Mineral Provinces

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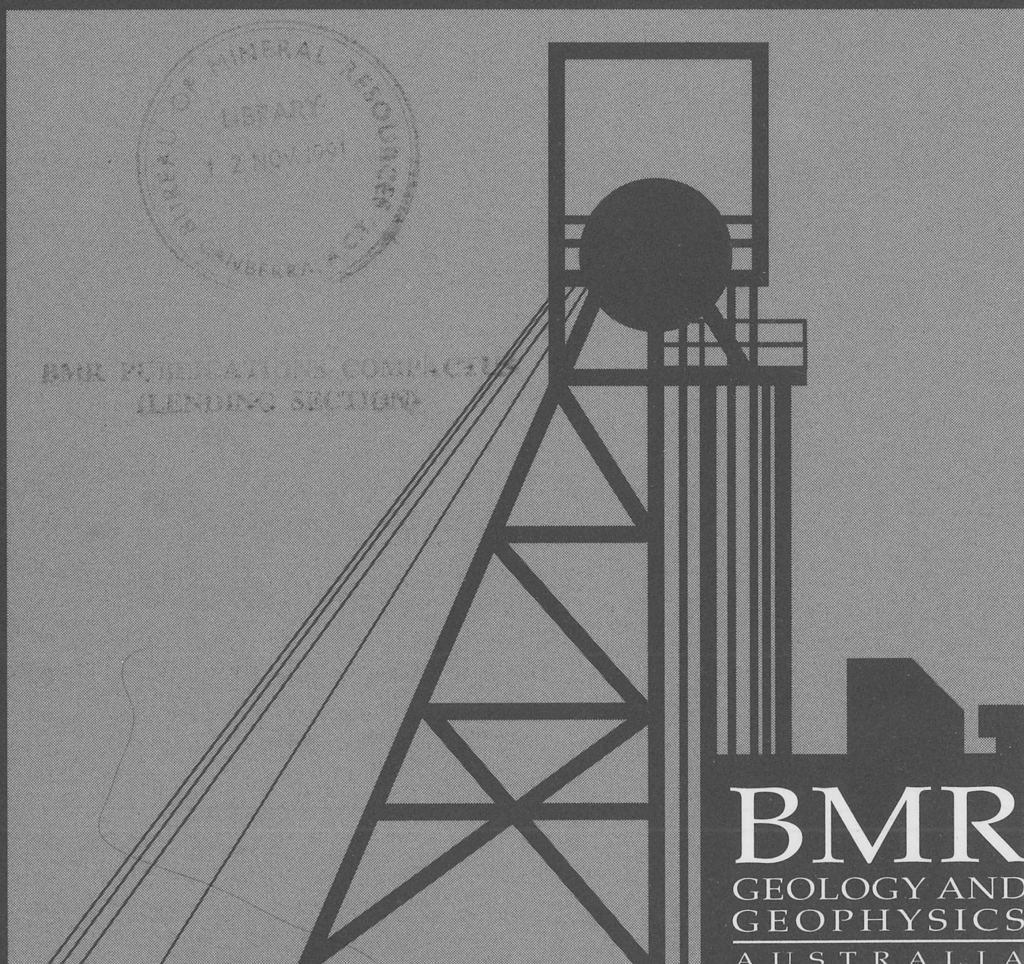
Geology of the Coen Metamorphics with special reference to the Coen and Ebagoola Shear Zones
Record 1991/14



BMR
GEOLOGY AND
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AUSTRALIA

by
R.S. Blewett and F.E. von Gnielinski

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

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DEPARTMENT
OF RESOURCE
INDUSTRIES

A contribution to the National Geoscience Mapping Accord
NORTH QUEENSLAND PROJECT

by

R.S. Blewett and F.E. von Gnielinski

Geoscience for Australia's future

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ABSTRACT

The Proterozoic Coen Metamorphics in the central Coen Inlier, Cape York Peninsula, are dominated by amphibolite-grade schist and gneiss with lesser quartzite and amphibolite dykes. The Coen Metamorphics are partly bound by the Coen Shear Zone to the east and the Ebagoola Shear Zone to the west and are surrounded and intruded by the mid-Palaeozoic granitoids of the Cape York Peninsula Batholith.

The structure of the NNW-trending Coen Metamorphics is attributed to refolding and ductile shearing of previously E-W oriented D_1 structures; climax metamorphism was associated with D_1. Well developed mylonites, chiefly within the Cape York Peninsula Batholith, record sinistral west-over-east ductile shearing along a number of discrete surfaces or zones. The shear zones, like most structural elements, dip steeply or sub-verti cally and have a strong spatial link with gold mineralization. They presently have the geometry of sub-vertical normal faults.

D_2 structures trend NNW to N and include tight to isoclinal folds that plunge moderately and have subvertical axial surfaces and associated axial-planar crenulation cleavages. The mylonites trend NNW and are overprinted by N-trending folds that may be F_2 in age. However, the NNW-trending crenulation cleavage is locally overprinted by less well developed N-trending crenulation cleavage, suggesting that the N-S overprint of the mylonite may be later than D_2.

D_3 structures are not common in the Coen Metamorphics, but where present, are either an E-W to NE-SW trending crenulation cleavage or kink band.

CONTENTS

1. INTRODUCTION

This record outlines the structural geology of the Coen Metamorphics (Willmott et al., 1973) in the Coen and Ebagoola 1:250,000 Sheets (SD54/08 and SD54/12). The work is the product of 15 weeks of field work between July and September 1990 as a contribution to the joint North Queensland project of the National Geoscience Mapping Accord between the Bureau of Mineral Resources (BMR) and the Geological Survey of Queensland (GSQ). Field work was conducted from a base camp located 50 km north of Coen, the largest settlement in the region with a population of 400. Approximately 600 sites were visited, 500 samples collected, 150 thin sections cut and over 950 structural observations made. Some thin sections from BMR/GSQ mapping in the 1960s were also re-examined.

1.1 Physiography and infrastructure

The study area (Fig. 1a, b and Fig. 2) lies between latitudes 14°45'S and 13° 44'S, at altitudes from 100 m to 700 m above sea level, in a narrow strip bisected by the main Peninsula Development Road, an all-weather gravel road linking Cairns (some 600 km SSE) with Weipa (255 km NW). The Coen airport (Fig. 2) is served by regular flights from Cairns.

Other access is provided by minor station tracks that lead off the Peninsula Devel opment Road and by a limited number of very rough, and largely overgrown, exploration tracks. The bush, ranging from rain forest to open scrub, is generally too dense to drive cross-country and most traverses were done on foot. A track map for the Coen Inlier is given by Trail and Blewett (1991).

The metamorphic rocks (particularly sillimanite schist and quartzite) form the high ground and narrow NNW-trending ridges, while the granites occupy the poorly exposed low ground between the ridges of the Coen Metamorphics. This is not the case to the N and NE, where granites principally form the McIlwraith Ranges (Fig. 2).

1.2 Maps and aerial photographs

Most of the mapping was compiled on RC9 black-and-white photographs at a nominal scale of 1:84,000, which were flown in the late 1960s to early 1970s. Some of the area is covered by poor quality 1:20,000 scale colour aerial photographs flown in N-S lines by Qascophoto in late 1986. These aided location and route-finding but some lines had gaps and poor overlap.

Topographical maps of the 1:100,000 series for the Coen, Ebagoola and Kalkah (7570, 7569, 7568) AUSLIG sheets were used as base maps, with individual site positioning assisted by the use of Magellan Geographical Positioning System NAV1000PRO (GPS) hand held receivers.

1.3 Regolith*

Regolith studies were carried out over the Coen Inlier by the BMR Regolith Group, in conjunction with the structural investigation. Results of these studies, including regolith maps and accompanying records covering the whole of Cape York Peninsula, will be presented separately.

Rock outcrops vary from relatively fresh to highly altered and deeply weathered. Saprolite and mottled weathering profiles are characteristic of the granitic terrains, while weathering of argillaceous lithologies is typified by the loss of the original rock texture and intense mottling, reflecting the movement of iron oxides and clays in the profile. Pediment slopes and colluvium fans fringe some hills. Relatively thin corridors of sandy alluvium have accumulated along streams and rivers. In many places the alluvium is indurated by clay and iron cement, forming blocky exposures along river banks.

* (J. Wilford - BMR Regolith Group)

1.4 Geographical Information Systems, databases and equipment

A Geographical Information System (GIS) is being constructed in ARC-INFO comprising several layers including: Thematic Mapper imagery (TM), topography, national grid, drainage, airborne magnetics and radiometrics, geology and cultural features. The "INFO" side of the database, in terms of field description attributes for each point and/or polygon is under review. This information is presently stored in the REGMAP hierarchical data management system. These data are currently released and available for purchase. REGMAP data have been loaded into ORACLE on the BMR Data General 20,000 mainframe computer and links with existing databases are being investigated (eg. PETCHEM and MAPDAT). See Blewett (1991) for more information.

Laptop computers with linked data management system and commercial stereographic software were tested. All data were entered into the REGMAP database system developed by the Geological Survey of Queensland. Details of this system are available in Lang et al., (1990).

The scale of the photographs (1:84,000), together with new software, enabled a geological compilation to be directly digitized from the aerial photographs into Intergraph Microstation PC, bypassing the normal compilation stage to create immediate preliminary maps. Automatic plotting of structural data and site locations from the REGMAP data management system, prevents duplication of entry and significantly improves the efficiency and accuracy of map production.

1.5 Remotely sensed data

No remotely sensed data were available for the re-mapped area prior to the 1990 field season. Thematic Mapper images (hard copy) were available for Lockhart River, Cape Weymouth and Batavia Downs 1:100,000 sheet areas, however, their use was limited in thickly vegetated areas. Ten metre pixel SPOT monochrome (non-stereo) images were tested, but these proved to be a poor alternative to aerial photography and lacked the spectral range of TM. The TM data did provide some enhancement of the lithological

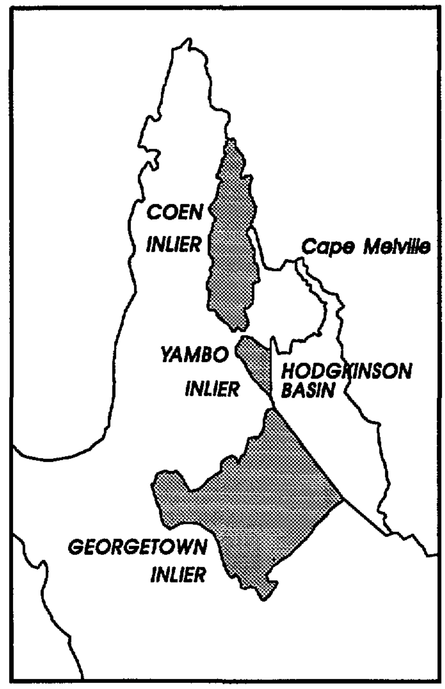


Figure 1a: Locality map of North Queensland showing the Proterozoic Coen, Yambo and Georgetown Inliers.

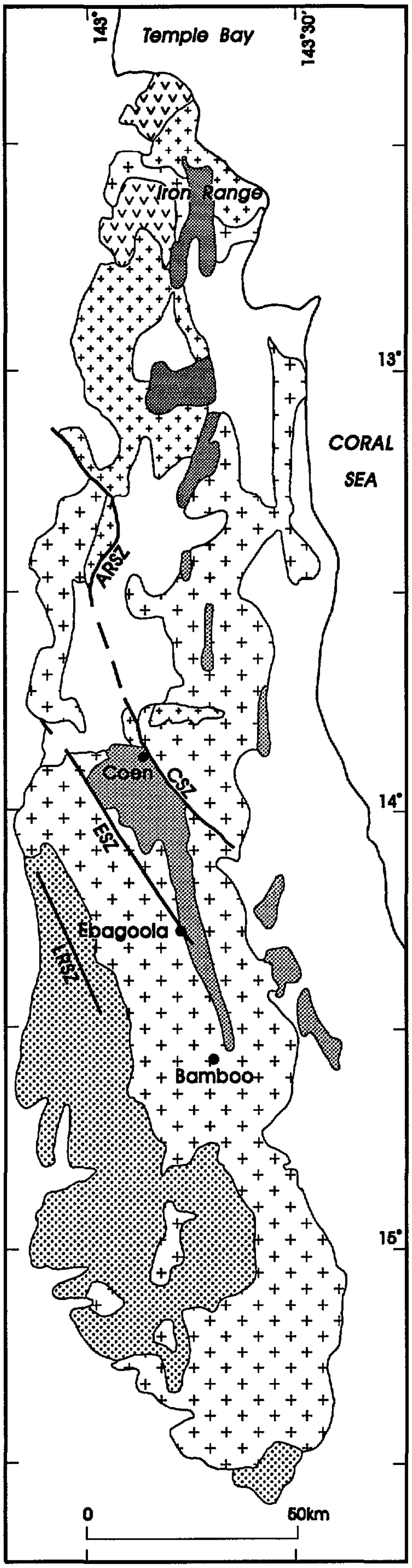


Figure 1b: Simplified geology of the Coen Inlier showing the Coen (CSZ), Ebagoola(ESZ), Archer River (ARSZ) and Lukin River Shear Zones (LRSZ)

- Cainozoic cover
- Janet Ranges Volcanics
- Permian Granitoids
- Cape York Peninsula Batholith
- Sefton Metamorphics
- Coen Metamorphics
- Holroyd Metamorphics

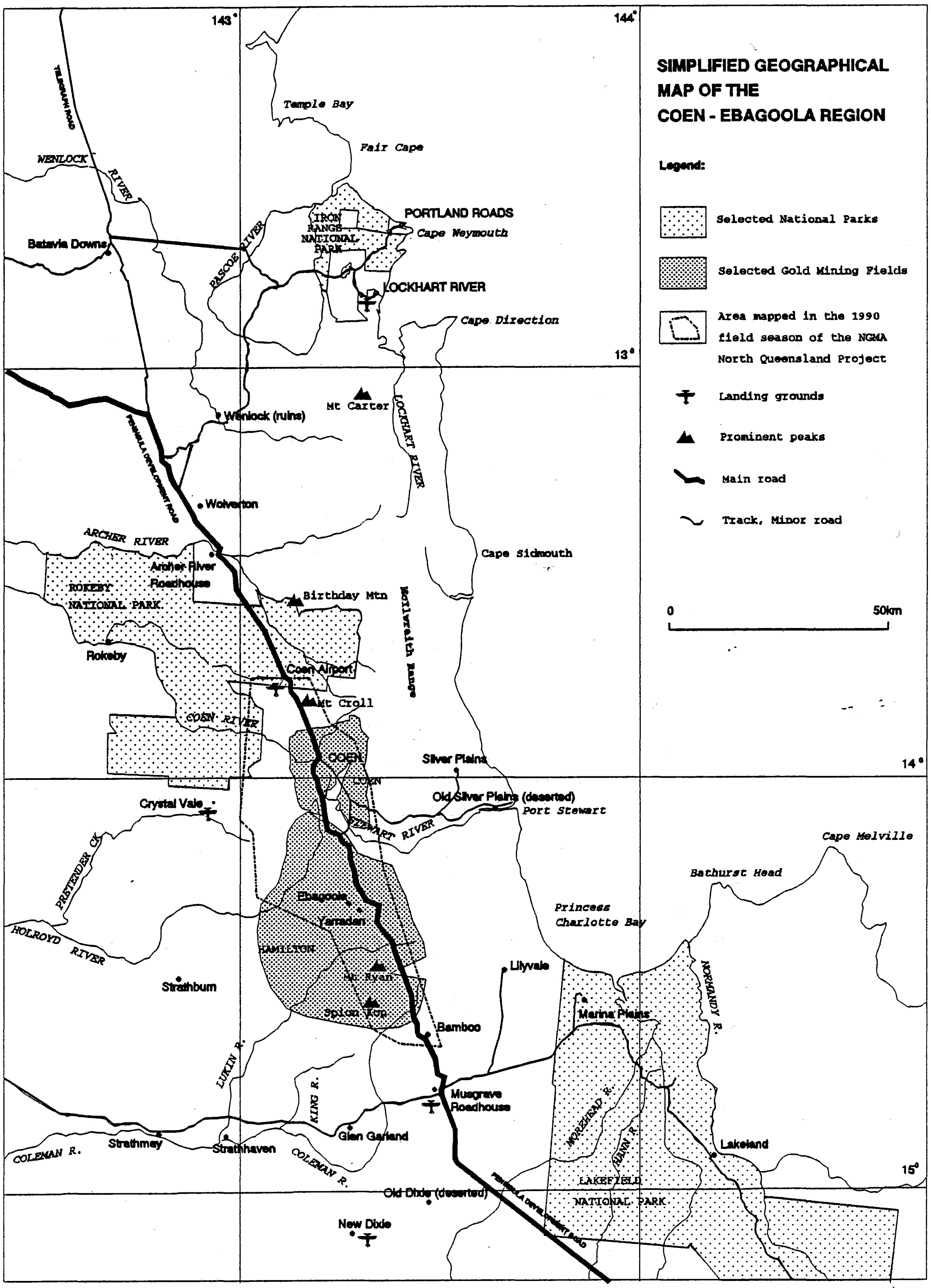
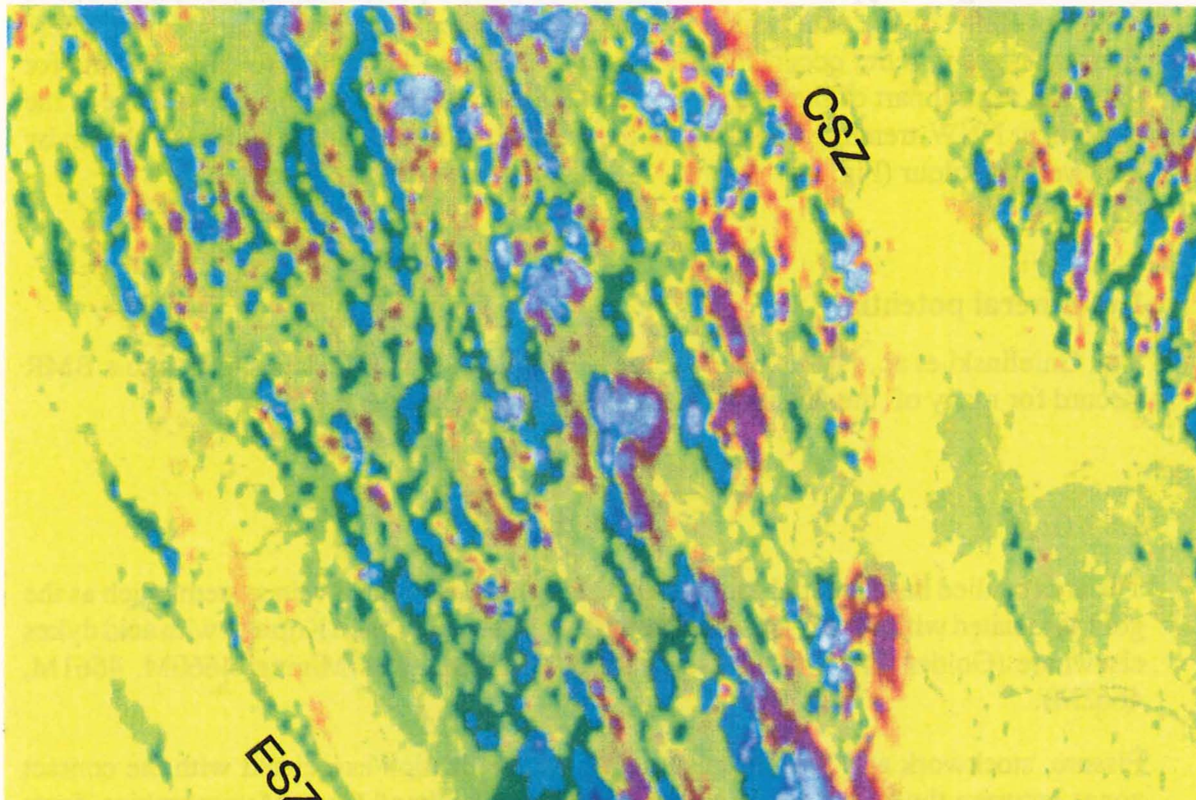


Figure 2: Simplified geography of the Coen - Ebagoola region, showing the mapped area of the 1990 BMR/GSQ field season.

Figure 3

Landsat Thematic Mapper (TM) scene merged with magnetics over some of the Coen Metamorphics. The granites have a low magnetic character and are coloured yellow. The metamorphics and their contact with the granites are well displayed. The Coen Shear Zone (CSZ) and Ebagoola Shear Zone (ESZ) are visible cutting thegranites of the Cape York Peninsula Batholith.


CSZ
ESZ

(spectral) differences between granite and metamorphic rocks. With the edges put back into band 5 of TM, enhancements of lineaments and the broad structure are possible.

Airborne geophysical data were acquired during July/August 1990 for the entire Ebagoola 1:250,000 sheet. The aeromagnetic data (400m line spacing) reveal major shear zones, and discriminate between magnetically responsive metamorphics (although there is correlation between high metamorphic grade and increased magnetic response) and the magnetically "flat" granites of the Cape York Peninsula Batholith. The associated radiometrics are being evaluated, they appear to be less useful than the magnetics in discriminating rock type and structure over the metamorphics. This may be partly due to poor "leveling" of the data, which is especially apparent over the metamorphics where sharp changes in relief occur. Figure 3 shows combined TM and aeromagnetic data for the north central part of the Ebagoola 1:100,000 sheet. The Ebagoola Shear Zone is the prominent NNW-trending lineament in the west of the frame. The granites are shown by their yellow colour (Fig. 3).

1.6 Mineral potential

Von Gnielinski et al., (1991) have recently compiled MINOCC data sheets into a BMR Record for many of the prospects mentioned in this text.

1.6.1 Gold

The area studied has potential for high-level (epithermal) quartz-vein systems such as the gold associated with Permo-Carboniferous (?) intrusives at Spion Kop and with acid dykes elsewhere (Golden Era Mining Syndicate, EP 3549M; Ross Mining, 4660M, 4661M, 4662M).

Fissure, stockwork and breccia-related gold mineralization associated with the contact zones between the Kintore Adamellite and the Holroyd and Coen Metamorphics, form known reefs in the Hamilton and Coen Goldfields. The Coen and Hamilton Gold fields (Fig. 2) are centered about the Coen and Ebagoola Shear Zones respectively, indicating a degree of structural-control on mineralizing solutions.

Gold also occurs in shoots associated with quartz-vein systems, and along the margins of acid dykes that intrude mylonites of the Coen and Ebagoola Shear Zones. The shear-zone-associated gold has a relatively high silver content and is commonly accompanied with arsenopyrite and locally pyrite, galena and other sulphides. The mylonites also show the effects of low-temperature hydrothermal alteration (K-feldspar and sericite alteration). See Ross Mining EP's (3549M, 4660M 4661M, 4662M).

There is some potential for stratabound gold mineralization in the metasediments of the Hamilton Goldfield (CRA EP 1880M), and low-grade (0.5 g/m^3) alluvial/eluvial gold (Ross Mining, EP's 3549M, 4660M, 4661M, 4662M).

A list of all Mining company activities within the study area is given in Appendix 2.

1.6.2 Heavy minerals

Some alluvial cassiterite, rutile, zircon, monazite and ilmenite occur in the river sands of the Coen, Holroyd and other major rivers as shown by Saracen (EP's 4125M, 4198M, 4241M, 4360M).

1.6.3 Base metals

Base metals occur in association with gold and silver as fissure, stockwork and breccia mineralization and disseminated in the metasediments (CRA, EP 1880M; Ross Mining, EP 3549M), however, no significant deposits have been discovered.

1.7 Regional geology

The principal belt of Coen Metamorphics in the Coen Inlier is partly defined by the Coen and Ebagoola Shear Zones (Fig. 1b), and is juxtaposed east and west against the Siluro-Devonian granitoids of the Cape York Peninsula Batholith (Willmott et al., 1973) (Rb/Sr ages by Cooper et al., 1974, U/Pb zircon ages Lance Black personal communica tion 1991). The Coen Shear Zone (Willmott et al., 1973) and Ebagoola Shear Zone (new name) form NNW-SSE trending lineaments, which have a strong spatial relationship with gold mineralization. The Coen Shear Zone (CSZ) forms the southern extension of the larger Coen-Archer River Shear Zone (new name), which continues NNW of the study area for a further 130 km (Fig. 1b).

A 1:100,000 scale geological map is in preparation, a reduced sample is shown in Appendix 1. The map covers the main outcrop of the Coen Metamorphics which stretch 85 km NNW-SSE across the COEN, EBAGOOLA and KALKAH 1:100,000 sheet areas, and taper from 16 km in the north to less than 3 km in the south. Metamorphic rocks dominate the area, but within and surrounding the belt of metamorphics, are granites and associated rock types of the Cape York Peninsula Batholith (Willmott et al., 1973). Within the mapped area, the batholith was subdivided by Willmott et al., (1973) into the Kintore and Lankelly Adamellites and Flyspeck Granodiorite. The Permian Twin Humps Adamellite (Trail et al., 1968; 1969; Willmott et al., 1973) also crops out in the north.

In this record, the principal changes to the 1:250,000 geological map (Whitaker and Gibson 1977a & b) are in the distribution of gneiss (which has been partly extended), the detail of granites within metamorphics (mainly schists) and the recognition of much of the Tertiary cover as deeply weathered basement.

The structural evolution (discussed below) is now considered to have had at least three penetrative and widespread phases of deformation, associated with coeval, progressive, strong mylonitization along major shear zones. Lower hemisphere projections (Schmidt) of some structural elements are contoured using the spherical Gaussian method with percent given per 1% of area, are presented. The age of the inlier and granite emplacement, and structural correlation with the Georgetown Inlier to the south, are also discussed.

2. STRATIGRAPHY

The principal rock units in the area are listed in Table 1. No new stratigraphic names have been suggested and the stratigraphy follows that of Willmott et al., (1973)

TABLE 1

STRATIGRAPHY OF THE COEN AND EBAGOOLA SHEAR ZONES

AGE	UNIT	LITHOLOGY
Tertiary	Lilyvale Beds	Clayey, quartzose sand
	Falloch Beds	Sandy clay, granule gravel, pebbly in part
Permian	Twin Humps Adamellite	Hornblende-biotite adamellite
	* Flyspeck Granodiorite	Biotite granodiorite, tonalite
Siluro-		
	* Kintore Adamellite	Muscovite-biotite adamellite, pegmatite, muscovite granite
Devonian		
	* Lankelly Adamellite	Porphyritic (KFS) biotite adamellite
Proterozoic	Coen Metamorphics	Schist, gneiss, migmatite, quartzite, amphibolite

* Cape York Peninsula Batholith

2.1 PROTEROZOIC METAMORPHICS

The Coen Metamorphics are divided into a number of (partly gradational) rock types. In decreasing order of abundance these are:-

- muscovite-biotite-quartz schists

- (± sillimanite) (± biotite)-quartz schist

- quartz-feldspar-biotite gneiss

- (± garnet) (± sillimanite) biotite-quartz-feldspar gneiss

- quartzite

- amphibolite

- calc-silicate schist

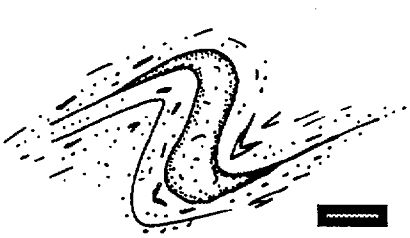
The structural geology of the Coen Metamorphics is outlined in Table 2.

2.1.1 Gneiss and migmatite

Gneiss crops out over 300 km^2, in three main NNW-SSE elongate belts within the study area where it is intimately interleaved with schist. In other parts of the belt it is also interlayered with quartzite and is present as screens 10 to 30 metres wide in the Cape York Peninsula Batholith. Migmatites occur locally as relatively narrow zones within the Coen Metamorphics. Amphibolites are occasionally found as pods or "dykes" in the gneiss. Talc occurs locally. The gneiss is often associated with sillimanite schist and is possibly gradational into the latter.

A prominent gneissic layering, trending mainly NW-SE (Fig. 4a) consists of alternations of quartzo-feldspathic layers with or without garnet and sillimanite, and biotite with (or without) garnet and opaques. Garnet is locally developed. Layering is commonly 1 to 2 cm thick and is generally continuous, although shearing mylonitization, folding and transposition disrupt gneissic layers. Micas are aligned parallel to and partly define the gneissic layering. Kyanite, previously unrecorded in the Coen Inlier (cf. Willmott et al., 1973) also occurs at a single location in the southernmost gneiss outcrop (Fig. 4b). Granite, aplite and pegmatite all cross cut the gneissic layering. The trends of S_1 in the closely associated schist are usually parallel to that of the gneissic layering. The gneissic layering trends NW to NNW and dips steeply like S_1.

Boudinaged gneiss, with garnet defining S_G



The gneiss is generally medium to coarse-grained, equigranular and commonly contains aggregates (augen) of undulous quartz and sericitized feldspar. Garnets where present, are colourless to light pink, and generally 1 mm in diameter. Biotite is commonly overgrown by chlorite. Garnet in trails, mirror the trends of the leucosome/melanosome contacts, or occurs as scattered small porphyroblasts. Garnets are

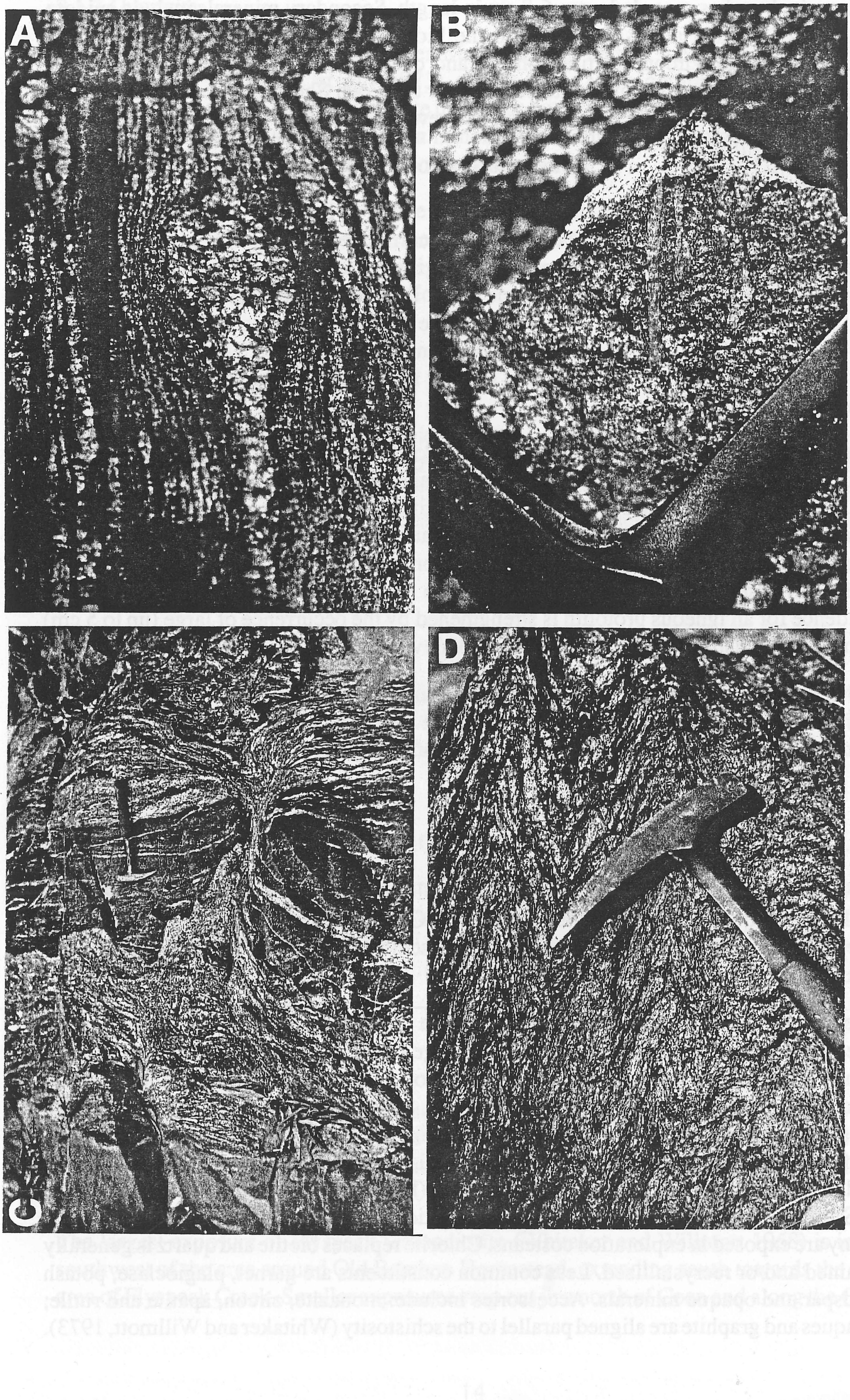
Figure 4

a) Layered gneiss with quartzo-feldspathic pod, Coen Gneiss (7569/508.5-443.5).

b) Bladed kyanite along gneissic layering, Coen Gneiss (7568/573-878).

c) Migmatite with pegmatite sweats cutting amphibolite dyke and cross cut by Kintore Adamellite in the far left, Coen Metamorphics (7570/313-552.5).

d) Symmetrical S_2 crenulation cleavage on S_1, Coen Schist (7569/402-227).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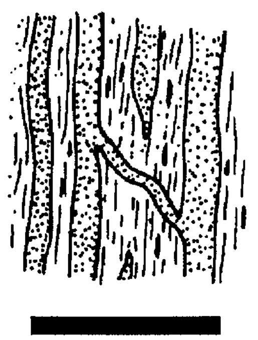
commonly 1 to 2 mm in diameter while sillimanite occurs as 1 to 2 mm laths. The largest sillimanite bunches recorded were 6-8 cm in length. Secondary minerals include epidote and opaques which are associated with the biotite melanosome. Accessory minerals include monazite, zircon, apatite, sphene, and opaque minerals. Sillimanite is mostly altered to muscovite and chiastolite occurs near the Coen Shear Zone on Station Creek, a tributary of Stewart River (Fig. 2).



Leucosome apophyses cross cutting the gneissic layering

The leucosome component is granitic in composition; apophyses of granite-pegmatite from layer-parallel leucosome show that there is an intrusive source for at least some of the gneissic protolith and suggest a later granitic addition to the gneiss. The pegmatites are typically lacking in biotite and show a higher muscovite content.

At the Coen River (Fig. 2) crossing of the old Pollappa Road, pegmatite sweats derived from migmatization transect amphibolite pods and overprint the gneissic layering (Fig. 4c). Here, the migmatites and associated pegmatite sweats are overprinted by the Kintore Adamellite and elsewhere by aplites. This indicates that at least some phases of the Cape York Peninsula Batholith post-date the metamorphic peak. In some granitic leucosome pods, phyllosilicates envelop the melanosome and are not overprinted by the pods. Evidence for an igneous protolith is strengthened by the occurrence of large (up to 5 cm) rounded K-feldspar porphyroblasts with well developed reaction rims.

Much of the folding in the gneisses is disharmonic and it is not known what component of refolding was responsible for this. It may be that the gneisses have a longer pre-D_1 history than the schists, or that there is more than one generation of gneiss.

2.1.2 Schist

Fine to medium grained, silvery grey to purple-brown weathered biotite-muscovite-(sillimanite)-quartz schist comprises most of the Coen Metamorphics. The schist are often deeply weathered, have a strong penetrative schistosity with commonly one or two generations of crenulation cleavage.

The schist occurs throughout the mapped area as thin screens within predominantly gneissic areas. The schist defines the outer edge of the belt and is juxtaposed with the Kintore Adamellite to the west by the Ebagoola Shear Zone and with the Lankelly Adamellite to the east by the Coen Shear Zone. Sillimanite, mostly pseudomorphed by muscovite, is present as fine needles or bunches of needles, with or without a strong preferred alignment. Sillimanite is a D_1 mineral as it is found within the S_1 schistosity and overprinted by the S_2 crenulation cleavage (Fig. 4d). Pegmatites are locally parallel to S_1 in the schists and are folded by F_2. Graphitic shears are common within the schists, many are exposed in exploration costeans. Chlorite replaces biotite and quartz is generally strained and/or recrystallized. Less common constituents are garnet, plagioclase, potash feldspar and opaque minerals. Accessories include: monazite, zircon, apatite and rutile; opaques and graphite are aligned parallel to the schistosity (Whitaker and Willmott, 1973).

2.1.3 Quartzite

Quartzites are less common in the Coen Metamorphics than in the lower grade Holroyd Metamorphics (Willmott et al., 1973) to the SW. They comprise grey to white, saccharoidal, medium-grained quartzite that crops out as narrow (5m) ridges within schist and locally in the gneiss. Muscovite, a minor component of the quartzite, is commonly aligned defining metamorphic foliations (especially S_2).

The quartzite ridges trend NNW, have strike lengths up to 5 km and show no evidence of macroscopic fold closures, unlike the Holroyd Metamorphics to the SW. The thickness of most quartzite beds precludes their discrimination on the 1:100,000 scale map, although a quartzite ridge is mapped through Mount Ryan (Fig. 2).

2.1.4 Amphibolite

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 (Fig. 4c). They are medium-grained, semi-equigranular and composed of large subhedral, pale yellow to greenish brown hornblende, plagioclase and quartz with opaque minerals, sphene and apatite (as common accessories).

2.1.5 Calc-silicate schist

Calc-silicate schist, although recorded by Willmott et al., (1973), is recessive and was not located in this study. There are large outcrops to the NE of the study area around the headwaters of the Peach Creek (Willmott et al., 1973).

2.2 PALAEOZOIC IGNEOUS ROCKS

The main granitic rocks of the Coen Inlier form the Siluro-Devonian Cape York Peninsula Batholith (Willmott et al., 1973). Rock units present in the study area are the Flyspeck Granodiorite, Kintore Adamellite and Lankelly Adamellite. The structural geology of the Cape York Peninsula Batholith is outlined in Table 3.

2.2.1 Flyspeck Granodiorite

The Flyspeck Granodiorite is a medium-grained, white to grey, equigranular rock with biotite and hornblende as minor mafic minerals (Willmott et al., 1973). Willmott et al., (1973) state that the Flyspeck Granodiorite grades into tonalite and adamellite, but these are probably separate units.

The largest exposure of Flyspeck Granodiorite (Whitaker and Willmott 1968) is in the southwest of the area around Old Bamboo Homestead, extending south towards the type area of Flyspeck Creek. Smaller exposures crop out just north of Coen and along the Coen

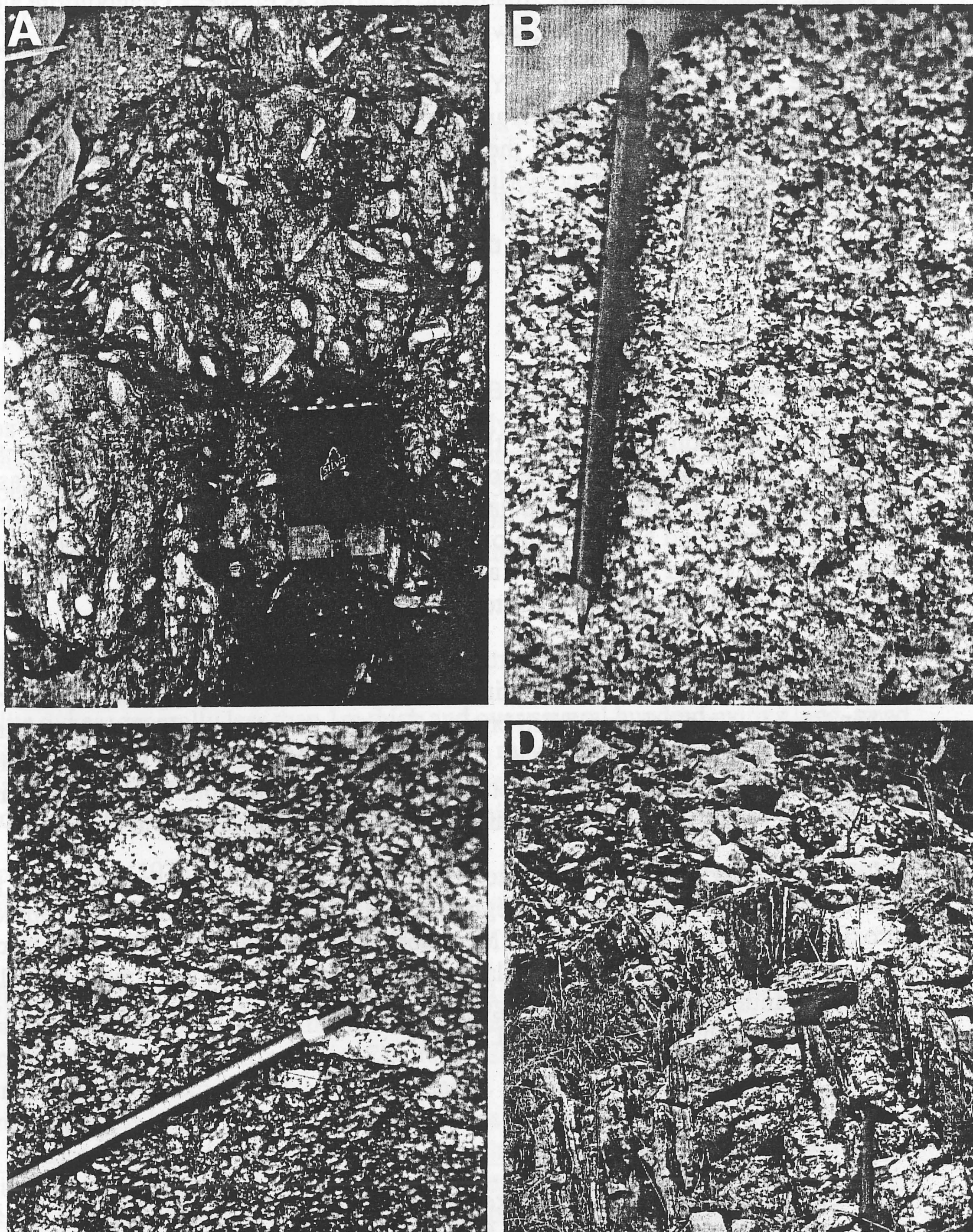
Figure 5

a) Non-aligned bunches of sillimanite in the Coen Schist (7569/288.5-448)

b) Porphyritic (zoned-KFS) coarse-grained Lankelly Adamellite (7570/422.5-534.5).

c) "Flow-aligned" feldspar with oblique quartz ribbons parallel to the pencil, Lankelly Adamellite (7569/467-416).

d) Rhyolite dyke intruded by vein quartz. A costean section of this small ridge revealed F_2 folds in the quartz vein (7569/242-598).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River (Appendix 1). The 1:250,000 map of Ebagoola (Whitaker and Gibson, 1977a) has a drafting error where Lankelly Adamellite is shown as Flyspeck Granodiorite along the Coen Shear Zone near the Port Stewart/Coen Road junction.

The three components of the Cape York Peninsula Batholith occur in close proximity in isolated outcrops along with gneiss and schist. The Flyspeck Granodiorite, the most mafic of the three, probably predates the Lankelly and Kintore Adamellites, as rafts and xenoliths of diorite and granodiorite are common in the adamellites. The correlation between these mafic inclusions and the Flyspeck Granodiorite (Trail et al., 1968, 1969) is uncertain, and it is possible that the mafic bodies may represent an as yet undefined unit.

2.2.2 Kintore Adamellite

The most common lithology of the batholith is an equigranular medium-grained muscovite-biotite adamellite. The rock is commonly deeply weathered. In areas which were previously mapped as colluvial sand around the Ebagoola Shear Zone, there are strongly sheared and altered granitoids probably representing Kintore Adamellite. The unit is mainly found in the SE, W and NW of the mapped area. It is foliated in many places, with well developed mylonites along the Ebagoola Shear Zone.

The rock comprises anhedral quartz, K-feldspar, plagioclase (twinned oligoclase or andesine), muscovite and lesser biotite. The biotite is commonly replaced by chlorite, but when fresh it is pinkish or reddish brown. Common accessories are pale pink garnet (in the leucocratic areas), zircon and apatite. Rare microcline has inclusions of mica, plagioclase and quartz. Willmott et al., (1973) considered the modal variations as a function of proportions of K-feldspar to plagioclase and muscovite to biotite.

Also mapped as Kintore Adamellite are irregular bodies, veins and dykes of garnet-muscovite granite and associated pegmatite and layered aplite. These are commonly in proximity to, or intrude the Coen Metamorphics. The "Kintore-type" (Whitaker and Willmott 1968) may prove to be a large batholith comprising a number of smaller but diverse granites with a range of ages and chemistry. The contact with the Flyspeck Granodiorite is sharp (Willmott et al., 1973).

2.2.3 Lankelly Adamellite

The Lankelly Adamellite (Whitaker and Willmott, 1968) ranges from an almost equigranular muscovite-biotite two-feldspar adamellite to a medium to coarse, highly porphyritic biotite-muscovite adamellite with large phenocrysts of K-feldspar.

Fresh exposures of this unit are common with the largest outcrops in the McIlraith Range to the east of Coen. The type area at Lankelly Creek is just east of Coen. The Coen Shear Zone partly juxtaposes the Lankelly and Coen Metamorphics to the east and north of Coen, but to the south, Lankelly Adamellite occurs on both sides of the shear zone, displaying a well developed mylonitic foliation within the zone.

The K-feldspar phenocrysts are occasionally 10 to 12 cm long, but more commonly 3 to 5 cm in length (Fig. 5b). Flow alignment is also common (Fig. 5c) and generally oriented

NNW, parallel to the mylonitic foliation. The phenocryst distribution ranges from making up the entire rock to almost absent, often over short distances. Locally, rhyolite dykes up to a few metres thick cut the adamellite. These dykes have well developed flow structures and local internal brecciation (eg. upstream from The Bend). Minor aplite dykes also occur.

The adamellite consists of quartz (generally strained), microcline, andesine, yellow to reddish brown biotite, muscovite and accessory apatite and zircon. Quartz, mica and plagioclase form inclusions in microcline. Andesine is commonly zoned and sericitized with mica along phenocryst boundaries (Fig. 5b).

2.2.4 Twin Humps Adamellite

Permian intrusions into the Cape York Peninsula Batholith are represented by the Twin Humps Adamellite in the northern part of the study area. The Twin Humps Adamellite (Whitaker and Willmott, 1968) forms the high ground north and northwest of Coen and the Coen Shear Zone comprising approximately 130 km^2 of medium-to-coarse grained, grey, equigranular to seriate (K-feldspar), hornblende-biotite adamellite. Some K-feldspar phenocrysts are pink, reflecting hematite alteration.

2.2.5 Dykes

Rhyolite dykes, generally less than 1m thick and over several hundred metres long, trend NW-SE to NNW-SSE. They are common near the major shear zones and are themselves locally strongly foliated and lineated. There appears to be a spatial link between the development of shear zones, rhyolites, quartz veining and gold mineralization.

Willmott et al., (1973) described dykes ranging from rhyolite through rhyodacite to andesite. They are commonly flow banded and consist of quartz, feldspar and accessory mica; the latter are mostly altered to chlorite.

Locally, rhyolite forms plugs, the largest of which is an elongate body 500 m wide by 4 km long which is found 10 km to the north of Yarraden and is visible on TM images. The mineralized hill of "Spion Kop" (Fig. 2), previously mapped as Flyspeck Granodiorite, is composed of brecciated rhyolite-rhyodacite bodies that intruded the Lankelly Adamellite, and is linked to the south with a series of almost N-S trending feeder-dykes (over 5 km of uninterrupted strike length). Another lens-like pod of strongly lineated rhyolite occurs 3.5 km SE of Coen and has been extensively costeaned. These rhyolitic dykes and plugs have been investigated by a number of exploration companies.

The age of the rhyolite dykes was considered to be Permo-Carboniferous by Willmott et al., (1973); new dating is planned to test this.

2.2.6 Quartz veins

Quartz veins are common near major shear zones. They form clear linear features on aerial photographs, dip steeply and trend NNW-SSE. A costean 14 km west of Coen revealed tightly folded quartz veins (in a synform) with a moderate plunge and a NNW- trending, steeply dipping axial surface (Fig. 6a). A crenulation cleavage is also associated with this fold. The quartz vein overprints a highly altered rhyolite dyke (similar to those described above) with an acute intersection.

Vein quartz has also been mylonitized together with the Kintore Adamellite along the Ebagoola Shear Zone, while later quartz veins, although principally parallel to the mylonitic foliation, have cross-cutting offshoots which post-date the mylonite (Table 3).

3. STRUCTURE

The study area is characterised by a strong NW-SE rectilinear structural grain or parallelism that has influenced all structural and metamorphic marker fabrics and minerals as well as rock types. This strong alignment produced by isoclinal folding, transposition and ductile shearing, and the steep dips hinder correlation of deformation episodes. The poor exposure and generally two-dimensional outcrop sections also hinder mapping and interpretation. The structural evolution of the Coen Metamorphics is summarized in Table 2 and that of the granitoids of the Cape York Peninsula Batholith in Table 3.

3.1 First deformation (D_1)

The dominant NNW-trending schistosity in the schists is interpreted as S_1. The "sheet-strike" seen where S_1 is little deformed by S_2 suggests that it was a steeply dipping, E-W to ENE-WSW trending schistosity (Figs. 7 and 8) prior to being folded. Type II and III fold interference patterns (Fig. 6b), coupled with the relatively steep F_2 fold plunge, also indicate that F_1 folds were originally shallow plunging. The stereonet of S_1 shows a scatter, but generally defines a steeply ENE-dipping foliation (Fig. 7). The pattern is also similar to that of the mylonites. F1 hinges are generally E-W trending while the L_1^1 stretching lineations lie within S_1 surfaces and are isoclinally refolded by F_2

F_1 fold closures are difficult to recognize in the gneiss, as the folds are isoclinal, locally transposed, have very high amplitude to wavelength ratios and are overprinted by later generations. They are identified by the above style and by the presence of melanosome phyllosilicates aligned parallel to the F_1 axial surface.

These observations are consistent with the less deformed and lower grade Sefton Metamorphics of the Mt Carter Block (Fig. 2) which represents a large scale refolded, upright F_1 structure that plunges east (Trail and Blewett 1991).

F_1 mesoscopic folds are common in the gneisses, where they fold the leucosome-melanosome layering with spectacular interference patterns developed by overprinting phases (Fig. 6c). L_1^1 lineations are generally shallowly plunging, periclinal and now trend NNW-SSE. Periclinal pitches along the gneissic layering (S_G) range up to 30^o. L_1^1 is defined by alignment of sillimanite needles and stretched quartz grains.

Boudinage of leucosome layers and granitoid pods within gneiss and migmatite is common, with discontinuous quartzo-feldspathic layers smeared out and defining the gneissic layering and foliation (S_1). Many of these boudins are folded by F_2.

Most F_1 folds are isoclinal with varying amounts of limb transposition. Locally, F_1 folds have a sheath-like geometry indicating that transposition may be, in part, a D_1 effect. The relationship between the F_1 fold axes and L_1^1 lineations is unknown.

3.2 Second deformation (D_2)

F_2 folds are generally tight and asymmetric with chevron-like hinge zones; they are S-shaped when viewed to the north (down-plunge), and the associated axial surface trends

Figure 6

a) Costean section with F_2 folded vein quartz (as 5d).

b) Type III interference patterns between F_1 isoclinal folds and tight, upright F_2 folds, Coen Gneiss (7570/405-525).

c) Coen Gneiss with asymmetrical F_2 folds overprinted by E-W kink-like F_3 folds (7569/404-486).

d) Asymmetrical S_2 crenulation cleavage in Coen Gneiss (as 6c).

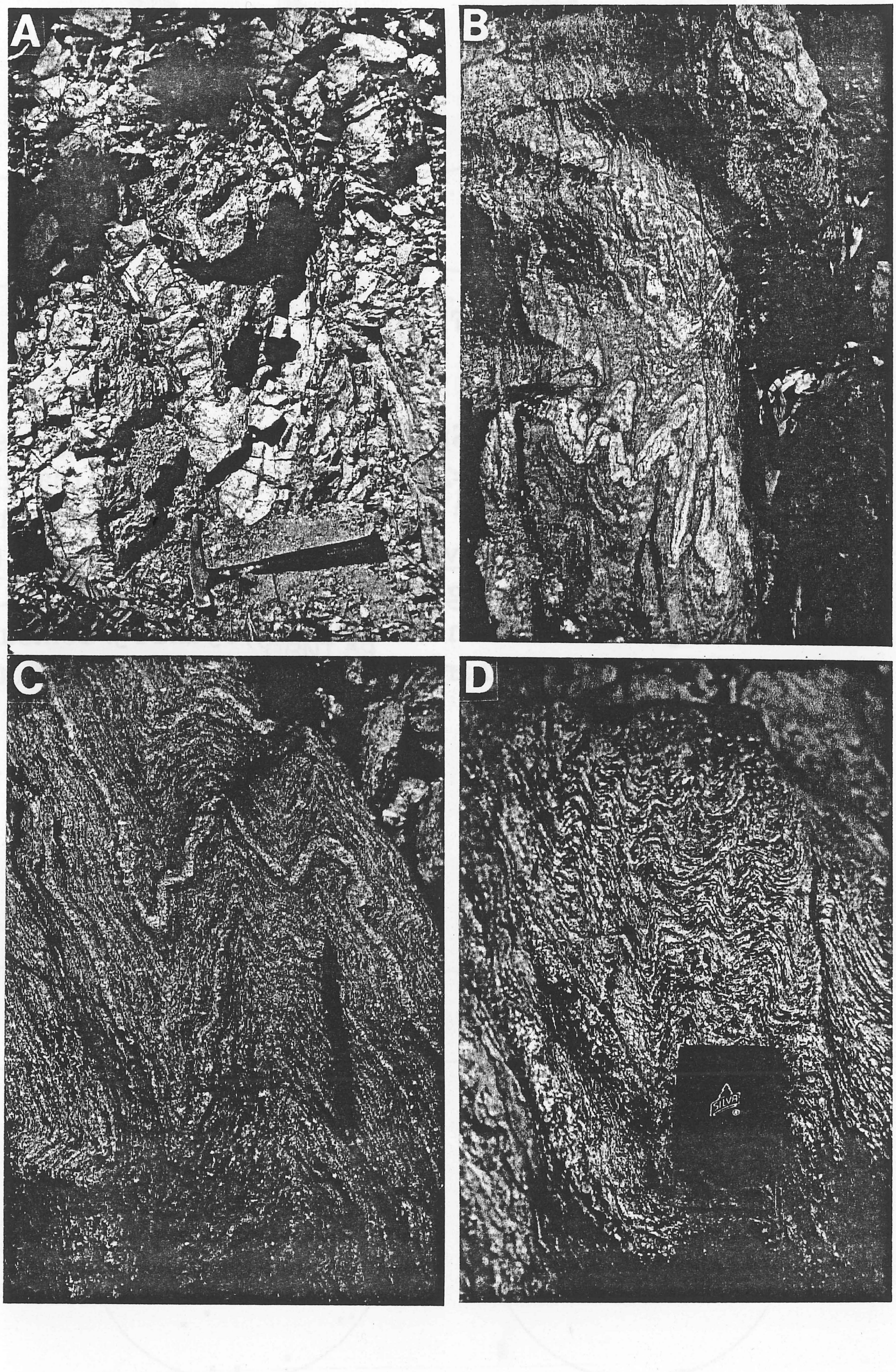

A
B
C
D

Figure 7

Poles to planes of S_1, S_2, S_M (mylonite C-plane), S_G (gneissic layering), F_2 (axial surface = circle, fold hinges of S_G = triangles, old hinges of S_1 = cross, L_2^1 = cross and square) , L_M (stretching lineations = triangles with average mylonite great circle), F_1 (L_1 stretch ing lineations = triangles and F_1 hinges = squares), GRNT (foliation in granite other than S-C mylonite), S_3 and F_3. Contoured plots are percent per 1% of area. All are lower hemisphere plots.

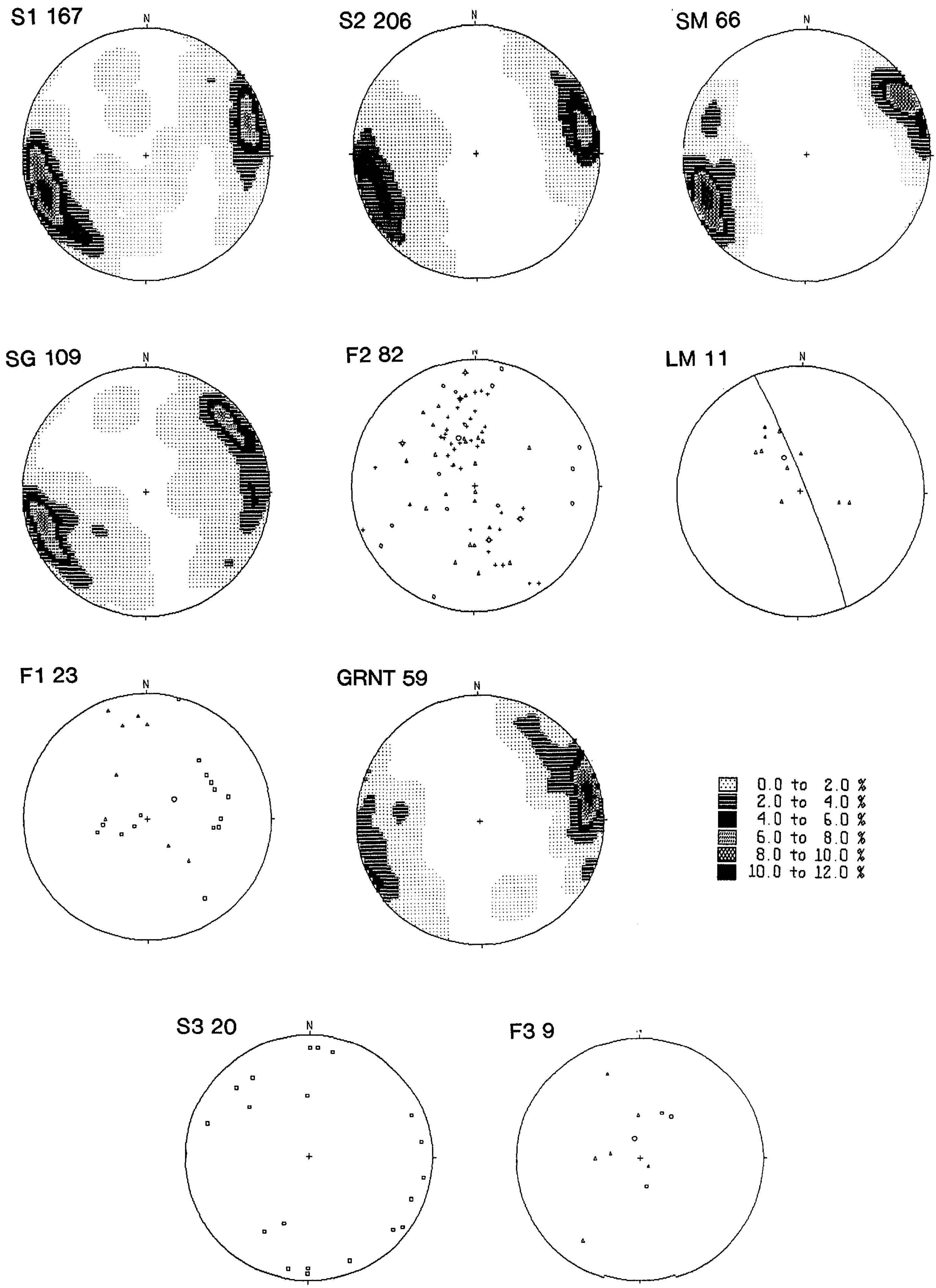

S1 167
S2 206
SM 66
SG 109
F2 82
LM 11
F1 23
GRNT 59
0.0 to 2.0 %
2.0 to 4.0 %
4.0 to 6.0 %
6.0 to 8.0 %
8.0 to 10.0 %
10.0 to 12.0 %
S3 20
F3 9

Figure 8

Diagrammatic fabric element sketch of the Coen Metamorphics.

a) Sillimanite bunches within S_1 and associated $L_1{}^1$, overprinted by S_2.

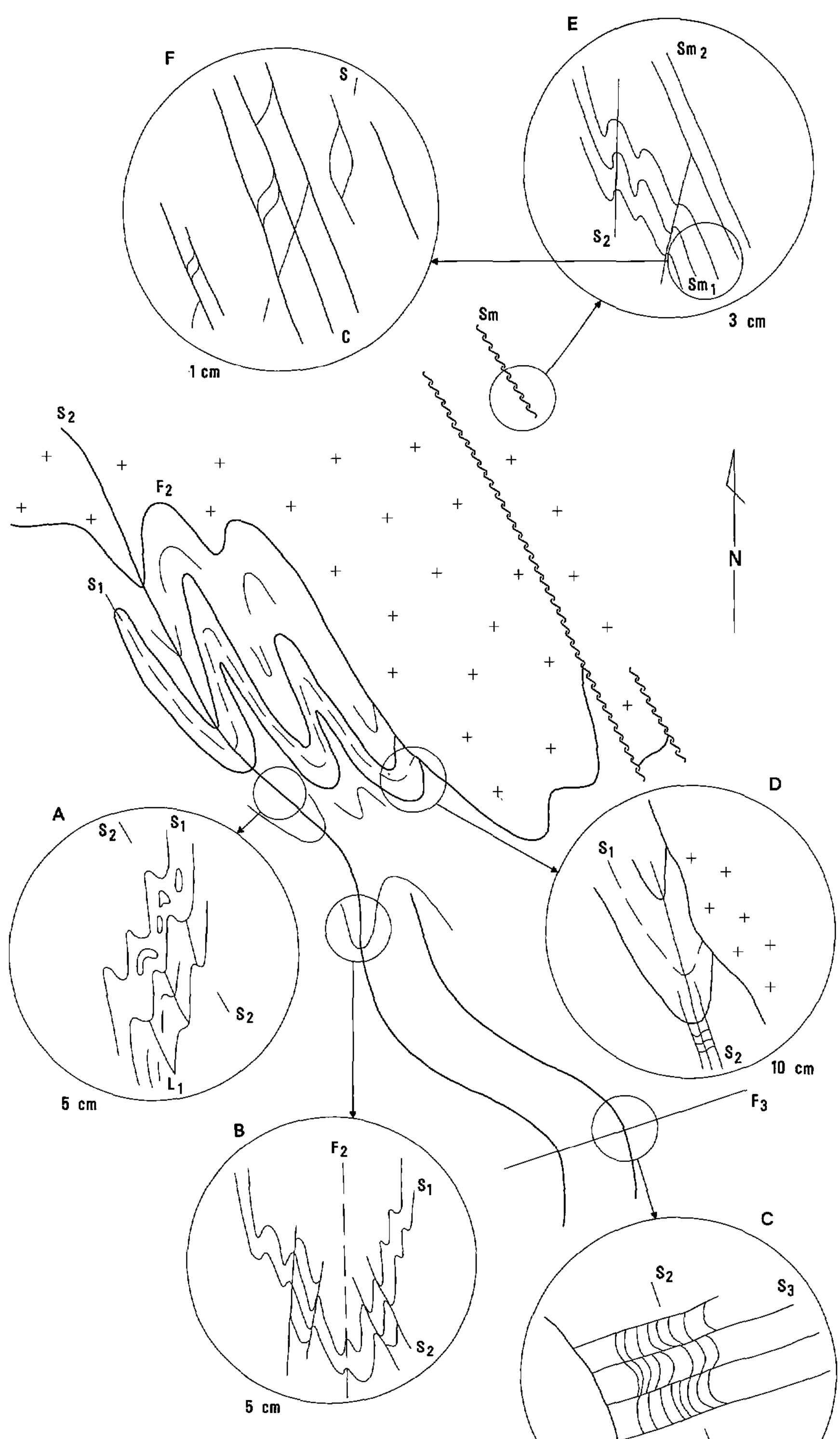
b) F_2 fold with divergent S_2 crenulation cleavage. F_2 asymmetry determines S_1 orienta tion (i.e. whether it strikes clockwise or anticlockwise of F_2).

c) ENE-trending S_3 crenulation overprint of S_2.

d) F_2 folded granite/metamorphic contact, where S_1 is cross cut by the granite.

e) Mylonite overprinted by D_2, which is in term deformed in a progressive ductile shear zone.

f) C-S mylonite showing sinistral shear sense in this section (the lineations plunge steeply, suggesting west-over-east dip-slip is the greater component).



F
S
C
1 cm
E
Sm 2
S2
Sm1
3 cm
Sm
S2
F2
S1
N
A
S2
S1
S2
L1
5 cm
D
S1
S2
10 cm
B
F2
S1
S2
5 cm
F3
C
S2
S3
S2
3 cm
0
50 m
16/Q/198

almost N-S. The resultant orientation of S_1 is NNW-SSE (Figs. 4d and 6d). In some areas, Z-asymmetric F_2 folds occur, giving rise to a more northerly trend for S_1 and a NNW-trend to S_2 (Fig 8). This change in F_2 plunge is seen in the scatter of the hinges shown in Figure 7. The average F_2 fold plunge is 52^o towards 345. The change in S_2 crenulation asymmetry suggests the presence of macroscopic F_2 closures with isoclinal fold limbs trending NNW. Macroscopic F_2 folds were not located during traverses, aerial photograph interpretation or in the Landsat TM enhanced imagery. The absence of macroscopic folds in the Coen Metamorphics is in contrast to the Holroyd Metamorphics to the west and Sefton Metamorphics to the north, where macroscopic folding (F_2) is common.

S_2 defines a consistent, steeply ENE-dipping foliation (Fig. 7). The pattern for S_2 from the metamorphic rocks is essentially parallel to the foliation pattern in the granites (Fig. 7). D_2 structures overprint the sillimanite and garnets that lie within the S_1 plane. No M_2 metamorphic marker minerals have been identified, however, chlorite is common and muscovite pseudomorphs after sillimanite may be related to D_2 retrogression. Occasional ly, the L_1^1 lineation as defined by sillimanite needles is rotated parallel to L_2.

S_2 is rare in the gneiss outcrops and the intensity and spacing varies greatly from millimetre scale, in phyllite, to several centimetres in the schist. In the gneiss, F_2 folds are tight to isoclinal, trend NNW to N and overprint isoclinal, variably oriented F_1 folds with type II and III patterns.

3.3 Third deformation (D_3)

D_3 structures are not well represented in the Coen Metamorphics and do little to deform the D_2 structural trends (Fig. 7). In the Coen Metamorphics, occasional S_3 crenulation foliations occur (Fig. 9a), but more commonly, E to NE-trending open to tight folding of gneissic layering, S_1 and S_2 foliations are recorded. There are no macroscopic F_3 folds in the Coen Metamorphics. The relationship of the D_3 structures is unclear, it is possible that there are several generations of ductile post-D_2 deformation.

F_3 folds occasionally occur as E-W to NE-SW trending open crenulations or monoclinal kinks (Fig. 6c). D_3 structures are well developed in the Sefton Metamorphics (to the north) with steeply NE-plunging, tight folds with a close-spaced, steeply-dipping axial planar crenulation cleavage (Trail and Blewett 1991).

3.4 Shear zones, mylonites and foliated granites of the Palaeozoic Cape York Peninsula Batholith

Major shear zones form discrete belts of intense deformation in NNW-SSE trending en-échelon zones up to 3 km wide. The exposed strike length of the Coen-Archer River Shear Zone is at least 150 km, and the subparallel Ebagoola Shear Zone (ESZ) is less than 100 km long (Fig. 1b). Well developed mylonites with kinematic indicators including S-C fabrics occur in narrow zones up to tens of metres wide within the shear zones. The kinematic indicators define a west-over-east sense of shear along stretching lineations that plunge moderately to steeply NW. The overall shear sense is oblique-slip and numerous kinematic indicators point to a very strong sinistral shear associated with the mylonite (Fig. 9b). Mylonites occur predominantly in the granites, hence the porphyroblasts are quartz or more commonly, feldspar. The porphyroblasts are generally of the σ-type (Passchier and Simpson 1986). Locally, vein quartz within mylonites is folded and transposed consistent with the shear sense determined from the S-C fabrics. In places, quartz veins also overprint mylonites demonstrating a number of vein generations.

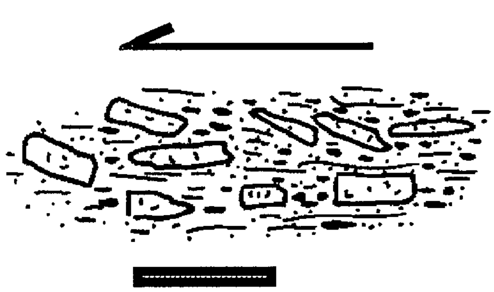
The shear zones described above dip steeply both NE and SW, and on average to ENE (86^{0} to 067). They presently have the geometry of a normal, oblique-slip, ductile shear zones. Stretching lineations with associated mylonite plunge NNW (average 65^{0} to 333) close to the calculated average mylonite surface. The stretching lineation (L_m) is defined by elongate quartz and aligned biotite. Strong L-S tectonites are visible within mylonitized rhyolite dykes that occur with the major shear zones.

Mylonites also occur in the metamorphics, with well developed S-C fabrics and asymmetrical quartz/feldspar augen suggesting sinistral west-over-east 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.

In a body of Kintore Adamellite in the Holroyd Metamorphics to the SW, a mylonite zone (the Lukin River Shear Zone) also shows a strong NNW-trending sinistral sense of shear, consistent with the Coen and Ebagoola Shear Zones to the east (Trail and Blewett 1991).

Locally, the mylonitic foliation is a composite of at least two generations of movement (all sinistral-west-over-east). The relationship between S_1 and the first mylonitic foliation is uncertain at this stage, but the mylonite is clearly overprinted by a N-S trending crenulation cleavage with an S-shaped asymmetry viewed north. The generation of this overprinting crenulation cleavage is uncertain; it is parallel to S_2 in the metamorphic rocks (Table 3). This crenulation of "SM_1" is itself strongly transposed into a second generation of mylonitization with a sinistral sense of shear. The S-shaped asymmetry and steep plunge of F_{2m} folds suggests maintenance of the sinistral shearing with a reduction of the dip-slip movement (Fig. 8). This also points to progressive deformation, where folia tions formed and were deformed in an active shear zone. The mylonitization is post sillimanite-grade metamorphism (which appears to be an M_1 marker).

The porphyritic Lankelly Adamellite provides useful shear indicators upon deformation. Quartz ribbons are commonly associated with the "rotation" of porphyroblasts. Foliation spacing in the granite varies from millimetre scale to tens of metres. The spacing reflects discrete shear surfaces and/or zones which are areas of flattening, phenocryst rotation, quartz ribboning and mica alignment.



Phenocryst alignment in the Lankelly Adamellite is generally oriented NW-SE about steeply dipping planes, suggesting a link between flow alignment and some stage of shear-zone development.

Horizontal pavement with clockwise oriented Kfs phenocrysts to the foliation.

In horizontal sections of granite pavement, the obliquity of phenocrysts to shear planes is almost

Figure 9

a) Z-asymmetrical S_3 kink bands along the Ebagoola Shear Zone (7569/334-353).

b) C-S mylonite showing sinistral shear in this section (horizontal). As above.

c) Steeply dipping, well developed foliation in the Lankelly Adamellite. Local Mylonites dissect the outcrop (7569/556-020).

d) Disharmonic F_3 folds overprinting F_1 isoclinal folds, Coen Gneiss (7570/345-575.5).

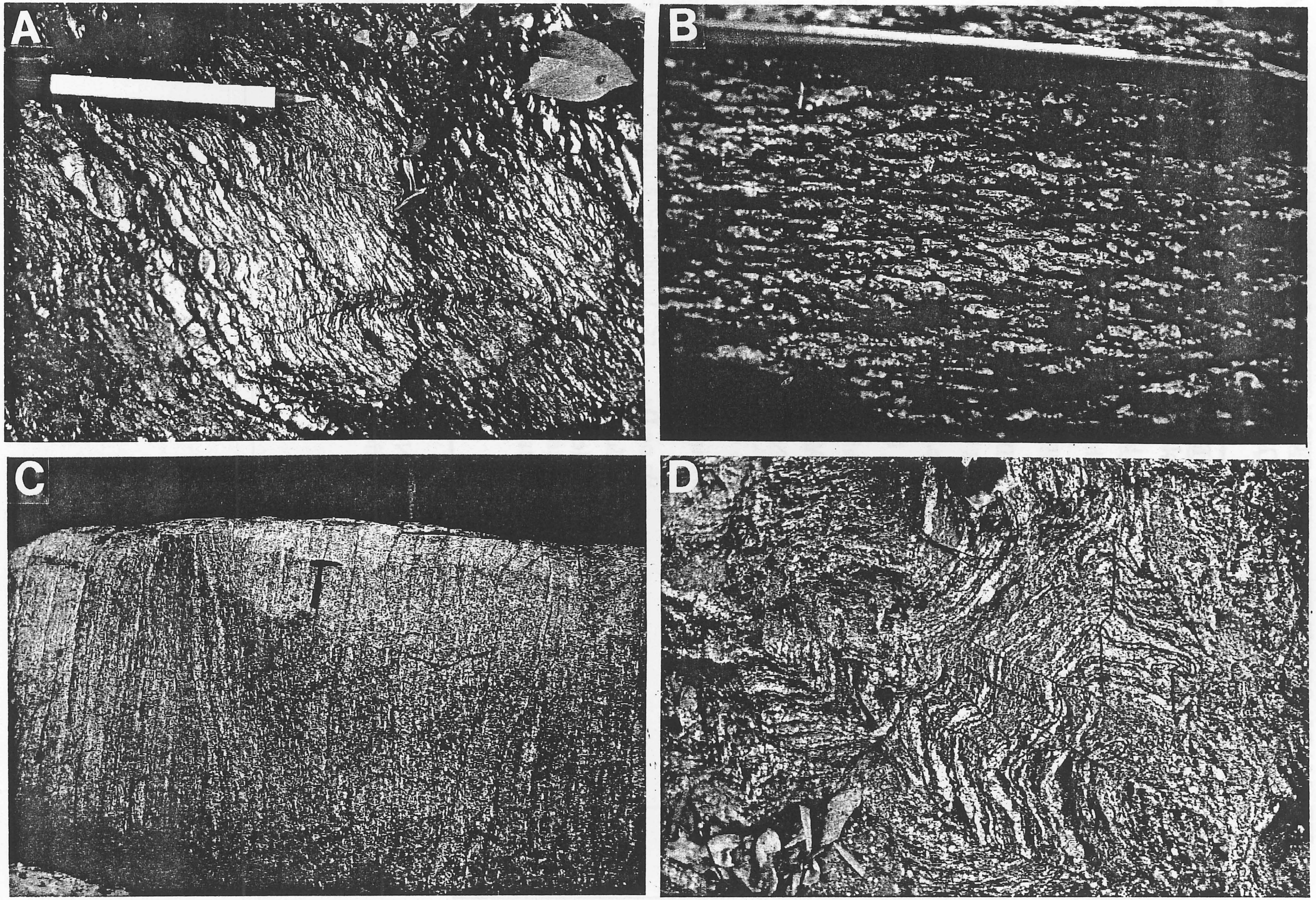

A
B
C
D

TABLE 2

SUMMARY OF PENETRATIVE STRUCTURAL ELEMENTS OF THE PROTEROZOIC COEN METAMORPHICS

	D_1
STYLE	Isoclinal, upright folds, E-W trending. Strong schistosity parallel to gneissic layering.
METAMORPHISM	Prograde to U. amphibolite.
AGE	Overprinted by Siluro-Devonian granitoids.
	D_2
STYLE*	NNW to N-trending (?), upright isoclinal folds,axial planar crenulation cleavage. N-trending generation locally overprints NNW-trending one. N-trending may be D_3. Strong transposition of D_1.
METAMORPHISM	Retrograde - Sill. - Musc. & Bi. - Chl.
AGE	Parallel to strong NNW-trending foliation in Siluro-Devonian granitoids (S_2??). N-trending folds possibly related to D_2 overprints mylonite 1.
	D_3 or D_4
STYLE	NE-trending, upright, open to tight folds. Local axial planar crenulation cleavage.
METAMORPHISM	Retrogressive ?
AGE	Post-D_2.

* Local N-trending foliation overprinting NNW-trending structures suggests that the former may be D_3. The parallelism of the folia tion in granites and S_2 and mylonites, suggest a tentative link and Devonian age for D_2.

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TABLE 3

SUMMARY OF THE DEFORMATION OF THE PALAEOZOIC CAPE YORK PENINSULA BATHOLITH

	D_1 MYLONITE
STYLE	S-C planes, asymmetrical augen, subvertical, NNW-trending. Moderate to steep lineations.
SHEAR	Sinistral west-over-east.
AGE	Overprints Siluro-Devonian granitoids.
	$^*D_2$
STYLE	Locally developed, tight to isoclinal, N-trending upright folds. Local, steeply dipping, N-trending crenulation cleavage.
AGE	Overprints quartz veins that overprint rhyolite dykes within the Siluro-Devonian granitoids.
	MYLONITE 2
STYLE	NNW-trending, rare.
SHEAR	as for mylonite 1
AGE	Overprints N-trending "S_2".

* The development of mylonites in the granites may correlate with D_2 in the metamorphic rocks. The folding of the first mylonite may correlate with the N-trending folds of D_2 or "D_3" age (see Table 2).

invariably clockwise, suggesting a sinistral component of shear upon them. Broken feldspar grains also confirm the sinistral sense of movement. In other areas, a weak foliation is developed (Fig. 9c), which is principally NNW-trending and steeply WSW-dipping (Fig. 9c). This orientation (Figs. 7 & 8) is parallel to S_2 in the metamorphic rocks. Locally, phenocryst alignment in the Lankelly Adamel lite is not parallel to the plane defined by quartz ribbons up to 2 or 3 cm long (Fig. 5c). The quartz ribboned surface represents an L-S tectonite oriented N-S, with phenocryst alignment rotated 25° clockwise relative to the surface. In the more equigranular Flyspeck Granodiorite, foliations are commonly defined by alignment of biotite grains.

The Ebagoola Shear Zone is generally less silicified than the Coen Shear Zone, although quartz veins do crop out along the former, especially between Mt Lee Bryce and the Ebagoola Gold Fields (Fig. 2). In the Coen Shear Zone, silicification is more wide spread and diffuse, and not necessarily restricted to vein material. A generation of black to smoky quartz veins are fairly common in areas along and adjacent to the Coen Shear Zone. S-C fabrics are less common in the Coen Shear Zone and the mylonites are characterised by flattened and ribboned quartz. Brittle fractures are also common along, and adjacent to, the Coen Shear Zone.

Strongly foliated and lineated rhyolite is commonly associated with the Coen Shear Zone, especially at the Hanging Rock and Homeward Bound mines, near Coen (Fig. 2). The Ebagoola Shear Zone has rare outcrops of this deformed rhyolite, although it has been noted 10 km north of the Holroyd River (Fig. 2).

Late stage kink-banding of the mylonites also shows a sinistral shear sense with the development of Z-asymmetrical kinks. Extensional shear bands locally overprint S_1 and S_G, but their regional significance is unknown.

3.5 Folded granites

The Kintore Adamellite contact with the metamorphics is locally folded about N-S oriented fold axes. These folds may be the same generation as the F_2 folds of the metamorphic rocks (Tables 2 & 3). A ductility contrast was created within a 10 m long diorite xenolith by pegmatite intrusions from a Lankelly Adamellite host. Subsequent deformation acting on this ductility contrast resulted in folding of the pegmatite about NNW to N-trending folds which may correlate with the F_2 folds in the metamorphic rocks (Tables 2 & 3). The Permian Twin Humps Adamellite shows no evidence of being deformed and there fore constrains all penetrative deformation in the Coen Inlier to pre-date the Permian.

4. METAMORPHISM

The metamorphic grade is amphibolite facies throughout the area, with sillimanite, lesser garnet, andalusite and rare kyanite as metamorphic marker minerals in the Coen Metamorphics. The presence of migmatite and leucosome in the Coen River area may indicate higher grades at this location.

Kyanite is also recorded in the south of the area, as waxy blue blades 8 to 10 cm long and 0.5 cm wide, pitching steeply within the gneissic foliation. The kyanite is pseudomorphed by muscovite.

Granite bodies (eg. Kintore Adamellite) cut the gneissic layering, the latter is defined, in part, by aligned sillimanite needles, indicating intrusion after peak metamorphic conditions which accompanied D_1.

Sillimanite porphyroblasts occur as bunches generally 1 to 2 cm long and are overprinted by the S_2 crenulation cleavage and are contained by the S_1 schistosity. The acicular habit occasionally shows a strongly preferred orientation ($L_1{}^1$). The gneissic layering formed during D_1; it is equivalent to S_1 in the schist of the Coen Metamorphics (Fig. 7). Sillimanite is generally pseudomorphed by retrogressive muscovite in bunches several centimetres long and a little fresh sillimanite is visible in thin section. Metamorphism during D_2 was largely retrogressive and probably responsible for the muscovite pseudomorphs after sillimanite, and chlorite after biotite.

Garnet, up to 2 cm across, is unevenly distributed and locally may constitute up to 20% of the gneiss. Garnet also overgrows the gneissic melanosome/leucosome layering indicating that M_1 and S_G are not coeval. Extensional shear bands also overprint the garnets; the generation of the shear bands is uncertain.

5. DISCUSSION

5.1 General structure

The Coen Inlier is dominated by a NNW-trending, steeply dipping structural grain, defined by subparallel S_0, S_1, S_2, mylonitic foliations and shear zones and to a lesser extent gneissic layering; the latter is equivalent to S_1 in the schists. Low-angle to recumbent axial surfaces (F_1 and F_2) are occasionally found, but these are probably only local in extent. Poor exposure and the prevalence of horizontal, two-dimensional outcrops mean that near-horizontal surfaces are under-represented and may be more common than observed. Original sedimentary layering is almost completely lost in the Coen Metamorphics, in contrast to the lower grade Holroyd Metamorphics to the west, where sedimentary structures are common (Trail and Blewett 1991).

5.2 Folding

No macroscopic folds were recorded in the area, which was probably a function of the lack of stratigraphic marker horizons. Granite-metamorphic contacts are poorly exposed but can be inferred to have complex shapes, possibly reflecting the folding of the contacts and is evident by the widespread foliation development in the granites. Mesoscale examples of this occur, where a Kintore Adamellite contact overprints S_1 in a schist, and the contact and S_1 are folded by N-trending, upright folds that are parallel to F_2 seen elsewhere in the Coen Metamorphics (Fig. 8). The apparent lack of macroscale folding is at variance with the Sefton and the Holroyd Metamorphics. The Coen Metamorphics differ from these latter units in that structures in the former are dominated by major shear zones. The NNW-trend of S_1 throughout the area is a function of transposition by shear zones and/or F_2 folding.

The alternation of quartzite bands and schist in the Coen Metamorphics may reflect initial sedimentary cycles, but preliminary results from the Holroyd area suggest that there are bedding sub-parallel repetitions (possibly thrusts) on long-limbed macroscopic folds (Trail and Blewett 1991).

5.3 Lineations and foliations

Lineations in the area are chiefly the result of foliation intersections, although there is a well developed, moderately to steeply NNW-plunging stretching lineation on shear zones and mylonites (Fig. 7). Alignment of acicular minerals defines a lineation locally in areas away from the shear zones. Sillimanite bunches or fine needles, commonly, define a strong lineation. Sillimanite needles within transposed S_1 are also known to plunge more steeply than the associated F_2 folds. This contrasts with the generally shallow F_1 plunges. Sillimanite needles are occasionally rotated parallel to F_2 crenulation axes. Other lineations, present throughout the area, include rodding of quartzo-feldspathic layers (L_2^2), and mullions from S_0/S_2 intersections in more psammitic schists. Lineation or rodding of the gneissic layering is predominantly shallowly and periclinally plunging.

Approximately 100 m west of the Coen Shear Zone along the Stewart River (Fig. 2), interbedded quartzite and schist crop out. In this area, a strong penetrative slaty cleavage (S_2) is axial-planar to moderately plunging, upright, F_2-folds. In the schists, S_2 is present as a crenulation cleavage, while S_1 is a bedding-subparallel foliation or schistosity which is not visible in the quartzites. S_2 in the quartzites is defined by the alignment of quartz grains and muscovite as a close-spaced penetrative cleavage. The S_1 sheet-strike is approximately E-W. A single graded bed of quartzite tentatively implies a westward-younging away from the Coen Shear Zone; this is more consistent with a thrust than a normal-fault geometry for the Coen Shear Zone at this location. S_2 is parallel to the mylonites of the Coen Shear Zone but may overprint the latter in other outcrops (as discussed above). The association between quartz veins, altered rhyolite dykes and shear zones suggests that the rhyolites were a locus of shearing and quartz vein emplacement.

5.4 Gneiss

Regional structural correlations of gneiss are tentative in this study, as they appear to be more deformed than the structurally more simple schists, although locally, schist and gneiss appear to be lithologically gradational. Several generations of gneiss are indicated both structurally and where leucosome apophyses overprint the gneissic layering. Boudinage of these leucosome layers and granitoid pods in gneiss and migmatite is common, with discontinuous quartzo-feldspathic layers smeared out and defining the gneissic layering and foliation (S_1). Many of the boudins are folded by F_2, suggesting transposition and/or shearing prior to D_2. Folding of gneissic layers is generally complex and may not necessarily follow the regional patterns of interlayered schist and quartzite. Folds may be disharmonic, transposed and/or ptygmatic. The generation of these folds (which commonly have no obvious penetrative axial-plane foliation) is uncertain but most are post-D_1. The very tight F_1 folding recorded in the gneisses implies that significant thickening of the section occurred prior to D_2.

The gneiss protolith may have been a dirty sandstone and mudstone, although there are abundant leucosome areas of granitoid gneiss indicative of a granitic source. Along the Coen River crossing of the old Pollappa Road, pegmatite sweats derived from migmatization transect amphibolite pods and overprint the gneissic layering (Fig. 4c).

Migmatites occur locally as relatively narrow zones within the Coen Metamorphics. No spatial significance between these localities and possible higher metamorphic grades associated with granite emplacement is inferred. The presence of local migmatites may indicate different host rock as migmatization can occur in amphibolite facies rocks. Willmott et al., (1973) suggest that the Cape York Peninsula Batholith was responsible for the thermal climax of metamorphism. This is clearly not the case as the climax metamorphism is D_1 in age, whereas these granites overprint D_1 deformed gneisses and schists and associated M_1 minerals.

5.5 Timing of deformation and possible correlation between the Coen and Georgetown Inliers

The Holroyd Metamorphics are at least 1400 Ma old, and possibly older according to Rb/Sr ages by Cooper et al., (1975). Cooper et al., (1975) also record a total reset of the

Coen Metamorphics at about 370 Ma. McCulloch (1987), with Sm/Nd isotopic model ages suggested the Coen Metamorphics had a source age between 2.1 and 1.9 Ga old. He obtained similar age ranges for the Einasleigh Metamorphics in the Georgetown Inlier to the south (Fig. 1). Cooper et al., (1975) dated post-metamorphic dolerites in the Yambo Inlier to the south (Fig. 1), which have possible correlatives in the Holroyd Metamorphics, as 1800 Ma old or as 2000 Ma old.

The Siluro-Devonian ages determined for the Cape York Peninsula Batholith (Cooper et al., 1974; Lance Black personal communication, 1991), indicate a period of approximately 1100 Ma of tectonic and metamorphic quiescence between the deformation of the Coen Metamorphics and granite emplacement (if the Coen Metamorphics are equivalent to metamorphics in the Georgetown Inlier). Proterozoic granites ca. 1550 Ma old such as the Esmeralda, Forest Home, Forsayth, Mistletoe and Lighthouse Granites are fairly common in the Georgetown Inlier (Black and McCulloch 1990), but appear absent in the Coen Inlier.

The Coen Inlier granites, especially the Kintore and Lankelly Adamellites, are locally strongly mylonitized and have folded contacts and crenulated mylonitic foliations that could be attributed to regional D_2. D_2 is similar in style in both the Coen (Table 2) and Georgetown Inliers (Table 4), with N-S trending, tight to isoclinal, upright folds with associated steeply dipping, axial-planar crenulation cleavages. However, the orientation of F_2 folds differs in the Coen Inlier in that they commonly trend either NNW (310) or N (360) with changes in trend being a function of mesoscale asymmetry related to larger scale fold-limb position with respect to the outcrop. In this area, rare outcrops of N-S oriented folds appear to overprint NNW-trending folds that are interpreted as F_2; thus the N-S folds may be a later generation (D_3). The N-S "overprint" is weaker and the associated folds are relatively open compared to the tight, asymmetrical F_2 folds (Figs. 7 & 9c). The dominance of S-asymmetric S_2 crenulation cleavages and F_2 folds may indicate that the Coen Metamorphics represent the eastern limb of a north-closing F_2 antiform or the western limb of a south-closing F_2 synform.

Near the confluence of Station Creek and the Stewart River, a N-S trending, S- shaped asymmetrical, steeply dipping crenulation cleavage overprints a NW-SE symmetrical crenulation cleavage, which in turn overprints an earlier foliation that is partly defined by sillimanite needles. This location indicates that the NW-SE trending foliation could be interpreted as S_2 and the N-S trending foliation as S_3; this would be consistent with the regional trends. It in turn indicates that the generally S-asymmetrical, N-trending crenulation cleavage reported elsewhere, could be S_3. However, critical N-S overprints of NNW- SEE (to NW-SE) crenulation foliations are very rare. In the field and hand specimen, it is not possible to see the predominant NNW-SSE foliation as a crenulation foliation, and overprinting of this foliation (S_1) by crenulation cleavages (S_2) are obvious (Fig. 4d).

Summary deformation chronologies for the Coen and Georgetown Inliers are outlined, respectively, in Tables 2, 3 and 4. There appear to be more differences than similarities between the two Inliers, except for the nature and timing (?) of D_1. Correlation is hindered by the uncertainty of the Rb/Sr ages of foliations in the Georgetown Inlier (Black et al., 1979) and the inability to reconcile the presence of three phases of deformation (Davis 1986) prior to regional D_2 (Withnall 1984). These are problems discussed in the footnote of Table 4.

If there were two phases of deformation prior to the emplacement of the Siluro- Devonian Cape York Peninsula Batholith, the deformation history would be more consistent with the "regional" pattern for the Georgetown Inlier (Table 3). Even if the N-S overprint of the NW-SE crenulation cleavage is D_3 in the Coen Inlier, it would be orthogonal to the E-W "D_3" (Withnall 1984) in the Georgetown Inlier. This suggests that there are several fundamental differences between the deformation history of the two Inliers. An obvious difference is the subparallelism of structural elements and intensity of major shear zones in the Coen Inlier (especially the southern half) compared to the Georgetown Inlier where deformation appears to have proceeded by orthogonal overprinting of later deformations.

TABLE 4

SUMMARY OF GEORGETOWN STRUCTURAL ELEMENTS

	D_1
STYLE	E-W to NW-trending, upright to S-verging, mostly macroscopic, tight to isoclinal. Heterogeneous. Slaty cleavage to schistosity.
METAMORPHISM	Prograde low greenschist to amphibolite.
AGE	1570 ± 20 Ma. (Black et al., 1979).
	D_2
STYLE	Tight to isoclinal, N to NE-trending, upright folds. Axial planar crenulation cleavage[1].
METAMORPHISM	Prograde greenschist (west) to granulite (east).
AGE	? 1470 ± 20[2]
	D_3
STYLE	Upright, overturned folds, E to SE-trending. Open to tight. Strong crenulations with tight folds.
METAMORPHISM	Low-grade retrogressive.
AGE	? 967 ± 28 Ma.[3]
	D_4
STYLE	Heterogeneous, mostly kinks and crenulations. Broad N-S warps. Some N to NE-trending mesoscopic folds.
METAMORPHISM	Retrogressive.
AGE	400 Ma.[4]
	$D_{5\&6}$
STYLE	5= E-trending open kink-like crenulations. 6= Upright N-trending crenulations.[5]
AGE	300 Ma. (Black et al., 1979).

[1] Davis (1986) records a composite of 3 discrete events and his 'D4' is equivalent to D2 outlined above.

[2] Black et al., (1979). The date is questionable because it is younger than the 1550 Ma. (U/Pb zircon) Forsayth Batholith (Black and McCulloch 1990), suggesting that D_1 and D_2 are not separated in time to the same degree. This is consistent with the M_1-M_2 prograde events.

[3] Black et al., (1979). The site has a strong NE-trending foliation, but few F_3 folds, and may be S_2 (Withnall 1984), and therefore represent a reset D_2 age. The doubt about the age of D_3 remains.

[4] Bell (1980) correlates with first cleavage in Hodgkinson Province. Withnall (1984), however, says this is late Devonian.

[5] Bell (1980) correlates with D_6 with late Permian Bowen Basin folds.

6. CONCLUSIONS

A chronology of deformation in the Coen Metamorphics and associated Cape York Peninsula Batholith is presented in Tables 2 and 3. Only one phase of deformation, accompanied by climax metamorphism can be clearly (regionally) identified as preceding emplacement of the Siluro-Devonian Cape York Peninsula Batholith. The development of mylonites in the major Coen and Ebagoola Shear Zones, and two or three phases of folding post-date emplacement of the batholith and indicate significant differences from the history of the much older deformation events reported from the Georgetown Inlier to the south. The major shear zones are principally dip-slip with sinistral west-over-east ductile shearing. The Coen and Ebagoola Shear Zones were the locus for gold mineralization.

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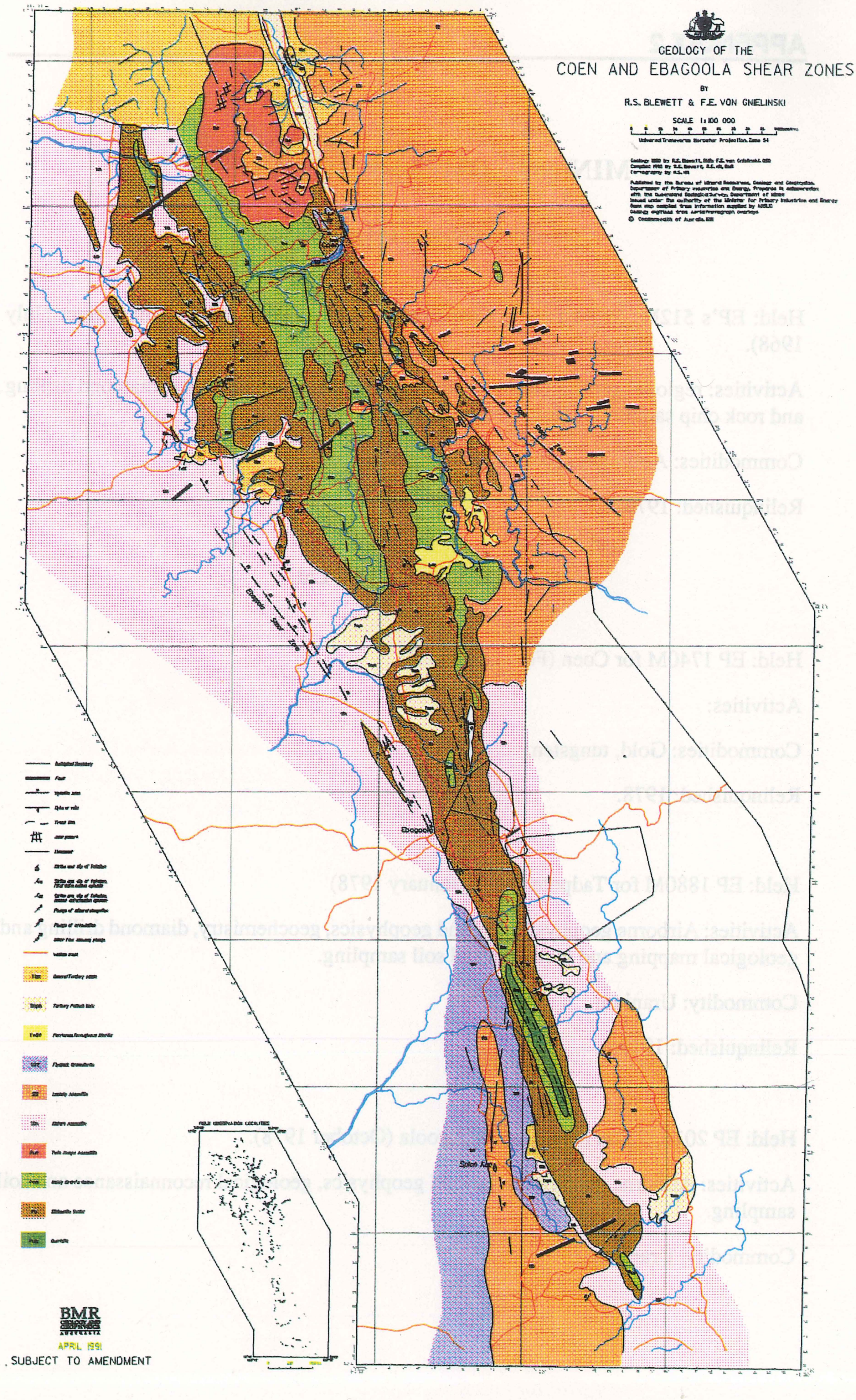
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APRIL 1991
SUBJECT TO AMENDMENT

APPENDIX 2

MINING COMPANY ACTIVITIES

Consolidated Mining Industries Ltd.

Held: EP's 512M, 520M for the Coen-Hamilton Goldfields and Coleman River (July 1968).

Activities: regional geochemical sampling, geological reconnaissance, diamond drilling and rock chip sampling of known mineralization.

Commodities: Antimony, gold, silver, copper, nickel.

Relinquished: 1970.

C.R.A. Exploration PTY Ltd.

Held: EP 1740M for Coen (February 1977)

Activities:

Commodities: Gold, tungsten.

Relinquished: 1978.

Held: EP 1880M for Tadpole Creek (January 1978)

Activities: Airborne geophysics, ground geophysics, geochemistry, diamond drilling and geological mapping and rock chip and soil sampling.

Commodity: Uranium

Relinquished: 1979.

Held: EP 2016, Spion Kop, Coen-Ebagoola (October 1978).

Activities: Airborne geophysics, ground geophysics, geological reconnaissance and soil sampling.

Commodity: Uranium.

Held: EP 2078M for Hit or Miss (October 1978).

Activities: Airborne geophysics, geological mapping and rock chip sampling for geochemical assays.

Commodities: Gold, silver, uranium.

Relinquished: 1979.

Held: EP's 2252M (Emu Creek), 2255M (Hit or Miss), 2256M (Spion Kop), 2257M (Tadpole Creek) (December 1979).

Activities: Reinterpretation of airborne geophysics, ground geophysics, and geochemistry, rotary and diamond drilling and geological mapping, rock chip, trenching, bedrock and soil sampling.

Commodities: Gold, base metals

Relinquished: 1982.

Pancontinental Mining Ltd.

Held: EP 1840M for Holroyd (1977).

Activities: Reconnaissance geological mapping, ground radiometric survey, rock chip sampling for geochemical assays (23), petrographic studies (48) and stream sediment samples (122).

A.C.A. Home Australia PTY Ltd.

Held: EP 2810M for Coen (December 1980)

Activities: Literature review, geological and metallogenic mapping, percussion and diamond drilling, rock chip, channel and stream sediment sampling for geochemical assays.

Commodities: Gold, base metals.

Relinquished: 1982.

AUGOLD N.L.

Held: EP 4058M for Leo Creek (July 1985)

Activities: Reconnaissance and detailed mapping, costeaning, rock chip and channel sampling.

Commodities: Gold, silver

Billington (Shell)

Held: Ebagoola

Activities: Rock chip sampling, trenching, percussion drilling of various old mine sites around the Hamilton Goldfields (17 holes - total length 1047 m of core).

Commodity: Gold.

Golden Era Mine Syndicate

Held: EP 3549M for Ebagoola.

Activities: Panning stream sediments and dollying reef rock chip samples, grid pitting/costeaning eluvials, core auger sampling and drilling (107 holes totaling 3250m of core).

Commodity: Gold

Relinquished: 1989.

Ross Mining N.L.

Held: EP's 3549M (Ebagoola), 4660M (Fox's Lookout), 4661M (Lukin River), 4662M (Flying Fox) (March 1988).

Activities: Bulk cyanide leach (BCL) stream sediment survey with follow-up BCL sampling and reconnaissance and detailed mapping, photolineament studies with geological interpretation, petrological studies of selected samples.

Commodity: Gold.

Tri State Mining Ltd.

Held: EP 4831M for Ebagoola (July 1988)

Activities: Geological mapping, stream sediment and rock chip sampling.

Commodity: Gold.

Granite Creek Mining Company PTY Ltd.

Held: EP'S 4742M, 4746M, 4748M, 4749M, (Ebagoola, Spion Kop, Holroyd Metamorphics).

Activities: Literature review, Landsat study, stream sediment and rock chip sampling.

Commodity: Gold.

Saracen N.L.

Held: EP's 4125M, 4241M, 4360M for Coen; EP 4445M for Ebagoola.

Activities: Aimed at veins and lode mineralization or disseminated mineralization in shear zones. Detailed literature review, regional geochemical sampling (rock chip and stream sediment), reconnaissance geological mapping.

Commodity: Gold.