1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

THROSSELL
WESTERN AUSTRALIA

SHEET SG/51-15 INTERNATIONAL INDEX

DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

DEPARTMENT OF MINES, WESTERN AUSTRALIA
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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COMPILED BY J. A. BUNTING, M. J. JACKSON & R. J. CHIN

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Explanatory Notes on the Throssell Geological Sheet

Compiled by J. A. Bunting[1], M. J. Jackson[2], & R. J. Chin[1]

The Throssell 1:250 000 Sheet (International Grid Reference SG/51-15) is bounded by latitudes 29°00'S and 28°00'S and longitudes 123°00'E and 124°30'E. The Sheet area is in the Eastern Land Division and Mount Margaret Goldfield, and takes its name from Lake Throssell.

The area is uninhabited except for a small transient population engaged in pastoral activities, mineral exploration, and vermin control.

The Cosmo-Newbery Aboriginal Reserve covers much of the southern part of the Sheet area. Some pastoral activity is carried out in the Mount Shenton-Jutson Rocks area and in the Ulrich Range area on Lake Wells Station. South of the Virginia Range is the abandoned property of Yamarna.

A graded road linking Laverton to Warburton Mission passes through the Sheet area. The Ulrich Range is reached by a graded track leading north from Cosmo Newbery in the Duketon Sheet area. Numerous tracks exist in the Mount Shenton-Mount Cumming area and the Yamarna area, but elsewhere travel is hampered by spinifex, salt lakes, sand dunes, and patches of thick mulga.

The climate is semi-arid to arid, with potential evaporation far in excess of precipitation. The rainfall is unreliable and falls in any season, although the heaviest falls are associated with summer thunderstorms. Mean annual rainfall throughout the Sheet area ranges from 180 to 200 mm, but variations from the mean are marked. Mean annual potential evaporation is slightly greater than 3000 mm. Summer temperatures are high, with an average maximum of 36°C and minimum of 20°C in the December-January period, whereas winters are mild, with an average maximum of 18°C and minimum of 5°C in July.

The Sheet area is part of the Great Victoria Desert. Vegetation consists mainly of spinifex (dominantly *Triodia*) and mallee (*Eucalyptus* spp.) on colluvial and residual soils, and halophytes, including saltbush (*Atriplex*), bluebush (*Kochia*) and samphire (*Arthrocnemum*), marginal to salt lakes and in saline drainages.

Previous investigations

The earliest reports of the area were made by explorers. Lawrence Allen Wells, in 1892, crossed the southern part of the Sheet area from west to east and named the principal landmarks. David Wynford Carnegie visited Mount Shenton in 1894, and in 1896 crossed the northern part of the Sheet area.

Early geological investigators delineated the areas of greenstone and assessed the gold discoveries and mineral potential. They examined the Ulrich Range (Gibson, 1960a), Jutson Rocks (Gourley, 1924; Larcombe, 1924; Montgomery,

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[1] Geological Survey of Western Australia.
[2] Bureau of Mineral Resources, Geology and Geophysics.

1924), Mount Shenton and Mount Warren (Gibson, 1906b), and Mount Gill (Talbot, 1920). Forman (1933) reported metamorphic rock near Minnie Creek. The earliest geological map of the Throssell Sheet area west of 123°30′E was made by Talbot (1926).

Recent investigations in the Officer Basin area by the Bureau of Mineral Resources (BMR) and the Geological Survey of Western Australia (GSWA) have provided geophysical and drill-hole information on the east of the Sheet area (Harrison, 1973; Harrison & Zadoroznyj, in prep; Jackson and others, 1975).

The present map and report are the results of a helicopter reconnaissance by a joint BMR-GSWA party in 1971, followed by more detailed ground traverses by M. J. Jackson (BMR) in 1972 and J. A. Bunting and R. J. Chin (GSWA) in 1973. The Bouguer anomaly information was obtained by BMR in 1972 during a reconnaissance helicopter survey of Western Australia (Fraser, 1973a).

PHYSIOGRAPHY

The physiography is largely controlled by the presence of an old peneplain (Jutson, 1934), which formed during an earlier, wetter, climatic period. The peneplain still forms a prominent feature of the scenery in parts of the area, but it has been extensively modified by more recent geological processes, and the landscape is now dominated by landforms more typical of a desert.

The formlines on the 1:250 000 geological map and on Figure 1 have been compiled by fitting barometric altitude information from BMR gravity surveys and levelled altitude data from topographic and seismic traverses to the shape of the ground visible on the air-photographs. Although the formlines are only approximate they provide the first systematic information on the topography of the region. The highest parts of the Sheet area are in the central and northern parts, where the land rises to over 525 m above sea level. From here the land falls in all directions. Southeast from the Ernest Giles Range the ground falls to below 375 m in Lakes Throssell and Yeo. In contrast, the gradients to the southwest of the Ernest Giles Range are more gentle. The land falls to around only 440 m in the trunk valleys in the northwest (Lake Wells) and southwest. The trunk valleys form part of an integrated, but largely inactive, drainage system which can be recognized throughout the Great Victoria Desert, Gibson Desert and the eastern part of the Western Australian Shield (Bunting and others, 1974).

Six physiographic units are recognized (Fig. 1).

Undulating laterite plain

Remnants of an undulating laterite plain that once dominated the landscape are present in the east and northeast of the Sheet area. The plain is well preserved east of Lake Throssell, where it forms gently undulating country between 400 and 450 m above sea level, comprising smooth rounded rises separated by broad elongate sandy depressions. The depressions are the dry, inactive valleys of a drainage system that developed during an earlier wetter period (Bunting and others, 1974). The rises are covered by pisoliths and irregularly shaped fragments of ferruginous sandstone in a loose red clayey to sandy soil. Vertical sections exposed in low breakaways show that this undulating plain is developed on the ferruginous and pisolitic duricrust of a weathering profile.

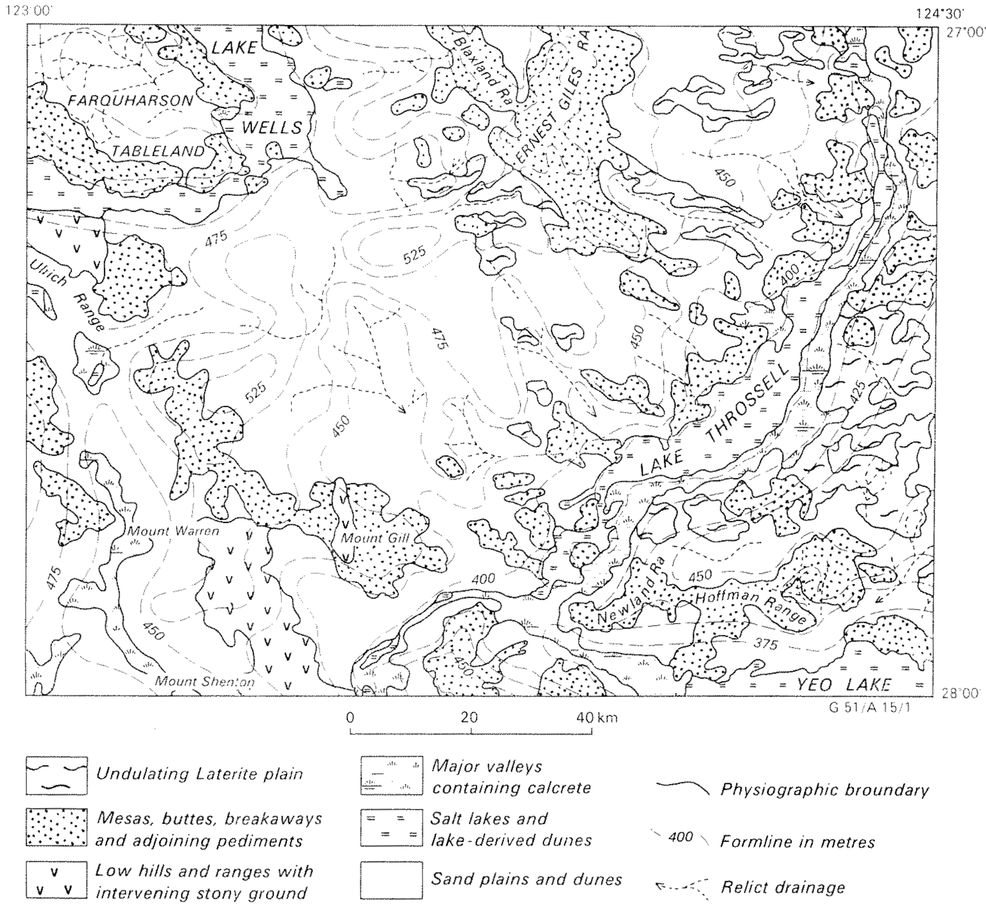

Fig. 1. Physiography.

To the east and southwest of the Ernest Giles Range the plain is present only as isolated pisolite-strewn rises. However, as the relict drainage system is also clearly visible in the extensive sandplain further to the southwest of the range, it is likely that the undulating laterite surface here is covered by only a few metres of aeolian sand.

In the higher parts of the topography erosion has cut into the duricrust and exposed the underlying softer rocks in steep breakaways, thus forming a new physiographic unit.

Mesas, buttes, breakaways and adjoining pediments

In areas such as the Newland Range, Hoffman Range, and Blaxland Range, steep cliffs (breakaways) flanked by wide, very gently sloping, scree-covered pediments are common. In other areas, e.g. Ernest Giles Range, where erosion is more extensive, mesas and buttes have formed.

As the ground is composed either of bed-rock or very coarse stony rubble, this physiographic unit is generally sparsely vegetated. Most vegetation is concentrated in the short incised ephemeral creeks that rapidly dissipate rainfall into sandy alluvial fans flanking the ranges.

Low hills and ranges with intervening stony ground

This unit comprises low, rounded hills and elongate, narrow strike ridges formed by the dissection of Archaean greenstone belts. It includes bouldery outcrops and tors of fresh granite marginal to the greenstone belts. However, deeply weathered and lateritised granitic rocks erode in a similar fashion to the Phanerozoic rocks to the east, and are, therefore, included in the physiographic unit consisting of breakaways and mesas. The low hills, ridges and intervening stony ground have an open stunted mulga cover, with dense stands of mulga, shrubs and annual grasses in short ephemeral creek channels.

Major valleys and salt lakes and lake-derived dunes

Although shown separately on Figure 1, these two units are described together as they are genetically related. The major valleys and salt lakes form bare flat expanses and are the foci for the present-day intermittent drainage. The major valleys contain low mounds of calcrete with open mulga, separated by flat, grassed areas of alluvial and colluvial red sandy soils. In the lowest parts of the topography salt lakes, such as Lake Wells and Lake Throssell, contain 'islands' of white gypsiferous dunes and have fringing belts of low dunes.

Sandplains and dunes

In the central west of the Sheet area the landscape is dominated by an extensive sandplain, which is partly covered by longitudinal and complexly shaped dunes. Elsewhere, small intricately shaped areas of sandplain are present in hollows. These small areas of sandplain, such as along the eastern edge of the Sheet area, are separated by laterite rises or other relief features. Southwest of the Ernest Giles Range there are extensive tracts of sandplain lacking dunes, an unusual feature for this physiographic unit in the Great Victoria Desert. The absence of dunes in this area may be due to the presence of granitic rather than sedimentary bedrock.

ARCHAEAN

Archaean rocks are exposed in the southwest of the Sheet area; elsewhere the crystalline basement is covered by flat-lying Proterozoic and Permian rocks.

GREENSTONES

The greenstone areas form isolated north-northwest-trending belts within large areas of granitic rock and are described separately as no continuity exists between the belts.

Ulrich Range belt

This belt consists principally of a mafic (Aba) and a felsic (Afa) metavolcanic sequence. From outcrop pattern and structural evidence, the mafic sequence appears to underlie the felsic sequence in a synform that plunges east-southeast.

The fine-grained mafic rocks are metamorphosed basalts with a distinct cleavage and a poor lineation. Amygdaloidal and possible pillowform varieties are also present. Plagioclase, hornblende and minor quartz are interlocked in a hornfelsic texture. Patches of quartz-epidote alteration are common.

Crenulated, micaceous schist (As) is interbedded with metabasalt on the north side of the Ulrich Range. Dark banding, which is cut by the foliation, is the only remaining bedding structure. Associated with the schist are weakly banded quartzite and fine-grained cherty rocks. Thin bands of metamorphosed and folded banded iron formation occur near the western edge of the range. In the southwest of the area, the boundary between the mafic and felsic sequences is marked by a thin layer of banded iron formation and chert (Aw).

The felsic sequence on the east side of the Ulrich Range consists of metamorphosed dacite and rhyodacite, and minor interlayered metamorphosed sediments, basalt, dolerite, and gabbro.

Volcanic cyclicity is expressed by bands, about 50 m thick, of basalt overlain by dacitic rocks followed by metamorphosed sediments. The dacite and rhyodacite are composed principally of quartz, plagioclase, and hornblende. Rarely some fragmental and amygdaloidal textures are preserved. Banding is common.

Medium to coarse-grained metamorphosed dolerites and gabbros (Ada) occur as thin, discontinuous bodies within the mafic and felsic successions. Textures are blastoporphyritic. The rocks have been altered to amphibole- (commonly actinolite) plagioclase-quartz assemblages, commonly with accessory carbonate and epidote.

The entire Ulrich Range area has been invaded by an intricate network of felsic and granitic dykes, sills, and plugs. The predominant rock type is a quartz-microcline-plagioclase granite porphyry with varying abundance of phenocrysts. A plug of porphyritic biotite granite (Grid Ref. 503974) contains abundant crystals of pyrite.

Near Mount Strawbridge the greenstone belt is fragmented by a strongly foliated, fine to coarse-grained granitic rock containing numerous xenoliths and granitic dykes. Xenoliths up to 1000 m long of metamorphosed banded iron formation and fine to coarse-grained mafic rocks occur in this marginal zone.

Mount Shenton-Mount Cumming belt

This greenstone belt is a continuation of the Mount Venn belt in the Rason Sheet area (Gower & Boegli, 1973).

Banded chert (Aq), in part ferruginous, is exposed in the southwest of the area at Mount Shenton. Intercalated with the chert are metamorphosed black shale and phyllite containing porphyroblasts of andalusite. The chert at Mount Shenton is probably continuous with a chert and black shale sequence 4 km northwest of Jutson Well. There are no occurrences of chert and black shale on the eastern side of the greenstone belt, although a hornfelsed quartz-magnetite-grunerite rock occurs within the marginal granite. Similar hornfelsed rocks are found within the granite east of Mount Cumming.

The eastern part of the belt is bounded by a sequence of ultramafic rocks (Ar). The northern part of the belt consists of an unusually thick sequence of ultramafic rocks (4 km wide) in the nose of a synform. The ultramafic rocks are principally of high-magnesium basalt, now represented by schistose tremolite-actinolite-chlorite assemblages and rare serpentinite. Some ultramafic schists contain abundant biotite, and 0.5 km east of Jutson Rocks, partly serpentinized olivine porphyroblasts are developed in a matrix of tremolite and chlorite. Northwest of Jutson Well, bands of chert and basalt occur within the ultramafic rocks. Folding and crenulation of the schistosity occurs in the ultramafic schists in the northern part of the area.

Foliated metamorphosed mafic rock in the north of the belt represents a pile of tholeiitic basalts with roughly concordant intrusions of gabbro and dolerite. The characteristic mineral assemblage is hornblende (rarely actinolite) and plagioclase with minor epidote, quartz, and carbonate. Localized alteration in gabbro in the Mount Cumming area has produced actinolite-prehnite-epidote assemblages. Metasomatised gabbro (rodingite) forms a thin band in the olivine-bearing ultramafics east of Jutson Rock.

The felsic sequence, which dominates the central southern part of the belt, consists of metamorphosed pyroclastic rocks, with minor interbedded lavas and sediments. The fragmental rocks include tuff, breccia, and agglomerate, and contain quartz, altered plagioclase, green amphibole, muscovite, biotite, and minor microcline. Accessory minerals include garnet, tourmaline, apatite, prehnite, sphene, calcite, epidote, and pyrite. Nematoblastic and granuloblastic textures have generally replaced primary textures, although mesoscopic features, such as banding, and larger fragments have been preserved. The larger fragments include quartzite, rhyolite, dacite, basalt and fragments of the same composition as the matrix. The metamorphosed lavas are mostly dacite with minor rhyolite. Blastoporphyritic and relict amygdaloidal textures are common. The metamorphosed sedimentary rocks are similar in composition to the felsic rocks and are not easily distinguished in the field. Sedimentary structures and textures have been largely obliterated, but abundance of muscovite is taken to suggest a pelitic sedimentary origin. The abundance of tourmaline in some rocks suggests either a sedimentary origin or a considerable amount of metasomatism of an igneous rock. Minor metamorphosed chert bands are present in the felsic sequences in the north of the area.

The structure of the area is considered to be synformal on the basis of a north-closing fold 1 km east-southeast of Jutson Rocks and a consistent southerly plunge of lineations and minor fold axes. The lineation is defined by mineral orientation, elongation of pyroclastic fragments and vesicles, and shadows around mineral grains. The sense of parasitic folding is also consistent with a synform.

Mount Gill belt

The Mount Gill greenstone belt is continuous with the Yamarna greenstone belt in the Rason Sheet area (Gower & Boegli, 1973), although the southern part in the Throssell Sheet area is covered by aeolian sandplain. Photolineaments indicate the continuity beneath the thin superficial cover. The maximum width of 5 km occurs near Mount Gill where the belt is bounded on either side by strongly foliated granodiorite. No facing evidence was found, but if the belt is structurally continuous with the Yamarna area, then facing is easterly.

Well cleaved metabasalt (Aba) predominates in the west of the belt, with minor schist (As), metagabbro (Ada), and banded iron formation (Aw). East of the mafic sequence is a metasedimentary sequence of interbedded black shale, laminated shale and chert (Aq). Most of the pelitic rocks are now metamorphosed to phyllite and schist.

Minor greenstone belts

Ten kilometres east of Minnie Creek a small belt of hornfelsed metabasalt marks the northern extension of the Dorothy Hills belt on the Rason Sheet (Gower & Boegli, 1973). The eastern contact against foliated adamellite is sharp and probably faulted. Photolineaments indicate that the belt continues north beneath the sandplain.

In the Virginia Range area there are several remnants of muscovite-biotite-quartz-microcline schist, of pelitic sedimentary origin, in strongly foliated gneissic granite. Some felsic paragneiss may be included in the gneissic granite, but the two are now indistinguishable, particularly where weathering is severe.

Granitic Rocks

The greenstone belts are intruded and broken up by granitic rocks ranging from granite to tonalite in composition and including some with nebulitic banding. The granitic rocks account for about 90 per cent of the Archaean rocks in the western third of the Sheet area, but they are largely covered by superficial deposits or are deeply weathered.

No isotopic dating of the granitic rocks in the Throssell Sheet area has been attempted, but a suite of foliated granitic rocks from the Rason Sheet area to the south gave a Rb-Sr age of 2588 $\pm$ 25 m.y. with an initial Sr^{87}/Sr^{86} ratio of 0.7014 (J. R. de Laeter, personal communication). The strong gneissic foliation in the rocks suggests that the age may reflect a metamorphic event.

Medium to coarse-grained adamellite (Agb) crops out below the Proterozoic rocks along the southern edge of Farquharson Tableland, as small exposures south of the Ulrich Range, in the Gladys Paterson Hills, and in the southwest corner of the Sheet area. The adamellite contains roughly equal amounts of plagioclase and microcline, the main mafic mineral being biotite. The quartz and biotite commonly exhibit a weak gneissic foliation.

Fine to medium-grained granite and adamellite (Age), are restricted mainly to within the west of the Mount Shenton-Mount Cumming greenstone belt. At Lang Rock a medium-grained granite that discordantly intrudes the greenstones contains slightly more microcline than plagioclase, and is characterised by large flakes of muscovite replacing albite. The main mafic mineral is chloritised biotite. The rock lacks visible foliation. At Jutson Rocks fine-grained adamellite contains similar muscovite and again the mafic mineral is chloritized biotite, but here there is a strong cleavage and parallel alignment of minerals striking 075°. A later crenulation is also developed. These discordant granitic rocks probably were intruded after the main phase of greenstone belt deformation and metamorphism.

At Ardagh Rocks fine to medium-grained adamellite (Age) contains brown biotite and no chlorite. There is a faint gneissic foliation defined by alignment of quartz and biotite. Minor coarse-grained adamellite is present and the complex could equally well be grouped with the regional mixed granitic rocks. The contact with the greenstone belt to the northeast of Ardagh Rocks is one of lit-par-lit intrusion of granite into fine-grained strongly foliated amphibolite. This contrasts with the sharp, but strongly foliated, contacts of the granites at Jutson Rocks and Lang Rock.

The unit of mixed granites (Agm) represents rocks ranging from granite to granodiorite, fine to coarse-grained (mostly medium), with minor gneissic and nebulitic varieties. Contacts between rock types are sharp or gradational, and the various types cannot be separated at 1:250 000 scale. The unit is interpreted as the result of multiple intrusion and anatexis of granitic rocks on a regional scale.

Strongly foliated gneissic granitic rocks (Agg) flank the greenstone belts in the south of the Sheet area. The predominant rock type is medium-grained granodiorite or adamellite with biotite and a little hornblende. Epidote is an accessory mineral in a sample from about 10 km northeast of Mount Shenton. In the Virginia Range strongly foliated granodiorite is intimately mixed with schistose pelitic metasediment and felsic paragneiss, and distinction between rock types is difficult.

Minor granitic dykes within the greenstone belts are common, especially near the margins. Pegmatite is abundant in the foliated granite east of Mount Cumming.

Regional Structure

The Throssell Sheet area is situated near the northeast margin of the Yilgarn Block, a stable craton of Archaean age. To the north and east the Archaean rocks underlie almost undisturbed flat-lying Proterozoic and Phanerozoic sediments of the Nabberu and Officer Basins. Seismic traverses along the southeast side of Lake Throssell suggest that the eastern edge of the Yilgarn Block is a major fault with a downthrow to the northeast of some 7 000 m (Harrison & Zadoroznyj, in prep). There is no gravity anomaly associated with the inferred fault, but this could be due to a lack of density contrast between the granitic rocks and the Proterozoic sediments to the east.

The non-granitic Archaean rocks occur in several north to northwest-trending belts separated by large areas of granitic rocks. Facing evidence is lacking, but lineations and parasitic folds indicate that at least the Ulrich Range and Mount Shenton-Mount Cumming belts are synforms with plunges to the southeast (Fig. 2). Folding has been complex, particularly in the Mount Cumming area, where folding along an east-west axis has involved both the mafic succession and the adjoining foliated granodiorite. The Mount Gill greenstone belt is apparently simpler and probably forms the western limb of a syncline on the Rason Sheet (Gower & Boegli, 1973).

In the granitic rocks the foliation trend ranges from north to northwest. Marginal to the greenstone belts, the gneissic foliation in the granitic rocks tends to dip towards the greenstone belts, thus accentuating the synformal structures. The gneissic foliations in the Virginia Range have a consistent northerly strike, but dip is varied, possibly indicating a period of folding during or after development of the foliation.

A major north-northwest-trending fault is postulated between the northerly trends of the Mount Warren area and the easterly trends of the Mount Cumming area. The southern extension of this fault may link up with a fault on the Rason

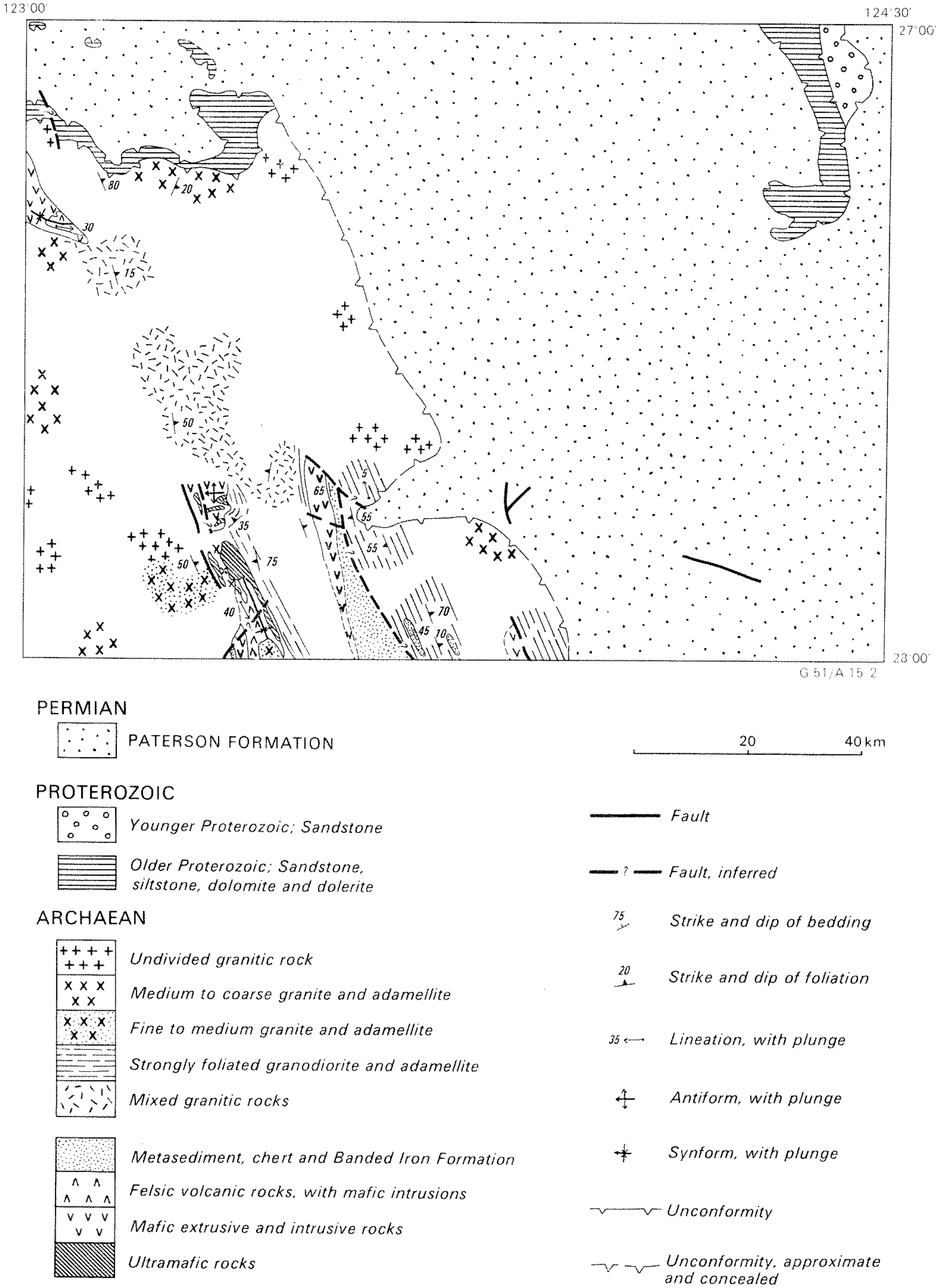

Fig. 2. General geology.

Sheet in the vicinity of Rutter Soak (Gower & Boegli, 1973). The granites of Jutson Rocks and Long Rock are probably postfaulting. The fault could also explain the non-appearance of the thick ultramafic unit southeast of Jutson Rocks.

The Bouguer gravity contours show a faint gravity ridge through the Mount Gill belt, extending for about 25 km north of the present exposure. No such ridge occurs over the Mount Shenton-Mount Cumming belt, and this is interpreted as an indication of the shallow depth to which the western belt extends. A broad, east-west gravity high in the central eastern part of the Sheet area has no apparent geological basis and may be related either to a variation in the thick pile of Proterozoic sediment or a structure within the basement underlying the sediment. Fraser (1973) interprets the anomaly as part of an extension of the Yilgarn Block under the Officer Basin, but if this is so then it must represent a new structural domain of the Yilgarn Block, characterized by an east-west rather than a north-northwest trend.

METAMORPHISM

Rocks in the greenstone belts have been metamorphosed to greenschist or lower amphibolite facies. Structures, such as vesicles and pyroclastic fragments, have been preserved, but recrystallization has destroyed most of the original igneous or sedimentary textures. A penetrative foliation is now the dominant fabric of most rocks. Typical assemblages in the dacitic and mafic rocks include green hornblende (rare actinolite) and plagioclase, with a little brown biotite. In the Mount Cumming-Mount Shenton belt clinopyroxene and garnet are common accessories of the metabasalt, indicating amphibolite-facies metamorphism. Post-metamorphic mobilization of calcium is indicated by an abundance of secondary epidote, prehnite and calcite, either as alteration products or in veins.

In pelitic rocks, quartz sericite or quartz-muscovite-feldspar assemblages are common. At Mount Shenton, porphyroblastic andalusite has grown in a quartz-sericite schist. On the east side of the Mount Shenton-Mount Cumming belt remnants of ferruginous chert in foliated granite have been converted to quartz-grunerite-magnetite rock.

Polyphase metamorphism is indicated in ultramafic rock near Jutson Rocks by the presence of porphyroblastic olivine in a matrix of tremolite and chlorite; nearby, mafic hornfels contains abundant clinopyroxene, and garnet is common. It is probable that the second metamorphism is a contact effect of the nearby intrusive granite at Jutson Rocks. Springer (1974) has shown that olivine forms at an early stage in the contact metamorphism of ultramafic rocks. Oliver and others (1972), however, suggest upper amphibolite facies metamorphism as the cause of olivine growth in the Pioneer area, Western Australia.

PROTEROZOIC

Proterozoic rocks crop out along the edge of the Farquharson Tableland in the northwest, and in low rises on either side of the valley running north from Lake Throssell in the northeast of the Sheet area. The Proterozoic rocks flanking the Farquharson Tableland (Ᵽq, Ᵽo and Ᵽn) and those cropping out to the west of the valley (Ᵽd) are tentatively grouped into the same informal sequence, here called the Older Proterozoic. The Proterozoic to the east of the valley (Ᵽs) is thought to form part of a Younger Proterozoic sequence. The paucity of outcrop, lack of structural information and absence of contact relationships means, however, that this subdivision of the Proterozoic within the Sheet area must remain tentative.

Older Proterozoic

A flat-lying to very gently north-dipping undeformed sequence of quartz and glauconitic arenite (Ꭾq), overlain by multicoloured oolitic and intraclastic sandstone, fine-grained flaggy micaceous sandstone and siltstone (Ꭾo), unconformably overlies Archaean granite in the Farquharson Tableland. Just west of the Sheet boundary, in the Duketon Sheet area, these two units are separated by a richly fossiliferous bed of stromatolitic dolomite. The quartz arenite is medium to coarse grained, well sorted, and sub-rounded to well rounded with a siliceous cement. Glauconite is present in places and forms up to 10 per cent of the rock. The multicoloured sandstone contains ferruginous ooids with poor concentric zoning.

Dolerite (Ꭾn) crops out below the Paterson Formation at the western edge of Lake Wells (grid ref. 530002). The rock is massive, spheroidally weathered, and consists of anhedral pyroxene and laths of zoned labradorite, with a sub-ophitic texture. Although no contacts were found, the dolerite is probably part of a sill, as dolerite sills commonly intrude the Proterozoic sequence in the Robert Sheet area immediately to the north (Jackson, in prep.). One of the sills in the Robert Sheet area has been dated at about 1050 m.y. (Compston, 1974).

The outcrops in northwest Throssell Sheet area represent only the basal 30 to 40 m of a sequence which is several thousands of metres thick and much better exposed in the Kingston, Robert, and Nabberu Sheet areas to the northwest. A tentative stratigraphy for the whole sequence has been suggested by Hall & Goode (1975); the units Ꭾq and Ꭾo on the Throssell Sheet are equivalent to their *Yelma Sandstone,* and *Frere Formation,* respectively. Samples of glauconitic sandstone collected during the 1972 mapping programme from near the base of the Yelma Sandstone in the adjacent Duketon Sheet area (27°07′S, 122°55′E) gave K-Ar ages of around 1700 m.y., and Rb-Sr ages of between 1590 and 1710 m.y. (Preiss and others, 1975).

A 10 000-m thick sequence of undivided Older Proterozoic rocks with seismic velocities of between 6000 and 6500 m/sec. is shown at the eastern end of the cross-section. The presence of this thick layered sequence to the northeast of the Yilgarn Block is based on the results of recent BMR geophysical work (Harrison and Zadoroznyj, in prep.). Its tentative correlation with the Proterozoic exposed in the northwest of the Sheet area is based solely on regional geological considerations.

Based on lithological similarities to outcrops in the Robert Sheet area, the stromatolitic dolomite, dolomitic siltstone and chert (Ꭾd) 20 km north of Buldya Soak are tentatively grouped with this Older Proterozoic sequence.

Younger Proterozoic

A thin sequence of Younger Proterozoic rocks overlies the Older Proterozoic in the east of the Sheet area. The presence of the younger sequence is based largely on extending the interpretation of the BMR seismic results from the Yowalga and Westwood Sheet areas into this Sheet area, and supplementing it with sparse outcrop information.

Based on the seismic interpretation, a thin interval (less than 400 m) of Younger Proterozoic rocks with seismic velocities of 3300 to 5700 m/sec. is shown overlying the Older Proterozoic between C and E on the section. To the east of

Throssell Sheet area this sequence thickens to a maximum of about 7000 m in the Yowalga Sheet area.

The cross-bedded quartz arenite (Ꝑs) cropping out north of Nullye Soak is at the southern end of a poorly defined north-trending outcrop belt of sandstone, which is traceable along the eastern margin of Robert Sheet area (Jackson, 1978). The strike of this belt is at right angles to that of the underlying Older Proterozoic sequence and the two appear to be structurally discordant. Ꝑs is therefore considered to be part of the Younger Proterozoic sequence. The only other information on the Younger Proterozoic sequence in the Sheet area is that provided by stratigraphic drill hole BMR Throssell 1. This hole intersected 101 m of ?Cainozoic lacustrine and calcrete deposits before penetrating 97 m of indurated claystone, siltstone and sandstone, which Jackson and others (1975) correlate with the Proterozoic Babbagoola Beds, previously known only in Hunt Oil-Placid Oil Yowalga 2 (200 km to the northeast).

Regionally, the Younger Proterozoic rocks in this Sheet area appear to be equivalent to the Proterozoic flanking the southern margin of the Musgrave Block in the Talbot and Cooper Sheet areas to the northeast. The sandstone north of Nullye Soak which delineates the western extent of the Younger Proterozoic rocks may be the lateral equivalent of the Townsend Quartzite (Daniels, 1971). In the Talbot and Cooper Sheet areas the Townsend Quartzite forms the base of the Younger Proterozoic sequence and delineates the northeastern margin of the Officer Basin (Lowry and others, 1972).

PERMIAN

Paterson Formation

The Lower Permian Paterson Formation is an extensive, thin, flat-lying terrestrial formation that forms the bedrock in all but the southwest corner of the Sheet area. Although the rocks comprising the formation have commonly been affected by duricrusting processes, there are good outcrops in prominent breakaways in the Ernest Giles Range in the north, in the Newland and Hoffman Ranges in the southeast, and at the edges of the Farquharson Tableland in the northwest. A line joining the Farquharson Tableland to the Virginia Range (southern central part of the sheet) roughly delineates the westward extent of continuously preserved Paterson Formation. This line was used by Lowry and others (1972, p. 51) as an arbitrary southwest boundary to the Officer Basin. Outliers of Paterson Formation to the west of this line, indicate that the Paterson Formation was originally more extensive.

Although the formation is probably not much more than about 100 m thick throughout much of the Sheet area, the outcrops contain a wide range of rock types, reflecting the formation's complex glacial, fluvial, and lacustrine depositional environments. Excellent outcrops of the lacustrine and fluvial facies are present in a 25-m high cliff face in the Hoffman Range. The lacustrine unit forms the lower 12 m of the cliff face. Generally it consists of laminated claystone and siltstone containing rare erratic pebbles and cobbles, but beds highly disturbed by penecontemporaneous slumping are also present. The lacustrine unit is overlain by 13 m of fluvial, conglomeratic to very coarse-grained, pebbly sandstone, containing well-developed decimetre-scale trough cross-stratification. The upper unit has a sharp erosional base with well-developed channels; it rests on a 2-m thick paleosol developed at the top of the lacustrine facies. A conglomeratic mudstone containing pebbles of weathered granite, interpreted as a tillite, is exposed in a conical hill at grid reference 643976.

The Paterson Formation unconformably overlies Archaean basement in the south-central part of the Sheet area and Proterozoic quartzite in the northwest. Palynological studies of samples from the formation in adjacent Sheet areas date it as Early Permian (Kemp, 1976).

CAINOZOIC

Silcrete (Czb)

The silcrete is a grey-green, silicified, poorly to well sorted sandstone, composed of angular to rounded quartz grains (rarely chert, chalcedony or quartzite). The quartz grains show solution embayments and are clear. The matrix is opaque microcrystalline silica with minor chalcedony, and is locally ferruginized.

The silcrete forms a resistant, slightly undulating capping up to two m thick, preferentially developed over quartz-rich Permian and deeply weathered Precambrian rocks. It is generally massive or cavernous. Weathering of the capping produces a colluvium of spherical boulders.

In places laterite is developed over silcrete, indicating that the silcrete is older than the laterite. However, they may have formed contemporaneously. The silcrete is thought to be Miocene or older.

Laterite (Czl)

Laterite occurs patchily throughout the Sheet area, but is best developed in areas of Archaean mafic and ultramafic rock. In these areas it is a ferruginous, pisolitic to massive crust, generally grading directly into bed-rock. However, at some localities, such as 6 km northwest of Jutson Rocks, it rests on a zone of deep weathering (Czo).

In the eastern half of the Sheet area the laterite profile grades upwards into a loose, progressively less-densely packed ironstone, and eventually into sand with scattered pisoliths (Czs).

Calcrete (Czk)

The term calcrete is used to describe impure carbonate deposits in relict drainage systems. The calcrete is nodular, laminated, massive, or cavernous, and is composed of calcium carbonate with fragments of quartz, laterite and silcrete. BMR Throssell 1 penetrated 27 m of calcrete (Jackson and others, 1975). Textures indicate that the carbonate has filled voids, and has both replaced and pushed apart pre-existing clasts. Replacement of carbonate by chalcedonic silica is common.

The major relict drainage systems, including Lakes Wells, Throssell, and Yeo, and a north-trending valley in the west of the Sheet area, contain extensive deposits of calcrete.

Precipitation of carbonate in the alluvial valleys began in or later than the Miocene, and has probably continued since.

Deep-weathering products (Czo)

Deep-weathering is extensive throughout the Sheet area, but has affected the Archaean rocks most. Feldspar and mafic minerals break down to form residual clay minerals (mostly kaolin) and oxides; the oxides are normally removed by leaching. The deep-weathering zone formed below the laterite/silcrete capping, but is probably contemporaneous with it. Many of the original structures and textures of the rocks are preserved, and it is therefore usually possible to roughly identify the original rock type.

Colluvium and alluvium (Czc)

Rock fragments, sand, silt, and clay at the foot of hills and breakaways, on long gentle slopes, and in depressions and water courses have been mapped as one unit. This unit is formed mainly by sheet-wash down uniform slopes, and channel flow in ephemeral streams. These sediments are still being deposited and older ones reworked. Aeolian sediments may be intermixed with the colluvium, and boundaries with the aeolian sandplain are often gradational. Thickness of the colluvium and alluvium averages a few metres.

Aeolian sandplain deposits (Qs)

A large portion of the Sheet area is covered by a veneer of red quartz sand, which forms a gently undulating plain with longitudinal (seif) dunes patchily developed on it. Individual quartz grains which are up to 0.4 mm across, are angular to rounded, and have an iron oxide patina.

Most dunes are between 5 and 10 m high and up to 10 km long. They are mostly sub-parallel and trend eastwards, although east of Lake Throssell there is a pronounced change in orientation to a northeasterly trend. Angles formed by merging dunes generally open westward, indicating that the dunes were formed by westerly winds (King, 1960).

The age of formation of the sand dunes is uncertain. King (1960) thought they accumulated during arid periods in the Quaternary. Movement of sand is impeded by spinifex and scrub cover, and little or no modification to dune shape has occurred in recent years.

Lake and associated deposits (Ql, Qg, Qd)

Lakes Wells, Throssell, and Yeo are portions of an infilled relict trunk drainage system and now are ponding areas for the present internal drainage. Recent lacustrine deposits of gypsiferous and saline clay, silt, and sand (Ql) occur in the salt lakes and claypans. Lake-derived aeolian deposits of mainly silt and sand (Qg) form lunette dunes and sheets associated with the salt lakes. Gypsum and quartz are the main constituents; halite is minor. Dunes of flour gypsum up to 10 m high occur predominantly on the eastern (lee) side of larger salt lakes.

Next to the lakes there are commonly flat areas of loamy colluvium (Qd) with small claypans. These are largely composed of silt and gypsiferous material derived by wind action from salt lakes.

BMR Throssell 1 penetrated Cainozoic lacustrine deposits from about 27 m to 101 m (Jackson and others, 1975).

ECONOMIC GEOLOGY

With the exception of a small amount of gold, no economic mineral deposits have been recorded from the Sheet area.

Gold

Production for the Throssell Sheet is small with only 1132.6 g of gold recorded.

At Chapman's Reward Mine near Jutson Rocks, gold occurs in quartz reefs in strongly foliated granite next to ultramafic rocks. The main reef occurs on the east side of a pegmatite dyke and carries free gold together with galena, pyrite, and sphalerite (Gourley, 1924; Montgomery, 1924). Gold amounting to 828.9 g was recovered from 15.24 tonnes of ore at an average grade of 54.39 g/tonne.

The Ulrich Range was prospected in 1905. A small gully on the eastern fall produced at least 303.75 g of alluvial gold (Gibson, 1906a) but there is no complete record of the amount recovered.

Small shafts, with no recorded production, were sunk on quartz veins 2.5 km and 6.0 km northwest of Mount Strawbridge. The former working is situated in weathered dacitic volcanic rock and the latter in metamorphosed basalt next to granitic dykes.

Copper

Malachite ocurs in small veins in metamorphosed basalt immediately southwest of Mount Cornell. In the Ulrich Range, a quartz vein bearing copper carbonate was noted by Gibson (1906a).

Groundwater

Prospects of finding small supplies of stock or potable water are moderately good in the colluvium and alluvium surrounding areas of relief, particularly in the greenstone belts. Most wells in the Sheet area are in such areas. An exception is Limestone Well, which is sunk in a broad calcrete drainage and this produces potable water (570 ppm TDS). Calcrete is the best potential aquifer in the Sheet area. Elsewhere prospects are poor. Surface supplies are confined to soaks and rock holes, which dry up quickly. The aeolian sands are generally only a few metres thick, and low rainfall and high evaporation prevent accumulation of groundwater in them. The areas of saline drainage and salt lake can be expected to produce only saline water.

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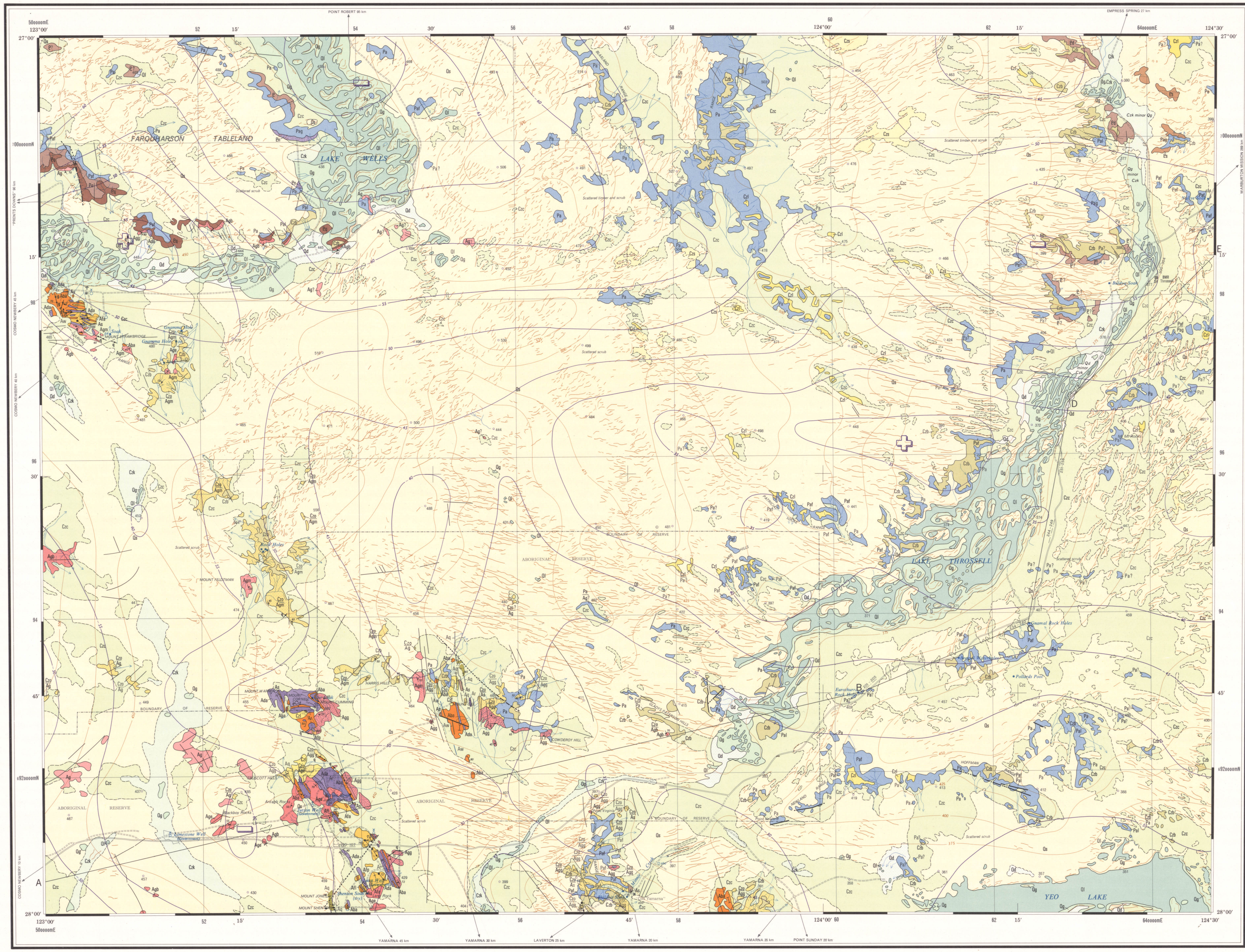
THROSSELL

WESTERN AUSTRALIA

AUSTRALIA 1:250 000 GEOLOGICAL SERIES

SHEET SG 51-15



Reference

Geological boundary

Fault (D, U indicate relative movement down, up)

Plunge of subsidiary fold

Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes

Strike and dip of strata

Strike and dip of strata, unmeasured

Vertical strata

Trend line | Joint pattern | Lineament — airphoto interpretation

Strike and dip of foliation

Strike and dip of foliation, dip inderterminable

Strike and dip of cleavage

Vertical cleavage

Direction and plunge of lineation

⊗ St — BMR Stratigraphic hole

Dyke, q-quartz, g-granite

Prospect, little or no production, abandoned

. Cu — Minor mineral occurrence

Cu — Copper

Bore

Abandoned bore

Windpump

Well

WH — Waterhole

Ephemeral stream

Sand dunes

450 — Form line in metres

Road

Vehicle track

Fence

"Old Yamarna" — Homestead

Landing ground

Astronomical station

.449 — Elevation in metres, approximate

pa — Position approximate

abd — Abandoned

300–304 — Seismic traverse line (BMR 1972) with shot point numbers

Seismic reflecting horizon, good to fair quality

Seismic reflecting horizon, poor to questionable quality

6100 — Seismic refracting horizon showing velocity (m/sec)

(section only)

o 450 — Gravity station with elevation in metres

— 50 — Isogal

Gravity anomaly — relative high

Gravity anomaly — relative low

Bouguer anomalies are based on the May 1965 observed gravity values at isogal gravity base stations in and near the area. For the calculation of Bouguer anomalies 2.2 g/cm³ has been adopted as an average rock density. The gravity data are preliminary only; refer to BMR gravity maps for more recent data

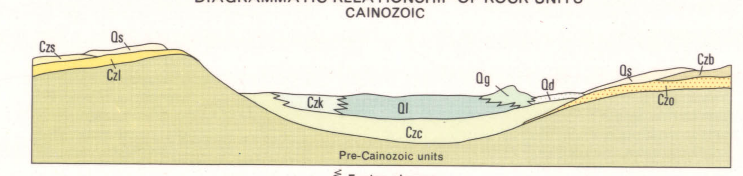
Reference

CAINOZOIC	QUATERNARY	Qd	Clay, silt, sand; marginal to salt lakes: colluvium, minor alluvium
		Ql	Clay, silt and sand, saline and gypsiferous: lacustrine
		Qg	Gypsum and quartz sand; marginal to salt lakes: aeolian
		Qs	Red to yellow quartz sand; longitudinal dunes and plains: aeolian
		Czc	Poorly sorted clay, silt, sand and rock fragments: colluvium, minor alluvium
		Czk	Nodular and cavernous limestone and sandy limestone; minor chalcedony and clay: calcrete
		Czs	Red quartz sand, ferruginous pisoliths, minor clay: residual lateritic soil, in part deflated
		Czl	Pisolitic, nodular and massive laterite
		Czb	Sub-vitreous siliceous rock with angular quartz grains, commonly ferruginized: silcrete
		Czo	Kaolinized, partly ferruginized and silicified crystalline rocks: weathered basement
PALAEOZOIC	EARLY PERMIAN — Paterson Formation	Pa	Undivided, includes one or more of the following facies: Paf Coarse, poorly sorted sandstone, conglomerate, minor siltstone: dominantly fluviatile; Pal Claystone, siltstone, fine sandstone; some erratics rare varves: lacustrine and glacio-lacustrine; Pag Tillite; minor sandstone, siltstone, conglomerate: glacigene
PROTEROZOIC (UPPER PROTEROZOIC*)	ADELAIDEAN	Ps	Flaggy quartz arenite, well sorted, some large-scale cross bedding, ripple marks, minor chert
		Pn	Dolerite
PROTEROZOIC (LOWER TO MIDDLE PROTEROZOIC*)	CARPENTARIAN	P — Pd	Dolomite, dolomitic siltstone and oolitic sandstone; abundant stromatolites; minor chert
		Po	Multicoloured oolitic sandstone, flaggy to fissile fine sandstone and siltstone
		Pq	Quartz arenite, quartzite, well sorted silicified; minor glauconite
ARCHAEAN		Ag	Undivided granitic rocks
		Agb	Medium to coarse granite and adamellite
		Age	Fine to medium granite and adamellite
		Agg	Strongly foliated adamellite and granodiorite
		Agm	Mixed granitic rocks, fine to coarse granite to granodiorite; some nebulitic structures
		Aq	Banded chert, minor phyllite and banded iron formation
		Aw	Quartz – magnetite banded iron formation, minor chert
		Afa	Felsic volcanic rocks, metamorphosed; mostly pyroclastic with minor lavas and pelitic rocks
		Afl	Fine felsic volcanic rocks, mainly lavas, minor tuff
		Afp	Quartz-feldspar porphyry
		As	Metamorphosed sedimentary rocks, phyllite and micaceous schist, metasiltstone
		Ass	Black siliceous shale
		Ada	Medium to coarse mafic rock; metagabbro, amphibolite
		Aba	Fine mafic rock, metabasalt amphibolite
		Ar	Tremolite-chlorite-talc assemblages; mafic to ultramafic; includes high magnesium basalt

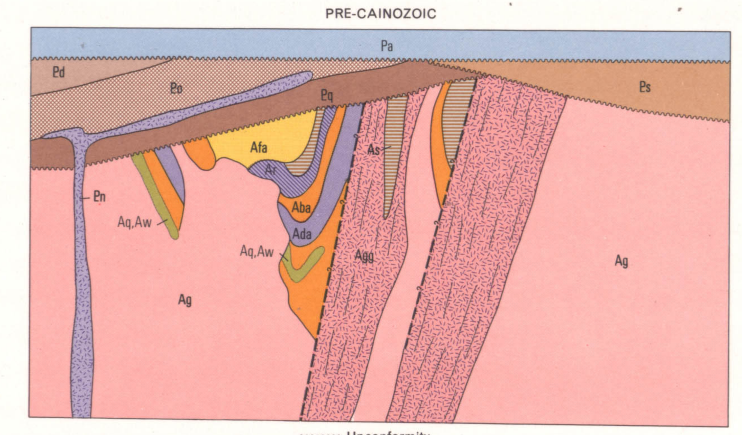
*Subdivisions of the Precambrian time-scale used by the Geological Survey of Western Australia, shown in grey

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

CAINOZOIC



PRE-CAINOZOIC



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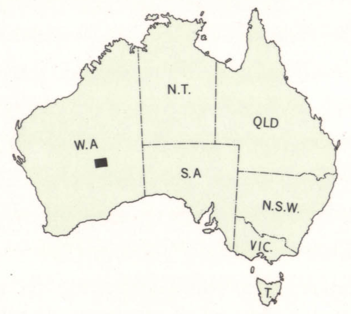


INDEX TO ADJOINING SHEETS

Showing Magnetic Declination 1975

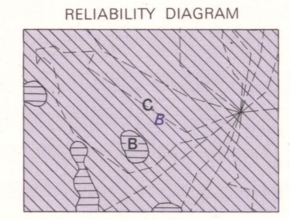
NABBERU SG 51-5	STANLEY SG 51-6	HERBERT SG 51-7	BROWNE SG 51-8	BENTLEY SG 52-5
WILUNA SG 51-9	KINGSTON SG 51-10	ROBERT SG 51-11	YOWALGA SG 51-12	TALBOT SG 52-9
SIR SAMUEL SG 51-13	DUKETON SG 51-14	THROSSELL SG 51-15	WESTWOOD SG 51-16	LENNIS SG 52-13
LEONORA SH 51-1	LAVERTON SH 51-2	RASON SH 51-3	NEALE SH 51-4	VERNON SH 52-1

Scale 1:250 000

5 0 5 10 15 20 25 KILOMETRES

GREY NUMBERED LINES ARE 20 000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID, ZONE 51 TRANSVERSE MERCATOR PROJECTION

RELIABILITY DIAGRAM



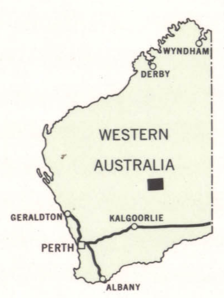
Geology B Detailed reconnaissance and airphoto interpretation

C General reconnaissance: few traverses, mainly airphoto interpretation

Helicopter traverse

Gravity B Reconnaissance

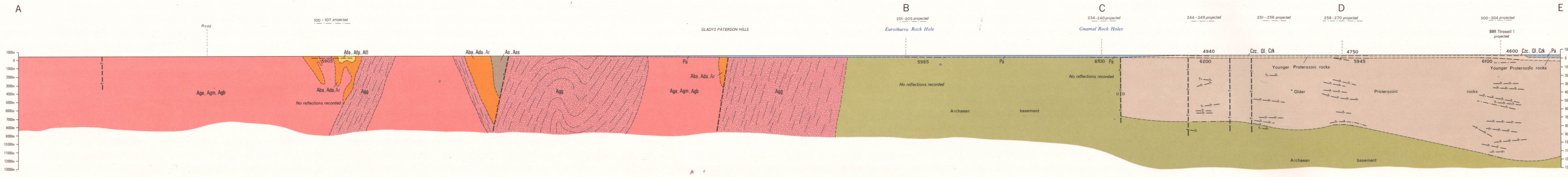
Geology 1971 by M. J. Jackson, P. J. Kennewell BMR, D. C. Lowry, W. J. E. Van de Graaff GSWA
1972 by M. J. Jackson
1973 by J. A. Bunting, R. Chin GSWA
Compiled 1974 by M. J. Jackson, J. A. Bunting, R. Chin, J. Kopras
Gravimetry 1971-72 by Geophysical Branch, BMR
Cartography by Geological Branch BMR
Drawn by Cartographic Drafting Services, Bendigo, Vic.
Printed by Mercury-Walch, Hobart, Australia



Section

Thin Cainozoic units omitted

Scale: $\frac{V}{H} = 1$



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THROSSELL

SHEET SG51–15

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