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EXPLANATORY NOTES

KENNEDY RANGE, W.A.

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Department of National Development
Bureau of Mineral Resources, Geology and Geophysics

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

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Compiled by M. A. Condon

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DEPARTMENT OF NATIONAL DEVELOPMENT.

Minister: SENATOR THE HON. W. H. SPOONER, M.M.

Secretary: H. G. RAGGATT, C.B.E.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

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Explanatory Notes on the Kennedy Range Geological Sheet

Compiled by
M. A. Condon

INTRODUCTION

The Kennedy Range Sheet covers the area between Latitudes 24° and 25° South and Longitudes 114° and 115°30' East. The geological map results from field work of parties of the Bureau of Mineral Resources in the years 1948 to 1953.

Air photographs obtained by the Royal Australian Air Force were used as bases for the plotting of geological boundaries. Information from individual photographs was transferred to controlled topographic base-maps at photo-scale prepared by the Lands and Survey Department, W.A., and these Sheets were reduced and compiled on the 1:250,000 base map produced by the Division of National Mapping.

In these notes, several new stratigraphic names are introduced. The units so named were recognized by the author and measured and mapped by himself and the other members of the Bureau parties.

Gregory's section (1861) eastward from Babbage Island (Carnarvon) is the earliest published record of geological work in the area of the Kennedy Range Sheet. West-dipping Palaeozoic sediments were shown as Devonian(?), Carboniferous(?) and Permian(?); the overlying 'Cretaceous(?)' included the sandstone of the Kennedy Range.

Hudleston (1883) described a collection of rock and fossil specimens forwarded by John Forrest. Fossils (from the Callytharra Formation between the Gascoyne and Minilya Rivers) were described and referred to the Lower Carboniferous.

Maitland discovered the glacial sediments in 1901, and named them the Lyons Conglomerate (1912). He examined the Palaeozoic sediments in the area between the Gascoyne and Lyndon Rivers (1909), and described limestone (belonging to the Callytharra Formation and the Moogooree Limestone) and sandstone (Kennedy Group). In 1919 he named 'North-West Artesian Basin' and showed the outlines of the basin on a very small scale map of Western Australia.

Waterford, in about 1937, examined the area south of Merlinleigh. This work was not published, but he made a good collection of fossils from the Callytharra Formation and Byro Group that were examined by Crespin (1937).

Between 1940 and 1950, Teichert did several reconnaissance trips through the area (Teichert, 1941, 1947, 1949, 1950, 1952).

Raggatt carried out a reconnaissance of the area north of the Gascoyne River for Oil Search Ltd in 1934. He established the main outlines of the stratigraphy of the Permian and Cretaceous (Raggatt, 1936). Raggatt & Fletcher (1937) listed the fossils then known from the Carnarvon Basin and examined the problems of the Carboniferous-Permian boundary in Australia and the Indian area generally.

Geologists of the Bureau of Mineral Resources mapped the Kennedy Range Sheet in 1949, 1953, and 1955 (Condon, 1954).

The present sheet is entirely the result of the mapping by the Bureau geologists, although much of the stratigraphic nomenclature is adapted from Raggatt's and Teichert's work.

PHYSIOGRAPHY

The area consists mainly of plains at two levels, the higher at 900 to 1,200 feet above sea level and the lower from about 100 to 800 feet above sea level; the two plains are generally separated by a steep scarp 100 to 400 feet high; both plains slope gently westward.

The Kennedy Range consists of the largest part of the high-level plain and the surrounding scarps. Smaller erosional remnants of the high-level plain include the mesa on which is Trig. Point K-43, buttes at K-35 and K-49, and the mesa 10 miles east-south-east of Moogooree Homestead. The low-level plain includes the alluvial fan of the Gascoyne River, the sand plain west of the Kennedy Range (probably a plain of marine erosion cut mainly in Cretaceous sedimentary rocks) and the outcrop plain to the north, east, and south of the Kennedy Range in the drainage of the Minilya, Lyons, and Gascoyne Rivers.

The north-flowing drainage in the north part of the area is tributary to the Minilya River; the Lyons River drains the eastern part and the Gascoyne River the southern. The drainage west of the Kennedy Range disappears in the sand plain — none of the streams reaches the sea or even the Salt Lake. All streams are intermittent, flowing only for short periods after heavy rain. In the Kennedy Range deep young gorges are cut, but elsewhere the valleys are open.

In the north-eastern part of the Sheet, the drainage is dendritic and the minor relief is about 100 feet. The surface is mainly undulating with some sharp ridges where quartz reefs crop out.

Longitudinal (seif) dunes, generally somewhat anastomosing, cover the high-level plain and much of the western part and small areas of the eastern part of the low-level plain. The dunes of red quartz sand range in height up to about 50 feet. They are fixed by spinifex and other vegetation.

A low range in the eastern plain is a strike ridge formed by the outcrop of Callytharra Formation and Moogooloo Sandstone.

STRATIGRAPHY

Rock units are named according to the Australian Code of Stratigraphical Nomenclature (A.N.Z.A.A.S., 1956).

TABLE I
ROCK UNITS OF THE KENNEDY RANGE SHEET

Age	Rock Unit		Lithology	Fossils	Thickness (feet)			Topography	Air Photo Pattern	Economic Geology	Remarks
	Group	Formation (Symbol)			North	Centre	South				
Recent		Alluvium (Qra)	Sand, silt, gravel, clay.	Land snails, plants	15-20	15-30	5-100	Flood plain	General dark band along drainage. Gascoyne delta: light coarse grained pattern with dark spots and dark anastomosing bands	Ground water 20 to 100 ft. depth. Possible agricultural soils.	Clay pans are included.
		Wash (Qrw)	Gravel, sand.	Land snails.	1-10	1-20	1-20	Scree slopes and erosion plains.	Very light coarse grained with fine dark lines anastomosing.	Gravel for road surfacing.	
		Residual Soil (Qrr)	Clay, some sand.	Derived fossils from underlying formation.	1-10	1-10	1-10	Flat, or very gently sloping or undulating.	Fine grained pattern; commonly medium tone.	Possible agricultural soils.	
		Travertine (Qrt)	Travertine, lime clay.	—	1-10	1-10	1-10	Undulating.	Speckled (fine grain with small dark spots) medium to moderately dark tone.		Developed over calcareous formations.
		Sand (Qrs)	Yellow sand.	—	5-20	5-20	5-20	Generally flat, small undulations, small clay pans.	Fine grain; medium tone.		Difficult to separate from Qps.
Pleistocene		Sand (Qps)	Red Sand.	—	5-50	5-50	5-30	Generally flat with seif dunes or small undulations. Clay pans.	Fine grain; medium tone with ovoid areas, small to large, of smooth tone.	Small supplies of good water in dunes.	Probably mainly derived from A-horizon of laterite profile; rearranged by wind action.
		Joolabroo Formation (Qpj)	Bedded sand, gravel, travertine, silty sand	—	30	10	20	Flat, capping minor interflues near main streams.	Fine grain; light tone; close dissection pattern at edges.		Flood plain deposits of an earlier stage of development of the rivers.
		Nadarra Formation (Qpn)	Bedded pale grey chalcidonic limestone.	—	—	20	—	Mesa cap			Only one small outcrop seen on this sheet.
? Upper Tertiary		Billy (Tub)	Hard pale grey chalcidonic quartzite, commonly with sand grains and quartz pebbles.	—	1-5	1-10	1-5	Flat, capping mesas.	Medium pattern; medium to light tone.		Developed near surface of laterite profile.
		Laterite (Tul)	Hard pisolitic ferruginous laterite at surface overlying mottled zone and pallid zone.	—	10-30	10-50	10-30	Flat to gently undulating.	Fine pattern; medium-dark tone.	Gravel for road surfacing.	No bauxite has been found; could be present over shaly formations.
Eocene		Merlinleigh Sandstone (Tem)	Quartz sandstone minor siltstone and conglomerate.	Aturia, corals, gastropods, wood.	20	55	20	Flat, capping mesas.	Fine pattern, medium-dark tone.	—	Invariably lateritized.
Cretaceous	Cardabia	Korojon Calcarenite (Kuk)	Calcarenite, calcilutite.	Inoceramus.	?200	?200	?200	Low undulating hills with small scarp on east side in places.	Smooth grain light to very light tone.	Possible source of agricultural lime and Portland cement.	Exposure very poor.
	Winning (K1)	Gearle Siltstone (Klg)	Bentonitic siltstone and shale.	Foraminifera, belemnites, radiolaria.	?300	?300	?300	Low crabhole plain.	Smooth, moderately dark.	Possible source of bentonite, brick clay.	Exposure very poor.
		Windalia Radiolarite (Klw)	Bedded to laminated radiolarite.	Radiolaria belemnites, pelecypods, ammonites.	50 to 100	50 to 144	30 to 100	Caps mesas & buttes & forms closely dissected undulating low hills.	Smooth, medium to light tone.	Possible source of material for filtration, insulation.	Commonly lateritized (leached and silicified.)
		Muderong Shale (Klm)	Laminated bentonitic shale.	Foraminifera.	10 to 50	5 to 40	3 to 30	Generally near base of scarp of Windalia Radiolarite.	—	Possible source of brick clay and bentonite. Cap rock for artesian water, and suitable cap for oil accumulation.	Generally poorly exposed.
		Birdrong Formation (Klb)	Sandstone, some glauconitic, siltstone, quartz greywacke, conglomerate.	Wood, spores.	10 to 50	5 to 105	10 to 70	At base of scarp or undulating.	Coarse pattern, medium tone.	Aquifer, artesian at depth; possible reservoir bed for oil. Doubtful structure between Hill Springs and Doorwarrah.	Contained oil in WAPET'S Rough Range No. 1.
BYRO Group	Kennedy	Binthalya Formation (Pkb)	Quartz greywacke, quartz sandstone, minor siltstone.	Few pelecypods.	—	1725	—	Strongly dissected west side of Kennedy Range.	Contour line pattern in valleys (smooth light and medium-dark fine bands). Fine grained medium tone on interflues.	—	Crops out only in Kennedy Range.
		Mungadan Sandstone (Pkm)	Quartz sandstone, fine quartz conglomerate.	Few pelecypods.	70	50	70 to 160	Commonly capping scarp of Kennedy Range.	Smooth, light to very light tone.	Ground water.	Ditto.
		Coolkilya Greywacke (Pke)	Quartz greywacke, calcareous beds.	Brachiopods.	565 to 650	450	400	Kennedy Range Scarp. Rounded hills	Smooth, dark tone.	—	
Permian	Minilya Subgroup (new name)	Baker Formation (Pak)	Dark siltstone and laminated quartz greywacke.	Chonetid brachiopod, foraminifera.	70 to 198	90 to 120	85 to 140	Plain with crabholes.	Smooth, light tone.	Source of brick clay. Oil source bed and possible cap rock.	
		Norton Greywacke (Pan)	Thin bedded quartz greywacke.	Brachiopods, pelecypods, goniatites.	160 to 250	140 to 160	90 to 173	Rounded strike ridge.	Smooth, dark tone.	Possible oil reservoir bed. Aquifer (stock water, variable supply).	
		Wandagee Formation (Pag)	Dark siltstone, quartz greywacke, calcareous beds.	Brachiopods, Calceolispongia, foraminifera, pelecypods etc.	650 to 800	525	250 to 750	Plain with very low strike ridges.	Smooth, banded in places, light to medium tone.	Source beds for oil. Possible brick clays. Possible evaporite salts.	
		Quinnian Shale (Paq)	Dark shale and siltstone, quartz greywacke.	—	85 to 125	—	—	Plain.	Smooth, light tone.	Source beds for oil. Brick clay.	Grades laterally (southward) into upper part of Cundlego Formation.
		Cundlego Formation (Pau)	Laminated quartz greywacke and siltstone.	Brachiopods, Calceolispongia.	975 to 1040	365 to 445	560	Plain with very low strike ridges.	Smooth, banded light and dark tone.		
	Newman Subgroup	Bulgadoo Shale (Pab)	Dark shale and siltstone, minor quartz greywacke. Evaporite gypsum.	Brachiopods, foraminifera, ostracods.	520 to 626	245 to 400	260	Plain.	Smooth, light tone.	Source beds for oil. Possible source of brick clay. Possible evaporite salts.	
		Mallens Greywacke (Pam)	Thin bedded quartz greywacke.	Pelecypods, brachiopods.	517	420 to 600	600	Sandy plain, rounded low hills.	Medium grain, medium tone.	Aquifer (good stock water, good supply). Possible reservoir bed for oil.	
		Coyrie Formation (Paj)	Dark siltstone, quartz greywacke.	Foraminifera, brachiopods, pelecypods, goniatites, Gangamopteris	470 to 613	330 to 400	420	Plain.	Smooth.	Oil source beds. Possible brick clay.	Redefined.
	Wooramel	Billidee Formation (Pae)	Quartz greywacke, dark siltstone.	Wood, foraminifera.	185 to 242	400	255 to 310	Strike ridge.	Smooth, dark tone.		New name (Lower part of original Coyrie Formation).
		Moogooloo Sandstone (Paw)	Quartz sandstone.	—	250	150 to 160	30 to 170	Strike ridge.	Medium grain, medium to light tone.	Aquifer (good water, good supply); possible reservoir bed for oil.	Previously (Condon, 1954) called Wooramel Sandstone.
Carboniferous		Callytharra Formation (Pac)	Calcarenite, calcilutite, quartz greywacke.	Crinoids, brachiopods, bryozoa, foraminifera.	412	412	210 to 355	Strike ridge.	Smooth, dark tone.	Limestone for road and concrete aggregate and possibly for lime and portland cement. Some source beds for oil.	
	Lyons (Psl)	Weedarra Shale (Psw)	Sandy shale, tillitic siltstone, quartz greywacke member, boulder beds.	Brachiopods bryozoa, pelecypods, crinoids.	800	—	480	Plain.	Smooth, light tone.	Brick clay; water in quartz greywacke member.	New name.
		Thambrong Formation (Pst)	Siltstone, quartz greywacke, tillite, limestone.	Brachiopods, bryozoa, crinoids.	1200	1120	320	Plain.	Smooth, light tone.		New name.
		Mundarie Siltstone (Psm)	Tillitic siltstone, tillite.	Brachiopods, pelecypods, bryozoa, Calceolispongia	800	720	750	Plain or low strike ridge.	Smooth, moderately dark tone.		New name.
		Koomberan Greywacke (Psk)	Quartz greywacke, tillite.	Brachiopods, pelecypods, byozoa.	720	1440	720	Plain, low hills	Smooth, light to medium tone.	Aquifer, stock water, variable supply.	New name.
		Dumbardo Siltstone (Psd)	Tillitic siltstone, tillite.	Brachiopods, pelecypods, bryozoa.	740	1300	850	Plain, low strike ridge.	Smooth, moderately dark tone.		New name.
		Coyango Greywacke (Psc)	Quartz greywacke, tillite.	Lepidodendron, brachiopods, bryozoa.	330	2900	—	Plain, low hills.	Smooth, light to medium tone.	Aquifer, stock water, variable supply.	New name.
		Austin Formation (Psa)	Quartz greywacke, siltstone, tillite.	—	—	1240	—	Strike ridge.	Smooth, moderately dark tone.	Aquifer, stock water.	New name.
		Yindagindy Formation (Cly)	Calcilutite, quartz greywacke.	Brachiopods, ostracods.	100 to 120	—	—	Strike ridge.	Smooth, finely banded light and medium tone.		
		Williambury Formation (Clw)	Quartz greywacke, conglomerate, siltstone.	—	?200	—	—	Strike valley.	—		Very poorly exposed.
Devonian		Moogooonee Limestone (Clm)	Calcilutite, calcarenite.	Brachiopods, corals, pelecypods.	820 to 1000	—	—	Rounded strike ridge.	Medium pattern, medium tone.	Limestone for aggregate, lime and portland cement.	
		Willaraddie Formation (Duw)	Quartz greywacke, conglomerate.	—	500	—	—	Flat-topped strike ridge.	Medium pattern finely banded, medium tone.		
		Munabia Sandstone (Dum)	Quartz sandstone, minor siltstone.	—	1200 to 4450	0 to 900	—	ditto.	Medium pattern, finely banded, medium tone, with dark bands.	Aquifer. Possible oil reservoir bed.	
		Gneudna Formation (Dug)	Calcarenite, quartz greywacke, sandstone, calcilutite.	Brachiopods, nautiloids, corals, stromatoporoids.	980 to 1900	0 to 900	—	Plain.	Smooth, finely banded, medium tone.	Some source beds.	
Precambrian		Nannyarra Greywacke (Dmn)	Quartz greywacke.	—	0 to 200	0 to 200	—	Strike ridge.	Smooth, dark tone.		
		(pC)	Granitic rocks.	—				Mature dissected undulating.	Fine grained, medium to moderately dark tone.	Possibly some metallic minerals.	Not mapped. (Photo interpreted only).
		(pCs)	Schist (biotite, hornblende, sericite, quartz, etc.)	—							

PRECAMBRIAN

Very little geological work has been done on the Precambrian rocks of the area. The distribution of rock types shown on the map results from air-photograph interpretation based on a few traverses by Bureau geologists.

Precambrian rocks crop out in the north-eastern part of the area and in an inlier in the south-east. They probably form the floor of the Palaeozoic sedimentary basin.

Crystalline schist covers the greater part of the outcrop area; quartz schist, biotite schist, quartz-feldspar-biotite schist (or micro-gneiss), amphibole schist, tremolite schist, sericite schist, talc schist are among the types represented. Discordant granite crops out in the north part of the Precambrian outcrop area. Dykes of quartz, pegmatite, and basic igneous rock ('dolerite') stand out clearly on the ground and in air photographs.

No mineral deposits have been reported from this area, although the Yinnietarra mica mines are only about 50 miles to the east, in probably the same suite of rocks.

DEVONIAN

The oldest Palaeozoic rocks exposed in the area are of Devonian age. The basal formation is the *Nannyarra Greywacke* (Condon, 1954), which was deposited on a surface of considerable relief (about 500 feet) on the Precambrian rocks. In this area the formation consists mainly of medium-grained and coarse-grained quartz greywacke with angular fragments of quartz and schist in the lower beds. The thickness ranges from 200 feet downwards and is variable within short distances.

The Frasnian (Hill, 1954; Veevers, 1959) *Gneudna Formation* (Teichert, 1949; Condon, 1954) consists of friable calcarenite and quartz greywacke, hard calcarenite and calcilutite, and soft siltstone, and rests conformably on the *Nannyarra Greywacke*. It is about 980 feet thick in the eastern outcrop belt. There is a transitional conformable passage upwards into the *Munabia Sandstone*, and in places, e.g. 12 miles south-south-east of Moogooree, the upper part of the *Gneudna* changes laterally into the *Munabia*.

The *Munabia Sandstone* (Condon, 1954) is a clean medium-grained and fine-grained quartz sandstone. In the western outcrop belt the thickness varies from 1,200 feet in the north to 4,450 feet near the middle and 900 feet near the south end. In the north of the area the *Willaraddie Formation* rests conformably on the *Munabia*, but farther south the *Moogooree Limestone*, *Austin Formation*, or *Coyango Greywacke* rests unconformably on it.

The *Willaraddie Formation* (Condon, 1954) consists of quartz greywacke, conglomerate, and siltstone, and minor limestone; in this area its thickness ranges downwards from about 500 feet. It is separated by a strong erosional unconformity from the overlying *Moogooree Limestone*.

CARBONIFEROUS

The *Moogooree Limestone* (Teichert, 1949; Condon, 1954) consists mainly of hard and friable calcilutite with minor calcarenite, coquinite and quartz grey-

wacke. It is 820 feet thick at the north end and 1,000 feet near the south end. It includes several richly fossiliferous beds containing *Spirifer fluctuosus*, *Punctospirifer plicatosulcatus*, and *Syringothyris spissus* (Glenister, 1956), and *Syringopora*, *Rhipidomella*, *Linoproductus*, *Schellwienella*, *Composita*, *Cleiothyridina*, *Camarotoechia*, and cf. *Eomartiniopsis* (Thomas, in McWhae et al., 1958). The age is certainly Lower Carboniferous and probably Tournaisian.

The overlying *Williambury Formation* (Teichert, 1949; Condon, 1954) is very little exposed in the area — only the top is exposed in a few places. The thickness indicated by the distance between the Moogooree Limestone and the Yindagindy Formation and the dips in those formations is about 200 feet downwards.

The *Yindagindy Formation* (Condon, 1954) crops out $1\frac{1}{2}$ miles north of Moogooree, where it is about 120 feet thick, and from the homestead southward, where it ranges from about 100 feet downwards. Brachiopods, crinoid stem ossicles and brachials, small gastropods, a nautiloid, and ostracods, have been found, but are difficult to develop, and no detailed work has been done on them. Their general appearance is Lower Carboniferous.

A major erosional unconformity separates the Devonian and Carboniferous sediments from the overlying Permian. In the area south of Moogooree this unconformity cuts obliquely across the whole Carboniferous and Devonian sequence and, about one mile north of Mount Sandiman homestead, reaches the Precambrian.

PERMIAN

The *Harris Sandstone* (Condon, 1954), which is the basal formation of the Permian in the Minilya Sheet area to the north, is not present in the Kennedy Range Sheet area. Its equivalent is the lowermost part of the Austin Formation.

The *Lyons Group* (Maitland, 1909; Raggatt, 1936; Condon, 1954) was indicated by Condon (1954) to be divisible into formations which at that time had not been mapped and therefore were not named. The formations have now been mapped, and are here named, in ascending order, Austin Formation, Coyango Greywacke, Dumbardo Siltstone, Koomberan Greywacke, Mundarie Siltstone, Thambrong Formation, and Weedarra Shale. This mapping has established a very strong erosional unconformity between the Lyons Group and the Callytharra Formation.

The *Austin Formation* (new name) is defined as the formation of pebbly quartz greywacke with several arenaceous tillite beds, and sandy siltstone with silty boulder beds, that rests unconformably on the Carboniferous and Devonian formations and on the Precambrian rocks and is overlain conformably by the Coyango Greywacke. The name is taken from Austin Creek, which flows into the Lyons River from the north $9\frac{1}{2}$ miles south of Mount Sandiman Homestead. The type locality is Mount Sandiman Homestead. Because the formation overlies an erosional unconformity of marked relief, the thickness is very variable; on this Sheet it is overlapped by Coyango Greywacke and does not crop out

from the northern edge of the Sheet to 15 miles south-south-east of Moogooree Homestead; is 1,240 feet thick in the type locality; 1,080 feet 8 miles north-north-east of Mount Sandiman Homestead; 920 feet 7 miles north-east of Lyons River Homestead; and absent (overlapped by Coyango Greywacke) on the west side of the Precambrian inlier east of Lyons River Homestead. No fossils have been found in the formation, but, because of the major erosional unconformity with the Lower Carboniferous and the presence of Lower Permian plants in the Coyango Greywacke, the Austin Formation is referred to the Lower Permian (Sakmarian).

The *Coyango Greywacke* (new name) is the formation of quartz greywacke with minor boulder beds and siltstone beds that is conformable between the Austin Formation and the Dumbardo Siltstone; it commonly overlaps the Austin Formation and rests unconformably on Carboniferous, Devonian, or Precambrian rocks. The type locality is half a mile to east and west of Coyango Well, Williambury, 13 miles west-north-west of the homestead (Minilya Sheet). In the type section the formation is 1,325 feet thick. On the Kennedy Range Sheet, the thickness is 330 feet north of Moogooree, where it is unconformable on Yindagindy Formation; 150 to 400 feet 7 to 13 miles southward from Moogooree, where it is unconformable on Moogooree Limestone or Munabia Sandstone; 2,900 feet $\frac{1}{2}$ to $2\frac{1}{2}$ miles west of Mount Sandiman Homestead, 1,480 feet 8 miles north-north-east of that homestead and 1,420 feet 6 miles north-east of Lyons River Homestead (conformable on Austin Formation at those three places); and 350 feet $4\frac{1}{2}$ miles east of Lyons River Homestead to absent 10 miles south-east of that homestead (unconformable on Precambrian schist and overlapped by Dumbardo Siltstone). The Lycopod plant fossils found north of Moogooree (Condon, 1954, p.33) are in the Coyango Greywacke; similar plant fossils have been found in the formation near Williambury (Minilya Sheet) and six miles south-south-east of Arthur River Woolshed (Mount Phillips Sheet). These plants are regarded as Permian by White (White & Condon, 1959). Brachiopods and bryozoa have been found $5\frac{3}{4}$ miles south-south-east of Mount Sandiman Homestead.

The *Dumbardo Siltstone* (new name) is the formation dominantly of tillitic siltstone with tillitic boulder beds, conformable between the Coyango Greywacke and the Koomberan Greywacke. The name is taken from Dumbardo Bore, Williambury Station (Minilya Sheet); the Dumbardo Siltstone crops out $2\frac{1}{2}$ miles east-north-east of Dumbardo Bore. The type locality is one mile west of Coyango Well, Williambury, and 13 miles west-north-west of Williambury Homestead (Minilya Sheet). In the type section, the Dumbardo Siltstone is 500 feet thick. In the Kennedy Range Sheet area, the Dumbardo Siltstone is 740 feet (\pm 50 feet) thick west of Moogooree, 1,280 feet four miles west of Mount Sandiman Homestead, 1,300 feet 2 to 4 miles east of Lyons River Homestead, and 850 feet at the far south of the Sheet. The Dumbardo Siltstone is unconformably overlain by the Callytharra Formation from $5\frac{1}{2}$ miles north-west to $3\frac{1}{2}$ miles west of Mount Sandiman Homestead, and rests unconformably on Precambrian schist 10 to 16 miles south-south-east of Lyons River Homestead.

Marine fossils have been found in the Dumbardo Siltstone $2\frac{1}{4}$ miles north of Moogooree and three and five miles north-west of Mount Sandiman Homestead; the fauna includes bryozoa, brachiopods (productids and spiriferids), pectinids, and solitary corals (Dickins & Thomas, 1959, p.73). The assemblage includes two species not known from the higher parts of the Lyons Group, but otherwise is similar to that found throughout the middle and upper formations of the Group; the general assemblage is regarded as Sakmarian (Dickins & Thomas, 1959).

The *Koomberan Greywacke* (new name) is the formation consisting mainly of quartz greywacke with several tillitic boulder beds and few siltstone beds, conformable between the Dumbardo Siltstone and the Mundarie Siltstone; in places it is unconformably overlain by the Callytharra Formation. The name is taken from Koomberan Bore, Middalya Station (Minilya Sheet); the formation crops out to the east of the Vermin-Proof Fence, which is the eastern fence of Koomberan Paddock. The type locality is $\frac{3}{4}$ to one mile west-south-west of Coyango Well, Williambury Station. In the type section the formation is 420 feet thick. In the Kennedy Range Sheet area, the Koomberan Greywacke is about 720 feet thick $2\frac{1}{2}$ miles south-west of Moogooree; 700 feet 12 miles south of Moogooree; 760 feet 4 miles south of west of Mount Sandiman Homestead; 1,440 feet three miles north of Lyons River Homestead; 560 feet 8 miles south of Lyons River Homestead, where it is unconformably overlain by Callytharra Formation; 360 to 720 feet 22 miles south-south-east of Lyons River Homestead, where the top of the formation is eroded and the lower part changes laterally into siltstone of the Dumbardo Siltstone; and 160 feet at the Arthur River $1\frac{1}{4}$ miles east of K-35.

Fossils have been found in the Koomberan Greywacke only at two localities: 1 mile north of Lyons River Homestead (mainly brachiopods), and $5\frac{1}{2}$ miles south-east of Grays Well, Lyons River Station (bryozoa, corals, crinoid stem ossicles, brachiopods including spiriferids, and pectinids). These fossils have not been examined critically, but by reference to the faunas in underlying and overlying formations of the Lyons Group, the Koomberan Greywacke is Sakmarian.

The *Mundarie Siltstone* (new name) is the formation, consisting of tillitic siltstone with tillitic boulder beds, conformable between the Koomberan Greywacke and the Thambrong Formation; in places it is unconformably overlain by younger formations of the Lyons Group or by the Callytharra Formation. The name is taken from Mundarie Well, Middalya Station (Minilya Sheet); the formation crops out across the north-eastern corner of Mundarie Paddock. The type locality is in the north-east corner of Mundarie Paddock and the adjoining south-east corner of Blairs Camp Paddock; there the Mundarie Siltstone is 520 feet thick. On the Kennedy Range Sheet, the Mundarie Siltstone is about 800 feet thick 2 miles south-south-west of Moogooree Homestead; 600 feet $5\frac{1}{2}$ miles west of Mount Sandiman Homestead; 720 feet 500 to 1,400 yards west of Lyons River Homestead; 480 to 600 feet 22 miles south-south-east of Lyons River Homestead, where it appears to rest on an eroded surface of the Koomberan Greywacke; and 660 to 750 feet at the Arthur River, 1 mile east of K-35, where

it is unconformably overlain by Callytharra Formation. The Mundarie Siltstone is absent in outcrop from one mile south-east to 20 miles east of south of Lyons River Homestead, where the Callytharra Formation rests unconformably on the Koomberan Greywacke.

The Mundarie Siltstone includes several beds containing marine fossils (fenestellid bryozoa, corals, spiriferids, productids, crinoid stem ossicles, pelecypods, and foraminifera); although preservation is poor at outcrop, good material may be found in some localities. Detailed examination of the faunas is not complete, but the work to date (including Dickins, 1957; Dickins & Thomas, 1959) indicates a Sakmarian age.

The *Thambrong Formation* (new name) is the formation of quartz greywacke, tillitic siltstone, shale, and tillitic boulder beds conformable above the Mundarie Siltstone and overlain conformably by the Weedarra Shale or unconformably by the Callytharra Formation or by younger Permian formations. Its name is taken from Thambrong Pool on the Minilya River 9 miles downstream from Williambury Homestead (Minilya Sheet). The formation crops out two to 5½ miles east of the Pool; the type locality is along the south side of South Branch, Minilya River, from its junction with Minilya River to 6½ miles upstream. In the type locality the Thambrong Formation is 1,840 feet thick in a syncline; it is 1,500 feet thick 2½ miles south-west of Moogooree Homestead; 1,100 feet 6 miles west of Mount Sandiman Homestead, where it is unconformably overlain by Callytharra Formation; 440 feet one mile west of Lyons River Homestead (unconformably overlain by Callytharra Formation); 320 feet 22½ miles south-south-east of Lyons River Homestead (unconformable under Callytharra Formation). The Thambrong Formation is absent in outcrop from 15 to 23 miles southward from Moogooree, from Lyons River Homestead for 23 miles southward, and at the Arthur River east of K-35. Fossils have been found in the type locality and in the Minilya sheet area. These indicate Sakmarian age.

The *Weedarra Shale* (new name) is the formation, consisting of sandy shale, sandy and pebbly siltstone with boulder beds and a quartz greywacke member with several boulder beds, that conformably overlies the Thambrong Formation and is unconformably overlain by the Callytharra Formation. It is the uppermost formation of the Lyons Group to crop out. The type locality is 3¼ to 5¼ miles west of Coondoo Well, Coondoo Outstation, and 3½ miles north of Weedarra Paddock, Bidgemia Station, from which the name of the formation is taken (Mount Phillips Sheet). In the type locality the Weedarra Shale is 1,200 feet thick; on the Kennedy Range Sheet it is 640 to 800 feet thick three miles west of Moogooree Homestead, where the unconformity truncates the formation; it is absent in outcrop southward from five miles south of Moogooree; it is 80 to 480 feet thick 10 miles east of Lyons River Homestead, on the eastern side of the Weedarra Ridge (Condon, 1956, and Fig. 1). Fossils have been found near the Lyndon River, in the type locality and west of Moogooree; these include species common to the older formations of the Lyons Group and to the Carrandibby Formation (Dickins & Thomas, 1959); the Weedarra Shale is regarded therefore as Sakmarian in age.

The *Callytharra Formation* (Raggatt, 1936; Condon, 1954) is here re-defined as the formation of fossiliferous hard and friable sandy and silty calcarenite and calcilitite unconformably overlying the Weedarra Shale or older Permian formations and overlain unconformably by formations of the Wooramel Group. In the Kennedy Range Sheet area it is 412 feet thick 4 miles south-west of Moogooree, and also 6 miles west of Mount Sandiman Homestead; 355 feet 10 miles south of east of Lyons River Homestead; and 210 feet at the Arthur River, in the south-eastern corner of the Sheet. The thickness of the Callytharra Formation is probably very much more variable than is indicated by the above figures: it rests on a surface, eroded in the sediments of the Lyons Group, with a minor relief of several hundred feet and very youthful valleys; thicknesses larger than the above are indicated in these valleys, and above the ridges the thickness may be very much less. A variable amount of the upper part of the Callytharra Formation was removed by erosion before the deposition of the sediments of the Wooramel Group. The abundant fossils include foraminifera (Crespin, 1958), bryozoa, corals, crinoids (*Calceolispongia* and other genera), brachiopods (*Chonetes*, *Neospirifer*, *Spiriferella*, *Syringothyris* (?), *Cleiothyridina*, *Phricidothyris*, *Dictyoclostus*, *Linoproductus*, *Streptorhynchus*), pelecypods, gastropods, nautiloids and a single goniatite (cf. *Metalegoceras*). The brachiopods and the goniatite indicate an early Artinskian age (Thomas & Dickins, 1954).

The *Wooramel Group* (Konecki et al., 1958, p.28) in the Kennedy Range Sheet area comprises the Moogooloo Sandstone and the Billidee Formation. The Cordalia Greywacke (Condon, 1954) is not present in this area. The unit now named Billidee Formation was included (by Raggatt, (1936) and Condon (1954)) in the Byro Group, but, in terms of the definition of the Wooramel and Byro Groups in their type localities, should be part of the Wooramel Group.

The *Moogooloo Sandstone* (Craig, 1950) is the formation (incorrectly given the name 'Wooramel Sandstone' by Raggatt, 1936, and Condon, 1954) that overlies the Callytharra Formation unconformably and is conformably overlain by the Billidee Formation; it consists mainly of quartz sandstone with minor thin beds of siltstone. The type locality is here defined as at the south end of Moogooloo Range on Middalya Station (Minilya Sheet), where the thickness is 170 feet. On the Kennedy Range Sheet it is 250 feet thick 4 miles south-west of Moogooree; 150 feet $6\frac{1}{2}$ miles west of Mount Sandiman Homestead; 160 feet 9 miles south of east of Lyons River Homestead; 170 feet 8 miles south of Lyons River Homestead; and 30 feet 21 miles south of Lyons River Homestead. Plant fossils have been found in the area west of Moogooree, but no marine fossils have been found in this Sheet area. By reason of its position between the Artinskian Callytharra Formation and Coyrie Formation, the Moogooloo Sandstone is Artinskian in age.

The *Billidee Formation* (new name) is the formation, consisting of quartz greywacke and minor siltstone, resting conformably between the Moogooloo Sandstone and the Coyrie Formation. It is the lower part of the sequence previously called the Coyrie Formation (Condon, 1954); it was included in the

'Byro Group' (Raggatt, 1936; Condon, 1954) but is now included in the Wooramel Group because it is dominantly arenaceous, like the formations of the Wooramel Group in its type locality.

The name is taken from Billidee Well, Moogooree Station, 5½ miles south of the homestead; the well is sunk in the Billidee Formation. The type locality is 3 miles north-west of Billidee Well at the original type locality of the Coyrie Formation.

In the type section the Billidee Formation is 242 feet thick; 5 miles west of Moogooree it is 185 feet; half a mile north of Mount Sandiman Woolshed it is about 400 feet; 9 miles east-south-east of Lyons River Homestead it is 310 feet; and 20 miles south of Lyons River Homestead it is 255 feet thick. Fossil wood is common in the Billidee Formation. Marine fossils are found only near the top; they include brachiopods, pelecypods, nautiloids, goniatites (?*Propinacoceras*) gastropods (bellerophontid and pleurotomarid), and calceolispongid plates. No precise work has been done on this fauna. The age of the formation by reference to the Callytharra and Coyrie Formations is Artinskian.

The *Byro Group* was named, as Byro Formation, by Condit (1935, p.870). Raggatt (1936) and Condon (1954a) included all the beds between the Wooramel Group and Kennedy Group in the Byro, although in the Minilya River Raggatt separated in other units the beds above the unit later named Bulgadoo Shale. This usage is now well established, although the sequence in the Kennedy Range Sheet area is much thicker and covers a greater stratigraphic interval than that in the type locality (Byro Plains, Wooramel River). As a disconformity has been established within the Byro Group, it is here proposed to subdivide the Group into the Newman and Minilya Subgroups.

The *Newman Subgroup* (new name) is defined as the sequence of siltstone, shale and quartz greywacke resting conformably on the Wooramel Group and overlain disconformably (locally unconformably) by the Minilya Subgroup. In the Kennedy Range Sheet area it consists of Coyrie Formation, Mallens Greywacke, and Bulgadoo Shale.

The name is taken from Newmans Creek on Mount Sandiman Station, which flows over the outcrop of the Subgroup for 8 miles north of Mount Sandiman Woolshed.

The *Coyrie Formation* is redefined as the formation consisting of fossiliferous siltstone and fine-grained quartz greywacke conformable between the Billidee Formation and the Mallens Greywacke. It is the upper part of the Coyrie Formation of Condon (1954).

The type locality of the formation is 4½ miles south-west of Moogooree Homestead. The base of the Byro Group in the Merlinleigh Basin is, as revised, at the base of the Coyrie Formation. This agrees with its lithological position in the type locality of the Byro Group at the change from dominantly arenaceous formations to the dominantly siltstone formation.

The Coyrie Formation is 613 feet thick in the type locality (Condon, 1954); 470 feet 8 miles west-north-west of Moogooree; about 400 feet half a mile north of Mount Sandiman Woolshed; about 330 feet 3 miles west of Lyons River Homestead; and 420 feet 20 miles south of Lyons River Homestead.

A fairly large and distinctive fauna is present in the Coyrie Formation at the type locality; this includes foraminifera — *Ammodiscus*, *Ammobaculites*, *Hyperammina*, *Reophax*, *Sacculinella*, *Spiroplectammina*, *Textularia*, *Thurammina* and *Thuramminoides* (Crespin, 1958) — bryozoa, brachiopods — chonetid, productid and spiriferid — pelecypods, small gastropods, *Propinacoceras*, and a trilobite (?*Ditimopyge*). Fossil wood and ?*Gangamopteris* leaves are also found. The fauna is different from that of the Callytharra Formation but generally similar to that of the Wandagee Formation, although with sufficient differences in species to allow faunal distinction.

The age is Artinskian by reference to the Artinskian Callytharra Formation and Wandagee Formation (Thomas & Dickins, 1954).

The Coyrie Formation may be correlated with the Madeline Formation of the Wooramel River area. The Bogadi Greywacke and Warrawarringa Formation may be equivalent to the upper part of the Formation.

The *Mallens Greywacke* (Teichert, 1950; Condon 1954a) is the formation of quartz greywacke resting conformably between the Coyrie Formation and the Bulgadoo Shale. The type locality is 5½ to 6½ miles south of west of Moogooree Homestead.

The Mallens Greywacke on the Kennedy Range Sheet is 517 feet thick at the type locality, 600 feet 10 miles west-north-west of Mount Sandiman Homestead, 420 feet 4½ miles west of Lyons River Homestead, and about 600 feet thick 22 miles south of Lyons River Homestead. It contains several beds of pelecypods and spiriferids in the lower part and several fossil beds containing foraminifera — *Ammodiscus*, *Hyperammina*, *Thuramminoides* (Crespin, 1958), — spiriferids, streptorhynchid, pelecypods, and gastropods. The age by reference to the Callytharra Formation and Wandagee Formation is Artinskian.

The Mallens Greywacke may possibly be correlated, by stratigraphic position, lithology and, indefinitely, by fossils, with the Bogadi Greywacke (Konecki et al., 1958) of the Wooramel River area.

The *Bulgadoo Shale* (Teichert, 1941; Condon, 1954) is the formation, dominantly of carbonaceous shale and siltstone with minor quartz greywacke and limestone, conformable on the Mallens Greywacke and disconformably overlain by the Cundlego Formation. The reference section, where relationships and thickness can be determined, is 6½ to 8 miles south of west of Moogooree Homestead in the northern scarp of the Kennedy Range. The Bulgadoo Shale is 626 feet thick in the reference section; 520 feet 3 miles south-east of Kimbers Well, Williambury, 400 feet 9½ miles north of west of Mount Sandiman Homestead; 245 feet 6½ miles west-south-west of Lyons River Homestead; and 260 feet near the south edge of the Sheet 7½ miles east of the Lyons River.

Fossils include foraminifera — *Ammobaculites*, *Ammodiscus*, *Hemigordius*, *Hyperammina*, *Nodosaria*, *Pelosina*, *Rectoglandulina*, *Reophax*, *Sacculinella*, *Spiroplectammina*, *Thurammina*, *Thuramminoides* (Crespin, 1958) — bryozoa, *Thamnopora*, *Calceolispongia* and crinoid stem ossicles, brachiopods — chonetid, spiriferid, productid — pelecypods, gastropods, nautiloid. The age of the Bulgadoo Shale by reference to its position between the Callytharra Formation and the Wandagee Formation is Artinskian.

The Bulgadoo Shale may perhaps be correlated by stratigraphic position and lithology with the Warrawarringa Formation of the Wooramel River area (Konecki et al., 1958). This correlation is not beyond doubt.

The *Minilya Subgroup* (new name) is defined as the sequence of fossiliferous siltstone, quartz greywacke, shale, and calcareous beds disconformably overlying the Newman Subgroup and disconformably (locally unconformably) overlain by the Kennedy Group. The sediments of the Minilya Subgroup were included by Condon (1954) and in the Kennedy Range area by Raggatt (1936) in the Byro Group. The Minilya Subgroup in the Kennedy Range area consists, in ascending order, of Cundlego Formation, Quinannie Shale, Wandagee Formation, Norton Greywacke, and Baker Formation. It includes many beds of marine fossils that indicate (Thomas & Dickins, 1954) an Artinskian age.

The *Cundlego Formation* (Teichert, 1941; Condon 1954a) is the formation of quartz greywacke and carbonaceous siltstone disconformably overlying the Bulgadoo Shale. The Quinannie Shale conformably overlies the Cundlego Formation or grades laterally into it; where the Quinannie Shale is absent the Cundlego Formation is overlain conformably by the Wandagee Formation.

In the Kennedy Range Sheet area, the Cundlego Formation is 1,040 feet thick 5 miles north of Paddys Outcamp, Middalya; 975 feet 3 miles south-east of Kimbers Well, Williambury; more than 730 feet in Bore BMR 7; 445 feet 2 miles east-south-east of Merlinleigh Homestead, 365 feet $7\frac{1}{2}$ miles west-south-west of Lyons River Homestead and about 560 feet near the south edge of the Sheet immediately east of the Lyons River.

Fossils occur sporadically in the Cundlego Formation; they include foraminifera — *Ammobaculites*, *Ammodiscus*, *Glomospirella*, *Hemigordius*, *Hyperammina*, *Lugtonia*, *Nodosaria*, *Pseudohyperammina*, *Reophax*, *Spiroplectammina*, *Streblospira* and *Trochammina* (Crespin, 1958) — bryozoa (rare), *Calceolispongia*, brachiopods — chonetid, productid, spiriferid, martiniopsid—, *Conularia*, pectenids, gastropods, nautiloids.

The age of the Cundlego Formation, because of its position between the Callytharra Formation and the Wandagee Formation, is Artinskian.

The *Quinannie Shale* (Teichert, 1950; Condon, 1954) is the formation of carbonaceous shale and siltstone and minor quartz greywacke conformable between the Cundlego Formation and the Wandagee Formation. In the Kennedy Range Sheet area it grades laterally into the Cundlego Formation.

The thickness of the Quinannie Shale is 125 feet 5 miles north of Paddys Outcamp, Middalya; 195 feet in Bore BMR 7, Muderong; 115 feet 5 miles of Bakers Bore, Middalya, 110 feet $3\frac{1}{4}$ miles south of Kimbers Well and 85 feet $4\frac{1}{2}$ miles south-east of Kimbers Well, Williambury; the stratigraphical equivalent of the Quinannie Shale has the same lithology as the Cundlego Formation east of the Kennedy Range and is therefore included in that formation.

Very few fossils have been found in the Quinannie Shale on the Kennedy Range Sheet. Foraminifera, bryozoa, and chonetids were noted.

The age of the Quinannie Shale is Artinskian.

The *Wandagee Formation* (Condit, 1935; Teichert, 1950; Condon, 1954) is the formation of siltstone, quartz greywacke (some calcareous), and minor limestone, very fossiliferous in the lower part and sporadically fossiliferous in the upper part, that is conformable between the Quinannie Shale or the Cundlego Formation and the Norton Greywacke.

On the Kennedy Range Sheet, the Wandagee Formation is 800 feet thick 5 miles north of Paddys Outcamp, Middalya; 295 feet in Bore BMR 6, Muderong; 280 feet in Bore BMR 7, Muderong; 695 feet 4 miles south of the mouth of Norton Creek, 650 feet $3\frac{1}{2}$ miles south-east of Kimbers Well, Williambury, 525 feet 9 miles west-south-west of Lyons River Homestead, 350 feet $\frac{1}{4}$ to 3 miles east of Walbarune Peak, 600 feet 10 miles north of east of Winnemia Woolshed, and 750 feet $6\frac{1}{2}$ miles east of Winnemia Woolshed. At the last locality (near Calvary Well) the Wandagee Formation is unconformably overlain by the Coolkilya Greywacke.

The rich fauna of the Wandagee Formation is still being studied by palaeontologists; it includes foraminifera — *Ammobaculites*, *Ammodiscus*, *Hyperammina*, *Giraliarella*, *Proteonina*, *Reophax*, *Thurammina*, *Tolypammina*, and *Trochammina* (Crespin, 1958) — bryozoa, crinoid stem ossicles, *Calceolispongia*, brachiopods — spiriferids, productids, streptorhynchids, chonetids — pelecypods, gastropods including bellerophontids, *Conularia*.

The age of the Wandagee Formation is fairly definitely established as Artinskian (Teichert, 1941, 1944, 1946; Thomas & Dickins, 1954; Coleman, 1957) although no fusulines have been found. The formation may be correlated with the Noonkanbah Formation of the Fitzroy Basin (Guppy et al., 1952).

The *Norton Greywacke* (Condon, 1954) is the formation of quartz greywacke conformably between the Wandagee Formation and the Baker Formation. Near Calvary Well, at the south-western end of Kennedy Range, the Coolkilya Greywacke is unconformable on the Norton Greywacke. The type locality is 5 miles south-west of Kimbers Well, Williambury, and 15 miles south-west of Moogooree Homestead.

The Norton Greywacke is 250 feet thick at Paddys Outcamp, Middalya; doubtfully present in BMR 6, Muderong; 240 feet thick in Bore BMR 7, Muderong; 235 feet at the type locality; 160 feet 7 miles south of the mouth of

Norton Creek; 190 feet 3 miles south-east of Kimbers Well; 160 feet $9\frac{1}{2}$ miles west of south of Merlinleigh; 140 feet 21 miles south of Merlinleigh; 173 feet 37 miles south of Merlinleigh, and 90 feet 10 miles north of east of Winnemia Woolshed.

Pelecypods and brachiopods are found in several beds near the bottom of the formation; several beds mainly containing brachiopods occur near the top. Fossils include brachiopods — chonetid, spiriferid, productid including *Strophalosia kimberleyensis*, *Etheridgina muirwoodae* (Coleman, 1957) — pelecypods including *Oriocrassatella stokesi* (Dickins, 1956), gastropods, and *Calceolispongia*.

The age is upper Artinskian.

The Norton Greywacke may be stratigraphically equivalent to the Nalbia Greywacke (Teichert, 1950); but because (1) the exposure in the type locality of the Nalbia Greywacke is so poor as to obscure relationships with other formations; (2) Teichert's mapping of the 'Nalbia Greywacke' in the Wandagee Hill area (Teichert, 1957) is not correct (e.g. the formation in the axial part of the Coolkilya Syncline is not 'Coolkilya' but Norton as it directly overlies the Wandagee Formation with its characteristic upper *Strophalosia* bed); (3) the Nalbia lithology is not present in the Minilya Syncline; and (4) the stratigraphical position of the Nalbia Greywacke is not certain; it is incorrect to extend it as a formation beyond its type locality.

The Norton Greywacke may be correlated with the upper part of the Noonkanbah Formation of the Fitzroy Basin.

The *Baker Formation* (Condon, 1954) is the formation of siltstone and quartz greywacke conformable on the Norton Greywacke and disconformably overlain by the Coolkilya Greywacke. At the south end of Kennedy Range the Coolkilya Greywacke is unconformable on the Baker Formation.

The type locality is $6\frac{1}{4}$ miles south-south-west of Kimbers Well, Williambury, and 15 miles south-west of Moogooree Homestead.

The Baker Formation is 70 feet thick $3\frac{1}{2}$ miles south of Paddys Outcamp, Middalya; probably absent in Bore BMR 6, Muderong; 310 feet in Bore BMR 7, Muderong; 125 feet 7 miles south of the mouth of Norton Creek; 198 feet in the type locality; 121 feet 9 miles south of Merlinleigh; 90 feet 21 miles south of Merlinleigh; 85 feet 37 miles south of Merlinleigh; and 140 feet 11 miles north of east of Minnemina Woolshed.

Fossils occurring sporadically in the Baker Formation include brachiopods (spiriferid, chonetid, and productid) and pectenid pelecypods.

The age of the Baker Formation is somewhat in doubt, but as there appear to be significant differences in the fauna of the overlying Coolkilya Greywacke and as there is a minor unconformity between the Coolkilya Greywacke and the Baker Formation, it is probably upper Artinskian. It probably correlates with the top of the Noonkanbah Formation of the Fitzroy Basin.

The *Kennedy Group* (Raggatt, 1936; Condon, 1954) is the sequence of predominantly arenaceous sediments disconformably overlying the Byro Group

and unconformably overlain by Cretaceous and Eocene sediments. It comprises the Coolkilya Greywacke, Mungadan Sandstone, and Binthalya Formation. The Kennedy Group is 2,540 feet thick near Venny Peak; elsewhere an erosion surface cuts into the Group so that the sequence represented is less than near Venny Peak.

The *Coolkilya Greywacke* (Teichert, 1950; Condon, 1954) is the formation of quartz greywacke, some calcareous, disconformable on the Baker Formation and conformable with the Mungadan Sandstone. At the south-western end of the Kennedy Range the Coolkilya Greywacke is unconformable on the Baker Formation, Norton Greywacke, and Wandagee Formation.

The reference section showing relationships and complete sequence is north and south of Southern Cross Bore, Middalya (Condon, 1954).

The Coolkilya Greywacke is 650 feet thick in the reference section; possible Coolkilya Greywacke is 280 feet (incomplete) in Bore BMR 6, Muderong; Coolkilya Greywacke is 190 feet (incomplete) in Bore BMR 7; 565 feet 15 miles south-south-east of the mouth of Norton Creek; about 450 feet along the eastern scarp of Kennedy Range; and 400 feet 7 miles north-north-east of Winnemia Woolshed.

Most of the many fossil beds in the Coolkilya Greywacke appear to be somewhat lenticular. Fossils found on the Kennedy Range Sheet include the foraminiferan *Hyperammina acicula* (Crespin, 1958), bryozoa, *Calceolispongia*, brachiopods (chonetid, productid, spiriferid — including *Aulosteges*, *Lino-productus cancriniformis* (Coleman, 1957) — pelecypods including *Nuculana*, *Parallelodon*, *Stutchburia*, *Astartila*, *Atomodesma*, *Pseudomyalina*, *Undulomya*, *Schizodus*, *Oriocrassatella* and *Middalya* (Dickins, 1956). The age is generally regarded as Kungurian (Teichert, 1951; Thomas & Dickins, 1954; Dickins, 1956).

The Coolkilya Greywacke may be correlated with the lower part of the Liveringa Formation (Guppy et al., 1952) of the Fitzroy Basin.

The *Mungadan Sandstone* (Teichert, 1950; Condon, 1954) is the formation of quartz sandstone conformable between the Coolkilya Greywacke and the Binthalya Formation. In the Kennedy Range Sheet area the Mungadan Sandstone is 70 feet thick one mile south of Southern Cross Bore, Middalya; 50 feet 10 miles west of Lyons River Homestead; 160 feet 6½ miles east-north-east of Winnemia Woolshed; and 70 feet 2½ miles north-west of K-38. No fossils have been found in the Mungadan Sandstone in the Kennedy Range area.

By reference to the Coolkilya Greywacke its age is Kungurian.

The *Binthalya Formation* (Condon, 1954) is the formation of quartz greywacke and quartz sandstone, with minor siltstone, conformably overlying the Mungadan Sandstone. It was termed 'Subgroup' by Condon, but as the smaller units within it are not named the unit should be called 'Formation'. As this is the uppermost Permian formation in the Carnarvon Basin, and as its maximum stratigraphic development is limited to a small area east of Venny Peak, the only

thickness available is 1,725 feet in the type locality east of Venny Peak. The only fossils found are sparse spiriferids and pelecypods in the lower part of the formation.

The Binthalya Formation, because of its position above the Coolkilya Greywacke, is not older than Kungurian. Because of its thickness, there is some possibility that it may range up into the Kazanian, but there is no palaeontological evidence for or against this.

JURASSIC

No outcrops of rocks of Jurassic age have been found on this Sheet.

CRETACEOUS

Cretaceous rocks crop out in an area running north-south across the middle of the Sheet, and underlie the sand of the western part of the Sheet. The Winning Group and the lowermost formation of the Cardabia Group are present.

The *Winning Group* (Raggatt, 1936; Condon, 1954; Johnstone et al., 1958) in this area comprises in ascending order the Birdrong Formation, Muderong Shale, Windalia Radiolarite, and Gearle Siltstone.

The *Birdrong Formation* (Condon, 1954) is the formation of quartz sandstone (some glauconitic), quartz greywacke, and siltstone, resting unconformably on the Permian rocks and conformably overlain by Muderong Shale. The type locality is 0.6 miles south-west of Birdrong Spring, which is 21½ miles north of east of Hill Springs Homestead.

The Birdrong Formation is very variable in thickness: it is 97 feet thick in the type locality, and elsewhere on the Sheet ranges from 5 feet (25 miles east of Mardathuna Homestead) to 105 feet (19 miles east of Mardathuna). The thickness variation is related to irregularities in the surface of the Permian rocks on which the formation was deposited.

Only fossil wood has been found in the formation on this Sheet. By reference to the overlying Muderong Shale, the age of the Birdrong Formation is probably Aptian or Neocomian. The Birdrong Formation is probably stratigraphically equivalent to the upper part of the Blythesdale Sandstone of Queensland.

The *Muderong Shale* (Condon, 1954) is the formation of bentonitic shale, claystone and siltstone conformable between the Birdrong Formation and the Windalia Radiolarite. The type locality is one mile south-west of Muderong Bore, Middalya Station. The Muderong Shale ranges from 3 feet to 50 feet thick in the area west of Kennedy Range.

Foraminifera and radiolaria have been identified in Muderong Shale in this area. Edgell (in Condon, 1954a) regarded the foraminifera as indicating Albian to Cenomanian age, but Crespín and Glaessner (in McWhae et al., 1958) regard the age as Aptian, and Cookson & Eisenack (1958) described Aptian microplankton from bores in the formation.

The *Windalia Radiolarite* (Condon, 1954; Condon et al., 1956) consists of radiolarite, sandy radiolarite, and chert, conformable between the Muderong

Shale and the Gearle Siltstone. On the Kennedy Range Sheet the junction with the Gearle Siltstone is not exposed. Exposed thickness ranges from 50 to 144 feet in the area west of Kennedy Range.

The Windalia Radiolarite contains many radiolaria, and few foraminifera, ammonites, pelecypods, ostracods, and belemnites. The formation was regarded by Brunnschweiler (in Condon, 1954) as of Albian to Cenomanian age. Glaessner (in McWhae et al., 1958) indicates a lower Albian to Aptian age, and Brunnschweiler (1959) agrees with this.

The *Gearle Siltstone* (Condon 1954; Condon et al., 1956) consists of bentonitic siltstone and claystone, conformable on the Windalia Radiolarite and disconformable beneath the Korojon Calcarenite. The Gearle Siltstone is very poorly exposed in the Kennedy Range area; on the basis of the separation of the outcrops of the Windalia Radiolarite and the Korojon Calcarenite the formation is about 300 feet thick.

No fossils have been found in the Sheet area; in coastal bores the age (McWhae et al., 1958) is regarded as Albian to Turonian.

The *Korojon Calcarenite* (Condon, 1954; Condon et al., 1956) is the only formation of the Cardabia Group cropping out in the Sheet area. It consists of calcarenite and calcilutite, disconformable on the Gearle Siltstone. It is overlain unconformably by the Eocene Merlinleigh Sandstone. It is poorly exposed in the plain to the west of Kennedy Range. Its thickness there is about 200 feet.

Only *Inoceramus* fragments have been recognized in this area; but in the coastal area the formation is very fossiliferous. Its age is Campanian to lower Maestrichtian (Belford, in McWhae et al., 1958).

TERTIARY

The only Tertiary rocks known in the Sheet area are the Eocene Merlinleigh Sandstone and the possibly Upper Tertiary laterite.

The *Merlinleigh Sandstone* (Teichert, 1950) consists of quartz sandstone with minor conglomerate and siltstone unconformably overlying Permian and Cretaceous formations. The type locality is one mile east-south-east of Merlinleigh Homestead. In the Kennedy Range area the Merlinleigh Sandstone ranges in thickness from 10 feet to 55 feet. Its surface is commonly lateritized.

Fossils occur sporadically: they include *Aturia clarkei*, corals, small pelecypods, fossil wood with boring molluscs. The Merlinleigh Sandstone is probably of Middle Eocene age (Glaessner, 1955; Brunnschweiler, Dickins, & Crespín, in Condon, 1955) and correlates with the coastal Giralia Calcarenite.

Laterite (in the sense of the profile of lateritization) is widespread in the Sheet area. It is developed on rocks ranging from Precambrian to Eocene. Eight miles west of Moogooree Homestead, laterite is developed on Permian Mallens Greywacke beneath Merlinleigh Sandstone which is also lateritized. Near Merlinleigh Homestead the Permian Wandagee Formation is lateritized beneath the Merlinleigh Formation, which is also lateritized. The surface of the Permian Coolkilya Greywacke beneath the Cretaceous Birdrong Formation west of Kennedy

Range is lateritized in places. The surface of the Callytharra Formation beneath the Moogooloo Sandstone is strongly ferruginized, silicified, and leached (i.e. lateritized). The surface of the Yindagindy Formation beneath the Coyango Greywacke is lateritized.

There is thus evidence of lateritization in the intervals between Lower Carboniferous and Lower Permian, between Callytharra Formation and Moogooloo Sandstone, between Permian and Lower Cretaceous, between Permian and Eocene, and post-Eocene. Thus, although the laterite on this Sheet is symbolized as Tul, Upper Tertiary is regarded as only the youngest likely age of the well-developed laterite. Some of the exposed laterite surfaces may have been covered by Cretaceous or Eocene sediments that have been stripped off.

Billy, the hard pale-grey chalcidonic quartzite with or without quartz grains and pebbles, is developed in some places near the top of the laterite profile. It is most common in profiles developed in sandstone, but occurs also above siltstone of the Lyons Group. As it is such a distinctive rock type, it has been mapped separately. It is also, apparently, more restricted in age than the laterite generally, as it has been observed only on the Tertiary surface and not on any of the pre-Tertiary unconformities.

QUATERNARY

Deposits probably of Quaternary age cover large areas of the Sheet. Their age has not been determined from fossils; mutual relationships and their relationships to the geomorphology have led to the deductions of their relative ages.

? *Pleistocene*

The *Nadarra Formation* (Condon, in McWhae et al., 1958) consists of silicified limestone, chert, limestone, siltstone and sandstone with detrital limonitic pisolites. In this Sheet area only a small outcrop was recognized, in the area 25½ miles east of Mardathuna Homestead, where 20 feet of chalcidonic limestone overlies Windalia Radiolarite. No fossils have been found in the *Nadarra Formation*.

The only evidence of its age is its relationship to the lateritized surface. As it is always found in low areas of the lateritized surface that have been deeply dissected by recent stream action, the *Nadarra Formation* is probably younger than the lateritization. As the Middle Eocene Merlinleigh Sandstone is strongly lateritized the *Nadarra Formation* is younger than Eocene. It is tentatively assigned to the Pleistocene, although it may be somewhat older.

The *Joolabroo Formation* (Condon, 1954) is a fluvialite deposit of gravel, sand, silt, and travertine, mainly on terraces related to the present stream system. No fossils have been found in the formation; its tentative Pleistocene age is indicated by its physiographic position — deposited on the flat floor of wide valleys cut in the ?Upper Tertiary lateritized surface, and dissected by the present streams, the beds of which are 15 to 30 feet below the base of the *Joolabroo Formation*.

The red *Sand* of both the high-level and the low-level plains was probably developed as the surface zone of the laterite profile. It has since been moved by wind action during an arid period into seif dunes. The most likely period for this aridity is during the Pleistocene glaciation, when the ice advances of the northern hemisphere were accompanied by relatively dry conditions elsewhere.

Recent

Recent deposits are mainly the superficial soils still in process of formation or deposition.

Travertine is formed at the surface of calcareous formations such as the Korojon Calcarenite, probably by deposition of calcium carbonate in the residual soil.

Residual Soil is developed from outcropping rock where the surface is flat or very gently sloping. It is common on the outcrop of the Lyons Group, Gneudna Formation, and Gearle Siltstone, but has been mapped only where the underlying formations are not exposed.

Alluvium covers the flood plains of rivers and smaller streams and, on this Sheet includes the upstream part of the deltaic flood plain of the Gascoyne River. The alluvium is dominantly arenaceous, with layers of gravel and silt. The sediment covering the clay pans has been mapped as alluvium, although it is only in part a stream deposit.

Wash is the thin veneer of alluvial gravel, sand, and clay over bedrock. It covers large areas, particularly at the base of scarps and in areas of sheet flow. Commonly small areas of outcrop are exposed through the wash.

Pale brown quartz *Sand* covers a fairly large area of the plain east of the east scarp of the Kennedy Range. It is in part a piedmont apron against this scarp and was deposited by streams draining the Kennedy Range.

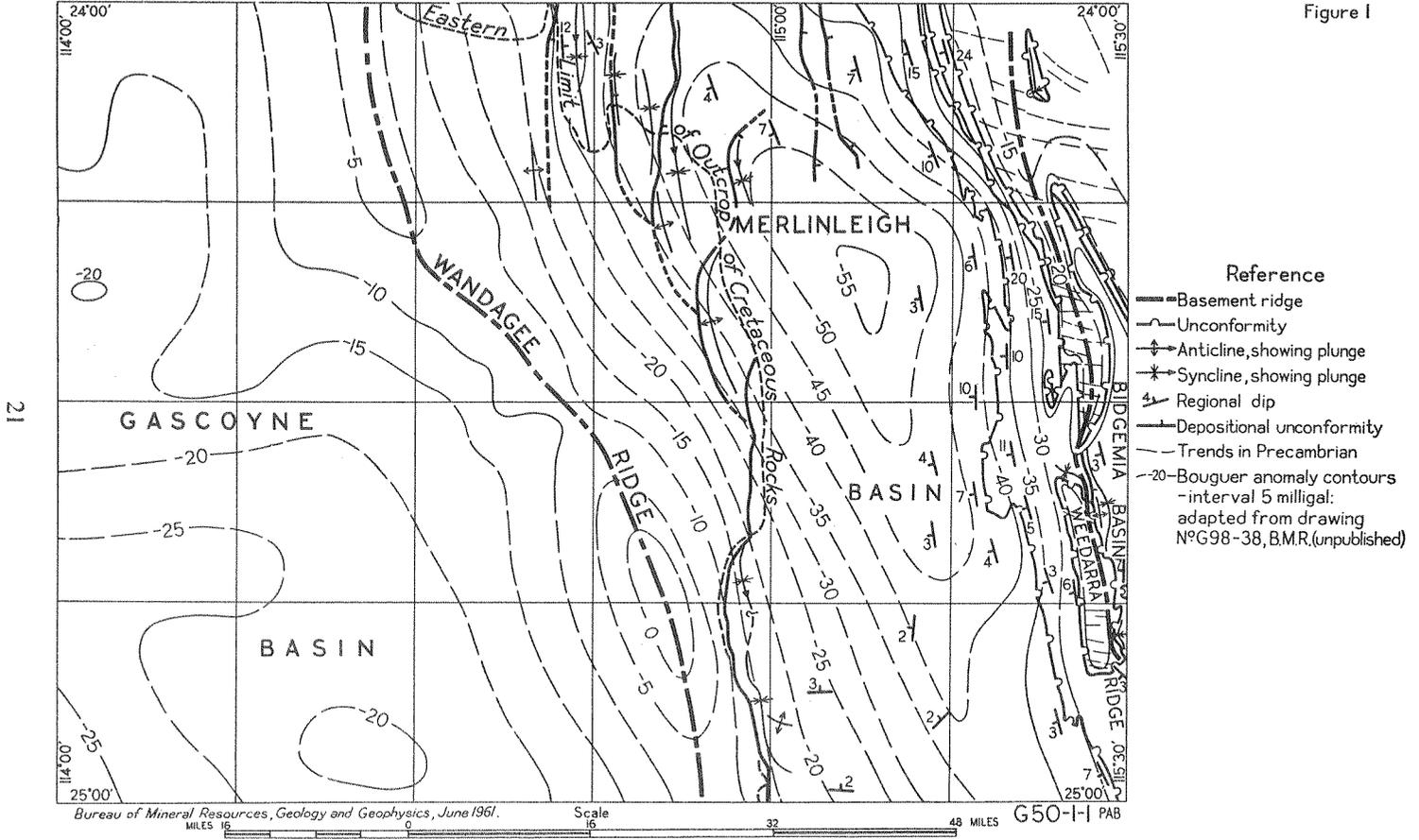
STRUCTURE

The main structural elements of the Sheet area are shown in Figure 1. The contours of the Bouguer gravity anomalies, from a Bureau of Mineral Resources unpublished map, No. G. 98-38, are also shown.

The Precambrian schist trends generally east-west. Steep north and south dips have been measured, but fold axes have not been established. Granite, intrusive into the schist, is known only at the far north of the Sheet. The only indication of major faulting is in the north-eastern corner of the Sheet, where a strong north-south dyke separates east-west trends (to the west) from northward trends (on the east). Dykes of quartz appear mainly to follow the trends of the schist foliation, although some are oblique to them. Dykes of basic rock have two main trends — east of north and north of east. The topography of the surface of the Precambrian rocks beneath the Palaeozoic sediments appears to be related more to the directions of these basic dykes than to the trend of the schist.

The regional dip of the Palaeozoic and Mesozoic sediments is westward at angles ranging from about 40° in the Devonian to less than 1° in the Cretaceous.

Figure 1



The Eocene sediments are sub-horizontal. The regional dip is interrupted by several synclines associated with angle of rest unconformities (Condon, 1956).

The gravity survey by the Bureau of Mineral Resources (Chamberlain, Dooley, & Vale, 1954), a later seismic reflection survey in the Wandagee Hill area, Minilya Sheet (Condon, 1955), geological work in the Murchison River area, and the results of WAPET's Yanrey No. 1 indicate that the Carnarvon Basin is divided into smaller structural basins by ridges of Precambrian basement. On the Kennedy Range Sheet the Wandagee Ridge separates the Gascoyne Basin from the Merlinleigh Basin, and the Weedarra Ridge (including outcropping Precambrian rocks in inliers) separates the Merlinleigh from the Bidgemia Basin.

The negative gravity anomaly (Fig. 1) indicates that the axis of the Merlinleigh Basin may run north-west and east of south from Merlinleigh Homestead. The axis of the Gascoyne Basin appears to run north-south near the western margin of the Sheet.

ECONOMIC GEOLOGY

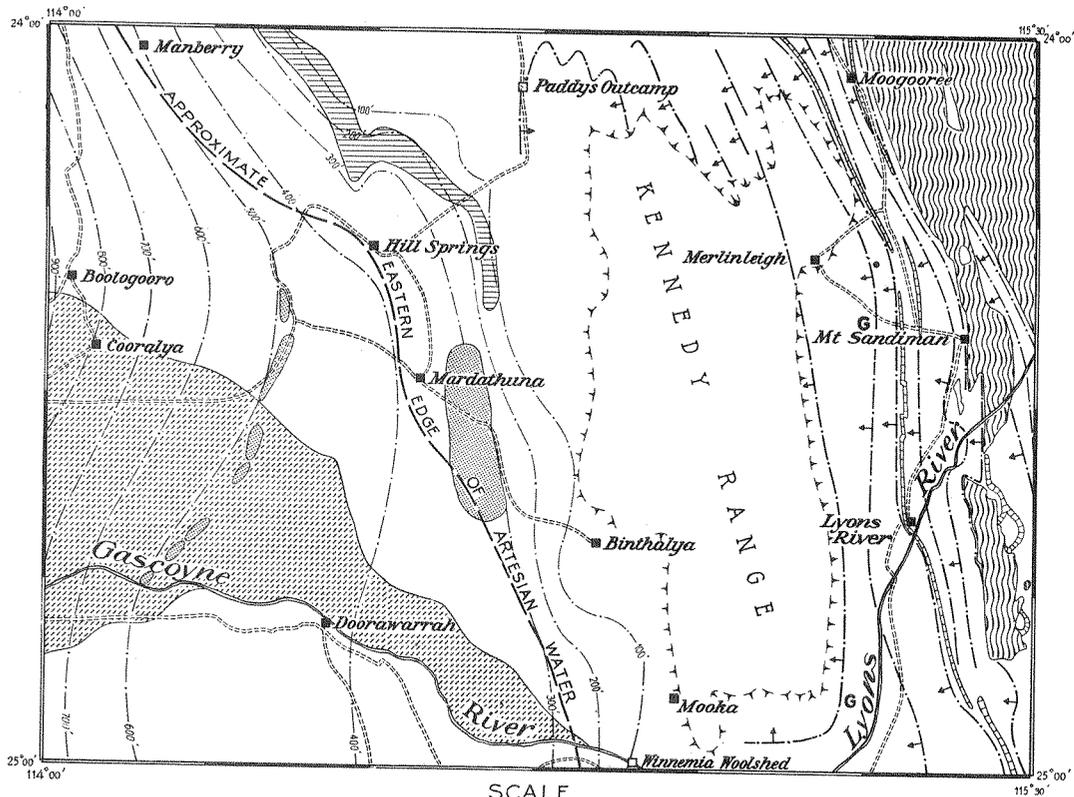
Water

The only mineral of economic importance produced in the Kennedy Range Sheet area is the underground water on which the pastoral industry largely depends. Although good stock water is obtained from springs, wells, and bores in many parts of the area, available underground water can be developed much more than it has been to date. In much of the western part of the Sheet large supplies of very good stock water are available in the Birdrong Formation at approximate depths indicated in Figure 2. Some drillers have been daunted by the 'black-jack' — the dark shale of the Winning Group — from continuing drilling in this area, but it is necessary to drill through this to reach the Birdrong aquifer. It is likely that artesian water will be encountered in the aquifer west of the line indicated from Manberry to about 4 miles west of Winnemia Woolshed.

East of the area underlain by the Birdrong aquifer, ground water is contained in the more permeable Palaeozoic formations, the outcrop and dip of which are indicated in Figure 2. These formations are the Munabia Sandstone (good water and supply, e.g. Redhill Well, Moogooree Station); Austin Formation (e.g. Gap Well, Moogooree); Coyango Greywacke (e.g. bores and wells along Woodcock and Austins Creeks, Mount Sandiman) and Koomberan Greywacke (e.g. Millers Bore, Mount Sandiman Station), some good stock water, generally small supplies; Moogooloo Sandstone (good water and supply e.g. Tabletop Well, Lyons River Station); Mallens Greywacke (good stock water, fair supply, e.g. Binthabooka Bore, Mount Sandiman Station); and Norton Greywacke (stock water, small to good supplies, e.g. Muderong Bores, Middalya Station).

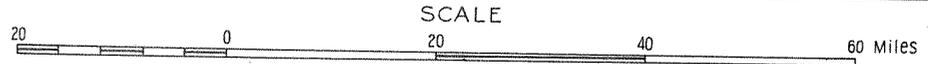
In the Precambrian rocks water can be obtained in alluvium in the larger stream valleys (e.g. 7-mile Well, Moogooree) and in quartz reefs, particularly where they cross stream courses. Elsewhere any water obtained is commonly too saline for stock water.

Fig 2



Reference

-  Gascoyne delta.
-  Precambrian rocks.
-  Bentonitic shale.
-  Friable limestone.
-  Hard limestone.
- G** Gypsum
-  Homestead
-  Road
-  Outcrop of water-bearing formation showing dip.
-  Depth to Birdrang formation aquifer.



In the area of alluvium west to north-west of Doorawarra Homestead good to small supply of good water can be obtained at depths of 50 to 100 feet.

Minerals

The following rocks and minerals of possible future economic significance have been found: *limestone* (for road surfacing, concrete aggregate, cement and lime manufacture, agricultural lime) in the Callytharra Formation extending from 8 miles west-north-west of Moogooree Homestead to the Arthur River at the south-east corner of the Sheet, in the Moogooree Limestone from 4 miles north to 9 miles east of south of Moogooree Homestead, and in the Gneudna Formation from 4 miles north-north-east of Moogooree to 4 miles north of Mount Sandiman Homestead; *friable limestone* (for cement and lime manufacture and agricultural lime) in the Callytharra and Gneudna Formations as above and in the Korojon Calcarenite from 10 miles east of Manberry Homestead to Rocky Pool on the Gascoyne River and from 8½ miles north of Hill Springs Homestead to 11½ miles west of Binthalya Homestead (covered intermittently by travertine and sand); *gypsum* and possibly other evaporites in the Bulgadoo Shale on Mount Sandiman, Lyons River, and Bidgemia stations; *bentonitic shale* in the Gearle Siltstone and Muderong Shale from 13 miles east of Manberry to 6 miles east of Hill Springs Homestead (mainly covered by thin Quaternary deposits); *radiolarite* (for filtration, insulation, and fine abrasive) in the Windalia Radiolarite from 15 miles east of Manberry to 2 miles north-west of Paddys Outcamp and southward to 2½ to 8 miles east of Binthalya Homestead; *shale* (for brick-making, portland cement manufacture) in the Gearle Siltstone and Muderong Shale, the Baker, Wandagee and Coyrie Formations and Bulgadoo Shale, the Weedarra Shale, the Mundarie and Dumbardo Siltstone, and the Austin Formation.

The following have not been found in the area, but geological evidence suggests that they may be found:—

Salt

The presence of outcropping evaporite gypsum in the Bulgadoo Shale and of brine in bores in Wandagee Formation in the west part of Lyons River station suggest the possibility of evaporite salt deposits in these formations below the water table.

Petroleum

The outcropping Palaeozoic sequence is about 14,000 feet thick, of which about 5,000 feet is of petroleum source-bed type or likely to pass into that type. Formations of permeability adequate for reservoirs and with impermeable formations overlying them include Nannyarra Greywacke, Munabia Sandstone, Austin Formation, Coyango Greywacke, Koomberan Greywacke, Moogooloo Sandstone, Mallens Greywacke, Norton Greywacke, and Birdrong Formation. The only large structure probably of anticlinal form is the Wandagee Ridge, where pre-Permian sediments may be present, covered by Lyons Group sediments. The Permian sediments probably wedge out against the east side of this ridge and may form stratigraphic traps there. There may be traps along the depositional un-

conformities to the west of Kennedy Range and there is some indication of an anticline or terrace in the Birdrong Sandstone between Hill Springs and Doorawarra.

The presence of stromatoporoids and corals in the outcropping Devonian indicates a possibility of Devonian reef development on the Wandagee Ridge.

No metalliferous minerals have been reported from the Precambrian rocks of this Sheet, although they are found to the east of Yinnietharra (Mount Phillips Sheet). As the rocks are schistose with quartz reefs and basic dykes, metallic minerals may occur.

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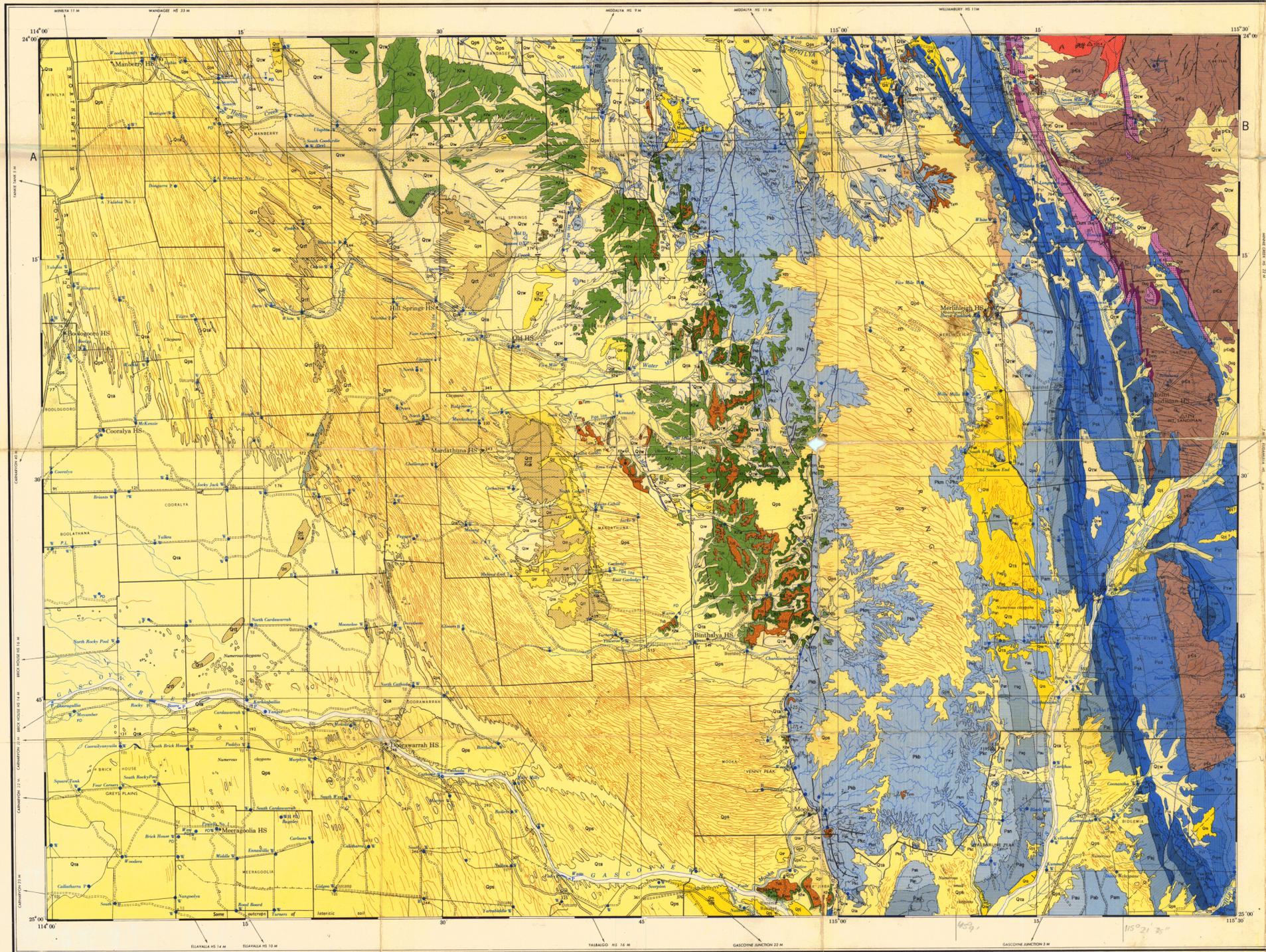
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- Reference**
- Established geological boundary, position accurate
 - Established geological boundary, position approximate
 - Inferred boundary
 - Strike and dip of strata
 - Horizontal strata
 - Dip < 15°
 - Trend lines
 - air-photo interpretation
 - Established anticlinal crest, position accurate, showing plunge
 - Established anticlinal crest, position approximate
 - Established synclinal trough, position accurate
 - Established synclinal trough, position approximate
 - Established synclinal trough, concealed
 - Monocline, concealed
 - Established fault
 - Inferred fault
 - Inferred fault, concealed
 - Depositional unconformity, position accurate, showing dip
 - Depositional unconformity, position approximate
 - Depositional unconformity, concealed
 - Unconformity, shown only where necessary
 - Strike and dip of foliation
 - Dyke
 - Sand dune
 - Significant small outcrop
 - Macrofossil locality
 - Plant fossil locality
 - Type section
 - Highway
 - Road
 - Vehicle track
 - Fence
 - Station boundary
 - Station name
 - Telephone line
 - Telephone line along fence
 - Homestead
 - Outcrop
 - Yard
 - Landing ground
 - Stratigraphic bore
 - Bore
 - Well
 - Spring
 - Pool
 - Waterhole
 - Windpump
 - Tank
 - Dam
 - Position doubtful
 - Trigonometrical station
 - Spot height

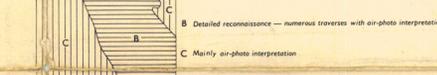
- Reference**
- Q1a Alluvium-sand, gravel, silt
 - Q1w Wash-sand, gravel
 - Q1c Residual soil, clay
 - Q1t Travertine
 - Q1s Brown sand
 - Q1r Red sand
 - Q1h Sand, gravel, travertine (old river deposits)
 - Q1n Limestone, chert
- RECENT**
- PLEISTOCENE**
- Joolabroo Formation
 - Nadarra Formation
- ? UPPER TERTIARY**
- T1a Silty-saline sandstone and conglomerate
 - T1c Limestones, sandstone, tuffaceous rock
- EOCENE**
- Merlinleigh Sandstone
- UPPER CRETACEOUS**
- Korojon Calcarenite
- LOWER CRETACEOUS**
- Wingin Group
 - Gearle Siltstone
 - Windala Radiolarite
 - Mudroong Shale
 - Birdroong Formation
- KUNGURIAN**
- Kennedy Group
 - Binthaya Formation
 - Mungadan Sandstone
 - Coolkiya Greywacke
- ARTINSKIAN**
- Byro Group
 - Baker Formation
 - Narvon Greywacke
 - Wandagee Formation
 - Quinnville Shale
 - Cundiego Formation
 - Newman Subgroup
 - Bulgadoo Shale
 - Mallens Greywacke
 - Coyrie Formation
 - Billides Formation
 - Moogbloo Sandstone
- SAKMARIAN**
- Wooramel Group
 - Callytharra Formation
 - Lyon Group
 - Weedarra Shale
 - Thambrook Formation
 - Mundarie Siltstone
 - Koomban Greywacke
 - Dumbaroo Siltstone
 - Coyango Greywacke
 - Austin Formation
- LOWER CARBONIFEROUS**
- Yindagindy Formation
 - Willamby Formation
 - Moogoree Limestone
- UPPER DEVONIAN**
- Willaraddie Formation
 - Munabla Sandstone
 - Gneudna Formation
- MIDDLE ? DEVONIAN**
- Nannarra Greywacke
- PRECAMBRIAN**
- P1g Granitic rocks
 - P1x Schist (Biotite, Quartz, Sericite, Talc, Hornblende)

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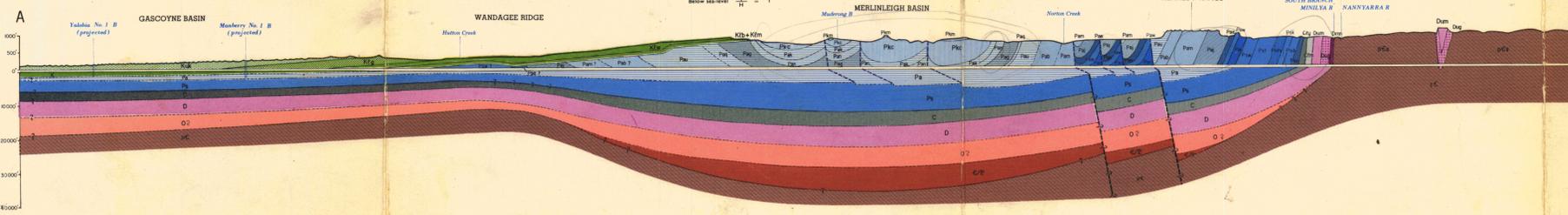
INDEX TO ADJOINING SHEETS
Showing Magnetic Declination



GEOLOGICAL RELIABILITY DIAGRAM



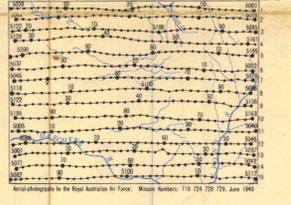
Section A-B



- IN SECTION ONLY:**
- Undifferentiated
 - CRETACEOUS
 - PERMIAN
 - ARTINSKIAN
 - SAKMARIAN
 - CARBONIFEROUS
 - DEVONIAN
 - ORDOVICIAN
 - CAMBRIAN OR PROTEROZOIC
 - PRECAMBRIAN



AIR - PHOTOGRAPH FLIGHT DIAGRAM



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