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OF THE
PATERSON RANGE, WA
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SF51-6

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PROTEROZOIC GEOLOGY OF THE PATERSON RANGE, WA 1:250 000 SHEET

by

R.J. Chin and A.H. Hickman

INTRODUCTION

The Paterson Range 1:250 000 Sheet (International Grid Reference SF51-6) is bounded by latitudes 21°00'S and 22°00'S, and by longitudes 121°30'E and 123°00'E. The area forms part of the Eastern Land Division, falls within the Marble Bar District of the Pilbara Goldfield, and contains part of the Great Sandy Desert.

Aridity and isolation have made the area unattractive to agriculture, and little interest was shown in the region until 1971 when gold was discovered at the Telfer Dome. Evaluation of the deposit by Newmont Pty Ltd has led to the establishment of a mine and supporting town at Telfer.

The main access road turns off the Port Hedland to Woodie Woodie road near Ragged Hills on the Nullagine Sheet and heads east-southeasterly to Telfer. Tracks in the Telfer area provide good access to many localities, but elsewhere vehicular travel is slow and uncomfortable in the sand dune and spinifex country.

The climate is arid; potential evaporation far exceeds the rainfall. The average annual rainfall is approximately 250 mm, but is unreliable. The heaviest falls occur between November and March and are associated with cyclonic and thunderstorm activity. In winter, the average daily maximum temperature is about 25°C, in summer about 40°C. Potential evaporation is approximately 2 700 mm per annum.

The area forms part of the Great Sandy Desert natural region of Beard (1969). Its vegetation may be divided into

3 major associations corresponding closely to physiographic divisions:

1. Eolian sand: spinifex (*Triodia* and *Plectrachne*), shrub (especially *Grevillea*), wattles (*Acacia*), soft shrubs (*Crotalaria*), eucalypts (*Eucalyptus*) and ti-tree (*Melaleuca*).
2. Salt-lake margins: samphire (*Arthrocnemum*), saltbush (*Hemichron*, *Bassia*, *Frankenia*) and spinifex (*Triodia*).
3. Rock outcrop and colluvium: spinifex (*Triodia*), small scrub, grasses and mulga (*Acacia*).

PREVIOUS INVESTIGATIONS

The earliest reports on the nature of the country were made by explorers. Colonel P.E. Warburton (1875) crossed the north-western corner on his expedition from Alice Springs to the Oakover River. W.F. Rudall (1897) traversed much of the area while searching for the lost members of the Wells expedition, and discovered Christmas Pool. Topographic features in the area were named after members of his search party.

The first geological investigation was made by H.W.B. Talbot from 1912 to 1914. The report and geological sketch map (Talbot, 1920) includes the southwestern portion of the Paterson Range Sheet. Talbot recognised two sedimentary groups, the 'Nullagine Series' and the 'Paterson Range Series'.

Reeves (1949) examined the Permian rocks in the Paterson Range during his investigation of the south-western margin of the Canning Basin, and made an aerial reconnaissance north of the Paterson Range. As part of the southwestern Canning Basin study, Traves, Casey, and Wells (1956) produced the first geological map of the Paterson Range Sheet (4 - mile Geological Series), which shows Proterozoic sedimentary rocks and granite, and Canning Basin stratigraphy.

A map of Bouger anomalies for the Paterson Range Sheet area (F51/B2-6) was prepared by the Geophysical Branch of the Bureau of Mineral Resources from field station measurement made in 1965.

PHYSIOGRAPHY

The area is almost completely covered by west-northwest-trending seif dunes. Areas not covered by sand include strike ridges of Precambrian rock; dissected, low-dipping, sedimentary rocks of Permian and Mesozoic age; and playa lakes. The main subdivisions are shown in Figure 1.

The strike ridges rise 50 to 100 m above the general level of the desert plain; most trend northwest, and are up to 20 km long, but generally less than 1 km wide. In the Throssell Range, complex folding has influenced the formation of a broad hilly area. The hills are extremely rugged and usually impossible to traverse by vehicle.

In the central-southern, northern and northeastern parts of the sheet, flat lying Permian and Mesozoic sedimentary rocks, in some cases covered by a thin capping of laterite, form mesas aurrounded by scree. Sand tends to bank up on the windward (eastern) side of these obstructions.

Lake Waukarlycarly is a salt lake whose surface is covered with soft powdery tufa and salt. Lake Dora is a more typical salt lake possessing a perfectly flat, unvegetated crust of salt and gypsum. The lakes remain dry except after periods of exceptionally heavy rain. Strings of small playas and pans commonly occur between sand dunes near the lakes.

The seif dunes of the desert plain vary up to 30 m high, and form parallel ridges from 100 m to 2 km apart. In general, the higher dunes are more widely spaced. Where the dune profile is not symmetrical, the southern slopes

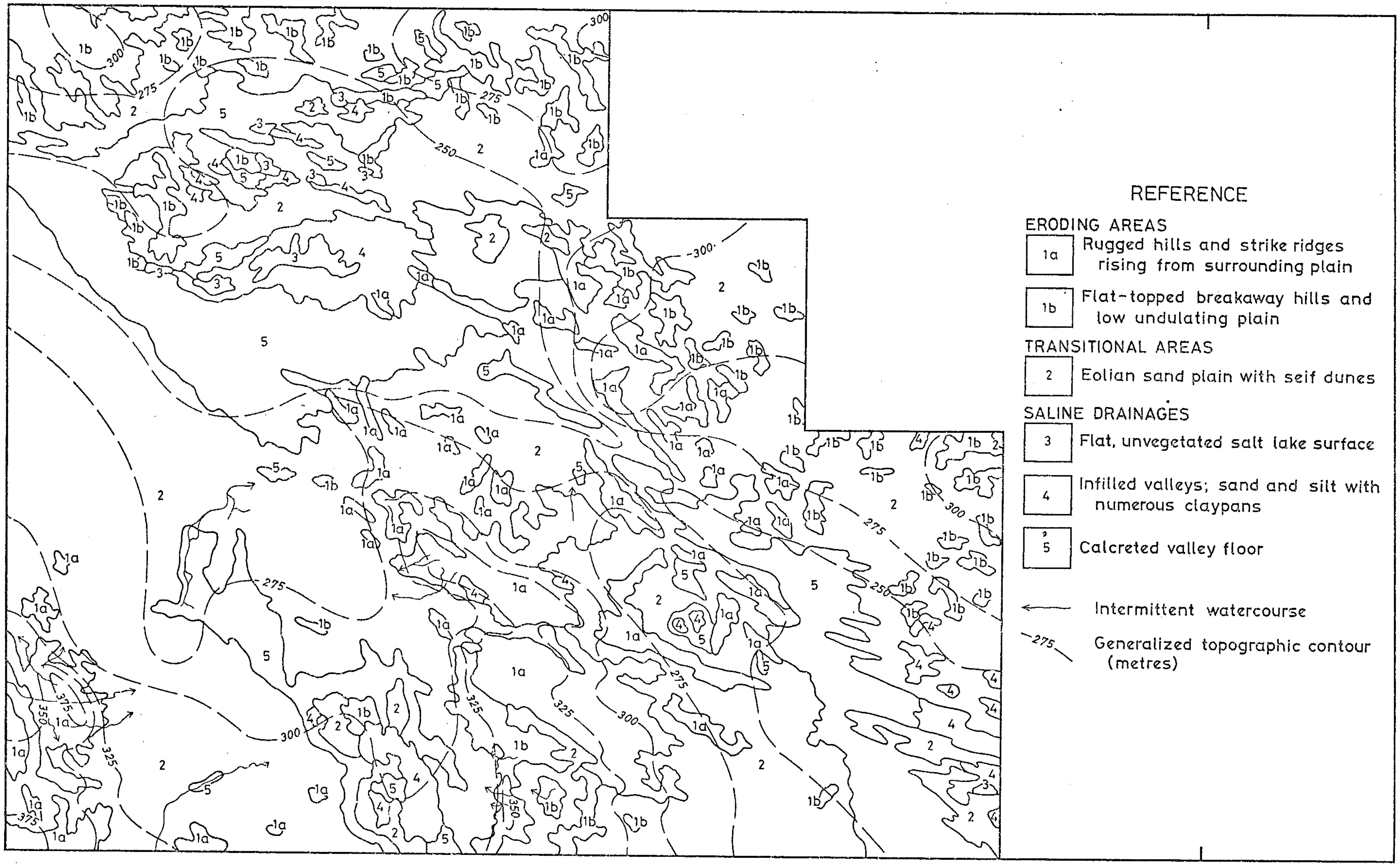


FIGURE 1
PHYSIOGRAPHIC FEATURES
PATERSON RANGE SHEET SF 51-6

GSWA 16438

are invariably steeper. Dune sides are fixed by spinifex, but their crests are normally unvegetated, and sand movement from the east-southeast is still active. Crowe (1975) discusses the origin of dunes in the Great Sandy Desert.

PROTEROZOIC GEOLOGY

YENEENA GROUP

The Yeneena Groups, (Williams and others, 1976), forms a large area of the Paterson Province (see structure section). Near the western margin of the Province, the Yeneena Group unconformably overlies Archaean granite with a high-angle unconformity, and the Lower Proterozoic Fortescue and Hamersley Groups with a low-angle unconformity. In the south, on the Rudall Sheet, it overlies the Rudall Metamorphic Complex, and is in turn overlain by the Bangemall Group. Its age therefore lies between the limits of about 1 000 and 2 000 m.y.

The Yeneena Group is inferred to be a marine-shelf sequence of sand, mud, and mixed carbonate deposits. The sandstone units form tabular or wedge-shaped bodies of well-sorted sand. Mud units were deposited during periods when the influx of sand temporarily ceased in areas where current circulation was restricted. The clastic carbonate rocks with cross-bedding and scour structures are probably platform-edge sands (Wilson, 1975) which were winnowed by intertidal and longshore currents. Fine-grained laminated dolomite and calcareous mud indicate a low energy environment such as a deep shelf-margin facies or a facies of restricted circulation on marine platforms (Wilson, 1975). Authigenic pyrite is widely distributed in all sediments.

Coolbro Sandstone (Eyc)

The Coolbro Sandstone (Williams and others, 1976) is the basal formation of the Yeneena Group except on the northeastern part of the Balfour Downs Sheet (de la Hunty, 1964) where it overlies the Googhenama Conglomerate. On the Balfour Downs and Nullagine Sheets (Hickman, 1975), it was mapped as part of the 'Bocrabee Sandstone' which has subsequently been discontinued by Williams and others (op. cit.). The base of the Coolbro Sandstone is not exposed on the Paterson Range Sheet; but on the Nullagine Sheet, the unconformity is overlain by a thin conglomerate containing chert and quartzite clasts, which is in turn overlain by well-bedded and cross-bedded quartz sandstone, pebbly in part, which constitutes the lower part of the formation.

The outcrop which forms the Throssell Range is higher in the succession and generally less well sorted and more lithic. Thin, shaly beds are common and wacke sandstone is developed at some levels. Graded bedding is uncommon but cross-bedding is well preserved. The rocks are generally well cleaved.

The thickness of the Coolbro Sandstone in the Throssell Range is at least 1 500 m, but its contact with the overlying Broadhurst Formation is not exposed. A comparable thickness exists to the southeast as far as the Broadhurst Range on the Rudall Sheet (Chin and others, in prep.), but the formation wedges markedly to the north and to the south of the Throssell Range.

Broadhurst Formation (Eyb)

An isolated outcrop of lateritized shale and sandstone 25 km west-southwest of Christmas Pool is correlated with the Broadhurst Formation (Williams and others, 1976) which conformably overlies the Coolbro Sandstone. The formation may be equivalent, at least in part, to the Wandy Wandy Shale (Hickman, 1975) on the Nullagine Sheet. Shale is the dominant lithology and also contains interbeds of fissile and sandy siltstone, and fine sandstone (Eyba). Banded, ferruginous chert within the shale may have originated as black shale. A strong, slaty cleavage is developed. These rocks are favourable hosts for quartz veins bearing copper and arsenic.

Isdell Formation (Byi)

Rocks south of Karakutikati Range are similar to part of the Isdell Formation in the Rudall area (Williams and others, 1976), and, although separated from the type area by Paterson Formation and eolian sand cover, is a likely continuation of that formation.

Fine-grained dolomite and dolomitic shale in white, buff, and pink bands up to 3 cm thick are the dominant rock types. There is continuous gradation between these types due to variation in the proportion of constituent clay minerals. Detrital quartz, tourmaline and muscovite grains, and allochemical calcite are present in small amounts. Analyses from the Karakutikati Range area are presented in Table 1 (samples 32657 and 32660). Thin beds of dolomitic sandstone, containing up to 50 per cent detrital quartz, are also present throughout the formation.

Common structures include small-scale cross-bedding and ripple-drift bedding. Many dolomite beds contain lentils up to 2 mm in diameter which are composed of dolomite stained by secondary iron minerals. They are aligned parallel to the foliation plane, and bounded on the flattened side by zones of sparry calcite. The grain texture inside the lentil is identical to the texture of the dolomite outside, suggesting that the lentil grew as a concretion during diagenesis. However, the distribution of calcite is related to the deformation and hence is a later feature.

In places, dolomite shows replacement by Tertiary cherty silica which has preserved the finely banded nature of the rock.

Malu Quartzite (Bym)

The Malu Quartzite (new name) is a sequence of metamorphosed quartz sandstone, estimated to be between 500 and 1 000 m thick, in the type area which embraces the Malu Hills. The central part of the formation is massive and uniform, but towards the top and the base of the exposed sequence thin pelitic interbeds are present. The base is not exposed in the type area where the formation is folded into a complex domal structure. Much of the quartzite is pyritiferous, and stratabound quartz veins are locally gossanous. Bedding is commonly difficult to identify.

At Telfer, the Malu Quartzite forms the central core of the Telfer Dome. However, farther south in the Karakutikati Range, the formation is absent from the succession, and is assumed to have wedged out.

Telfer Formation (Eyt)

The Telfer Formation (new name) is of special interest because it is host to the main gold mineralization. It is a conformable transition sequence between the Malu Quartzite and the Puntapunta Formation, and comprises a succession of alternating quartzite, siltstone, and shale, approximately 600 m thick. The type area is the Telfer Dome where the formation crops out over about 30 km^2. Four quartzite, and four shale members comprise the formation, the upper half being principally shale and siltstone with several thin intercalations of sandstone. Blockley (1974) informally refers to the lower three shale units as the Lower, Middle and Upper Vale Shale. A quartzite (Eyta) member (informally termed the 'Camp Sandstone') occurs at the top of the formation and forms a prominent wish-bone shaped outcrop rimming the northwestern half of the dome. This quartzite, like several others in this part of the Yeneena Group, contains pyritiferous beds. The base of the formation is defined by the outcrop of Malu Quartzite in the centre of the dome.

Figure 2 shows the regional distribution of the Telfer Formation. The Karakutikati Range is formed of sandstone and siltstone which are correlated with the Telfer Formation. Medium to coarse-grained, well sorted, siliceous sandstone forms the strike ridges whereas interbedded fine-grained flaggy sandstone, fissile siltstone, and minor shale occur in the intervening valleys. Below the highest quartz sandstone unit of the formation is a fine-grained laminated dolomite and dolomitic shale unit (Eytl).

Shale and siltstone near the northeastern margin of the Telfer Dome have undergone static metamorphism (see section on metamorphism) and are now hornfelses consisting of a mosaic of quartz, interstitial muscovite and a myriad of small, garnet porphyroblasts. Original sedimentary layers are outlined by concentrations of ilmenite and zircon. Chemical analyses of these rocks are presented in Table 1.

Puntapunta Formation (Eyp)

The Puntapunta Formation (new name) forms an extensive unit of dolomite, limestone and sandstone between the Telfer Formation and Wilki Quartzite. The type area is situated on the northern side of the Karakutikati Range, 5 km west of Puntapunta Hill. The dominant rock is a well-bedded, medium to coarse-grained clastic dolomite, containing up to 10 per cent detrital quartz and a smaller proportion of muscovite. Individual beds, up to 0.5 m thick, are characterized by differences in grain size and proportion of quartz. Interfering trough-type cross-bedding, and scour channels are common.

A common rock type, forming massive beds near the base of the formation but elsewhere thinly interbedded with the dolomite, is a fine to coarse-grained dark grey calcarenite (Eypk) composed essentially of recrystallized calcite grains with accessory quartz, muscovite, dolomite, and tourmaline. Sedimentary structures resemble those in the dolomite beds. Some scour channels contain intraformational conglomerate with rounded clasts of earlier compacted dark-grey calcarenite up to 10 cm in diameter. Small euhedral crystals of pyrite are common.

Impure dolomite east of the Telfer Dome contains, as a result of the static metamorphism, randomly orientated porphyroblastic phlogopite and muscovite in a recrystallized quartz and dolomite matrix (see section on metamorphism).

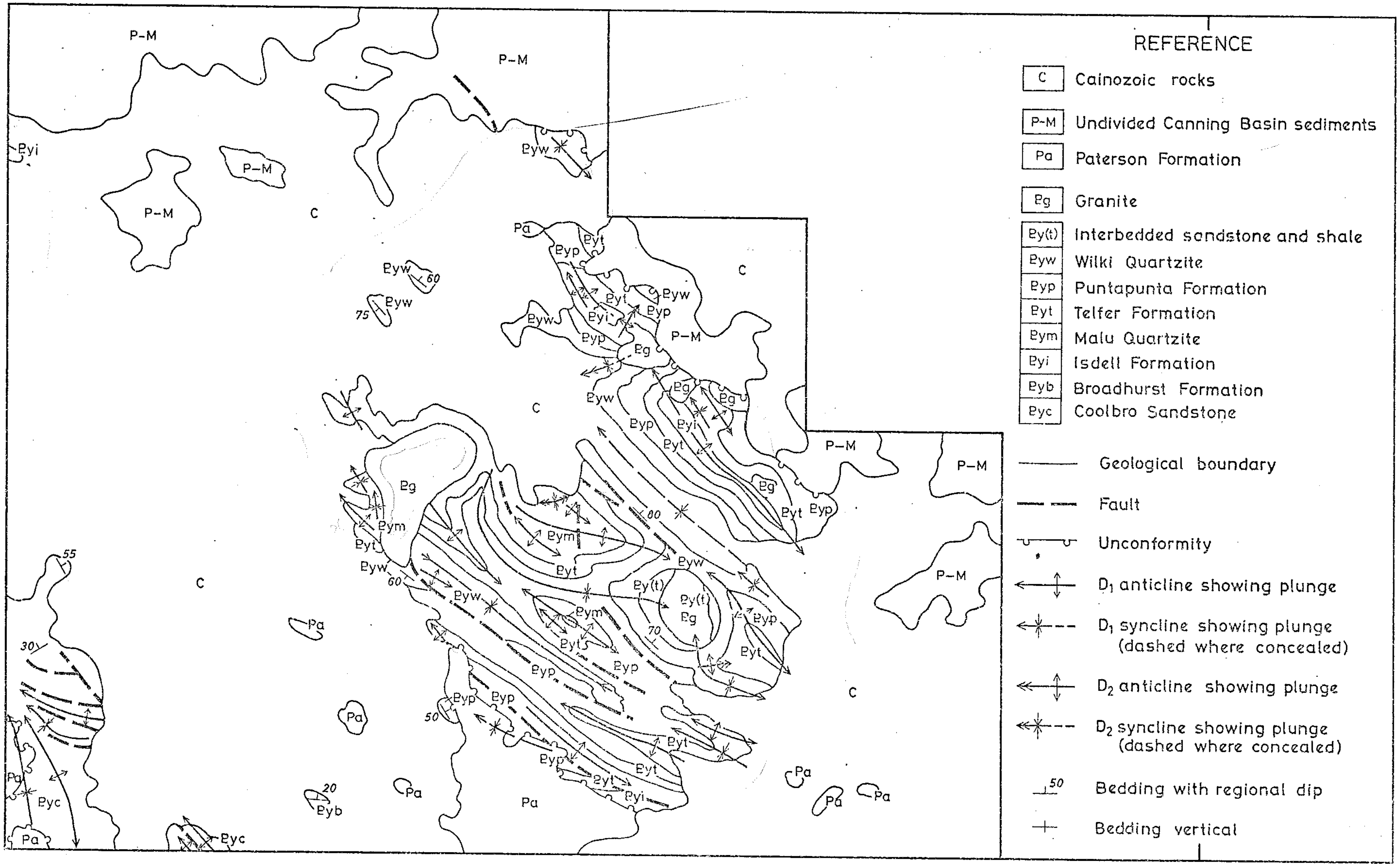


FIGURE 2

STRATIGRAPHIC AND STRUCTURAL INTERPRETATION

PATERSON RANGE SHEET SF 51-6

0 15 30 45 kms

GSWA 16939

TABLE 1: Analyses of metasediments from the Yeneena Group

Major oxides (per cent)	GSWA Sample 32657	32658	32659	32660	32661	32662	32663
SiO_2	49.9	54.7	48.6	63.0	64.8	86.1	75.0
TiO_2	0.42	0.54	0.53	0.50	0.96	0.56	0.38
Al_2O_3	8.4	11.5	11.4	11.1	20.2	8.6	9.1
Fe_2O_3	0.9	0.8	0.6	0.7	1.0	0.0	0.8
FeO	1.48	1.35	1.29	1.35	0.19	1.29	1.09
MnO	0.12	0.05	0.11	0.07	0.00	0.00	0.06
MgO	7.3	5.1	7.2	4.0	0.9	0.0	4.6
CaO	11.17	8.31	10.18	6.33	0.35	0.19	1.72
Na_2O	0.22	0.18	0.36	0.72	5.83	2.44	0.03
K_2O	1.9	3.4	2.9	3.1	3.0	1.4	0.8
P_2O_5	0.21	0.22	0.24	0.18	0.10	0.11	0.07
H_2O+	1.37	1.81	1.53	1.46	2.53	0.91	3.69
H_2O-	0.21	0.16	0.13	0.11	1.05	0.22	0.56
CO_2	16.60	12.30	15.30	9.44	0.05	0.19	2.46
Total	100.2	100.4	100.4	102.1	101.0	102.0	100.4
Trace elements (ppm)							
As	9	30	7	32	2	50	4
Ba	75	115	103	90	390	25	65
Cu	20	15	10	15	70	25	35
Pb	20	30	30	20	20	15	10
Rb	85	140	120	125	155	85	35
Sn	1-10	1-10	1-10	1-10	10	10-100	1
SO_3	140	410	30	170	380	170	480
Sr	25	10	20	15	40	20	5
Zn	24	47	20	18	79	29	40
Au	0.2 all samples						

Analyst: Government Chemical Laboratories, West. Australia
Methods: Chemical and XRF
Samples 32657-32660 are dark grey shales, 32661-32662 are hornfelsed siltstones.
Coordinates: 32657-60, 122°10'30"E, 21°49'30"S; 32661, 122°12'30"E, 21°43'10"S; 32662, 122°13'10"E, 21°43'40"S; 32663, 122°11'10"E, 21°43'10"S.

Siliceous quartz sandstone (Bypa) is irregularly distributed throughout the formation in massive beds up to 10 m thick. The abundance of fine-grained silica in the matrix suggests that there has been replacement of a carbonate cement.

Cleaved shale (Byps) and interbedded shale and sandstone (Bypt) occur north and east of the Telfer Dome, near the top of the formation. These indicate a change in the depositional environment preceding deposition of the Wilki Quartzite.

Wilki Quartzite (Byw)

The Wilki Quartzite (new name) is a 1 000-m thick quartzite formation conformably overlying the Puntapunta Formation. In its type section in the Wilki Range, the basal part contains several dark-grey shale and siltstone members (Byws), each about 5 m thick, intercalated with quartzite units of comparable thickness. This thin lower interval is overlain by thickly bedded quartzite devoid of shale.

Arenaceous schist and sheared sandstone (Bywi) cropping out east and west of Mount Crofton represents intensively deformed parts of the formation.

Unassigned units of the Yeneena Group

Isolated rocks in the northeastern quarter of the Proterozoic outcrop are not assigned to formations on the face of the map because of uncertainty of correlation. A stratigraphic interpretation of these units is suggested in Figure 2.

Quartzite and quartz sandstone (By(a)) includes both thick-bedded and thin-bedded types and commonly contains minor interbeds of shale and siltstone. Thick-bedded quartzite on the Minyari, Tyama and Kaliranu Hills is similar to the Wilki and Malu Quartzites. Thin-bedded quartzite forms discontinuous small ridges in sequences of pelitic or carbonate rocks. The sandstone and quartzite are commonly well sorted and fine to medium-grained and, rarely, coarse-grained.

Quartz is the dominant constituent forming a mosaic with accessory feldspar, tourmaline, and heavy minerals. Metamorphism is shown by the development of interstitial biotite and muscovite. However, sedimentary textures are generally preserved.

An intercalated, sandstone, siltstone and shale unit (Ey(t)) is exposed at localities 10 km and 25 km southeast of Kaliranu Hill. It is pyritiferous, and gossanous where intruded by quartz veins. Lithological similarity suggests correlations with the Telfer Formation (Figure 2).

Dark-grey shale and siltstone (Ey(s)) stratigraphically overlies the Wilki Quartzite 17 km east of Telfer. This outcrop is the uppermost unit recognised in the Yeneena Group.

Small outcrops of buff, cream, and brown, fine-grained laminated dolomite (Ey(l)) near the western margin of the sheet, lithologically resemble the dolomite of the Isdell Formation. The outcrop, 19 km south of Cuncudgerie Hill, correlates with similar rocks on the Yarrie Sheet which overlie a thin basal sandstone which is unconformable on the Fortescue Group (Hickman and Chin, 1977), and may correlate with the Isdell Formation.

Marble and calc-silicate hornfels (Ey(m)) forming low outcrops about 50 km east-northeast and north of Telfer probably include thermally metamorphosed rocks of the Puntapunta and Isdell Formations. Thin sections range from pure calcite marble to speckled calc-silicate hornfels which contains poikiloblasts of tremolite, diopside, and scapolite enclosed by a fine-grained mosaic of quartz, calcite and microcline. Diopside is partly altered to hornblende. Accessory minerals include tourmaline, phlogopite, clinozoisite, sphene, and epidote. Porphyroblastic scapolite grows across bedding.

The abundance of potash feldspar in some samples, and the lack of potash minerals in the unmetamorphosed rocks suggests that potassium metasomatism accompanied the metaphism. Melilite and vesuvianite were reported from a calc-silicate hornfels 7 km east-southeast of Minyari Hill by Traves and others (1956).

CHERT BRECCIA (Ecb)

Outcrops of massive chert breccia occur on the northern side of the access road, 10 km west-northwest of Telfer. Angular, deformed blocks of banded cherty sediment are set in a structureless siliceous groundmass. The rock resembles the Pinjian Chert Breccia (Nullagine Sheet) which is a residual deposit of Lower or Middle Proterozoic age, but it may be significant that the unit is positioned on the axial plane trace of the Telfer Dome. It is concluded that the chert breccia represents part of the Puntapunta Formation, brecciated during folding, and subsequently silicified, probably during the Tertiary Period.

AMPHIBOLITE AND METADOLERITE (Ed)

Concordant bodies of amphibolite within carbonate rocks occur at localities 30 km east-northeast, and 50 km north, of Telfer. The rock is typically dark grey to black, and resembles coarse-grained dolerite. Field relations do not indicate whether the amphibolite is metadolerite or metabasalt. In thin section, the rock is composed of plagioclase (An_{50}) laths up to 2 mm long, and prismatic pale-green hornblende associated with minor magnetite, biotite and quartz. Clinozoisite, carbonate, actinolite, and epidote were noted in one specimen which shows relict dolerite texture.

GRANITE-ADAMELLITE (Eg)

A suite of granite bodies, the largest of which is situated 25 km northwest of Telfer and is defined as the Mount Crofton Granite (new name), intrudes the Yeneena Group. In the area between the southern part of the Lamil Hills and Mount Crofton, it is well exposed, but elsewhere is covered by eluvial quartz-feldspar sand (Qeg). It probably underlies an area of approximately 150 sq km.

The Mount Crofton Granite and related bodies are biotite adamellite with some granite. The texture is equigranular, even, and medium grained, but there is commonly gradation to coarse and porphyritic textures. There are rare patches of granophyric texture. The proportion of biotite is variable, and it is only an accessory mineral in some areas. Plagioclase is zoned from oligoclase (An_{25}) at the core to albite (An_7) at the rim. Accessory minerals are epidote, muscovite, magnetite, sphene, zircon, apatite, chlorite, and fluorite. Chemically (Table 2) it is a strongly fractionated adamellite which shows affinities with the alkaline granite of Nockolds (1954).

The bodies cut the first cleavage and folds of the Yeneena Group and remain undeformed except for local shear zones. Intrusive contacts with the Yeneena Group are well exposed south of the Lamil Hills. At this locality, tongues of granite and pegmatite have intruded along bedding and cleavage planes wedging out blocks of quartzite. Aplite and pegmatite are more abundant near the granite margins.

Xenoliths of veined migmatite and mafic schlieren are abundant in a small granite body 17 km east of Kaliranu Hill. Trails of biotite outline a flow texture around the xenoliths.

The static metamorphism of the Yeneena Group accompanied the intrusion of the granite. The intrusion forced apart units of quartzite, but assimilated areas of carbonate rocks. Adamellite at the contacts in these areas is slightly enriched in calcium with a corresponding decrease of potassium, and contains abundant accessory diopside, hornblende and chlorite as contaminants.

Age dating, using Rb-Sr methods, was carried out by Trendall (1974). Seven samples generated an isochron of 614±57 m.y. (initial ratio 0.7093±0.0073). By including an aplite from a dyke which intrudes the granite an age of 594±2 m.y. (initial ratio 0.7122±0.0025) for the granite is obtained. However, this age is only valid if the granite and aplite differentiated from their source at the same time.

The strongly fractionated chemical composition of the

TABLE 2: Analysis of adamellite from Mount Crofton Area

GSWA Sample 30562 (Location 21°33'05"S, 121°57'45"E)

Major elements (per cent)			Trace elements (p.p.m.)		
SiO_2	76.6	(x)	Ba	255	(x)
Al_2O_3	13.3	(x)	Li	19	(c)
Fe_2O_3	0.4	(x)	U	10	(c)
FeO	0.77	(c)	Zr	85	(x)
MgO	0.0	(x)			
CaO	0.86	(x)			
Na_2O	3.30	(c)			
K_2O	5.2	(x)			
H_2O+	0.36	(c)			
H_2O-	0.11	(c)			
CO_2	0.12	(c)			
TiO_2	0.10	(x)			
P_2O_5	0.08	(x)			
MnO	0.03	(x)			
TOTAL	101.2				

Method: x = XRF
c = Chemical methods

Analyst: Government Chemical Laboratories, West. Australia

Mount Crofton Granite and the minor occurrence of granophyric texture suggest that the granite was emplaced at a relatively high level.

Pegmatite and granite dykes (g) from the granite intrude the Yeneena Group along the early cleavage. The granite is of similar composition to the parent body. The pegmatite contains only quartz and potash feldspar with small amounts of biotite and muscovite. Coarse, granular quartz is an unusual, rare form of the pegmatite.

STRUCTURE

The sheet covers the northern part of the Paterson Province. The boundary of the province in the north and east is the unconformity against overlying Phanerozoic rocks of the Canning Basin (Gentilli and Fairbridge, 1951), and in the south and southwest the unconformity against the rocks of the Bangemall Basin. The western contact has been interpreted in different ways by several authors. Daniels and Horwitz (1969) show it to be a metamorphic or igneous contact. Blockley and de la Hunty (1975, p. 115) include rocks now referred to as the Gregory Granitic Complex and the Koongaling Volcanics (Hickman, 1975), but add that the former 'represents tectonically an eastern continuation of the Pilbara Block.' On the Nullagine Sheet (Hickman, 1975), the basal unconformity of the Yeneena Group is taken as the western boundary of the Paterson Province. It could be argued, however, that the western boundary of the province should be defined by the western limit of northwest trending folds that are characteristic of the province as a whole.

On the Paterson Range Sheet, the Yeneena Group is deformed by tight to isoclinal upright folds with northwest striking axial planes. The folds are noncylindrical, plunging both northwest and southeast are moderate to steep angles. Folding in quartzite is approximately concentric, but shale and carbonate units are generally deformed into similar folds. As can be seen from the cross-sections accompanying the map, the wavelength of the larger folds exeeeds 10 km. In plan, the structures exhibit en echelon and interference patterns.

Major faults in the Telfer area, shown on the cross-section accompanying the map, like parallel to the main structural trend and were probably formed during the main period of folding.

Evidence for a second phase of deformation comes from the Malu Hills where an east-northeast-striking crenulation cleavage crosses the axes of the major structures. Complex interference patterns visible on air photos in this area could result from refolding by folds with axes trending east-northeast.

East of Telfer, the arcuate quartzite ridge of the Wilki Range closes to the north to form a basin structure bounded by steeply dipping sides. It is unlikely that this fold is due to a single episode of deformation, and it is probable that granitic rock in the centre of the basin has forced its limbs apart in the same way as the forceful intrusion at the northeastern margin of the Mount Crofton Granite.

In the Throssell Range, northwest-plunging folds possess a well developed axial-plane cleavage. The cleavage is steeply inclined and parallel to the attenuated and partly faulted out limbs of the folds. In profile, the folds exhibit a microlithon type of structure on a macroscopic scale. This style differs from that around Telfer since, as can be seen from the map, the dominant strike is that of the plunging crests and troughs.

METAMORPHISM

The regional metamorphism which accompanies the main deformation of the Yeneena Group is very low grade, and is caused more by directional pressure than by elevated temperature. The effects are restricted to recrystallization of quartz, particularly in areas of strong deformation, regrowth of calcite and dolomite in the plane of the foliation, and growth of sericite to replace clay minerals.

Overprinting the regional metamorphic fabric is a static metamorphic fabric related to the emplacement of the granite. In the general Telfer area, the metamorphism is low grade, characterized by the growth of muscovite and tourmaline. The growth of tourmaline (schorl with a dravite margin) forms spotted hornfels.

North and northeast of the Wilki Range, metamorphism has attained the hornblende-hornfels facies (Turner, 1968). Original clinopyroxene in mafic rocks is replaced by green hornblende, and the assemblage quartz-hornblende-diopside-scapolite is present in the calc-silicate hornfels. The abundance of microcline in the latter rocks is evidence of potassium metasomatism. Northeast of the Telfer Dome, metamorphosed shale and siltstone contains idioblastic garnet which grows across bedding and cleavage. On the southern side of the Wilki Range weathered voids in metashale are suggestive of staurolite crystals.

The occurrence of melilite in a calcite-quartz-actinolite-diopside-vesuvianite hornfels reported by Traves and others (1956) is indicative of high temperature, pyroxene-hornfels contact metamorphism.

PERMIAN GEOLOGY

PATERSON FORMATION

Talbot (1919, 1920) originally called these rocks the 'Paterson Range Series of sandstones and grits'. The name was modified by Fairbridge (1953) to 'Paterson Range Sandstone' and finally by Traves and others (1956) to 'Paterson Formation'. The type section lies in the northern part of the Paterson Range at 122°10'E, 21°45'S.

The basal unit is a poorly sorted unstratified conglomerate and tillite with a clayey to sandy matrix. The clasts range from small pebbles to boulders 3 m in diameter, and are composed of quartzite, granitoid rocks and, rarely, basalt, chert, gabbro and dolomite. Although some clasts derive from local sources, others have been transported at least 75 km from the closest known source. Evidence of ice transport is shown by faceted and striated boulders. On the Nullagine and Rudall Sheets, glaciated pavements underlie rocks of a similar nature (Hickman, 1975; Chin and others, in prep.). The basal unit attains a maximum observed thickness of 18 m, but is locally absent.

Cross-bedded fluvial sandstone and conglomerate overlie the basal unit. The sandstone is medium to coarse grained, poorly sorted, composed dominantly of quartz, but some beds contain a high proportion of feldspar. The matrix is clay. Well-bedded sandstone forms repetitious units up to 1 m in thickness defined by bedding joints. Concentrations of well-rounded quartz and quartzite clasts up to 15 cm in diameter commonly form lenses and beds that grade laterally into sandstone. Claystone and mudstone constitute only a small part of the formation on the Paterson Range Sheet. Varves have not been observed.

In the northern part of the Paterson Range, well-bedded sandstone is folded into stratabound zones of disharmonic, tight, concentric folds which are commonly cut by thrusts and steeply dipping faults. These structures are attributed to deformation by the movement of glaciers, or to slumping of sediments made unstable by the melting of ice, either supporting or binding the sediment.

The basal conglomerate and tillite of the Paterson Formation is correlated with similar rocks in the Oakover Valley called 'Braeside Tillite' by Clapp (1925). The upper sequence of cross-bedded sandstone is equivalent to the Bunmardie Beds (Noldart and Wyatt, 1962) on the Nullagine and Balfour Downs Sheets. Hickman (1975) incorporates these formations in the Paterson Formation. Spores and pollen from the Paterson Formation on the Yarrie Sheet indicate an Early Permian (Late Sakmarian) age (Hickman and Chin, 1977).

CUNCUDGERIE SANDSTONE

Traves and others (1956) define the Cuncudgerie Sandstone in the type locality, 16 km east-southeast of Cuncudgerie Hill. Marine fossils include brachiopods, pelecypods, gastropods and bryosoans. The formation is possibly the marine equivalent of the Paterson Formation.

The basal unit is a coarse quartz sandstone with ferruginous matrix, grading to a conglomerate with quartz and quartzite clasts up to 10 cm in diameter. The overlying unit is composed of: a generally massive sandstone, in places containing clay pellets, and with bedding defined by pebbly bands; and a yellow or white, fine to medium-grained micaceous sandstone, generally well bedded. Mudstone and claystone are commonly interbedded with the latter. Most exposures contain ripple marks, organism burrows and grazing trails. Many beds appear leached and friable possibly due to the removal of a calcareous cement.

The maximum observed thickness is 40 m at Cuncudgerie Hill. The lateral extent is uncertain because of poor exposure, lateritization and the lack of diagnotis markers to distinguish it from later units. It may be more extensive around the margin of the basin than was represented by Traves and others (1956). The formation is considered to be a correlative of the Nura Nura Member of the Poole Sandstone (Northeast Canning Basin) and shows a faunal link with the Callytharra Formation of the Carnarvon Basin (Traves and others, 1956).

PERMIAN-MESOZOIC GEOLOGY

UNASSIGNED LITHOLOGIES

Stratigraphic subdivision of various rock units, ranging in age from Permian to Mesozoic, has been deferred until the Canning Basin section of the sheet has been remapped. Outcrop is generally poor, extensively lateritized and lacks distinguishing features. Formations represented probably include the Paterson Formation, Cuncudgerie Sandstone and the Cretaceous Anketell Sandstone, (Traves and others, 1956).

The undivided Permian-Mesozoic sediments (P-M) are interbedded sandstone, mudstone, and shale, with minor conglomerate. Photointerpreted sediments are also assigned to this unit.

Sandstone with minor interbedded mudstone, grit and conglomerate (P-Ma) ranges from massive to well-bedded quartz sandstone and arkose. Yellow to brown, medium to coarse-grained moderately well sorted varieties are common. Structures include cross-bedding, organism burrows and grazing trails.

Medium-grained quartz sandstone and arkose (P-Ms) is generally uniform and well-bedded. An outcrop 9 km west-northwest of Tyama Hill contains a small bed of silicified, oolitic sediments.

Dark grey siltstone, mudstone and shale (P-Mp) contains minor interbedded sandstone. Pale yellow mudstone (P-Mm) is characterized by granule-sized quartz grains.

CAINOZOIC GEOLOGY

TERTIARY

Nodular, massive, and locally pisolitic ferruginous duricrust (Td) on the Tertiary peneplain of the 'Great Plateau of Western Australia' (Jutson, 1950, p. 205), is preserved in small scattered outcrops. The fact that laterite forms low mounds on, or close to, the present level of the plain indicate that the plain closely corresponds to the Tertiary land surface, known in the Pilbara as the Hamersley Surface (Campana and others, 1964). Nodular and pisolitic laterite cropping out along an ancient drainage channel 25 km west of Mount Crofton lithologically resembles the Poondano Formation (McWhae and others, 1958).

Fine-grained siliceous cap rock (Tr), commonly chalcedonic, replaces carbonate rocks in many parts of the area. Relict bedding proves the rock to be a replacement deposit, and in some cases there is a gradation to unaltered bedded carbonate rock. Tr typically caps hills and mounds, and its distribution appears to be largely controlled by the Tertiary land surface.

Silicification of sandstone is relatively common, but it is difficult to ascertain whether this is Tertiary replacement or metamorphism. Shale is rarely replaced by Tr.

TERTIARY OR QUATERNARY

Calcrete (Czk) of Tertiary or Quaternary age crops out at the level of the plain over about 15 per cent of the area. Its distribution follows the low-lying country around Lake Waukarlycarly and Lake Dora, a palaeodrainage that connects the two lakes, and another drainage between the Throssell and Paterson Ranges. The calcrete is a massive, nodular and vuggy, sandy limestone partly replaced by veins of chalcedony. Brecciation, probably caused by solution and/or dessication, is a common feature, and in thin section the rock is seen to consist of angular fragments of calcareous mudstone and interstitial quartz grains cemented by calcite. The thickness of the unit is difficult to estimate because its base is rarely exposed, but in many places it exceeds 5 m.

The calcrete was formed by the deposition of calcium carbonate in alluvium infilling low, poorly drained areas. Much of the calcium carbonate is derived from adjacent carbonate rocks of the Yeneena Group. On the Nullagine Sheet (Hickman, 1975) the unit is correlated with the Oakover Formation (Noldart and Wyatt, 1962).

QUATERNARY

Saline and gypsiferous clay and silt (Ql) forms on the surface of Lake Waukarlycarly, Lake Dora, and also in a few other salines pans. Below the surface crust is a layer at least 0.5 m thick of brine-saturated sand and mud (Traves and others, 1956).

Partly saline clay, silt and sand (Qd) occupies low-lying flats and evaporation pans, and fringes Ql in Lake Waukarlycarly. Saltbush, samphire and spinifex are the main vegetation types. The unit has a distinctive photopattern. The closely spaced small circular pans appear as white patches on a pale grey background representing the sand and spinifex.

Calcareous silt and sand (Qt) forms the surface of low-lying areas and dry lakes 40 km east of Telfer. The sediment is derived from adjacent outcrops of calcrete by wind and water action.

Alluvium (Qa) consisting of sand and fine rock debris fills creek channels on the eastern side of the Throssell Range. The channels truncate seif dunes.

Colluvium (Qc) is composed of mineral and rock fragments which form sand, gravel and boulders in scree and outwash fans at the margins of the hills.

Eolian sand containing laterite pebbles (Qp) occurs in areas of sandplain, overlying or flanking laterite. The laterite pebbles are sub-rounded, less than 5 mm in diameter and concentrated in the upper 10 cm of the deposit. On air photographs the deposit is darker than the surrounding sandplain. In contrast to Qs, the Qp surface is smooth.

Eluvial pebbly sand (Qep) and minor colluvium surrounds and overlies outcrops of the Paterson Formation. The pebbles of the deposit are well rounded and obviously derived from the Permian conglomerate. Eluvial sand over granitic rocks (Qeg) occurs north of Mount Crofton and in the Wilki Range area. It consists of grains of quartz and feldspar, and fragments of granite intermixed with windblown sand. The unit is slightly redder than the adjacent eolian sand.

Eolian sand (Qs) forms sandy flats and seif dunes over the greater part of the area. Clumps of spinifex trap the sand forming an uneven surface. North-south traverses across the area are especially slow and tedious as many of the dune are impassable and require major circumventions.

ECONOMIC GEOLOGY

The area has no history of economic mineral production, but at the time of writing, new gold mining operations had commenced at Telfer.

GOLD

In the Telfer Dome, saddle reefs, up to 2 m in thickness, of auriferous quartz and quartz limonite form stratabound bodies. Newmont Pty Ltd report that ore reserves to June, 1977 were 3.8 million tonnes with an average grade of 9.6 g/t.

The Main Reef varies in thickness up to several metres. Supergene levels of the deposit contain visible gold and one sample of gossanous quartz collected from the northwestern closure of the reef assayed 62.9 g/t while limonite gossan from the northeast limb of the dome contained 45.4 g/t (Table 3).

These deposits are situated close to the base of the Telfer Formation, but gossanous reefs of grey quartz also occur higher in the unit of the northeastern limb of the dome (the Eastern Reefs). Lower concentrations of gold have been recorded from the West Dome which is a minor parasitic structure on the western flank of the Telfer Dome.

Blockley (1974) reports that gold has also been found at Thompson dome (informal name), 16 km northwest of Telfer.

Metasomatic introduction of sodium, (e.g. Spec. 32661, Table 1) and metamorphic growth of garnet in the Telfer Dome suggests that a granitic intrusion, which may be responsible for the mobilisation of gold, may underlie the structure.

In 1974, Carr Boyd Minerals Limited reported gold values up to 90 g/t from mineral claims in the Malu Hills and the 'Black Hills' (informal name for outcrops of By(t) 28 km east-northeast of Telfer). In the Malu Hills, gold occurs in gossanous sandstone within a tight anticline, and the

TABLE 3: Selection of gossan analyses (Localities asterisked on plate)

GSWA Sample	Long.	Lat.	Cu	Ni	Cr	Mn	Co	Pb	Zn	As	Ag	Au
32905 C(B)	122°15'00"E	21°36'30"S	410	130	60	290	50	2000	490	7	-	-
32907 B(B)	122°14'40"E	21°37'20"S	1400	150	80	560	460	430	170	125	-	-
32908 B(A)	122°15'50"E	21°37'50"S	1700	70	60	100	50	55	60	39	8.0	0.2
32909 C(B)	122°14'20"E	21°38'10"S	780	2900	120	370	1700	275	60	162	10.4	-
32909 E(B)			1500	3500	100	520	2300	380	80	149	2.3	0.2
32926 A(C)	122°06'50"E	21°37'00"S	1850	25		270	140	385	140	80	-	0.2
32928 (B)	122°12'10"E	21°43'10"S	400	25		50	95	120	10	2700	8.3	62.9
32929 (C)	122°13'40"E	21°43'25"S	4050	470		1000	2000	890	230	4000	6.6	45.4
32936 (C)	122°26'10"E	21°44'30"S	1850	50		75	50	110	45	65	-	-
32938 A(C)	121°53'30"E	21°56'30"S	1140	55		180	70	490	50	990	0.6	-
32939 (C)	122°28'40"E	21°36'00"S	2450	70		500	60	65	110	6	0.2	0.2
32941 A(C)	122°30'20"E	21°36'20"S	1190	200		350	140	90	15	5	1.8	-
32941 C(B)			1110	140		230	170	105	10	28	0.2	0.2
32941 D(C)			3040	280		300	270	420	90	18	4.3	1.2
34222 (B)	122°11'45"E	21°51'30"S	1700	50		2900	45	8	15	2600	-	-
34223 A(A)	121°59'10"E	21°38'00"S	2800	45		140	65	90	100	4000	-	-
34223 B(A)			1410	35		75	30	270	45	3500	-	-

Analysts: C.J. Dodd and G. Bialecki, Government Chemical Laboratories, West. Australia

Methods: Atomic absorption (Cu, Ni, Cr, Mn, Co, Pb, Zn)
Spectrophotometry (As) Fire assay (Ag, Au)

Description of samples: (A) - quartz (B) - quartz and gossan (C) - gossan

Black Hills deposits are saddle-reef quartz bodies. About 90 samples of gossan were collected and analysed by the Survey during 1974. Outside the areas known to contain gold mineralization, only one notable anomaly was detected. This was obtained from a gossan 33 km east-northeast of Telfer (see map) which assayed 1.2 g/t gold, 4.3 g/t silver and 3 040 ppm copper (Table 3). Quartz and granite veins intrude calc-silicate hornfels and amphibolite in this area.

COPPER

Malachite-chryscolla-chalcocite mineralization occurs in the Karakutikati Range as pods up to several metres in width within small irregular bodies of brecciated dolomite that cross-cut bedded carbonate rocks of the Isdell Formation. One of the larger deposits is shown as a prospect on the 1:250 000 map, and the other occurrences are located within 3 km of this.

As can be seen in Table 2 minor but significant concentrations of copper (<0.5 per cent) occur in the auriferous gossans.

WATER

No permanent surface water exists in the area, but a few temporary pools and rock holes occur in the Throssell Range. Christmas Pool in the Paterson Range contains water at most times of the year. Company bores near Telfer yield moderate to poor-quality potable water (about 1 500 ppm dissolved solids), but better quality water has been obtained from test bores into quartzite in the Wilki Range. Water for industrial purposes might be sought in the large areas of calcrete. Another possible source of potable water may be the creek channel in the southwestern part of the area, but no testing has been carried out.

TABLE 4: Latitude and longitude of localities cited in text

Broadhurst Range	122°05'E	22°12'S
Christmas Pool	122°07'E	21°54'S
Cuncudgerie Hill	121°31'E	21°01'S
Isabella Range	121°04'E	21°57'S
Kaliranu Hill	122°15'E	21°27'S
Karakutikati Range	122°09'E	21°49'S
Lake Dora	122°52'E	22°00'S
Lake Waukarlycarly	121°52'E	21°18'S
Lamil Hills	121°58'E	21°30'S
Malu Hills	122°12'E	21°36'S
Minyari Hill	122°12'E	21°19'S
Mt Crofton	122°01'E	21°40'S
Oakover Valley	121° E	21°15'S
Paterson Range	122°08'E	21°55'S
Puntapunta Hill	122°13'E	21°49'S
Ragged Hills	121°09'E	21°17'S
Telfer	122°13'E	21°43'S
Telfer Dome	122°13'E	21°44'S
Throssell Range	121°33'E	21°50'S
Tyama Hill	122°10'E	21°09'S
West Dome	122°11'E	21°43'S
Wilki Range	122°17'E	21°43'S

REFERENCES

Beard, J.S., 1969, The natural regions of the desert of Western Australia: Jour. Ecology, v.57, p.677-711.

Blockley, J.G., 1974, Notes on the Paterson Range gold prospects: West. Australia Geol. Survey Ann. Rept., 1973, p.71-73.

______ and de la Hunty, L.E., 1975, Paterson Province, in Geology of Western Australia: West. Australia Geol. Survey Mem. 2, p.114-119.

Chin, R.J., Williams, I.R., and Williams, S.J., in prep., Explanatory notes on the Rudall 1:250 000 Geological Sheet: West. Australia Geol. Survey Rec. (unpublished).

Clapp, F.G., 1925, Geology and geography of North-west and desert basins, Western Australia: Proc. Linn. Soc. N.S.W., v.50, p.47.

Crowe, R.W.A., 1975, The classification, genesis and evolution of sand dunes in the Great Sandy Desert: West. Australia Geol. Survey Ann. Rept., 1974, p.46-49.

Daniels, J.L., and Hortwitz, R.C., 1969, Precambrian tectonic units of Western Australia: West. Australia Geol. Survey Ann. Rept., 1968, p.37-38.

de la Hunty, L.E., 1964, Balfour Downs, W.A.: West. Australia Geol. Survey 1:250 000 Geol. Series Explan. Notes.

Fairbridge, R.W., 1953, Australian Stratigraphy (2nd edn.): Perth, University of West. Australia Press.

Gentilli, J., and Fairbridge, R.W., 1951, Physiographic divisions of Australia: New York, The Geographic Press, Columbia Univ.

Hickman, A.H., 1975, Explanatory notes on the Nullagine 1:250 000 Geological Sheet, W.A.: West. Australia Geol. Survey Rec. 1975/5 (unpublished).

________ and Chin, R.J., 1977, Explanatory notes on the Yarrie 1:250 000 Geological Sheet, W.A.: West. Australia Geol. Survey Rec. 1976/16 (unpublished).

Jutson, J.T., 1950, The physiography of Western Australia: West. Australia Geol. Survey Bull. 95.

McWhae, J.R.H., Playford, P.E., Lindner, A.W., Glenister, B.F., and Balme, B.E., 1958, The stratigraphy of Western Australia: Geol. Soc. Australia Jour., v.4, pt.2.

Nockolds, S.R., 1954, Average chemical composition of some igneous rocks: Geol. Soc. American Bull. 65, p.1007-1032.

Noldart, A.J., and Wyatt, J.D., 1962, The geology of portion of the Pilbara Goldfield covering the Marble Bar and Nullagine 4-mile map sheets: West. Australia Geol. Survey Bull. 115.

Reeves, F., 1949, Geology and oil prospects of the desert basin: W.A. Rept. for Vacuum Oil Co. (unpublished).

Rudall, W.F., 1897. Report to the Surveyor-General, Department of Lands and Survey: West. Australia Parl. Pap. 1898, append. M, 1897.

Talbot, H.W.B., 1919, Notes on the Geology and mineral resources of parts of the Northwest, Central and Eastern Divisions: West. Australia Mines Dept. Ann. Rept., 1918, p.83-93.

________ 1920, The geology and mineral resources of the Northwest, Central and Eastern Divisions between Long. 119° and 122°E, and Lat. 22° and 28°S: West. Australia Geol. Survey Bull. 83.

Traves, D.M., Casey, J.N., and Wells, A.T., 1956, The geology of the southwestern Canning Basin, Western Australia: Australia Bur. Mineral Resources Rept. No. 29.

Trendall, A.F., 1974, The age of a granite near Mount Crofton, Paterson Range Sheet: West. Australia Geol. Survey Ann. Rept., 1973, p.92-96.

Turner, F.J., 1968, Metamorphic Petrology: McGraw-Hill, New York.

Warburton, P.E., 1875, A journey across the western interior of Australia: South Australia Parl. Pap. 28.

Williams, I.R., Brakel, A.T., Chin, R.J., and Williams, S.J., 1976, The stratigraphy of the eastern Bangemall Basin and the Paterson Province: West. Australia Geol. Survey Ann. Rept., 1975.

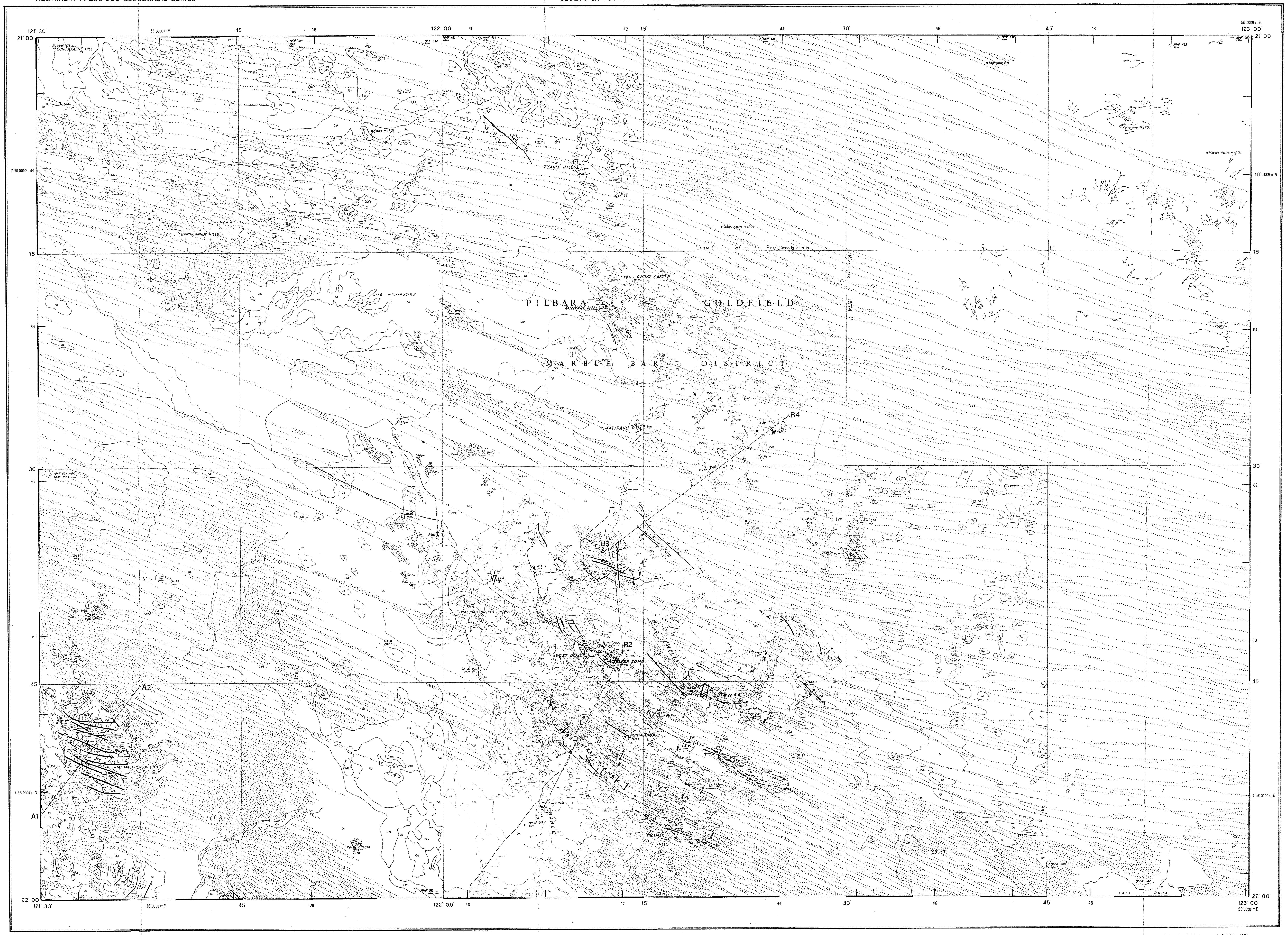
Wilson, J.L., 1975, Carbonate Facies in Geological History: Springer-Verlag Berlin Heidelberg, New York.

AUSTRALIA 1 : 250 000 GEOLOGICAL SERIES

PATERSON RANGE

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SF 51 - 6



SYMBOLS

Geological boundary
- Accurate
- Approximate

Fault
- Accurate
- Inferred

Fold
- Anticline axis, showing plunge
- Syncline axis, showing plunge
- Minor anticline, showing plunge — 30
- Minor folds, showing plunge and general trace of bedding — 20
- Contorted bedding, showing plunge of minor folds — 45

Bedding
- Inclined — 50
- Vertical
- Horizontal
- Air photo interpretation, dip 15°-45°
- Air photo interpretation, dip >45°
- Trend line

Cleavage
- Inclined — 80
- Vertical

Foliation
- Inclined — 75
- Vertical

Jointing
- Inclined — 40
- Vertical

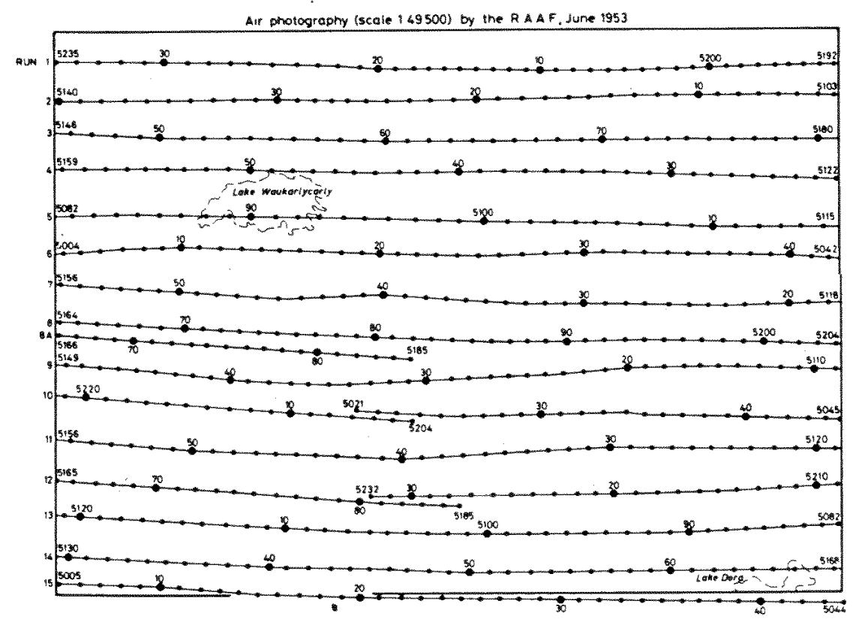
Lineation, showing plunge — 70
Facing from cross-bedding
Gossan
Fossil locality — 6

Formed road
Track
Building
Locality — • Telfer Camp
Landing ground
Horizontal control: major, minor — △ ⊙
Bench mark, height accurate — GA 8 305m
Sand dune
Well
Rockhole — RH
Position doubtful — (PD)
Watercourse
- Intermittent
- Ancient

Prospect
Open cut
Mineral occurrence
- Copper — Cu
- Gold — Au
- Manganese — Mn

Geochemical anomaly from gossan assay
- Arsenic (>1000ppm) — As
- Cobalt (>1000 ppm) — Co
- Copper (>1000 ppm) — Cu
- Gold (>1ppm) — Au
- Lead (>1000ppm) — Pb
- Nickel (>1000ppm) — Ni
- Silver (>10ppm) — Ag
- Zinc (>1000ppm) — Zn

Air photography (scale 1:49 500) by the R A A F, June 1953



REFERENCE

CAINOZOIC — QUATERNARY

Qs	Qeg	Qep	Qp	Qc	Qa	Qt	Qd	Ql

Code	Description
Qs	Eolian sand
Qeg	Eluvium—quartz-feldspar sand, containing scattered rock fragments, over granitic rocks, partly transported
Qep	Eluvium and minor colluvium—sand and well-rounded pebbles derived from the **PATERSON FORMATION**
Qp	Eolian sand containing laterite pebbles (derived as eluvium or colluvium from Td)
Qc	Colluvium—sand and gravel forming outwash fans and scree
Qa	Alluvium—sand, silt and gravel
Qt	Calcareous silt and sand derived from Czk
Qd	Clay, silt and sand, saline in part, forming low-lying spinifex, saltbush and samphire flats. Commonly surrounds salt lakes
Ql	Saline and gypsiferous clay and silt, restricted to salt lakes
Czk	Calcrete—massive, nodular and vuggy sandy limestone, locally replaced by sheets and veins of chalcedony; partly correlated with the **OAKOVER FORMATION**

TERTIARY

Code	Description
Td	Ferruginous duricrust, nodular, massive and pisolitic. Some consolidated breccia
Tr	Fine-grained siliceous (commonly chalcedonic) capping generally over carbonate rocks, but locally over sandstone and shale. Relict bedding preserved at many localities

PALAEOZOIC AND/OR MESOZOIC

Code	Description
P-M	Sandstone, siltstone, mudstone, shale, commonly interbedded, not further differentiated. May include **CUNCUDGERIE SANDSTONE**
P-Ma	Medium to coarse-grained, poorly sorted, ferruginous quartz sandstone and minor conglomerate
P-Ms	Sandstone
P-Mp	Shale
P-Mm	Pale yellow mudstone containing scattered grit-sized quartz grains

PALAEOZOIC — PERMIAN

Code	Description
Pc	**CUNCUDGERIE SANDSTONE**: sandstone and wacke, minor claystone and conglomerate. Marine fossils
Pa	**PATERSON FORMATION**: basal polymictic conglomerate overlain by poorly sorted, cross-bedded sandstone with minor claystone and conglomerate. Basal unit contains some striated and faceted quartzite boulders

Minor intrusive rocks

Code	Description
g	Granite dyke/vein
q	Quartz vein (age variable)

PROTEROZOIC — ?UPPER PROTEROZOIC

Code	Description
Ᵽg	Medium-grained biotite granite with rare migmatitic and nebulitic varieties. Includes the **MOUNT CROFTON GRANITE**
Ᵽd	Amphibolite and metadolerite
Ᵽcb	Massive chert breccia

PROTEROZOIC — ?MIDDLE PROTEROZOIC — Yeneena Group

Code	Description
Ᵽyw	**WILKI QUARTZITE**: fine to medium-grained quartzite and quartz sandstone, massive bedding, locally well-bedded
Ᵽyws	Dark grey shale and siltstone
Ᵽywi	Arenaceous schist and extremely sheared sandstone
Ᵽyp	**PUNTAPUNTA FORMATION**: bedded, dominantly clastic carbonate rocks, commonly dolomitic and arenaceous. Sedimentary structures include cross-bedding and scour structures
Ᵽypa	Fine to medium-grained quartzite and quartz sandstone
Ᵽyps	Dark grey shale and siltstone
Ᵽypt	Transition beds of intercalated sandstone and shale
Ᵽypk	Dark grey limestone and calcarenite
Ᵽyt	**TELFER FORMATION**: intercalated sandstone, siltstone and shale
Ᵽyta	Fine to medium-grained quartzite and quartz sandstone, locally pyritiferous
Ᵽytl	Thinly bedded fine-grained carbonate rocks
Ᵽym	**MALU QUARTZITE**: fine to medium-grained quartz sandstone and quartzite, locally bedded but commonly massive
Ᵽyi	**ISDELL FORMATION**: thinly bedded, fine-grained carbonate rocks. Includes dolomite and shale
Ᵽyb	**BROADHURST FORMATION**: well-bedded dark grey shale, shale and siltstone, rare ferruginous chert
Ᵽyba	Fine-grained sandstone
Ᵽyc	**COOLBRO SANDSTONE**: massive quartz sandstone and quartzite with minor wacke and shale, locally schistose and cleaved
Ᵽy(a)	Fine to medium-grained quartzite and quartz sandstone, massive to well-bedded, locally flaggy
Ᵽy(s)	Dark grey shale and siltstone
Ᵽy(t)	Transition beds of intercalated sandstone, siltstone and shale
Ᵽy(l)	Thinly bedded, fine-grained carbonate rocks
Ᵽy(m)	Marble and skarn. Bedding and other sedimentary structures preserved

Compiled and published by Geological Survey of Western Australia. Cartography by Geological Mapping Section, Department of Mines. Topographic base from compilations by Department of National Mapping, Canberra, A.C.T. Printed by Government Printing Office, Perth, 1976

Copies of this map may be obtained from the Geological Survey of Western Australia in Perth.

Geology by A.H. Hickman and R.J. Chin, 1974

HON. A. MENSAROS, M.L.A.
MINISTER FOR MINES
J. H. LORD, DIRECTOR, GEOLOGICAL SURVEY

SCALE 1 : 250 000

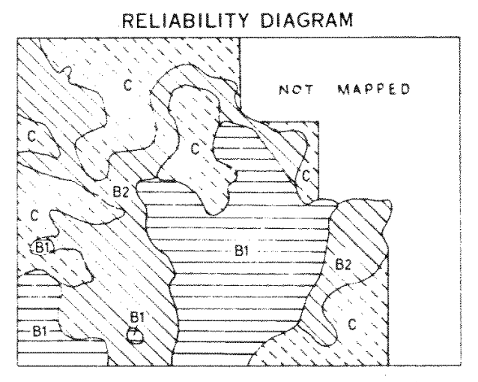
0 5 10 15 20 25 30 Kilometres

TRANSVERSE MERCATOR PROJECTION

ZONE 2 AUSTRALIA SERIES

Ticks inside the sheet edge represent 10 000 metre intervals of the superimposed Australian Map Grid, Zone 51 AUSTRALIAN NATIONAL SPHEROID. Caution in use of the grid in relation to geographicals should be observed because of difference of datum.

RELIABILITY DIAGRAM

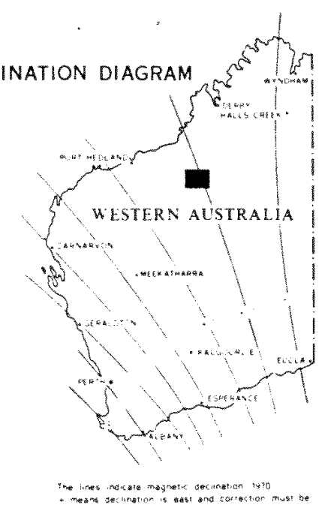


- B1 Numerous traverses with air photo interpretation
- B2 Air photo interpretation with a few traverses
- C Air photo interpretation

INDEX TO ADJOINING SHEETS

YARRIE SF 51 - 1	ANKETELL SF 51 - 2	JOANNA SPRING SF 51 - 3
NULLAGINE SF 51 - 5	PATERSON RANGE SF 51 - 6	SAHARA SF 51 - 7
BALFOUR DOWNS SF 51 - 9	RUDALL SF 51 - 10	TABLETOP SF 51 - 11

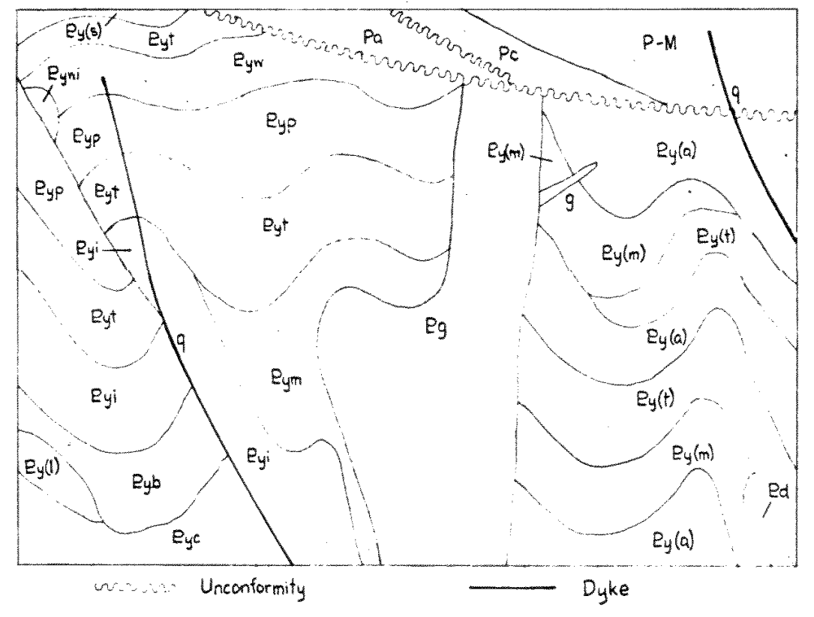
DECLINATION DIAGRAM



The lines indicate magnetic declination 1970
+ means declination is east and correction must be added to compass bearing to give true bearing
− means declination is west and correction must be subtracted from compass bearing to give true bearing

Annual change is −1' westerly

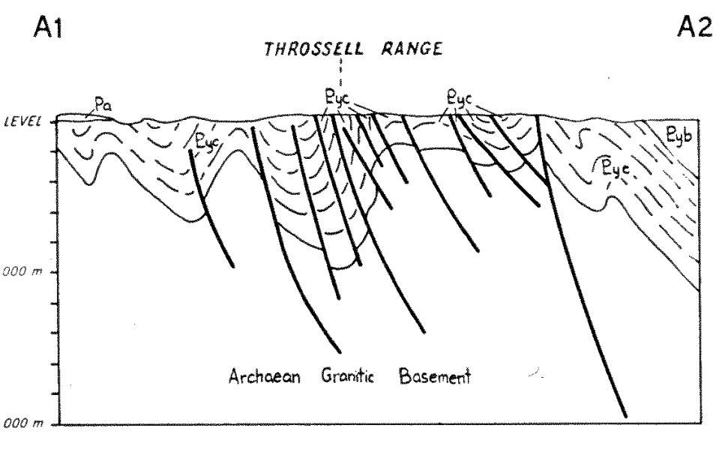
DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



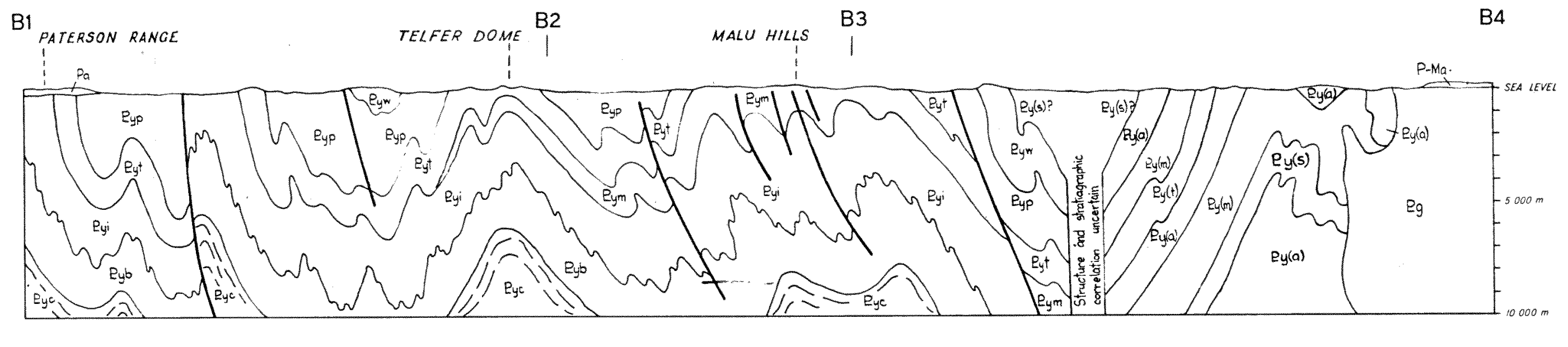
DIAGRAMMATIC SECTIONS

NATURAL SCALE

SECTION A1 - A2



SECTION B1 - B4



PATERSON RANGE
SHEET SF 51 - 6

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