rich bed.

Silty-hematite rock.

Laminated quartzite with some hematite. May be slumped and X-laminated.

A slightly hematitic medium grained quartzite. Massive

Massive hematitic siltstone, has the very rare small clast. Does contain rounded coarse quartz sand grains.

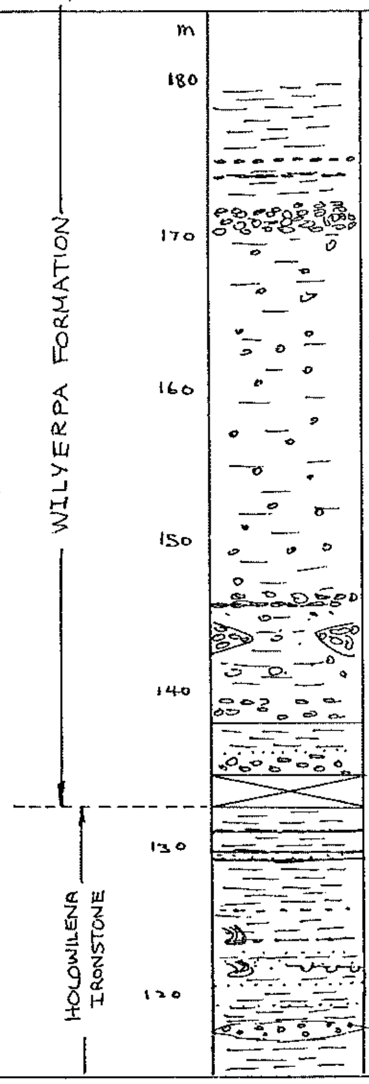
Interbedded well laminated siltstone and hematitic sands

A clast rich hematitic siltstone. Massive. Clasts are small, generally < $\frac{1}{2}$ cm, and are angular to subrounded. Clasts are dominantly siltstone, sandstone and dolomite. At 3m have very little Iron, much more sandier and has a dolomite matrix

Gritty layer with a calc matrix. Clasts of dolomite, quartz, quartzite and siltstone less than 1cm.

Described above.
outcrop below this is poor.

UNIT | LITHOLOGIC DESCRIPTIONS



Typical Wilyerpa Siltstones.

Green laminated siltstones with gritty layers. Sandy in places very gritty layers, non hematitic. Clasts to 20cm (quartzite). Other clasts include siltstone and quartz as well as rounded quartz grains..

Massive with few clasts as you go up the section.

Gritty layers & clasts to 10cm, common dolomite, siltstone and quartzite clasts.

Has pods ~10m long of gritty material. Non hematitic, little matrix. Has sandstone, silt and quartzite clasts to 10cm

Very gritty hematite matrix rock. Clasts < 3mm. Rounded to subangular - qtz, qtzite, silt and dolomite. fewer clasts further up section.

Quartz rich hematitic silts, bedded.

Massive fine clastic rock, clasts < 3-4mm
Hematitic matrix.

Common non-hematitic sandy layers.

Thin jasper layers.

laminated hematitic siltstone.

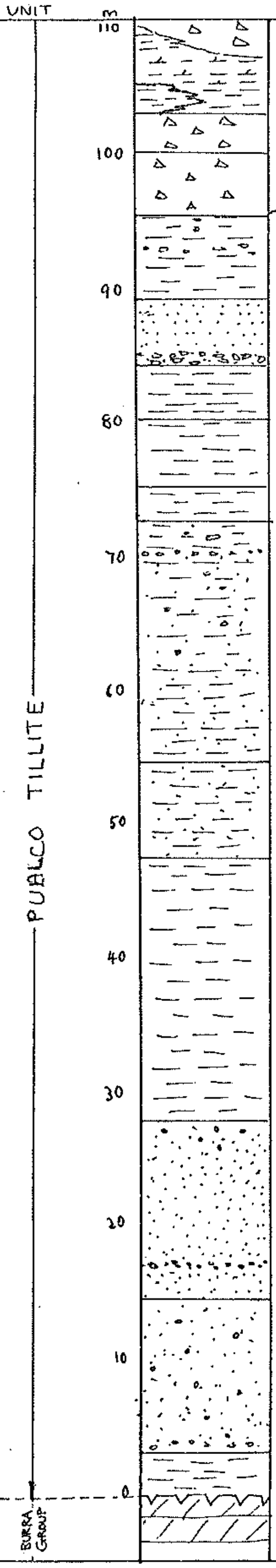
Very thin sandy layers in hematitic siltstone. These sandy beds can be loaded and slumped.

lensoidal gritty band, with ss clasts <2cm diam in hem silt.

Very well laminated siltstone.

SECTION 4

PUALCO TILLITE and HOLOWILENA IRONSTONE



LITHOLOGIC DESCRIPTIONS

Diamictite, described on next page.

Dolomite rich massive silt.

Clastless laminated sandy silt – passes into iron-rich sandy rocks to the west.

A massive diamictite – green matrix. Max ~ 10cm. Include quartzite, dolomite, siltstone and quartz.

A massive diamictite. Clasts generally less than 5cm. Many are rounded. Flat ones aligned parallel to bedding. Include quartzite, siltstones and sandstones, also chert, quartz and dolomites. Some striated (quartzite) and faceted. Silty matrix with sand grains.

Green-grey silty rock with no clasts. Massive.

Generally well laminated, clast poor, sandy silt. Do get some clasts in more massive units.

Quartzite with rare clasts underlain by a sandy clast rich rock. Clasts include sandstone, quartzite, quartz and chert. Have common coarser rounded sand grains.

Very well laminated, shaley rock.

A massive greencoloured siltstone. No clasts.

Laminated and clastless sandy silt.

Dolomite clast to 15cm seen here. Rock is green and siltyer.

Thin gritty band.

A very similiar rock type to that below but a dark grey colour. Base has no clasts. Do eventually get some clasts which include dolomite (to 2½ cm) and quartzites but these are small and rare. Also get coarser rounded sand grains.

A massive greenish silty-sand. No clasts.

Very well laminated shale.

Massive, clastless grey coloured sandy rock, has the odd small clast towards the top.

15cm thick gritty bed with small clasts of quartz, siltstone and quartzite in a silty matrix.

Clastless laminated sandstone

Massive, colour now a much lighter grey.

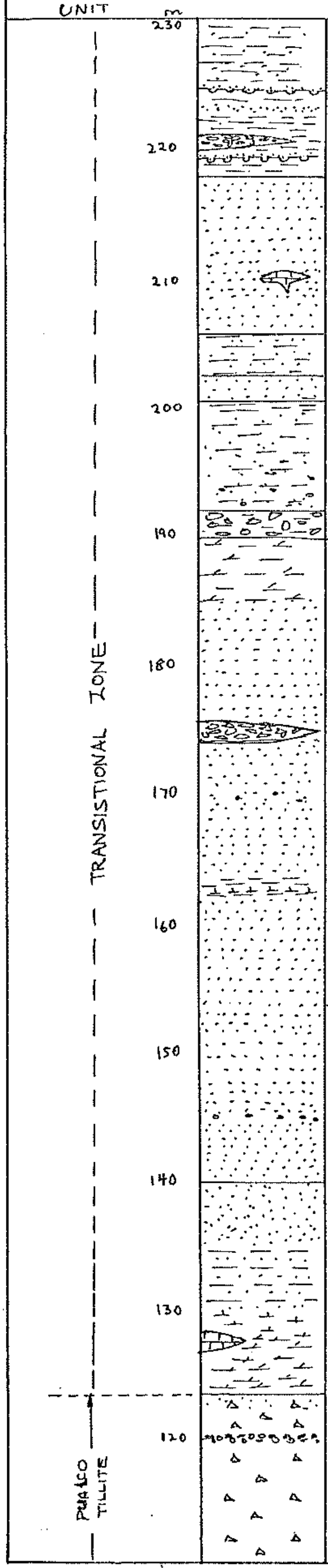
rare clasts, coarser sand grains

Thin, darkgrey, small clast rich sandy rock. Has small quartz grains in it.

A laminated green-grey shaley rock

Dolomites, quartzites and siltstones of the Burra Group.

UNIT | m | LITHOLOGIC DESCRIPTIONS



Bedded

Much sandyer

Very gritty lens. max 2m thick. Mainly siltstone clasts, angular. Also dolomite, quartz and quartzite in a dolomitic matrix.
Alternation of sandy bands on scale of ½cm → are loaded.

Massive sandstone, no clasts, little hematite.
Black limestone also occurs as rather patchy outcrop.

Bedded more sandy and hematitic rock.

Massive sand stone
Laminated silty sand.

A slightly hematitic sandy rock. Massive. Near base has small clasts (<3mm) of sandstone, quartzite, siltstone and dolomite

Hematitic silt with some large dolomite and siltstone clasts.

Bedded dolomitic and hematitic siltstone.

Massive fine grained sandstone. Very little hematite.

A 2m thick clastic rock, in a hematitic siltstone matrix. Mainly dolomite clasts, also siltstone, quartzite, and quartz. Max size 10cm. Mean ~1cm. Most Angular. Lenticular unit

Massive, iron poor, sand stone, Can have clasts to 3mm further up. These are mainly quartz and sand stone.

Bedded to well laminated sandy hematitic rock interbedded with carbonate beds. Also get laminated hematitic siltstones.

More iron rich, bedded sandstone.

Iron poor.

Massive with the odd small clast of sandstone. Does have rounded quartz grains in it.

Bedded hematitic sand.

Massive hematitic sand.

Alternation of sandy beds rich and poor in hematite on the scale of ½cm.

Sandy well laminated rock with some hematite

More limestone rich rock.

A very well laminated rock consisting of alternations of dolomite rich - dolomite poor bands. Green coloured. Can have pods of a grey limestone with it.

Sandyer near top.

Thin gritty layer.

Massive diamictite with a sandy silt matrix with larger quartz grains. Clasts include granite, chert, quartz, quartzite, and sandstone. Dominantly angular but can be well rounded.
A lenticular unit passing into silts to the west.

UNIT | m | LITHOLOGIC DESCRIPTIONS

HOLOWILENA IRONSTONE

Depth marks (m): 350, 340, 330, 320, 310, 300, 290, 280, 270, 260, 250, 240

Massive clast rich hematitic silty sand. Rounded quartz grains, fine matrix. Slightly calcareous. Can see bedded towards the top.

Hematitic siltstone, can get sandy.

Massive hematitic sandstone, rare small clasts.

Sandier with slumping and load casts.

Very little sand in hematitic siltstone.

Bedded sandy unit loaded into siltstone.
X-laminations showing a W→E direction. Also slumped.

Bedded sandstone, very little hematite in them.

Laminated hematitic siltstone with coarser sandy layers

Massive hematitic sandstone with small clasts of sandstone, silt and quartz. Towards top becomes coarser and laminated.

Extensive development of jasper over about 2m. Interbedded with slumped and loaded hematitic siltstone.

Hematitic silt with the occasional coarser sandy layer.

Bedded sandy rich rock.
Jasper rich band.
Massive sandy generally hematite poor rock.

Normal sandy hematite - silt rock. Underlain by a finely laminated dolomitic rich rock.

Hematitic siltstone with some sandy beds.

Thin jasper band
Laminated hematitic siltstones, also sandy

Hematitic sandstone with small clasts, usually < ½ cm including silt, quartzite and dolomite. Rounded coarser quartz grains are also seen.

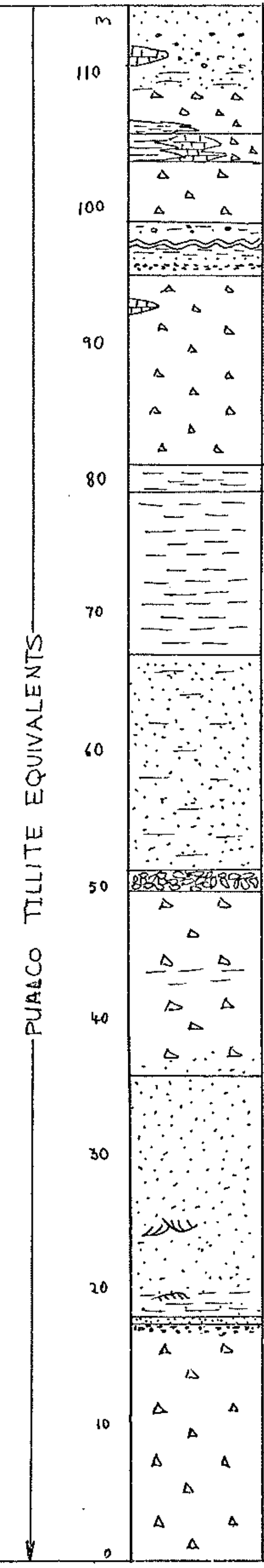
Possible Scours giving a 290 → 110° Palaeocurrent direction.
Also slumped
Massive gritty sand with hematitic silt interbeds. Fragments of laminated hematitic silt occur in gritty beds → soft sediment clasts.
Bedded sands, little hematite. Shaley rocks also present.
laminated, hematitic siltstones.
Bedded sand and thin gritty unit.
Dolomitic rich unit.
Hematitic siltstone.

Massive sandy rock.

UNIT	m		LITHOLOGIC DESCRIPTIONS
WILYERPA FORMATION			siltstones of the Wilyerpa Formation
			fine grained clean quartzite, bedded
			Boulder bed full of exotic clasts including schists, granitic rocks, volcanics. Also intrabasinal rocks quartzite, siltstone and dolomite.
	390		Bright yellow dolomitic clastic rock. Has a irregular contact with underlying clastic rock.
			Greenish coloured clast rich, sandy rock.
HOLOWILENA IRONSTONE	380		laminated hematitic siltstone.
	370		Very thin sandy beds
	360		Very well laminated hematitic siltstone. No sandy layers. No clasts. No jasper rich beds.

SECTION 5 PUALCO TILLITE and HOLOWILENA IRONSTONE

UNIT	LITHOLOGIC DESCRIPTIONS



Massive fine, clastless sandy unit.

Limestone pod, clastless, interbedded with massive silt, dark grey, containing some small clasts and sand grains.

Iron rich fine sandy rock, rare clasts.

Lam silt interbedded with till. Till has granitic clasts to 15cm chert, silt, qtz grains, qtzites. Silts can be striated and faceted. Lam silts are clastless.

Interbedded laminated silts, limestones and massive tills. L.S. has carbonate rich – carbonate poor layer with clasts, esp near the till. These include dolomite, silt and granitic clasts

Massive till. Clasts generally small and include quartz, chert, siltstone, quartzite, dolomite and granitic. Matrix is grey and dolomitic and has round qtz sand grains. Larger clasts parallel to bedding. Max 7cm, most <2cm. Clasts rounded to subrounded and faceted. Granitic clasts common.

Laminated silty sands with convolute bedding. Can have rare clasts.

15cm gritty layer with qtz, qtzite & silt clasts. also rounded qtz sand grains

A rather discontinuous pod of silty clastic limestone.

A till matrix rock with a silty matrix with rounded quartz grains. Clasts generally small and include granitic clast (10cm) siltstones, quartzite, black chert and rare dolomite, usually less than 1cm. Angular to rounded. The siltstones being rounded. Can have a calc matrix – grey colour.

A massive grey coloured siltstone.

A green shaley-silt. Very well laminated on a scale of 2-3mm. On clean surface looks massive. Seems to have a great deal of quartz in it. Can have sulphide in it.

A fine grey quartzite. Seen to be bedded on a weathered surface but looks massive on a fresh surface. Does appear to have poorly developed sulphide (pyrite) through it.

1½m of reworked material, clasts include rare dolomite, common quartzite and quartz. Max is dol 10-15cm. Matrix sandy and slightly dolomitic.

A generally massive till like rock with a silty matrix which is slightly dolomitic. Some stratification of silty-sands with clasts can be seen → water deposited. Most clasts are weathered out → Dolomite. Clasts are generally quite small.

The base is a clast rich sandy unit with quartz, silt, dolomite and quartzite, schistose clasts. Generally <1cm and rounded.

Pale grey coloured bedded quartzite. Fine grained. Can be X-bedded in places.

A dark grey, well laminated silty sand which is x-laminated near the top.

A 30cm thick reworked gritty unit consisting of small clasts and sand.

Above dolomites of the Burra Group have a massive till with a dark grey silty and dolomitic matrix. Clasts are generally small <1cm but as large as 20x10cm (silt) and are rounded to subangular. These include quartzite, siltstones, black chert, dolomite and rare granitic clasts. Siltstone clasts can be striated and at times appear faceted. Also have rounded sand grains present which seem to get more common near the top.

UNIT | LITHOLOGIC DESCRIPTIONS

HOLOWILENA IRONSTONE

PUALCO TILLITE EQUIVALENTS

m

230

220

210

200

190

180

170

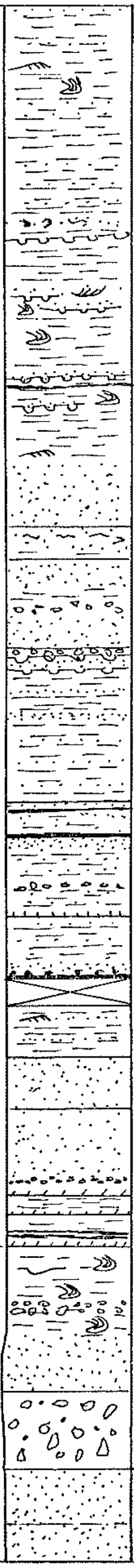
160

150

140

130

120



Very little sand

X-laminations give a W→E palaeocurrent direction.

Sandy hematitic siltstone. Amount of sand can vary from being dominant to be almost nonexistant

Sand with soft sed fragments of hematitic siltstone. Also loaded.

Trough X-beds showing a E→W direction. Sands are loaded and slumped. Palaeocurrent directions are mainly E→W but a W→E component is also present

Jasper rich unit
Loaded sand
Hematitic siltstone. Thin sandy beds
X-laminae W→E palaeocurrent.

Sandy hematitic unit.

Mainly massive sands, have bedded units in it. Within it are clasts of hematitic silt → soft sed clasts ripped up by currents. Sand is fine and rounded.
Mainly massive sand with some iron rich layers
Laminated & bedded sands and silts. Have Iron-rich layers.

Bedded sands.
Unit with coarser grains (sand) in a fine matrix. Loaded into underlying sands.

Bedded hematitic silts and fine grained sands
Sand with some hematite. Not well laminated but get alternation of hematite rich - hematite poor bands on scale of <1cm.

Thin jasper rich units in hem sands and silts.
Bedded hematitic sands
Very well rounded iron poor sand, overlain by a 30cm thick jasper unit.
Fine gritty layer
Thin limestone unit. Grey colour.
Interbedded iron rich sands with iron poor sands

Jasper rich zone, upper part is brecciated.
Fine hem silt with sandy units - X-laminated W→E.
Non hematitic green laminated shale
laminated iron rich rock. Some jasper. Sandy layers

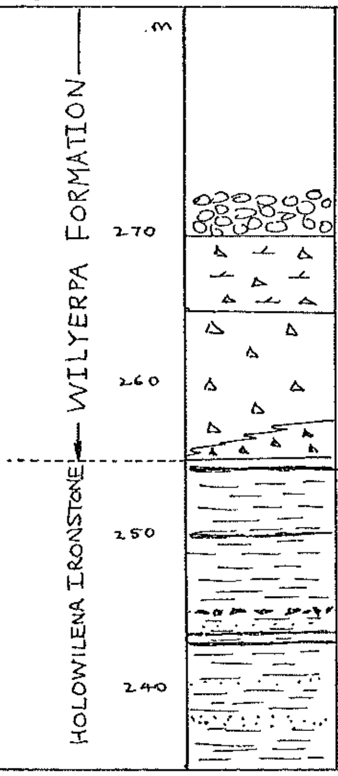
Massive sandy rock, more iron rich, Has small clasts (silt and sand)

Bedded sands with very little hematite.

Thin gritty bed, angular clasts, not large
Carbonate beds & interbeds of hematitic sand and silt.

Jasper rich units (thin)
Carbonate bands with hematite sand interbeds
Flute cast in sand & hem silt.
Clast rich unit, massive. Has some hematite. Clasts dominantly angular & include qtz, silt, chert & quartzite. Sandy matrix
Interbeds of hematitic silty-sand and sand, well bedded slumped.
Clastless grey silty sand

Very lenticular massive till. Very dolomitic. Bright yellow in colour. Massive. Clasts include dolomite, chert, schist, sandstone, quartzite, quartz and granite. Most angular but can be rounded. Max size is about 35cm. Very lenticular (~15m outcrops) seems to have eroded into underlying sediments. Flat clasts may be parallel to bedding.
A more iron rich sandstone with the odd larger qtz grain
Massive
Massive sandy unit, no clasts.

UNIT	LITHOLOGIC DESCRIPTIONS
	

Normal Wilyerpa Formation – laminated siltstones and thin sandy beds.

Boulder bed full of exotics

Clast rich dolomitic quartzite. Yellow colour. Clasts here are rare but include quartzite and silt, and quartz grains. Angular to subrounded.

This unit is a green (pale) till. Silty matrix, clasts are angular to rounded include quartzite and silt, chert, dolomite schist and jasper. Calc matrix. Overlies the ironstone 15m to the west!

Thin till. Black-green matrix (hematite) clasts include silt, chert, qtz & granites. Silty matrix. Clasts angular to rounded, max 4cm. Lenses out to the west.

Very little sandy material here. Seems to have magnetite euhedra in it.

Jasper unit which seems contorted and brecciated.
Jasper rich units, thin, in hematitic silt and sand

Very finely laminated hematitic siltstone overlain by sandier units.
Small clasts to 2mm here.

APPENDIX II

THIN SECTION AND POLISHED SECTION DESCRIPTIONS

All sections and specimens described are held within the Department of Geology and Mineralogy at the University of Adelaide under the accession number 548. Locations of samples are shown on figure 5.

A) THIN SECTION DESCRIPTIONS

548-06

A quartz-potassium feldspar - plagioclase porphyry found as a clast in the Wilyerpa Formation and having possible affinities to the Gawler Range Volcanics. Consists of euhedra (to 5mm) of quartz, potassium feldspar and plagioclase in a fine recrystallized matrix showing no remnant igneous texture. Staining for potassium-feldspar (Appendix IIIC) reveals that potassium-feldspar is the dominant phenocryst.

Fine matrix	70%
Phenocrysts	29%
Pyrite	1%

Phenocryst proportions:	
Potassium feldspar	45%
Plagioclase	35%
Quartz	20%

548-07

Green siltstone from the Wilyerpa Formation (approx. 980 metre mark of Section 2). In the field this sample appeared to be varved consisting of alternations of silt and very fine sand. Observation under the microscope reveals that it is graded on a scale of up to 2cm. The coarser fraction is a very fine sand generally 0.05-0.15 mm with a maximum of 0.2mm sitting in a fine carbonate silt. These grains are usually angular and are composed mainly of quartz with some carbonate and rare plagioclase. The base to the coarser beds is sharp. At the top of one silty bed a crack is infilled by sand from the overlying sandy bed. This represents some sort of subaerial mud crack. These graded beds do represent possible varves.

548-08

Clastless green laminated siltstone of the Wilyerpa Formation consisting of graded beds up to 2cm thick but generally much thinner. Some beds do not show grading but have sharp contacts between coarser and finer beds. In hand specimen cross-laminae can be seen. The fine sandy material is generally 0.05-0.1mm with a maximum of 0.2mm and composed mainly of quartz with some carbonate and rare plagioclase. These grains sit in a matrix of silt containing some ferroan dolomite (staining procedure appendix IIIB). One layer contains pyrite euhedra (now limonite) 0.1 to 0.3mm across which seem to have nucleated around a detrital grain.

548-09

Green laminated siltstone of the Wilyerpa Formation. Graded beds are seen on a scale of 1mm. Maximum size of sand grains is about 0.1mm consisting mainly of angular quartz grains and some plagioclase. These sit in a silt-dolomite matrix (staining has shown ferroan dolomite to be present). A trace amount of opaques are present. Not all beds are graded consisting of an alternation of fine sand and silt. Fine sand makes up 10-15% of the section with silt making up the remainder.

548-71

A porphyritic basalt clast from the Wilyerpa Formation. Consists mainly of large plagioclase phenocrysts to 7mm long and much smaller plagioclase microlites. These microlites are randomly oriented and are generally 0.2 to 0.3mm long. A dark mineral surrounds the microlites, this is now chlorite but was once probably clinopyroxene. Staining for potassium feldspar revealed no potassium feldspar to be present. The texture is subophitic. Magnetite cubes can be common. Other opaques have the same size and shape as the microlites.

548-83

A rhyodacite clast from the Wilyerpa Formation. Contains common phenocrysts ranging in size from 1 to 5mm. Phenocrysts include embayed quartz which is commonly rimmed by very fine grained material suggesting they were out of equilibrium with the melt. Other phenocrysts include plagioclase which shows multiple twinning and sericitization. Staining for K-feldspar revealed that K-feldspar is only present in the matrix. Grains of biotite can be seen but most are now sericite and limonite. The matrix is a primary volcanic texture - microgranular, it was originally glass but is devitrified now. Possibly from the Gawler Ranges.

Matrix	70%
Plagioclase	20%
Quartz	5%
Limomite	3%
Biotite	2%

Phenocryst proportions:	
Plagioclase	70%
Quartz	20%
Biotite	10%

548-94

Laminated siltstone of the Wilyerpa Formation. It consists of graded beds on the scale of 1-2mm. Maximum grainsize is 0.1mm. Within the graded beds are common angular grains of detrital dolomite, quartz with some microcline and plagioclase. The matrix is a dolomitic silt. Staining for carbonate (Appendix IIIB) revealed the presence of ferroan dolomite. Acid digestion (Appendix IIIE) showed that carbonate made up 33.7% by weight of the sample. Within the coarser fraction are rare pods rich in pyrite euhedra as large as 0.15 to 0.2mm and probably of secondary origin. X-Ray Diffraction (Appendix IIID) of the sample revealed the following minerals to be present - dolomite, ankerite, calcite, quartz, pyrite, albite (high and low), oligoclase, muscovite and chlorite.

548-95

A poorly sorted, red coloured, quartzite from the Wilyerpa Formation. The red colour is due to hematite in the matrix. In hand specimen it is seen to contain grains greater than 1mm with a siltstone clast greater than 5mm. In thin section it is seen to contain mainly well rounded quartz grains to 2mm across but mainly being 0.5mm across. These quartz grains have mainly undulose extinction. Grains are interlocking so very little matrix is present. Also present are rare grains of plagioclase and microcline. Small sand sized grains of siltstone are also present. Large euhedra of limonite after pyrite to 1.5mm are seen and are of secondary origin.

Quartz	85%
Matrix	10%
Feldspar	2%
Silt Fragments	2%
Opaques	1%

548-96

A medium to coarse grained sandstone consisting of well rounded mainly quartz grains in a fine silty matrix. Other grains include rare plagioclase and microcline. The quartz is generally well rounded averaging about 0.5mm diameter but is angular when smaller. Maximum size is 1.5mm. Quartz shows signs of being of metamorphic origin showing undulose extinction and composite texture. Some siltstone grains can be seen. Secondry pyrite euhedra is also present in the section. The matrix which supports the grains and is slightly dolomitic makes up about 30% of the section. This sandstone comes from the Wilyerpa Formation.

548-120

A dolomitic-silt matrix diamictite from the Wilyerpa Formation. In hand specimen it is seen to contain very rare large clasts, the largest being a black quartzite about 2 x 1cm. For the main part it consists of dolomitic silt with fine to medium sandsized grains of quartz showing composite texture, rare microcline, rare plagioclase and siltstone. These are subrounded to well rounded. A small possibly granitic clast is also seen in thin section. The sample is unsorted. Sand makes up about 15% of the section.

548-129

A very fine, well laminated hematitic siltstone from the Holowilena Ironstone. It appears to contain a significant amount of detrital material but a great deal of this is apatite. These apatite grains are very common generally occurring as irregular elongate bodies parallel to the bedding and having a maximum size of 0.3 to 0.5mm. These apatite grains make up about 5% of the section and are primary or very early as they can define bedding planes. Small grains of detrital quartz and some carbonate are also present.

548-137

A dolomitic diamictite of the Wilyerpa Formation. The sample in hand specimen is yellow due to the very fine grained possibly detrital dolomite present. Staining has shown this to be non-ferroan dolomite. Clasts in handspecimen range in size up to 3cm but are generally less than 5mm. Lithologies of these clasts include - quartz grains which are generally well rounded ranging from silt to sand size, siltstone clasts are present but not very common being well rounded, and rare small grains of plagioclase. Opaques are rare. The sample is totally massive, matrix supported with about 60% matrix.

548-154

A fine grained hematitic siltstone which in part is well bedded and in part very sandy and massive. The bedded part consists of fine sand 0.1 to 0.2mm across containing generally angular quartz, plagioclase and dolomite grains in a dolomitic siltstone matrix. These appear somewhat graded and can have loaded bases and contain very little iron. The main part of the section is a massive hematitic siltstone with fine sand grains in it, the lithologies of these being similar to above. Small displacements - probably syndepositional are quite common.

548-160

Jaspilite from the Holowilena Ironstone. The jasper is a bright red colour and is seen to make up jasper beds as well as making up small lenses to 2mm across. These lenses are all flattened parallel to the bedding. A variety of zonations can be seen within these structures, some have a core of hematite surrounded by clear chert which is surrounded by jasper which is in turn surrounded by hematitic dominated sediment. Others are composed entirely of hematite with a core of jasper, this hematite seems to be a secondary enrichment - probably remobilisation of hematite in the sample. Others are composed entirely of clear white chert. In the clear cherty layers there are very common euhedral skeletons whose shape is rhombic and are probably after dolomite. These are about 0.1mm across and are primary or early diagenetic. These rhombs which are now infilled with silica and have rims of more iron silica are seen to define certain beds but seem to cut the very fine lamination of the sediment so are probably early diagenetic. Some of these have carbonate in them. Large secondary euhedra of calcite occur in the section, these grow to 2-3mm, are zoned and seem to grow along fractures. Hematite in the sample shows evidence of secondry enrichment forming zones of almost pure hematites being controlled by fractures in the rock.

548-183

A fine grained silty sand from the Pualco Tillite containing a few small siltstone clasts to 3mm. Pale grey colour. In thin section it is a very fine matrix supported sand. Maximum size of grains is about 0.5mm with most being about 0.1mm. Grains are most commonly quartz having both straight and undulose extinction and are rounded to angular. Other constituents are siltstone clasts with rare plagioclase, microcline and muscovite. Opaques are small and rare. The matrix is very fine slightly dolomitic siltstone.

548-190

A pale brown poorly sorted fine to medium grained quartzite. Quartz grains are dominant in a rock containing very little matrix. The matrix consists of about 5% of the section. Quartz grains show straight extinction, undulose extinction and show composite texture indicating that some of it is metamorphic. Maximum size is 0.75-1mm with these larger grains being very well rounded. The smaller grains are more angular and tend to be interlocking. Feldspars are absent and opaques are present in trace amounts.

548-225

A hematitic diamictite from the Holowilena Ironstone. Matrix consists of hematitic siltstone. Clasts include siltstones, possible volcanic clasts, plagioclase, microcline, granitic clasts (in hand specimen), dolomitic siltstones, dolomites. The maximum size to these is about 2mm in thin section but yet as large as 5mm in hand specimen. These clasts are mainly angular. Quartz sand sized grains are present and vary from angular to well rounded. A crude alignment of clasts can be seen. Some hematitic siltstone is well laminated but is discontinuous showing soft sediment deformation having been disturbed by massive clast rich hematitic siltstone indicating a high energy environment for the clastic material.

548-226

Gritty rock from the Holowilena Ironstone containing very little matrix. This matrix is fine grained dolomite (staining has shown it to be non-ferroan). Clasts within this rock include ferroan dolomite, dolomitic siltstones, angular to rounded quartz grains to a maximum of 2mm diameter and shows undulose extinction, siltstone clasts, grains of potassium feldspar and plagioclase are also present. The maximum size of the clasts is 0.5cm. Later stage pyrite euhedra can also be seen. The sample is totally massive.

548-232

Massive hematitic diamictite of the Holowilena Ironstone. Clasts to about 1mm can be seen and include quartz which also has strained extinction, dolomite, plagioclase, possible igneous clasts. They are mainly well rounded but can be angular. Layering if present is very poor being represented by alignment of small clasts of hematitic siltstone which was probably ripped up upon deposition of the massive hematitic sandstone. Matrix makes up 50% with sand grains making up the remaining 50%.

548-235

A clast rich diamictite from the Wilyerpa Formation. Maximum size of clasts seen in hand specimen is 5cm. Clasts show no orientation making up over 50% of the section and are supported by the matrix. The matrix is a poorly sorted dolomitic silty sand. Clasts include sandy siltstones, bedded siltstones which seem to be metamorphic, microcline (to 8mm x 3mm), common plagioclase grains, quartz grains are the dominant clasts, these are generally less than 0.5mm in diameter and well rounded. The larger clasts are also reasonably well rounded. In hand specimen a possible igneous clast can be seen. Also present are growths of limonite after pyrite which grow as euhedral shapes growing over the rest of the sediment.

548-241

Reworked diamictite from the Wilyerpa Formation. It has a dolomitic matrix with clasts to 3cm but most being about 1-2mm. Clast lithologies include quartz which is the most abundant, it has strained extinction and composite texture hence is metamorphic, generally angular. Other clast types are basalt and other volcanic clasts, common plagioclase and microcline, micas, siltstone clasts which are generally well rounded are quite common, and dolomite clasts. Clasts are matrix supported which is a dolomitic siltstone.

548-252

A poorly sorted, generally well rounded medium to coarse grained quartzite from the Wilyerpa Formation. Larger grains are well rounded with smaller ones being more angular. A great proportion of the grains are quartz which is observed to have undulose extinction. Feldspar is seen, both plagioclase and microcline. Matrix is not very common and is silty.

Quartz	93%
Matrix	<5%
Feldspars	2%
Opaques	trace

548-258

A vesicular basalt clast from within the Wilyerpa Formation. Consists of plagioclase laths 0.1 to 0.5mm long with some fine grained quartz. Groundmass appears glassy. Vesicles are commonly rimmed by a thin band of fine grained quartz but in hand specimen are seen to be infilled with quartz as a secondary filling. These vesicles are about 5mm in diameter. Staining for potassium feldspar (Appendix IIIC) has revealed that some is present in the matrix.

548-266

This is a section of the dyke material cut at right angles to the sides of the dyke. No layering can be seen in thin section but some is present in the hand specimen. It consists grain to grain contact fine to medium grained sand grains which are commonly interlocking. These grains are mostly well rounded consisting dominantly of quartz with minor plagioclase and feldspar. Some of these quartz grains have undulose extinction. Matrix is not common and appears to be mainly dolomite.

548-272

A fine grained quartzite which in hand specimen is a green colour. Grains are mainly angular. The main component is quartz with some feldspars. Opaques make up 2-3% of the secion are quite common. The groundmass to the grains appears to be a sandy-dolomite and is responsible for the colouration of the sample.

548-273

A sample of the Holowilena Ironstone having jasper, white chert and magnetite euhedra. Jasper occurs as beds about 1cm thick within the thin section. Some of this jasper does appear to cross cut bedding slightly which would point to a secondry origin to the jasper. The rest of the section contains fine white chert with carbonate minerals through it. Detrital quartz grains around 0.3mm diameter occur in some beds, these are mainly angular and form small lenses of sediment 0.5cm thick. Magnetite euhedra are totally random in orientation not being concentrated along bedding. These euhedra are hexagonal and generally 0.05-0.2mm diameter and seem to have grown later. They make up about 5% of the sample.

548-275

A well laminated hematitic siltstone from the Holowilena Formation. Bedding is easily seen and comprises of alternation of hematite rich beds and hematite poor beds which are composed of quartz and dolomite. These laminations occur on a scale of a fraction of a millimetre. Small magnetite euhedra which have in polished section been observed to be altered to martite can be observed. They have a size of about 0.1mm. Small displacement of bedding of about 2mm can be seen.

548-281

Jaspilite from the Holowilena Ironstone. The sample is dominated by hematite and red jasper with some detrital material in a few layers consisting mainly of angular quartz grains with an average size of 0.1mm. The jasper lenses described in TS/160 are observed in a 5mm layer. They reach a length of 2mm having a core of irregular hematite surrounded by the jasper. They seem early diagenetic in origin as they seem to push the rest of the sediment aside. Other irregular bodies of jasper may indicate a secondary origin to it. Clear chert is also present as small lensoids in hematite or dominating some beds. Secondry veins of white chert are seen perpendicular to the bedding and show evidence of being early as they show buckling due to compaction.

548-283

A fine grained green coloured quartzite from the Wilyerpa Formation. Grain size is generally less than 0.25mm with rare grains to 1mm. Matrix is present but grains are in contact and some are interlocked due to compaction. Grains are subangular to well rounded with most being subrounded. Fairly well sorted. Almost 100% quartz grains with rare siltstone grains and no feldspars.

548-284

A fine to medium grained well rounded sandstone. Larger grains are about 0.5mm across, the smaller grains tend to be more angular. From hand specimen the quartzite is a honey colour and is seen to contain rare small yellow siltstone clasts to a maximum of 1mm. Small angular plagioclase grains are seen but are rare. Quartz is the dominant grain and is at times observed to have undulose extinction. Matrix is slightly iron rich thus giving the brownish colour. Opaques occur in trace amounts.

Quartz	88%
Matrix	10%
Feldspar	1%
Siltstone	1%

548-287

Finely laminated black shale of the Tapley Hill Formation. It is very calcareous containing abundant dolomite (staining has shown it to be ferroan dolomite). Within one layer is common pyrite which is easily seen in hand specimen. In thin section it is very fine grained consisting of silt, dolomite and pyrite. Very well laminated and possibly graded. Dolomite matrix is somewhat recrystallised.

548-288

A fine to medium grained poorly sorted pale coloured quartzite from the Wilyerpa Formation. Consists mainly of grains of interlocking quartz with rare plagioclase and microcline. The maximum size is about 1mm but are mainly between 0.2 and 0.5mm. Quartz show both undulose and straight extinction. Grains are mainly subrounded but can be subangular. In hand specimen siltstone clasts to 5mm can be seen. The matrix is not common and is slightly hematitic.

Quartz	93%
Matrix	5%
Siltstone clasts	1%
Feldspars	$<1\%$

548-290

A medium grained white quartzite from the Wilyerpa Formation. Contains very little matrix (about 10%) which is silty when present. The rest of the section is almost entirely quartz grains which vary from silt sized to about 1mm. The smaller grains being subangular with the larger grains being well rounded. Rare siltstone grains and possible carbonates can be observed. Feldspars are almost non-existant. Opaques are not present.

548-291

A medium grained non calcareous white quartzite from the Wilyerpa Formation. Consists mainly of quartz grains ranging in size from very fine sand to 1mm. Quartz grains are interlocking, the larger ones seem to be very well rounded and the smaller grains vary from angular to well rounded. Quartz grains have both straight and undulose extinction and commonly show composite texture hence are of metamorphic origin. Rare angular plagioclase grains can be seen as well as rare rounded siltstone clasts. The matrix is a slightly dolomitic siltstone making up about 5% of the section. Small euhedra of limonite after pyrite are present.

548-298

Hematitic siltstone of the Holowilena Ironstone containing a lens of jasper which is 7 x 2cm and discoid parallel to the bedding. The jasper lens is very fine grained with very little,if any,internal structure. This lens is in the sandy carbonate facies consisting of units of non hematitic rich sands in a hematitic siltstone matrix interbedded with hematite rich hematitic siltstone. Surrounding the jasper lens is a 1-2mm thick layer of brown dolomite. This jasper lens seems to be of secondry origin. Along fractures in the jasper lens are rhombs of secondary dolomite.

548-305

A porphyry clast from within the Wilyerpa Formation. Contains quartz, sericite, plagioclase, epidote and limonite. Phenocrysts are mainly plagioclase with potassium feldspar occurring only in the groundmass (verified upon staining). The plagioclase phenocrysts have a complex combined pericline and multiple twin which according to Chris Giles (Pers. comm.) is typical of the Gawler Range Porphyry. Groundmass is microlitic - devitrified from glass. Quartz phenocrysts are also common. Limonite is present throughout the section.

Matrix	80%
Plagioclase	10%
Quartz	4%
Potassium feldspar	2%
Epidote	2%
Limonite	2%

Phenocryst proportions:	
Plagioclase	65%
Quartz	25%
Epidote	10%

548-306

Carbonate sandy facies of the Holowilena Ironstone. In hand specimen the sample is seen to be well laminated consisting of alternations of iron-rich and iron-poor sediment (dominantly dolomite). Staining for carbonate has shown the presence of ferroan dolomite. Inspection of the thin section reveals that the sample consists of a well laminated mixture of hematite, dolomite grains and carbonate mud and silt. The carbonate grains forming graded beds on the scale of 0.5 to 1mm. Maximum grainsize of the dolomite sand is 0.1 to 0.2mm. Lamination occurs on a scale of a fraction of a mm. Dolomite grains that form the graded bedding are angular.

548-310

A white chert found only in float and is possibly a part of the Holowilena Ironstone. The sample is well bedded containing layers rich in pyrite and limonite which is after the pyrite. Little or no detrital material is present in the section. Rhombs are also present and appear to be after carbonate not pyrite. These are commonly infilled with coarser crystalline clearer chert than the chert which forms the main part of the sample. These rhombs are also concentrated in certain layers.

548-315

A fine grained dolomite from the Pualco Tillite. In hand specimen it is a yellow colour and shows signs of bedding. It is seen to contain limonite cubes after pyrite as well as MnO dendrites. In thin section it is a very pale brown colour and is very fine. Bedding can be seen but is not clear. Contains some silt. Recrystallization has occurred, resulting in a coarser grained clear carbonate in places.

548-318

A granule rich rock from the Holowilena Ironstone. Contains grains most commonly between 1 and 1.5mm but do get as large as 1.5cm. Staining of the sample for carbonate has shown that about 60% of the grains are ferroan dolomite which contain varying amounts of iron. The matrix to the sample appears to be a dolomitic siltstone which at times seems to be recrystallized. Matrix is not very common. Dolomite is the main clast type followed by quartz which gets as large as 1.5cm. Most are well rounded showing plain and undulose extinction with some showing composite texture. Rare small grains of plagioclase and microcline are also present. Small flakes of chlorite are present but rare. Some of the grains are surrounded by limonite after pyrite which was secondry.

548-335

Laminated siltstone of the Wilyerpa Formation. A green colour and is seen to contain clasts to 5mm whose lithologies are marble and granitic. Common feldspar - both microcline and plagioclase can be seen as well as quartz with composite texture. Large clasts are generally angular. In hand specimen clasts reach 1.5 x 0.5cm (marble) and are concentrated in one layer. Staining for carbonate has shown that ferroan dolomite is present. Also in hand specimen there can be seen small scale slumps and cross-laminations in the silt sized fraction. The silty part of the specimen is poorly sorted containing material ranging from clay to fine sand size.

548-339

Jaspilite facies of the Holowilena Iron formation. Within this sample there are thin beds of detrital fine sand sized material to 1mm thick composed of angular quartz grains 0.05 to 0.1mm diameter. This material may contain some carbonate grains and have common loaded bases and seem to define graded beds. The sample contains jasper lenses to 2-3mm long, all parallel to the bedding and mainly being replaced by hematite. These are seen to occur in a white chert matrix which is very fine grained and contains much fine hematite which is seen to define bedding. Both the jasper and the white chert appear to show soft sediment deformation - slumps. Rhombic euhedra after dolomite, now chert rimmed with iron rich silica are seen to occur in some bedding planes.

548-347

A yellow dolomite from the Burra Group. Staining has shown it to be slightly ferroan. It is generally fine grained although throughout the section larger irregular grains of dolomite less than 0.1mm are seen and probably represent recrystallization of the dolomite. Acid digestion (Appendix IIIE) of the sample has shown it to contain about 29% by weight carbonate, the rest being silt. Opaques (limonite after pyrite) can be common.

548-353

A carbonate-sandy rock from the Holowilena Ironstone. The sample is well bedded consisting of alternations of hematite rich beds containing some detrital carbonate and quartz with beds composed almost entirely of carbonate and quartz. Detrital material consists of quartz, dolomite and rare plagioclase generally 0.05 to 0.1mm across with a maximum of 0.2mm diameter in a dolomitic-silt-hematite matrix. Staining has shown that some ferroan dolomite is present. Detrital material has approximately equal portions of quartz and dolomite with about 1% feldspar. Hematite rich beds contain some detrital material of similar composition to that above. Hematite would make up about 30% of the section. The dominantly detrital beds are commonly loaded into the hematite rich beds. X-Ray Diffraction (Appendix IIID) of the sample has also indicated the presence of oligoclase in the sample.

548-355

Jaspilite from the Holowilena Ironstone showing excellent banding consisting of alternations of jasper and white chert. Hematite is dispersed throughout the sample and defines very fine laminations on a scale of a fraction of a mm. Small rhombs, up to 0.1mm, after dolomite but now iron rich silica occur within the section.

Small faults are seen to displace beds by up to a few mms and are syn-sedimentary as not all layers are affected. Detrital material is rare, although in one layer detrital quartz grains all less than 0.1mm are present. Small thin veins of silica perpendicular to the bedding occur in the section.

548-363

Laminated hematitic siltstone from the Holowilena Ironstone. Consists dominantly of hematite and siltstone. Apatite makes up about 10% of the sample occurring as small lensoid or irregular bodies always flattened parallel to the bedding generally 0.3mm long but can get as long as 1.0mm. Apatite seems to be concentrated along some bedding planes hence is initially primary. The small bodies are seen to push bedding aside indicating they grew at a later stage but prior to compaction. X-Ray Diffraction (Appendix IIID) revealed the presence of carbonate apatite, albite, hornblende, dolomite, hematite and unnamed iron-oxides.

548-370

Sandy-carbonate facies of the Holowilena Ironstone. The sample is a well laminated fine sand containing detrital dolomite and quartz which form graded beds on the scale of 0.5 to 1mm. Maximum grainsize is 0.1 to 0.2mm. These detrital grains sit in a matrix of dolomite, silt and hematite. Sandy beds are usually loaded into finer hematitic siltstone and are composed mainly of dolomite. Staining for carbonate has shown it to be normal dolomite with a small amount of ferroan dolomite. Small euhedra - probably of magnetite (martite after magnetite) of up to 0.1mm diameter can be seen. X-Ray Diffraction (Appendix IIID) on the sample has also indicated the presence of amphibole, oligoclase and orthoclase.

Silty-Dolomite	50-55%
Hematite	15-20%
Dolomite	15%
Quartz	14%
Magnetite, feldspars	trace

548-371

Laminated green siltstone of the Wilyerpa Formation containing abundant dropstones. In hand specimen it is seen to contain quite large dropstones to 2-3cm. Clasts include banded chert, quartzo-feldspathic schist, quartz, potassium feldspar, plagioclase and chlorite. The sample consists of fine sandy layers alternating with siltstone in what look like graded beds. Sandy beds commonly being loaded into the siltstone layers. Two types of sandy bed exist. The first consists of fine sand 0.05 to 0.1mm with a maximum of 0.5mm and contains quartz (dominant), some plagioclase and carbonates. Grains are mainly angular and occur in a yellow carbonate matrix, these beds seem lensoidal. The second type of sandy material does not have the carbonate associated with it. The siltstone has common scattered sand sized grains and carbonate in it. The larger quartz grains are well rounded. The dropstones in the sample are seen to pierce the bedding and have overlying beds draping over them.

548-374

Diamictite from the Pualco Tillite having clasts up to 1.5cm diameter (granite and chert in hand specimen). Most grains are less than 0.5cm and range right down to the silty-clay matrix. Quartz is the most common clast being commonly rounded but can be angular. It can have undulose extinction as well as composite texture. Feldspars - both microcline and plagioclase can be common as angular and rounded grains. Siltstone and calcareous siltstone clasts are also common. Others include possible igneous grains and cherts. The matrix is a brown dolomitic silt and in places looks recrystallized. In hand specimen a crude layering can be seen. This is as a result of variations in the amount of dolomite in the matrix. Opaques occur in trace amounts.

Clast: matrix is about 50:50.

Proportions of clasts:	Quartz	85%
	Silt	5%
	Feldspar	1%
	Others	9%

548-375

A massive diamictite from the Pualco Tillite which contains clasts to 2cm. The larger clasts are mainly dolomite with some siltstones and chert. Grains are all well rounded and sit in a dolomitic silt matrix. Other grains include quartz, plagioclase and microcline. Much more clast rich than 548/374. Opaques occur in the thin section as limonite after pyrite.

548-375a

Laminated siltstone of the Wilyerpa Formation. Contains common graded beds on the scale of 1mm or less. Sandy material is not common making up about 5% of the section and consists of quartz and some dolomite up to 0.2mm diameter. The siltstone contains a great deal of carbonate.

548-378

Quartzite of the Wilyerpa Formation containing quartz, plagioclase, microcline, some siltstone grains and rare opaques in a fine grained matrix. Most grains are well rounded and are of medium sand size 0.25 to 0.75mm. Sorting is reasonably good.

Quartz grains show straight and undulose extinction and can have composite textures. The smaller quartz grains being subangular to subrounded. Feldspars are reasonably common, staining for K-feldspar (Appendix IIIC) showed about 3% K-feldspar. The matrix is slightly calcareous and hematitic hence giving the quartzite a pale brown colour. Opaques occur in trace amounts.

Quartz	82%
Matrix	10%
Potassium feldspar	3%
Plagioclase	2%
Siltstone grains	2%

548-401

A well laminated dark grey dolomite from the Tapley Hill Formation. Staining (Appendix IIID) has revealed the dolomite to be ferroan dolomite. The section consists of thin bands of black carbonate alternating with thicker bands of grey carbonate some ½-1mm across. Laminae are not straight but seem irregular. Dark colouration is due to fine pyritic material. Carbonate within the section is very fine and appears to be partially recrystallized being a silty-carbonate mixture. Calcite veins are seen in the section.

548-405

A fine grained quartzite from the Wilyerpa Formation consisting of grains of quartz 0.05 to 0.1mm in a fine grained silty matrix. The matrix is not dolomitic but is hematitic giving it a brown colouration. Quartz grains are all angular. Rare plagioclase and microcline are present. Irregular masses of limonite, probably after pyrite, occur throughout the section. These are of secondary origin containing quartz grains within their boundaries. A bright red secondry iron rich banding can be seen to occur in the section. These bands can be parallel to bedding, can cross cut bedding or can be small irregular bodies of iron rich sand.

548-419a

A pale grey bedded dolomite from within the Wilyerpa Formation. Staining has revealed it to be ferroan dolomite. The sample is very fine grained except for detrital layers which consists of mainly quartz with some microcline, plagioclase carbonates, and rare siltstone fragments reaching a maximum size of 0.3mm. Grains are mainly angular. This detrital material usually occurs as graded beds and is supported by a carbonate-silt matrix. The dolomite has very faint layering in it, contains rare detrital grains and is in places recrystallized. Detrital quartz can have undulose extinction.

Dolomite mud	94%
Quartz	5%
Opaques	< 1%
Feldspars	trace

<u>548-419b</u>

Porphyritic basalt clast from within the Wilyerpa Formation. Contains phenocrysts of mainly potassium feldspar and quartz with rare plagioclase in a fine grained matrix. Staining (Appendix IIIC) has shown the presence of K-feldspar. The ratio of K-feldspar to quartz phenocrysts is about 50-50. Phenocrysts are as large as 2mm some containing granophyric texture indicating a high level intrusive or an extrusive. Quartz phenocrysts can show embayment. Groundmass is not recrystallized but is very finely devitrified and shows possible flattened shards. Phenocrysts are not perfectly formed being fractured or chipped. This implies some sort of ash flow tuff. Chlorite after an equigranular mineral, probably amphibole or clinopyroxene is present. Opaques can be present as small cubes or in association with the chlorite.

Groundmass	70%
K-feldspar	14%
Quartz	13%
Plagioclase	1%
Opaques	1%
Chlorite	1%

<u>548-420</u>

Clast rich rock from the Holowilena Ironstone consisting of clasts 1-2mm in diameter with very little matrix. The dominant clast lithology is a purple coloured dolomitic siltstone. Hematitic siltstone clasts are small and make up about 2% of the section. Quartz is present making up about 5% of the section is generally rounded and can show composite texture. Siltstone clasts are also present. Bedding is defined by the flat clasts which are all parallel to each other. The deposit is winnowed.

<u>548-421</u>

A siltstone from the Tapley Hill Formation. Staining for carbonate (Appendix IIIB) has revealed the presence of ferroan dolomite. In thin section it is seen to be composed of fine quartz and dolomite with a maximum size of 0.05mm.

Dark colour to the sample is probably due to pyritic material which seems to concentrate in small pods flattened parallel to bedding and easily seen in hand specimen. The sample does not appear to be well bedded.

(B) POLISHED SECTION DESCRIPTIONS

All polished sections are of the Holowilena Ironstone.

548-160a

Jasper rich unit containing jasper lenses. These lenses sometimes have a core of jasper devoid of any hematite surrounded by hematite mixed with silica. The core to these structures seems to be non-jasper gangue. Other lenses consist of jasper surrounded by gangue with very little hematite in it. Hematite is seen to define the bedding in the sample and usually occurs as small flakes less than 0.01mm diameter. Rare irregular grains of magnetite are also seen.

548-160b

Similar to the previous section but hematite now shows signs of secondary enrichment. Hematite is much more common. Jasper lenses have a core of gangue plus hematite which is surrounded by jasper which is surrounded by the hematite rich zone. Rhombic clasts after dolomite are also seen.

548-160c

Jasper rich unit showing the enrichment of hematite and how it is controlled by fractures within the rock. This results in a coarse grained intergrowth of hematite needles about 0.50 x 0.15mm. Normal hematite occurs as flakes 0.01 to 0.02mm. The zones enriched in hematite are almost pure hematite.

548-161

A well banded jasper rich rock consisting of alternation of hematite rich beds and hematite poor beds on the scale of millimetres. Very fine laminations are also present. Dolomite euhedra are present in a few layers. In hand specimen the bedding is easily seen as well as possible tabular cross-bedding as a jasper layer seems to truncate other layers. Displacements of up to 2 to 3mm's can be seen and appear to be synsedimentary.

548-225

A hematitic diamictite which from hand specimen is seen to contain clasts of siltstones, dolomites and quartzites to 5mm. Hematite is interstitial between the gangue grains and is very fine grained. It tends to be more concentrated in some pods which seem to be randomly distributed. Some rare irregular grains of detrital magnetite also seem present. Some of the clasts are of hematitic siltstone.

548-227

Laminated hematitic siltstone containing about 50% hematite. In the section there are lensoids of gangue mineral to 1mm long which are parallel to the bedding. These probably represent apatite. Hematite is fine grained occurring as flakes which are generally less than 0.01mm and oriented randomly.

548-232

Hematitic diamictite containing clasts to 2cm including siltstones, quartzites, dolomites and common round quartz grains. Hematite is present as small flakes generally less than 0.01mm. Magnetite (martitized) occurs as irregular detrital grains.

548-273

The sample contains many randomly distributed magnetite euhedra which have been almost completely martitized. These euhedra are about 0.3mm or less in diameter but can get as large as 1mm. Magnetite seems to be the main oxide present also existing as non euhedral layers defining bedding. Magnetite in the euhedra is a slight brown colour possibly indicating titanium in the magnetite. Euhedra are perfectly shaped, randomly distributed and may have grown at a later stage in the cherty gangue. Some euhedra have a darker core possibly ilmenite.

548-275

Laminated hematitic siltstone in which gangue dominates. Iron oxides are in the form of magnetite euhedra to about 0.5mm diameter and hematite flakes generally less than 0.01mm long. These make up about 10% of the section. Bedding is defined by variation in the amount of iron-oxide as well as differences in gangue mineralogy.

548-280

Laminated hematitic siltstone containing about 50% hematite. Laminations are defined by variations in the percentage of gangue and hematite. Gangue minerals are of two types, the first the fine silt mixed with the hematite and the second occurring as large grains up to 1mm which are flattened parallel to bedding - these are probably apatite grains.

548-281

Hematite rich jaspilite containing small jasper lenses up to about 1mm long and flattened parallel to bedding. Core consists of hematite and gangue which is surrounded by hematite poor jasper which is in turn surrounded by hematite and chert. Hematite consists of small flakes generally less than 0.01mm long. Perpendicular to bedding are silica veins.

548-282

Hematitic siltstone containing 40-45% hematite which is fine grained with a maximum grain size of 0.02mm. These are randomly oriented and occur in a matrix containing silt and sand. Very well laminated.

548-310

A cherty rock containing grains of euhedral pyrite, some of which have been rimmed by an iron-oxide. These get as large as 0.75mm but are generally much smaller. Some of the pyrite cubes have undergone alteration having been replaced by magnetite which has since undergone martitization.

548-321

A laminated hematitic siltstone consisting mainly of gangue with interstitial flakes of hematite generally about 0.01mm long and making up about 10% of the section. Secondry movement of hematite seems to have occurred resulting in some of the gangue minerals being rimmed by hematite. Some of these hematite concentrations are elongate parallel to bedding.

548-370

Carbonate-sandy facies of the ironstone consisting mainly of gangue with some hematite, usually as fine flakes and some magnetite euhedra which are about 0.05mm in diameter. Sample is well bedded due to variations in the proportions of gangue to hematite as well as changes in gangue mineralogy and texture.

APPENDIX III

ANALYTICAL TECHNIQUES

A) WHOLE ROCK AND TRACE ELEMENT ANALYSES

1) Sample preparation

(i) clean fresh sample was first crushed then ground using a Siebtecknik chrome-steel mill.

(ii) the sample was then placed in a weighed silica crucible and accurately weighed. The sample was ignited at 950^{o}C for six hours to determine loss on ignition.

(iii) 280mg of the ignited sample was weighed with 20mg of sodium nitrate and 1.5 grams of lithium tetraborate flux. This was used to make a fused button for use in the whole rock analysis of the sample.

(iv) Pressed buttons were made for the determination of trace elements, these using approximately 5 grams of sample.

2) Methods

(i) Determination of Sodium

Approximately 30mg of ignited powder was digested in a solution containing 2ml of 50% H_2SO_4 and 10ml of HF in teflon beakers overnight. The digested sample was then diluted and made up accurately to 100ml. Determination of sodium was made on the flame photometer using Blackhill Norite II as the standard.

(ii) Whole rock analyses

The whole rock analyses were determined by XRF on the Siemens SRS.

(iii) Trace element analyses

All trace element analyses were determined on the Phillips XRF machine according to the following conditions:

(a) Cerium - Neodymium

Tungsten tube 60KV 40mA
LiF220 crystal
Flow proportional counter
Coarse collimnator
Eht = 369
Vacuum
Counting time = 100 seconds

Lines measured	Angle
Ce bgd	110.43^{0}
Ce $L\beta_1$	111.63^{0}
Nd $L\alpha_1$	112.67^{0}
Nd bgd	113.87^{0}

Counting Standard used was 331/693

Other standards used were G2, BCR-1

(b) Rubidium-Strontium

Molybdenum tube 60KV 40mA

LiF220 crystal

Scintillation counter

Fine collimnator

Eht = 359

Air

Counting time = 100 seconds.

Lines measured	Angle
Sr bgd	34.75^{0}
Sr $K\alpha$	35.62^{0}
Rb bgd	36.69^{0}
Rb $K\alpha$	37.76^{0}

Counting standard used was MBM + BLC + Y

Other Standards used were AGV-1, G2, BCR-1.

(c) Yittrium

Molybdenum tube 60KV 40mA

LiF220 crystal

Scintillation counter

Fine collimnator

Eht = 352

Air

Counting time = 100 seconds.

Lines measured	Angle
Y $K\alpha$	33.66^{0}
Y bdg	34.66^{0}
Rb $K\alpha$	37.77^{0}
Rh-Th bgd	38.39^{0}
Th $L\beta$	39.02^{0}

Counting Standard used was MBM + BLC + Y

Other Standards used were GSP-1, G2, BCR-1.

(d) Zirconium

Gold tube	50KV	40mA
LiF220 crystal		
Scintillation counter		
Fine collimnator		
Eht = 354		
Air		
Counting time = 100 seconds		

Lines measured	Angle
Zr Kα	31.88^{o}
Sr-Zr bgd	32.88^{o}
Sr Kα	35.42^{o}
Th bgd	36.42^{o}
Th Kα	39.02^{o}

Counting Standard used was 331/371

Other Standards used were BCR-1, JG-1, GSP-1

(e) Niobium

Gold tube	50KV	40mA
LiF220 crystal		
Scintillation counter		
Fine collimnator		
Eht = 352		
Air		
Counting time = 100 seconds		

Lines measured	Angle
Nb bgd	29.61^{o}
Nb Kα	30.21^{o}
U bgd	36.38^{o}
U Kα	37.09^{o}

Counting Standard used was 331/371

Other Standards used were BCR-1, GSP-1.

(f) Barium-Titanium

Chromium tube	60KV	40mA
LiF220 crystal		
Flow proportional counter		
Coarse collimnator		
Eht = 363		
Vacuum		
Counting time = 100 seconds		

Lines measured	Angle
Ti Kα	86.18°
Ba Lα	87.22°
Ba bgd	88.22°

Counting Standard used was VHG + Ba + Sc

Other Standards used were BCR-1

(g) Zinc

Gold tube 50KV 40mA

LiF220 crystal

Scintillation counter

Coarse collimnator

Eht = 383

Air

Counting time = 100 seconds

Lines measured	Angle
Zn Kα	60.45°
Zn bgd	59.47°

Counting Standard used was BCR-1

Other Standards used were DTS-1, SY-1, AGC-1.

(h) Nickel

Gold tube 50KV 40mA

LiF220 crystal

Scintillation counter

Coarse collimnator

Eht = 366

Air

Counting time = 100 seconds

Lines measured	Angle
Ni Kα	71.12°
Ni bgd	70.12°

Counting Standard used was PCC-1

Other Standards used were BCR-1, AGC-1, SY-1, DTS-1.

B) METHOD OF STAINING FOR CARBONATE MINERALS

Staining for carbonates was carried out using the three stage process of Dickson (1965). Samples to be stained were cut into small blocks which were then subjected to the three stages of the process outlined in Table 4.

Reference:

DICKSON, J.A.D., 1965., A modified staining technique for carbonates in thin section. Nature V.205, p587.

C) METHOD OF STAINING FOR POTASSIUM FELDSPAR

Staining for potassium feldspar was carried out in order to determine the amount of potassium feldspar in volcanic clasts within the Wilyerpa Formation. The process involves etching of a clean sample with fumes of hydrofluoric acid for one minute followed by immersion of the etched surface in a solution of 50 grams/100ml of Sodium Cobaltinitrate for a total of three minutes. The sample was then washed. Potassium feldspar stains a bright yellow.

D) METHOD OF X-RAY DIFFRACTION

The sample was powdered and spread evenly as a slurry in ethanol on a glass plate then allowed to dry. This mount was then placed in the rotary sample holder of the X-Ray Diffractometer (Phillips X-Ray Diffraction 1010) and analysed under the following conditions:

Cobalt tube, Co $K\bar{\alpha}$ beam.
Filter - graphite goniometer
Scan speed $\frac{1}{2}^{0}$/minute
Chert speed 5mm/minute
Time constant 10
Slit widths $2^{0}/\frac{1}{2}^{0}$
Range 100 cps
Kv/mA 30/30

A trace of the resulting peaks was obtained for the angles between 3^{0} and 70^{0}.
The Bragg equation:

$$n\lambda = 2d \sin \theta$$

where n is an integer
λ is the wavelength = 1.79021 Å for $CoK\bar{\alpha}$
d is the interplanar space
θ is the angle of incidence and reflection of the x-ray beam

was used to work out the interplanar spacings once 2θ was measured from the peaks. The minerals present were determined using Berry (1974).

TABLE 4 Technique for carbonate staining

Procedure	Time	Carbonate	Result
ETCHING 1·5% HCl	40–45 sec	Calcite Ferroan Calcite	Considerable etch
		Dolomite Ferroan dolomite	Negligible etch
STAINING* 0·2g A.R.S. per 100c.c. 1·5% HCl 2·0g P.F. per 100c.c. 1·5% HCl Mixed in ratio A.R.S.: P.F. = 3 : 2	30–45 sec	Calcite	Very pale pink–red
		Ferroan Calcite	Very pale pink–red Pale blue–dark blue Two superimposed give Mauve–purple–royal blue
		Dolomite	No colour
		Ferroan Dolomite	Pale–deep turquoise
STAINING 0·2g A.R.S. per 100c.c. 1·5% HCl	40–45 sec	Calcite Ferroan calcite	Very pale pink–red
		Dolomite Ferroan dolomite	No colour

* A.R.S. = Alizarin red S
P.F. = Potassium ferricyanide

by G. CIRCOSTA 1978
after DICKSON 1965

Reference

BERRY, L.G., (ed), 1974, Selected powder diffraction data for minerals. Joint committee on powder diffraction standards. Philadelphia, Pa.

Results of X-Ray Diffraction

Minerals underlined are the dominant minerals in each sample.

548-8 Laminated siltstone - Wilyerpa Formation.
Quartz, Dolomite, Chlorite - Ripidolite, Muscovite, Orthoclase, Albite (low).

548-94 Laminated siltstone - Wilyerpa Formation
Quartz, Dolomite, Ankerite, Calcite, Chlorite - Ripidolite, Muscovite, Pyrite, Albite (high and low), Oligoclase.

548-335 Laminated siltstone - Wilyerpa Formation.
Quartz, Dolomite, Ankerite, Chlorite - Clinochlore, Albite (low), Muscovite.

548-337 Dolomite - Wilyerpa Formation.
Dolomite, Ankerite, Quartz, Muscovite, Anorthite (low).

548-339 Jasper rich rock - Holowilena Ironstone
Hematite, Unnamed Iron-oxides, Calcite, Quartz.

548-342 Finely laminated hematitic siltstone - Holowilena Ironstone
Hematite, Unnamed iron-oxides, Quartz, Dolomite, Amphibolite, Muscovite.

548-347 Limestone - Burra Group
Dolomite, Calcite, Quartz.

548-353 Hematitic silty-sand - Holowilena Ironstone
Hematite, Unnamed iron-oxides, Dolomite, Quartz, Anorthite (low), Oligoclase (high).

548-363 Hematitic siltstone - Holowilena Ironstone
Hematite, Unnamed iron-oxides, Carbonate apatite, Horneblende, Dolomite, Quartz, Albite (low).

548-370 Carbonate-sandy facies of the Holowilena Ironstone.
Hematite, Unnamed iron-oxides, Dolomite, Quartz, Oligoclase (high), Orthoclase, Amphibole.

548-371 Laminated siltstone - Wilyerpa Formation.
Quartz, Dolomite, Chlorite (Clinochlore), Muscovite, Albite (low and high), Amphibole.

E) PROCESS OF ACID DIGESTION IN DETERMINATION OF PERCENTAGE CARBONATE

Approximately 5 grams of accurately weighed crushed sample was placed in a 100ml plastic beaker. To this sample was added 60-100ml of 1:10M HCl. This was allowed to digest overnight. When digestion was complete the acid was decanted and replaced by distilled water. The distilled water was used to dissolve any calcium chloride which precipitated from solution during digestion. This was left overnight then the water was decanted and the remaining sample was dried by placing it in an oven at 65^{o}C for twenty four hours. Once dry and cool each sample was accurately weighed. From the resulting weight loss percentage carbonate present in each sample was calculated.

RESULTS OF ACID DIGESTION

Sample	Sample weight	Residue	% Carbonate
548-8	6.18375	5.83047	5.71
548-94	6.35339	4.21121	33.72
548-335	5.23455	5.01862	4.13
548-337	6.40452	3.3522	47.66
548-342	7.95291	7.42273	6.67
548-347	8.20969	5.83302	28.95
548-353	7.70682	4.90427	36.36
548-370	6.77337	4.4394	34.46
548-371	7.18315	6.32301	11.97
548-390	10.33985	10.04626	2.84

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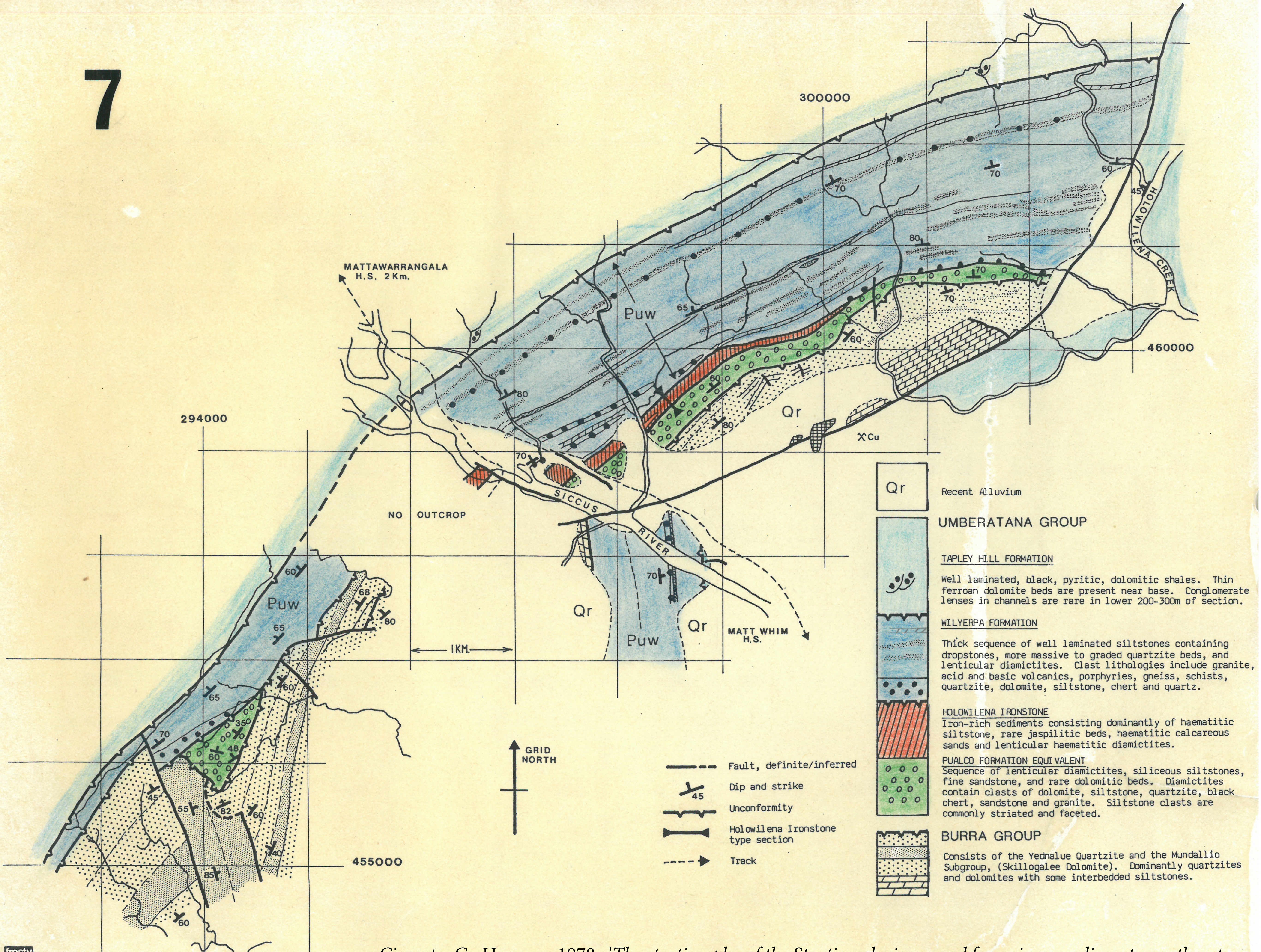

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