Mineral Provinces

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Preliminary Map Commentary — Australia 1:250 000 Basement Geology and Regolith Landforms: Ebagoola (SD54-12), Queensland Record 1992/71

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Compiled and edited by G R Ewers and J H C Bain

MINERALS AND LAND USE PROGRAM
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Preliminary Map Commentary — Australia 1:250 000 Basement Geology and Regolith Landforms: Ebagoola (SD54-12), Queensland Record 1992/71

A Contribution to the National Geoscience Mapping Accord

NORTH QUEENSLAND PROJECT

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

DEPARTMENT OF RESOURCE INDUSTRIES

Compiled and edited by G R Ewers and J H C Bain

Minerals and Land Use Program *October 1992*

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

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Frontispiece: Airborne gamma spectrometry displayed as a perspective by ray-tracing over a digital elevation model. This view of EBAGOOLA is looking north with false sun illumination from the WNW (from Chopra & others, in press).


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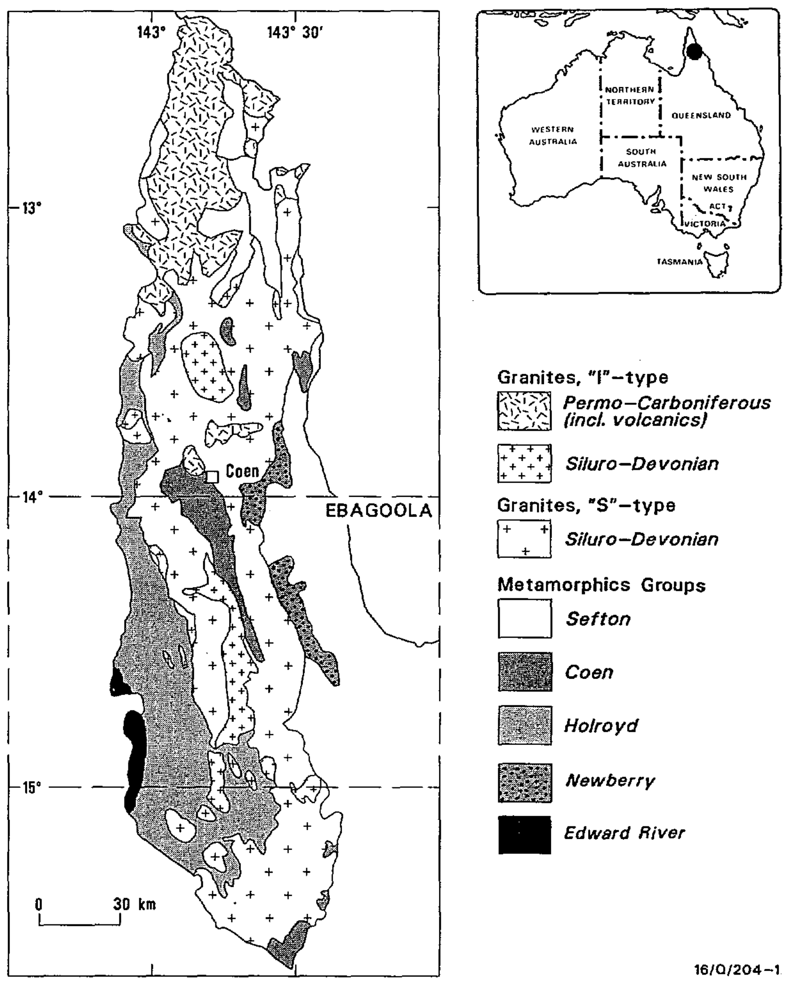


Figure 1. Generalised locality map and Coen Inlier geology (modified from Bain and others, 1992).

INTRODUCTION

This Record is a preliminary map commentary for the Ebagoola 1:250 000 Sheet area (EBAGOOLA) basement geology and regolith landform maps and is based on fieldwork carried out during July to September 1991 by the Australian Geological Survey Organisation (AGSO) in conjunction with the Geological Survey of Queensland (GSQ), Department of Resource Industries. It reports the preliminary results of an integrated study of the basement geology, geophysics, regolith, and mineralisation of EBAGOOLA. AGSO and Queensland Resource Industries Records describing different facets of this work in greater detail are nearing completion (e.g. Black & others, in press; Blewett, in press; Blewett & others, in press; Culpeper & others, in press; Mackenzie and Knutson, in press; Wilford, in press; Wellman, in press, a & b).

The pre-Mesozoic geology and regolith of EBAGOOLA were mapped using a combination of (1) Landsat TM, (2) 1990 colour air photography at 1:50 000 scale covering the Coen Inlier, (3) a recently acquired airborne magnetic and gamma ray spectrometric survey at 400 m line-spacing for the entire Sheet area, (4) complete coverage by 1:80 000 black and white photography flown in 1970, and (5) field work. This work has resulted in subdivision of the igneous and metamorphic rocks, and a comprehensive revision of the tectonic, magmatic, and metallogenetic history of the area.

Location, access, and land use

EBAGOOLA lies between latitudes 14°00' and 15°00'S and longitudes 142°30' and 144°00'E on the east coast of Cape York Peninsula, west of Princess Charlotte Bay (Fig. 1).

Access by road throughout EBAGOOLA is generally poor and suitable only for four-wheel drive and heavy vehicles; during the wet season most roads become impassable. The Peninsula Developmental Road, which connects the tip of Cape York Peninsula and Weipa in the north with Laura to the southeast of the Sheet area, is the main access route that passes through EBAGOOLA. Formed public roads diverge from the Peninsula Developmental Road to the Edward River Community and to Aurukun in the west and to the mouth of the North Kennedy River and Port Stewart on Princess Charlotte Bay to the east. A network of private tracks links homesteads throughout the area. A regular airline route operates to the township of Coen immediately north of EBAGOOLA, and light aircraft also service some station homesteads.

Pastoral holdings used for cattle grazing are the dominant form of land tenure within the Sheet area. The southeastern corner of EBAGOOLA is covered by the Lakefield National Park.

Climate

Cape York Peninsula has a monsoonal climate with most of the region's annual rainfall (generally 1000-1800 mm per year) received in the summer months from November to April. Temperatures (in degrees celsius) in the summer months range from maximums in the low to mid 30's to minimums in the low to mid 20's; corresponding winter temperatures are usually 5°C cooler than those in the summer months (Connell Wagner, 1989).

Physiography and vegetation

Topographic relief within the Sheet area is characterised by gently undulating plains and rises with subsidiary development of level plains, hills, and mountains. Whitaker and Gibson (1977) divided EBAGOOLA into three broad physiographic regions: the uplands of Cape York Peninsula (corresponding to the outcrop area of the Coen Inlier), the eastern coastal plains, and the western plains. The boundaries between these physiographic units tend to coincide with major geological boundaries because of the varying intensities and effects of weathering and erosion on different rock types, and the effect that landform has on sedimentation and vice versa. A more in-depth treatment of the distribution and genesis of landforms is provided later in a discussion of the regolith.

Vegetation over most of the Sheet area consists of an open forest and woodland of eucalypts with an understorey of shrubs and grasses (Connell Wagner, 1989).

Previous investigations

Many of the early geological observations in the Sheet area were related to the discovery and description of gold deposits in the Hamilton and Coen Mining Fields late last century (e. g. Jack, 1881; Ball, 1901; Cameron, 1906).

Whitaker and Gibson (1977) summarised the nature and extent of geophysical surveys related to petroleum exploration during the 1950s and 1960s in and around EBAGOOLA. BMR (now AGSO) provided offshore and onshore reconnaissance gravity surveys (Goodspeed & Williams, 1959; Dooley, 1965; and Shirley & Zadoroznyj, 1974) and in 1973 completed an airborne magnetic and gamma ray spectrometric coverage (1500 m line spacing and 150 metre height) for EBAGOOLA. Pinchin (1973) reviewed the geophysics of the Carpentaria, Laura, and Olive River Basins, and Pinchin (1974) reinterpreted onshore seismic results from the Laura Basin.

The most comprehensive geological investigations in the Sheet area resulted from joint AGSO/GSQ field mapping from 1962 to 1974. These included surveys of the Laura Basin (deKeyser & Lucas, 1968), the Coen Inlier (Trail & others, 1968; Whitaker & Willmott, 1968; Willmott & others, 1973) and the Carpentaria and Karumba Basins (Doutch & others, 1973; Powell & others, 1976; Smart & others, 1980).

REGIONAL GEOLOGICAL SETTING

The geology of EBAGOOLA comprises the pre-Mesozoic basement rocks of the Coen Inlier flanked by the Mesozoic Carpentaria Basin and Cainozoic Karumba Basin to the west and the Mesozoic Laura Basin to the east.

The north-trending Coen Inlier is the exposed part of an extensive province of Proterozoic metasedimentary rocks widely intruded by Siluro-Devonian granites and, in the northern parts of the Inlier, overlain and intruded by Permo-Carboniferous igneous rocks (Fig. 1). The Proterozoic rocks comprise greenschist grade pelitic sediments and sandstones grading to upper amphibolite facies schist, gneiss, and quartzite. The dominant igneous rocks are the granitoids (both S- and I-type) of the Siluro-Devonian Cape York Peninsula Batholith (CYPB), which constitutes more than half of the exposed pre-Mesozoic basement in EBAGOOLA. The northern areas of the Coen Inlier are overlain by a poorly exposed sequence of Carboniferous fresh-water sediments and extensive Carboniferous-Permian felsic volcanic rocks (pyroclastics and lavas) which have been intruded by the Permian granites. In EBAGOOLA, dykes of rhyolitic to andesitic or basaltic composition, rhyolite plugs, and one small stock of microgranite, all of probable Late Carboniferous-Early Permian age intrude the CYPB and its metasedimentary host rocks. An isolated exposure of Early Pliocene (Sutherland, 1991) nephelinite lava crops out in the northeastern part of the Sheet area.

Mesozoic sedimentary basins (Carpentaria and Laura Basins) overlap the Coen Inlier to the west, south and east; they consist of a conformable Jurassic to Lower Cretaceous sequence of continental sandstone and conglomerate overlain by marine sandstone and mudstone (Smart & others, 1980; Hawkins & Williams, 1990).

The Cainozoic Karumba Basin (Smart & others, 1980) unconformably overlies the Carpentaria Basin and is characterised by fluvial sediments, the products of weathering, and residual materials. Probable correlatives of units within the Karumba Basin overlie the Laura Basin along the eastern margin of the Sheet area.

MAP UNITS

The stratigraphy of EBAGOOLA is summarised in Table 1.

PROTEROZOIC

by R.S. Blewett, D.S. Trail (AGSO), and F.E. von Gnielinski (GSQ)

A number of changes are proposed for the metamorphic stratigraphy that was published by Willmott & others (1973); the rocks are now divided into the Edward River Metamorphic Group, Holroyd Group, Coen Metamorphic Group, Newberry Metamorphic Group and undifferentiated metamorphic rocks.

Wellman (in press, a) used geophysical data to divide units of concealed and unidentified metamorphic rocks on the western and eastern margins of EBAGOOLA. Some of these geophysical units on the eastern side of EBAGOOLA may crop out to the north in the McIlwraith Range and Rocky River regions of the Coen 1:250 000 Sheet (COEN).

Edward River Metamorphic Group — Pe

The Edward River Metamorphic Group (Fig.2; group 1) is poorly exposed along the southwestern edge of the outcropping Coen Inlier. It was originally included in the "Holroyd Metamorphics" as defined by Willmott & others (1973). Two units within one domain have been defined and a further 2 domains have been recognised on the basis of their geophysical characteristics; all three domains form narrow, elongate north striking strips. The Edward River Metamorphic Group occupies approximately 1000 km^2 on EBAGOOLA, of which less than 40 km^2 crops out.

Drovers Lagoon Quartzite — Ped

(new name after Drovers Lagoon – Strathmay 1:100 000 sheet area)

The Drovers Lagoon Quartzite is around 800 m thick and comprises quartzite, some slate and phyllite; its colour ranges from cream and buff to light and mid-grey. Grainsize generally ranges from very fine to medium and accessory muscovite is common. In some massive beds (up to 1 m thick), coarse bases grade up into fine metasandstone. The quartzite commonly has a saccharoidal texture, and a high degree of sorting and roundness. These well sorted, even-grained quartzites are interbedded with very fine-grained slates and phyllites that are more highly magnetic.

The unit forms a north-trending belt about 30 km long in the southwestern part of EBAGOOLA, cropping out as ridges rising around 40 to 60 m above the surrounding country, but much of the unit is covered by weathered siltstone of the Mesozoic Rolling Downs Group (Vine & others, 1967).

TABLE 1 Stratigraphy of EBAGOOLA
(modified from Blewett & others, in press; Mackenzie & Knutson, in press)

GROUP	UNIT	SYMBOL	THICKNESS	ROCK-TYPE
CAINOZOIC		Cz		basanitic nephilinite
MESOZOIC		Mz		siltstone, mudstone, sandstone, minor conglomerate
EARLY CARBONIFEROUS TO LATE PERMIAN		CPr		porphyritic rhyolite
	Lindsay Flat Microgranite	CPg		pale to very pale grey porphyritic biotite microgranite
EARLY SILURIAN TO LATE DEVONIAN				
Kintore Supersuite				
Ebagoola suite	Ebagoola Granite	SDe		White to pale cream or pink garnet-biotite-muscovite leucogranite, pegmatite, and aplite.
	Lindalong Granite	SDl		Pale grey, foliated, garnet-muscovite-biotite granite to leucogranite
	Warner Granite	SDw		Pale grey to buff, equigranular muscovite-biotite granite
	Kintore Granite	SDk		Pale grey to cream or brown variably porphyritic muscovite-biotite granite
	Leconsfield Granite	SDd		Pale grey muscovite-biotite granite
	Barwon Granite	SDb		Pale grey to cream or brown weakly porphyritic muscovite-biotite granite
	Heneage Granite	SDh		Pale grey to buff or cream porphyritic muscovite-biotite granite
	Burns Granite	SDu		Pale grey to cream or brown medium to coarse muscovite-biotite granite.
	Tadpole Granite	SDt		Mid to pale grey garnet-bearing biotite granite, mostly foliated.
Lankelly suite	Lankelly Granite	SDl		Pale grey, abundantly porphyritic muscovite-biotite granite
	Kendle River Granite	SDn		Pale grey, variably porphyritic to megacrystic muscovite-biotite granite
Flyspeck Supersuite	Kirkwood Monzogranite	SDo		Pale grey, moderately porphyritic biotite monzogranite to granodiorite
	Carleton Monzogranite	SDc		Pale grey, weakly porphyritic biotite monzogranite to granite
	Two Rail Monzogranite	SDr		Pale grey, sparsely and weakly porphyritic, allanite-biotite monzogranite to granodiorite
	Artemis Granodiorite	SDa		Pale to mid-grey allanite-biotite monzogranite to granodiorite
	Flyspeck Granodiorite	SDf		Mid-grey, sparsely megacrystic allanite±hornblende-biotite granodiorite
	Glen Garland Granodiorite	SDg		Mid-grey, weakly porphyritic allanite-hornblende-biotite and biotite-hornblende granodiorite
	Tea Tree Granodiorite	SDtt		Mid-grey, weakly porphyritic allanite-biotite-hornblende granodiorite
	Peringa Tonalite	SDp		Mid to dark-grey, weakly porphyritic allanite-biotite-hornblende tonalite
PROTEROZOIC				
Edward River Metamorphic Group	Olkolo Schist	Peo	1500 m	Metasiltstone, slate, phyllite, garnet-muscovite-quartz schist, locally graphitic
	Drovers Lagoon Quartzite	Ped	800 m	Saccharoidal quartzite, muscovite-quartz slate and phyllite.
Coen Metamorphic Group	Goolha-Goolha Schist	Pcg	?	Sillimanite-muscovite-quartz schist and muscovite quartzite.
	Lochs Gneiss	Pcl	?	Sillimanite-garnet-mica-feldspar gneiss, amphibolite and feldspar-mica gneiss
	Yarraden Schist	Pcy	?	Sillimanite-biotite-muscovite schist and quartzite
	Mount Ryan Quartzite	Pcr	<1000 m	Quartzite, mica-sillimanite quartzite
Newberry Metamorphic Group	Penny Gneiss	Pnp	?	Granitic garnet-muscovite-bitoite gneiss.
	Kitja Quartzite	Pnk	?	Quartzite, sillimanite-mica schist and gneiss
Holroyd Group	Strathmay Formation	Plm	?	Spotted slate and phyllite to garnet-mica schist
	Strathburn Formation	Plb	>500 m	Fine metasandstone/siltstone, slate and phyllite
		Pkpa	?	Graphite-andalusite schist interbedded with quartzite
		Pkg	?	Sericite-quartz slate, grades to andalusite phyllite/schist
		Pki	?	Coarse-grained sillimanite-andalusite-graphite-garnet-mica schist, gneiss
		Pkt	?	Sillimanite-garnet-mica-quartz gneiss and schist
		Pkj	>1500 m	Sillimanite-andalusite-mica schist, some andalusite-garnet-feldspar gneiss
	Gorge Quartzite	Plg	1300 m	Buff-cream medium-grained, thick-bedded quartzite
		Pkp	>500 m	Massive, thick-bedded mica quartzite
		Pkl	1000 m?	Massive quartzite with interlayered sillimanite-mica schist
		Pku	1300 m	Mica quartzite, garnet-mica schist, staurolite-andalusite-garnet schist
	Newirie Formation	Pln	3000 m	Purple slate/sandy slate; spotted biotite schist, andalusite-mica schist
		Pka	1500 m	Flaggy, fine biotite-muscovite schist
		Pkb	3000 m	Phyllite to garnet-mica schist with quartzite
	Carysfort Quartzite	Plc	1000 m	Cream, medium-grained saccharoidal quartzite
		Pke	1000 m	Muscovite-biotite quartzite and anadalusite-mica schist.
	Carew Greenstone	Plp	500-1000 m	Deeply weathered metadolerite/basalt
		Pkr	?	Medium-grained metadolerite
	Astrea Formation	Pla	1500 m	Spotted steel -grey slate to graphite-mica schist, quartzite and phyllite
		Pko	1500 m?	Andalusite-cordierite-mica schist; garnet-graphite schist
	Sugarbag Creek Quartzite	Pls	1200 m	Cream to purple thick-bedded quartzite to orthoquartzite
		Pkk	?	Coarse, granular mica quartzite
	Dinah Formation	Pld	>500 m	Fine-grained slate and quartzite
		Pkd	?	Sillimanite-graphite-mica schist; andalusite-sillimanite-mica schist
	Coleman River Gneiss	Pkc	2000 m?	Coarse sillimanite-andalusite-mica-feldspar gneiss

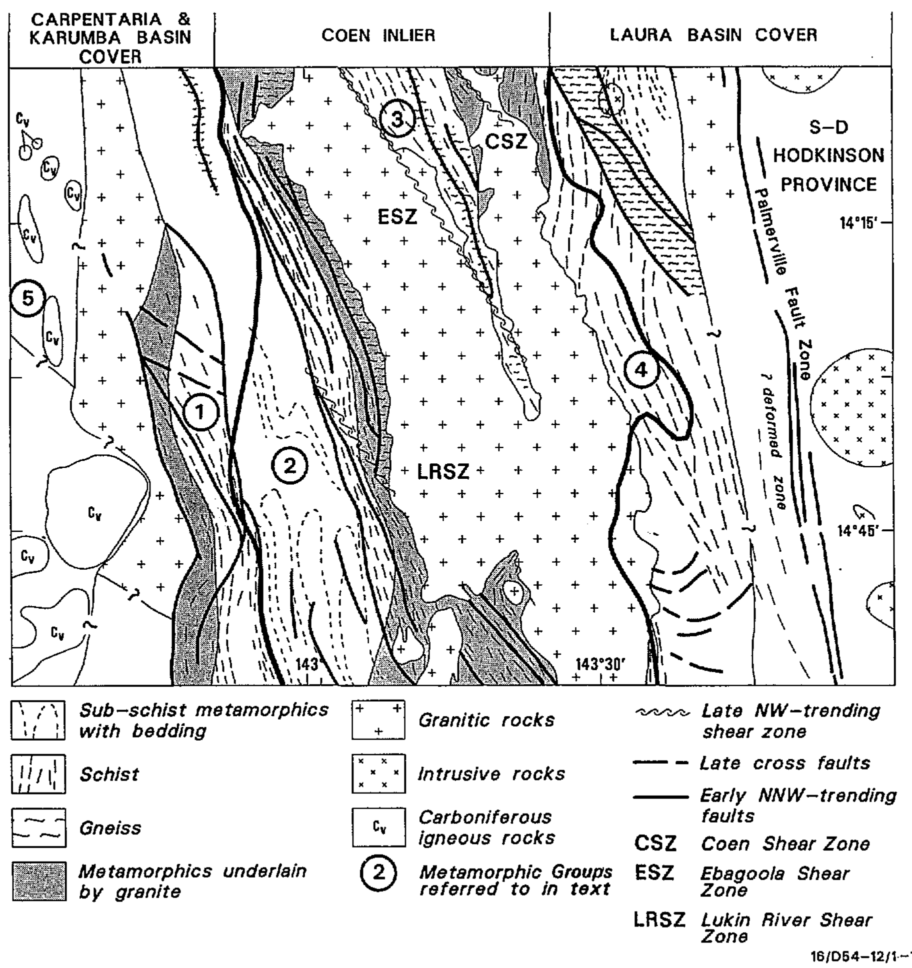


Figure 2. Main structural elements in EBAGOOLA (modified from Bain & others, 1992).

Olkolo Schist — Peo

(new name after the Olkolo Aboriginal language-group, occupying the southwestern part of EBAGOOLA; Tindale, 1974)

The Olkolo Schist consists of slate, phyllite, graphitic schist, muscovite schist, and metasiltstone and is around 1.5 km thick. The metasiltstone/sandstone is light to medium grey, fine-grained, well-bedded and moderately well sorted. The dominant minerals are quartz with a fair degree of recrystallization, and muscovite as fine needles. The phyllite is silver-grey and fine to very fine-grained with a well developed foliation. The rock comprises quartz and muscovite with a trace of graphite. Some phyllites are garnet-bearing. The schist is a white to pale grey, generally fine to medium-grained, (garnet-)muscovite-biotite-quartz schist. Garnet porphyroblasts are rare and commonly 2-3 mm in diameter. Feldspar and graphite are minor components, with graphite locally concentrated along S0 forming up to 5% of the rock mass. The more graphitic schists commonly comprise several 10 cm thick individual beds over an aggregate thickness of about 3 m.

The unit is very poorly exposed and deeply weathered, though bedding is well defined and generally dips steeply to the east. The Olkolo Schist has a possible conformable contact with the Drovers Lagoon Quartzite to the west, and a faulted contact (Cattle Swamp Shear Zone) with the Holroyd Group to the east.

Undifferentiated units — Pe1, Pe2, Pe3

Extensive Mesozoic and Teriary cover conceals the greater part of the Edward River Metamorphic Group. However, regional gravity and aeromagnetic data have been used to delineate the extent of the Group and to distinguish several constituent units on the basis of their magnetic characteristics:

- Pe1 – very high magnetisation (includes Ped and Peo)
- Pe2 – high magnetisation
- Pe3 – patchy magnetisation

A number of poor outcrops of granite and foliated granite/gneiss occur in the headwaters of the Edward River just east of the road to Strathburn homestead. Strongly foliated, cream to silver, medium to coarse-grained, garnet-biotite-muscovite-feldspar-quartz gneiss is exposed along a 60 m section of the Edward River. The garnet porphyroblasts are generally 1-2 mm in diameter. The layering and foliation in the gneiss are cut by a light grey dolerite dyke (2 m thick).

Holroyd Group — Pl, Pk

The Holroyd Group (Fig. 2; group 2) crops out over 3500 km^2 in the western third of EBAGOOLA and comprises all the rocks previously assigned to the Holroyd Metamorphics (by Willmott & others 1973) except the western edge which is now called the Edward River Metamorphic Group. The Holroyd Group is divided into the Lukin and Kalkah Structural Domains (Figs. 3 & 4). A near complete stratigraphic succession of ten formations has been defined in the Lukin Structural Domain (Pl). Their more deformed and metamorphosed equivalents are recognised further east in the Kalkah Structural Domain (Pk), which contains a less complete stratigraphy and is separated from the Lukin Structural Domain by the Lindalong

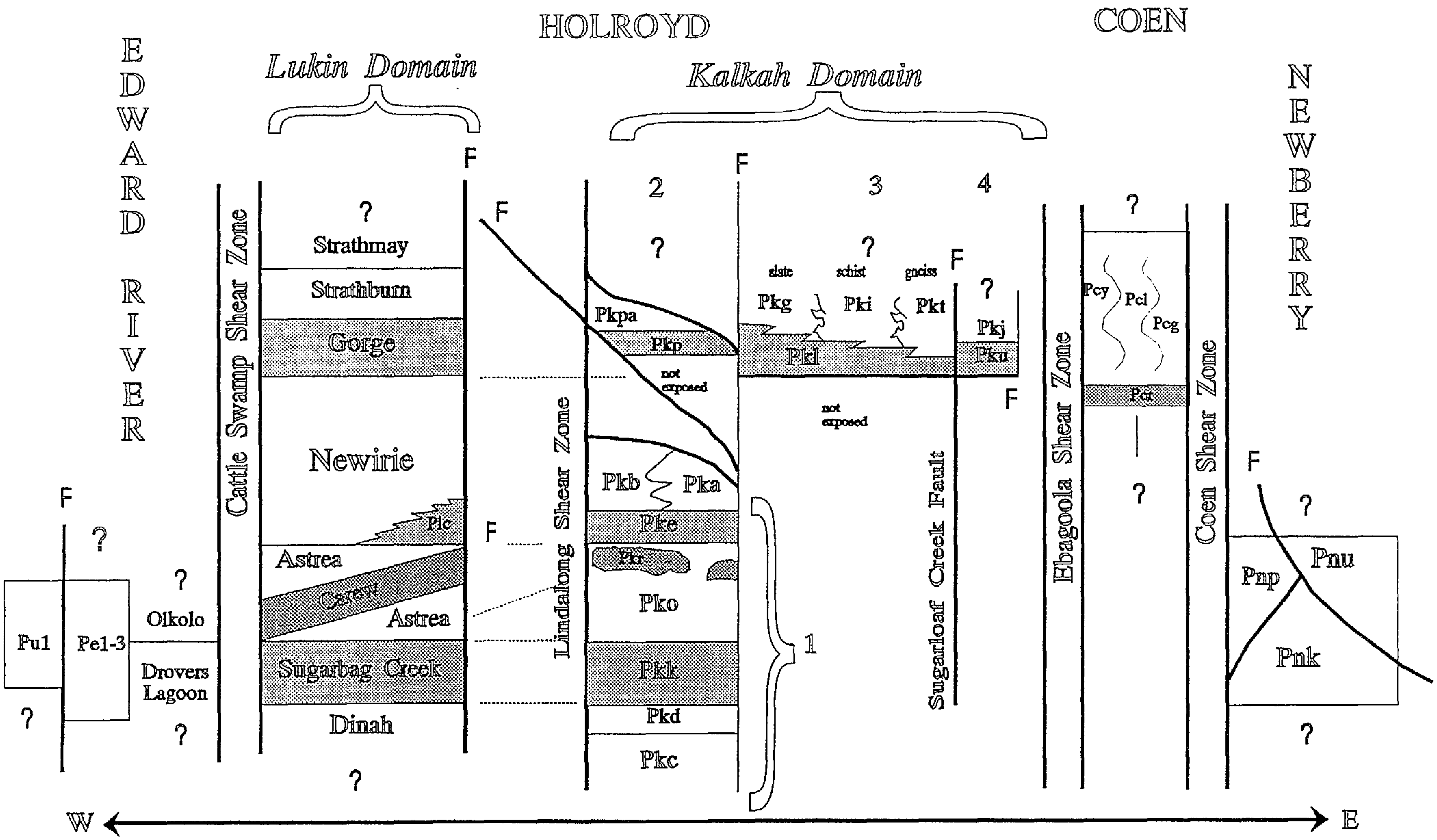


Figure 3. Unit relationship diagram for the metamorphic rocks of EBAGOOLA (from Blewett & others, in press).

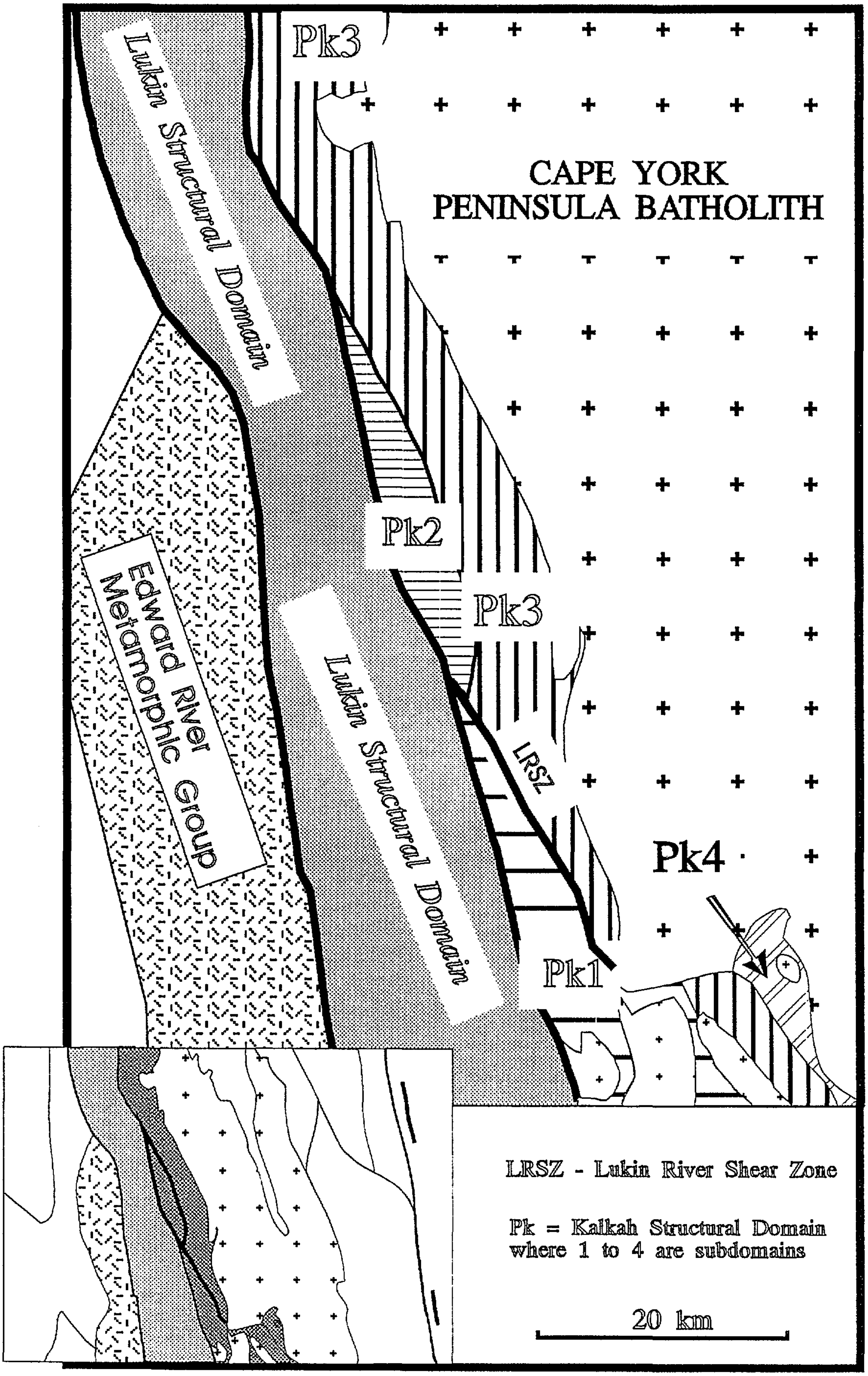


Figure 4. Distribution of the Kalkah Structural Domain (subdivided into four subdomains) and the Lukin Structural Domain.

Shear Zone. Metamorphic grade generally increases eastwards in the Kalkah Structural Domain towards the outcropping granitic rocks of the CYPB.

The rocks of the Lukin Structural Domain are modified from the *Lukin-type schist* of Whitaker & Willmott (1968). The Lukin Structural Domain occupies about 1500 km^2 in a NNW-trending belt between the Cattle Swamp and Lindalong Shear Zones, principally in the southwestern part of EBAGOOLA, and is generally coincident with areas of low magnetisation (Fig. 5).

The Kalkah Structural Domain (Fig. 6) lies between the Lukin Structural Domain and the CYPB, is generally coincident with areas of high magnetisation, and is divided into four shear zone-bounded subdomains. The units are assigned unique letter symbols within these subdomains to indicate the range of rock types across the Kalkah Structural Domain. Therefore, the Gorge Quartzite (shown as Plg in the Lukin Structural Domain) is Pkp, Pkl, and Pku, respectively, in three subdomains of the Kalkah Structural Domain.

Subdomain 1 lies between the Lindalong Shear Zone and the Lucy Swamp/Lukin River Shear Zones; it occupies the lowest tectono-stratigraphic level in the Kalkah Structural Domain and is correlated with its lower metamorphic grade equivalents in the Lukin Structural Domain. Units within this Subdomain include the Coleman River Gneiss (Pkc), Dinah Formation (Pkd), Sugarbag Creek Quartzite (Pkk), Astrea Formation (Pko), Carew Greenstone (Pkr), Carysfort Quartzite (Pke), and the Newirie Formation (Pka, Pkb).

Subdomain 2 is the duplex structure on the eastern side of the Lindalong Shear Zone; it contains equivalent units of the Gorge Quartzite (Pkp) and the Strathburn Formation (Pkpa).

Subdomain 3 lies between Subdomain 2 and the CYPB and comprise a unit equivalent to the Gorge Quartzite (Pkl) and several units equivalent to the Strathburn Formation (Pki, Pkg, and Pkt) that are lateral depositional and subsequent metamorphic facies equivalents.

Subdomain 4 is in the far south east between the CYPB and the Sugarloaf Creek Fault, and contains the Gorge Quartzite (Pku) and the overlying Strathburn Formation (Pkj).

Units of the Holroyd Group within the Lukin and Kalkah Structural Domains are described below.

Coleman River Gneiss — Pkc

(new name after the Coleman River – Kalkah 1:100 000 Sheet area)

The Coleman River Gneiss is a red to grey, medium to coarse-grained sillimanite- andalusite-mica-feldspar gneiss. Graphite is present in places. It crops out near the Curlew Range north of Opera Hill, and in the Coleman River at the junction with Lucy Creek. It is only exposed in the Kalkah Structural Domain.

The main outcrop near the Curlew Range is intensely sheared and estimates of thickness (2000 m) are very tentative. The unit appears to pass conformably into the more resistant Sugarbag Creek Quartzite (Pkk) to the east, but is faulted against Pkk to the west. The outcrop shape of the Coleman River Gneiss suggests that it occupies a fold core, although no macroscopic closures were recorded. The gneiss is well foliated and locally approaches a schist in texture. The foliation (S2) is also relatively flat-lying in some areas of the unit. This may point to the presence of post D2 folding about approximately N-S axes.

Dinah Formation — Pld (slate), Pkd (schist)

(new name after Dinah Creek – Kalkah 1:100 000 Sheet area)

Pld is predominantly a grey fine-grained slate with thin interbedded quartzites. It forms the cores

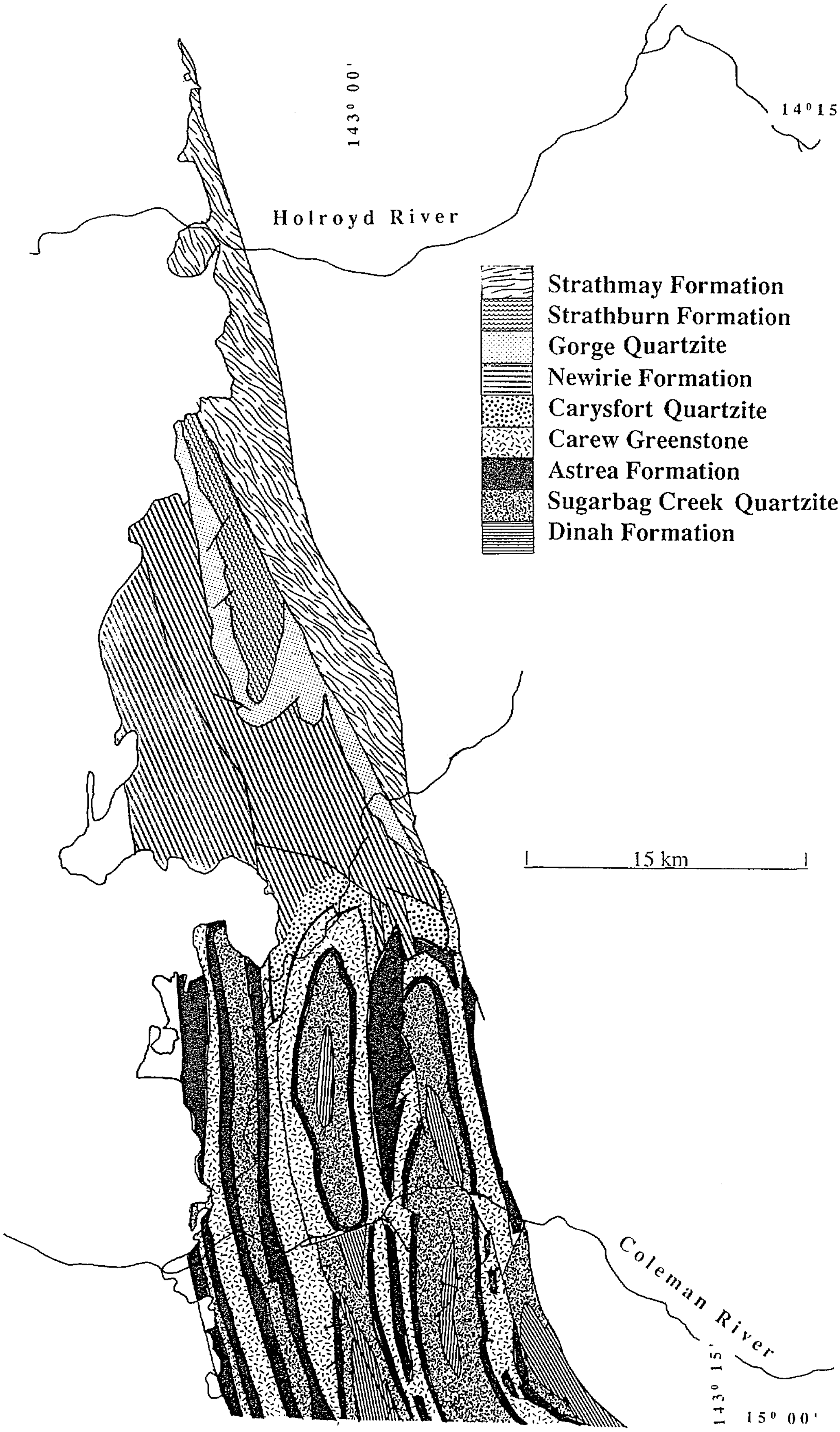


Figure 5. Distribution of metamorphic rocks in the Lukin Structural Domain (from Blewett & others, in press).

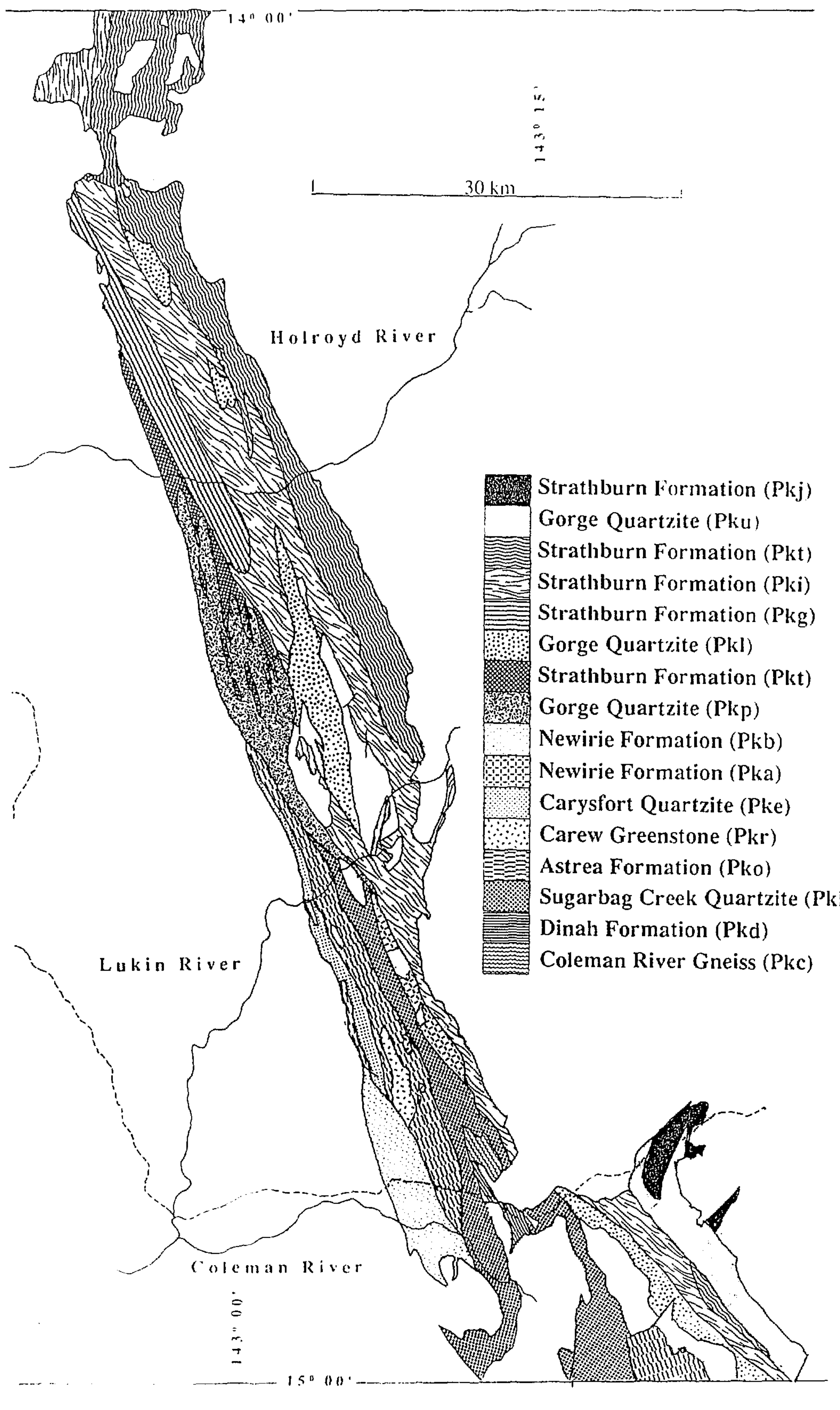


Figure 6. Distribution of metamorphic rocks in the Kalkah Structural Domain (from Blewett & others, in press).

to major F2 antiforms in the south west of the Kalkah 1:100 000 Sheet area. The base is not exposed and the unit is greater than 500 m thick. Pld is recessive and poorly exposed, and passes conformably up into the Sugarbag Creek Quartzite (Pls).

Pkd is predominantly a grey, medium-grained sillimanite-graphite-mica schist, in which andalusite and cordierite are largely retrogressed to sericite. Weathered red to brown sillimanite-mica-quartz schist is also common. Sillimanite is common as felted laths of fibrolite; the porphyroblasts are up to 1 cm long. The presence and relative abundance of sillimanite is a characteristic of this unit, especially when compared to the andalusite-cordierite-garnet-bearing schist (Pko) of the Astrea Formation to the west.

This unit has an across-strike thickness of up to 2000 m, and is found 10 km west of Glen Garland homestead. It has a faulted western contact and a conformable eastern contact with the Sugarbag Creek Quartzite (Pkk). Pkd is faulted against the Coleman River Gneiss; however, schists within the gneiss are similar to Pkd. A well developed schistosity is defined by S2. In the western outcrop (NE of Opera Hill), the S2 schistosity is sub-horizontal with dips ranging from 5 to 15^{o}.

Sugarbag Creek Quartzite — Pls (quartzite), Pkk (quartzite)

(new name after Sugarbag Creek – Kalkah 1:100 000 Sheet area)

Pls is up to 1200 m thick and consists of quartzite and lesser phyllite and slate. The quartzite ranges from purple to cream, buff, light grey and mid-grey, with purple beds common in the upper part and cream and buff beds in the lower part of the sequence. The grain size ranges from 0.06 mm to 4 mm (very fine sand to granules), but is mostly about 0.75 mm. Some thick to very thick beds (2 m) have very coarse bases which grade up to very fine metasandstone. Beds in the upper part of the unit are commonly thicker and coarser than those lower down, and it appears to be a thickening-upward and coarsening-upward sequence in general. In places quartzite is interbedded with very fine-grained spotted purple phyllite, which preserves thin depositional laminae.

Pls approaches an orthoquartzite with a saccharoidal texture in sedimentary terms, but metamorphic muscovite and rare iron-stained spots occur; some beds have feldspar. The quartzite has recrystallized in many outcrops and these weather to white, sub-vitreous, massive blocks. Accessory minerals include tourmaline, zircon, and opaques.

The unit crops out mostly in the cores of the main F2 antiforms, and forms ridges up to 80 m above the surrounding country. Sedimentary structures include rare ripple cross-lamination, graded bedding and parallel lamination.

Pkk is mostly purple to brown and pink, medium to coarse-grained micaceous quartzite. The quartzite has a granular texture where not overprinted by a strong foliation. Some beds contain muscovite and biotite and are more like psammitic schists; others have rare garnet. Parallel laminae are the only recorded sedimentary structures in the medium to thick-bedded quartzite. Muscovite and biotite are concentrated along the S2 surface, and biotite is commonly aligned within this surface. Quartzite is interbedded with brown to red/purple, fine-grained sillimanite-mica-quartz schists similar to the schistose part of the Dinah Formation (Pkd). Some schists are andalusite-graphite-cordierite(?)-bearing. The interbedded schists to the southwest are probably of lower metamorphic grade and tend to be muscovite-biotite-bearing schists.

Pkk extends south from the Lukin River to beyond the southern edge of the Kalkah 1:100 000 sheet area and from the Lindalong Shear Zone in the far south west to the Lucy Swamp Shear

Zone (an extension of the Lukin River Shear Zone) in the west. The thickness of the unit is difficult to calculate as most contacts are faulted; some slices are up to 2000 m in across strike thickness.

Astrea Formation — Pla (slate), Pko (schist)

(new name after Astrea Holding – Ebagoola 1:250 000 Cadastral Map)

Pla is mainly grey, fine to very fine-grained spotted slate, but steel grey, fine-grained graphite-muscovite schist has also been recorded. The unit generally becomes finer grained and more pelitic up section with grey to maroon or purple, fine to very fine-grained slate as the most common rock type. Minor laminated and ripple cross-laminated metasandstones are interbedded with the slate beds. Foliation ranges from a weak parting or fracture cleavage to a moderately well formed schistosity.

Pla is a recessive unit that is folded with and conformably overlies the Sugarbag Creek Quartzite and is overlain conformably by the Carysfort Quartzite. Marked thickness changes in the Astrea Formation are a function of the discordance of the 1 km thick intrusive Carew Greenstone which at its lowest level (stratigraphically) is near the base of the Astrea Formation and at its highest level is in contact with the overlying Carysfort Quartzite. The Astrea Formation has an estimated total thickness of 1500 m.

Astrea Formation above the Carew Greenstone sill ranges upwards from more psammitic to more pelitic lithologies with a thickness ranging up to 1 km. Small outliers of medium to coarse-grained, cream coloured quartzites crop out in the synclinal axes of the major F2 folds just west of the Coleman River Fault. A narrow sliver is also found west of the Lindalong Shear Zone forming the eastern limb of a major north-trending F2 anticline. Light grey, medium-grained quartzites and interbedded mica schist crop out adjacent to the greenstone contact. Metamorphic grades are variable, especially close to the sill, where garnet-actinolite(?)-biotite-muscovite schist occurs. Some slates have rounded, pale coloured spots less than 1 mm in diameter that consist of quartz and muscovite probably after cordierite.

Pko is typically a brown, medium to fine-grained andalusite-cordierite-mica-quartz schist grading to a grey, medium-grained garnet-mica-graphite schist. Garnet porphyroblasts are up to 2 mm in diameter, and pale-coloured ellipsoids of cordierite are up to 1 mm in diameter. Biotite is commonly aligned; some grains have steep-plunging elongation azimuths.

The schists are interbedded with more psammitic, "flaggy" thin-bedded rocks with quartz and muscovite. Parallel laminae were the only recorded sedimentary structures in these beds. As the schist is more recessive, the flaggy psammites are preferentially exposed. Grey, fine-grained, garnet-mica phyllitic schist is also common. Interbedded sandy schist tends to be thin to medium-bedded, and the sequence may have represented sand, mud and silt interbeds. At GR7568-190890 on Fish Creek porphyroblasts of andalusite (chiastolite variety, up to 3 cm long) with intergrowths of sillimanite are present in addition to garnet, muscovite and biotite in the schist. This andalusite/sillimanite-bearing schist is commonly associated with graphite schist. Cordierite spots are recorded in the "knotted" schists with some porphyroblasts up to 2 cm in diameter.

There are several small (1-2 m thick) metadolerite bodies throughout the unit north of the Lukin River. Some are strongly foliated with acicular actinolite(?) along the foliation; these are small bodies of the Carew Greenstone (Pkr). Small rafts of Pko in the Warner Granite are hornfelsed.

Pko crops out in four main NNW-trending, elongate belts within the Kalkah Structural Domain. These slices range from 1500 to 1800 m in across strike thickness, although there may be internal thickening.

Carew Greenstone — Plp (metabasalt/metadolerite), Pkr (amphibolite)

(new name after Carew Parish – Kalkah 1:100 000 Sheet area)

Plp is generally deeply weathered, but a few rubbly or spheroidally weathered outcrops indicate that it is a fine to medium-grained, greenish black equigranular metabasalt/dolerite. Plp commonly weathers to a speckled, pale khaki colour with iron-bearing minerals leached and feldspar remaining. Few fresh outcrops occur and the rock has been totally recrystallized with a fine grained groundmass overprinted by "felted", strongly pleochroic actinolite. Locally, quartz fills a number of spherical vug-like bodies with sharp contacts with the groundmass. Willmott & others, (1973) named the unit *greenstone* and described the mineralogy as being a tremolite–actinolite or altered hornblende rock with plagioclase, quartz, clinozoisite, sphene, chlorite, biotite, sericite and carbonate. The greenstone is generally unfoliated although a weak fracture cleavage occurs in places.

Plp ranges from 500 m to 1 km thick and crops out as a folded sill-like body within the Astrea Formation. However, it is discordant within the Astrea Formation and cuts up through the stratigraphy from near the base of the Astrea Formation to the overlying Carysfort Quartzite.

Pkr is dark grey, medium-grained equigranular amphibolite, characterised by deep red soil and dense vegetation which show as a darker coloration on aerial photographs. Pkr is generally weakly foliated or unfoliated and comprises hornblende and feldspar. A small body near the Lukin River contains abundant hornblende, feldspar (some microcline) and rare allanite.

The unit is very poorly exposed and mostly crops out within the Astrea Formation (Pko). Two small metadolerite bodies are exposed in the Sugarbag Creek Quartzite (Pkk) and in the Carysfort Quartzite (Pke), demonstrating that the sill penetrated the top and bottom of the Astrea Formation in the Kalkah Structural Domain. An estimate of the true thickness of Pkr is not possible.

Carysfort Quartzite — Plc (quartzite), Pke (quartzite)

(new name after Carysfort Parish, 1:250 000 Ebagoola Cadastral Map)

Plc is mainly cream, medium-grained, saccharoidal quartzite. It is generally poorly foliated although it has well spaced joints which locally concentrate iron staining. Some interbedded, more pelitic rock types tend to be well crenulated (by S2) garnet-muscovite phyllites, or spotted slates. The very fine-grained quartzites have a spaced S2 crenulation cleavage.

The unit has a minimum thickness of about 1 km, and is exposed north of the homestead on Astrea Holding, where it crops out as low ridges. To the west it is poorly exposed and generally covered by alluvium from the Lukin River. The base of the unit is a conformable contact with the Astrea Formation; however, this contact is in some places the Carew Greenstone where the sill has cut through the top of the Astrea Formation. The unit is conformably overlain and possibly interfingered with the Newirie Formation.

Pke is mostly white, fine to medium-grained, recrystallised or saccharoidal quartzite with muscovite, biotite and limonite-staining. Zircon occurs as an accessory. The quartzite is interbedded with recessive schist which ranges from highly magnetic (100 SI units) carbonaceous/graphitic schist or phyllite, to a more common brown, medium-grained andalusite-muscovite-biotite schist similar to the underlying Astrea Formation (Pko).

A number of small elongate bodies of the Carew Greenstone (Pkr) up to 300 m thick crop out in the quartzite around the Lukin River. The metadolerite is dark green, medium to coarse-grained and occasionally displays a weak foliation. These represent metamorphosed gabbros and dolerites that are related to Pkr in the Carew Greenstone.

The unit is up to 1 km thick and faulted against the Strathmay Formation of the Lukin Structural Domain by the Lindalong Shear Zone. It is poorly exposed, forms a low NNW-trending ridge line and conformably(?) overlies the more pelitic unit (Pko) of the Astrea Formation.

Newirie Formation — Pln (slate), Pkb (phyllite), Pka (schist)

(new name after Newirie Creek – Kalkah 1:100 000 Sheet area)

Pln is mostly grey to purple, fine to very fine-grained slate or sandy slate. Thinly bedded slate is intercalated with fine to medium-grained, green metasandstone. Spectacular symmetrical rippled bedding surfaces have been recorded in the unit, however parallel laminae and ripple cross laminae are more common. In the southeast of the outcrop area, Pln is dominated by quartzite that forms higher ground than the slate. This quartzite passes laterally along strike (through an antiform/synform pair) into the slate typical of the unit.

In the southwestern outcrop areas, very low grades of metamorphism occur and rock types include indurated mudstone, siltstone and sandstone. The sandstone is generally medium-bedded with an average thickness of 20 cm, and is interbedded with siltstone on a millimetre scale, ranging down to laminae.

Spotted tourmaline-bearing biotite-muscovite-quartz schist is well developed about 9 km ESE of Strathburn homestead; the lithology is predominantly a silvery grey to maroon, fine to medium-grained phyllite that grades into schist. The phyllite contains muscovite, biotite, and quartz, with biotite porphyroblasts 1-2 mm long. The schist predominantly comprises garnet, andalusite (now sericite), cordierite(?), muscovite, and biotite. These andalusite-bearing rocks are rather anomalous in terms of the general low grade and greenschist facies metamorphism of the Lukin Structural Domain.

Pln appears to conformably overlie and partly interfinger with the Carysfort Quartzite. It is a recessive unit probably at least 3 km thick, although it may be thickened by internal structure.

Pkb is typically brown to mid-grey, fine-grained phyllite. The mineralogy is predominantly quartz and muscovite with local spots of cordierite(?) and porphyroblasts of garnet up to 1 mm in diameter. The phyllite grades into a garnet-muscovite schist, with muscovite (after andalusite)-quartz schist also present; it is thin-bedded with intercalated fine-grained to recrystallized, cream to pink quartzite. The quartzite beds generally are not foliated. Most interbedded quartzites are thin-bedded, but some are thick and massive.

Pkb is faulted to the west against Astrea Formation (Pla in the Lukin Structural Domain) by the Lindalong Shear Zone and to the east by a subparallel fault. The unit has a minimum thickness of about 2.5 km.

Pka is predominantly a brown to grey "flaggy", fine-grained biotite-muscovite-quartz schist. The schistosity is a moderately well developed composite of S1 and S2. The more biotite-rich nature of Pka distinguishes it from Pko in the Astrea Formation and Pkb in the Newirie Formation. Pka is a poorly exposed, fault-bounded unit in the northeast of Subdomain 1 of the Kalkah Structural Domain. It is truncated by the southern extension of the Lukin River Shear Zone and has an across-strike thickness of 1.5 km.

Gorge Quartzite — Plg (quartzite), Pkp (quartzite), Pkl (quartzite), Pku (quartzite/schist)

(new name after The Gorge – Kalkah 1:100 000 Sheet area)

Plg is cream to buff, medium-grained quartzite with muscovite and a saccharoidal texture. Bedding tends to be thick with no visible internal structure. A foliation is generally absent in the purest quartzite beds. Plg is approximately 1.3 km thick and forms a ridge 200 m above the surrounding country that stretches in a NNW direction from the Lukin River to Middle Branch Creek in the Strathburn 1:100 000 sheet area. The base is conformable with the Newirie Formation. To the east, the top of the quartzite is juxtaposed with the Strathmay Formation across the NNW-oriented Gorge Fault. The top of the Gorge Quartzite is conformable with the Strathburn Formation, which lies in a broad synform outlined by ridges of Gorge Quartzite. These units are folded by macroscopic F2 folds that may be complementary to the F2 folds defined by the greenstone to the south.

Pkp consists of several layers of quartzite up to 30 m thick interlayered with graphitic schist of similar thickness. The main unit is a quartzite which ranges in colour from white to pink, cream and shades of grey. It is composed almost entirely of quartz, with scattered muscovite and biotite locally. It is commonly medium-grained, and although the thick layers appear massive and recrystallized, centimetre-scale layering can be seen on weathered surfaces. Near the contacts of thick quartzite with interlayered graphitic schist, thin 10 to 15 cm layers of hematite-muscovite quartzite occur in the schist. Andalusite-graphite schist is also interleaved with massive quartzite beds in a few places.

Cobbles and boulders of tourmaline-bearing pegmatite are common in small streams cutting the quartzite outcrop; the pegmatite consists largely of quartz and muscovite with scattered biotite and tourmaline. Small amphibolite dykes up to 2 m thick are also found within the unit.

The unit crops out along the eastern side of the Lindalong Shear Zone, north of the Lukin River Shear Zone, where the quartzite forms abrupt NNW-trending bevelled ridges extending over 20 km along strike with an across strike width of 5 km. The ridges rise over 400 m above sea level and are separated by steep valleys occupied by the interlayered Strathburn Formation (Pkpa). Spectacular exposures occur above the plunge pool of Pollappa Falls in the Ebagoola 1:100 000 Sheet area and through the gorges dissected by the superimposed drainage of Fish Creek in the Kalkah 1:100 000 Sheet area.

The repetition of quartzite layers makes an accurate estimate of thickness very difficult; Pkp is at least 500 m thick. This estimate is a minimum because the base is faulted against the Lukin Structural Domain by the Lindalong Shear Zone – it places the Gorge Quartzite over the stratigraphically higher Strathmay Formation.

Pkl comprises dark grey to brown, medium to coarse-grained, massive, and saccharoidal or equigranular quartzite interlayered with (sillimanite-) muscovite-quartz schist commonly containing knots of andalusite up to 6 cm long. The quartzite generally contains a little muscovite and in places biotite and garnet. It tends to be finer grained in the south than in the north. In less deformed areas, the quartzite is even-grained with moderately well sorted grains.

South of the Holroyd River, the outcrop of Pkl east of Pollappa Creek consists of one 20 m-thick layer of quartzite and many thinner layers interbedded with sillimanite?-muscovite-quartz schist, containing some graphite and/or hematite locally. The unit extends NNW for 25 km from the Lukin River almost to the Holroyd River, and occurs again farther north as two large, fault-bounded, boudin-like masses about 1 km across and 4-6 km long, within Strathburn Formation (Pki and on the boundary of Pkt). Pkl also crops out near Glen Garland homestead, where it is separated by the Lucy Swamp Shear Zone from the Sugarbag Creek Quartzite (Pkk) to the west, and by another fault from the Strathburn Formation (Pki) to the east. This belt of quartzite extends SSE into the Hann River 1:250 000 Sheet area (HANN RIVER).

Pku varies in colour depending on weathering and composition from red and brown to silver and dark grey to black. Lithologies are generally medium- to coarse-grained, and consist of garnet-mica-hematite schist, andalusite-staurolite-garnet-graphite-mica schist, and staurolite-chloritoid-garnet-mica schist. Interbedded with the schist are thin horizons of muscovite-biotite quartzite. Much of the staurolite is retrogressed to randomly oriented chloritoid with sericite and coarse recrystallized quartz. The relicts of staurolite preserve S1 with intergrown blebs of fine quartz.

Pku has an estimated thickness of 1.3 km, which is consistent with the thickness of the Gorge Quartzite: it is conformably overlain by more recessive schist of the Strathburn Formation (Pkj). Pku is a resistant unit forming ridges and hills up to 311 m above sea level at Manganese Hill, 3.5 km NE of Wolfram Swamp. Linear ridges of Pku also extend SSE from the Coleman River to the edge of the Great Divide escarpment at Sugarloaf Creek.

Strathburn Formation — Plb (siltstone/phyllite), Pkg (slate), Pkpa (schist), Pki (schist), Pkt (gneiss), Pkj (schist)

(new name from Strathburn Holding on the Ebagoola 1:250 000 Cadastral map)

Plb comprises very low-grade, scarcely foliated siltstone and mudstone, slate and phyllite. Typically beds of mudstone up to 5 cm thick alternate with beds of siltstone or sandstone up to 50 cm thick. The colour ranges from cream and grey to green, red, purple and blue. The slate and muscovite-quartz phyllite are generally very fine-grained and have few spots, unlike the adjacent biotite and garnet-bearing rocks of the Strathmay Formation (Plm), east of the Gorge Fault. The unit is recessive and exposures are few in the northern part.

Plb crops out principally in the core of the synform outlined by the Gorge Quartzite in the head-waters of the Edward River, from where the unit extends for 18 km NNW to Boggy Creek, about 15 km ENE of Strathburn Homestead. The top is not exposed, and the entire unit appears to cut out northwards against the Gorge Fault and the Strathmay Formation. The minimum exposed thickness of the unit is likely to be about 1 km.

Pkg is a blue-grey sericite-quartz slate mostly located north of the Holroyd River. The slate commonly contains small andalusite spots or pseudomorphs; in a few places it contains biotite and it may locally be represented by phyllite or fine-grained schist. Along the eastern, gradational boundary with the Strathburn Formation (Pki), the grade of metamorphism is noticeably higher and the unit is represented generally by a spotted phyllite or even a fine-grained schist; biotite partly replaces the sericite in two samples. On the western boundary of the slate with Pkpa and the Gorge Quartzite (Pkp), layers of quartzite up to 10 m thick are interlayered with blue-grey spotted phyllite and knotted schist with many andalusite porphyroblasts. The quartzite layers also contain large, 2 to 3 cm muscovite porphyroblasts in places. Muscovite-quartz pegmatite layers up to 1.5 m thick are also present in the spotted phyllite.

Thin quartz veins with coarse cassiterite have been reported near the contact between Pkg and schist in the Strathburn Formation (Pki), about 2.5 km south of the Yarraden/Aurukun road (Culpeper & others, in press). This contact is gradational; spotted phyllite increases steadily in grain-size towards the schist over a distance of only 50 to 100 m in low hills north of the Yarraden/Aurukun road.

Pkg crops out as a NNW-trending belt about 30 km long by 2 km wide, extending from the Holroyd River to the edge of the Mesozoic cover near the northern boundary of EBAGOOLA.

Pkpa consists of graphitic schist folded with quartzite of the Gorge Quartzite (Pkp) and crops out between the top of the Pkp and the fault that juxtaposes Subdomains 2 and 3. The unit is at least 500 m thick. The schist contains small well sutured quartz grains with smaller interstitial flakes of graphite (which in places form stringers), muscovite and hematite; one sample contains scattered grains of greenish zircon. Porphyroblasts of muscovite with no preferred orientation may be pseudomorphs of andalusite.

North of the Holroyd River, blue-grey medium-grained spotted phyllite and fine-grained knotted schist (which occurs as an extension Pkpa) look more like adjacent Pkg within the Strathburn Formation. However they are mapped as Pkpa because of the clear continuity across the Holroyd River seen on the aeromagnetic image. The fine schist and phyllite are interlayered with quartzite bands up to 1m thick, some of which are black and carry muscovite porphyroblasts 1-2 cm across. Layers of muscovite-quartz pegmatite in the phyllite resemble those in Pkpa south of the Holroyd River.

Pki consists of schist, gneiss and quartzite, and crops out as a NNW-trending belt about 5 km wide, over a strike length of 60 km, extending from the headwaters of Pretender Creek southwards beyond the Coleman River. Exposures mapped as schist in this unit are commonly intensely weathered. The unit is generally recessive and ridges are formed by quartzite layers rather than gneiss, so it has been assumed that the most abundant rock type is schist. The proportion of gneiss in the unit increases eastward, and overall may be as much as half. Pki forms a large proportion of what Trail & others (1968) called the *Pollappa-type Schist.*

The unit is typically a medium to coarse-grained deeply weathered, grey to red schist composed essentially of muscovite and quartz, commonly accompanied by biotite and containing a small proportion of graphite, sillimanite or garnet. Sillimanite appears to be more common in the south (a good example is 3 km SE of Cockers Knob), although fibrolite bunches up to 2 cm long were recorded from schists east of Pollappa Falls.

Coarsely knotted andalusite schist with chiastolite crosses is common. The andalusite generally occurs as porphyroblasts up to 2 cm across that are mostly replaced by sericite, with chiastolite zoning preserved; some andalusite has intergrowths of tabular sillimanite. Cordierite is also common as elliptical porphyroblasts up to 3 mm in diameter, but it is largely retrogressed to muscovite/sericite. Garnet commonly forms porphyroblasts 1-2 mm in diameter. Kyanite porphyroblasts, largely retrogressed to muscovite/sericite, were found at only one site in the Holroyd Group, on the Lukin River north of Cockers Knob: the presence of kyanite indicates local regions of higher than the average pressure.

Layers of muscovite(-garnet) quartzite up to 10 m thick are common in the schist. In the southern outcrops near the Coleman River, thin to medium bedded schist and quartzite are interlayered. Most quartzite is grey, cream or pink, foliated to recrystallized muscovite-bearing rock. Some grey garnet-mica schist is interleaved with fine-grained, grey to black graphite-mica schist and andalusite-garnet-graphite-mica schist. The foliation in the graphite schist is commonly phacoidal, and may be overprinted by a spaced S3 crenulation. The graphite-dominated schists tend to be recessive and where exposed are commonly less than 10 metres thick.

Eastward towards the Pkt, muscovite-quartz schist is replaced as the dominant rock type by biotite-quartz-feldspar gneiss; the proportion of gneiss in Pki rises, and its contact with the gneiss forming Pkt is gradational.

Pkt is medium to coarse-grained cream or grey to brown muscovite-biotite-quartz gneiss, interlayered with schist. Pkt is commonly deeply weathered such that exposure in general is poor and largely confined to deeply incised creek beds. Ridges within the gneiss outcrop are commonly formed by quartzite or quartz-rich layers, generally less than 10 m thick; in a few places near the granite contact gneiss forms small tors on ridges.

The gneiss is typically composed of folia of muscovite and biotite alternating with schlieren of quartz commonly containing some feldspar (both K-feldspar and some plagioclase); knots, rods and augen of quartz (and feldspar) are common. Porphyroblasts of muscovite occur in places as feathery or fibrous material and even quite large crystals. The schist contains rare knots of andalusite and a small amount of graphite is commonly present in interlayered schist and the gneiss. Garnet also occurs, and garnet aplite is interlayered with gneiss near its contact with the CYPB. Lenses of pegmatite common in the gneiss, particularly near granite, are generally coarse massive aggregates of muscovite and quartz.

Pkt crops out as a belt between 0.5 and 7 km wide along the western margin of the CYPB, from the headwaters of Pretender Creek southwards for over 60 km to the Lukin River. Trail & others (1968) named this unit as *Pretender-type Schist* but described it as having incipient gneissic texture, or as gneissic rocks with a schistose matrix.

Pkj is predominantly grey to red, medium to coarse-grained sillimanite-muscovite-biotite schist. Andalusite-garnet-muscovite-biotite schist, and minor muscovite-biotite schistose quartzite are also present; minor amphibolite dykes up to 2 m thick cut the schist in places. Small bodies of grey, medium to coarse-grained, garnet-biotite-muscovite-feldspar gneiss with gneissic layering 2-3 cm thick occur in the schist. Pods and xenoliths of this gneiss are common and well exposed on water-washed pavements of Ebagoola Granite just south of the Pormpuraaw (Edward River) Road crossing of the Coleman River.

This unit crops out at the southeastern limit of the Holroyd Group. It lies in the core of a macroscopic F2 syncline and has a conformable lower contact with the more psammitic Gorge Quartzite (Pku). The top is not exposed as the unit is intruded by the CYPB, but a minimum thickness of 1.5 km can be estimated. Small pods of Pkj are scattered through the contact zone with the batholith. The relative abundance of sillimanite and the transition from schist to gneiss within Pkj distinguishes it from Pku in the Gorge Quartzite which has little or no sillimanite, no gneiss and tends to be more psammitic.

Strathmay Formation — Plm

(new name after the Strathmay 1:100 000 Sheet area)

This unit ranges from slate to schist. The slate and phyllite are commonly grey (some are black and carbonaceous), fine-grained, and have a finely spaced foliation defined by muscovite growth. Many phyllites are biotite-bearing with porphyroblasts generally less than 1 mm in diameter. The biotite porphyroblasts are cylindrical aggregates, uncharacteristically well formed without ragged edges. The schist is generally found in the lower 2/3 of the unit, with slate and carbonaceous slate more common toward the top. The lower parts of the unit are dominated by brown to purple, fine-grained, garnet-biotite-muscovite schist. Garnet porphyroblasts are generally less than 1 mm in diameter. One sample of schist has hematite, quartz and sericite aggregates after pyrite. The schist is interbedded with grey to purple, fine-grained quartzite, and commonly preserves parallel and ripple cross-laminae as well as graded bedding. The quartzite is medium to thin-bedded and shows Tb to Te Bouma sequences.

The Strathmay Formation is faulted against the Gorge Quartzite to the south and against the Strathburn Formation to the north by the Gorge Fault.

Coen Metamorphic Group — Pc

The rocks of the Coen Metamorphic Group (Fig. 2; group 3) have been redefined from Willmott & others (1973) to include only the central, N-S trending belt of metamorphic rocks in EBAGOOLA; they are partially bounded on the east by the Coen Shear Zone and the Ebagoola Shear Zone to the west, and are surrounded by granites of the CYPB. The Coen Metamorphic Group crops out over 700 km^2 and is subdivided into a number of metamorphic units (Fig. 7).

Four units are defined although the boundary relationships are uncertain. They consist mainly of mid- to upper-amphibolite facies schist and gneiss with lesser quartzite, are strongly sheared and contain the important Hamilton Goldfield in EBAGOOLA and Coen Goldfield in COEN. The Lochs Gneiss is gradational from the two schist units and the Mount Ryan Quartzite is the only quartzite large enough to be distinguished at 1:250 000 scale.

Yarraden Schist — Pcy

(new name after Yarraden Homestead – Ebagoola 1:100 000 Sheet area)

The Yarraden Schist is dominated by a fine to medium-grained, silvery grey to purple-brown weathered sillimanite-biotite-muscovite-feldspar-quartz schist. Sillimanite-muscovite-hematite schist, and sillimanite-garnet-muscovite-feldspar schist also occur. The unit can be distinguished from the Goolha-Goolha Schist by the greater variability in mineralogy and a significant content of biotite, garnet and feldspar; the Goolha-Goolha Schist tends to be coarser-grained and muscovite-dominated.

Within the Yarraden Schist, chlorite replaces biotite, and quartz is generally strained and/or recrystallized. Less common constituents are garnet, plagioclase, K-feldspar and opaque minerals. Accessories include monazite, zircon, apatite and rutile; opaques and graphite are aligned parallel to the schistosity (Willmott & others, 1973).

The Yarraden Schist forms much of the western two-thirds of the Coen Metamorphic Group. It is faulted against the Goolha-Goolha Schist to the east by the Stewart River Fault, and is intruded by the CYPB to the west and southeast. The unit extends northwards into COEN and south into the Kalkah 1:100 000 Sheet area.

Mount Ryan Quartzite — Pcr

(new name after Mount Ryan – Ebagoola 1:100 000 Sheet area)

The Mount Ryan Quartzite is the only area of volumetrically significant quartzite in the Coen Metamorphic Group, but it is lithologically similar to the thin quartzites found throughout the Goolha-Goolha Schist. It is essentially white to cream, medium to coarse-grained foliated quartzite with minor muscovite and biotite. The Mount Ryan Quartzite crops out as a 1 km wide NNW-trending ridge of quartzite and lesser schist, that rises to 400 m above sea level in the southern part of the Ebagoola 1:100 000 sheet area. The eastern contact is defined mostly by the Ebagoola Shear Zone, and the western contact although partly faulted is apparently conformable with the Yarraden Schist and Lochs Gneiss.

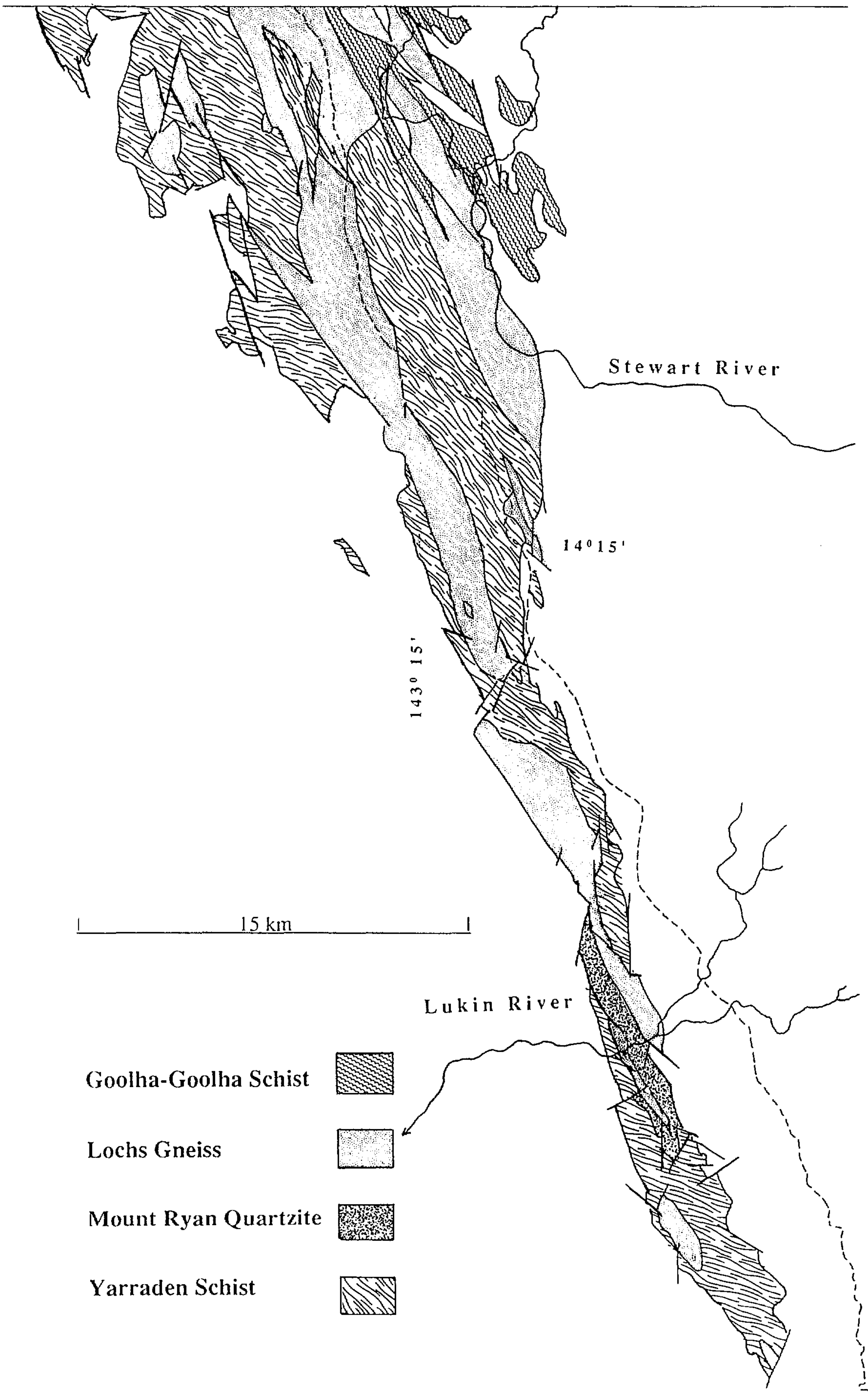


Figure 7. Distribution of metamorphic rocks in the Coen Metamorphic Group (from Blewett & others, in press).

Goolha-Goolha Schist — Pcg

(new name after the abandoned Goolha-Goolha mine – see Culpeper & others, in press)
The schist is dominated by red, purple and brown-weathered, fine-grained sillimanite-muscovite-quartz schist; rare fresh rock is generally grey. Some schists also contain feldspar and/or actinolite; one atypical exposure on the old Coen/Laura road is weathered sillimanite-biotite-graphite-muscovite schist. Bunches of sillimanite are commonly 1-3 mm long; fibrolite bunches range up to 1 cm long; sillimanite needles are variably aligned within S2. The Goolha-Goolha Schist is characterised by a scarcity or absence of biotite, garnet and andalusite; biotite is found in some of the small gneissic outcrops which in places grade into schist, and 1-2 mm garnets occur in a few exposures. Small bodies of granite are also common in the schist.

The schist is locally interbedded with thin to medium-bedded white saccharoidal quartzite (less quartzite is found in the Lochs Gneiss). The quartzite is generally completely recrystallized, hard and resistant to weathering and forms strike-parallel bands up to 5 m thick which crop out as narrow, elongate ridges. Sillimanite, muscovite and biotite have been recorded from quartzites within the Goolha-Goolha Schist. Muscovite, a minor component of the quartzite, is commonly aligned defining metamorphic foliations (especially S2). The NNW-trending quartzite ridges have strike lengths up to 5 km but show no evidence of macroscopic fold closures, unlike the more abundant quartzites of the Holroyd Group.

The Goolha-Goolha Schist is found in a number of fault-bounded slivers that form NNW-oriented ridges between the topographically lower gneiss and granite dominated areas.

Lochs Gneiss — Pcl

(new name after Lochs Creek – Ebagoola 1:100 000 Sheet area)
The Lochs Gneiss is predominantly a grey biotite-muscovite-feldspar gneiss, with sillimanite-(garnet)-mica-feldspar gneiss also present. The gneiss is generally medium to coarse-grained, equigranular and commonly contains aggregates (augen) of undulous quartz and sericitized feldspar. Mica is aligned parallel to and partly defines the gneissic layering; biotite is commonly overgrown by chlorite. The K-feldspar is partially sericitized and generally has a graphic intergrowth with quartz. Garnet is colourless to light pink; garnet trails mirror the trends of the leucosome/melanosome contacts, or occur as scattered small porphyroblasts 1 mm in diameter. Sillimanite occurs as 1 to 2 mm laths though bunches range up to 8 cm in length; it is variably aligned, with well developed L-S fabrics in some outcrops and a random arrangement in others. The sillimanite is mostly altered to retrograde muscovite formed during the M3 event. Chiastolite is rare in the Coen Metamorphic Group, but occurs in the Lochs Gneiss near the Coen Shear Zone in Station Creek. Kyanite occurs at a single location in the southernmost gneiss outcrop; it is pseudomorphed by fine sericite. Secondary minerals include epidote and opaques which are associated with the biotite melanosome. Accessory minerals include monazite, zircon, apatite, sphene, and opaque minerals.

Generally gneissic layering or banding is well developed, with a leucosome comprising quartz and feldspar, and a biotite-rich melanosome. The gneissic layering is typically thin, with 1-3 cm alternations of melanosome and leucosome; the leucosome tends to be thicker. The trends of S2 in the closely associated schist are usually parallel to the gneissic layering, which trends NW to NNW and like S2 generally dips steeply. The leucosome component is granitic in composition; apophyses of granite-pegmatite from layer-parallel leucosome show that there is an intrusive source that was derived in-situ or locally for at least some of the gneiss. The granitic pegmatites are typically lacking in biotite and show a higher muscovite content. The gneiss is commonly intruded by 2-3 m thick, coarse-grained leucocratic, garnet-bearing pegmatite dykes. These dykes are probably intrusions from the Ebagoola Granite phase of the batholith.

Minor greenish-black amphibolite dykes, pods and boudins, concordant with gneissic layering, are generally 1 to 2 m long and 20 to 30 cm thick. They are medium-grained and semi-equigranular, and are composed of large subhedral, pale yellow to greenish brown hornblende, plagioclase and quartz with opaque minerals, sphene and apatite as common accessories.

The Lochs Gneiss is scattered throughout the Coen Metamorphic Group, with the largest outcrop/subcrop along the Coen Road north of the Port Stewart Road turn off. Gneiss also crops out along the Ebagoola Shear Zone and is found in the Hamilton Gold Field. In many places in the Lochs Gneiss it is apparent that coarse schist (like the Yarraden Schist) grades into gneiss. Therefore the difference between gniess and schist reflects metamorphic grade changes where the increasing abundance of pegmatite (leucosome) is the product of local melting.

Calc-silicate schist

Calc-silicate schist recorded by Willmott & others, (1973) is recessive and was not located in this study.

Newberry Metamorphic Group — Pn

(new name after Mount Newberry in the Ebagoola 1:100 000 Sheet area)
The Newberry Metamorphic Group (Fig. 2; group 4) is poorly exposed, but based on estimates from the aeromagnetic data occupies over 2000 km^2 in the eastern third of EBAGOOLA. Trail & others (1968) originally defined these rocks as Dargalong Metamorphics (correlated with the rocks of the Dargalong and Yambo Inliers to the south). Willmott & others (1973) later included them with the Coen Metamorphic Group further west (defined above). The Newberry Metamorphic Group is divided into a number of units.

Kitja Quartzite — Pnk

(new name after Kitja Parish, Ebagoola 1:250 000 Cadastral Map)
The Kitja Quartzite is generally a white to light pink coarse-grained rock, consisting of layers over 100 m thick which form prominent ridges east of the abandoned Telegraph Line. No estimate can be made of the overall thickness of the unit, even though it crops out (subcrop) south of the Stewart River and forms the southern two-thirds of the Newberry Metamorphic Group. The quartzite is apparently massive but commonly displays a centimetre-scale layering on weathered surfaces which reflects the S2 foliation. A quartzite layer about 120 m thick and with grains up to 1.5 cm long crops out south of Scrubby Creek; the large grains may represent small pebbles in the original sediment.

The quartzite generally contains less than 5% muscovite, a little hematite, and is commonly moderately magnetic; rocks without hematite have a very low magnetic susceptibility. In a few exposures, layers at least 1 m thick consisting of weathered ferruginous muscovite-quartz schist are contained in the quartzite.

At Eel Creek a light and dark banded gneiss crops out. The light bands are muscovite-bearing, coarse feldspathic quartzite and pegmatite. Large blocky feldspar crystals are developed in the pegmatitic parts of the light layers. The dark layers are mainly smaller quartz crystals with equigranular feldspar (oligoclase and K-feldspar), parallel laths of biotite and muscovite (associated with sillimanite in one section), and rounded and corroded fragments of garnet. The bands generally range from 0.5 to 10 cm in thickness but some are 50 cm thick. Irregular dykes of pegmatite up to 3 m thick strike NE.

A single small exposure of recessive tremolite-actinolite schist 5.5 km south of Mt Newberry is described by Trail & others (1968) as a calc-silicate rock made up of tremolite with lesser amounts of talc and muscovite.

East of Mount Newberry several occurrences of amphibolite within the Kitja Quartzite are lines of boulders thought to represent dykes up to several metres thick. These are mainly massive rocks in which relatively fresh plagioclase (labradorite) has an ophitic relationship with a yellow-brown, uralitic? hornblende. A few small remnants of pyroxene and a little secondary quartz are generally present; in one section red-brown biotite is associated with the hornblende. One rock has a few crush zones, but they appear otherwise to be undeformed. A few small boulders of weathered leucogranite are associated with one of the dolerite occurrences.

Penny Gneiss — Pnp

(new name after Penny Creek – Ebagoola 1:100 000 Sheet area)

The Penny Gneiss is almost everywhere closely associated with granite, pegmatite and amphibolite and is a light and dark banded muscovite-biotite-feldspar-quartz rock. Quartz makes up more than 50% of the gneiss, predominating in the leucosome which also contains a small amount of plagioclase (oligoclase) and K-feldspar (microcline, myrmekite). The dark bands consist of muscovite and biotite or chlorite, generally parallel to the banding; some muscovite and chlorite diverge. Mica-rich bands range up to 40 cm thick and contain boudins of quartz or quartzite.

Amphibolite is common in the Penny Gneiss, generally as boulders close to most exposures of gneiss; in a few gneiss exposures bodies of amphibolite are exposed in situ. The amphibolite occurs as:

- lenses within gneiss typically 10 to 20 cm thick and 1 to 2 m long, concordant with the gneissic layering,
- lenses similar to the above, generally concordant with the gneissic layering, but displacing some bands,
- larger (1 m thick) bodies of amphibolite within and disrupted by pegmatite and granite.

The Penny Gneiss crops out north of the Stewart River, in the Little Stewart Creek/Penny Creek area.

Concealed Metamorphic Rocks — Pu2, Pu3, Pu4, Pu5, Pnu

Concealed metamorphic and igneous rocks occur under the coastal plain around Princess Charlotte Bay. These concealed metamorphic rocks are subdivided on the basis of metamorphic grade (inferred from comparison with the magnetic character of exposed units) and high or low magnetization. The sub-divisions (Pu2, Pu3, Pu4, and Pu5) are separated from each other, and from the outcropping Newberry Metamorphic Group to the west, by major linear discontinuities or faults.

South of Princess Charlotte Bay, the Newberry Metamorphic Group extends from the CYPB in the west, to the Palmerville Fault Zone. The undivided eastern part (Pnu) cannot be correlated definitely with the named formations.

Other Proterozoic Rocks — Pu1, Pg?

Areas of low average magnetisation and high gravity are thought to be Proterozoic metamorphic rocks (Pu1). Proterozoic granitoids (Pg?) are interpreted in areas of low gravity.

PALAEOZOIC

by D.E. Mackenzie, J. Knutson, L.P. Black, S-S. Sun (AGSO)

Siluro-Devonian — Cape York Peninsula Batholith

The CYPB extends the full length of EBAGOOLA Sheet from north to south, and is up to 60 km wide. Outcrop and known subcrop (beneath thin regolith cover) area is almost 4000 km^2, and an additional 1000 km^2 is probably concealed beneath Cainozoic sediments.

The eastern margin of the CYPB is close to the base of the coastal escarpment over most of its length, and the western margin corresponds at the surface to the eastern margin of the Holroyd Group. However, aeromagnetic and regional gravity data (Wellman, in press, a) indicate that the western contact of the batholith dips at about 30^0 westward beneath the metamorphic rocks: several small bodies of granite exposed within the Holroyd Group are probably apophyses. Gravity data also indicate the presence of granitoid bodies beneath most of the area of metamorphic rocks to the south of the western lobe of the CYPB (although only a fraction of this granitoid is exposed at the surface), and are consistent with the presence of granitoid bodies beneath the westernmost exposed part of the Edward River Metamorphic Group. Granitoid bodies also underlie much of the northeastern and southern parts of the Coen Metamorphic Group (Wellman, in press, a), which partly divides the CYPB in two (Fig. 2).

U-Pb zircon dating (using the SHRIMP ion microprobe at ANU) of granitic rocks throughout the Coen Inlier has produced a pooled age of about 407 Ma for the CYPB (Black & others, in press). Individual ages for five samples collected from EBAGOOLA are summarised in Table 2.

The CYPB within Ebagoola may be divided into two major petrographic-geochemical groups (supersuites): the I-type Flyspeck Supersuite and the S-type Kintore Supersuite (Fig. 8). Both are of Early Devonian - Late Silurian age (Black & others, in press), and both have been emplaced at moderately deep crustal levels, as indicated by the abundance of pegmatites and a close association with migmatites.

Kintore Supersuite

The Kintore Supersuite is the dominant component of the CYPB in EBAGOOLA, extending the full length of the Sheet and constituting about 70% of the total exposed (and subcropping) area of granitic rocks. It is divided into the Ebagoola and Lankelly Suites on the basis of textural (e.g. Lankelly Suite rocks are more consistently porphyritic) and subtle geochemical (see below) differences (Fig. 8).

Ebagoola Suite

The Ebagoola Suite comprises the Kintore, Barwon, Leconsfield, Warner, Lindalong, Burns, Heneage, Tadpole, and Ebagoola Granites (Fig. 8).

Kintore Granite (SDk)

The name "Kintore Adamellite" was used by Willmott & others (1973) to describe the muscovite-biotite-bearing granites, leucogranites, pegmatites, and aplites which make up a large proportion of the CYPB. We restrict the term Kintore Granite to a geographically discrete body of muscovite-biotite±garnet granite.

TABLE 2 U-Pb Emplacement Ages for EBAGOOLA Granitic Rocks
(from Black & others, in press)

SAMPLE NUMBER	UNIT	LOCATION		AGE (Ma)
		1:100 000 sheet	AMG Grid	
89837510	Kintore Granite	Ebagoola	546070	408±10
89837511	Kintore Granite	Kalkah	642813	405±9
90834330	Ebagoola Granite	Ebagoola	397247	~400
70570129	Artemis Granodiorite	Marina Plains	744416	406±10
70570190	Glen Garland Granodiorite	Kalkah	494863	398±10

Kintore Granite is a light grey, buff, or cream, medium to coarse-grained biotite-muscovite± garnet granite. It is typically even-grained, but in some areas grades into a strongly porphyritic variant with K-feldspar phenocrysts up to 6-8 cm long. Typical modal proportions are quartz 30-35%, K-feldspar 15-25%, plagioclase 20-30%, muscovite 3-8%, and biotite 2-7%. Apatite (up to 2 mm long) is a prominent minor mineral; other accessory minerals are pink to violet (Mn-rich) garnet, monazite and ilmenite.

The Kintore Granite extends the full length of EBAGOOLA (110 km), and averages 10-12 km in width. Exposures of typical Kintore Granite in road cuttings where the Peninsula Development Road crosses the coastal escarpment 1 km north of New Bamboo homestead comprise the type area (GR 7644-83817). Other good exposures can be seen at the Big Coleman River crossing on the Peninsula Development Road (GR 7618-83870).

The granite in most outcrops shows evidence of mild to intense deformation. Alteration in and near the shear zones is moderate to intense, but elsewhere it is generally slight, and manifested principally in ubiquitous sericitisation of the cores of plagioclase crystals. Other secondary minerals include muscovite, chlorite, epidote, calcite, and titanite.

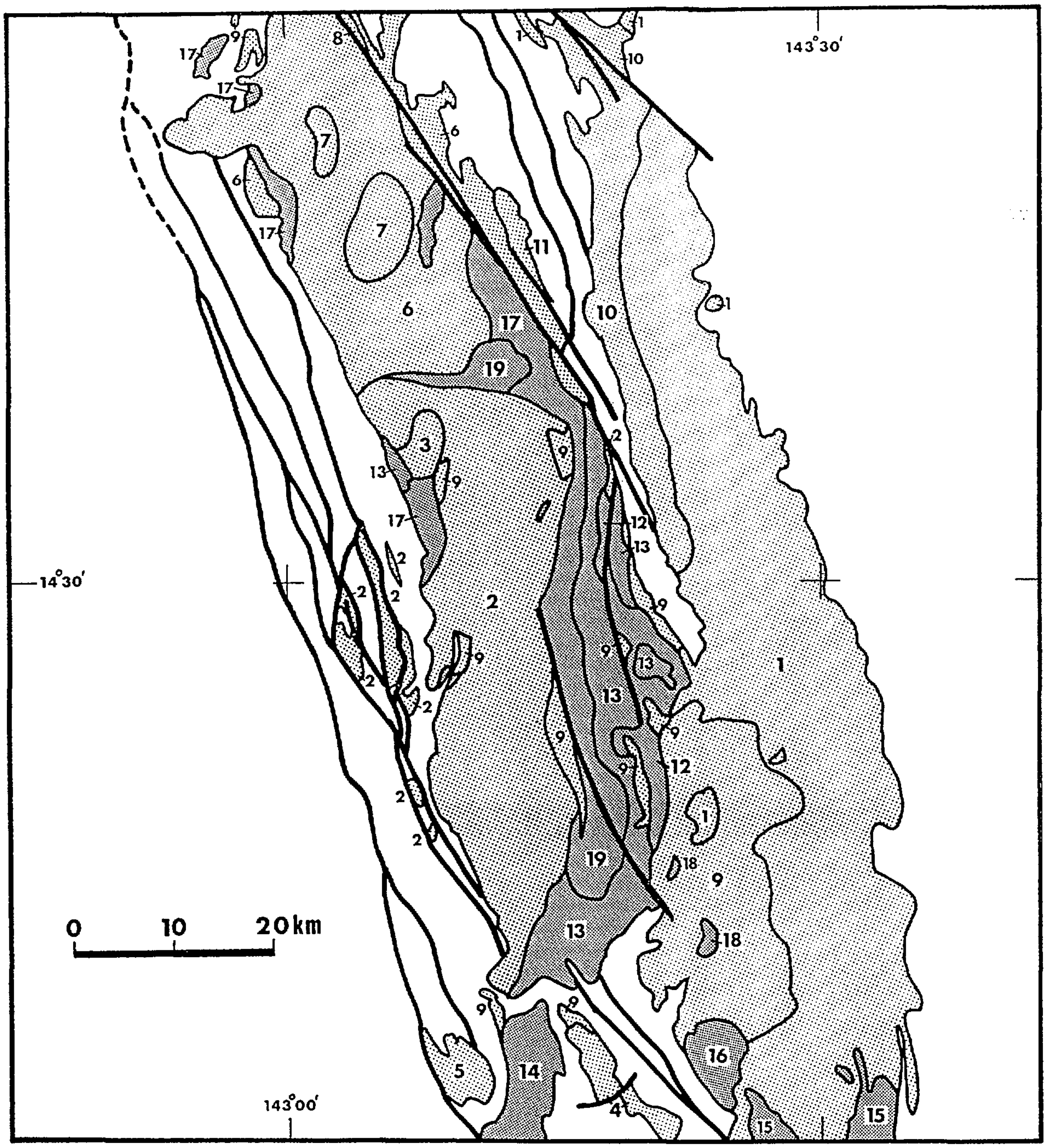
Masses of coarse-grained pegmatite (similar to that in the Ebagoola Granite) crop out within the Kintore Granite as rock platforms, mostly about 15 m across, particularly to the south and west of New Bamboo homestead. Rhyolite, quartz, and garnet-bearing pegmatite veins and dykes up to 2 m wide are common in some areas.

Contact relationships between the Kintore Granite and other components of the CYPB are equivocal in most areas. However, a dyke of muscovite-biotite granite cuts the Lankelly Granite in the Little Stewart Creek area, suggesting that, in this area at least, Kintore Granite intrudes Lankelly Granite.

Barwon Granite (SDb)

(new name after Barwon Creek – Kalkah 1:100 000 Sheet area)

Barwon Granite is a fine to medium-grained muscovite-biotite granite which is weakly to moderately porphyritic in places (notably most of the isolated bodies in the Holroyd Group), but otherwise relatively uniform in appearance and in modal mineralogy when compared to granitoids of the Flyspeck Supersuite. It consists typically of about 35% quartz, 40-45%



CAPE YORK PENINSULA BATHOLITH

KINTORE SUPERSUITE

EBAGOOLA SUITE

1 Kintore Granite
2 Barwon Granite
3 Leconsfield Granite
4 Warner Granite
5 Lindalong Granite
6 Burns Granite
7 Heneage Granite
8 Tadpole Granite
9 Ebagoola Granite

LANKELLY SUITE

10 Lankelly Granite
11 Kendle River Granite

FLYSPECK SUPERSUITE

12 Flyspeck Granodiorite
13 Glen Garland Granodiorite
14 Peringa Tonalite
15 Artemis Granodiorite
16 Tea Tree Granodiorite
17 Two Rail Monzogranite
18 Carleton Monzogranite
19 Kirkwood Monzogranite

Figure 8. Subdivision of granites in the Cape York Peninsula Batholith (from Mackenzie & Knutson, in press).

microcline, 15% plagioclase, 5% red-brown biotite, and 2-3% muscovite. Accessory minerals are abundant fine zircon, abundant, relatively coarse (up to 1.0 mm), apatite, and rare ilmenite and monazite; Mn-rich garnet and allanite(?) are very rare and sporadically distributed. Gently dipping, sill-like bodies of layered pegmatite and aplite up to 3 m thick are a common feature. The Barwon Granite is affected by mostly slight to locally moderate propylitic alteration; more intense alteration is restricted to rocks close to the Ebagoola Shear Zone.

The main body of Barwon Granite extends from near the Edward River road west-southwest of Glen Garland homestead 60 km northward to Sandalwood Creek. Small, mostly fault-bounded bodies of granite equated with Barwon Granite crop out adjacent to or near the Ebagoola Shear Zone near the Lukin River and on Station Creek. A number of small, partly fault-bounded bodies of granite similar to the Barwon Granite also intrude the Holroyd Group to the west of the main pluton; they are extensively to completely sheared or mylonitised. The Barwon Granite typically forms low-lying, low-relief terrain with very little outcrop and extensive areas of thick residual deposits (mainly sand). Outcrop is typically deeply weathered, with a characteristic pale brown surface colour.

The type area of Barwon Granite is along the Lukin River, from about 4 km below the crossing on the Ebagoola-Spion Kop track. More extensive, less weathered, but less accessible outcrop may be found along lower Bamboo Creek.

Barwon Granite intrudes the Holroyd Group, Coen Metamorphic Group, and the major plutons of the Flyspeck Supersuite. It is intruded by Ebagoola Granite, and is either intruded by, or grades into, Leconsfield Granite.

Leconsfield Granite (SDd)

(new name after Leconsfield Parish, County of Kalkah)

The Leconsfield Granite is a porphyritic muscovite-biotite granite containing moderately abundant, conspicuous, euhedral phenocrysts of microcline typically 3-4 cm long and 1 cm wide. Typical modal proportions are: microcline 45-50%, quartz 30%, plagioclase 10-15%, biotite 3-5%, muscovite 3-5%; accessory minerals are zircon, apatite, rare monazite(?), and very rare ilmenite. Irregular, finer-grained patches occur sporadically, and the granite also contains rare, scattered, biotite-rich schistose enclaves and very rare quartz xenocrysts. Alteration, to sericite + chlorite ± muscovite, is slight to moderate.

Leconsfield Granite crops out over an area of about 20 km^2 in the headwaters of Wallaby Creek. Unlike most other granitoids in the region, it is very well exposed: the most accessible (from the old Ebagoola-Aurukun track) typical outcrop is around GR7569-289072. Most of the outcrop area is characterised by a very conspicuous outcrop style, unique in the region, of large tors and boulders in a semi-regular, strongly joint-controlled, pattern with relatively high relief; etched-out K-feldspar phenocrysts are prominent on weathered surfaces.

The relationship between Leconsfield Granite and Barwon Granite is uncertain: Leconsfield Granite may be part of the differentiated roof zone of the Barwon Granite, but there are sufficient differences between the two to suggest that it is a distinct intrusive phase intruding Barwon Granite. Leconsfield Granite intrudes Glen Garland Granodiorite and Two Rail Monzogranite, and is intruded by sills or dykes of pegmatite and aplite (equivalent to Ebagoola Granite) and by dacite dykes of possible Carboniferous-Permian age.

Warner Granite (SDw)

(new name from County of Warner, EBAGOOLA and HANN RIVER)

Warner Granite is a muscovite-biotite granite similar in some respects to the Barwon Granite; however, it is more porphyritic, richer in K-feldspar and muscovite, and poorer in plagioclase. It contains up to 30% by volume of K-feldspar phenocrysts up to 3 cm long; in places these phenocrysts are strongly aligned parallel to the Lucy Swamp Shear Zone which bisects the northern portion of the pluton. Estimated modal composition of the granite is: K-feldspar 45-50%, quartz 30-35%, plagioclase 15-20(?)%, biotite 2-5%, muscovite 3-5%; accessory minerals are very fine-grained zircon and apatite, and very rare ilmenite.

Warner Granite extends from 5 km south of Glen Garland homestead 15 km south-southeast to the boundary of EBAGOOLA, and ranges in width from 2 to 3 km. The type area is along the Coleman River, between GR7568-469440 and -490452. The granite is mostly characterised by low-lying, low-relief terrain with very little outcrop, similar to that developed on the Barwon Granite.

The granite intrudes the Holroyd Group, and is intruded by leucogranite and pegmatite equated with Ebagoola Granite. Regional gravity data indicate that it may be an apophysis of the Barwon Granite, which appears to extend beneath the metamorphic rocks at least to the boundary of EBAGOOLA.

Lindalong Granite (SDi)

(new name after Lindalong Creek – Kalkah 1:100 000 Sheet area)

Lindalong Granite is a biotite-muscovite granite consisting of 35-40% quartz, 35-40% microcline, 10-20% plagioclase, 7-10% muscovite, 1% to 3% biotite, and rare, accessory apatite and zircon; it grades locally into (biotite[<1%])-garnet-muscovite leucogranite and pegmatite. The granite is intermediate in composition and mineralogy between Barwon Granite and Ebagoola Granite. It is variably deformed and/or foliated, especially along the western margin, with a foliation parallel to the Lindalong Shear Zone, and is slightly altered to sericite and iron oxide(s).

Lindalong Granite underlies an area of about 30 km^2 in upper Lindalong Creek, 15 km southwest of Glen Garland homestead (around GR7568-360450). It is well exposed in the headwaters of Lindalong Creek (GR7568-337449), and also crops out in a tributary of Lindalong Creek, at GR7568-308490; elsewhere, outcrop is very rare, and deeply weathered.

Although Lindalong Granite is a discrete body intruding the Holroyd Group, its petrological affinity with Barwon and Ebagoola Granites suggests a genetic link. That possible link, combined with the geophysical evidence of the southward extension of the CYPB beneath the Holroyd Group in the area, suggest in turn that Lindalong Granite may be a cupola of relatively differentiated Barwon Granite.

Burns Granite (SDu)

(new name after Burns Creek – Ebagoola 1:100 000 Sheet area)

Burns Granite is a medium to coarse-grained muscovite-biotite granite similar to the Barwon Granite in some respects, but differs from it significantly in being richer in plagioclase and apatite, and poorer in K-feldspar and quartz. Some parts of the granite, particularly those near the Heneage Granite, contain scattered phenocrysts of microcline up to 2 cm long. Average modal composition is 30% quartz, 35% microcline, 30% plagioclase, 4% biotite, and 3% muscovite;

accessory minerals are apatite (up to 1%), zircon, sporadic garnet, rare monazite, and very rare ilmenite. The granite is slightly to moderately altered to combinations of sericite and/or muscovite, chlorite, epidote, calcite, and hematite. Alteration is generally more intense near the Ebagoola Shear Zone, where the granite is moderately to intensely foliated or sheared.

Burns Granite underlies an area of about 650 km^2, extending from the southern side of the Holroyd River 39 km north-northwestward to the margin of EBAGOOLA Sheet, and northwestward into the Lagoon Creek area, west of Crystal Vale homestead; it also extends eastward across the Ebagoola Shear Zone in places. Outcrop is very scarce, and most is deeply weathered; however, large boulders of slightly atypical, porphyritic granite are exposed in the Holroyd River at GR7569-339255. More typical, but weathered outcrop is exposed in Brumby Creek, at GR7569-185336.

Burns Granite intrudes Holroyd Group, Coen Metamorphic Group, Two Rail Monzogranite, Kirkwood Monzogranite, and, probably, Kendle River Granite and Tadpole Granite, which are separated from it by the Ebagoola Shear Zone. It may also be intruded by Barwon Granite, but their relationship is uncertain. Ebagoola Granite is partly faulted against, and partly intrusive into, Burns Granite, and Heneage Granite either intrudes it or is part of a relatively differentiated roof(?) zone.

Heneage Granite (SDh)

(new name after Parish of Heneage, County of Coen)

Heneage Granite is a porphyritic, medium to coarse, muscovite-biotite granite grading into biotite-muscovite alkali-feldspar granite. It contains phenocrysts of microcline, up to 7 cm long, which are largest and most abundant (about 10-15% by volume) in the centres of the bodies. The northern body contains between 55% and 75% microcline, 5% to <1% biotite, and about 2% muscovite. The southern body appears to be less differentiated, and contains about 45-50% microcline, 25-30% quartz, 15-20% plagioclase, 5% biotite, and 2% muscovite. Alteration is slight, and mainly confined to sericitisation of plagioclase cores and partial chloritisation of biotite.

Heneage Granite forms two rounded bodies in northern EBAGOOLA, within the Burns Granite. The boundaries of both bodies are almost entirely unexposed, and have been inferred from a combination of ground observations and interpretation of the gamma ray spectrometric data: the more northerly body forms prominent hills with a bright salmon-pink gamma ray spectrometric pseudocolour signature. Abundant outcrop of typical Heneage Granite is exposed in these hills, at the head of Dead Horse Creek, on or close to the road from Coen to Crystal Vale (*e.g.* GR7569-197406 and -196399).

Heneage Granite forms apparently discrete, mappable bodies within the Burns Granite. Like the Leconsfield Granite, it may be a separate intrusive phase, possibly differentiated from the host (Burns) granite, or part of a differentiated roof(?) zone of the host granite.

Tadpole Granite (SDt)

(new name after Tadpole Creek – Ebagoola 1:100 000 Sheet area)

The Tadpole Granite is a variably sheared and/or foliated, variably recrystallised, porphyritic (muscovite-)biotite granite containing abundant phenocrysts, up to 1.5 cm long, of K-feldspar and plagioclase. Approximate modal composition is quartz 20-30%, K-feldspar 35-45%, plagioclase 25-30%, biotite 6-8%, and (secondary) muscovite up to 1%; accessory minerals are garnet, zircon, apatite, and monazite. Alteration is moderate, to sericite and/or muscovite, chlorite, and iron oxide(s).

Tadpole Granite underlies a narrow, wedge-shaped area about 6 km long and up to 2 km wide to the east of Tadpole Creek, on the northern margin of EBAGOOLA. It is best exposed in a creek crossing on the Coen-Crystal Vale track at GR7569-229503. Intensely foliated Tadpole Granite is well exposed on a small, prominent hill on the eastern side of this track at GR7569-230499.

Tadpole Granite intrudes Coen Metamorphic Group, is intruded by Ebagoola Granite (or its equivalents), and is cut by, and extensively deformed adjacent to, the Ebagoola Shear Zone. It is separated from the Burns Granite by a splay of the Ebagoola Shear Zone, and the relationship between the two is uncertain: Tadpole Granite may represent a relatively less-differentiated precursor of the Burns Granite.

Ebagoola Granite (SDe)

(new name after Ebagoola village/Parish of Ebagoola, County of Sidmouth)

Ebagoola Granite consists of pale grey to white, medium to coarse, mostly even-grained, muscovite and biotite-muscovite leucogranites, muscovite and biotite-muscovite pegmatites,and muscovite aplite (some with a trace of biotite); all varieties contain garnet, in places (up to 5%). The leucogranites mostly form extensive, relatively homogeneous masses, but there are numerous small pods, dykes, and veins intruding other units.The pegmatites and aplites are rhythmically interbanded in many places, and form gently-dipping, sheet-like bodies and dykes 15 cm to 3 m thick. Typical modal composition of the leucogranite is 30-35% quartz, 40-45% K-feldspar, 15% plagioclase, 5-10% muscovite, up to 1% biotite, and up to 1 % garnet. Accessory minerals are apatite (up to 1-2% in some rocks), zircon, and very rare ilmenite. Parts of the granite, particularly those along and close to the Ebagoola Shear Zone, are strongly sheared and/or foliated, with extensive recrystallisation of quartz.

Bodies of leucogranite and pegmatite assigned to the Ebagoola Granite are widespread throughout EBAGOOLA. By far the most extensive mass of (predominantly) Ebagoola Granite (about 37 km long and up to 15 km wide) extends from the headwaters of Emu Creek in the south to the WRC track about 1 km north of the Big Coleman River-Little Coleman River junction. Smaller bodies of leucogranite and pegmatite assigned to Ebagoola Granite are distributed around the periphery of the Barwon Granite, along the western margin of the Coen Metamorphic Group, and in the Opera Hill, Glen Garland, Stew Creek-Coleman River, and old Bamboo homestead areas.

The type area comprises numerous large boulders of equigranular leucogranite along the base of the Great Escarpment, near the Musgrave-Edward River road (GR 7606-836270). Similar granite is well exposed along the road to the Telecom microwave repeater tower near the Gulf Developmental Highway (GR 7623-83784). Excellent outcrops of pegmatite and garnet-bearing aplite, intruding and including rafts of wallrock schists/gneisses, are exposed in a tributary of the Coleman River close to the Musgrave-Edward River road crossing.

The Ebagoola Granite is generally characterised on colour air photographs by very pale (virtually white) surface tones due to residual sand, and on gamma ray spectrometric imagery by a bright, pale pink pseudocolour signature.

Field relationships suggest that the Ebagoola Granite is gradational into, and in many instances marginal to, the Kintore Granite and probably also the Barwon and Burns Granites. It also intrudes these granites, as well as granitoids of the Flyspeck Supersuite. In the vicinity of the Coleman River crossing of the Musgrave-Edward River road, extensive rock platforms (up to 50 metres across) consist of rhythmically banded garnet-rich aplite and pegmatite, containing schlieren and blocks of gneiss up to 20 metres across, grading into massive gneiss (Holroyd Group). Bands, dykes, and veins of pegmatite, leucogranite, and aplite are abundant in the gneisses.

Lankelly Suite

The Lankelly Suite comprises the Lankelly and Kendle River Granites (Fig. 8).

Lankelly Granite (SDl)

The Lankelly Granite typically is a light to medium grey, coarse-grained, porphyritic muscovite-biotite to biotite granite which contains abundant biotite-rich inclusions up to 6 cm diameter in some areas. The K-feldspar phenocrysts (typically 3 x 1 cm; up to 8 cm long) are commonly aligned to various degrees, due to magmatic flow, syn-emplacement deformation, or both. Near the Stewart River-Little Stewart Creek confluence, the granite contains abundant large (up to several metres) enclaves of a fine-grained dioritic rock.

The average modal composition is quartz 20-30%, K-feldspar (phenocrysts and groundmass) 25-35%, plagioclase 20-25%, biotite 10-15%, muscovite <5%. Accessory minerals are apatite, which is up to 0.5 mm long but generally less abundant than in the Kintore Granite, zircon, and rare ilmenite. Secondary minerals include muscovite, sericite, chlorite, calcite, and titanite.

Rocks assigned to the Lankelly Granite crop out extensively in northeastern EBAGOOLA, and throughout an area approximately 50 km long and 3-6 km wide between the Coen Metamorphic Group and the Kintore Granite. Well-exposed, typical Lankelly Granite occurs in three areas: in Lankelly Creek about 1 km northeast of Coen (COEN), at the Little Stewart Creek crossing on the Coen-Port Stewart Road (GR 7501-84434), and in the Stewart River gorge (GR7503-84345). Relief is moderate steep (in the Stewart River area) to subdued, and outcrop is scarce, particularly in the south. The Lankelly Granite is distinguishable from Kintore Granite on airborne gamma ray spectrometric images (as discussed below), and by its greater biotite content, lesser muscovite content, and ubiquitous strongly porphyritic texture.

In one location, Lankelly Granite is cut by a 10-15 cm-wide dyke of biotite-muscovite granite similar to the Kintore Granite, but in other areas contacts between Lankelly and Kintore Granites appear to be gradational. Lankelly Granite is also intruded by aplite and pegmatite dykes probably related to the Ebagoola Granite.

Kendle River Granite (SDn)

(new name after Kendle River – Ebagoola 1:100 000 Sheet area)

The unit comprises porphyritic muscovite-biotite granite (or monzogranite), superficially similar to porphyritic variants of the Burns and Barwon Granites. It differs from these rocks, however, in being richer in plagioclase and highly variable in texture: some areas are equigranular, some contain abundant, aligned K-feldspar phenocrysts 2-4 cm long, while other, highly irregular, areas are crowded with K-feldspar megacrysts up to 10 cm long. Estimated modal composition is: 25-30% quartz, 30-35% K-feldspar, 30-35 % plagioclase, 3-5% biotite, 1% primary muscovite, and up to 1% secondary muscovite. Accessory minerals are apatite, zircon, and rare, violet, Mn-rich, garnet. Some of the muscovite is post-magmatic, and the granite is slightly to moderately altered to sericite and/or muscovite, and chlorite.

Kendle River Granite underlies an area up to 3 km wide and 12 km long along the eastern side of the Ebagoola Shear Zone, between Thompsons Creek and Spring Creek; the type area is along the Kendle River between GR7569-400273 and -409252.

Kendle River Granite intrudes Coen Metamorphic Group, and is apparently intruded by Burns Granite, although contacts between the two are mostly faulted (including the Ebagoola Shear Zone). It is also intruded by Ebagoola Granite.

Flyspeck Supersuite

The Flyspeck Supersuite consists of Flyspeck Granodiorite, Glen Garland Granodiorite, Peringa Tonalite, Artemis Granodiorite, Tea Tree Creek Granodiorite, Two Rail Monzogranite, Carleton Monzogranite, and Kirkwood Monzogranite (Fig. 8). It includes all of the rocks originally assigned to the Flyspeck Granodiorite by Willmott & others (1973).

Flyspeck Granodiorite (SDf)

Flyspeck Granodiorite is a dark-grey, typically coarse to medium-grained, porphyritic hornblende-biotite granodiorite grading into biotite monzogranite and biotite granite. Its most characteristic feature is the randomly and very unevenly distributed, stumpy prismatic phenocrysts (or megacrysts) of K-feldspar up to 6 cm, or even 7 cm, long. Modal proportions of the major minerals are typically in the range quartz 30%, plagioclase 40%, K-feldspar 15-25%, biotite 7%, hornblende 5% to quartz 35%, plagioclase 25-20%, K-feldspar 30-35%, biotite 5%. Accessory minerals are allanite (abundant, and up to 1 cm long, as in Glen Garland Granodiorite), titanite, zircon, apatite, and rare monazite.

The name Flyspeck Granodiorite is restricted to very coarsely porphyritic granodiorite to monzogranite that crops out in the Flyspeck Creek area, and extends 26 km northward along the southwestern margin of the Coen Metamorphic Group (Blewett & others, in press) to the Lukin River. The type area comprises bouldery exposures on the southern side of the Water Resources Commission track, 12 km west of the Peninsula Development Road (GR7568-510840). Flyspeck Granodiorite is generally difficult to distinguish from Two Rail Monzogranite and Glen Garland Granodiorite, except that it is characterised in many areas (*e.g.*, the type area) by rounded boulders, up to 6-7 m in diameter, containing conspicuous white K-feldspar megacrysts typically 6 x 4 cm.

Alteration, to sericite + chlorite + epidote-clinozoisite ± calcite ± titanite + opaque(s), ranges from slight to intense, the components most affected being plagioclase, especially the cores, and biotite. The most intensely altered rocks are near Lapunya Mount and 4 km west-southwest of Mount Ryan. The granodiorite is intensely sheared and variably altered close to the Spion Kop Fault, and a gneissic fabric is evident in rocks up to 3 km east of the fault.

Flyspeck Granodiorite intrudes Coen Metamorphic Group, is intruded by Ebagoola Granite (or its equivalents), and is probably intruded by Glen Garland Granodiorite, Two Rail Monzogranite, and Barwon Granite.

Glen Garland Granodiorite (SDg)

(new name after Glen Garland Homestead – Kalkah 1:100 000 Sheet area)

The predominant rock type is mesocratic, slightly porphyritic, biotite-hornblende granodiorite which in many outcrops contains scattered enclaves of darker grey microdiorite. The enclaves are generally rounded, 5 - 20 cm in length, and rarely up to 1 m. The granodiorite contains typically 30% quartz, 35-45% plagioclase, 10% orthoclase, 5-8% biotite, and 5% hornblende; it grades to more felsic, hornblende-poor compositions to the southwest, west, and in particular, to the north. Accessory minerals are abundant allanite and titanite, zircon, apatite, and very rare monazite. The boundary between Glen Garland Granodiorite and Two Rail Monzogranite to the west is subtle and gradational: it is taken as the point of disappearance of hornblende. This boundary is reflected in a subtle change of airborne gamma ray spectrometric signature, from orange-red or red-brown to purer, deep red tones.

Glen Garland Granodiorite crops out extensively over the southeastern portion of the western lobe of the CYPB on EBAGOOLA. The main outcrop area (about 105 km^2) extends from about 7 km west-southwest of Glen Garland 60 km northward to the Station Creek area. Small bodies crop out southwest of Lapunya Mount, between Battery Creek and Station Creek, and in upper Wallaby Creek on the western margin of the Batholith. The type area is around Glen Garland homestead; a reference area (more mafic granodiorite) is 1.5 km north-northwest of old Bamboo homestead (GR7568-495880).

Alteration, to propylitic assemblages (sericite ± calcite + chlorite ± epidote ± titanite ± anatase/ brookite) is generally slight, but more intense alteration was noted in parts of the type area, and in the Battery Creek-Lukin River area. Plagioclase and biotite are most affected, and K-feldspar is unaltered or only slightly altered.

Glen Garland Granodiorite intrudes, or in places, is faulted against, the Holroyd Group and the Coen Metamorphic Group. It probably intrudes Flyspeck Granodiorite, but its relationship to Two Rail Monzogranite is unclear: the latter either intrudes the former or is a differentiate of it, with gradational contacts. The granodiorite is intruded, in places, by dykes of granite similar to Barwon Granite; however, the contact between the main bodies of the two units is not exposed; it is also cut by dykes and small stocks of Ebagoola Granite.

The granodiorite is cut by several north-northwesterly trending faults parallel to the Ebagoola Shear Zone. In places, such as near the old Bamboo homestead site, these faults form the contacts between Glen Garland Granodiorite and adjacent granitoids, and they may be largely responsible for the banded pattern over the area seen on airborne gamma ray spectrometric images.

Rb-Sr mineral and whole-rock isotopic dating (Cooper & others, 1975), and ion microprobe zircon U-Pb dating (Table 2) of the Glen Garland Granodiorite indicate a *ca.* 400 Ma age; this age is also consistent with the Sm-Nd data (Black & others, in press).

Peringa Tonalite (SDp)

(new name after the Parish of Peringa, County of Warner)

Peringa Tonalite is a medium-grained, sparsely porphyritic (hornblende phenocrysts up to 1 cm x 4 mm), biotite-hornblende tonalite grading into mafic granodiorite. It is petrographically similar in some respects to the Glen Garland Granodiorite, but contains less K-feldspar, more plagioclase and hornblende, and generally more hornblende than biotite; allanite is a less conspicuous accessory mineral. A typical approximate modal composition is plagioclase 55%, quartz 25-30%, K-feldspar up to 5%, hornblende 5-9%, biotite 5-6%; accessory minerals are titanite, zircon, apatite, allanite, and rare Fe-Ti oxide. The granodiorite, where exposed, is affected by moderate propylitic alteration.

Peringa Tonalite is about 5 km wide, and extends from 7 km southwest of Glen Garland homestead 12.5 km southward to the margin of Ebagoola. Gravity data (Wellman, in press, a) suggest that Peringa Granodiorite may be connected, beneath a thin 'cover' of Holroyd Group, with the Glen Garland Granodiorite. The type area is in the Coleman River, 11.5 km southwest of Glen Garland (GR7568-380477 to -383475). Weathered outcrop may be found 2 km to the south, at GR7568-378452, but elsewhere the unit is unexposed or extremely poorly exposed and very deeply weathered.

Peringa Tonalite intrudes the Holroyd Group, but no contact relationships with other granitoids were observed. It is assumed to be approximately coeval with the Glen Garland Granodiorite because of their spatial proximity and petrological similarities.

Artemis Granodiorite (SDa)

(new name after Artemis Homestead – Marina Plains 1:100 000 Sheet area)

The Artemis Granodiorite is a mid-grey, medium to coarse-grained, allanite-biotite granodiorite, which is porphyritic in part and contains subrounded to rounded dioritic and microdioritic xenoliths up to 30 cm diameter. Approximate modal mineral proportions are plagioclase 35-40%, K-feldspar 10%, quartz 20%, biotite 20-25%. Allanite is a prominent minor mineral. Accessory minerals include apatite and zircon, and secondary minerals are sericite, chlorite and titanite.

The most extensive body (about 30 km^2) of Artemis Granodiorite is in the headwaters of Thirteen Mile, Fifteen Mile, and Marys Creeks west of Artemis homestead, in the south of EBAGOOLA. A smaller (14 km^2) body crops out between upper Emu Creek and the head of Dixie Creek, and a 2 km^2 body crops out in O'Briens Creek. The type area is a small, bouldery hill near O'Briens Creek (GR 7668-710471). Artemis Granodiorite may be distinguished from Kintore Granite by significantly darker soil tones where not overlain by thick residual sand, and by deeper red tones on airborne gamma ray spectrometric pseudocolour images.

The granodiorite is spatially associated with, and is probably intruded by the Kintore Granite. It is cut by aplite and garnet-bearing pegmatite dykes and veins similar to components of the Ebagoola Granite, and by rhyolite dykes of possible Carboniferous-Permian age.

Tea Tree Granodiorite (SDtt)

(new name after Tea Tree (or Kalkah) Creek – Kalkah 1:100 000 Sheet area)

The Tea Tree Granodiorite is a mid-grey, coarse-grained, porphyritic allanite-hornblende- biotite granodiorite which is texturally and mineralogically similar to the Glen Garland Granodiorite. It contains phenocrysts of plagioclase (up to 1.5 cm long), hornblende (up to 1 cm long), and allanite (up to 2 cm long), and modal mineral composition is quartz 30%, plagioclase 35%, perthite/microcline 10%, biotite 15-20%, hornblende 5-10%; accessory minerals are titanite, zircon, and apatite. It also contains fine-grained, biotite-rich microdioritic schlieren and enclaves up to 0.5 m long and 15 cm thick. Plagioclase and biotite show slight propylitic alteration.

Large, dark grey, rounded boulders are scattered sparsely throughout the 35 km^2 outcrop area of the Tea Tree Granodiorite, which is almost entirely confined to the middle and lower catchment of Tea Tree (or Kalkah) Creek, in the south of EBAGOOLA. The type area is in Tea Tree Creek (GR7568-604516); it is also well exposed at GR7568-591458 where it is close to outcrops of Kintore Granite. In areas of no outcrop not blanketed by thick residual sand, Tea Tree Granodiorite may be distinguished from Kintore Granite by red-brown soil tones and a relatively dark, deep red gamma ray spectrometric pseudocolour signature.

Tea Tree Granodiorite crops out in close association with both the Kintore and Ebagoola

Granites: no contact relationships have been observed, but the granodiorite is cut by pegmatite veins about 3 cm across that may be related to the Ebagoola Granite.

Two Rail Monzogranite (SDr)

(new name after Two Rail Creek – Kalkah 1:100 000 Sheet area)

Two Rail Monzogranite is a slightly porphyritic allanite-biotite monzogranite to granite, grading locally (adjacent to Glen Garland Granodiorite) into hornblende-bearing biotite monzogranite or granodiorite. It contains phenocrysts of K-feldspar up to 1.5 cm long, abundant (up to ~1%) accessory allanite up to 1.5 cm long, and accessory titanite, zircon, apatite, and very rare Ti-Fe oxide. Modal composition varies considerably but averages about 30% quartz, 30% plagioclase, 30% K-feldspar, 10% biotite. Hornblende occurs only on the eastern side of the main body, whereas plagioclase and biotite decrease and K-feldspar increases in abundance towards the western side.

The main mass of Two Rail Monzogranite extends from the southern branch of Barwon Creek to the northern side of the Holroyd River, about 66 km to the north-northwest. Several smaller, separate bodies of monzogranite, which crop out extremely poorly and were mapped mainly on the basis of a characteristic deep red airborne gamma ray spectrometric signature, are equated with Two Rail Monzogranite. These are located on the eastern margin of the Burns Granite (adjacent to the Ebagoola Shear Zone), on the western bank of the Lukin River below the junction with Ryans Creek, and scattered along the northwestern margin of the Barwon Granite and the western margin of the Burns Granite.

The type area is in upper Bamboo Creek (northern branch and main channel), west-southwest of Spion Kop (between GR 7568-925448 and -921412). The monzogranite is also sporadically exposed in the Lukin River and Station Creek, downstream from the Ebagoola-Spion Kop track, and near the Ebagoola-Holroyd River track around GR7569-373260.

Most of the Two Rail Monzogranite is affected by slight to moderate propylitic alteration, which affects mainly plagioclase (particularly the cores) and biotite. More intense alteration is localised in areas near the contacts with the Barwon and Ebagoola Granites and near the Ebagoola Shear zone.

Two Rail Monzogranite has an apparently gradational relationship with Glen Garland Granodiorite, from which it may have been derived by fractional crystallisation. However, there is also evidence in places of intrusion of the granodiorite by the monzogranite (*e.g.* dyke at GR7568-542856). The monzogranite is intruded by Barwon, Leconsfield, Burns, and Ebagoola Granites. Its relationship to the Kirkwood Monzogranite is uncertain, although the apparent shape of the latter suggests that it may be younger.

Carleton Monzogranite (SDc)

(new name after the Parish of Carleton, County of Hann)

The Carleton Monzogranite is a pale grey, slightly porphyritic, medium grained (average grainsize 1-2 mm), felsic allanite-biotite monzogranite to granite. Approximate modal abundances are quartz 30%, plagioclase 25%, microcline 25-30%, biotite 15%. Allanite is a conspicuous minor phase, and apatite and zircon are moderately abundant accessory minerals. Secondary minerals include muscovite, sericite, chlorite, and epidote.

Carleton Monzogranite comprises two small (5.5 and 2 km^2), kidney-shaped stocks on the eastern side of the Coleman River south and north of the Musgrave-Edward River road. Large tors of monzogranite approximately 1 km south of the Musgrave-Edward River road and 3 km east of the Coleman River (GR7568-575615) comprise the type area.

The only contact observed is with the Tea Tree Granodiorite, where the relationship is equivocal. However, the more evolved chemical composition of the Carleton Monzogranite suggests that it may have been derived from a Flyspeck Supersuite granodioritic parent. Carleton Monzogranite is probably about the same age as other, isotopically dated rocks of the Flyspeck Supersuite.

Kirkwood Monzogranite (SDo)

(new name after Kirkwood Creek – Ebagoola 1:100 000 Sheet area)

The Kirkwood Monzogranite is a sparsely porphyritic biotite monzogranite, similar in most respects to the more mafic parts of the Two Rail Monzogranite. However, it is generally more obviously porphyritic, with K-feldspar phenocrysts up to 3 cm long and plagioclase phenocrysts up to 1.5 cm long, and is richer in biotite and poorer in allanite. Approximate modal composition ranges from 35% quartz, 20% plagioclase, 35% K-feldspar and 8-10% biotite to 30% quartz, 45% plagioclase, 15% K-feldspar, and 10% biotite; the K-feldspar/plagioclase ratio decreases westward. Accessory minerals are apatite and zircon (abundant), allanite, titanite, and ilmenite(?). Propylitic alteration is slight to moderate, affecting mainly plagioclase and biotite, although allanite is variably replaced and/or mantled by epidote.

Kirkwood Monzogranite crops out in the upper catchments of Kirkwood, Burns, Brumby and Sandalwood Creeks, and extends in a narrow "neck" along the main channel of Sandalwood Creek; outcrop area is about 31 km^2. Boulders of typical Kirkwood Monzogranite are exposed close to the Aurukun road at GR7569-378171 and -383160; however, best exposure is along Sandalwood Creek, between 7569-289150 and -320150. It is characterised on pseudocolour airborne gamma ray spectrometric images by bright, pale pink to white and orange-pink tones.

Kirkwood Monzogranite probably intrudes Two Rail Monzogranite, is intruded by Barwon and Burns Granites, and is cut by dykes and pods of pegmatite and leucogranite equated with Ebagoola Granite. It is probably about the same age as the Two Rail Monzogranite, and therefore approximately coeval with the Glen Garland Granodiorite.

Undivided granitoid (SDgr)

This area of concealed basement in the NE corner of EBAGOOLA is thought to be a Siluro-Devonian granitoid because of its relatively low gravity, and because the high magnetic anomalies over the adjacent strip of Pu4 are similar to interpreted contact metamorphic effects in rocks adjacent to Siluro-Devonian granitoids to the north in COEN.

Late Carboniferous — Early Permian

Outcropping igneous rocks of probable or possible Carboniferous-Permian age are rare in the EBAGOOLA: those recognised are a small stock of microgranite (Lindsay Flat Microgranite), two narrow dykes of microgranite, and several dykes of rhyolitic to dacitic and andesitic to basaltic/doleritic composition.

However, there is strong geophysical (principally aeromagnetic) evidence for the existence of numerous bodies of igneous rocks of probable Late-Carboniferous to Early Permian age (Wellman, in press) beneath Mesozoic and Tertiary sedimentary cover flanking the exposed Coen Inlier. Intrusive(?) bodies are dominant to the east of the Inlier, and include a circular mass about

21 km in diameter centred below the Saltwater Creek-North Kennedy River junction. To the west, a possible ring complex, about 20 km in diameter, is located between the upper Edward River and Mistake Creek, but the area is dominated by bodies of felsic(?) extrusive rocks of up to *ca* 200 km^2.

Lindsay Flat Microgranite (CPg)

(new name after Lindsay Flat – Kalkah 1:100 000 Sheet area)

Lindsay Flat Microgranite comprises two small stocks of porphyritic biotite microgranite at the southwestern end of Lindsay Flat, between Flying Fox and Barwon Creeks. The more northerly of the two forms the prominent Flying Fox Hill (GR7568-394706). Aeromagnetic data indicate that the two stocks merge into a single body at shallow depth (a few hundred metres) below the surface; this body is elliptical in plan, about 4 km long and 2 km wide.

The southern stock comprises biotite microgranite which contains abundant phenocrysts of quartz, K-feldspar (up to 1.5 cm long) and plagioclase, and about 5% biotite. Accessory minerals are zircon, apatite, and rare magnetite(?). The rock is moderately to strongly sericitised, is cut by veinlets of calcite and quartz, and contains up to 2-3% pyrite. The northern body is made up of porphyritic biotite microgranite which is less conspicuously porphyritic and much less altered than the southern body. It contains phenocrysts of sanidine up to 1cm long ; alteration is slight.

Lindsay Flat Microgranite intrudes Barwon Granite, and may be genetically related to spatially associated dykes of porhyritic rhyolite. These observations, and the fact that it is petrographically and geochemically similar to high-level Carboniferous Permian granitoids throughout north Queensland suggest a Late Carboniferous-Early Permian age.

Minor intrusives

The southwestern portion of the CYPB on EBAGOOLA is cut by a number of dykes of rhyolitic to andesitic or doleritic composition, and, at Spion Kop, by a plug of extremely fine-grained rhyolite (CPr). The most common lithologies are (1) weakly porphyritic rhyolite (to rhyodacite), and (2) sparsely porphyritic to aphanitic andesite and porphyritic dacite. All are moderately to intensely altered.

Andesitic to doleritic dykes are mostly narrow (up to 30 m wide) and crop out extremely poorly or not at all; most were detected only by their aeromagnetic signature (Wellman, in press, a). An andesite dyke in the Stew Creek area (GR7568-497810) swells to about 200 m wide, and here its central portions are mainly dioritic.

Most of the dykes are east-northeasterly trending, parallel to a very well-developed regional fracture pattern. However, some are subparallel to the Ebagoola Shear Zone, and one group trends north-northwest. The dykes cut across all other rock units and all structures, with the exception of the Napabina Fault. Rhyolite dykes in the vicinity of the Lindsay Flat Microgranite appear to be genetically related to the granite. These observations suggest that most, if not all, of the dykes are probably of Late Carboniferous-Early Permian age.

Other igneous rocks (concealed — CPv, CPi1, CPi2, CPa, CPb, CPc)

On the western margin of EBAGOOLA there are numerous magnetic lows due to reversely magnetised bodies. The anomaly with the largest diameter is oval-shaped and has a concentric internal structure: comparison with similar anomalies in the Georgetown region suggest that it is due to a Permo-Carboniferous ring complex (CPi1, CPi2) which is in part intrusive and in part volcanic. Other nearby negative magnetic anomalies are thought to be troughs in the basement containing related Permo-Carboniferous volcanic rocks (CPv).

On the eastern margin of EBAGOOLA, there are also numerous oval-shaped magnetic anomalies interpreted as Permo-Carboniferous intrusions. Dome-shaped magnetic highs (without lows) are thought to indicate discoid-shaped bodies below the basement surface (CPa). Where there are associated positive and negative anomalies, the body is interpreted to be a vertical sided intrusion, positively magnetised when the positive anomaly is to the north (CPb), and negatively magnetised when the negative anomaly is to the north (CPc). Some of these bodies intrude the Hodgkinson Basin (Bultitude & others, 1990), which on geophysical evidence is thought to extend to the north below the Laura Basin on the eastern side of the Palmerville Fault.

Geochemistry of the Palaeozoic intrusive rocks

Cape York Peninsula Batholith

Classification of granitoids into Supersuites is based on mineralogical and chemical similarities and general coherence of compositional trends. The twofold subdivision of the CYPB into S- and I-types on mineralogical grounds (*i.e.* the presence of primary muscovite and/or garnet in the former, hornblende and/or allanite and/or titanite in the latter) is supported by the analytical data which allow division into two Supersuites. These data show a clear separation between the I-type Flyspeck Supersuite, with ASI (alumina saturation index) consistently below 1.1, and the Kintore Supersuite, which has a broad range of ASI values above 1.1, increasing significantly in rocks with more than 72% SiO_2 (Fig. 9A). The intermediate to felsic Flyspeck Supersuite has a relatively even distribution of SiO_2 ranging from 64 to 73%. The felsic Kintore Supersuite SiO_2 content ranges from 66% to 75% SiO_2, but most samples have 71% SiO_2. The S-types are also generally slightly higher in K_2O/Na_2O. Other differences include different trends, although commonly with some degree of overlap, on plots of:

- P_2O_5 *versus* Fe_{total} as FeO (Fig. 9B) and P_2O_5 *vs* SiO_2, reflecting the lower Fe_{total} and higher average P_2O_5 contents of the Kintore Supersuite relative to those of the Flyspeck Supersuite;
- Ce *vs* SiO_2, with the S-types showing a strong linear decrease with increasing SiO_2 (Fig. 9C);
- Ba *vs* SiO_2; and Pb *vs* SiO_2.

Ba, Sr, Nb, and Zr all show flat trends with increasing SiO_2 in the I-types, but steeply decreasing trends in the S-types.

Both Supersuites are very iron-poor and highly reduced, resulting in their being magnetically very flat (susceptibility is typically in the range 1-15 x 10^{-5} SI units). These properties are normal for S-type granitoids, but unusual for I-types (*e.g.* Chappell & White, 1984), and reflect unusual source compositions, as discussed below.

The S-type Ebagoola and Lankelly Suites have initial εNd values (at 400 Ma) of -13.8 to -14.7 and -13.4 to -14.1 respectively, and although there is some overlap of values the Lankelly Suite tends to be the more radiogenic. A single value on a Flyspeck Supersuite granodiorite suggests that it is less evolved (εNd -12.7), however data presently available do not indicate a clear distinction between the various granite suites. Preliminary Sm-Nd isotopic results, along with zircon U/Pb chronology indicate that all the Siluro-Devonian granites were derived by partial

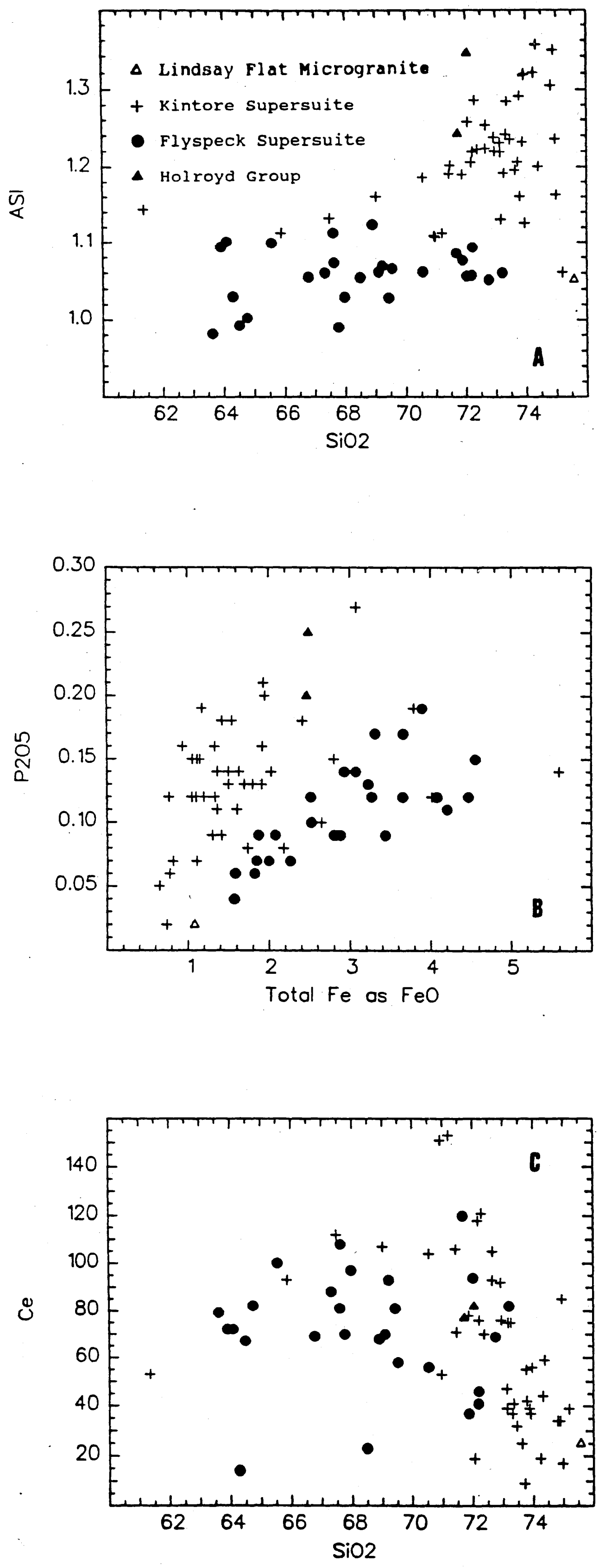


Figure 9. Variation diagrams showing separation of I-type (Flyspeck Supersuite) and S-type (Kintore Supersuite) granites (from Mackenzie & Knutson, in press).

melting of relatively old (Precambrian) crust, with the restitic zircons documenting an earlier tectonothermal event at approximately 1600 Ma. An older 2500 Ma crustal component also has been identified (Black & others, in press).

Two Sm-Nd determinations on Holroyd Group gneisses give εNd values (at 400 Ma) of -15.2 and -18.9. These values indicate that the Holroyd Group gneisses alone could not be the source of Kintore Supersuite melts, but do not preclude the possibility that they were a major component along with a less evolved component (e.g. underplated younger material).

Kintore Supersuite

Ebagoola Suite — Apart from their characteristically high ASI values, rocks of the Ebagoola Suite are mostly high in SiO_2 (72%). Most components (*e.g.* TiO_2, FeO, MgO, CaO, K_2O, P_2O_5, Ba, Sr, Zr, Nb, Y, and Ce) decrease linearly with increasing SiO_2; a few (*e.g.* Na_2O, Rb, Pb, and U) increase. These variations are consistent with compositional evolution by means of separation of restite composed of plagioclase + biotite + zircon, and fractionation of K-feldspar and monazite. Other components show little or no discernible systematic variation relative to one another.

Lankelly Suite — In most variation diagrams, the Ebagoola and Lankelly Suites have distinct, commonly well-separated, trends, the main differences being:

- the generally lower SiO_2 contents, more extended compositional range and higher FeO and MgO contents of the Lankelly Suite;
- the relatively high Zr and Ce contents of the Lankelly Suite;
- contrasting trends in Sr, Rb, Ce; those in the Ebagoola Suite being much steeper than in the Lankelly Suite;

Low Ni and Cr values, mostly less than 3 and 5 ppm respectively, in the Kintore Supersuite rocks are similar to those recorded for the Georgetown Inlier Esmeralda Supersuite (Champion, 1991). They contrast markedly with the S-type granites of the Lachlan Fold Belt and the Georgetown Inlier Forsayth Supersuite where high values are attributed to a pelitic contribution (Hine & others., 1978; Chappell and White, 1984; Champion, 1991). Another distinction with the Lachlan Fold Belt granites is in the trends exhibited by CaO, Na_2O, K_2O, Sr and Pb. The distinct trends of these elements in the S- and I-type granites of the Lachlan Fold Belt are not seen in the granites of the CYPB, indicating there is a fundamental difference in either the source and/or generation of the granites in these two areas.

Flyspeck Supersuite

Members of the Flyspeck Supersuite are less compositionally diverse than those of the Kintore Supersuite, but there are several differences between the various granitoid units. On most variation diagrams, Two Rail Monzogranite, Carleton Monzogranite, and Flyspeck Granodiorite form a single coherent trend, while Peringa Tonalite, commonly along with Artemis Granodiorite and Tea Tree Granodiorite, form trends that are clearly separate from those of the other units, and generally separate from each other; Kirkwood Monzogranite also shows some differences from the other granitoids. The main differences between individual units are:

- Peringa Tonalite, Glen Garland Granodiorite, and possibly Artemis Granodiorite have lower ASI values, and Kirkwood Monzogranite has higher values, than the other units.
- Peringa Tonalite, and Glen Garland, Artemis and Tea Tree Granodiorites are high in MgO and Ni relative to the other granitoids.
- Peringa Tonalite, Artemis Granodiorite and Tea Tree Granodiorite are relatively high in Na_2O and Sr, and low in K_2O and Rb.
- Peringa Tonalite is also high in CaO and Y, and low in Ba, Nb, and Ce relative to the remainder of the Supersuite.
- Artemis Granodiorite is relatively high in CaO and Sr, and low in Ba, Pb, and Li.
- Kirkwood Monzogranite is higher than the other units in Fe_{total} as FeO, P_2O_5, Zr, and Y; it is also relatively high in Na_2O, and low in K_2O and Th/U.

Compositional variation in the members of the Flyspeck Supersuite is probably due to a combination of restite separation, involving a plagioclase- and hornblende-rich residue, and fractional crystallisation involving separation of melt from predominantly the same minerals. However, there is only minor enrichment in the strongly incompatible trace elements Rb, Th and U, indicating that fractional crystallisation processes have not been important in the evolution of these rocks. This is supported by the absence of any trends indicative of fractionation processes on variation diagrams such as Rb versus K/Rb.

Late Carboniferous — Early Permian

The only chemical data available for the probable Late Carboniferous-Early Permian rocks are from the Lindsay Flat Microgranite. This granite has a fractionated I-type composition, characterised by a low ASI and Al_2O_3, low Fe_{total}, CaO, P_2O_5, Ba, Sr, Y, high Na_2O, and low primordial mantle-normalised Ba, La, Ce, Sr, P, and Ti relative to the CYPB I-types.

Geometry and Emplacement of the CYPB

There are four principal constraining factors that must be taken into account in any model for the three-dimensional geometry and mode of emplacement of the CYPB granitoids.

- **The long, relatively narrow shape** at the surface of the batholith and most of its components, subparallel to the regional strike of the host rocks.
- **The tectonic setting of the Batholith in a sinistral transpressive regime.** In places, such as the southern end of the Barwon Granite, major shear zones are truncated. However, most of the exposed granitoids show evidence of various degrees of deformation – shearing where identifiable – and those in and near the Ebagoola and Coen Shear Zones (as well as the small bodies within the Holroyd Group to the west of the CYPB) are extensively mylonitised or sheared.
- The evidence that **the granitoids are approximately syn-metamorphic.** This is chiefly in the form of gradations from gneiss, increasingly leucogranite- and pegmatite-rich migmatite, leucogranite and pegmatite with abundant migmatite/gneiss rafts, and enclave-rich leucogranite/pegmatite to relatively homogeneous leucogranite (*e.g.* around the Coleman River crossing on the Musgrave-Edward River road). There is also evidence of sillimanite-grade metamorphism in a small granite body close to the Warner Granite.

- Regional gravity evidence that **low-density, felsic granitoids** (*i.e.* the exposed Kintore Supersuite and felsic Flyspeck Supersuite rocks) **extend to greater depths in the west than in the east** (Wellman, in press, a).

The tectonic setting of the batholith and its elongate shape at the surface suggest that it should be relatively deep and narrow in cross-section. However, the depth extent of the granitoids in the CYPB, as calculated from gravity anomaly changes and estimates of average densities, ranges from about 6 km on the eastern side to 8-11 km on the western side (Wellman, in press, a). Such depth extents are consistent with estimates made elsewhere from seismic reflection studies (e.g. Pinchin, 1980), and heat flow and seismic studies (Costain and Decker, 1987; Vigneresse & others, 1987; Webb & others, 1987).

Geochemical data discussed previously indicate that restite separation has played an important role in the evolution of the CYPB, especially the Kintore Supersuite. It is therefore proposed, in the light of the observations made above, that the plutons of the CYPB grade at depths of up to 6-10 km into mixtures, similar in density to the metamorphic country rocks, of magma and restite (e.g. Chappell & others, 1987). Restite masses may range in size from crystals and polygranular aggregates to blocks or schlieren of schist/gneiss or migmatite up to several kilometres across. With increasing abundance and size of these blocks/schlieren, the mix grades with increasing depth into migmatite, granitoid-veined metamorphics, and, finally, massive metamorphic rocks.

Emplacement of the CYPB may have been essentially by means of dilational 'jogs' in pre-existing northerly to north-northwesterly trending transpressive structures such as the Coen and Ebagoola Shear Zones (cf. Hutton, 1988; McCaffrey, 1992; Hutton & Reavy, in press; D'Lemos & others, 1992). In such a model, sheet-like bodies of the Flyspeck Supersuite granitoids would have been emplaced first, accounting for their mostly elongate form as now exposed (cf. McCaffrey, 1992). Emplacement of the Kintore Supersuite rocks would have been *via* subsequent further dilation of the same broad structure(s). This further dilation may have been localised mainly within the last-emplaced (still crystallising?) Flyspeck Supersuite unit, the Two Rail Monzogranite, which could explain its being split into widely separated eastern and (discontinuous) western portions.

The Ebagoola Granite was probably the last phase of the Batholith to be emplaced. This is consistent with it being commonly in close proximity to metamorphic country rocks at the margins and (as proposed above) at the roof of the batholith. It is also consistent with it being partly a late differentiate of Kintore Supersuite rocks and partly a small percentage partial melt of the same source rocks as the other units of the supersuite. There is evidence that such partial melting has occurred not only at depth but also at the roof of the batholith (e.g. Coleman River crossing).

Mesozoic

The Coen Inlier is overlain to the west and south by the Carpentaria Basin and to the east by the Laura Basin. These basins contain a Jurassic to Lower Cretaceous sequence of continental sandstone and conglomerate overlain by shallow marine sandstone and mudstone. The Carpentaria Basin consists of sandstone belonging to the Gilbert River Formation which grades upward into the predominantly pelitic Rolling Downs Group. Rocks of the Laura Basin crop out poorly; however, petroleum exploration wells drilled in the southeast of EBAGOOLA have bottomed in Permian sedimentary rocks beneath the Laura Basin and pass through the predominantly sandy Dalrymple Sandstone overlain by the Gilbert River Formation and the Rolling Downs Group. These basins were not investigated in this survey but have been described in greater detail by Smart & others (1980) and Hawkins & Williams (1990).

Cainozoic

Discussion of sedimentary units within the Cainozoic stratigraphy is covered later in this commentary as part of the regolith.

Silver Plains Nephelinite (Tb)

This unit consists of black, very fine-grained, basanitic nephelinite containing abundant olivine microphenocrysts averaging 0.2 to 0.4 mm long, and sparse, small (mostly 5 mm) peridotite xenoliths in a matrix of nepheline, clinopyroxene, olivine and opaque minerals. Potassium-argon dating (Sutherland, 1991) produced a 3.72 ± 0.06 Ma, or Early Pliocene, age.

The Silver Plains nephelinite forms a prominent, thickly vegetated, flat topped hill about 2 km x 3 km centred on GR7669-747262, near Balclutha Creek, 24 km southwest of Port Stewart. Two or three benches, each representing a lava flow about 2 to 3 metres thick are exposed at the top of the hill. It has an estimated thickness of about 40 m. Aeromagnetic data suggest the presence of similar nephelinite flows below Cainozoic cover about 40 km to the southeast.

The nephelinite has a SiO_2 content of 39.04%, a Mg/(Mg + Fe^{2+}) value of 68 (based on $Fe^{3+}/Fe^{3+}+Fe^{2+}$ = 0.8), and CIPW normative olivine, nepheline and leucite values of 20.79, 20.59 and 10.95 respectively. It is one of the most silica-undersaturated volcanic rocks produced by the widespread east Australian Cainozoic volcanism. The Mg value and the presence of peridotite xenoliths indicates a primary melt sourced directly from the mantle. The nephelinite has relatively high Sr and Ba contents (1601 and 912 ppm respectively) and low Cr and Ni contents (213 and 176 ppm respectively).

METAMORPHISM

by R.S. Blewett (AGSO)

The exposed metamorphic rocks of EBAGOOLA comprise four metamorphic groups: Edward River, Holroyd, Coen, and Newberry (Fig. 2; groups 1-4), and range from greenschist-facies slate, phyllite and quartzite to upper amphibolite-facies sillimanite-bearing schist, gneiss and migmatite. Three superimposed metamorphic events (M1, M2, M3) roughly synchronous with the first three regional deformation events (D1, D2, D3) are recognised. The regional metamorphic climax occurred during the second metamorphism (M2) at the time of the Coen Orogeny (D2) (see below) and there is a strong spatial link between M2 metamorphic grade and proximity to the CYPB. Geophysical data indicate the presence of metamorphic rocks (Fig.2; group 5) west of the Edward River Metamorphic Group. The Hodgkinson Province east of the Palmerville Fault Zone is, by extrapolation from exposed areas to the south, also composed of low-grade metamorphic rocks (Bultitude & others, 1990).

The metamorphic grade throughout the Coen Metamorphic Group is mid to upper amphibolite facies gneiss and schist, with sillimanite as a common mineral. Metamorphic grades in the Holroyd Group are more variable than in the Coen Metamorphic Group, with rock types ranging from indurated sediment to sillimanite schist and lesser gneiss. The Holroyd Group (Kalkah

Structural Domain) is dominated by andalusite - mica schist; it has far less gneiss than the Coen Metamorphic Group. The greatest range is found in the western and least sheared belt (Lukin Structural Domain) of the Holroyd Group, where sub-greenschist to mid and upper amphibolite-facies rocks are exposed. The Newberry Metamorphic Group is dominated by upper amphibolite-facies gneiss and lesser schist. Little is known about the metamorphic history of the Edward River Metamorphic Group.

M1 Metamorphism

The intensity of the Coen Orogeny means that little is known about the pre-Coen (D2) deformation and metamorphic history of the Coen Inlier. M1 grades were at or below greenschist facies metamorphism in the least deformed units of the Lukin Structural Domain (indurated sediments and slates). Elsewhere, however, M1 is overprinted and obliterated by the generally high grade M2 mineralogy.

M2 Metamorphism

In EBAGOOLA it is clear that there was a spatial and temporal link between emplacement of the Siluro-Devonian granites of the CYPB and deformation and metamorphism during the Coen Orogeny. Willmott & others (1973) first suggested that the CYPB was responsible for the thermal climax of metamorphism, and Wellman (in press, a & Gb) has suggested that the highest metamorphic grades and the CYPB are essentially the products of Palaeozoic reworking of the eastern edge of the Proterozoic craton (Wellman, in press, b).

Common minerals formed during M2 include sillimanite, andalusite, garnet, biotite, tourmaline, graphite, muscovite and quartz; less common are staurolite and kyanite. The mineralogy indicates that EBAGOOLA was a high temperature-low pressure regime, with the thermal source also resulting in the emplacement of the CYPB. The CYPB has a regional metamorphic aureole that is well displayed in the Kalkah Structural Domain by the change from mainly andalusite-bearing schist into mainly sillimanite-bearing schist towards the contact with the CYPB. The Coen Metamorphic Group is mainly sillimanite-bearing and also comprises a greater proportion of gneiss and migmatite.

The regional aureole and almost total absence of hornfels, suggests that the depth of emplacement of the CYPB into the Proterozoic margin was at depths where high temperature amphibolite-facies metamorphism occurs. The only hornfels is found in small areas of Astrea Formation (Pko) on the top of low hills in the Warner Granite south of Glen Garland homestead. The gravity data indicate that the Glen Garland region is shallowly underlain by the CYPB, and that the metamorphic rocks in this area are the roof pendants of the Batholith.

Kyanite is present in the south of the Coen Metamorphic Group and in the Kalkah Structural Domain on the Lukin River north of Cockers Knob (Kalkah 1:100 000 Sheet area). Both kyanite and sillimanite porphyroblasts generally are pseudomorphed by muscovite. Andalusite and sillimanite are locally intergrown indicating a temperature close to the phase boundary. Garnet is unevenly distributed and locally may constitute up to 20% of a gneiss or less in a schist. Andalusite is very common in the Kalkah Structural Domain, uncommon in the Lukin Structural Domain, and rare in the Coen Metamorphic Group. Much of it is retrogressed to sericite, but the porphyroblasts, commonly with chiastolite crosses, are well preserved. Staurolite is restricted to the Gorge Quartzite (Pku) of the Kalkah Structural Domain and has been retrogressed to chloritoid, probably during M3. Muscovite and biotite generally define the S2 schistosity. Graphite is a relatively common mineral in the schists of the Kalkah Structural Domain.

M3 Metamorphism

Metamorphism during D3 was largely retrogressive and probably responsible for the muscovite pseudomorphs after sillimanite, chloritoid and sericite after staurolite, sericite after andalusite, tremolite-actinolite after sillimanite(?), and chlorite after biotite.

STRUCTURE

by R.S. Blewett (AGSO)

Four phases of penetrative, regional deformation have been recognised in EBAGOOLA (Fig. 10). In the model described below, the area is a Proterozoic belt dominated by Siluro-Devonian transpressional orogenesis that extended 110 km west from the Palmerville Fault Zone (Wellman, in press, a). Figure 10 is a simplified, two dimensional fabric-element sketch combined with a simplified interpretation of the total magnetic intensity image that can be used as a reference guide to the structural geology.

The climax of deformation and metamorphism (D2/M2) was associated with emplacement of the Siluro-Devonian CYPB. The NNW-trending D2 fabric and subsequent shearing dominate the distribution of rock types and the orientation of mesoscopic and macroscopic structures throughout the sheet, and most of the Coen Inlier. Substantial shearing subparallel to the NNW-trending D2 strike occurred along the margins of the CYPB during the early stages of its emplacement, and this shearing (principally sinistral oblique-slip) continued in localised zones after the solidification of the Batholith.

First Deformation (D1)

D1 structures are widespread but difficult to recognise in the metamorphic units. D1 structures were probably upright and E-W trending; the age of deformation and associated metamorphism is not known.

Folding (F1)

In the Kalkah Structural Domain and Coen Metamorphic Group, intense D2 transposition has almost completely obliterated D1 structures. D1 structures are well developed in the lower grade, and least deformed units of the Lukin Structural Domain, where the style of deformation is one of tight to isoclinal, variably plunging F1 folds with an axial planar S1 slaty cleavage. Fine examples of F1 folding may be found in the low-grade Newirie Formation north of Astrea Holdings Homestead. F1 fold closures are generally difficult to recognize; this is due to their isoclinal nature, transposition, their very high amplitude to wavelength ratios, together with the intensity of overprinting by later generations of deformation.

Foliations and Layering (S1)

S1 is commonly visible in the Q-domains of the S2a crenulation foliation, though rare isoclinal F1 fold closures occur as part of complex fold interference patterns in the gneissic units. In other

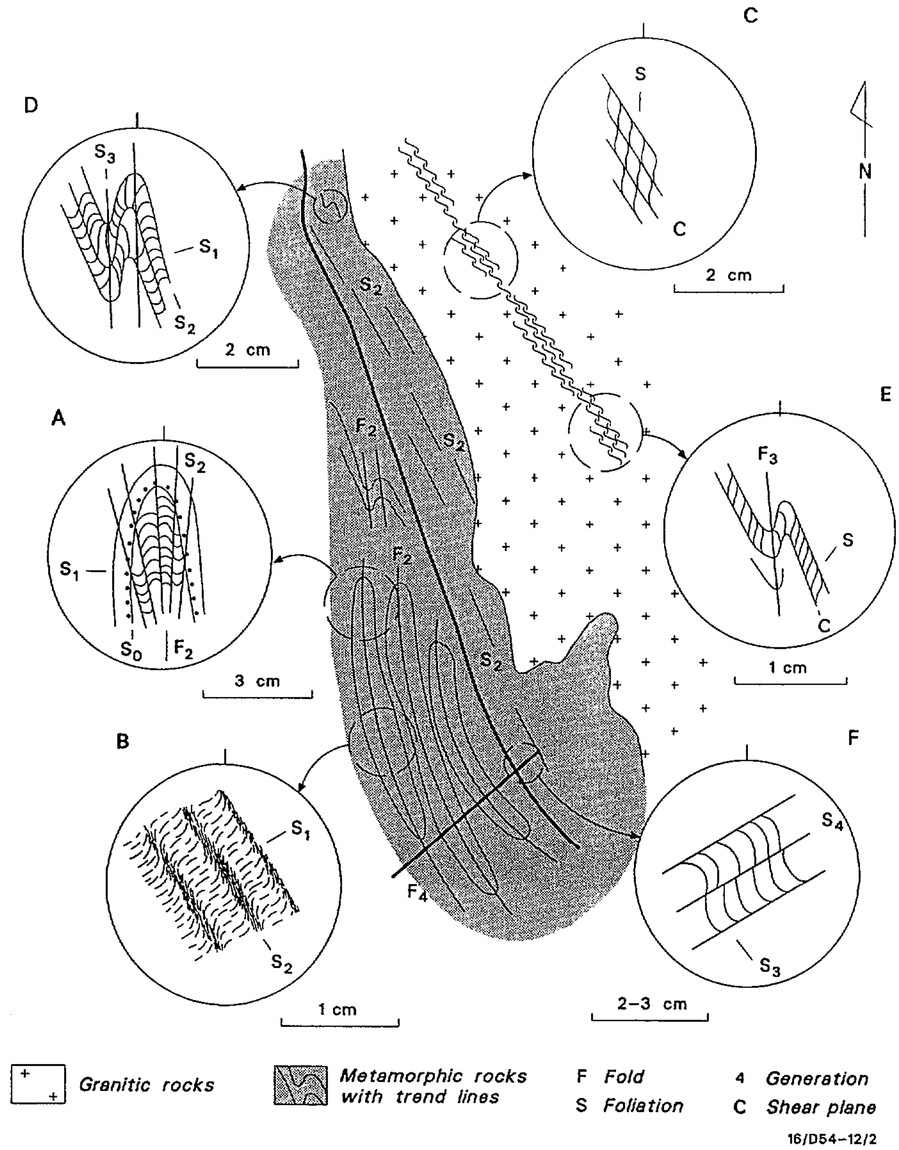


Figure 10. Simplified fabric element sketch of the structural geology of EBAGOOLA. The diagram provides a summary of the deformation history. A – F1 fold closure with axial plane cleavage. B – S2 as a NNW trending crenulation cleavage. C – S-C composite fabrics in mylonitic granites. D – S3 as a coarse, asymmetric N-trending crenulation cleavage. E – F3 folding of S-C mylonites. F – Broad, open ENE-trending crenulation by F4 (from Blewett, in press).

areas of less D2 interference, especially to the west in the Lukin Structural Domain, S1 is clearly visible around hinge zones of tight F2a microfolds. In the low-grade slates, or in regions where bedding is visible, the S1 surface is sub-parallel to bedding.

S1 was a steeply dipping, E-W to ENE-WSW trending schistosity prior to being folded by F2a (Blewett, in press). Type II and III fold interference patterns (Ramsay, 1967), coupled with the relatively gentle F2a fold plunge, also indicate that F1 folds were originally shallow plunging and possibly recumbent. S1 is scattered but generally is a steeply ENE-dipping foliation (Blewett, in press).

Second Deformation — Coen Orogeny (D2)

The abundant and widespread NNW-trending, steeply dipping D2 structures dominate the fabric of EBAGOOLA: they are linked to the climax tectono-thermal event in the Coen Inlier referred to here as the Coen Orogeny. The Coen Orogeny was a period of progressive deformation and can be considered in broad terms as D2. D2a structures predate the emplacement of the CYPB and are associated with climax metamorphism M2. There are three discernible events of D2: D2a is pre-CYPB, D2b is syn-CYPB, and D2c is post-CYPB.

D2a structures are dominated by sub-horizontal to gently NNW-plunging isoclinal folds with an axial planar schistosity (S2a) that dips subvertically. The gentle F2a fold plunge and subvertical axial surfaces suggest coaxial deformation at least during fold and foliation development in EBAGOOLA.

Folds (F2a)

All F2a folds in the Coen Metamorphic Group are mesoscopic, whereas those in the south and west of the Holroyd Group are kilometre scale. This general absence of macroscopic folding in the Coen Metamorphic Group could be attributed to the lack of competence contrasts coupled with the intensity of subsequent shearing and/or transposition. The degree of transposition of D2a fabrics and frequency of ductile shear zones increased eastwards towards the Palmerville Fault Zone.

F2a folds have steeply dipping axial surfaces, and axial planar S2a foliations that generally trend NNW and have gentle plunges. The folds are upward facing, although only a few younging directions were observed, and only in the Lukin Structural Domain. In the macroscopic folds in the southern Lukin Structural Domain, there is a slight overturning to the west. These folds are also periclinal with shallow north and south plunging hinges.

Spectacular macroscopic F2a folds are also found in Subdomain 2 of the Kalkah Structural Domain. Here, the very thick bedded and competent quartzites of the Gorge Quartzite (Pkp) define subhorizontal N-plunging F2a antiforms with shear zones transecting the complementary synforms. These shear zones form the NNW to N-trending magnetic troughs typical of the "early" or D2b shear zones that dominate the Kalkah Structural Domain.

Foliations (S2a)

S2a is a widespread, steeply ENE-dipping foliation (Fig. 10), and in almost all schists it defines the penetrative fabric. The trend of S2a in the metamorphic rocks is essentially sub-parallel to the flow foliation in the granites of the CYPB (Blewett, in press); this foliation tends to increase in intensity towards the eastern margins of the Batholith and develops into a D2c S-C mylonite. Although D2 accompanied granite emplacement in the broad sense (as a product of the thermal pulse), numerous observations show that individual intrusions cross-cut the S2a surface. The foliations in the granite are therefore considered to be D2c surfaces, and are slightly later than the main D2 (a&b) deformation in the progressive development of the Coen Orogeny.

The S2a foliation is commonly seen as a penetrative schistosity (0.1 mm spacing is common) with occasional gently plunging lineations, or as an intense crenulation foliation with preserved S1 closures. In the more competent units, S2a may occur as a spaced fracture cleavage and yet interbedded schist is penetrated by S2a as a crenulation cleavage or schistosity. With increasing metamorphic grade and intensity of D2a, the competent quartzite units like the Gorge Quartzite (Pkp) begin to take on a rudimentary schistosity with S2a defined by muscovite and biotite between strongly recrystallized quartz. In lower grade units like the Sugarbag Creek Quartzite in the Lukin Structural Domain, S2a refracts from the more argillaceous units (where S2a is at a low angle to bedding) into a more steeply dipping foliation. S2a is also more widely spaced in the more competent beds.

In areas of intense D2b non-coaxial deformation, S2a is seen as a crenulated cleavage in the strain shadows of large porphyroblasts such as andalusite or garnet, while the rest of the rock comprises a decrenulated S2a schistosity. Some garnet-hematite-quartz porphyroblasts preserve a symmetrical curving S2a surface that appear to have rotated through 90^{0}. These may indicate the rotation of porphyroblasts during D2 (Hanmer & Passchier, 1991) or the overgrowth of early stages of crenulation development (Bell & Hayward, 1991).

Prograde metamorphic minerals associated with S2a envelope porphyroblasts of andalusite and intergrown sillimanite. Graphite is a common mineral in the Strathburn Formation (Pki) and the Astrea Formation (Pko); it is parallel to and in a sense defines S2a. The S2a schistosity is in most cases principally defined by fine muscovite and sometimes biotite as the P-domain. Q-domains are made up of quartz which is generally strained, together with fine-grained mica.

The intersection of S2a with S0 and/or S1 commonly results in a steeply plunging lineation (Fig. 10). These lineations are generally crinkle-like in the more phyllitic rocks whereas they are defined by the alignment of biotite in the more schistose units.

Early shear zones (D2b)

The Kalkah Structural Domain has been intensely sheared, probably during later stages of the Coen Orogeny (D2b). Many of the shear zones have been reactivated, and are extensions of the mylonite zones found in thin granitic slices within the Kalkah Structural Domain (e.g. near Dingo Creek and Lukin River). Many of the D2b shear zones form the contacts of the metamorphic units; this is especially so in the Kalkah Structural Domain, and Edward River and Coen Metamorphic Groups.

Some of the early shear zones are cross-cut by granites of the CYPB – examples can be found at Dead Horse and Opera Creeks, 6 km west of Glen Garland homestead. Another example is found at Lagoon Creek in the northeast of the Strathburn 1:100 000 Sheet area, where a westward protruding tongue of Burns Granite transects the NNW-trending Kalkah Structural Domain and associated shear zones.

The majority of NNW to N-trending faults in the Lukin Structural Domain are probably D2b in age; for example, the Coleman River Fault with a 7 km horizontal offset of the Carew Greenstone, and a NNW-trending fault that transects the syncline between the western and central macroscopic anticlines of the Carew Greenstone.

The "early" shear zones are visible on the aeromagnetic data as linear troughs or lows; many stretch for tens of kilometres and trend more northerly than the regional NNW-oriented strike. They commonly are expressed as shear planes subparallel to the S2a schistosity, and therefore visible where they cross-cut S2a. Along the Coleman River where the Strathburn Formation (Pki) crops out, a number of shear planes are highlighted by the boudinage of quartz veins that are parallel to S2a. Other early shear zones that may have been re-activated are common around the Curlew Ranges NW of Glen Garland homestead.

A number of major D2b shear zones overprint F2a folds or juxtapose differing M2 metamorphic grades. The N-S trending Cattle Swamp Shear Zone separates the Edward River Metamorphic Group from the Lukin Structural Domain. The Lindalong Shear Zone juxtaposes the mid-amphibolite facies Kalkah Structural Domain with the largely greenschist facies Lukin Structural Domain. The Gorge Fault trends NNW, dips steeply and transects the Gorge Quartzite, and removes the complementary anticline to the syncline (F2a) whose core is defined by the outcrop of Strathburn Formation. This fault cuts down the structural section northwards as the F2a syncline plunges to the north and juxtaposes successively higher levels of the Strathburn Formation against the Strathmay Formation.

The aeromagnetic data over the Coen Metamorphic Group are more difficult to interpret. D2b shear zones are less continuous (on the TMI images) and the contrast between them and the surrounding metamorphic rocks is less than that seen in the Kalkah Structural Domain. D2b shear zones trend in a more northerly orientation than the more obvious D2c Coen and Ebagoola Shear Zones. The Stewart River Fault separates the biotite-bearing Yarraden Schist from the biotite-free Goolha-Goolha Schist. The kinematics of these D2b shear zones is unknown; they are probably similar to those found in the Kalkah Structural Domain to the west and described above.

Later shear zones (D2c)

The most intense D2c shear zones are mylonites and are most easily recognised where they intersect the granites. Spectacular S-C composite fabrics are found along these shear zones, all seeming to indicate a significant component of sinistral shear. D2c shear zones tend to be NNW-oriented and they locally crosscut the earlier and more N-trending D2b shear zones. A fine example of this angular discordance is where the Lukin River Shear Zone cuts the D2b shear zones of the Kalkah Structural Domain northeast of the Lukin River.

These shear zones are of low metamorphic grade (biotite) and overprint the CYPB (Ebagoola, Warner and Barwon Granites). They have important spatial links with gold mineralization. Some movements on the Coen and Ebagoola Shear Zones deform rhyolite dykes, which on regional considerations could be Carboniferous in age.

Major shear zones form discrete belts of intense deformation in NNW-SSE trending en-échelon zones up to 3 km wide. The Coen and Ebagoola Shear Zones dip steeply, generally ENE. Stretching lineations plunge NNW close to the calculated average mylonite surface. The Lm lineation or stretching lineation is defined by elongate quartz and aligned biotite. Strong L-S tectonites are visible within mylonitized rhyolite dykes that occur in the major shear zones.

Mylonites also occur in the metamorphics: well developed S-C fabrics and asymmetrical quartz/feldspar augen in gneissic units of the Newberry Metamorphic Group along the Coen Shear Zone suggest sinistral reverse movements. The gneissic layering is the locus of shearing, with occasional strong rodding of the leucosome layers. Thin graphitic shears also occur within the metamorphics, some of which have associated gold mineralization.

The Ebagoola Shear Zone is well exposed in the granites around Tadpole Creek to the north of the Ebagoola 1:100 000 Sheet area, where it contains very thin slivers of highly attenuated schist. Ribbons of the Ebagoola Granite are distributed along the Ebagoola Shear Zone with thin slivers of metamorphics along the length of the shear zone: this results in a higher magnetic response relative to the rest of the CYPB which it cuts. In the south near Mount Ryan, the Ebagoola Shear Zone forms the eastern contact of the Mount Ryan Quartzite with the Lochs Gneiss and Yarraden Schist. There is no significant horizontal offset of the Coen Metamorphic Group by the Ebagoola Shear Zone.

The Ebagoola Shear Zone has rare outcrops of highly deformed rhyolite similar to that found along the Coen Shear Zone – for example 10 km north of the Holroyd River. Quartz veins crop out along the Ebagoola Shear Zone, especially between Mt Lee Bryce and the Hamilton Goldfield, but silicification is less than along the Coen Shear Zone.

The Lukin River Shear Zone (Blewett & von Gnielinski, 1991), is well exposed near Eighteen Mile Lagoon along the Lukin River on the Kalkah 1:100 000 sheet. The Lukin River Shear Zone is a complex, anastomosing zone of ductile shear up to 2 km wide within a sheared pod of granite in the Kalkah Structural Domain. The shear zones dip steeply to the ENE, while the shear sense is consistently sinistral oblique-slip with well developed gentle SE-plunging stretching lineations indicating transport up to the NNW. Kinematic indicators are common and include S-C and C-C' composite fabrics, mica fish and tiling structures. The stretching lineations at the crossing of the Lukin River (just east of Eighteen Mile Lagoon) are subhorizontal, with 5^{0} plunges towards the southeast. Here, the mylonite approaches an ultramylonite in textural terms, and is the most intense example located in EBAGOOLA. Significant grain size reduction has occurred in this area.

The Lukin River Shear Zone extends SSE and is crosscut by a tongue of Barwon Granite: it becomes the Lucy Swamp Shear Zone and is manifested by mylonitized Warner Granite to the west of Glen Garland. The Lucy Swamp Shear Zone is developed over 2 km across strike, it dips steeply ENE and has a gentle to moderate SE-plunging stretching lineation. The geometry is one of oblique thrusting towards the NNW, with the Kalkah Structural Domain as the hangingwall above the footwall Lukin Structural Domain.

The timing of shearing is problematical. The ductile shearing event may have begun while the CYPB was in a magmatic state as phenocrysts are commonly flow aligned parallel to the ductile shear zones. However, some granites overprint the shear zones and the S2a schistosity while other (similar looking) granites are overprinted by S2c (as above). At this stage, no dates on the CYPB differ significantly from the pooled 407 Ma ages obtained (Black & others, in press). It has been established that the shear zones overprint some of the granites, transect F2a folds, and deform the S2a schistosity (utilizing the strong anisotropy). However, the tongues of granite north of Glen Garland (Dead Horse Creek) and in the north of EBAGOOLA around Lagoon Creek, transect the shear zones of the Kalkah Structural Domain and indicate that reactivation of S2b shear zones was not uniform.

In summary, the shear zones followed folding and metamorphism of the metasediments; they were probably active during emplacement of the earliest phases of the CYPB, and partly controlled it. Deformation continued on some shear zones, while others were not reactivated and were overprinted by later pulses of the CYPB.

Third Deformation (D3)

D3 structures are widespread and include mesoscopic folding and associated crenulation of earlier fabrics. F3 folds are tight, trend N-S, have steeply dipping limbs and plunge N, and less commonly S. The S3 crenulation is characterised by retrogressive muscovite and biotite growth and is generally more obvious in hand specimen than the S2a crenulation of S1. D3 structures overprint the S-C mylonites of the major shear zones indicating that D3 is younger than the CYPB.

Folds (F3)

F3 folds are generally tight and asymmetric with chevron-like hinge zones; they are mostly S-shaped viewed north (down plunge), and the associated axial surface trends almost N-S. The resultant orientation of S2a is NNW-SSE. In some areas, Z- asymmetric F3 folds occur, giving rise to a more northerly trend for S1 and a NNW-trend to S2a. This change in F3 plunge is seen in the scatter of the hinges plotted on stereonet figures.

Visible F3 folds are invariably mesoscopic in scale. There are no macroscopic F3 fold closures; however, some localities have an anomalous flat lying S2a schistosity (commonly without an S3 overprint). These regions (e.g. in the Coleman River Gneiss northwest of Glen Garland homestead) may be the hinge zones of macroscopic F3 folds.

D3 structures overprint the sillimanite and garnet that lie within the S2a surface. No M3 metamorphic marker minerals have been identified; however, chlorite is common and muscovite pseudomorphs after sillimanite may be related to D3. In places the L2 lineation as defined by sillimanite needles is rotated parallel to L3.

Foliations (S3)

The S3 surface generally trends N-S, dips steeply and is developed patchily across all structural domains of the basement. It ranges from a coarse, asymmetric, spaced crenulation cleavage to a fine millimetre-scale crenulation cleavage. F3 folding is not always apparent in regions where S3 foliations are present. In thin section, S3 crenulations tend to be angular with fractured mica, and in some sections, muscovite and biotite growth is recorded along S3.

Fourth Deformation (D4)

D4 structures are seen as NE to E-trending folds with associated weak crenulation foliations. Kink bands that are found in the more argillaceous units are also considered to be D4. The macro-scale folding found east of Glen Garland in the Strathburn Formation (Pkj) may be F4, as well as the E-W oriented folding of the Lindalong Shear Zone in the headwaters of Lindalong Creek.

D4 structures are not well represented in the Coen Metamorphic Group and do little to deform the D2 structural trends. In the Coen Metamorphic Group, some S4 crenulation foliations occur, but more commonly E to NE-trending open to tight folding of gneissic layering, S1 and S2a foliations are recorded. There are no macroscopic F4 folds in the Coen Metamorphic Group.

F4 folds occasionally occur as E to ENE and NE-trending open crenulations or monoclinal kinks. The best examples of F4 folding are found in the low-grade Newirie Formation just north of Astrea Holdings Homestead. Here, F4 folds have curvilinear hinge lines that plunge moderately to steeply and variably to NNE or NE. These are open folds with kink-like or chevron hinge zones.

Palmerville Fault

The Palmerville Fault was called a "fundamental" structure in north Queensland by de Keyser (1963) as it was considered to coincide with the Tasman Line (Hill, 1951), which separates the Precambrian craton to the west from the Tasman "Geosyncline" to the east.

The Palmerville Fault or a splay of it, has a weak surface expression in EBAGOOLA; the youngest movements (down throw to the west) are clearly visible on the gamma ray spectrometrics, where an older, deeply weathered alluvial surface is adjacent to more recent alluvium associated with the Five and Fifteen Mile Creeks (Pain & Wilford, 1992).

The magnetic response of the splay of the Palmerville Fault is a zone of deformation shown by a series of broad wavelength anomalies up to 8 km wide, extending in a northerly direction from the SE corner of EBAGOOLA through Princess Charlotte Bay to the NE corner of the sheet (Wellman, in press, a).

Other Faults

An unexposed short wavelength, high amplitude, linear magnetic anomaly trends N-S in the Newberry Metamorphic Group. This feature is interpreted as a fault, however the kinematics are unknown.

The airborne magnetics show a number of NE-trending fractures without any discernible offsets. They are subparallel to the dyke swarm in the central part of the Kalkah 1:100 000 sheet. The dykes have not been dated, but are thought to be of Permian-Carboniferous age.

GEOPHYSICS

Magnetic and Gravity Data

by P. Wellman (AGSO)

During 1973/74 BMR (now AGSO) carried out a magnetic survey over the whole of EBAGOOLA with a 1.5 km flightline spacing over land and 3.0 km spacing over the sea, 150 m terrain clearance, and using a fluxgate magnetometer. AGSO carried out similar surveys over adjacent sheet areas at about this time. In 1990, Geoterrex under contract to AGSO carried out a survey of the land area of EBAGOOLA at 400 m flight line spacing, 100 m terrain clearance, and using a cesium vapour magnetometer (Geoterrex, 1991). The results of these surveys have been interpreted using filtered and unfiltered flight-line profiles, contour maps, and images of the total magnetic intensity and east-west horizontal gradient (Figs. 11 & 13). Enhanced displays of the magnetic data were prepared to try to map adjacent granitic bodies, but magnetic anomalies due to the granites were below the noise level.

Gravity data for EBAGOOLA are derived from an underwater gravity survey in Princess Charlotte Bay (Goodspeed and Williams, 1959), and a helicopter survey on an approximately 11 km grid, carried out in 1966 (Shirley & Zadoroznyj, 1974). Gravity anomalies can be shown either as Bouguer anomalies (Fig. 14) or residual anomalies (Fig. 15). The Bouguer anomalies have the advantage that they have been calculated with fewer assumptions, and the disadvantage that that they are dominated by a regional anomaly that is irrelevant to upper crustal structure, and caused by regional topography and its isostatic compensation. The residual anomalies are optimized to show anomalies due only to the upper crust, but the parameters used in the filtering are somewhat arbitrary, and some long-wavelength upper crustal anomalies have been removed.

Interpretation of anomalies

Magnetic anomaly interpretation has been used extensively in preparing the EBAGOOLA basement geology map – as the primary mapping tool in areas that do not crop out, and in

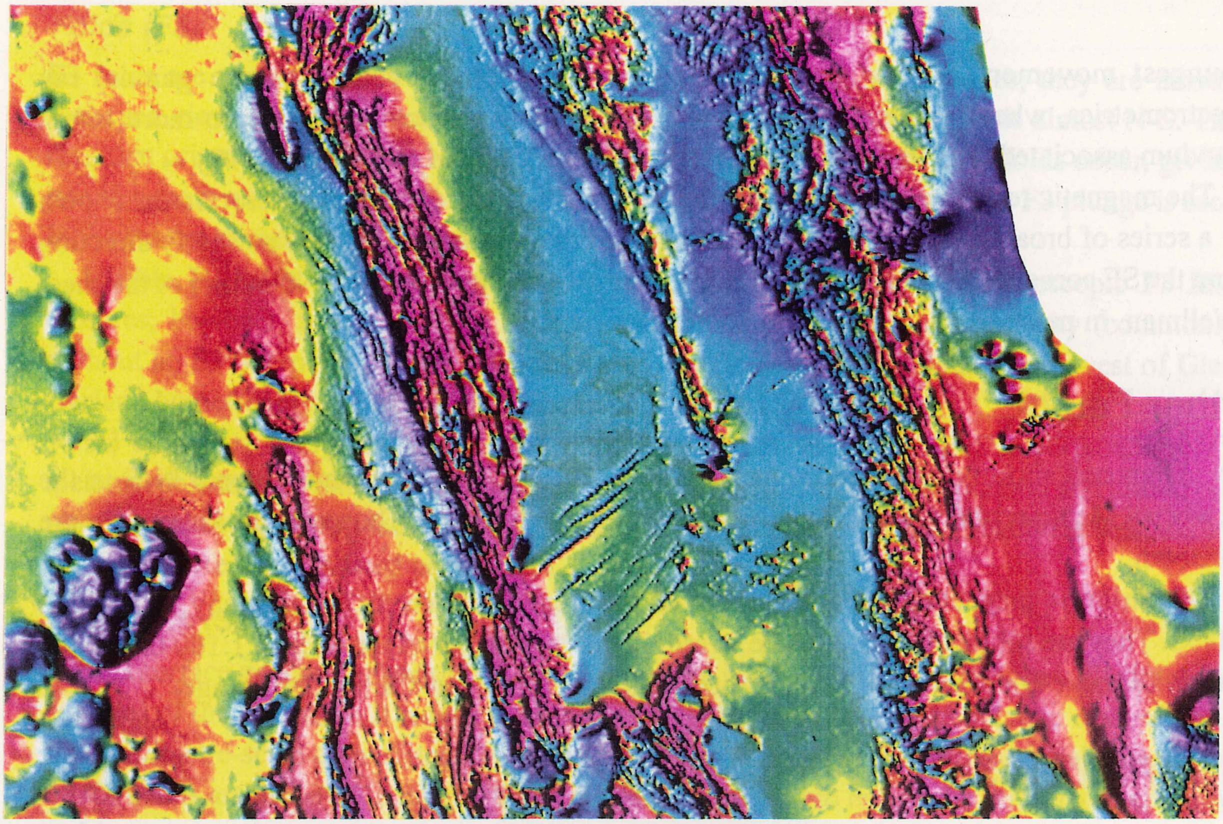


Figure 11. Total magnetic intensity with easterly illumination. Reduction of Milligan & Rajagopalan (1992).

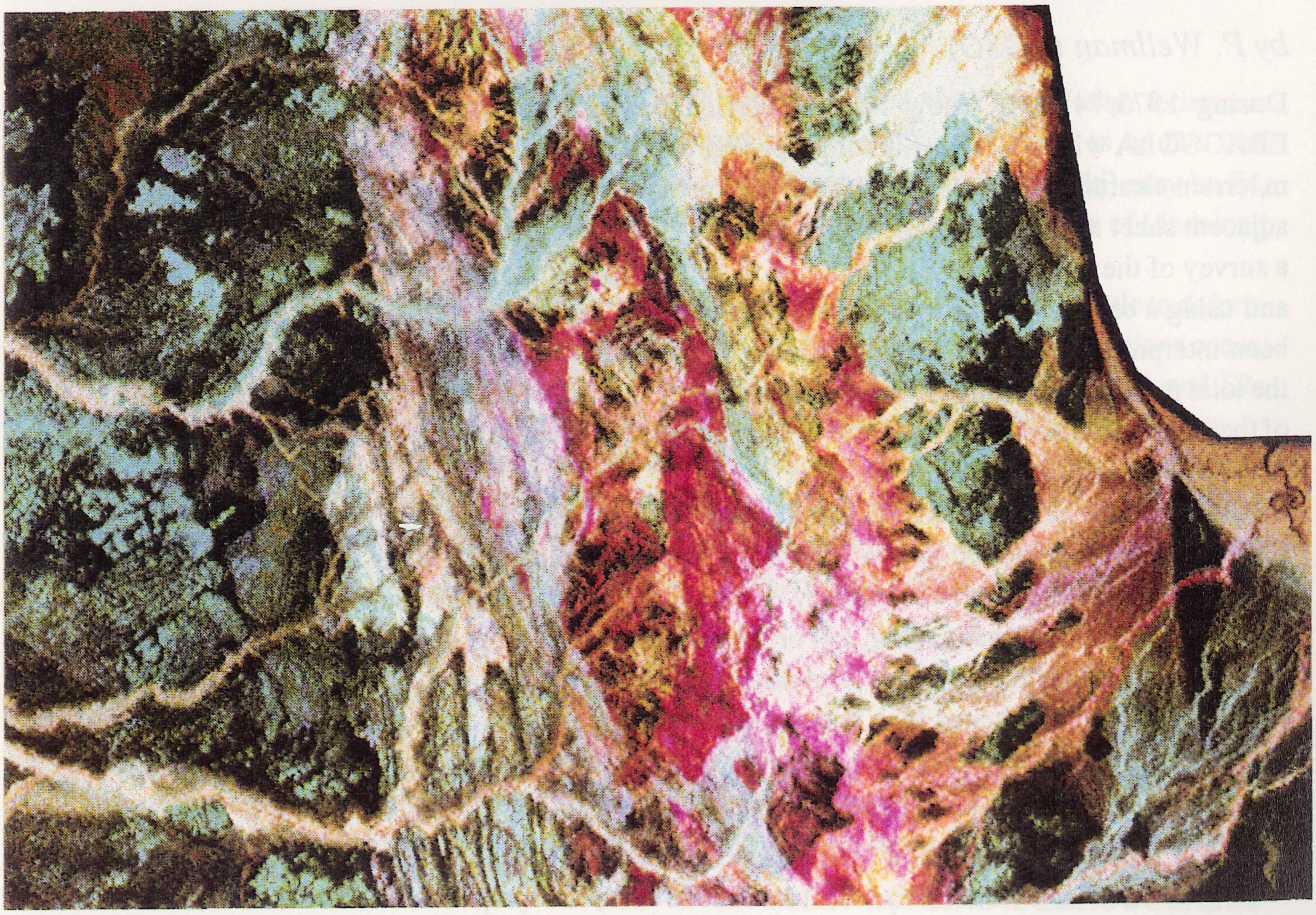


Figure 12. Red (K), blue (Th), green (U) composite gamma ray spectrometric image for EBAGOOLA (from Wilford, in press).

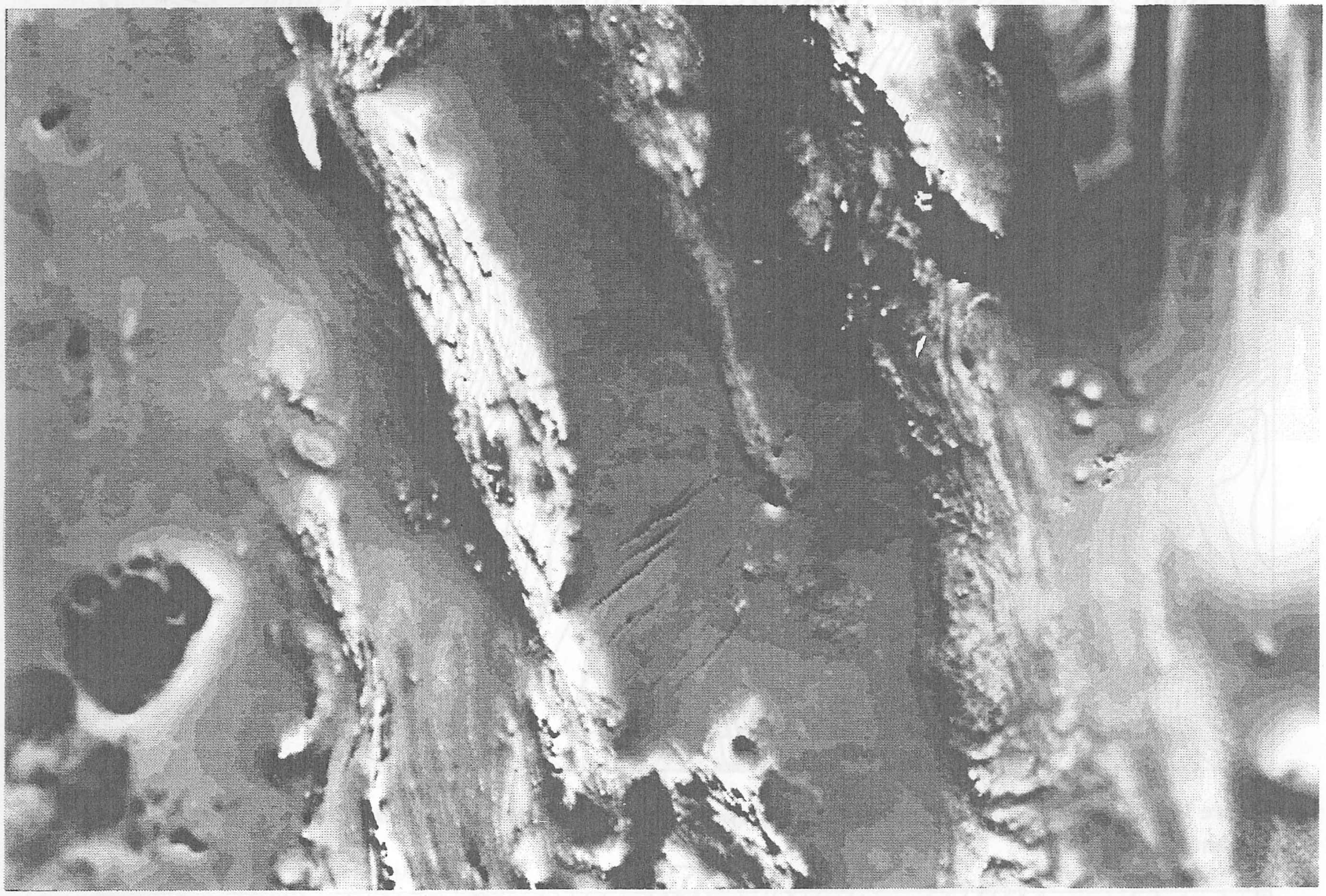


Figure 13. Total magnetic intensity (400m line spacing) for EBAGOOLA (from the AGSO's national airborne geophysical database, 1992).

providing supplementary data in areas of outcrop. This interpretation is incorporated in other sections of this map commentary, and is given as a whole in Wellman (in press, a).

Where basement is exposed in EBAGOOLA, to a first approximation, the gravity anomalies are relatively high over the belts of metamorphic rock, and relatively low over the belts of granitic rock. This observation has been used to subdivide basement west of the Palmerville Fault Zone in areas where basement is not exposed.

The dip of the boundary between metamorphic units and granite is indicated by the offset between the boundary at the surface (from mapped geology or magnetics) and the inflexion of the gravity residual (Fig. 16). The western boundary of the Coen Metamorphic Group and the western boundary of the Newberry Metamorphic Group (except in the extreme north) are near vertical and fairly straight. These boundaries may be structurally or fault controlled; the western boundary of the Coen Metamorphic Group has the Ebagoola Shear Zone along much of its length. Contacts between the CYPB and the Holroyd Group have moderate west dips, consistent with the higher grade of metamorphism, and the distribution of outlying plutons. Areas of negative gravity anomaly, and scattered small areas of granite show that granite shallowly underlies metamorphic units in the following areas: the northern and southern parts of the Kalkah Structural Domain, the northeastern part of the Coen Metamorphic Group, and the northwestern part of the Newberry Metamorphic Group. Figure 17 shows east-west cross sections across the

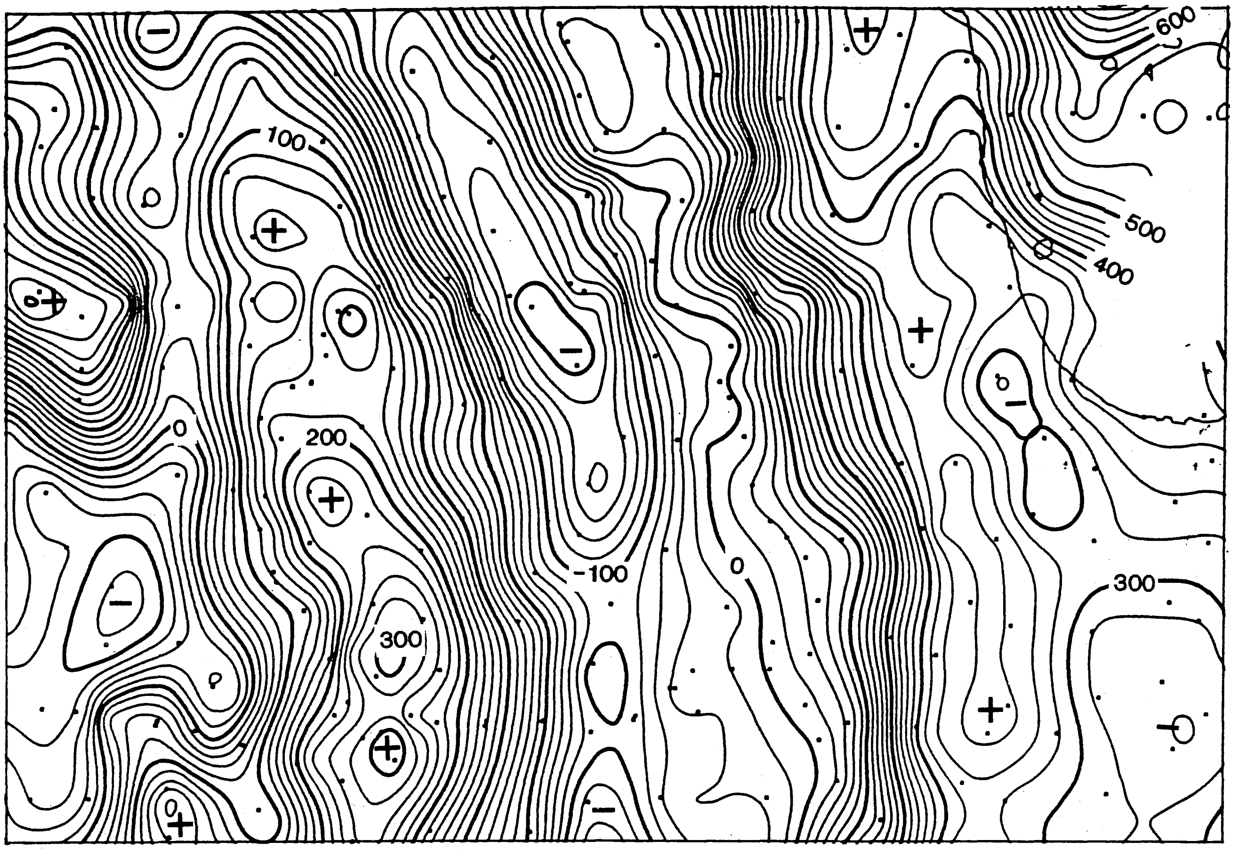


Figure 14. Bouguer gravity anomalies, contour interval 20 um.s^{-2}. Dots show gravity station positions (from Wellman, in press).

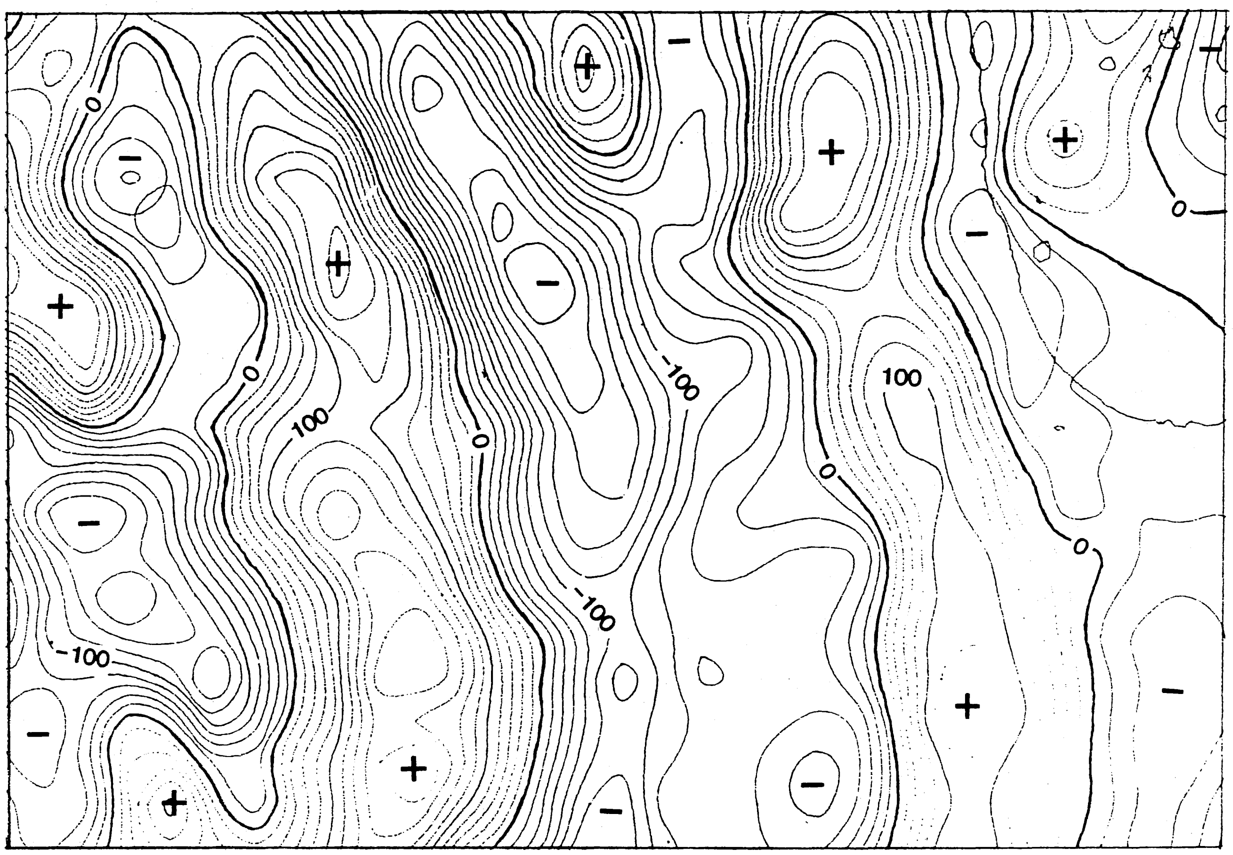


Figure 15. Residual gravity anomaly, contour interval 20 um.s^{-2}. Prepared by removing a 24-minute wavelength regional anomaly from the Bouguer anomaly (from Wellman, in press).

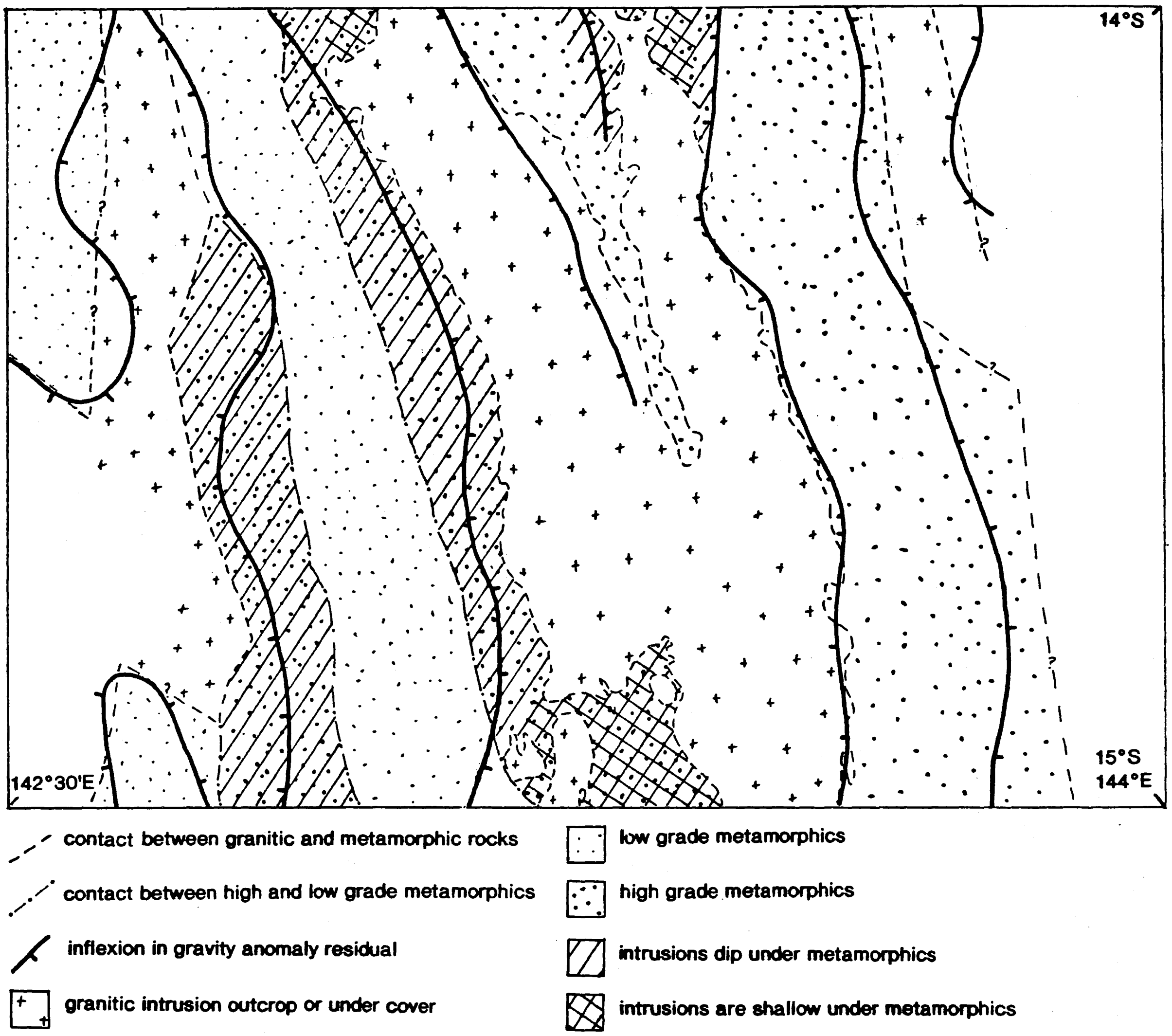


Figure 16. Relation between surface geological contacts (from geology and aeromagnetics), the inflexion of the gravity anomaly residual, and the areas thought to be underlain by granitic intrusions (from Wellman, in press).

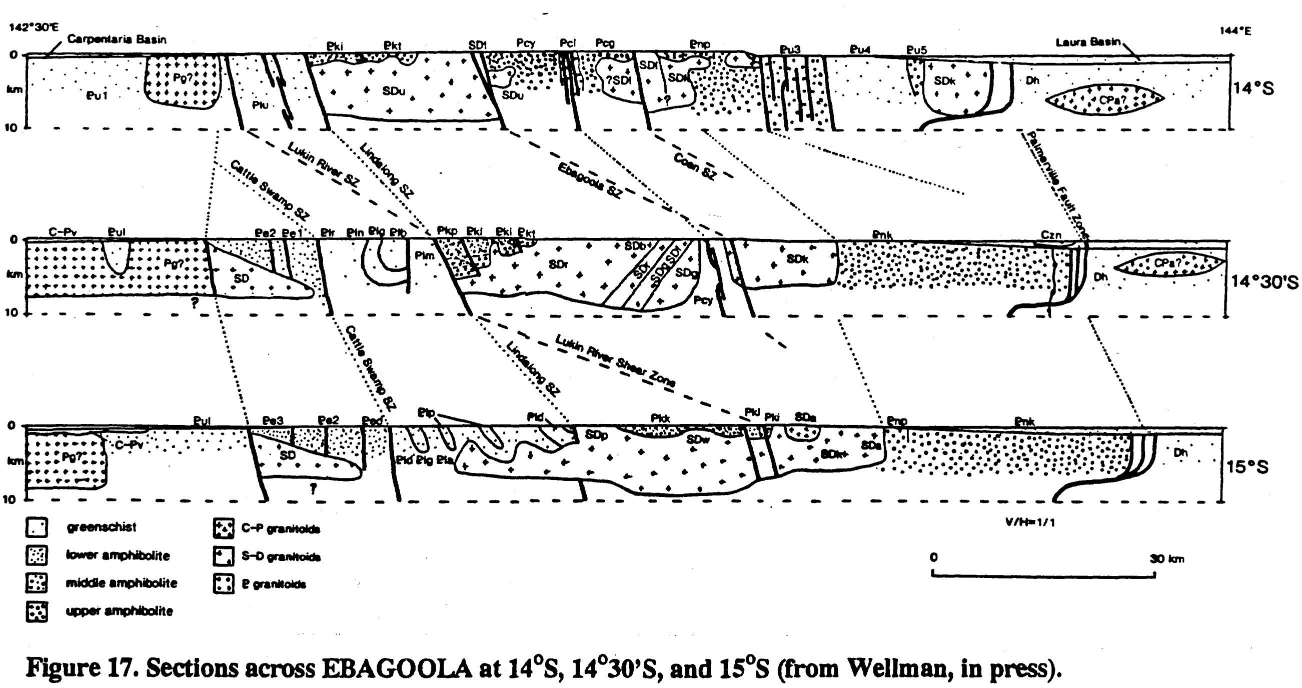


Figure 17. Sections across EBAGOOLA at 14°S, 14°30'S, and 15°S (from Wellman, in press).

EBAGOOLA sheet area. In this section the average depth to the base of the granitic rocks is assumed to be about 7 km, and the Palmerville Fault Zone structure has been taken from Shaw & others (1987; Fig. 13). In summary, the major findings from analysis of gravity and magnetic anomalies are:

1. Gravity and magnetic data have been used to map the major units of basement geology under the cover of Mesozoic sediments and thick regolith.
2. The gravity has shown the extent of the granitic rocks at depth, and in particular those areas of basement that are underlain at shallow depth by granitic rocks, or have granitic rocks dipping under them.
3. Three major periods of faulting have been recognized from the magnetic anomalies:
   - NNW-trending mainly strike-slip faults, subparallel to regional layering, and predating the metamorphic maximum,
   - NW-trending shear zones (the Coen, Ebagoola and Lukin River Shear Zones) and sinistral and reverse movement on the NNW faults shortly after the metamorphic maximum,
   - NE-trending fractures with demagnetization on the fracture plane.
4. EBAGOOLA can be subdivided into three areas of different basement geology. Over the eastern eighth of the sheet, basement is not exposed, but is almost certain to be deformed metasediments of the Hodgkinson Basin. Most of the sheet comprises outcropping and subcropping (beneath thin regolith cover) metamorphic and granitic rocks of the Coen Inlier. The western eighth of the sheet has basement that differs from the Coen Inlier; it is inferred to be low-grade metamorphics rocks and granitic intrusions of possible Proterozoic age with intrusions and volcanic rocks of probable Carboniferous/Permian age.

GAMMA RAY SPECTROMETRIC DATA

by D.E. Mackenzie and J.R. Wilford (AGSO)

Airborne gamma ray spectrometry was obtained over EBAGOOLA in 1973/74 by BMR (now AGSO) as part of the regional coverage at a 1.5 km flight line spacing and 150 m terrain clearance. A more detailed gamma ray spectrometry survey at a 400 m line spacing (100 m terrain clearance) was flown during the 1990 Geoterrex contract arranged by AGSO. Hardcopy images have proved invaluable in assisting the mapping of both regolith and granitic areas throughout EBAGOOLA (Fig. 12).

Application to granitoid mapping

Airborne gamma ray spectrometry has been a very useful tool in recognising different granitoid types, assessing the true positions of boundaries between them, and between granitoids and the host metamorphic rocks.

Distinguishing between areas underlain by Flyspeck Supersuite and those underlain by Kintore Supersuite was relatively straightforward in most cases. Flyspeck Supersuite rocks, because of their relatively lower total K + Th + U and higher K/(Th + U) are generally represented by deep to bright red or pinkish-red pseudocolour tones. The Kintore Supersuite, in contrast, produces a stronger response, with bright orange-pink, pink, and white tones on the red-blue-green (RBG) image.

Discrimination between units within each Supersuite is much more difficult and equivocal. An apparent tonal banding, striking north-northwest, in the area between the Coleman River and Battery Creek, led, upon field checking, to the division of the Flyspeck Granodiorite of Willmott & others (1973) into Glen Garland Granodiorite, Two Rail Monzogranite, and Flyspeck Granodiorite. Glen Garland Granodiorite is characterised, where relationships are clearest (such as in the old "Bamboo" homestead area), by deep orange-red to medium pinkish-brown tones, Flyspeck Granodiorite by deep red to pinkish red tones, and Two Rail Monzogranite by brighter red to pink-red tones. Artemis and Tea Tree Granodiorites are similar to Glen Garland Granodiorite, but, because they are relatively more differentiated, tend to the redder tones. Carleton Monzogranite is equivalent to differentiated Two Rail Monzogranite, and appears a relatively bright red to pink-red. Kirkwood Monzogranite appears a very bright, pale pink grading to red-brown. This is partly because of the relatively elevated terrain that it underlies, and partly because of a thinner regolith cover due to its location on and below the Holroyd Escarpment; however, the primary reason is its high U content and low K/(Th + U) relative to the Two Rail Monzogranite.

Discrimination between components of the Kintore Supersuite is even more difficult and uncertain than in the case of the Flyspeck Supersuite. Larger (200 m wide), discrete bodies of Ebagoola Granite are relatively easily distinguished by their bright pink or purplish pink to white colours, but other units appear a fairly consistent salmon pink to orange-pink. A small (*ca.* 3 km^2), bright-toned, kidney-shaped area to the east of the Coleman River and adjacent to the main body of Carleton Monzongranite is interpreted as predominantly pegmatite (Ebagoola Granite) with possible rafts of Holroyd Group schists.

Lankelly Granite may be distinguished from Kintore Granite in the south by slightly paler/brighter, more neutral, tones; in the north it appears much paler and brighter because of a relatively greater amount of outcrop and/or thinner regolith cover. A narrow band of darker red tones separating the two granites over much of their length, but extending south-southeastward beyond the contact, is probably a shear zone along which selective weathering and/or potassic(?) alteration have been concentrated.

Superimposed on all these subtle tonal changes is an almost continuous blanket of varying opacity caused by regolith. The effect of this cover ranges from a slight reduction in intensity of response (pseudocolour) by thin soil and/or saprolite cover to nil response (black) from thick residual quartz sand, or blue-green tones from transported material (*e.g.*, along the Holroyd River). Most of the Kintore Supersuite is covered by moderate to thick residual sand, and its true gamma ray spectrometric response is only seen along the coastal escarpment, along some of the stream channels, and from the hills at the head of Dead Horse Creek, east of "Crystal Vale".

Despite only sparse, sporadic outcrop and deep weathering, the gamma ray spectrometric signature of the Flyspeck Supersuite is generally distinct south of about 14^{o} 24' S. However, it is much more diffuse and equivocal farther north because of thicker, more extensive residual regolith and extensive transported regolith associated with the Holroyd River and the Thornbury Creek-Goose Creek system. Boundaries of the Two Rail Monzogranite in the northeast (Holroyd River, upper Six Mile Creek) were delineated mainly from ground observation data. The body of Two Rail Monzogranite in the upper Lagoon Creek-upper Little Rock Creek area (northwestern margin of the Batholith on Ebagoola) was not detected by earlier mapping (Willmott & others, 1973). However, its boundaries are clearly delineated by the red pseudocolour gamma ray spectrometric response, despite a cover of residual material, deep weathering, and an almost total lack of outcrop. The location of its eastern boundary was confirmed by the only outcrop that was located – a few corestone boulders in the channel of upper Lagoon Creek.

Application to regolith mapping

Although different lithologies were discriminated on the basis of their potassium, thorium and uranium signatures – higher frequency and textural variations in the imagery within these lithological groups relate to the regolith cover and more specifically soils. The imagery allowed the distribution of soils, weathering profile characteristics, and geomorphic features to be mapped.

Potassium values recorded by the gamma ray spectrometry relate to major rock forming minerals including alkali feldspars and micas, and potassium-rich clays such as illite. Therefore the potassium channel could be used to gauge weathering maturity of soils and sediments by measuring the relative amount of feldspar and mica at the surface. Recent (as indicated by high potassium values) and old beach ridge sands (low potassium) could be discriminated in this manner. The distribution and concentration of these minerals at the surface directly relate to the underlying lithology, and the degree and style of weathering.

Uranium and thorium are concentrated mainly in accessory minerals such as zircon and monazite. High uranium and thorium values are related to higher grade metamorphic rocks, garnet-biotite-muscovite leucogranites and pegmatites, and sediments derived from them. High values are also associated with deeply weathered regolith profiles containing heavy minerals (e.g. zircon) in the residual sandy cover. Deeply weathered bauxitic plateaus over parts of the Western Plains, and old residual sandy soils developed over granite in the Central Uplands, were discriminated by their high thorium signatures.

Deep weathering profiles were generally identifiable in the imagery by high uranium-thorium to potassium ratio. Relationships will vary according to the proportion of potassium, thorium and uranium in the bedrock or the transported cover. However, low values for all three radioactive elements indicated thick accumulation of residual quartz sand which characterised many of the old and deeply weathered areas.

REGOLITH

by C.F. Pain and J.R. Wilford (AGSO)

The 1:250 000 Regolith-Landform map of Ebagoola was prepared following fieldwork in July-September 1991. Preparation of regolith-landform maps has been covered by Pain & others (1991) in some detail; however, it is useful to consider some of the main points as a background to descriptions of the map units.

Regolith-landform units are units of land with similar landform and regolith associations. They are mapped mainly on the basis of landform type as defined by Pain & others (1991), and then described in terms of landform-regolith associations. Regolith information was derived largely from reconnaissance field work. Site locations and details of sites are contained in Pain & Wilford (1992).

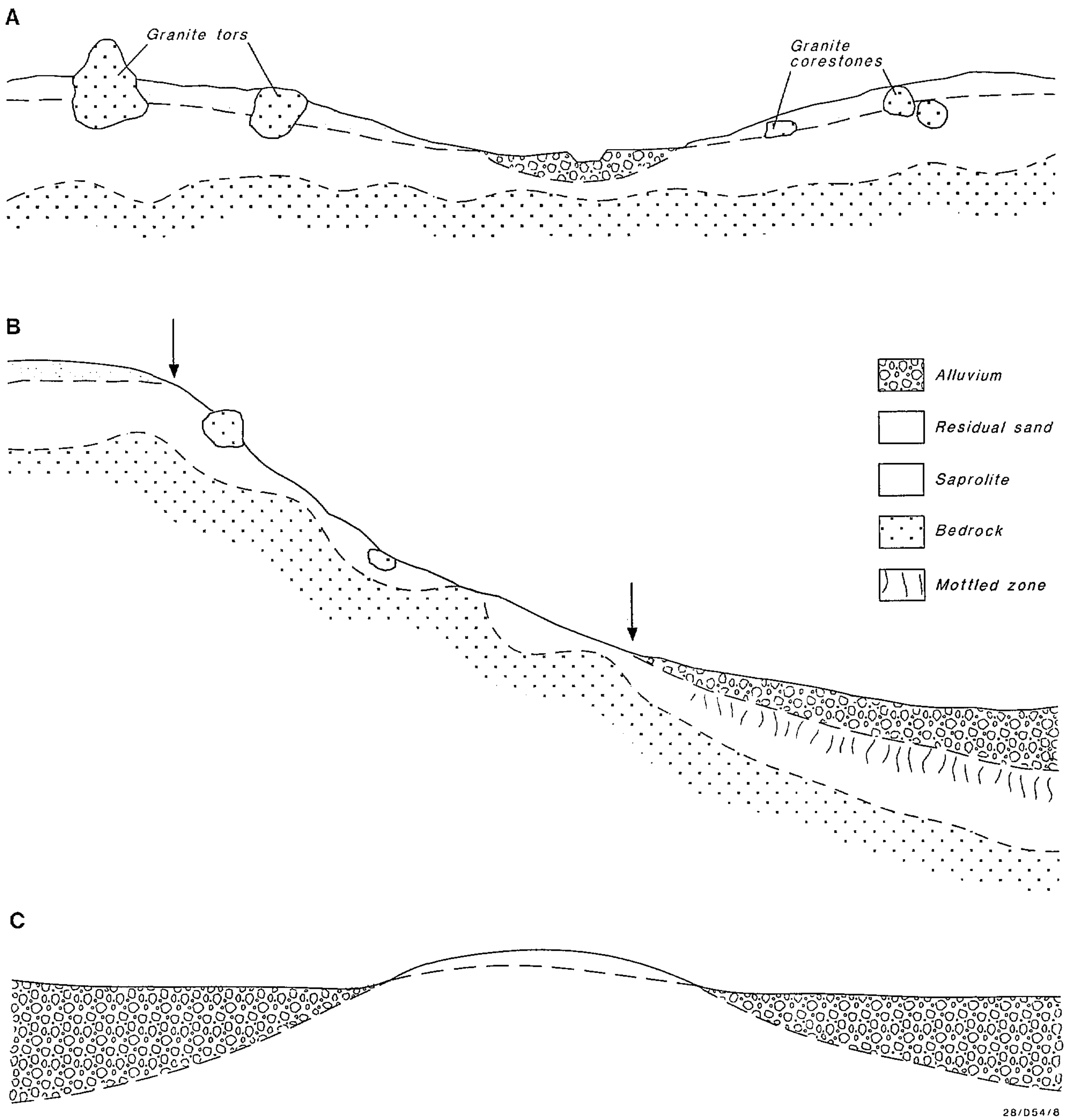


Figure 18. Cross sections of regolith cover on the EBAGOOLA Regolith Landform map. A – residual sand over highly weathered saprolite above the Great Escarpment. B – moderately weathered saprolite on the Great Escarpment. C – residual sand on bedrock surrounded by alluvium on the eastern lowlands.

Landsat TM imagery in conjunction with airborne gamma ray spectrometric imagery assisted in locating regolith-landform unit boundaries. Details of the techniques used and the interpretations can be found in Wilford (in press).

Each polygon on the map face is labelled with a symbol made up of codes, as:

$$\frac{\text{Regolith Type + Induration}}{\text{Landform Type + Bedrock Lithology}}$$

The legend lists the codes together with their meaning, and the database (RTMAP) codes that are defined in Pain & others (1991). This coding system means that the map can be coloured according to any of the codes. However, in practice regolith type and landform type will be the most commonly used for such an exercise. The map legend is set out in the expectation that it will be coloured according to regoilith type.

Saprolite

The term saprolite is used to refer to all those parts of a weathering profile which have been formed in situ with interstitial grain relationships being undisturbed. Commonly primary rock fabric is apparent in the material. In EBAGOOLA it is subdivided into highly weathered saprolite, moderately weathered saprolite, and mottled zone.

Highly Weathered Saprolite (D1) – Highly weathered saprolite is bedrock weathered in place to the point where more than 50% is earth material. Corestones, if present, are free and rounded. Nearly all feldspars are decayed. This material is mapped mainly on granite and metamorphic rocks, although there are some small areas on Mesozoic sandstone.

On granite this regolith type consists of a thin sandy soil over weathered granite with many unweathered mineral grains. Corestones and tors are common, especially on lower valley slopes (Fig 18A). Generally the regolith cover is less than 10 m thick. A few other regolith types fall within this mapping unit as unmapped inclusions. Almost all valley floors have a narrow belt of shallow alluvium, usually less than 10 m wide, and less than 2 m deep. Valley floor material, both alluvium and saprolite, is sometimes silicified to form a siliceous hardpan (Fig. 19A). Rises with 9-30 m relief are the predominant landform type.

On metamorphic rocks the saprolite below the shallow soil normally shows the original metamorphic structures quite clearly, although the material is soft, and considerable alteration of primary minerals to clay materials has taken place. Thickness of regolith is generally less than 10 m. The main landform types in areas of least resistant saprolite (derived from slate and schist) are rises and low hills, with low slope angles. This contrasts to areas of quartzite which have higher relief with higher slope angles and a cover of shallow soils. Regolith cover on metamorphic rocks is thus related closely to the details of lithology and to slope angles.

Unmapped inclusions associated with saprolite on metamorphic rocks include shallow coarse angular to subangluar alluvium in valley floors, and some thin colluvial mantles along lower valley slopes. Ferruginous induration of valley floor materials is also common.

Moderately Weathered Saprolite (D2) – This material is saprolite which contains less than 50% earth material, and still contains easily recognisable rock fabric. Corestones, if present, are rectangular and interlocked. It is found in three main areas in the Ebagoola Sheet area.

In the western part of EBAGOOLA, moderately weathered saprolite on fine sandstone of the

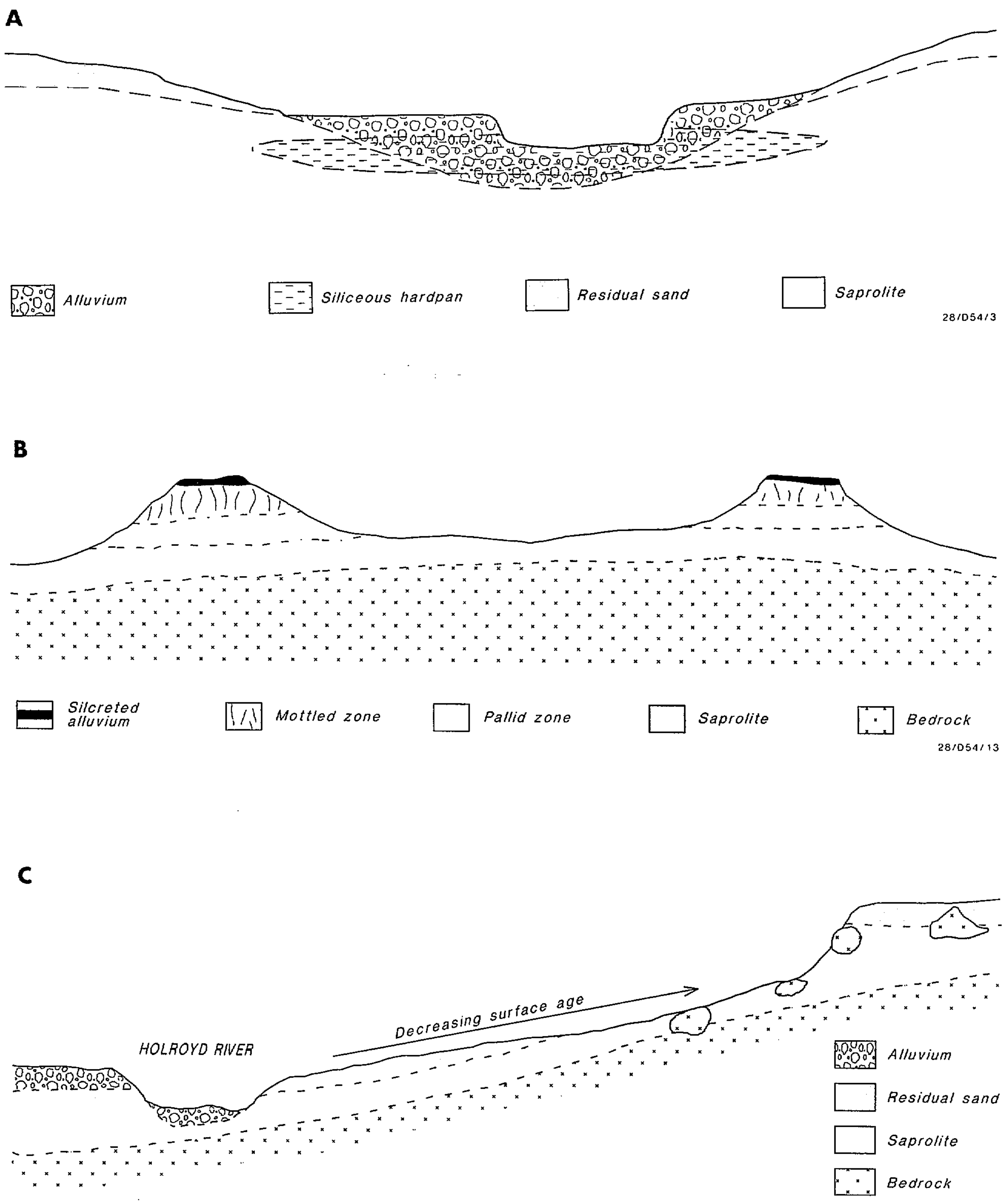


Figure 19. A – Siliceous induration of alluvium and adjacent weathered bedrock. These regolith materials are too small to map. B – Regolith types interpreted as drainage inversion in the area between Strathmay and Strathburn, on the western lowlands. On many hills the silcreted alluvium is missing, but silicified mottled zone and pallid zone material can still be found. C – Regolith types above and below the erosional scarp on granite. The surface below the scarp is time-transgressive, being essentially modern at its eastern edge just below the scarp, and much older at its western edge next to the Holroyd River.

Mesozoic (Rolling Downs Group) covers large areas mainly on erosional plains. The regolith consists of a thin layer of residual sand, sometimes with iron pisoliths, on moderately weathered saprolite (Fig.19B). The depth of weathering is not known, but intensely weathered regolith cover is generally less than 5 m thick.

Units of moderately weathered saprolite on sandstone contain inclusions of deeper residual sand. There are also small areas of deeper weathering on low hill remants (Fig. 19B). These deeper regolith profiles usually have silicified mottled zones (above the moderately weathered saprolite), and may have silcreted rounded quartz gravels and cobbles capping the hills. Valley floors contain small thin alluvial sequences. A siliceous hardpan also occurs in most valley floors, cementing both alluvium and the surrounding weathered bedrock.

Moderately weathered saprolite is found on quite large areas of metamorphic rocks. Here the regolith consists of a thin soil formed on moderately weathered metamorphic units which underlie rises to low hills. The regolith cover is generally thin, ranging from 1-5 m.

Moderately weathered saprolite is also found along the length of the Great Escarpment. Here, slopes up to 25^0 are covered by a thin soil on granitic saprolite (Fig. 18B). Corestones and tors are common. This regolith type is also found along most of the small erosional scarps on granite in the Sheet area, but they are too small to map.

Mottled Zone (D3) – This material is strongly weathered and contains abundant reddish, usually ferruginous mottles. The mottled zone is part of the lateritic deep weathering profile, and its occurrence at the surface may imply some removal of surface material. In EBAGOOLA, there is sometimes a thin layer of residual sand with scattered pisoliths overlying the mottled zone material. Commonly the upper part of the mottled zone consists of nodules and pisoliths, whereas at deeper levels the mottles are more tubular or reticulate.

There are three types of mottled zone in the Sheet area:

- A ferruginous mottled surface layer on metamorphic rocks in the south. This layer may be strongly indurated in places, and contains some iron nodules and pisoliths. It is restricted to small areas, overlies highly weathered saprolite, and the total regolith thickness ranges from 5-15 m.

- A cover of bauxitic nodules over mottled zone material on plateaux and erosional plain areas in the northeastern part of the EBAGOOLA Sheet area (D3 + N1). The regolith profile consists of a few centimetres of residual sand and soil over well developed bauxitic nodules up to 1 m deep. This in turn overlies a mottled zone on saprolite. The mapped areas are commonly bounded by low erosion scarps, along which bauxitic material is exposed. Some of these areas include small unmapped inclusions of saprolite, some of which is strongly silicified.

- Some small areas of mottled zone north of Strathmay on low narrow hills; they are commonly silicified, with some silcrete. Some of the silcrete contains well rounded quartz cobbles, and quartz cobbles also occur as surface material on the tops of some of these hills. The regolith cover here is a deep silicified lateritic profile, now confined to the tops of small low hills (Fig. 19B). This association of regolith materials is interpreted as inverted drainage.

Residual Sand (R2)

Residual sand is sand-sized material, commonly quartz, covering the land surface, and derived from the removal of finer material either in solution or suspension in subsurface water (Pain & others 1991). Residual sand lies at the surface over much of the in situ weathered bedrock in the Sheet area; however, it is mapped only where it is at least 50 cm thick. The gamma ray spectrometric imagery was used to determine the distribution of residual sand in many places, because residual sand more than 40 cm thick shows up as very dark tones (low in potassium, thorium and uranium) on the gamma ray spectrometric image (Wilford, in press).

On the western side of EBAGOOLA, residual sand is most common on Mesozoic sediments, with small areas on metamorphic rocks. On the latter, the sand may well represent a former cover of Mesozoic sediments. The residual sand overlies moderately weathered saprolite; the boundary between the two usually being distinct. The saprolite varies in thickness from 1 - 5 m on metamorphic rocks to more than 10 m on Mesozoic sediments. Residual sand in this area lies on erosional plains, with the exception of a few small areas near the Coen Inlier.

On the eastern side of EBAGOOLA, residual sands overlie moderately weathered saprolite on sediments of the Laura Basin (Fig. 18C). The regolith cover is very similar to that on the western side of the Inlier.

Within the Coen Inlier, residual sand is confined mainly to granitic bedrock. There is a cover of residual sand up to 2 m thick overlying highly weathered granitic saprolite on rises above low erosional scarps. These areas are the oldest parts of the granitic landscape, and therefore have the deepest cover of weathered regolith. Below and some distance from the same low scarps, residual sand overlies moderately weathered saprolite (Fig. 19C). In this situation it is formed on a time-transgressive surface formed by the retreat of the scarp, and is therefore oldest on that part of the surface furthest from the scarp.

Soil on Bedrock (Z)

The regolith type, soil on bedrock, is a soil profile generally less than 2 m deep formed on unweathered or weakly weathered bedrock. In EBAGOOLA it is confined mainly to metamorphic bedrock, although there are small areas on granite, and one small area on basalt.

On metamorphic rocks this regolith type consists of a skeletal soil only a few tens of centimetres thick. Angular blocks of fresh or weakly weathered metamorphic material lie on the surface, and in a sandy matrix below the surface. Quartzite ridges commonly occur along ridge crests. Landforms with this regolith type are either hills or low hills, with a few small areas of plateau surface on high ridges.

Shallow soils on granite consist of sandy earth material up to 1 m thick lying directly on fresh or weakly weathered granite. Tors commonly rise above the general soil surface, so the soils are discontinuous. On granite this regolith type is restricted to low hills.

The Tertiary Silver Plains Nephelinite also has a cover of shallow soil. The nephelinite forms a low hill with a few small benchs on the sides, and has a shallow red clay soil with many boulders.

Alluvial Sediments

Alluvial sediments are found along most of the streams and rivers in EBAGOOLA. However, they can only be mapped along the large channels. Where possible a distinction has been made between channel and overbank deposits. However, where this is not possible, the alluvium is mapped as undifferentiated.

Undifferentiated Alluvium (A0) – This material is mapped over much of EBAGOOLA, particularly in the east. There are two main kinds of undifferentiated alluvium. In the western part of the Sheet area there are numerous valleys with alluvial sediments. These valleys are too small to allow discrimination between channel and overbank deposits at the scale of mapping. Moreover, in some cases the distinction is not obvious in the field because of the lack of channels. However, in general the regolith consists of mainly sandy channel deposits either at the surface or overlain by finer overbank deposits. This coarse base and fining upwards sequence is typical of alluvial deposits in many areas.

In the east there are large areas of undifferentiated alluvium on low angle fans and broad floodplains (Fig. 18C). The gama ray spectrometric image makes it clear that these areas consist of numerous anastomosing channels and intervening floodplain areas. However, the resulting pattern is too intricate to map at 1:250 000 scale. Typicial regolith consists of a coarse channel deposit (mainly sand) overlain in the floodplain areas by finer overbank sands.

In the east, undifferentiated alluvial deposits have been subdivided into sediments derived mainly from granites, from metamorphics, and from a mixture of the two. This subdivision is on the basis of the gamma ray spectrometric signature.

Channel Deposits (A1) – These deposits are regolith materials laid down by stream channel processes. They are found both in active stream channels, and in relict channels. As a surface material, however, channel deposits are usually confined to presently active channels.

Channel alluvium is mapped along all the major streams flowing to the west. It is particularly widespread in the lower parts of the Holroyd and Coleman Rivers. The alluvium is predominantly sandy, and the gamma ray spectrometric image indicates that the sand is derived mainly from granite in the Coen Inlier. Within the Inlier, channel alluvium is generally thin (m), with bedrock exposed in most channel floors. West of the Inlier, channel alluvium in the main rivers is also thin, although thicknesses are not so readily observed. In many places the channel alluvium is cemented by silica to a siliceous hardpan. This hardpan often includes weathered in situ bedrock adjacent to the channels.

There are also mapped areas of channel alluvium in the southeastern corner of the map area. These materials have a similar gamma ray spectrometric response, and are similar to those along the rivers on the western side.

Overbank Deposits (A2) – These deposits are those deposited by stream flow outside the perimeter of the active channel. They tend to be finer than channel deposits.

In EBAGOOLA, mapped overbank deposits are confined to a few active floodplain areas along the Holroyd and Coleman Rivers on the western side, and the Moorehead River in the southeast. These deposits consist of fine sandy alluvium, in some cases overlying coarser channel alluvium at depths of more than 1 m. On the gamma ray spectrometric image they are clearly distinguished as darker areas adjacent to the bright active channel areas.

There is also an area of older overbank deposits on a terrace between the Holroyd River and Station Creek, towards the northern part of the Coen Inlier. This terrace, at 15m above the Holroyd floodplain, is one of the rare occurrences of older alluvial material in the Sheet area, and the only one big enough to map.

Colluvial Deposits (CO)

Colluvial deposits, resulting from downslope movement of materials by slope processes, are confined to areas adjacent to hills composed of metamorphic rocks. They occur in footslope locations, and consist mainly of sheet flow deposits and fanglomerate. Usually they lack bedding, but in places there is weak bedding suggesting deposition from sheet wash. Towards the base of slopes, near valley floors, the colluvial deposits often interfinger with alluvium. There are stoney soils on the colluvium, which is rarely more than 5 m thick.

Coastal Sediments

Coastal sediments are mapped along the coast of Princess Charlotte Bay, in the eastern part of the Sheet area. Where possible, these sediments have been divided into beach and estuarine deposits. However, there are some areas where this was not possible, and undifferentiated coastal deposits have been mapped.

Beach Sediments (S1) – These sediments are found on beach ridges and in chenier plains. They are sandy, and appear to be derived from granitic materials brought down rivers from the Coen Inlier. An older set of beach deposits (S1(1)) can be distinguished from a younger (S1(2)) on the basis of location and composition. The older beach deposits consist of strongly leached beach ridge quartzose sands. Soils have deep sandy uniform-textured profiles with a grey-brown organic stained A1 horizon. These older deposits now occupy a truncated beach strand-line up to 15 km inland from the present coast. This strand-line is probably coeval with Pleistocene beach ridges along the west coast of Cape York Peninsula (Smart, 1976).

Younger (Holocene) beach ridge sands lie within 4 km of the coastline and consist of quartz, mica and shelly material. Soils on these younger deposits have poor horizon differentiation, and are characterised by sandy uniform textured profiles with weak organic stained A horizons.

On the gamma ray spectrometric image, older beach deposits appear as dark areas while the younger deposits appear in pinkish hues. This is because the younger deposits contain potassium-rich minerals such as mica and K-feldspar. In the older deposits, these minerals have been removed, leaving quartzose sand which has virtually no gamma ray response.

Estuarine Sediments (S2) – These sediments are common between the beach ridges, and in particular in the tidal flats at the lower end of Princess Charlotte Bay. They consist of fine sand, mud, and minor evaporitic salt forming low relief clay flats and salt pans. Two types of estuarine deposits have been mapped. They differ in that one is frequently covered by tides and consists mainly of black organic muds (S2(2)), while the other is slightly higher in elevation, is less frequently inundated by tides, and consists of dark grey to greyish brown cracking clays, saline alkali soils and black organic muds (S2(1)).

Undifferentiated Coastal Sediments (S0) – This material consists of alluvial and estuarine sand, fine sand, silt and clay. The sediments have been deposited on a broad coastal depositional plain. The plain is characterised by meandering channels with point-bar deposits, oxbow lagoons, mudflats, saltpans and tidal creeks. Soils are variable, consisting of sandy uniform profiles and sandy earths on channel sands, cracking clays, saline alkali soils on floodplains and supratidal plains, and black organic muds adjacent to tidal creeks.

Both estuarine and undifferentiated coastal sediments appear as pink hues on the gamma-ray spectrometric images. This is probably due to potassium from mica and feldspar in the sediments derived from weathering of granites further inland.

GEOLOGICAL HISTORY

by R.S. Blewett, J. Knutson, D.E. Mackenzie, and C.F. Pain (AGSO)

Early Sedimentation

During the Proterozoic, probably less than 1500 Ma ago, at least 10 km of mostly thin bedded clastic sediments, comprising alternations of dominantly pelitic and psammitic sequences, were deposited in a generally shallow marine basin to the east of their source terrain. Palaeocurrent indicators and the overall decrease in grainsize and in the proportion of psammitic to pelitic sediments suggest that the depositional basin was oriented N-S with more distal regions to the east. The most complete record of this sequence is preserved in the Lukin Structural Domain of the Holroyd Group where many of the rock-types include low-grade metasandstone/quartzite and slate or metasiltstone. Most units (e.g. Dinah, Astrea, Newirie and Strathburn Formations) are thin-bedded and fine-grained suggesting quiet water and distal environments of deposition. These more pelitic units are intercalated with more psammitic units (e.g. Sugarbag Creek, Carysfort, and Gorge Quartzites). The psammitic units tend to be thick-bedded, medium-grained, well-sorted metasandstones more typical of shallow water high energy environments. Many of the thick-bedded horizons are massive, with pure white quartzite beds up to 2 m thick.

During or after deposition of the sediments, mafic to intermediate sills (Carew Greenstone) were intruded into the Astrea Formation in the lower part of the Holroyd Group with slight disconcordance to the lower part of the stratigraphy. The generally high metamorphic grade (upper amphibolite facies) and structural complexity of the other metamorphic groups preclude correlation with the Holroyd Group, and geochemical and geophysical evidence suggest that there are substantial differences that may not be entirely attributable to metamorphism and deformation.

Deformation, Igneous Activity, and Uplift of the Coen Inlier

The onset of widespread deformation during D1 with folding, faulting and metamorphism at least to greenschist grade resulted in the closure of the basin. D1 structures are widespread, difficult to recognise and were probably upright and E-W trending (as seen by D1 enveloping surfaces). The age of deformation and associated metamorphism can only at present be established as being earlier than the Siluro-Devonian CYPB.

Oblique collision between the eastern Australia margin and a terrane further east or southeast may have initiated a second far more intense regional metamorphism (M2) and ductile deformation (D2) event (Coen Orogeny) which occurred during Late Silurian-Early Devonian time. It was accompanied by emplacement of voluminous crustal melt granitoids (CYPB).

As the orogeny progressed abundant and widespread NNW-trending, steeply dipping D2 structures developed to dominate the fabric of the entire Sheet area. Generally low pressure-high temperature metamorphism ranging from greenschist to upper amphibolite facies resulted in the formation of slate, phyllite, schist, gneiss, and migmatite. Sinistral transpressional shearing slightly oblique to the NNW trending structures reactivated some of them and accompanied emplacement of the granitoids.

Field, structural, petrographic and geochemical data indicate that the metamorphic maximum coincided with the generation and emplacement of the granites. Migmatites are well exposed in areas of highest metamorphic grade, and melts apparently derived from the metamorphic rocks range from leucosomes in a gneissic unit of the Strathburn Formation to more extensive pods and dykes which appear contiguous with the Ebagoola Granite. Such field relationships, along with geochemical similarities, suggest that the source for the Kintore Supersuite was an assemblage of metamorphics similar to the Holroyd Group which underwent various degrees of partial melting.

The bulk of the granites outcropping in EBAGOOLA, including both I- and S-types, were emplaced during a short-lived intrusive episode at about 407 Ma. This was followed by a long period of quiescence before the intrusion of I-type granites and associated dykes at about 285 Ma. During the intervening period the Siluro-Devonian granites were largely unroofed, resulting in their being at a similar stratigraphic level to the high-level Early Permian granites. The younger granites are rare in the EBAGOOLA, but become increasingly more prominent in the northern part of COEN where they intrude coeval rhyolites.

Field relationships suggest that the Flyspeck Supersuite I-type granites were emplaced before the Kintore Supersuite S-type granites, although the U-Pb zircon ages of the two granite types largely overlap. The same tectonothermal event caused simultaneous partial melting at different source rocks, probably at different crustal levels, to produce geochemically distinct I- and S-type granites. No Siluro-Devonian rocks of demonstrable mantle origin that could be related to crustal underplating were observed. Field and textural criteria indicate that the intrusion of the both granite types was largely syn-tectonic, and in some instances shearing outlasted solidification. There is an absence of Siluro-Devonian mantle-derived rocks that could be co-magmatic with any possible igneous underplating associated with the Siluro-Devonian tectonothermal event.

Numerous dykes and veins of pegmatite, aplite, and Ebagoola-type granite cut both Flyspeck and Kintore Supersuite rocks. They represent highly felsic melts generated by fractional crystallisation of Kintore Granite, or small degrees of partial melting of country rocks, or both, probably during the waning stages of the Siluro-Devonian tectonothermal event.

Subsequently, E-W oriented compression resulted in widespread D3 structures; they include mesoscopic folding and associated crenulation of earlier fabrics. F3 folds are tight, trend N-S, dip steeply and have steep N, and less commonly S-plunges. D3 structures overprint the S-C mylonites of the major D2 shear zones indicating that D3 is younger than the emplacement age of the CYPB. A further period of compression oriented N-S, resulted in NE to E-trending folds with associated weak crenulation foliations (D4).

The Coen Metamorphic Group and western Holroyd Group comprise a wide zone of sillimanite-bearing schist and gneiss; their level being close to the top of the CYPB. No precise geothermometry or geobarometry exists for the emplacement of the CYPB, but such a wide regional upper amphibolite facies aureole suggests emplacement depths for the CYPB could be as much as 10 km. There is a significant amount of erosion in the 100 km adjacent to the Palmerville Fault Zone in the southern half of the Coen Inlier. Here, there is about a 200 Ma gap in time and perhaps 10 km in vertical space between the top of the CYPB (present erosion level for central east EBAGOOLA) and the base of the Mesozoic basins. The fact that the late Palaeozoic is missing suggests that the Coen Inlier was probably an area of significant sediment bypass at that time. The Coen Inlier basement is overlain by Carpentaria Basin sediment (Smart & others, 1980) and was therefore at the land surface by Early to Mid Jurassic times. With the termination of folding events in the Coen Inlier around the Carboniferous period, uplift from these ductile regions to the surface occurred through the Permian, Triassic and perhaps earliest Jurassic, with the main structural development (flexure) of the basin occurring in Albian/Aptian (Cretaceous) times (Smart & others, 1980).

Mesozoic Sedimentation

Formation of the Carpentaria and Laura Basins during Mid to Late Jurassic (Gilbert River Formation) and Early Cretaceous time (Rolling Downs Group) (Smart & others, 1980), covered the Palaeozoic and Proterozoic rocks of the Hodgkinson and Coen Provinces with a veneer of coarse terrestrial to fine marine sediment. These lie with a marked unconformity on the basement. The unconformity is sub-horizontal (it does partly reflect the surface it was deposited on with the result that depressions contain thicker deposits of sediment) above subvertically dipping rocks of the Holroyd Group and to a lesser extent the granites of the CYPB. The basin may have covered most, if not all, of the Coen Inlier (see below); if it did, then post-Mesozoic erosion subsequently uncovered the basement to form the Inlier.

The strong assymetry of the Laura Basin, with greatest depths occurring adjacent to the Palmerville Fault, is evidence of strong influence the Fault had over the formation of this basin during the Mesozoic (de Keyser, 1963).

Post Mesozoic Regional Tectonics and Erosion

The Mesozoic Carpentaria Basin was subsequently cut by Tertiary or younger N to NNW-trending faults. These faults are easily seen as linear contrasts on the gamma ray spectrometry and are just visible on the magnetics. A good example is the fault 7 km west of Strathburn Homestead. This fault has an east-facing scarp with a relief of about 40 m. Fault movement diverted streams flowing to the west causing them to agrade, leading to broad areas of alluvium. The Mesozoic basins and their faults in some areas reflect the structural framework of the basement. Many of the faults that cut up through these young levels are probably the reactivation of this basement anisotropy.

Substantial erosion and surface lowering in the area following emergence at the end of the Cretaceous is evidenced by the landforms. There are many examples of rivers which cross the grain of the basement rocks. Rivers such as the Holroyd, the Lukin and the Coleman show clear evidence of superimposed drainage, rising on tableland surfaces just west of the Great Divide, and then flowing through gorges cut through higher country on the west of the Coen Inlier before entering the erosional plain on Carpentaria Basin sediments. Such superimposition of drainage reflects an early drainage pattern inherited from the post-Palaeozoic cover. This inheritance strongly suggests that the Mesozoic cover extended over a large part of the Coen Inlier.

In EBAGOOLA, erosion following emergence left the basement rocks high in the landscape, forming the Peninsula Uplands. Initial drainage directions were to the west and northwest from a divide east of the present Great Divide. Indeed, it is likely that rivers at that time had their headwaters east of the present coastline, because the continental edge was then much further to the east.

The breakup of the northeastern part of the Australian continent and the opening of the Coral Sea had a profound effect on landforms in EBAGOOLA. Such effects are well known from studies of a number of passive continental margins (e.g. Ollier, 1985); most have their origins in pre-separation rifting. In the study area, separation occurred about 60 million years ago, but the major geomorphic affects could have occurred perhaps as much as 10 Ma earlier.

Downwarping to the east of EBAGOOLA formed the Great Divide, which runs from north to south along the eastern edge of the Coen Inlier. This downwarping had two major results. First, the headwater streams of the formerly west flowing rivers were reversed, to flow towards the newly formed depression and then ocean to the east. In EBAGOOLA, the Stewart River is the best example of this. Some of the sediment supply to the lower reaches of major rivers such as the Holroyd was cut off, and this may have resulted in some down cutting along their valleys. This downcutting appears to have initiated small scarps along some rivers within the Coen Inlier. These scarps have subsequently retreated up to 10 km from their place of initiation. The low scarp between Ebagoola and the Holroyd River is a good example. Second, the new easterly flowing steams were steeper than those flowing to the west, and increased energy and resulting erosion in both the river channels and on adjacent hill slopes led to the formation of the Great Escarpment. Subsequent retreat of the Great Escarpment formed the lowlands to the east, some of which are now covered with a thin (10 m) layer of alluvium. Scarp retreat has also caused river capture in a few places.

West of the Coen Inlier, on erosional plains formed on Mesozoic sediments, there is clear evidence for relief inversion. Valley floor materials, both alluvium and adjacent weathered bedrock, were cemented by silica to form silcrete. Subsequent erosion has left this very resistant silcrete as a cap on the higher parts of the landscape. The best examples are between Strathburn and Strathhaven homesteads, where long narrow sinuous ridges with a central depression mark former stream courses. These remnants may have resulted from scarp retreat initiated along rivers such as the Coleman and the Holroyd. Further north, both west and east of Pretender Creek, plateaus with a deep bauxitic weathering profile on Rolling Downs Group sediments provide further evidence of the retreat of low scarps across the landscape.

The youngest igneous event recorded in EBAGOOLA was the volcanic activity responsible for the Silver Plains Nephelinite dated at 3.72±0.06 Ma (Sutherland, 1991).

MINERAL RESOURCES AND EXPLORATION HISTORY

by G.R. Ewers, B.I. Cruikshank (AGSO), and L.G. Culpeper (GSQ)

Gold

Gold is the only commodity to have been mined in the Sheet area in economic quantities, and has been recovered mainly from workings in the Hamilton Goldfield in the Ebagoola-Yarraden area. Some gold was also won during the 1890s from The Springs (includes the mines at Sirdar, Westralia P.C., Westralia No. 1 South, and Goolha-Goolha), about 12 km north of Ebagoola in the southern part of the Coen Goldfield. John Dickie discovered gold at Ebagoola in 1900 and further south near the Lukin River in the following year sparking a minor gold rush, particularly from the Coen Goldfield.

Willmott & others (1973) reported that total gold production for the period 1900 to 1951 was officially 2291.58 kg, made up of 1371.63 kg of reef gold from 34196 tonnes of ore, 682.41 kg of alluvial gold, and 237.54 kg from the treatment of 19256 tonnes of tailings. A more recent compilation of production data (Dugdale, 1991) indicates that the total gold recovered in the

TABLE 3 Mines, prospects, and mineral occurrences on EBAGOOLA

DEPOSIT I.D. NUMBER	NAME	STATUS	COMMODITY	PRODUCTION (Grade in g/t)	LOCATION		HOST ROCKS		NATURE OF MINERALISATION
					1:100 000 sheet	AMG grid	Formation	Lithology	
1	Goanna Creek Prospect	M	Sn	-	Strathburn	100228	Pkg, Strathburn Fm	schist, pegmatite; alluvium	veins, alluvial
2	Spion Kop	A, P	Au	-	Kalkah	482945	Flyspeck Granodiorite	granite;rhyolite, breccia	veins, alluvial, residual
3	Flying Fox Hill	M	Au	-	Kalkah	393707	-	porphyritic rhyodacite; rhyolite and rhyodacitic dykes	veins
4	The Bustard	-	Cu, Pb, Zn	-	Kalkah	559449	Pku, Gorge Fm	-	-
5	Saddle Skarn	P	Au	-	Ebagoola	416510	Goolha-Goolha Schist	calc-silicate skarn	veins
6	Goolha-Goolha	A, P	Au	12.5 kg Au (43.0)	Ebagoola	412507	Goolha-Goolha Schist	quartzite	veins
7	Westralia P.C.	A, P	Au	26.5 kg Au (48.6)	Ebagoola	430498	Goolha-Goolha Schist	schist, quartzite	veins
8	Westralia No 1 South	A	Au	-	Ebagoola	431496	Goolha-Goolha Schist	schist, quartzite	veins
9	Horseshoe Creek	P	Au	-	Ebagoola	435490	-	rhyolite breccia	veins
10	Unnamed	M	Au	-	Ebagoola	455483	Goolha-Goolha Schist	quartzite	veins
11	Sirdar	A, P	Au	13.4 kg Au (64.7)	Ebagoola	454479	Kintore Granite	granite; rhyolite breccia	veins
12	Windmill Reef	M	Au	-	Ebagoola	365478	Yarraden Schist	-	veins
13	Tadpole Creek Prospect	P	U, Au	-	Ebagoola	244466	Lochs Gneiss?	mylonitic metasediments; graphitic schist	veins
14	Thornbury Creek	M	Au	-	Ebagoola	340450	Yarraden Schist?	schist	veins
15	Thornbury North	P	Au	-	Ebagoola	328418	Yarraden Schist?	schist	veins, alluvial
16	Thornbury Prospect	A, P	Au	-	Ebagoola	331404	Yarraden Schist?	schist	veins, alluvial
17	Gossan Hill	P	Au	-	Ebagoola	348392	Yarraden Schist	schist	-
18	Stewart Cataracts	P	Au	-	Ebagoola	510370	Lochs Gneiss?	gneiss	veins
19	Eldorado 2	A	Au	-	Ebagoola	508359	Lankelly Granite	granite	veins, residual
20	Ebagoola South	P	Au	-	Ebagoola	440220	Yarraden Schist	quartzite, gneiss, schist; laterite	veins, alluvial
21	Unnamed	M	Au	-	Ebagoola	436191	Lochs Gneiss?	-	-
22	All Nations Creek	M	Au	-	Ebagoola	455186	-	alluvium	alluvial
23	Rhys Demon	A	Au	-	Ebagoola	438177	Kendle River Granite	granite	veins
24	Caledonia	A, P	Au	105.6 kg Au (29.0)	Ebagoola	441172	Burns Granite	granite	veins, stockwork
25	Rats	A	Au	-	Ebagoola	446171	Yarraden Schist	schist, granite, granitic gneiss	veins
26	Hidden Treasure	A, P	Au	53.2 kg Au (28.7)	Ebagoola	452170	Yarraden Schist	schist	veins
27	Hamilton King	A, P	Au	162.1 kg Au (67.9)	Ebagoola	450164	Burns Granite	biotite granite	veins, stockwork, alluvial
28	All Nations	A, P	Au	38.0 kg Au (69.9)	Ebagoola	449163	Burns Granite	granite	veins
29	St Albans	A, P	Au	1.6 kg Au (41.0)	Ebagoola	450160	Burns Granite	granite	veins, residual
30	Golden Treasure	A, P	Au	34.9 kg Au (36.4)	Ebagoola	451159	Yarraden Schist/ Burns Granite	schist/granite; rhyolite; alluvium	veins, alluvial
31	St Albans South	A, P	Au	-	Ebagoola	453156	Burns Granite	granite	veins, residual
32	May Queen	A, P	Au	85.5 kg Au (38.0)	Ebagoola	463155	Yarraden Schist	gneiss; rhyolite	veins, stockwork
33	Hit or Miss	A, P	Au	69.1 kg Au (59.7)	Ebagoola	464149	Yarraden Schist	granitic gneiss, amphibolite gneiss, schist	veins, residual
34	Racecourse Creek	M	Au, Ag	-	Ebagoola	440145	-	alluvium	alluvial
35	Good Luck	P	Au	-	Ebagoola	447143	Burns Granite	granite, gneiss	veins
36	Last Hit	P	Au	-	Ebagoola	449140	Burns Granite	granite	veins
37	Red Gold	A	Au	-	Ebagoola	455140	-	laterite, alluvium	alluvial
38	Queenslander North	A, P	Au	-	Ebagoola	469137	Yarraden Schist	schist	veins, stockwork
39	Never Mine	A, P	Au	-	Ebagoola	494135	Lochs Gneiss	limonitic schist	veins, stockwork
40	Queenslander	A, P	Au	2.5 kg Au (26.6)	Ebagoola	469130	Burns Granite	granite	veins
41	Queenslander East	A, P	Au	-	Ebagoola	471128	Yarraden Schist/ Burns Granite	quartzite/ granite	veins
42	True Blue	A, P	Au	1.0 kg Au (28.6)	Ebagoola	470127	Burns Granite	granite	veins, alluvial
43	Johannesburg	A, P	Au	0.5 kg Au (55.6)	Ebagoola	484125	Yarraden Schist	schist	veins, stockwork
44	Station Creek	M	Au	-	Ebagoola	458114	-	alluvium	-
45	Trafalgar	A, P	Au	75.1 kg Au (72.1)	Ebagoola	485112	Yarraden Schist?	schist, gneiss	veins, breccia
46	De Gem	A	Au	-	Ebagoola	485107	-	eluvium	residual
47	Random	A	Au	-	Ebagoola	478100	Lochs Gneiss	gneiss; rhyolite; alluvium	veins, alluvial
48	Violet	A, P	Au	68.6 kg Au (65.6)	Ebagoola	474093	Ebagoola Granite?	granite, granodiorite	veins
49	Gold Mount	A, P	Au	36.4 kg Au (33.0)	Ebagoola	509060	Lochs Gneiss/ Flyspeck Granodiorite	schist, gneiss/ biotite granodiorite	veins, stockwork
50	Lukin King	A, P	Au	118.4 kg Au (46.8)	Ebagoola	494043	Lochs Gneiss/Glen Garland Granodiorite	schist, gneiss/ granite	veins
51	Golden King North	A, P	Au	-	Ebagoola	472025	Flyspeck Granodiorite	granite	veins
52	Lady Jayne	A	Au	-	Ebagoola	473013	Glen Garland Granodiorite	granite; rhyolite	veins
53	Savannah	A, P	Au	157.6 kg Au (58.6)	Ebagoola	478009	Ebagoola Granite	granite; rhyolite	veins
54	Golden King	A, P	Au	245.4 kg Au (31.7)	Ebagoola	474007	Ebagoola Granite	granite	veins
55	Savannah South	A, P	Au	-	Ebagoola	477006	Ebagoola Granite	granite, rhyolite	veins
56	J & B Sinters Grid	P	Au	-	Ebagoola	469005	Glen Garland Granodiorite	granite, rhyolite dyke	veins
57	Golden King South	A, P	Au	-	Ebagoola	473002	Ebagoola Granite	granite	veins

Abbreviations A = abandoned mine P = prospect M = mineral occurrence

Hamilton area for the same period was higher (2397.69 kg) with most of that production between 1900 and 1914 (2288.55 kg of gold).

Table 3 summarises data for mines, prospects, and mineral occurrences on the Ebagoola 1:250 000 Sheet area drawn from GSQ compiled and field checked mineral occurrence (MINOCC) data sheets. Production figures for individual mines have been sourced from Dugdale (1991), and indicate that the most productive workings have been the Caledonia, Golden King, Hamilton King, Lukin King, and Savannah mines, although virtually all mines in the area now lie abandoned. Workings consisted of shafts, shallow pits, adits, and trenches. Although gold grades were consistently high (26.6 - 72.1 g/t) and exceptional by present standards, this resulted from the selective mining of auriferous quartz veins and rich eluvials and alluvials derived from them.

In the Ebagoola area, free gold principally occurs in numerous single and multiple quartz veins that formed within the Ebagoola and Burns Granites and the Flyspeck and Glen Garland Granodiorites and along or near their contact with schist, gneiss, and quartzite belonging to the Coen Metamorphic Group. The mines and prospects of the Hamilton Goldfield are spatially related to the northwest trending Ebagoola Shear Zone and associated faults; those in The Springs area are within or adjacent to the Coen Shear Zone. At the mine scale, vein systems with a similar north to northwesterly trend are commonly associated with shear zones. Individual veins are typically less than 1 metre wide and may give way to quartz stockworks; they have variable but commonly steep dips and workings may extend up to 300 m along their strike length.

The veins consist of massive milky (and less commonly glassy) quartz through to coarse grained comb quartz. Radiating bunches of coarse milky quartz crystals are sometimes present and some veins contain multiple generations of quartz with later vein sets typically more translucent. Sulphides (mainly pyrite and arsenopyrite with lesser galena, sphalerite, and stibnite) are minor, but because of the shallow water table (<20 m in the dry season) are usually found close to the surface. Eluvial gold has been derived from the in situ weathering of the quartz reefs and alluvial workings occur near some mines. Wallrock alteration about the vein systems is dominantly sericitic with lesser silicification.

Rhyolite dykes with a similar trend to the quartz veins have been recognised in many of the old workings (at Golden King, Golden King South, Golden Treasure, Horseshoe Creek, J & B Sinters Grid, Lady Jayne, May Queen, Random, Savannah, and Sirdar) and Spion Kop is associated with a rhyolite plug intruding the Flyspeck Granodiorite. These rhyolites are presumed to be of Permo-Carboniferous age. However, at this stage, it is not clear whether the gold-bearing quartz veins are associated with the Siluro-Devonian granitoids or these later intrusive rhyolite bodies.

Base metals

Anomalous geochemical values for copper, lead, and zinc have been reported from The Bustard lease (Table 3) for metamorphic rocks and ironstone in the Holroyd Group. These anomalous values coincide with magnetic/electromagnetic anomalies and are within 2 km of granitic intrusions.

Tin

Coarse cassiterite has been recognised in thin quartz veins hosted by schist belonging to the Holroyd Group at the Goanna Creek prospect (Table 3). Follow up stream sediment and pan concentrate sampling yielded anomalous values, but the size and strength of the anomaly did not warrant further investigation.

Uranium

Uranium mineralisation with weakly anomalous gold values has been reported from a shear zone in the Tadpole Creek prospect (Table 3). The mineralisation is associated with thin concordant quartz veins in mylonitic metasedimentary rocks and graphitic mica schist within the Coen Metamorphic Group. The shear zone was anomalously radioactive over a length of 1300 m and to a width of 2.6 m, but the mineralisation is not regarded as economic.

Petroleum

Petroleum exploration in the Ebagoola 1:250 000 sheet area has been confined to the Laura Basin where three exploration wells and one stratigraphic bore have been drilled (Hawkins & Williams, 1990). The onshore exploration wells (Marina No.1, Breeza Plains No.1, and Lakefield No.1) were drilled along a north-northwest trending anticlinal feature and encountered only minor spotty fluorescence and staining from trace hydrocarbons in the Gilbert River Formation and Dalrymple Sandstone: similar results were obtained from the GSQ Ebagoola 1 stratigraphic drillhole. Although no production has occurred, the Laura Basin sequence has achieved a level of organic maturation conducive to oil generation in some areas, with horizons within the Dalrymple Sandstone providing the most favourable source richness and oil-prone kerogen types (Hawkins & Williams, 1990).

Coal

Thin coal laminae have been intersected in the three exploration wells referred to in the previous section. The stratigraphic drillhole (GSQ Ebagoola 1) has confirmed the presence of two thin coal seams (each approximately 1 m thick) at 1074.37 m and 1077.07 m near the base of the Dalrymple Sandstone (Williams, 1988). The coals are of coking rank, but are considered to be too deep and too thin to be of economic importance (Hawkins & Williams, 1990).

Groundwater

The main aquifers in the Laura Basin, which Smart & Senior (1980) consider is in partial hydraulic continuity with the adjacent Carpentaria Basin, are sandstones in the Jurassic Dalrymple Sandstone and Gilbert River Formation. In the eastern part of the Sheet area, some shallow bores draw water of variable quality from the Lilyvale Beds and residual sand of Tertiary to Quaternary age.

Exploration history

Systematic exploration in the sheet area over the last 25 years has been mainly for gold, base metals and heavy minerals (including rare-earth minerals). Minor targets have been tin, tungsten, uranium, antimony, silver, platinum, and diamonds. To date no major discoveries have been made and the only mining activity currently undertaken in the area is by one or two man operations exploiting small alluvial lodes or surface quartz vein systems.

Exploration (either as Authorities to Prospect (AP) or more recently as Exploration Permits for Minerals (EPM)) for **gold** has concentrated on the granites and metamorphics of the Coen Inlier; exploration targets included quartz fissure lodes and stockworks, epithermal quartz veins and eluvial and alluvial deposits. Methods applied to the whole or selected areas of an individual AP or EPM range from rotary percussion and diamond drilling around known mineralisation and the sampling of mullock heaps from previous mining activity, to costeaning, auger sampling, rock chip sampling, stream sediment sampling (recently including Bulk Cyanide Leach separation) and pan concetrate sampling for chemical analysis and mineralogical examination. Overall results have not been encouraging and the few promising anomalies generally have not warranted serious evaluation because they proved to be too erratic or not reproducible.

Exploration for **base metals** (Cu, Pb, Zn) tailed off in the mid 1980s and has only recently been revived through interest from BHP, CRAE, and MIM; these companies currently hold EPM's over much of the Coen Inlier in the EBAGOOLA sheet area. Stream sediment geochemistry, either regionally-based or localised over geophysical anomalies, has been the most extensively used exploration technique, with more detailed stream sediment sampling, rock chip sampling, soil grid sampling and, very rarely, diamond drilling, used to follow up anomalies. As with gold, results to date have been discouraging; anomalies can be traced to low grade mineralisation, small pockets of base metal accumulations in weathered mafics or rock units carrying high lithological concentrations of target elements. Only one Mining Lease (The Bustard Lease from AP 513) appears to have been taken out.

In the late 1970s a number of APs were explored for **uranium**. Graphitic and chloritic schists in the Holroyd Group and Coen Metamorphic Group near contacts with granitoids attracted most attention. Airborne gamma ray spectrometry and magnetic surveys generally were followed by ground work which included gamma ray spectrometry, stream sediment sampling, rock chip sampling and soil radon gas surveys. Rotary airblast and diamond drilling were used on several interesting anomalies but all proved to be too low grade to be of economic interest.

Sporadic exploration for **tin** and **tungsten**, usually by stream sediment sampling and pan concentrate sampling, has been no more rewarding than for the other target elements. Several promising anomalies of up to 400ppm tin were shown to be derived from either quartz veins in a garnet-mica schist associated with a tin-bearing rhyolite dyke (130ppm), or from pegmatitic quartz veins in the Holroyd Group. Neither was of economic interest.

The search for alluvial **heavy** (resistant) **minerals** picked up in the late 1980s after lapsing for about 15 years, and with greater apparent emphasis on the rare-earth element minerals such as xenotime (YPO_4) and monazite ($(Ce,La,Th)PO_4$). Exploration concentrated on the coastal regions and alluvium in the larger river/stream systems. Air photo interpretation has been used to delineate palaeo-shorelines and other coastal features. Stream sediment sampling and pan concentrate sampling have been used along watercourses, and surface sampling, hand augering and reverse circulation drilling used in dunal areas. Some rock chip sampling and ground scintillometer traverses were also carried out. Several stream sediment and surface samples showed some promise but proved disappointing on further investigation. Samples from the Morehead River area showed high diamond indicator mineral ratings.

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