1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

KINGSTON

WESTERN AUSTRALIA

SHEET SG 51-10 INTERNATIONAL INDEX

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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COMPILED BY J. A. BUNTING

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
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Explanatory Notes on the Kingston Geological Sheet

compiled by J. A. Bunting

INTRODUCTION

GENERAL

The Kingston 1:250 000 Sheet (International Grid Reference SG 51-10) is bounded by latitudes 26°00'S and 27°00'S, and longitudes 121°30'E and 123°00'E. The area is located within the Eastern Land Division, and forms part of the Mount Margaret and East Murchison Goldfields. The northern boundary of the sheet forms the northern limit of both Goldfields.

The only permanent population in the area is involved in running the pastoral stations of Windidda, Wongawol, and Lorna Glen*. At the time of this study, Prenti Downs homestead was temporarily unoccupied, and Old Windidda and Yelma were abandoned. A small transient population is occupied in kangaroo shooting, vermin control, and sandalwood cutting.

The graded, gravel road from Wiluna to Warburton Mission, via Carnegie Station, and the Gunbarrel Highway, crosses the northwest part of the area. Similar roads link Prenti Downs and Windidda with this road, and Lorna Glen with Wiluna.

Tracks southwards link Prenti Downs with Laverton via Cosmo Newbery Mission, and the Wiluna to Carnegie road (near Mount Eureka) with Leonora via Wonganoo. Station tracks in the northern two-thirds of the area provide moderate access to most areas. Away from these tracks, vehicle access varies from good on sheetwash and flood plains, to very difficult in rocky hills. In the southern part of the area, travel is hampered by sand dunes and spinifex.

The climate is semi-arid to arid; summers are hot and winters cool to mild. Mean annual rainfall is between 200 and 250 mm, but unreliable; and the area is subject to drought as well as localized short-term floods. The wettest period is December to May. Annual potential evaporation is about 2800 mm. January is the hottest month: average maximum 38°C, and minimum 23°C. July is the coolest month: average maximum 20°C, and minimum 6°C.

Subdivisions of vegetation communities (Beard, 1974) largely correspond to physiographic units. Stony hills and ranges support low mulga (*Acacia aneura*) scrub and other small shrubs; sheetwash plains and floodplains contain low woodland of mulga and a ground cover of grasses. The larger watercourses support lines of eucalypts along the banks. The marginal flats around salt lakes are characterized by halophytes such as saltbush (*Atriplex*), bluebush (*Kochia*), and samphire (*Arthrocnemum*). Sand plain in the southern third of the area is dominated by spinifex (*Triodia*) associated with scattered mallee (*Eucalyptus*), mulga, and marble gum (*Euclyptus gongylocarpa*).

* Coordinates of localities mentioned in the text are presented in Table 1.

PHYSIOGRAPHY

Elevations range from 440 m to 600 m above sea level; local relief is small. Drainage is towards Lake Carnegie and Lake Wells in the northern and eastern parts of the area.

Some drainage lines in the southern part of the area are now inactive, and, together with the major salt-lake systems, they form part of an extensive palaeodrainage system which ceased significant flow in the middle Miocene (Bunting and others, 1974). The inactive drainages are preserved on a lateritized Tertiary erosion surface (the 'Older Plateau' of Jutson, 1934). The active drainages, which flow only after heavy rain, occur on a more recent erosion surface. Larger creeks have incised channels up to 4 m deep and 30 m wide which are flanked by extensive flood plains (e.g. Wongawol Creek), and which are mainly confined to areas underlain by the Earaheedy Group.

For the purpose of this report, the physiography (Fig. 1) has been divided into three groups: 1) degradational areas, 2) intermediate areas and 3) aggradational areas.

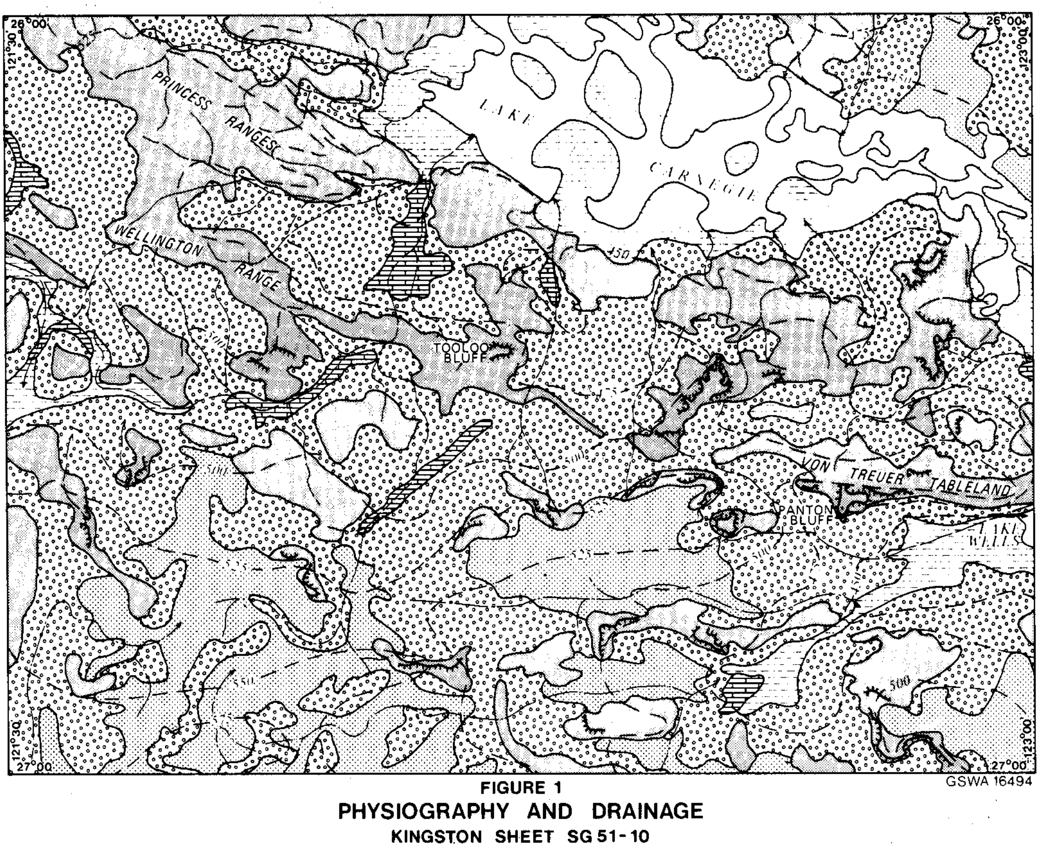


FIGURE 1
PHYSIOGRAPHY AND DRAINAGE
KINGSTON SHEET SG 51-10

10 0 10 20 30 40km

REFERENCE

DEGRADATIONAL AREAS

1 Upland areas, low hills, cuestas, laterite and silcrete-capped mesas, and associated pediments

INTERMEDIATE AREAS (material derived from 1)

2a Flat sheet-wash plains and valley floors consisting of alluvium and colluvium

2b Eolian sand plain, with patchy cover of longitudinal dunes

AGGRADATIONAL AREAS (material derived from 1 and 2)

3a Flat, bare salt lake surface

3b Dunes and sheets of eolian and alluvial material marginal to salt lakes and in major valley floors

3c Calcrete-filled valley floors, low-lying with hummocky surface

Modern drainage (ephemeral)

Ancient drainage

Breakaway

—450— Topographic contour in metres

Degradational areas include all those of relatively high relief, such as hills, breakaways and cuestas, and their associated pediments. Archaean greenstone belts form elongate ranges of low hills. Chert and banded iron-formation form long, resistant strike-ridges. In much of the area underlain by the Earaheedy Group, topography is controlled by the gently north-dipping, resistant bands of chert, iron-formation and quartz arenite. These have produced south-facing cuestas, which are separated by low-lying ground corresponding to shaley intervals (e.g. Princess Ranges, Wellington Range, Von Treuer Tableland). Breakaways, up to 30 m high, are best developed in Permian rocks capped by silcrete or laterite (e.g. Tooloo Bluff, Panton Bluff). Low breakaways are characteristic of deeply weathered granitic rocks in the southwestern part of the area, and are also common in flat-lying shales in the Earaheedy Group.

The intermediate areas can be subdivided into two units: (a) sheet-wash plains and valley floors, and (b) eolian sand plain. Unit (a) includes flat, mulga-covered or bare plains of colluvium and alluvium, which have broad, ill-defined drainages characterized by thick vegetation. Eolian sand plain occurs over the granitoid rocks in the southwest part of the area, and over Permian rocks in the northeast and southeast corners, but is largely absent from the area underlain directly by the Earaheedy Group. The sand plain is gently undulating, and contains patchy development of longitudinal dunes 3 to 5 m high and up to 5 km long which have been stabilized by growth of spinifex.

Aggradational areas are characterized by the infilling of trunk drainages in the Cretaceous-Tertiary palaeodrainage system. Three physiographic units are present: (a) flat, bare salt lakes containing saline clay, which collect shallow saline water after heavy rain; (b) dunes and sheets of eolian and alluvial material marginal to salt lakes and containing numerous small salt lakes and claypans; and (c) calcreted valley floors in which low mounds of rubbly calcrete are separated by soil-filled depressions. In some areas the calcrete is being eroded by present-day drainage, leaving remnants of calcrete above the newly eroded valley floor.

PREVIOUS INVESTIGATIONS

The earliest reports are by explorers; Lawrence Wells traversed the area from east to west in 1892, and crossed the northwest corner in 1896; David Carnegie crossed the southeast corner in 1897 on his return journey from Halls Creek to Coolgardie.

The first geological studies were by Talbot (1920, 1926), who produced regional maps showing the extent of the sedimentary rocks ('Nullagine Series'), greenstones and granite. He recognized the glacial origin of the Permian beds (but mistakenly called them Cretaceous), and noted the occurrence of limestone, jasper, glauconitic sandstone, and dolerite, in the Proterozoic succession.

Mabbutt and others (1963) included the Kingston Sheet in an integrated study of the geology, geomorphology, climate, soils, vegetation, pastoral aspects and water supply of the Wiluna-Meekatharra area. The section on geology (by J. Solfoulis and J. A. Mabbutt) briefly describes the stratigraphy of Proterozoic rocks.

Sanders and Harley (1971) briefly described the geology in a report on the regional hydrogeology. They noted algal structures and oolites in the carbonate rocks, and recognized two periods of folding in the Proterozoic sequence.

Horwitz and Daniels (1967, p.51) reported ". . . a grouping of rocks that overlie the Archaean, south and west of Lake Carnegie in the Kingston Sheet area, where four bands of rhyolite have been recognized, interlayered with sediment and possible tuffs". No location details were given, and subsequent surveys have not found these rhyolites. It is probable that some pelletal cherts were misidentified (R. C. Horwitz, pers. comm.).

Hall and Goode (1975) distinguished the Lower Proterzoic rocks of the Nabberu Basin from those of the Middle Proterzoic Bangemall Basin, and proposed stratigrahic subdivisions, which were modified slightly and formally defined by Hall and others (1977). Horwitz (1975a, b) also recognized the existence of a Lower Proterzoic basin in this region. He divided the rocks below the Bangemall Group into two units separated by a major unconformity corresponding to a period of granitic intrusion. No evidence for this unconformity was found in the present study.

Aeromagnetic data have been compiled by the Bureau of Mineral Resources, and interpreted by Lambourn (1972). A Bouguer-anomaly map has been compiled by the Bureau of Mineral Resources.

ARCHAEAN

LAYERED SUCCESSION

Granitic and metamorphic rocks of the Yilgarn Block occupy the southwest part of the sheet (Fig. 2). These rocks are poorly exposed and commonly deeply weathered. The terrain is predominantly granitoid, but two greenstone belts are present. The westernmost belt, centred on Mount Eureka, forms the northern end of the Dingo Range greenstone belt which has been mapped on the Sir Samuel Sheet (Bunting and Williams, 1976). The eastern belt is part of a small, greenstone belt which, to the south, terminates against granitoid rocks on the Duketon Sheet (Bunting and Chin, 1975).

Mount Eureka greenstone belt

This belt contains steeply east-dipping, metamorphosed mafic, ultramafic, sedimentary, and possible felsic volcanic rocks. No facing evidence was found, but the sequence probably occurs on the eastern limb of the Wonganoo Anticline (Bunting and Williams, 1976).The predominant rock type, particularly southwest of Red Bluff, is fine-grained metabasalt (*Ab*) which commonly lacks a strong foliation, but which has a lineation defined by intersecting fracture cleavages. The metabasalt contains thin bands of chert, shale, and chlorite schist. Medium- to coarse-grained metagabbro (*Ad*) intrude the basalt. The metagabbro is also unfoliated, and has stumpy prisms of metamorphic amphibole set in an actinolite-plagioclase groundmass.

Ultramafic rocks (*Au*) are represented at the surface mainly by buff, silicic, ferruginous cap-rock (*Czj*). Only rarely have altered ultramafic rocks, in the form of talc-carbonate (sideritic)-serpentine-chlorite schist and serpentinized peridotite, survived weathering. The original nature of these ultramafic bodies is uncertain; they appear to be concordant with the surrounding layered succession.

A few scattered fragments of phyllite and kaolinized schist in the areas of non-exposure around Mount Eureka, and in small gold workings, indicate that much of the unexposed sequence may be fine-grained metasediments (*As*). Kaolinized, felsic volcanic rocks (*Af*) south of Irwin Bore are poorly bedded; and display vague shard textures, flow laminae, and irregular fragments 10 to 20 mm in size, which indicate a tuffaceous origin. The felsic volcanic rock is generally coarse grained, contains about 30 per cent quartz, and is interbedded with shaley layers.

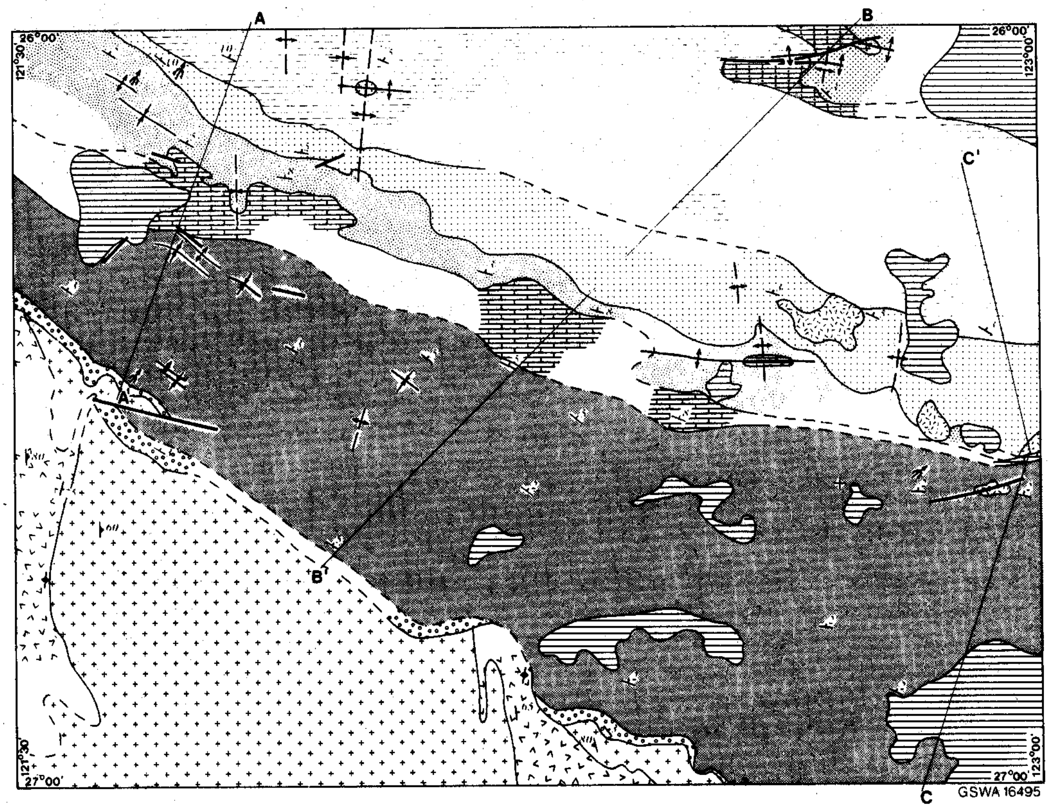
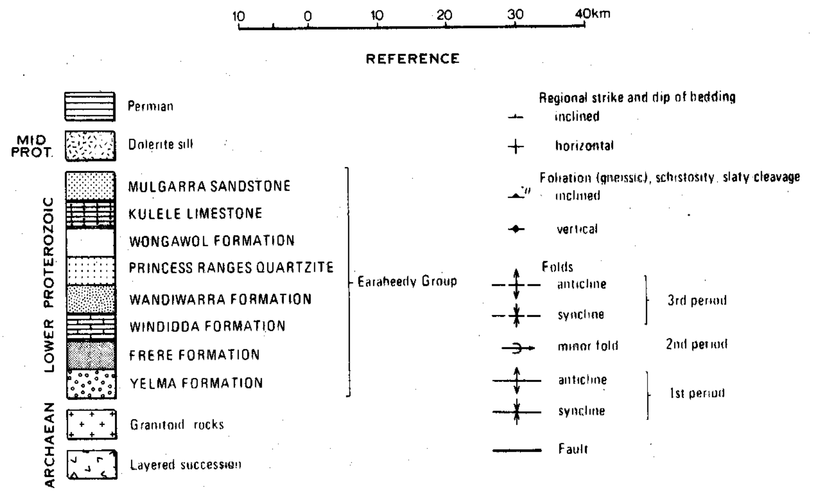


FIGURE 2

SOLID GEOLOGY AND STRUCTURE

KINGSTON SHEET SG 51-10



Banded iron-formation and associated ferruginous banded chert (*Ai*) form an intermittent strike-ridge 20 km long, extending from south of Doyle Well to 20 km southeast of Irwin Bore. Weathered magnetite bands, 1 to 3 mm thick, alternate with white quartz or grey chert bands 2 to 20 mm thick; rarely, the chert bands are red and jaspilitic.

Eastern greenstone belt

The main exposure in this greenstone belt form a complex strike-ridge of banded iron-formation, ferruginous chert, and interbedded shale, 35 km south-southeast of Old Windidda. Red-and-black banded jaspilite predominates on the eastern side of the ridge. Bands are 5 to 40 mm wide, and faint microbanding, less than 1 mm thick, is preserved in some bands. Grey chert-breccia, in which no primary banding is preserved, forms the western side of the ridge.

A few kilometres northeast, below breakaways in Permian glacial rocks, are poor exposures of felsic volcanic, and banded shaley rocks with minor chert. The felsic volcanic rocks are white, kaolinitic, and contain sparse feldspar laths and sub-rounded quartz grains. Where the rock is coarse grained, it contains angular blocks of possibly flow-banded lava up to 0.2 m across, and shows a crude banding 1 to 2 m wide.

GRANITOID ROCKS

Most outcrops of granitoid rock are deeply weathered (kaolinized) and poorly exposed; they have been included under the general symbol *Ag*. Where further subdivision is possible, three lithological types have been recognized. Of these, the most abundant is a fine- to medium-grained adamellite (*Age*), containing sub-equal amounts of plagioclase, microcline, quartz, and minor biotite. The rock commonly exhibits a weak gneissic foliation due to parallel alignment of quartz and biotite, and, in places, variable grain size causes a faint, irregular banding.

Adjacent to the layered succession south of Doule Well is a 2 to 3 km-wide zone of fine- to coarse-grained, deeply weathered granitoid having a strong gneissic foliation (*Agg*). This zone grades eastwards into the poorly foliated medium-grained adamellite (*Age*). Close to the contact with the layered succession, the granitoid contains irregular rafts of deeply weathered metasediments. A similar, foliated granitoid that intrudes the layered succession west of Mount Eureka contains alkali feldspar slightly in excess of plagioclase, as well as minor biotite, and abundant muscovite on foliation planes.

Coarse-grained biotite adamellite (*Agb*) in a single exposure 9 km northwest of Yelma is unfoliated and contains small clots of fluorite which weather as dark spots. The adamellite is similar to the Mount Boreas Adamellite which is shown on the Duketon Sheet to the south (Bunting and Chin, 1976). The Mount Boreas Adamellite has alkaline affinities, and has been dated at about 2 480 m.y. The exposure northwest of Yelma is directly in line with the north-northwest trend of the Mount Boreas Adamellite.

STRUCTURE

In both greenstone belts, the rocks dip steeply and strike north to north-northwest. Penetrative slaty cleavage or schistosity is developed in most rocks, and this deformational fabric is sub-parallel to the bedding in most cases. Neither belt reveals facing, or structural and stratigraphic evidence to indicate the presence of major folds. Minor asymmetrical folds are well-developed in the banded iron-formations south of Doyle Well, but the sense of asymmetry is contradictory along strike, which may indicate tight folding of these rocks. The axial surfaces are parallel to the regional foliation.

PROTEROZOIC

EARAHEEDY GROUP

The Lower Proterozoic Earaheedy Group occupies 80 per cent of the sheet. Stratigraphic terminology is as defined by Hall and others (1977); this is a refinement of the undefined terminology of Hall and Goode (1975).

Yelma Formation

The Yelma Formation is the basal unit of the Earaheedy Group along most of the unconformity with Archaean rocks (Figure 3). In the type section, 5 km northwest of Yelma, the formation is about 130 m thick, but it thins rapidly southeastwards; and near the southern sheet boundary, it is only 1 to 2 m thick. It may be absent over the eastern Archaean greenstone area.

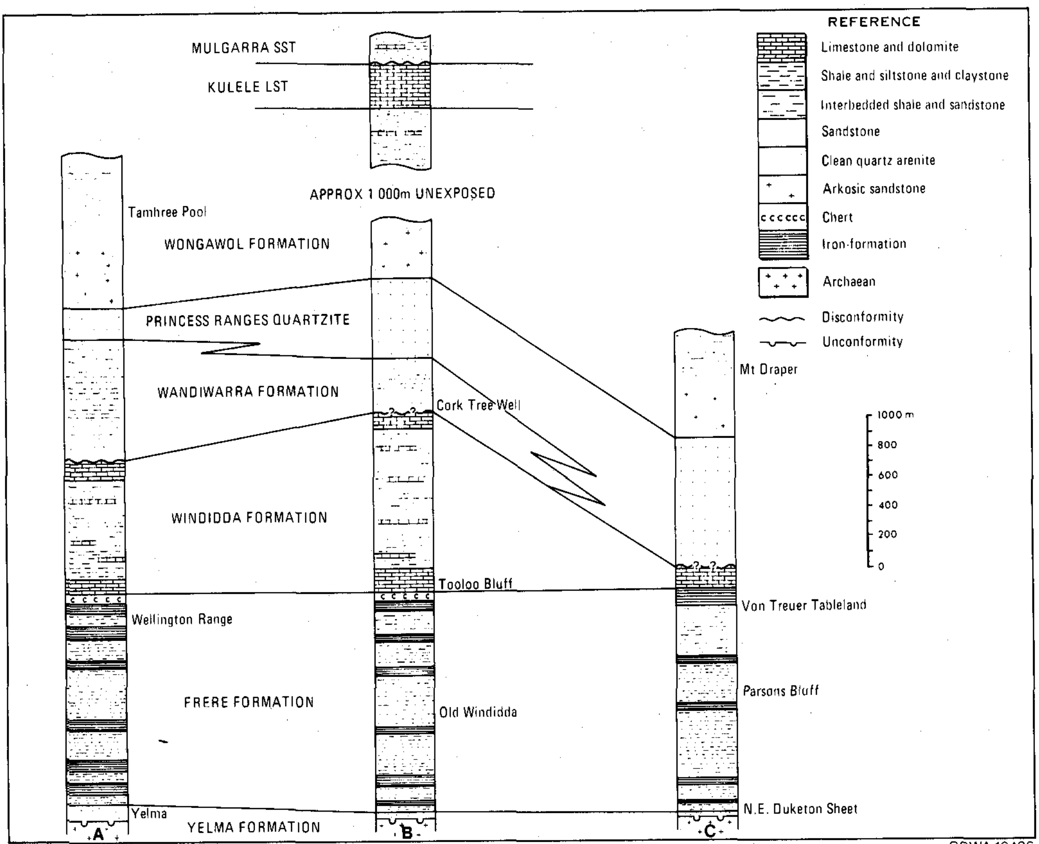


FIGURE 3
STRATIGRAPHIC COLUMNS
KINGSTON SHEET SG 51-10
Note : See Figure 2 for approximate lines of sections

The predominant lithology is fine- to coarse-grained quartz arenite. Grains are generally well-rounded, and cemented by authigenic silica. Locally, quartz-pebble conglomerate or pebbly arenite may be present as discontinuous bands close to the unconformity. Arkosic bands are common. Glauconite pellets occur sparsely in southeastern exposures, and glauconite from the Duketon Sheet gave a K-Ar age of 1 696 m.y. (Preiss and others, 1975).

The unconformity with the underlying granitic rocks can be seen at several localities in the vicinity of Yelma, including at the type section and near the southern boundary of the sheet. Regionally it is very flat, but local irregularities of a few metres do occur. The rock in contact with the granite is typically a clean, well-sorted quartz arenite, except where the basal beds are locally conglomeratic. This, combined with the general flatness of the unconformity surface, indicates deposition on a mature peneplain.

Ripple marks (predominantly symmetrical, but including linguiod and crescentic types), trough cross-bedding, and the presence of glauconite indicate a shallow-marine environment. The Yelma Formation represents a strand-line deposit associated with an extensive marine transgression.

Frere Formation

The Frere Formation lies conformably between the underlying Yelma Formation and the overlying Windidda Formation. Near the southern boundary of the sheet the Frere Formation may rest on Archaean basement.

Rock types include pelletal and oolitic iron-formations, chert, siltstone, fine-grained sandstone, and limestone; but siltstone forms over 90 per cent of the sequence. The next most abundant rock is iron-formation which occurs as 1 to 2 m bands within the siltstone. These bands are resistant to weathering and form the tops of hills in the cuesta-style topography. The ratio of iron-formation to shale increases slightly towards the northwest corner of the sheet, but increases dramatically further northwest on the Nabberu Sheet.

On the 1:250 000 map, the unit *ꝐEf* refers to this alternation of siltstone and iron-formation. Thick sequences of siltstone with sparse, thin bands of chert and fine-grained sandstone, are designated *ꝐEfs*. The siltstone is typically well laminated, buff, white, or maroon, and commonly displays small-scale cross lamination. The cross lamination occurs either as single sets of ripples, or as multiple sets of climbing ripples.

The iron-formations vary from virtually iron-free, greyish-green chert, through ferruginous chert to red, jasperoidal iron-formation containing secondary specular hematite. Apart from thin (20 mm) chert bands, which are commonly fragmented, these rocks are characterized by a granular texture which may be either pelletal, oolitic or a mixture of both. The pellets are rounded, sub-spherical grains consisting of ferruginous chert with red hematite dusting, and abundant steel-grey specular hematite alteration. The ooliths consist of concentric layers of hematite and chert, and show a complex history of fragmentation and re-growth. Both pellets and ooliths range from 1 to 2 mm in diameter and are enclosed in a matrix of chert. Shrinkage cracks are common in the pellets and ooliths. Individual beds of iron-formation range from a few centimetres to 1 m thick, and commonly display wavy bedding due to differential compaction of the bands. The textures and sedimentary structures of these iron-formations are comparable to the Superior-type iron-formations of North America (Gross, 1965; Dimroth and Chauvel, 1973).

Sparse lenses of carbonate (limestone and dolomitic limestone) occur in the Frere Formation. Near the southern boundary of the sheet a 4 m-thick band of grey-pink, laminated, and locally brecciated limestone marks the base of the formation. Carbonate bands occur at the same horizon on the Nabberu Sheet (Hall and Goode, 1978; Bunting and others, 1979) and Duketon Sheet (Preiss, 1976; Bunting and Chin, 1975). About 300 m above the base, 8 km west-southwest of Old Windidda, there is a 10 m-thick lens of pink to grey, poorly laminated limestone. A similar limestone forms a 5 m-thick lens near the top of the formation at the western end of the Wellington Range.

Pale green-grey, non-ferruginous, massive to pelletal chert (*ṔEfc*) forms a distinctive, but intermittent, marker band at the top of the formation from a point 3 km south of Lorna Glen to Tooloo Bluff. The chert typically contains abundant radial anastomosing cracks, probably dessication structures, which are filled with white vein-quartz.

Windidda Formation

The Windidda Formation, which lies conformably on the Frere Formation, consists of interbedded carbonates and shaley mudstone. It is about 1 200 m thick at the type section near Windidda homestead, but thins eastward and westward. On the Kingston Sheet, the formation is disconformably overlain by the Wandiwarra Formation, but to the northwest it probably grades laterally into the Wandiwarra Formation.

The lower contact with the Frere Formation is well exposed near Tooloo Bluff where striped, pink and grey limestone interfingers with grey pelletal chert. Hall and Goode (1978) report chamositic chlorite in ankeritic carbonate rock near the base of the Windidda Formation. Thin shale bands are rare in the lower part of the formation, but become more abundant in the central part. In the type section, this central part, from about 400 m to 1 100 m above the base, consists of green or maroon micaceous mudstone with thin bands of grey, stromatolitic limestone, and limestone breccia.

The top of the formation is well exposed north of Wongawol Creek, where ferruginous sandstone (Wandiwarra Formation) overlies limestone and limestone breccia. The contact is marked by a small scarp which can be followed intermittently for some 30 km. The breccia contains flat, angular clasts of laminated limestone in a micritic carbonate matrix. The contact with the overlying sandstone is sharp, and is probably an erosional disconformity between the limestone and the transgressive sandstone.

Stromatolites are common in the lower part of the formation. The predominant forms are bulbous domes 50 to 200 mm high which are rarely interconnected. Preiss (1976) described stromatolites from the Windidda Formation at Mount Elisabeth, just off the eastern boundary of the Kingston Sheet. Principal forms present are *Tungussia heterostroma*, a bulbous branching form, and *Minjaria granulosa* which occurs as elongate colums, rarely branching. Jackson (1978) describes the regional setting of this locality.

Wandiwarra Formation

The Wandiwarra Formation, on the Kingston Sheet, disconformably overlies the Windidda Formation. It consists of clastic rocks ranging from coarse sandstone to shale. The sandstone is a moderately well-sorted, pale-grey, ferruginous quartz arenite which locally contains glauconite pellets. Sedimentary structures include shaley or sandy intraclasts, ripple marks, cross beds, and rare flute casts.

At the type section, near Cork Tree Well, the formation is about 350 m thick. Northwestward it thickens to about 500 m, and southeastward it thins and disappears, as it grades laterally into the overlying Princess Ranges Quartzite.

North of Wongawol Creek, the basal unit of the formation is a thin, ferruginous and glauconitic sandstone, which sits disconformably on carbonate breccia of the Windidda Formation. The sandstone displays lustre mottling due to "poikilitic" calcite crystals. At a point 10 km bearing 060° from Mount Wellesley this basal unit contains abundant sub-angular fragments of the underlying Windidda Formation limestone, up to 0.3 m across.

A 150 to 200 m-thick unit of shale and fine-grained sandstone near the top of the formation underlies a strip of low ground between Skull Soak and Two Mile Creek. The sandstone is grey brown, micaceous, and chloritic. The shale, which is best exposed at Skull Soak, is green-grey and finely laminated. It probably is the deepest marine facies in the Earaheedy Group. At the top of the formation, a shallowing of the water is indicated by tongues and thick lenses of mature quartz arenite—the precursors of the overlying Princess Ranges Quartzite.

Horwitz (1975b) reported a K-Ar age of 1 685 m.y. from glauconite in sandstone from the Princess Ranges. The locality cited (121°57′E, 26°14′S) places this sample near the base of the Wandiwarra Formation.

Princess Ranges Quartzite

The Princess Ranges Quartzite is a clean, white, well-sorted quartzite. The grains are rounded, and cemented by authigenic silica, which is commonly in optical continuity with the overgrown grain. Glauconite and tourmaline are scarce accessories. Rhomboid, ferruginous spots, up to 30 mm long, form up to 30 per cent of the rock, and are probably weathered-out rhombs of carbonate cement.

The formation typically forms rugged hills and cuestas covered with quartzite rubble. Where major creeks have cut through the ranges (for example, at the type section 6 km east-southeast of Skull Soak) the quartzite is seen to form bands from 1 to 20 m thick, interbedded with white, kaolinitic siltstone and clayey sandstone. The quartzite bands are thick bedded, and show a 10 to 20 mm lamination. Sedimentary structures are abundant and include trough cross-bedding, ripple marks (mostly symmetrical), sandy intraclasts, and enigmatic, vermiform flute- or load-casts. In the type section, some beds show evidence of intraformational folding, ball and pillow structures, and injection of material into the overlying bed.

The Princess Ranges Quartzite is about 250 m thick in its type section, but thickens southeastward, at the expense of the Wandiwarra Formation, the upper part of which becomes more mature. Near the sheet boundary east of Prenti Downs, the Princess Ranges Quartzite overlies Windidda Formation.

Wongawol Formation

The Wongawol Formation (Hall and others, 1977) is a combination of the Wongawol Sandstone and Sholl Creek Formation orginally proposed by Hall and Goode (1975). The Sholl Creek unit was given member status (Hall and others, 1977). It forms a carbonate-bearing unit at the top of the Wongawol Formation, but, because the first carbonate band, marking the base of the unit, is too discontinuous to map in detail, the member is not distinguished on this map.

The Wongawol Formation is conformable on the Princess Ranges Quartzite, and marks the transition from coarse clastic to carbonate deposition. The lower part of the formation is a monotonous sequence of grey to pinkish-brown, fine-grained sandstone and siltstone. The sandstone is arkosic, micaceous, and displays spectacular convolute bedding. Small-scale cross-beds, ripple marks and load casts are common. About 1 km southwest of the point where Wannabooline Creek crosses the Wiluna to Carnegie road, and band of ferruginous and manganiferous breccia is interbedded with the shale. The breccia contains chert and shale fragments set in a matrix of quartz, glauconite, carbonate, and iron-oxide minerals. Adjacent to the large fragments, glauconite and carbonate grains have been smeared out and moulded against each other and against quartz grains, in a compaction texture similar to the 'accommodation shards' described by Dimroth and Chauvel (1973). Much of the original glauconite and carbonate have been replaced by coarsely crystalline calcite, giving a lustre-mottled appearance to the rock.

The formation is largely obscured by Lake Carnegie but on the Stanley Sheet it becomes finer upwards and intermittent carbonate bands appear (Commander and others, 1979). The upper part of the formation is well exposed in the northeast part of the sheet near Bulljah Pool, where it consists of very fine micaceous sandstone and shale with rare limestone and limestone breccia beds.

Total thickness is probably 1 500 to 2 000 m, but shallow dips and abundant gentle folds make precise calculations difficult. The formation is conformable on the Princess Ranges Quartzite, and the transition between the two formations is rapid. South of Wongawol homestead the contact is marked by several metres of alternating quartzitic and fine-grained impure sandstone beds.

Kulele Limestone

The Kulele Limestone conformably overlies the Wongawol Formation, and is about 300 m thick. It consists of repeated bands of limestone, breccia, calcarenite, and shale. Minor but prominent sandstone bands occur between 150 and 200 m above the base. The limestone can be either planar laminated, stromatolitic, massive crystalline, or oolitic. The stromatolities form elongate domes several metres across, each of which contains abundant stromatolite columns, 20 to 30 mm in diameter. The calcarenite consists of quartz and carbonate grains in a carbonate matrix, and displays abundant trough and herringbone cross bedding.

Mulgarra Sandstone

The Mulgarra Sandstone lies with sharp, and probably disconformable contact, on the underlying Kulele Limestone. The dominant lithology is a medium-grained, grey to brown, ferruginous quartz arenite with minor glauconite. The middle part of the formation contains minor shale and carbonate bands; on the Stanley Sheet this interval is overlain by sandstone similar to that in the lower part of the formation.

The Mulgarra Sandstone is the youngest known formation of the Earaheedy Group. To the east it is overlain by Phanerozoic sediments of the Officer Basin.

STRUCTURE

On the Kingston Sheet, the Earaheedy Group dips gently north-northeastwards on the southern side of the Nabberu Basin. The main synclinorial axis of the basin lies some 10 to 20 km north of the sheet boundary, on the Stanley Sheet.

Dips vary from about 5° in the northwest corner of the sheet to about 2° in the southeast. This stable area forms part of the Kingston Platform (Bunting and others, 1977; Hall and Goode 1978), which is characterized by gentle dips, lack of penetrative deformation, and lack of metamorphism.

Despite the absence of penetrative deformation, three periods of minor folding are recognized. Intensity and abundance of folds decrease from northwest to southeast.

The earliest and dominant folding took place along roughly west-northwest-trending axes, parallel to the regional strike. Folds are generally asymmetrical, with short, steeply southward-dipping limbs and long, gently northward-dipping limbs; some are almost monoclinal. Axial surfaces dip moderately to steeply northward. These folds are commonly associated with small reverse or high-angle thrust-faults, and probably reflect reverse faulting in the Archaean basement. This style of folding is best illustrated in the Wellington Range and west of Banjo Well.

A second period of folding, along north-northeast-trending axes took place in the northwest corner of the sheet. These folds are generally asymmetrical, have steeply dipping axial surfaces, and produce complex fold-patterns where they affect the earlier asymmetrical folds.

The last period of folding was a gentle warping along north-trending axes. Examples can be seen near Lynne Bore and Boondin. To the west and northeast of Lake Carnegie these later folds have produced a dome-and-basin interference pattern where they intersect east-trending asymmetrical folds of the earliest period.

Faulting has played only a minor part in the deformational history of the group, although steep thrust, or reverse, faults in the granitic basement may have been responsible for some of the asymmetric and monoclinal folds. Most faults trend $090 \pm 20°$ and have a downthrow to the south. In the Yelma area, one such fault is inferred to have repeated the Yelma Formation on the south side of a wedge of granite.

DEPOSITIONAL HISTORY

The Yelma Formation records a major marine transgression across a peneplained surface of Archaean rocks. Although some arkosic material was derived from the underlying granitoid rocks, the maturity of much of the sandstone is indicative of a lengthy period of transportation prior to deposition. This was followed by a long period of shallow-water sedimentation, in which iron formations, cherts, siltstones and carbonates were deposited. The presence of abundant ripple cross-laminae, including climbing ripples, in the siltstones and fragmentary textures and ooliths in the iron formations, indicate current or wave action in shallow water. The Windidda Formation marks a regression of the sea, accompanied by the development of tidal flats (mudstones) and carbonate banks, which culminated in a short period of emergence.

This emergence and the subsequent transgression (Wandiwarra Formation) were probably restricted to the south eastern part of the Nabberu Basin. To the northwest (Nabberu Sheet), there was an apparently continuous deposition of shale and sandstone during the period of Windidda and Wandiwarra sedimentation. The Wandiwarra Formation indicates a gradual deepening of the basin which was terminated by a partial regression with the incoming of mature, shallow water arenites of the Princess Ranges Quartzite. This partial regression appeared earlier in the southeast part of the sheet and gradually worked its way northwestwards, either as a deltaic front or, more likely, as a series of sand bars.

The Wongawol Formation is a slightly deeper water facies than the underlying arenite. A further shallowing, with reduced sediment input, produced the carbonate-shale interval at the top of the Wongawol Formation, and came close to emergence with the appearance of stromatolitic carbonate in the Kulele Limestone. Fluctations in sea level and amount of coarse, clastic material resulted in the alternate sandstone, shale, and carbonate bands of the upper part of the Kulele Limestone. The Mulgarra Sandstone represents a minor transgression, possibly following a brief period of emergence.

In summary, the Earaheedy Group records a variety of marine, shelf, and shoreline environments, characterized by variable amounts of clastic input, and fluctuating, but predominantly shallow, water.

DOLERITE INTRUSIONS

Fine-grained dolerite sills intrude the Earaheedy Group on the eastern part of the sheet. Upper contacts display slight discordance and chilled margins against the country rock. The dolerite consists of a sub-ophitic intergrowth of pyroxene and saussuritized plagioclase, and shows little variation in texture or mineralogy in outcrop. It intrudes all formations from the Frere Formation to the Princess Ranges Quartzite, and is known to intrude the Kulele Limestone and Mulgarra Sandstone on the adjacent Stanley Sheet.

Compston (1974) records a Rb-Sr age of 1050 ± 50 m.y. for similar dolerite from the central Robert Sheet area.

PERMIAN

The early Permian Paterson Formation (Lowry and others, 1972) is a mixed unit of conglomerate (diamictite), sandstone, and claystone representing glacial, fluviatile, and glacio-lacustrine environments. The formation is exposed in breakaways where it is seen to be flat-lying and undeformed; only rarely is there a measurable dip.

The glacial rocks (*Pag*) are diamictites in which pebbles and boulders are set in a sandy clay matrix. Stratification is absent or ill-defined. Clasts include pelletal iron-formation, chert, quartzite, quartz, a variety of granitoid rocks, and rare mafic and felsic rocks from the Archaean layered succession. Scarce striated boulders testify to a glacial origin. Clast size ranges from a few centimetres to over 2 m. The diamictite commonly weathers to leave areas of colluvium strewn with boulders. The distribution of rock types in these boulder fields suggests ice movement in a northerly or northeasterly direction, off the Yilgarn Block. Boulders of Frere Formation are common immediately over, and north of, the area underlain by Frere Formation, whereas boulders from the equally distinctive and resistant Princess Ranges Quartzite are absent south of the Princess Ranges, but present northwards in the vicinity of Boondin and Mount Draper.

Lacustrine and glacio-lacustrine rocks (*Pal*) occur interbedded with, and overlying, the glacial rocks. The claystone and siltstone of this unit are white, kaolinitic, thinly laminated and contain rare dropstones. At Mount Wellesley, laminated siltstone contains friable carbonaceous beds 0.1 to 0.15 m thick.

The fluviatile deposits (*Paf*) generally occur at the top of the Paterson Formation but may be interbedded with either the glacial or the glacio-lacustrine facies. The typical fluviatile deposit is poorly sorted, kaolinitic, coarse-grained sandstone which is poorly bedded and occasionally trough cross-bedded. Lenses of siltstone and quartz pebble conglomerate are common. Five kilometres west of The Jump Up well-exposed outwash plain (sandur) deposits are exposed in a 20 m-high breakaway. These consist of alternate sandstone and conglomerate beds which are better sorted than the glacial diamictite, but less well-sorted than the fluviatile deposits. Bedding is very irregular. Scour structures and single sets of trough and planar cross-bedding are abundant.

CAINOZOIC

UNDIFFERENTIATED

Except for calcrete (*Czk*), the undifferentiated Cainozoic units are restricted to the deep weathering profile, which consists of siliceous or ferruginous duricrust passing downward into mottled and pallid zones. Silcrete (*Czb*) forms a siliceous duricrust on top of deeply weathered granitic rocks, Phanerozoic rocks, and sediments of the Earaheedy Group. It is a hard, grey-green rock consisting of angular to rounded grains (mostly quartz) set in a matrix of micro-crystalline silica.

Ferruginous duricrust, or laterite (*Czl*), occurs mainly over rocks of the Archaean layered succession, but it can occur over Permian rocks, Proterozoic iron-rich or shaley sediments, and dolerite. It varies from pale-brown, pisolitic limonite and goethite, to dark-brown, massive hematite and goethite. On ultramafic rocks, the equivalent of laterite is a capping of ferruginous opaline silica (*Czj*) which varies from pale buff over talc-carbonate rocks to dark brown over serpentinite.

Silcrete and laterite generally pass downward into the mottled and pallid zones of the weathering profile (*Czo*), although in some areas (e.g. the dolerite southeast of Prenti Downs) the laterite passes abruptly into fresh bedrock. Deep-weathering in the mottled and pallid zones involves the breakdown of feldspar, mica and mafic minerals to form clay minerals (mostly kaolin) and oxides. Many of the original structures are preserved, and it is usually possible to identify approximately the original rock type.

Calcrete (*Czk*) is a deposit of limestone and opaline silica, formed by partial replacement of soil material in major drainages. It formed after the trunk valleys of the palaeodrainage system had been filled, probably in the late Tertiary, and is now being eroded in those drainage lines which are still active (e.g Banjo Creek). The calcrete may be nodular, massive or laminated and is typically cavernous. On the adjacent Robert Sheet drilling shows that the calcrete is up to 40 m thick (Jackson and others, 1975), but most of the calcrete in the Kingston Sheet is probably under 10 m thick.

QUATERNARY

Colluvial deposits, which consist of unconsolidated rock and quartz fragments in loam (*Qc*), form a blanket of debris extending from scree slopes below outcrop, through gently sloping pediments, to extensive, flat, low-lying plains; a variation consists of clayey and sandy loam with no coarse fragments (*Qz*). Over much of the sheet, both units pass downward, at very shallow depth, into an iron-cemented hardpan, termed the Wiluna Hardpan by Bettenay and Churchward (1974). Hardpan may be absent in low-lying areas of colluvium flanking salt lakes, major drainage washes, and in scree areas close to outcrop.

Alluvium (*Qa*) occurs in broad, ill-defined drainage lines ranging from small creeks with thick mulga growth, to wide flood plains in the lower reaches of the drainage systems. The deposits are poorly sorted and contain material ranging from clay to pebble size.

Eolian quartz sand (*Qs*) forms one of the most extensive units on the sheet, particularly over Archaean and Permian rocks. The quartz is well-sorted and has an iron-oxide patina which gives the sand a pale-yellow to red-brown colour.

Two units related to the salt-lake system are recognised. Clay and silt form bare expanses of lacustrine material (*Ql*) which contains sand, salt, and gypsum. This unit is usually covered by a few centimetres of saline water after heavy rain. Marginal to the lacustrine unit, and in places completely covering it, is a mixed unit

(*Qg*) containing eolian dunes and sheets of gypsum or quartz sand. Alluvial flats and small claypans that may contain fresh water are scattered between the dunes. Some dunes in the Lake Carnegie area contain sand deposits similar to *Qs*, but because the deposition of the sand was controlled by the presence of the bare lake surface, these sand deposits are included in the *Qg* unit.

ECONOMIC GEOLOGY

GOLD

The only mineral production recorded for the sheet is from the Mount Eureka gold-mining centre. Between 1932 and 1937, 2 997 g of gold was won from 144.5 t of ore at an average grade of 20.74 g/t. The gold occurs in quartz veins in silicified talc-carbonate schist, often at the contacts with thin chert bands. Some occurrences east of Mount Eureka are in quartz reefs in deeply weathered metasediment.

IRON

Since 1973, the iron formations of the Frere Formation have been explored for iron ore. To date, no ore bodies have been reported, and on the Kingston Sheet, the beds of iron formation are too thin (1-2 m) and show insufficient secondary enrichment to provide any prospect of an orebody.

GROUNDWATER

Aquifers in superficial deposits supply most of the existing bores and wells, and are the only potential sources of usuable groundwater. The Permian fluvio-glacial deposits are not extensive enough to provide a catchment area. The Proterozoic and Archaean rocks are generally too impervious to make suitable aquifers, although small amounts of water may be obtained from joints and fracture systems.

Most areas, with the exception of the salt lakes and saline drainages where the salinity is too high, and the sandplain areas where there is insufficient concentration of run-off to produce recharge, will supply small quantities of stock water. Calcrete and alluvial valley-fills are the best potential groundwater sources, and these have been discussed by Sanders (1969) and Sanders and Harley (1971). Both these reports give salinity information, and delineate the extent of the usable deposits. Three recommended aquifer areas are at Lorna Glen, Banjo Creek between Beru Pool and Alf Bore (saline in its lower part), and between Lake Jefferies and Miningarra Creek. The hydrological characteristics of the Lorna Glen aquifer were investigated in some detail by Chapman (1962) who concluded that 0.45×10^6 kL of irrigation water per year was available from a catchment area of about 130 km^2.

Brookfield (Mabbutt and others, 1963) related the distribution and yield of groundwater to a variety of physiographic units.

ACKNOWLEDGEMENTS

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Petrological work on some samples was carried out by J. R. Muhling of the Geological Survey of Western Australia.

TABLE 1: Co-ordinates of localities mentioned in text

	Latitude	*Longitude*
Alf Bore	26°27′	121°58′
Banjo Creek	26°20′	122°04′
Banjo Well	26°29′	121°47′
Beru Pool	26°25′	121°38′
Boondin	26°28′	122°47′
Bulljah Pool	26°03′	122°39′
Cork Tree Well	26°23′	122°21′
Doyle Well	26°34′	121°34′
Irwin Bore	26 44′	121°31′
Jump-up	26°37′	122°48′
Lake Carnegie	26°10′	122°25′
Lake Jefferies	26°37′	122°04′
Lake Wells	26°40′	122°59′
Lorne Glen	26°13′	121°33′
Lynne Bore	26°21′	122 32′
Miningarra Creek	26°19′	122°14′
Mount Draper	26°19′	122°53′
Mount Eureka	26°34′	121°32′
Mount Wellesley	26°16′	121°41′
Old Windidda	26°38′	122°03′
Panton Bluff	26°39′	122°43′
Parson Bluff	26°49′	122°59′
Prenti Downs	26°31′	122°48′
Princess Ranges	26°07′	121°50′
Red Bluff	26°23′	121°31′
Skull Soak	26°02′	121°40′
Tamhree Pool	26°02′	121°55′
Tooloo Bluff	26°26′	122°13′
Two Mile Creek	26°12′	121°56′
Von Treuer Tableland	26°37′	122°50′
Wannabooline Creek	26°02′	122°01′
Wellington Range	26°18′	121°47′
Windidda	26°23′	122°13′
Wongawol	26°07′	121°56′
Wongawol Creek	26°14′	121°49′

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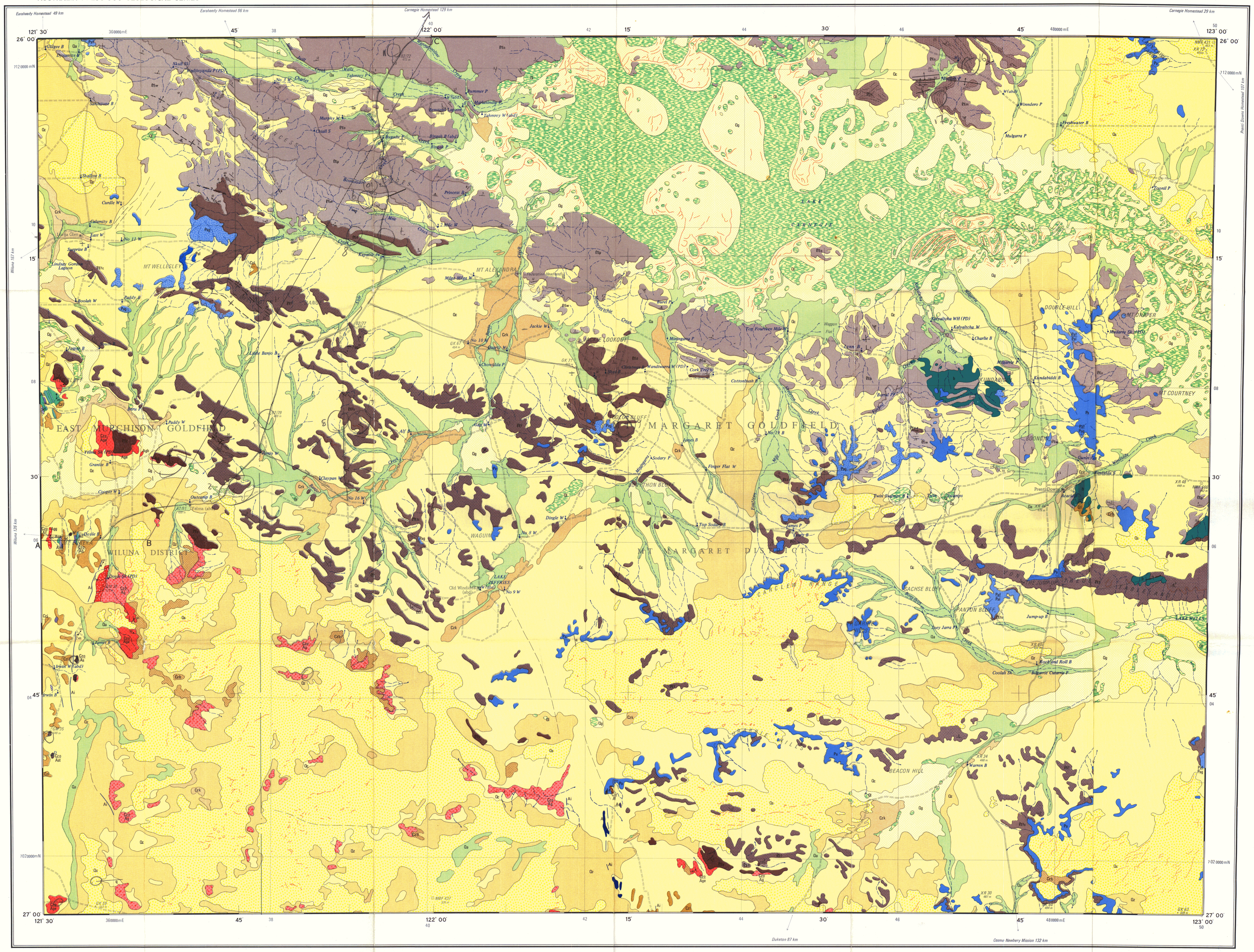
AUSTRALIA 1 : 250 000 GEOLOGICAL SERIES

KINGSTON

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SG 51-10



SYMBOLS

- Geological boundary
- Fault
  - Accurate
  - Inferred
- Fold
  - Anticline, accurate
  - Anticline, approximate
  - Syncline, accurate
  - Syncline, approximate
  - Minor anticline, azimuth and plunge of axis, dip and strike of axial surface
- Bedding
  - Inclined
  - Horizontal
  - Trend line
- Air photo interpretation of bedding
  - Dip < 5°
  - Dip 5°– 10°
- Cleavage, vertical
- Foliation
  - Inclined
  - Vertical
- Lineation, azimuth and plunge
- Air photo lineament
- Stromatolite locality
- Type-section locality

- Goldfield boundary
- Formed road
- Track
- Homestead — Windidda
- Building
- Landing ground
- Horizontal control, minor
- Vertical control, height accurate — GK 67 454 m
- Breakaway
- Sand dune

- Watercourse, intermittent
- Pool — P
- Bore — B
- Well — W
- Windpump
- Soak — Sk
- Dam — D
- Abandoned — (abd)
- Position doubtful — (PD)

- Mine (gold, abandoned)

REFERENCE

CAINOZOIC

QUATERNARY

Ql	Lake deposits – clay, silt, sand, saline and gypsiferous
Qg	Quartz sand and gypsum deposits marginal to salt lakes; eolian
Qa	Alluvium – poorly sorted clay to pebble deposits in drainage lines and adjacent flood plains
Qc	Colluvium – quartz and rock fragments in loam; commonly contains hardpan
Qz	Colluvium – clayey to sandy loam; sheet-wash deposit; commonly contains hardpan
Qs	Eolian sand
Czl	Laterite – massive and pisolitic ferruginous duricrust
Czb	Silcrete – sub-vitreous siliceous duricrust with angular quartz grains
Czj	Jasperoidal chalcedony and siliceous limonite deposits over ultramafic rocks
Czk	Calcrete – massive, nodular and sheet carbonate with minor chalcedony
Czo	Deeply weathered rock; kaolinized, subsequently ferruginized and silicified

PALAEOZOIC — LOWER PERMIAN

Pa	**PATERSON FORMATION:** poorly sorted sandstone, siltstone claystone and conglomerate
Paf	Poorly sorted sandstone, conglomerate, minor siltstone, dominantly fluviatile
Pal	Claystone and siltstone, minor erratics; lacustrine
Pag	Conglomerate, minor sandstone; glacigene, probably tillite

PROTEROZOIC

MIDDLE PROTEROZOIC

b	Dolerite sill

LOWER PROTEROZOIC — Earaheedy Group

PEm	**MULGARRA SANDSTONE:** fine to medium-grained quartz sandstone, locally glauconitic; minor carbonate bands
PEk	**KULELE LIMESTONE:** stromatolitic limestone and calcarenite; minor sandstone and shale bands in upper part
PEo	**WONGAWOL FORMATION:** fine arkosic sandstone grading upwards into mudstone and carbonate
PEp	**PRINCESS RANGES QUARTZITE:** clean white quartz arenite; minor clayey sandstone and siltstone
PEw	**WANDIWARRA FORMATION:** fine to coarse-grained quartz sandstone and shale; locally glauconitic
PEd	**WINDIDDA FORMATION:** limestone, shale, minor carbonate-clast conglomerate; stromatolitic in part
PEf	**FRERE FORMATION:** pelletal and banded iron-formation, hematitic shale, chert, shale
PEfc	Pale grey-green pelletal chert
PEfs	Shaley siltstone, minor chert and fine-grained sandstone
PEfl	Limestone and dolomite, stromatolitic in part
PEy	**YELMA FORMATION:** quartz arenite, minor arkose and shale

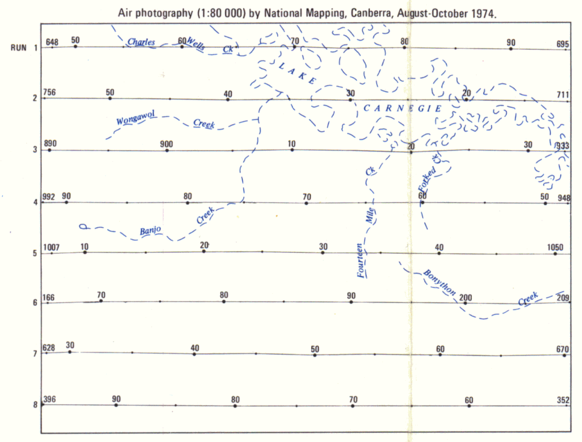
q	Quartz dyke

ARCHAEAN

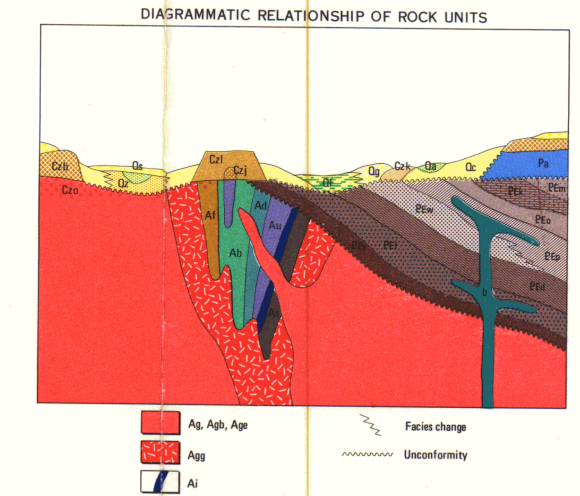
Ag	Undivided granitic rock
Agb	Adamellite; coarse-grained, minor fluorite
Age	Adamellite; fine to medium-grained
Agg	Granitic rock; strong gneissic foliation, fine to coarse-grained
Ai	Banded iron-formation, jaspilite, ferruginous chert
As	Metasedimentary rock, fine-grained, schistose, kaolinitic
Ast	Fine-grained, bedded quartz-sericite-kaolin rocks; probably volcanoclastic; schistose
Af	Felsic volcanic rocks; crudely banded with volcanic fragments
Ab	Fine-grained mafic rocks; metamorphosed tholeiitic basalt
Ad	Medium to coarse-grained mafic rock; metamorphosed dolerite and gabbro
Au	Undivided ultramafic rock
Aup	Serpentinized medium to coarse-grained peridotite
Aue	Altered ultramafic rocks; talc-carbonate-chlorite-serpentine assemblages, schistose

FLIGHT DIAGRAM

Air photography (1:80 000) by National Mapping, Canberra, August-October 1974.



DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



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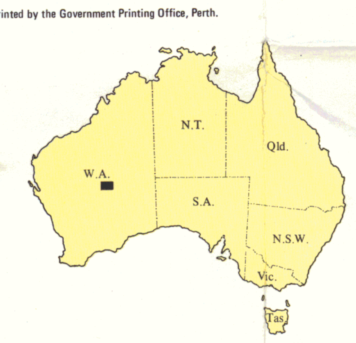
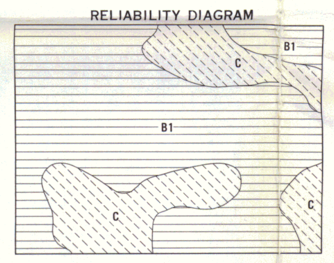


RELIABILITY DIAGRAM



B1 Numerous traverses with air photo interpretation
C Air photo interpretation

HON. P.V. JONES, M.L.A.
MINISTER FOR MINES
A.F. TRENDALL, DIRECTOR, GEOLOGICAL SURVEY

SCALE 1 : 250 000

5 0 5 10 15 20 25 30 Kilometres

TRANSVERSE MERCATOR PROJECTION
ZONE 2 AUSTRALIA SERIES
Grid represents 10000 metre superimposed Australian Map Grid

INDEX TO ADJOINING SHEETS

NABBERU SG 51-5	STANLEY SG 51-6	HERBERT SG 51-7
WILUNA SG 51-9	KINGSTON SG 51-10	ROBERT SG 51-11
SIR SAMUEL SG 51-13	DUKETON SG 51-14	THROSSEL SG 51-15

Geology by J.A. Bunting (G.S.W.A.) 1975–1976, with supplementary information from mapping by W.D.M. Hall and A.D.T. Goode (Broken Hill Pty. Co. Ltd.) and M.J. Jackson (Bureau of Mineral Resources, Canberra)

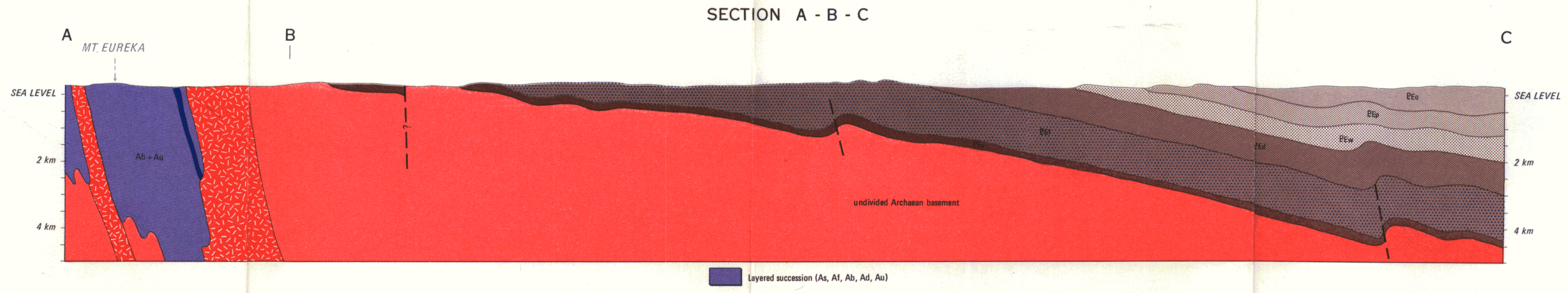
DECLINATION DIAGRAM

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 SECTION

SECTION A - B - C



Layered succession (Au, Af, Ab, Ad, As)

KINGSTON
SHEET SG 51-10

FIRST EDITION 1980