COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT 128

Geology of the Ayr 1:250,000 Sheet Area, Queensland

BY

A. G. L. Paine, C. M. Gregory (Bureau of Mineral Resources)
and D. E. Clarke (Geological Survey of Queensland

Issued under the Authority of Hon. R. W. Swartz
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MINISTER: THE HON. R. W. SWARTZ, M.B.E., E.D., M.P.

SECRETARY: L. F. BOTT, D.S.C.

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SUMMARY

The Ayr Sheet area was mapped at 1:250,000 scale in 1964 by the Bureau of Mineral Resources and the Geological Survey of Queensland as part of a regional survey of the Townsville, Hughenden, Charters Towers, Ayr, Bowen, and Proserpine Sheet areas.

Most of the Sheet area is covered by alluvial, deltaic, and littoral deposits of the coastal plain, whose most important feature is the Burdekin River Delta. Plutonic igneous rocks are exposed over about 600 square miles. The mapping of the northern half of the Bowen Sheet area in 1965 and the isotopic ages obtained in 1966-67 have led to a better understanding of the age and relationships of the plutonic rocks than was possible from the Ayr Sheet area alone.

The oldest rocks are roof pendants of metasediments, most of which are believed to be Silurian or older. West of the Burdekin River the metasediments have been intruded by granodiorite which is thought to be part of the Silurian to Lower Devonian Ravenswood Granodiorite*, which underlies 2000 square miles in the Charters Towers and Townsville Sheet areas. Acid volcanics, which are correlated with Upper Carboniferous volcanics in the Townsville and Bowen Sheet areas, crop out in the southwest. Most of the bedrock east of the Burdekin River is generally contiguous with similar rocks in the Bowen Sheet area which have been dated isotopically as Upper Carboniferous and Lower Permian. Carboniferous to Permian intermediate volcanics extend southeast from Townsville into the northwestern part of the Sheet area. They are intruded by Lower Permian epizonal granites; similar granites intrude the Upper Carboniferous to Lower Permian granites and diorites east of the Burdekin River. Dyke swarms are abundant in most of the rock units.

No metalliferous deposits have been worked in the Ayr Sheet area, but nickel, copper, and molybdenum have been detected by spectrochemical analysis of rocks collected during the regional mapping. A regional geochemical survey of the Ayr Sheet area was carried out by the Bureau of Mineral Resources in 1965.

* See footnote, p. 13

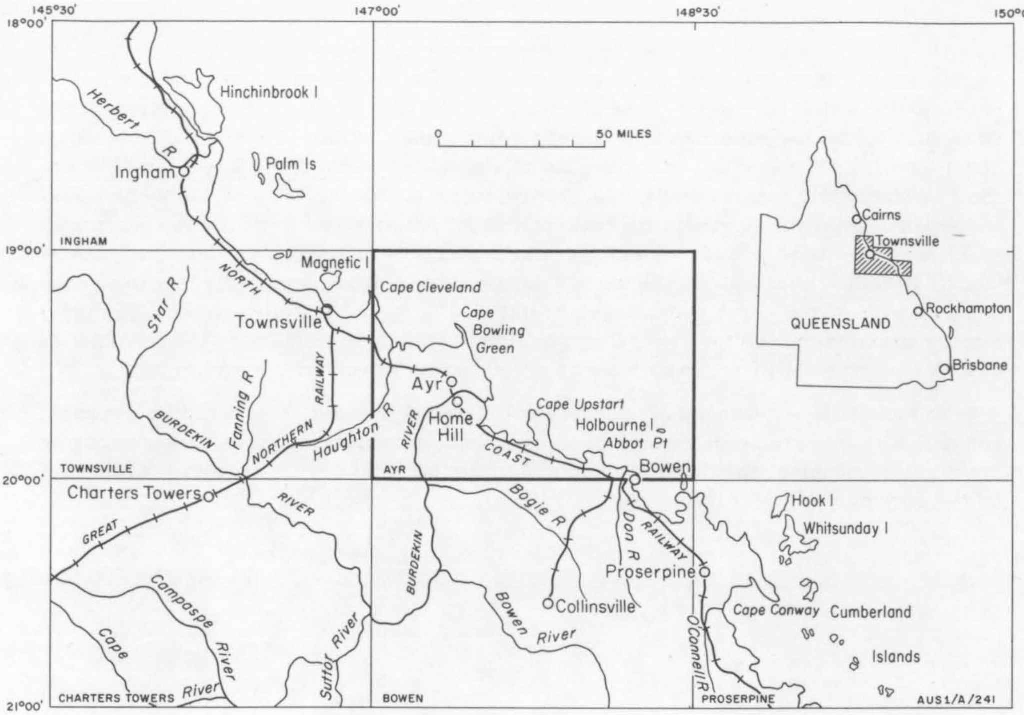

Fig. 1: Locality map.

INTRODUCTION

The Bureau of Mineral Resources in conjunction with the Geological Survey of Queensland mapped the Ayr 1:250,000 Sheet area from July to October 1964, as part of a programme of regional mapping of the Townsville/Charters Towers/Bowen region (see Fig. 1).

As a result of field work in the Bowen and Proserpine Sheet areas in 1965 (Paine et al., in prep.; Clarke et al., 1968, unpubl., and in prep.), some of the rock units initially erected (Paine et al., 1966, unpubl.) were reappraised. The plutonic rock units were further reconsidered in 1967, partly because isotopic age determinations became available. In brief, it was decided not to use the name Urannah Complex in the Ayr Sheet area, to confine the name Ravenswood Granodiorite to rocks west of the Burdekin River, and to group the more acid plutonic rocks into two main categories, 'Upper Carboniferous to Lower Permian' (C-Pg) and 'Permian to Mesozoic' (P-Mg).

The Ayr Sheet area is situated between latitudes 19°S and 20°S and longitudes 147°E and 148°E. The area is served by two towns, Ayr (population 8010)* and Home Hill (population 3217)* on the northern and southern sides of the Burdekin River respectively, and the smaller centres of Giru, Brandon, Clare, and Millaroo. The North Coast Railway and the Bruce Highway link Ayr and Home Hill with other centres of population along the coast. A sealed road follows the western side of the Burdekin River, and joins Dalbeg in the Bowen Sheet area with Ayr. In the Ayr, Home Hill, and Giru districts many miles of sealed roads serve the sugar-cane farms. Gravel roads connect the cattle stations with the sealed roads.

Access is good except for a few rugged areas and some coastal outcrops. The survey used four-wheel-drive vehicles as the main form of transport, and a launch to visit otherwise inaccessible coastal outcrops and islands. A light aircraft was used briefly towards the end of the survey for a final appraisal of the area, and for spotting outcrops in the Burdekin River.

The climate is mild and usually dry in winter, and hot and wet in summer. The annual rainfall, which is about 40 inches at Ayr, decreases away from the coast. Three-quarters of the rain usually falls between November and April, and heavy falls sometimes close all roads for short periods.

Sugar production is the main industry around Ayr, Home Hill, and Giru. In the Ayr and Home Hill districts water for irrigation is obtained from the alluvium of the Burdekin Delta. Cane farms have also been established farther upstream, wherever suitable land and water for irrigation are available. Around Giru the rainfall is just sufficient to grow cane without irrigation. Beef-cattle raising is the main industry in the rest of the area. Minor primary industries include small-scale fruit and vegetable growing, some grain and fodder production, and quarrying of 'earth lime' and rock aggregate. There is no port at Ayr, and all products are transported to markets or ports by rail or road.

Air-photographs at 1:85,000 scale, flown by Adastra in 1961, cover all the Sheet area, except for Holbourne Island and Nares Rock.

The following base maps cover the Sheet area:

4 miles to an inch	Ayr, E55-15	Australian Army	1943	Few contours
1:1,000,000	Townsville, 3219	ICAO	1958	
1:100,000	Bowling Green Bay, 8359	RASC	1967	Contour interval 100 ft
"	Ayr, 8358	"	"	"

* 1961 Commonwealth Census

"	Cape Upstart, 8458	"	1967	"
"	Abbot Point, 8558	"	"	"

Cadastral maps at 4 miles to 1 inch and 2 miles to 1 inch are published by the Department of Public Lands, Brisbane.

The planimetric base for the geological map which accompanies this Report was compiled from 1:75,000 topographic compilations supplied by the Royal Australian Survey Corps.

In 1965, A.W. Webb of the Bureau of Mineral Resources collected samples for isotopic dating from the Ayr Sheet area, mostly from the plutonic rocks, and all dates cited in this Report are the result of his work.

Acknowledgments

One hundred and sixty three thin sections were described briefly by R. Townend and A.R. Turner of the Australian Mineral Development Laboratories, and by W.R. Morgan of the Bureau of Mineral Resources. W.B. Dallwitz materially assisted in the examination of some of the thin sections.

We are indebted to the Queensland Irrigation and Water Supply Commission for the data in Appendix No. 4 on waterbores in the Burdekin River Delta. Mr W. Hickmott, of Guthalungra, freely shared with us his knowledge of mineral occurrences and interesting geological features in the Home Hill/Bowen district, and his assistance is gratefully acknowledged.

Previous and Contemporary Investigations

In 1950 the Land Research and Regional Survey Division of the Commonwealth Scientific and Industrial Research Organisation carried out a land-use survey of the Townsville-Bowen region, including the Ayr Sheet area. Their report (Christian et al., 1953) contains a brief account by D.M. Traves (BMR) of the geology of the region based on a fuller report by Traves (1951, unpubl.).

Apart from Traves' survey, no regional geological work had been carried out before the present survey by the Bureau of Mineral Resources and Geological Survey of Queensland. Mineral occurrences have been investigated from time to time. They include the graphite near Cape Upstart (Dunstan, 1921); the phosphate deposit at Holbourne Island (Saint-Smith, 1919; Reid, 1944; Young, 1944, unpubl.); the Cainozoic 'earth lime' deposits near Home Hill (Connah, 1958); and the vermiculite and asbestos occurrences near Home Hill (Carruthers, 1954).

In recent years, much attention has been devoted to the study of the groundwater potential of the Burdekin River Delta (Irrigation and Water Supply Commission, Queensland, 1964, unpubl.). Watkins & Wolff (1960, unpubl.) reported on the geology of the delta and its neighbourhood. More recently, at the request of the Queensland Irrigation and Water Supply Commission, the Bureau of Mineral Resources carried out extensive geophysical investigations to determine the structure and distribution of the sediments in the delta, the movement of groundwater, and the behaviour of the interface between fresh water and salt water (Andrew & Wainwright, 1964, unpubl.; Andrew et al., 1965; Wiebenga et al., 1966, unpubl.).

In 1964, three geologists, J.M. Coleman, S.M. Gagliano, and W.G. Smith from Louisiana State University, USA, surveyed the Quaternary sediments of the coastal plain between Cape Cleveland and Cape Upstart to obtain information on deltaic sedimentation, with special reference to petroleum exploration.

In 1963 the Bureau of Mineral Resources carried out a reconnaissance helicopter gravity survey (Darby, 1966, unpubl.) of the northern part of the Bowen Basin and the Ayr Sheet area.

In 1965 the Bureau of Mineral Resources carried out a regional geochemical survey of the Sheet area (Marshall, 1967, unpubl.). Samples were collected from stream sediments, soils, and rocks.

PHYSIOGRAPHY

The Ayr Sheet area contains five main physiographic units: coastal plain, isolated hills, areas of low hills, a feature called the Plumtree 'plateau-basin', and rugged hills (Fig. 2). The mud flats, salt pans, mangrove swamps, and coastal sand dunes together form a subunit of the coastal plain.

The coastal plain covers most of the land surface. The plain is flat to gently undulating. The watercourses are generally steep-sided, and the Burdekin River is incised in places down to 80 feet below its levees. Most of the plain consists of alluvial and deltaic deposits.

The coastal plain includes a few steep isolated hills, most of which form prominent landmarks, rising abruptly from the plain.

The areas of low hills surround the Plumtree 'plateau-basin', and occupy the southwest corner of the Sheet area. The land surface ranges from open undulating country to small areas of rough hilly terrain with a local relief of up to 500 feet. There is a sharp break between the areas of low hills and the coastal plain.

The name Plumtree 'plateau-basin' is used to describe a remnant of a southerly directed mature drainage basin (Plumtree Creek) which has been truncated on its western, northern, and eastern sides by the headwaters of more youthful streams which flow radially outwards from it. The surface of this feature is a mature gently undulating erosion surface which slopes gently southwards. The northern and eastern sides are bounded by irregular scarps 100 to 200 feet high; the western margin, although scarp-like locally, is poorly defined and, like the southern margin, merges with the base level of the creeks which drain the areas of low hills. The northern part of the Plumtree 'plateau-basin' is a low plateau, but the southern half is basinal in relation to the bordering hills.

The rugged hills occur as isolated ranges which rise steeply to between 1500 and 3000 feet above sea level. The summit of Mount Elliot, just west of the Sheet area, is 4025 feet above sea level. Deep straight fault-controlled ravines have been eroded in the Cape Cleveland, Saddle Mountain, and Cape Upstart ranges (Fig. 9). The Cape Cleveland and Cape Upstart ranges are peninsulas, connected to the mainland only by sand dunes and mud flats.

Much of the area is drained by short coastal streams that commonly merge with the tidal areas or broaden out and lose their identity in the plains adjacent to the coast. The Burdekin River is by far the largest watercourse in the Sheet area, but it drains only a relatively small part of the area.

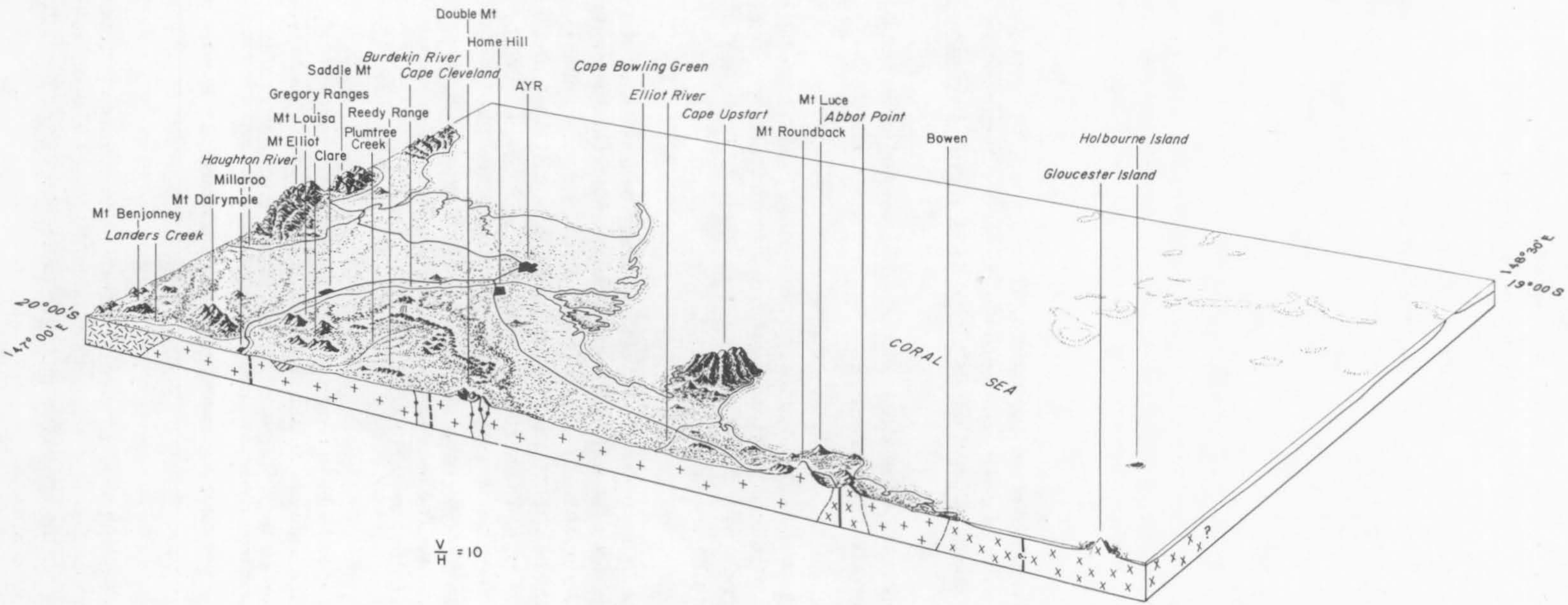

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Fig. 2: Physiography (block diagram).

EARLY PALAEOZOIC

The Palaeozoic rock units are summarized in Table 1.

METAMORPHICS (Pzu)

Remnants of a metamorphosed arenite-siltstone sequence which is intruded by granodiorite correlated with the Ravenswood Granodiorite crop out in the southwest. The sediments have been dynamothermally metamorphosed to the quartz-albite-muscovite-chlorite subfacies, and locally to the quartz-albite-epidote-biotite subfacies of the greenschist facies. The metamorphic regime was not a regional one in the generally accepted sense as the dynamic and thermal metamorphism was related to intrusions and fault zones.

If the granodiorite which intrudes these rocks is part of the Ravenswood Granodiorite then they are Silurian or older. They are regarded as broadly equivalent to the Cape River Beds of the Charters Towers Sheet area and to unnamed metamorphics (Pzu) in the southeastern part of the Townsville Sheet area.

Hornfelses, some of which are also metamorphosed arenites and siltstones, crop out near Guthalungra, where they are intruded by Upper Carboniferous to Lower Permian granites. Their age is unknown, but they could be as young as late Palaeozoic.

Topography

In the southwest the largest occurrence of metamorphosed sediments is an irregular area of about 4 square miles 5 miles southwest of Mount Woodhouse. In places the metasediments form a range of hills rising about 400 feet above the surrounding alluvium-covered Ravenswood Granodiorite. Similar metamorphosed sediments form steep ridges a few hundred feet high 2 miles west of Mount Benjonney. Low outcrops occur just west of Landers Creek homestead, and in the bed of the Burdekin River near Millaroo.

Similar rocks crop out in the hills northwest of The Cape homestead. They have been intruded by Carboniferous to Permian granite; the contact is very irregular and has been simplified on the map. Metasediments also crop out to the west of the Seven Sisters, and there is a small spur of andalusite quartzite to the west of the Bruce Highway, half a mile southeast of Clevedon railway siding.

Lithology and Metamorphism

Five miles southwest of Mount Woodhouse the low-grade dynamothermally metamorphosed sediments comprise coarse to medium-grained micaceous sandstone, well sorted subarkose, poorly sorted micaceous pebbly sandstone, micaceous silty arenite, and pebble conglomerate. Oligomictic cobble conglomerate, quartzite, subarkose, and thinly bedded carbonaceous siltstone crop out 2 miles northwest of Mount Benjonney. The cobbles in the conglomerate consist of quartz porphyry, quartz-feldspar porphyry, biotite schist, quartzite, and fine-grained amphibolite. The sediments form a roof pendant on the Ravenswood Granodiorite, and were further metamorphosed by the granodiorite (C-Pg) immediately to the east.

The sediments southwest of Mount Woodhouse also form a roof pendant on the Ravenswood Granodiorite, and have been thermally and dynamically metamorphosed. Metamorphic grade is higher where the roof pendant is thinner, as for example, in the headwaters of Sandy Creek, where metamorphosed siltstone and quartz-chlorite-sericite-muscovite schist crop out. The metamorphosed siltstone consists of subspherical aggregates of silt-size quartz, chlorite, and muscovite surrounded by an intensely foliated groundmass of muscovite, rare sericite, and quartz grains. Similar metamorphics crop out in the southeastern part of the Townsville Sheet area.

TABLE 1. PALAEOZOIC STRATIGRAPHY AND IGNEOUS ACTIVITY

(includes some possibly Mesozoic granites)

Period or Epoch	Rock Unit and Map Symbol	Lithology	Topography	Relationships	Structural/Depositional Environment	Remarks
PERMIAN TO MESOZOIC	(P-Mg)	Leucocratic adamellite and granite; granophyre, syenite, and rhyolite porphyry; rare intermediate and basic rocks	Rugged hills and mountains up to 3000 ft above sea level; some small hills; Holbourne Is	Youngest plutonic bodies; intrude U Carboniferous/ L Permian volcanics (C-Pv) and granites (C-Pg)	Epizonal stocks, some of which may be ring complexes	Rarely intruded by dykes
	(P-Md)	Gabbro, diorite, dolerite	E part of Holbourne Is (300 ft asl); other small outcrops at sea level along coastline	Probably older than Permian/Mesozoic granites (P-Mg), but in places may be essentially contemporaneous (net-veined complexes)	Mainly small marginal slivers around stocks (P-Mg); probably early differentiates of 'P-Mg' magma	Size of outcrops (except on Holbourne Is) exaggerated on map
	(P-Mv)	Hornfelsed siliceous tuff or tuffaceous sediments	Nares Rock, 20 ft high 200 ft in diameter	Unknown	Unknown	

UPPER CARBONIFEROUS TO LOWER PERMIAN

(C-Pv)	Intermediate lavas and pyroclastics; minor acid volcanics	Uneven slopes and foothills adjoining Saddle Mt and Mt Elliot; steep narrow Cape Cleveland promontory	Intruded by Permian/ Mesozoic granites (P-Mg); continuous with <u>Glossopteris-bearing</u> volcanics near Townsville; correlated with Lizzie Creek Volcanics (Bowen Sheet)	Generally structureless except at Cape Cleveland, where dip is consistently SE; abundant coarse pyroclastics indicate local derivation	Maximum thickness 4000ft at Cape Cleveland; elsewhere thickness unknown; strongly epidotized in places
(C-Ph)	Rhyolite, trachyte, trachyandesite	Steep high hills with cliffs in places; Mt Louisa	Intrudes Carboniferous/ Permian granite (C-Pg)	Plug with some extrusive phases; vertical flow banding	
(C-Pg)	Adamellite, granite, some granodiorite; minor fine-grained variants	Coastal inselbergs up to 700 ft; uneven hills, in places quite rugged; uneven undulating country, with some prominent dyke ridges	Intrudes Carboniferous/ Permian diorite (C-Pd) and U Carboniferous volcanics (Cuv); relationship to Carboniferous/Permian volcanics unknown, but latter probably younger; small roof pendants near The Cape homestead	Sheared or foliated in places	Age postulated mainly by analogy with contiguous granite in Bowen Sheet
(C-Pd)	Diorite, quartz diorite, tonalite, gabbro, norite; minor granodiorite, adamellite, and granite	Undulating rises, uneven hills, dyke ridges S of Home Hill; inselbergs up to 900 ft high; low-lying country S of Guthalungra; roof pendants near summit of Mt Roundback	Intruded by Carboniferous/Permian granite (C-Pg) and by Permian/Mesozoic granite (P-Mg); small roof pendants near Guthalungra	Sheared or foliated in places; primary layering in places	Age postulated mainly by analogy with similar rocks in Bowen Sheet; may include undetected roof pendants of Ravenswood Granodiorite S of Home Hill

UPPER CARBONIFEROUS	(Cuv)	Flow-banded rhyolite, massive welded tuff; minor andesite and andesite tuff	Rugged range (Mt Dalrymple), small hill (Mt Woodhouse)	Intruded by Carboniferous/Permian granite (C-Pg); correlated with Ellenvale Beds (Townsville Sheet) and Bulgonunna Volcanics (Bowen Sheet)	Fault-controlled; Mt Dalrymple is a downfaulted block	Horse Camp Hill is SE limit of Ellenvale Beds which thereafter become 'Cuv' (see text)
	Ellenvale Beds (Ce)	Flow-banded rhyolite, rhyolite breccia, andesite	Prominent hill (Horse Camp Hill) above 700 ft high	Not seen in Ayr Sheet area; continues into Townsville Sheet where, in type area, it is late M to U Carboniferous	Fault-controlled	
UPPER DEVONIAN(?)	(Pzj)	Strongly hornfelsed calcareous cobble and pebble conglomerate; some interbeds of calcareous quartzite	Charlies Hill, 1200 ft by 700 ft	Isolated inlier in Burdekin R Delta; strongly resembles conglomerate of U Devonian Dotswood Formation (Townsville Sheet)	Cross-beds indicate that beds have been overturned	Phenoclasts of quartz, marble, and gneissic diorite

SILURIAN TO LOWER DEVONIAN	Ravenswood Granodiorite	(S-Da)	Biotite granite, leucocratic adamellite	Steep hills, low rises	Not known in Ayr Sheet area; in Townsville Sheet intrudes granodiorite phase (S-Dr) and is overlain nonconformably by M Devonian sediments	Late acid phase of batholith	Photo-interpreted extensions from Townsville and Bowen Sheets
		(S-Dr)	Deeply weathered hornblende-biotite granodiorite; minor adamellite, quartz diorite, diorite, and alkali granite	Low-lying, poorly exposed	Intrudes early Palaeozoic metamorphics (Pzu) at Barrata Cr; overlain unconformably by U Carboniferous volcanics (Cuv)		E limit of large batholith which caused widespread 'regional/contact' metamorphism
EARLY PALAEOZOIC		(Pzu)	Schist, phyllite, quartzite, hornfels; weakly metamorphosed subarkose, conglomerate, and carbonaceous siltstone	Hills, small steep ridges, low rises	Intruded by Ravenswood Granodiorite and younger plutonic units	Roof pendants, dynamothermally metamorphosed sediments and minor igneous rocks; metamorphism and folding related to intrusions and faults rather than to orogeny; bedding and cleavage attitude appear to lack regional control	Probably at least partly equivalent to Cape River Beds of Charters Towers Sheet; outcrops near Guthalungra and The Cape homestead may be as young as L Permian

The metamorphosed sediments near the margins of the roof pendant include various assemblages of the quartz-albite-muscovite-chlorite subfacies of the greenschist facies. They are chiefly poorly foliated chlorite-muscovite-sericite-quartz schist. Only at the thinner southeastern end of the roof pendant is the schistosity sufficiently well developed to be clearly visible in hand specimen. Recrystallization has generally been confined to the matrix of the sediments, especially towards the northwest, where thermal effects are weakest.

Half a mile west of Landers Creek homestead strongly foliated quartz-chlorite-muscovite-sericite schist, quartz-chlorite-sericite-muscovite schist, and black schistose argillite form an isolated rise above the alluvium bordering Landers Creek. The meta-sediments appear to lie in a shatter zone associated with strong faulting. The spotted sericite schist and metamorphosed pebbly arenites exposed in the bed of the Burdekin River a little to the east also lie in this zone.

The metamorphics northwest of The Cape homestead have been intimately intruded and hornfelsed by granite, tonalite, and gabbro (C-Pg, C-Pd). They include a variety of hornfelses, some of which are moderately high in grade: biotite-alkali feldspar-quartz hornfels; epidote-hornblende-andesine-quartz hornfels; garnet-biotite-albite-potash feld-spar-quartz hornfels; garnet-biotite-microcline-plagioclase-quartz hornfels; biotite-quartz-sericite hornfels; biotite-andalusite-quartz-sericite hornfels; andalusite-biotite-muscovite-oligoclase-quartz hornfels; andalusite-biotite-sericite-quartz hornfels;and fer-ruginous biotite-cordierite-chiastolite-quartz schist.

The biotite-alkali feldspar-quartz hornfels, epidote-hornblende-andesine-quartz horn-fels, garnet-biotite-albite-potash feldspar-quartz hornfels, and garnet-biotite-microcline-plagioclase-quartz hornfels are strongly foliated, and in places they are coarse-grained and gneissic in texture. They crop out on the southern slopes of a southwesterly trending ridge, 1 mile west-southwest of The Cape homestead. They resemble granodiorite, and in places the foliation is intricately folded. Rare spherical aggregates of epidote, quartz and hornblende, up to 3 cm in diameter, which developed later than the foliation, occur in the foliated rocks. The hornfelses are all close to a contact with garnetiferous ton-alite, which is also foliated in places. The contacts are generally sharp, or gradational over a few inches. The biotite-alkali feldspar-quartz hornfels may be a metamorphosed rhyolite or microgranite with relict phenocrysts of quartz, sodic plagioclase, and biotite. The epidote-hornblende-andesine-quartz hornfels is possibly a metamorphosed calcareous and aluminous sandstone; some of the andesine and hornblende have been partly replaced by epidote. The garnet-biotite-albite-potash feldspar-quartz hornfels contains a few partly recrystallized megacrysts of albite, which suggests that the original rock was an acid porphyry. The rare colourless garnet (probably almandine) has been partly replaced by biotite and chlorite, and knots of biotite flakes may also represent altered garnet. The garnet-biotite-microcline-plagioclase-quartz hornfels contains garnet porphyroblasts in the coarser (0.5 mm) layers. The main metamorphism of the hornfelses was probably caused by the gabbro (C-Pd) and the later retrograde metamorphism of plagioclase and hornblende to epidote was probably caused by the tonalite (C-Pg).

Dark grey biotite-quartz-sericite hornfels forms the southwestern end of a spur $1\frac{1}{2}$ miles west-southwest of The Cape homestead. The banding presumably represents bedding. In places the rock is cleaved by sericitic parting planes. The hornfels is composed of amoeboid quartz grains (30%), aggregates of fine sericite flakes pseudomorphing feldspar or andalusite (?), and randomly oriented chloritized biotite.

The biotite-andalusite-quartz-sericite hornfels, andalusite-biotite-muscovite-oli-goclase-quartz hornfels, and andalusite-biotite-sericite-quartz hornfels crop out as thin roof pendants and large xenoliths in granite in the centre of the range which extends for several miles west of The Cape homestead. The biotite-andalusite-quartz-sericite hornfels contains tabular porphyroblasts of partly sericitized andalusite. It is probably a more strongly metamorphosed version of the biotite-quartz-sericite hornfels. The andalusite-biotite-muscovite-oligoclase-quartz hornfels was probably a tuff. It contains 50 to 60 percent inequigranular (0.03-4.0 mm) anhedral crystals of recrystallized quartz and tabular slightly recrystallized twinned oligoclase set in a matrix of fine biotite and muscovite, with some granoblastic quartz and feldspar; groups of partly sericitized crystals of andalusite are present in places. Both rocks are dark blue-grey, dense, and flinty.

A fragment of ferruginous biotite-cordierite-chiastolite-quartz hornfels was found in the valley between this range and the mountains to the north. It is a dark brownish black fine-grained rock with a resinous lustre, and contains numerous small euhedral pinkish brown crystals of chiastolite. Two kinds of porphyroblasts are present: crystals of chiastolite with their long axes in the plane of schistosity, and xenoblastic crystals of cordierite(?) containing many inclusions of iron oxide. Parts of the cordierite crystals are in optical continuity with neighbouring crystals of altered chiastolite which they appear partly to replace. The xenoblastic cordierite is unusual in that it is uniaxial or biaxial negative with a small optic axial angle. The fine-grained matrix consists of ferruginous biotite, iron oxide dust, and quartz.

A piece of blastomylonite was found on the southern slopes of the range west of The Cape homestead. The matrix has a grainsize of 0.01 to 0.03 mm, and consists of amoeboid grains of plagioclase (probably labradorite), prismatic to granular pale brownish green amphibole, and granules of iron oxide. The poikiloblastic porphyroblasts of almost colourless clinopyroxene are about 0.3 mm in diameter. There are a few residual megacrysts of clinopyroxene and orthopyroxene. This rock is probably a gabbro which has been mylonitized and subsequently thermally metamorphosed; the criss-crossing veinlets and porphyroblasts of clinopyroxene were probably formed at the same time.

Biotite-quartz-sericite hornfelses similar to some of the hornfelses west of The Cape homestead form undulating rises immediately west of the Seven Sisters. They have been intruded by tonalite (C-Pd) and by the granite of the Seven Sisters (C-Pg). They are fine-grained brownish red and brownish green impure arenites. Cleavage has been developed in the fine-grained interbeds.

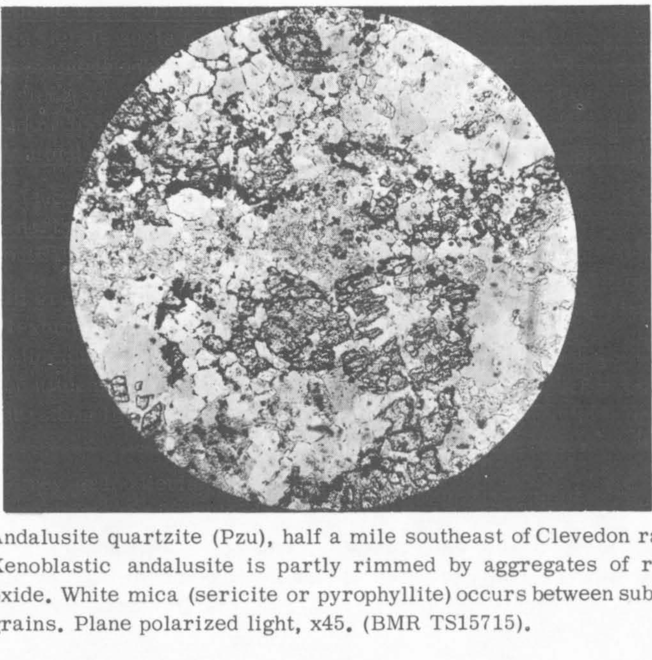

Fig. 3: Andalusite quartzite (Pzu), half a mile southeast of Clevedon railway siding. Xenoblastic andalusite is partly rimmed by aggregates of rutile and iron oxide. White mica (sericite or pyrophyllite) occurs between subhedral quartz grains. Plane polarized light, x45. (BMR TS15715).

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A small spur of andalusite quartzite (Fig. 3) abuts against the northeastern foot of the Saddle Mountain granite (P-Mg), half a mile southeast of Clevedon railway siding. Xenoblastic grains of andalusite form up to 20 percent of the rock; most of them have an alteration rim of sericite or pyrophyllite, and in places the mica has completely replaced the andalusite. The quartzite is even-grained: individual quartz grains range from 0.05 to 0.1 mm, and the largest andalusite crystals measure 0.4 by 0.2 mm. The rock is rich in aggregates of rutile and opaque minerals which do not seem to be detrital.

Structure and Thickness

In the west, the sediments are well bedded, and southwest of Mount Woodhouse they dip at moderate to steep angles to the north-northeast, except for reversals near the Woodhouse Fault. The preserved thickness of the sediments is estimated at 6000 feet. Graded bedding is apparent in thin section, and rare cross-bedding was observed in outcrop. The sediments of the roof pendant southwest of Mount Woodhouse have been faulted in two principal directions. The Woodhouse Fault trends southeast, and is marked by a wide zone of silicified sandstone and breccia, which has been displaced by later dextral wrench faults. Many smaller faults are indicated by areas of intense quartz veining.

The roof pendant northwest of Mount Benjonney is complexly faulted, and appears to be a resistant remnant preserved by the hornfelsing associated with the granodiorite (C-Pg) immediately to the east.

Foliation, cleavage, and relict bedding are visible in different places in the hornfelses west of The Cape homestead. The cleavage and bedding strike east-southeast to southeast. Near the Seven Sisters, where the cleavage and bedding probably coincide, the strike is roughly the same as in the hornfelses west of The Cape homestead.

Age and Relationships

The metasediments southwest of Mount Woodhouse are intruded by poorly exposed granodiorite which is correlated with the Silurian to Lower Devonian Ravenswood Granodiorite. The contacts are both faulted and intrusive; the granodiorite, masked by alluvium, crops out in gullies along the southern boundary of the metasediments. The metasediments are also intruded by rhyolite, quartz porphyry, felsite, and feldspar porphyry dykes. The metasediments are probably early Palaeozoic and are tentatively correlated with the Cape River Beds which commonly form the country rock around the Ravenswood Granodiorite in the Charters Towers Sheet area (Wyatt el al., 1967, unpubl., and 1970b.). However, it is possible that the cobbles in the conglomerates were derived from the Cape River Beds or their equivalents, and that the granodiorite is late Palaeozoic.

The age of the hornfelses in the Guthalungra/Cape homestead district is uncertain. They are intruded by gabbro and granite, which are probably Upper Carboniferous or Lower Permian, and are unlikely to be younger than Carboniferous.

Mineralization

A few small costeans have been bulldozed in the hornfelses west of the Seven Sisters. It is not known whether they were made in the search for minerals or for road-making materials. Early this century a small shaft was sunk in graphitic hornfels 2½ miles west of The Cape homestead.

RAVENSWOOD GRANODIORITE (S-Dr and S-Da)

The poorly exposed granodiorite in the southwestern corner of the Sheet area is tentatively regarded as part of the Ravenswood Granodiorite, a large and complex batholith which is exposed over about 2000 square miles in the Charters Towers and Townsville Sheet areas. Isotopic age determinations indicate a Silurian age for the batholith, but it may range into the early Devonian*.

Two main phases have been recognized in the Charters Towers and Townsville Sheet areas: an earlier granodioritic phase (S-Dr), and a later more leucocratic phase (S-Da). In the Ayr Sheet area, the granodioritic phase consists chiefly of hornblende-biotite granodiorite, adamellite, quartz diorite, and minor alkali granite. The rocks are deeply weathered and eroded, and largely covered by soil. Two small areas of the later more leucocratic phase have been photo-interpreted from adjoining Sheet areas: the outcrop south of Horse Camp Hill forms a steep east-northeasterly ridge and the outcrop south of Mount Benjonney forms low hills and rises.

UPPER DEVONIAN(?)

CALCAREOUS HORNFELS (Pzj)

The calcareous hornfelses at Charlies Hill, about 4 miles southeast of Home Hill, may be Upper Devonian.

The hill is elongated northeast and is about 1200 feet long, 300 feet wide, and 70 feet high. It consists of dark grey strongly hornfelsed calcareous cobble and pebble conglomerate with interbeds of grey cross-bedded calcareous quartzite. Calcareous sediments of this type are unknown elsewhere in the Sheet area.

The metasediments dip at about 20° to the southeast, and the cross-bedding in the quartzite indicates that they are overturned. The conglomerate contains phenoclasts of white quartz, marble, and foliated to gneissic diorite to granodiorite. The conglomerate is a tremolite-wollastonite-diopside-garnet-quartz hornfels, in which some of the minerals show a zonal arrangement around the phenoclasts. The interbeds consist of fine-grained sheared actinolite quartzite. All the phenoclasts in the conglomerate are ellipsoidal and lie with their long axes in the plane of the bedding. The structure suggests that the rocks were compressed, and perhaps also sheared, during folding. In places, the conglomerate has been intruded by post-tectonic veins of medium-grained leucocratic diorite up to 6 inches wide.

The age of the hornfelses is unknown. The conglomerate closely resembles the distinctive 'Deadmans Gully conglomerate' at the base of the Upper Devonian Dotswood Formation in the Reid River district in the Townsville Sheet area (Wyatt et al., 1970a).

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* Further isotopic age determinations have become available since the map which accompanies this Report was printed. As a result of detailed mapping of the Ravenswood 1-mile Sheet area (Charters Towers 1:250,000 Sheet area) in 1966, the Ravenswood Granodiorite has been subdivided into separate phases and has been renamed the Ravenswood Granodiorite Complex (Clarke, in prep.). Rb/Sr whole rock dating has shown (A.W. Webb, pers. comm.) that most phases of the complex were intruded about 450 million years ago (Middle Ordovician, Harland et al., 1964), and the rest about 400 million years ago (Silurian-Devonian boundary).

UPPER CARBONIFEROUS

ELLENVALE BEDS (Ce)

Horse Camp Hill is bisected by the boundary between the Ayr and Townsville Sheet areas. It consists of grey flow-banded rhyolite, rhyolite breccia, andesite, and porphyritic rhyolite with phenocrysts of feldspar or rounded quartz.

These volcanics were mapped with the Ellenvale Beds in the Townsville Sheet area, where they are assigned to the late Middle or Upper Carboniferous in the type area in the valley of the Reid River (Wyatt et al., 1970a). The evidence for this age is: (i) the presence of fragments of cf. Rhacopteris sp. and indeterminate equisetalean stems (McKellar, 1963, unpubl.) in the interbedded sediments, (ii) the stratigraphic position of the Ellenvale Beds above Tournaisian strata, and (iii) the absence of Glossopteris.

ACID VOLCANICS (Cuv)

Acid volcanics and minor intermediate volcanics form Mount Dalrymple and a number of smaller hills and rises in the southwest. The volcanics comprise rhyolite and rhyolite pyroclastics (commonly welded) with subordinate andesite. They are probably equivalent to the Ellenvale Beds in the Townsville Sheet area and the Bulgonunna Volcanics in the Bowen Sheet area. Malone et al. (1966) regarded the Bulgonunna Volcanics as Upper Carboniferous because they rest unconformably on the Lower Carboniferous Drummond Group, and because they are unconformably overlain by the Lower Permian Lizzie Creek Volcanics. The volcanics crop out in isolated fault blocks. No sedimentary interbeds have been found in them.

Topography

These volcanics form most of the steep rugged range culminating in Mount Dalrymple (1900 ft above sea level). They also form Mount Woodhouse, which rises only a few hundred feet above the alluvial plain. The small occurrences in the southwest have insignificant topographic expression.

Lithology

The fine-grained rhyolite and welded tuff on the southwestern flank of Mount Dalrymple are highly brecciated by a strong southeast-trending fault. The welded tuffs are composed of feldspar and quartz crystals and rock fragments set in a devitrified felsitic matrix of sericitized and saussuritized feldspar and quartz. The rock fragments are of three main types: altered glassy fragments which have been devitrified and partly or wholly converted to sericite and quartz, quartz-rich fragments, and welded(?) tuff. The volcanics are intruded by dykes of red-brown feldspar-hornblende porphyry.

At the eastern end of the Mount Dalrymple range, near the headwaters of Deep Creek, dense fine-grained light grey rhyolite and rhyolite-breccia predominate. Blue-black dacite welded tuff also occurs. The volcanics are strongly jointed, and locally appear to have been thermally metamorphosed.

White siliceous strongly sheared vitric tuff(?) and spherulitic rhyolite crop out 2 miles west of the junction of Deep Creek and the Burdekin River. The volcanics contain abundant pyrite, and locally resemble pyritic quartzite. The strong shearing is related to the southeasterly fault, and the pyrite may have been introduced hydrothermally from the microgranite (C-Pg) north of Deep Creek. White pyritic hornfelsed rhyolite also occurs next to the smaller body of microgranite (C-Pg) along Deep Creek.

The small occurrences of brecciated intermediate volcanics in the Burdekin River, and the brecciated volcanic breccia in Landers Creek, are small blocks caught up in a strong shear zone along the southwestern side of Mount Dalrymple.

The low hills east of the Burdekin River, on the southern edge of the Sheet area, are sparsely covered with rubble of acid volcanics and siliceous rock resembling quartzite. The acid volcanics are poorly exposed; exposures are much better just within the Bowen Sheet area. They are pale green, pink, and white; some of the rocks contain small phenocrysts of quartz and feldspar in a flow-banded or massive groundmass. The flow banding is steep and generally contorted. The siliceous rock, which consists of angular quartz grains with strongly oriented threads of sericite, may be older than the volcanics.

Andesite breccia and tuff, rhyolite tuff, and subordinate rhyolite and andesite predominate at Mount Woodhouse; some of the tuff is partly welded. Strongly banded rhyolite crops out close to the Woodhouse Fault, 5 miles southwest of Mount Woodhouse.

Structure and Relationships

The volcanics at Mount Dalrymple form a downfaulted block in the Ravenswood Granodiorite. They are probably mainly extrusive and partly intrusive. Along the Woodhouse Fault, the acid volcanics are strongly sheared, brecciated, and recrystallized, and in places they are also pyritic.

The granite aplite and alkali microgranite (C-Pg) north of Deep Creek intrude the volcanics, but the contacts with the granophyric alkali granite (C-Pg) north of Landers Creek homestead are obscured by poor exposure and strong faulting.

The tuffaceous volcanics at Mount Woodhouse unconformably overlie the Ravenswood Granodiorite. The small outcrops south-southwest of Mount Woodhouse are strongly brecciated along the Woodhouse Fault; the three small areas of volcanics near the southern edge of the Sheet area have been severely brecciated in the east-southeasterly shear zone along the southwestern flank of Mount Dalrymple.

Age

The precise age of the volcanics is uncertain. They are younger than the Ravenswood Granodiorite, and are intruded, particularly in the Leichhardt Range in the Bowen Sheet area, by Upper Carboniferous or Lower Permian granites.

UPPER CARBONIFEROUS TO LOWER PERMIAN

Most of the plutonic rocks in the Ayr Sheet area are thought to have been emplaced in the Upper Carboniferous or Lower Permian. An arbitrary twofold subdivision has been used on the map: (1) the basic to intermediate plutonic rocks (C-Pd) such as gabbro, norite, diorite, quartz diorite, and granodiorite; and (2) the more acid rocks (C-Pg) such as adamellite, granite, and minor granodiorite and tonalite. In places, the intrusions have been assigned to one or other group mainly on the basis of photo-interpretation. The contacts are poorly exposed, but the more acid rocks are generally younger.

Paine et al. (1966, unpubl.) included the granodiorite and diorite between Arkendeith and Beaks Mountain with the Ravenswood Granodiorite (Silurian-Lower Devonian), but recent isotopic ages and mapping in the Bowen Sheet area suggest that they are more likely to be the same age as similar rocks in the eastern half of the Bowen Sheet area. In 1966 the Urannah Complex in the southern half of the Bowen Sheet area (Malone et al., 1966) was extended into the Ayr Sheet area, but the name is no longer used in the northern part of the Bowen Sheet area or in the Ayr Sheet area. The plutonic rocks in the eastern half of the Ayr Sheet area, which were formerly mapped as part of the Urannah Complex, are now incorporated in the two Upper Carboniferous to Lower Permian groups, and most of the remaining acid plutonic rocks in the Sheet area are also included in one of these groups (C-Pg).

INTERMEDIATE TO BASIC PLUTONIC ROCKS (C-Pd)

Topography

The area between Arkendeith and Beaks Mountain includes rough hilly country with a relief of up to 300 feet; areas of parallel dyke ridges with a relief of about 100 feet; and gently undulating country. The dyke ridges are clearly visible on the air-photographs, but most of the area is difficult to map by photo-interpretion.

The gabbro and diorite to the south and southwest of the Seven Sisters form low undulating rises only slightly higher than the soil-covered plains. Elsewhere, the gabbro and diorite generally crop out in isolated steep hills rising abruptly from the coastal plain. The hills vary in height; for example, Bald Hill is 250 feet above sea level and Mount Luce 900 feet. Dioritic roof pendants occur near the summit of Mount Roundback (2400 ft). Camp Island consists of rocks mapped with this group.

Slopes devoid of vegetation and covered with large rounded boulders of gabbro occur in places on the hills as, for example, on the northern side of Mount Luce. The slopes appear black when seen from a distance, and are clearly recognizable on air-photographs.

Lithology

Arkendeith to Beaks Mountain

The area from Arkendeith to Beaks Mountain contains a large number of rock types: granodiorite, diorite, and adamellite, and their fine-grained equivalents, predominate; there are lesser amounts of gabbro, granite, and microgranite. Hornblende is a major constituent of the calcic rocks.

Between Plumtree Hill and Plumtree homestead the country is gently undulating and outcrop is sparse. The area consists mainly of diorite and granodiorite, with subordinate adamellite, gabbro, and granite. Dykes of microdiorite and microadamellite were also noted. Some of the granodiorite is weakly foliated. Most of the rocks are calcic, and weather to a dark brown to black soil containing abundant lime-rich nodules.

South of the Bobawaba Range many parallel swarms of dykes intrude diorite and granodiorite. The dykes are so abundant that in places they predominate over the host rocks. The trend of the dykes swings from approximately meridional in the south to north-northwest in the north, where they are normal to the Inkerman Shear Zone.

The dykes include porphyritic microgranite, microadamellite, microdiorite, microgranodiorite, and dolerite. The coarse-grained more leucocratic rocks are foliated parallel to the trend of the dykes. The more melanocratic rocks are not foliated.

South of Arkendeith there is a second zone of dyke swarms which intrude granodiorite, diorite, and adamellite. The dykes continue into, and are younger than, the Inkerman Shear Zone. Epidotization along joints is common, and may extend a few inches out from the joints.

A small deposit of asbestiform tremolite was noted by Carruthers (1954) about 1 mile south of Arkendeith. The outcrop is similar to the material found in Six-Mile Creek in the Inkerman Shear Zone.

The Rocks is a large area of waterworn outcrop in the bed of the Burdekin River southeast of Kellys Mount. Most of the rock types in the adjacent areas are exposed here in almost continuous outcrop, and the sequence of events was as follows:

(1) Emplacement of tonalite, containing fairly abundant tabular xenoliths of melanocratic foliated hornblende-biotite microgranodiorite up to 1 foot long.

(2) Intrusion of a second granodioritic phase as irregular masses of coarse-grained hornblendic rocks.

(3) Intrusion of irregular masses of porphyritic microgranodiorite. The microgranodiorite contains abundant hornblende xenoliths of the coarse-grained hornblende granodiorite. Epidotization is common along joints in the microgranodiorite.

(4) Intrusion of dykes of flow-banded spherulitic dacite. The dacite is porphyritic in places, and the coarse flow layering ranges from pink to pinkish grey. The dykes are up to 40 feet thick and have no consistent trend.

(5) Intrusion of irregular masses of medium-grained porphyritic microdiorite. The microdiorite contains phenocrysts of plagioclase and has been extensively epidotized along joints.

(6) Intrusion of microdiorite dykes. The dykes are fine-grained and dark green to almost black; they are commonly porphyritic in the centre and generally have fine-grained chilled margins. The dykes are of at least three ages, and have no regular trend.

The Inkerman Shear Zone is at least 2 miles wide. Shearing and metasomatic alteration of diorite and granodiorite have produced many varieties of rocks, but some of the original rocks are unaltered.

In Six-Mile Creek, near Leichhardt Downs homestead, a section across most of the shear zone can be seen. There are wide exposures of diorite gneiss, which in places contain lenses of massive diorite. Rocks rich in vermiculite, dyke-like masses of garnet rock, epidote rocks, thin quartz veins, magnetite bodies, amphibole-epidote-garnet rocks, and amphibolite are also found in the zone of alteration.

The grainsize of the gneiss is variable. Some of it is fine-grained, uniformly banded, and strongly cleaved owing to parallel growth of hornblende crystals. Coarse-grained pegmatitic pods with biotite flakes and plagioclase crystals up to 1 inch across are also present. In places the gneiss is contorted. The banding is commonly lenticular and of variable width. Hornblende-rich bands are plentiful.

Two tabular bodies of metasomatic garnet rock, probably dykes, were noted. The first is composed of about 95 percent brown garnet with a little intergranular quartz and small grains of diopsidic(?) pyroxene. The garnet shows excellent sector twinning and multiple twinning. Some of the crystals are strongly zoned. The second body is composed of pale yellow-green isotropic garnet crystals rimmed by anisotropic brown garnet, and about 5 percent intergranular quartz. The garnetiferous rocks appear to have been formed after the shearing, possibly by metasomatic alteration of microdiorite dykes. Turner (1933) has described a suite from Westland, New Zealand, in which highly garnetiferous rocks were developed from gabbro during metasomatism and strong regional metamorphism. Benson (1913) noted numerous occurrences of garnet-bearing altered gabbro in the Great Serpentine Belt in northern New South Wales, in which the proportion of garnet ranges from a few percent to almost 100 percent. White (1959) has noted the coexistence of two calcium garnets in the same rock in South Australia; it occurs in a zone where calc-silicate rocks are veined by migmatite, gneiss, and granite, and was formed as a result of metasomatism and interaction between mineral phases.

The magnetite-epidote-quartz-garnet rocks contain about 60 percent euhedral brown sector twinned garnet, 20 percent quartz, 10 percent epidote, and 10 percent magnetite.

Epidote rocks, which were not seen in situ, consist of about 98 percent epidote and 2 percent of an amorphous brown material which has possibly been formed by the replacement of biotite.

Amphibole-rich rocks are common in Six-Mile Creek. One consists entirely of colourless tremolite, and another consists of 85 percent green hornblende and 15 percent aggregates of talc poikiloblastically enclosed in the hornblende. Other specimens examined contain tremolite and talc in about equal quantities, and in one of them the talc appears to replace tremolite. All the amphibole-rich rocks have a foliation due to the orientation of the amphibole crystals.

Foliated quartz-garnet-augite rock and garnet-wollastonite-diopside rock have been noted 8 miles south-southeast of Home Hill. Both have a granulitic texture. In the first the quartz grains are elongated and the garnet is largely segregated into distinct layers; plagioclase is extensively altered to clinozoisite. In the second, there is little evidence of foliation apart from the parallelism of the inclusions in the garnet; it is composed of about 50 percent garnet, together with wollastonite, diopside, calcite, and quartz. Two types of garnet are present; one is colourless and isotropic, the other is brown and anisotropic and shows sector twinning. Both rocks appear to have been formed by metasomatic alteration of gneisses.

Traces of secondary copper minerals and sporadic grains of chalcopyrite were found in parts of the shear zone; spectrographic analyses of four samples are given in Appendix 1.

Intruded into the shear zone are two swarms of dark green fine-grained microdiorite and porphyritic hornblende gabbro dykes, and small plugs of massive granite. Most of the dykes trend either parallel to or normal to the shear direction.

At various places in the bed of the Burdekin River there are large areas of waterworn outcrop. Between The Rocks and the southern edge of the Sheet area there are a number of similar outcrops consisting of foliated granite, granodiorite, and diorite which have been sheared and mylonitized in places. The foliation and shear directions are variable, and are not parallel to the Inkerman Shear Zone. The sheared rocks are intruded by dykes of microadamellite, porphyritic microdiorite, micromonzonite, and dark green fine-grained microdiorite. Quartz veining and epidotization, especially along joints, are common in places.

A low ridge of crudely banded basic plutonic rocks, surrounded by alluvium, occurs 1 mile southwest of Sandalwood Waterhole, west of the Burdekin River. The specimen sectioned is an olivine microgabbro. The outcrop strongly resembles similar layered gabbroic outcrops in the eastern part of the Sheet area.

Eastern Part of Sheet Area

In the eastern part of the Sheet area this unit includes diorite, dolerite, gabbro, and norite. Some of the rocks are massive, others are layered.

One specimen from the eastern foothills of Mount Little is a coarse massive diorite which has been slightly recrystallized by the granite (P-Mg) in the saddle between Sprole Castle and Mount Little. A similar diorite crops out at the summit of Sprole Castle, and blocks of augite diorite and banded microdiorite occur on the southern slopes, in the Bowen Sheet area.

Olivine gabbro, olivine microgabbro, and leucocratic olivine norite form a low rise immediately east of Alligator Swamp (north of the railway line, 5 miles west-northwest of Bowen). In places they are weakly banded; the bands trend east-west and dip subvertically. Segregations of gabbro pegmatite occur in places, and some of the rocks are intruded by biotite pegmatite and aplite dykes. The olivine norite contains 10 percent fresh olivine with a ubiquitous reaction rim of pale brown hornblende. An intervening rim of hypersthene may also be present. The opaque grains are also rimmed by amphibole.

Banding is well displayed in waterworn boulders and to a lesser extent in outcrops of the basic rocks at Abbot Point. The gabbros are generally coarse-grained, but there is considerable variation in the grainsize, texture, and composition of individual bands and boulders. In places the banding in the gabbro has been truncated by a later banded intrusion (Fig. 4). The banding may be sharp or vague, and small folds and contortions are common within individual bands (Fig. 5).

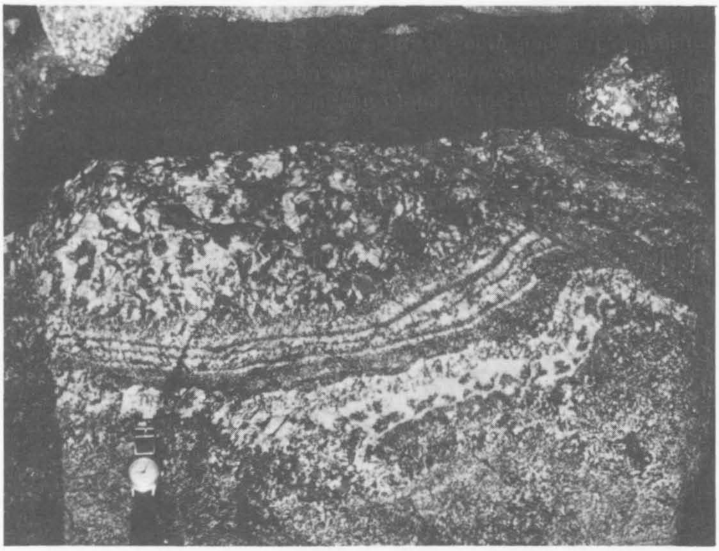

Fig. 4: Contortion and truncation of banding in gabbro (C-Pd). Waterworn boulder at Abbot Point.

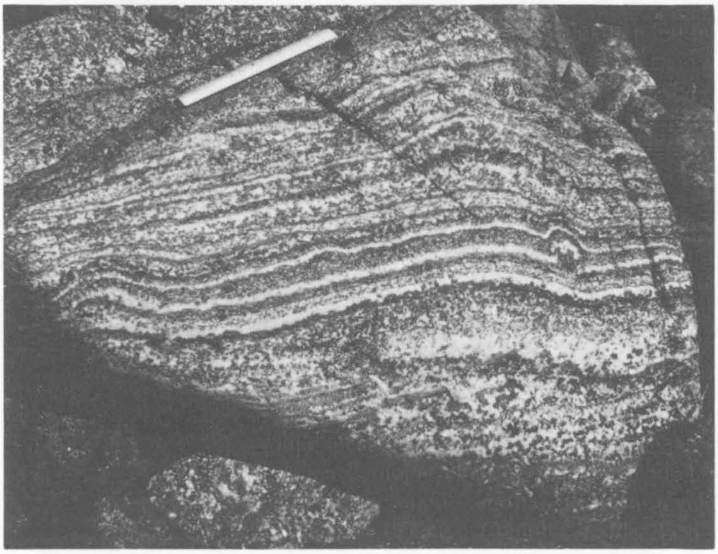

Fig. 5: Waterworn boulder of banded gabbro (C-Pd) at Abbot Point. Truncation, disruption, and wedging of bands (probably due to contemporaneous erosion during gravitational deposition) are visible in the lower part of the boulder. The small disharmonic folds (e.g. right centre and extreme left) were probably caused by slumping during deposition. The scale is 6 inches long.

Fig 6

Waterworn boulder of gabbro (C-Pd) at Abbot Point. The squat euhedral plagioclase phenocrysts, 2 to 3 cm in diameter, contain small ferromagnesian nuclei, and in places concentric bands of ferromagnesian minerals. The groundmass consists of roughly equal proportions of plagioclase and ferromagnesian minerals. The scale is 6 inches long.

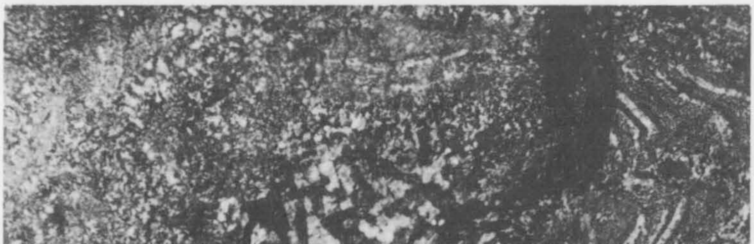

Fig. 7: Waterworn boulder of gabbro (C-Pd) at Abbot Point. A gabbro pegmatite segregation occupies the core of a 'rootless' fold in the banding. A finer-grained vein-like extension of the pegmatite has been intruded along the axial plane of the fold. The largest feldspar and ferromagnesian crystals are 2 inches long.

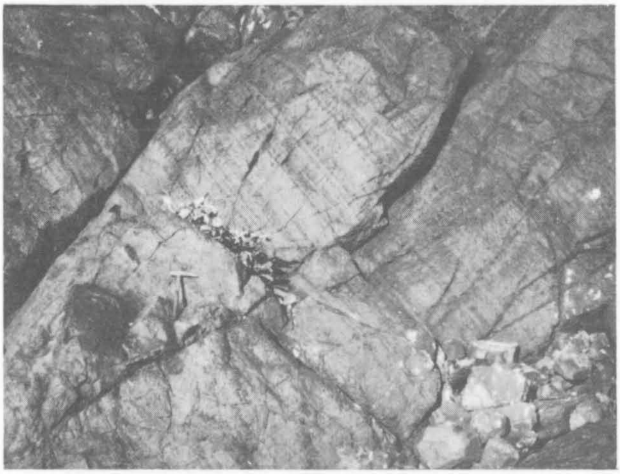

Fig. 8: Planar banding in anorthite gabbro (C-Pd), on the coast half a mile northeast of Mount Luce.

Some of the coarsely porphyritic rocks contain large squat euhedral crystals of plagioclase 2 to 3 cm across (Fig. 6). Some of the phenocrysts have a small mafic nucleus and one or more thin concentric zones of fine-grained mafic minerals. Segregations of gabbro pegmatite are common in the cores of folds in the banding (Fig. 7). Rare thin veins and lenticles of a fine-grained melanocratic rock transgress most of the other structures. Finally a thin network of late pegmatitic veins is present in places.

Coarse inequigranular massive uralitized gabbro crops out in the southwestern foothills of Mount Luce, and banded uralitized anorthite gabbro, containing large poikilitic crystals of hornblende, forms the small hill on the coast northeast of Mount Luce. The banding, which dips at 60^{o} south (Fig. 8), is regular, but the bands do not show such marked variation in composition, texture, and grainsize as the banding at Abbot Point. The beach sands along the shore near Mount Luce and Abbot Point contain a high concentration of heavy minerals derived from basic rocks. The mineralogical composition of the beach sand compared with the composition of the augite-hornblende gabbro from the small hill northeast of Mount Luce is given in Appendix 2.

The basic plutonic rocks near the summit and on the shoulders of Mount Roundback appear to be roof pendants in granite (C-Pg). They are probably similar to outcrops at Abbot Point. Massive melanocratic dolerite(?), permeated by veins and stringers of gabbro pegmatite, crops out in the western foothills.

Numerous rounded boulders of gabbro emerge from the black soil in the low-lying country south and west of the Seven Sisters. Diorite and tonalite are also present. Both the diorite and tonalite contain melanocratic xenoliths.

Medium-grained massive hornblende-augite norite crops out at Moosie Hill and coarse massive hornblende-hypersthene gabbro is intruded by or interlayered with thin bands of hypersthene-hornblende microgabbro in the small hill immediately to the northeast.

Coarse medium and fine-grained basic or intermediate plutonic rocks crop out on the northeast side of Camp Island. They are commonly dyke-like and cut each other. Layering is not as marked as at Abbot Point. A thin dyke of spinel-bearing 'uralitized' diallagite intrudes gabbro or diorite; 90 percent of the rock consists of fibrous to prismatic richterite(?) and subordinate diallage; the richterite has been formed by replacement of diallage. Numerous fractured crystals of green spinel and a few anhedral grains of bytownite are also present.

At Red Hill, 8 miles northwest of Guthalungra, the Bruce Highway crosses low hills of olivine microgabbro and gabbro.

Two small hills near Green Hill, on the coast north of Gumlu, consist of coarse to fine-grained melanocratic gabbro with random patches of leucocratic gabbro. A local weak foliation trends at 110^{o}. Large xenoliths of sheared granite are present in the gabbro in a wavecut platform on the seaward side of the more northerly of the two hills.

Structure

Arkendeith to Beaks Mountain

The intermediate to basic rocks between Arkendeith and Beaks Mountain are strongly foliated in places. The direction and intensity of the foliation are not constant, and in places it is clearly associated with shear zones and faults.

The joint patterns are generally irregular, but some outcrops are closely jointed. Polygonal joint patterns are common, but the angles between the joints vary in the adjacent rock types.

In addition to the Inkerman Shear Zone several faults are shown on the map. All have caused strong foliation locally. The Inkerman Shear Zone dips vertically, and is at least 2 miles wide.

Eastern Part of Sheet Area

Shearing was not observed in the intermediate to basic rocks in the eastern part of the Sheet area.

No primary layered structures of regional extent are manifest from the isolated measurements which have been made, and the contortions in the banding at Abbot Point suggest that the structures in the banding are of local significance only.

Age and Relationships

The country rocks of the intermediate to basic plutonic rocks have been entirely removed by erosion except for small roof pendants of hornfels (Pzu) near Guthalungra. The age of the hornfels is unknown. In the Bowen Sheet area the relationships of the plutonic rocks to fossiliferous sediments are inconclusive, but the balance of evidence suggests that they are older than the Lizzie Creek Volcanics (Lower Bowen Volcanics of Malone et al., 1966) which contain Lower Permian fossils. Isotopic ages ranging from 270 to 285 m.y. have been obtained by the K/Ar method on biotite and hornblende from a similar group of rocks (C-Pd) in the Bowen Sheet area. However, recent Rb/Sr total rock determinations on some of the same specimens indicate that the true age of emplacement was about 310 m.y. (Upper Carboniferous), and that the younger ages obtained by the K/Ar method may be due to loss of argon during the widespread intrusion of granite in the Lower Permian (A.W. Webb, pers. comm.).

Three isotopic age determinations on amphiboles have been carried out by the K/Ar method on sheared rocks from the Inkerman Shear Zone. Two specimens of diorite gneiss have yielded ages of 265 to 275 m.y. (Lower Permian); and a specimen of green amphibole rock has yielded an age of 245 m.y. (Upper Permian). However, it is not known to what extent these ages reflect recrystallization and metasomatism.

The presence of cobbles of sheared diorite in the Upper Devonian(?) calcareous conglomerate at Charlies Hill suggests that equivalents of the Ravenswood Granodiorite (Silurian/Lower Devonian) may exist south of Home Hill.

ACID PLUTONIC ROCKS (C-Pg)

The acid intrusions (C-Pg) crop out at scattered localities throughout the Sheet area.

Two small hills 3 miles south of White Rock Bay (Cape Cleveland peninsula) consist of fine-grained foliated biotite adamellite. The hills are much lower than the main part of the Cape Cleveland range, which is composed of massive coarse biotite adamellite (P-Mg). The foliated adamellite appears to have been intruded by the massive adamellite. In the foliated rock, which is gneissic in places, the foliation dips at 45^{o} to the southeast. It is composed of xenomorphic quartz, perthite, and sodic plagioclase traversed by thin trails of biotite.

Artillery Hill/Major Creek Mountain. Pink coarsely porphyritic microgranite forms two north-northwesterly ranges, up to 900 feet high, northwest of the Haughton River; the ranges include Artillery Hill and Major Creek Mountain. In the northern bank and bed of Major Creek, south of Artillery Hill, the pink and red porphyritic microgranite is brecciated.

The microgranite in the eastern range contains rounded phenocrysts of quartz and white euhedral crystals of feldspar averaging 5 to 6 mm, but up to 3 cm, across set in a fine-grained pink groundmass. The microgranite is aphyric in places. Rare chloritized biotite is the chief mafic mineral. Microdiorite dykes are abundant in both ranges.

The contact between the microgranite and the Carboniferous to Permian volcanics (C-Pv) to the northwest was not seen, and their age relationship is unknown.

The microgranite close to a microdiorite dyke which intrudes it near a gravel pit at the northern end of the steep hill immediately southeast of Mount Ironbark has been altered to a white siliceous rock containing disseminated pyrite.

A sheet-like intrusion, which ranges from medium-grained biotite granite to granophyric alkali microgranite, forms a low hill half a mile west-southwest of Mount Woodhouse. The intrusion is 300 feet thick and dips at a moderate angle to the east-northeast. The rock is generally weakly foliated, particularly the granophyric microgranite at the southern end. Several different microgranite intrusions are present, and in places they have been contaminated by the assimilation of country rock. The microgranite intrudes deeply eroded blue-grey hornblende-biotite granodiorite (Ravenswood Granodiorite).

Two small intrusions of fine-grained white leucocratic granodiorite and quartz diorite intrude the Ravenswood Granodiorite 2 miles north-northwest of Mount Woodhouse. Both intrusions are strongly fractured in a north-south direction.

Mount Benjonney is a roughly oval stock of alkali granite which is sparsely vegetated and strongly jointed. The granite is grey, even textured, fine to medium-grained, and leucocratic, and contains numerous small hornblendic xenoliths. It intrudes the Ravenswood Granodiorite. Biotite is the chief mafic constituent. No dykes were noted in the alkali granite, which postdates the various dykes intruding the Ravenswood Granodiorite nearby.

An irregular mass of medium-grained blue-grey granodiorite intrudes quartzite (Pzu) 2 miles west of Mount Benjonney; it may also intrude the hornblende granodiorite (Ravenswood Granodiorite) which partly surrounds it. The granodiorite is leucocratic, and contains abundant large phenocrysts of plagioclase which in places are surrounded by micropegmatite. Some hornblende is present. The granodiorite is intruded by glomeroporphyritic plagioclase-hornblende porphyry dykes.

Red alkali microgranite crops out in an arcuate ridge, 250 feet high, 3 miles west of Mount Benjonney; two smaller areas east and west of the ridge have been photo-interpreted as microgranite. The alkali microgranite has a graphic texture in places, and contains scattered small basic and intermediate xenoliths, some of which have been converted to mafic clots by assimilation. Biotite, amphibole (ferroactinolite?), and subordinate clinopyroxene together constitute less than 5 percent of the rock. Chlorite and epidote have been formed by deuteric alteration.

The scattered fragments of hornblende granodiorite in the microgranite were derived from the Ravenswood Granodiorite. Other xenoliths, chiefly feldspar-hornblende porphyry, are similar to the dyke in the Ravenswood Granodiorite to the east of the microgranite. No dykes were noted in the microgranite.

An oval stock of pink medium-grained biotite adamellite crops out in the headwaters of Barratta Creek. The adamellite intrudes the Ravenswood Granodiorite, and closely resembles the biotite adamellite stock in Molybdenite Creek in the northeastern corner of the Charters Towers Sheet area (Wyatt et al., 1967, unpubl., and in prep.). No dykes appear to be present.

The spur of the Mount Dalrymple range which rises west-northwest from the junction of Deep Creek and the Burdekin River consists of granite aplite and alkali microgranite. The intensely fractured pinkish brown granite aplite in the west bank of the Burdekin River is locally very fine-grained and commonly flow banded. It is intruded by a porphyritic microdiorite dyke and a thin fine-grained biotite adamellite dyke.

The fine-grained brownish grey alkali microgranite in the main spur of the range also shows irregular banding, with the rare micaceous minerals strung out in fine irregular layers. One and a half miles up Deep Creek, a small body of similar brownish grey microgranite intrudes and hornfelses Upper Carboniferous volcanics (Cuv). Near the contact the microgranite contains blocks of hornfelsed vesicular porphyritic volcanics.

The alkali microgranite is strongly fractured by the Woodhouse Fault. It intrudes the Ravenswood Granodiorite, which is covered by scree and alluvium at the eastern end of Mount Dalrymple.

A poorly defined body of granite forms the southeastern extremity of the Mount Dalrymple range. Pink medium to coarse-grained leucocratic alkali granite, which is slightly porphyritic and granophyric, is exposed in a quarry north of Landers Creek homestead. To the southwest, the granite contains rounded quartz phenocrysts averaging 2 mm in diameter. The granite is closely associated with a pink granophyric microgranite containing rare phenocrysts of fine feldspar. In the quarry, the granite is strongly shattered by a northwesterly fault zone which is intruded by numerous greenish grey porphyritic microdiorite dykes.

One mile northwest of the quarry, grey to pink medium-grained granophyre is intruded by dark greenish blue microdiorite dykes.

The contact between the granophyre and the Upper Carboniferous(?) Volcanics (Cuv) was examined in this area, but the relationships were not established; the volcanics at the contact do not appear to be metamorphosed, and the granite may therefore be the older.

Pink fine-grained leucogranite, intruded by numerous rhyodacite and rhyolite dykes, forms a broad, almost imperceptible rise surrounded by alluvium, between Gladys Lagoon and the Burdekin River.

Kellys Mount, 8 miles southwest of Ayr, is an uneven granite hill rising 600 feet above sea level; it is surrounded by a broad apron of sand. The northern spur consists of coarse massive leucocratic biotite granite composed of microcline perthite, quartz, albite-oligoclase, and biotite. A little chlorite and rutile (after biotite), and zircon associated with iron oxides and muscovite, are present. The plagioclase shows incipient sericitization, and the potash feldspar is commonly cloudy. Greisen is extensively developed on the northeastern slopes of the hill. Several costeans and benches have been bulldozed in it. No mineralization was seen in the field, but one specimen was found to contain 300 ppm of molybdenum (see Appendix 1). Thin basic to intermediate dykes intrude the granite on the southern slopes.

The range 2½ miles southwest of Kellys Mount consists of adamellite, and is also surrounded by a broad apron of sand. The rock is well exposed in a road-metal quarry at the southeastern end of the range. It is a massive medium-grained pink biotite adamellite composed of oligoclase, perthite, quartz, and biotite which has been mostly altered to chlorite and epidote. Potash feldspar and quartz are commonly intergrown; the biotite has been partly replaced by potash feldspar; and the quartz crystals are strained. The accessories include iron oxides, apatite, and zircon. The adamellite is generally slightly epidotized, particularly along small faults. Aggregates of pyrite occur in association with quartz and small rosettes of muscovite in rare pegmatitic segregations. Coarse aggregates of quartz, calcite, epidote, and pyrite occur as lenses and as the linings of small vugs. A swarm of thin amygdaloidal pyritiferous augite dolerite dykes intrudes the adamellite.

The granitic rocks form the Gregory Ranges, and extend east to Beaks Mountain, but form low-lying country in places, where outcrop is poor, and weathering deep.

The main rock types are deeply weathered leucocratic pink adamellite and biotite granite, which in places are strongly sheared. Jointing is generally well developed.

There are numerous dykes of microdiorite, microadamellite, microgranite, rhyolite, rhyodacite, dacite, and related porphyries. They commonly occur in swarms, and in some areas the dykes are so close together that outcrop of the host rock is rare (e.g., near Beaks Mountain). Most of the dykes trend between 315^{o} and 045^{o}.

Shearing is common in some areas, especially east of the Burdekin River, but it is not related to any of the known major shear directions. The trend of the shearing ranges from about 060^{o} to 160^{o}, and the dip is generally vertical.

The Mount Louisa rhyolite plug (C-Ph) intrudes granite mapped with this unit. No contacts were seen with the dioritic rocks (C-Pd) to the north.

Mount Inkerman is an inselberg which rises steeply to 700 feet above sea level, and is elongated in a northeasterly direction. It is composed of strongly sheared and jointed foliated granite. The foliation trends northeast by east, and Mount Inkerman is interpreted as lying within the Inkerman Shear Zone, which has affected the granodiorite and diorite (C-Pd) in the hills to the southwest. The granite at Mount Inkerman contains xenoliths of biotite schist and is cut by dykes of microdiorite which postdate the shearing. The geology of Mount Alma is similar.

A small hill near Stud Lagoon, 4 miles southwest of Mount Inkerman, also lies within the Inkerman Shear Zone. It consists of sheared, recrystallized, and hydrothermally altered granite composed mainly of equigranular quartz and feldspar with cubes of magnetite and small crystals of red garnet.

Sparse outcrops of probable granitic rocks along the southern boundary of the Sheet area 5 miles southwest of Guthalungra have been included in this unit. On the air-photographs the area appears to consist almost entirely of low rises, from which emerge rare corestones. Biotite adamellite crops out 2 miles to the south on the Bowen Sheet. An isotopic age of 270 m.y. (K/Ar on biotite, ±3 percent) has been obtained from adamellite in Finlay Creek 8 miles south of Guthalungra.

Beach Hill is a steeply rounded inselberg rising abruptly to over 400 feet above sea level. It consists of granulated and brecciated granite which has been recrystallized. Most of the granite is strongly joined; the most prominent joints trend 090° and dip north at between 50° and vertical. In a few areas the granite has a weak easterly foliation, but it is generally granular and massive.

Some of the microdiorite dykes in the granite are foliated, others are massive. It appears that the microdiorite was intruded during and after the brecciation and shearing of the granite.

Probably more than one period of faulting affected this area. The prominent 090°-joint direction does not appear to be related to the northeasterly trend of the Inkerman Shear Zone (which, unless it has died out, should pass close by) or the north-northwest to northwesterly trend of the Sugar Loaf Fault. Beach Hill culminates in a central spine aligned on strike with the Sugar Loaf Fault.

Sugar Loaf, an inselberg rising 100 feet above sea level, consists of sheared granite. The shearing trends southeast, parallel to the beach. The shear zone (Sugar Loaf Fault) terminates in a cliff of mylonite on the seaward side of the hill. About 30 feet inland from the cliff, the rock is less sheared and grades into gneiss containing augen of feldspar and quartz. Sixty feet farther inland the rock becomes recognizable as granite. All the rocks are strongly jointed and weathered.

A few low outcrops of deeply weathered and sheared granite crop out near the mud flats on the northwestern side of Green Hill. Green Hill is terminated at its northeastern edge by a wide mass of quartz which was probably intruded along the continuation of the Sugar Loaf Fault.

Nobbies Lookout, another 400 foot inselberg 5 miles northwest of Guthalungra, is composed of weathered massive fine-grained granodiorite.

The outcrops extending westwards from The Cape homestead include low rises, gentle slopes, and steep hills and spurs. These culminate in a steep irregular west-north-westerly range which rises 600 feet above sea level 4 miles west-northwest of The Cape homestead. The range is separated from the main Cape Upstart peninsula range (2400 ft) by an east-west valley with a low central saddle.

The range trending west from The Cape homestead consists of tonalite and adamellite. Medium-grained garnetiferous biotite tonalite (locally foliated) has intruded and hornfelsed the sediments (Pzu) 1 mile west-southwest of the homestead. It consists of oligoclase-andesine (50%); anhedral strained and granulated quartz (30%), in places recrystallized; clots of fine biotite (15%) (recrystallized?); interstitial to poikilitic microcline (5%); and rare red-brown garnet.

The rock immediately north of the homestead is a massive coarse inequigranular biotite adamellite composed of recrystallized quartz (35%), oligoclase-andesine (30%), perthite (30%), and fine-grained aggregates of biotite (5%). The rock contains some fine-grained dioritic xenoliths.

A thick dyke-like body of biotite leucoadamellite trends east-west along the northern slopes of the range. It consists of oligoclase (40%), poikilitic quartz (35%), perthite (25%), and a little biotite.

An isolated hill on the coast north of Nobbies Inlet consists of massive brown medium-grained biotite leucoadamellite composed of strained quartz (35%), poikilitic microcline perthite (35%), andesine (30%), and a few flakes of biotite.

The Maiden Mountain, a 400-foot hill immediately north of the Bruce Highway 2 miles east of Guthalungra, consists of fine-grained biotite-hornblende alkali granite aplite.

It is composed mainly of albite, potash feldspar, and quartz, and has an inequigranular xenomorphic texture. A few crystals of poikilitic green hornblende and chloritized biotite are also present. The accessories are iron oxide and sphene. In places the rock is banded, and some bands are noticeably more aplitic than others. Rubble of strongly epidotized basic to intermediate dykes is abundant.

The Seven Sisters is a steep-sided linear inselberg of slightly to moderately foliated leucocratic granite south of the Bruce Highway, 3 miles east-southeast of Guthalungra. The inselberg, which rises gradually to 500 feet above sea level at its eastern end, has a pronounced east-west trend parallel to the foliation. The foliation is only slight at the western end, but is more pronounced in the east, where the mafic aggregates are drawn out into lenses. The western end of the range consists of aplitic, leucocratic hornblende-biotite granite composed of quartz, oligoclase, poikilitic microcline, and a little biotite, hornblende, pyrrhotite, and epidote. A few phenocrysts of plagioclase and quartz are present. Rubble from epidotized dolerite and microdiorite dykes is abundant at the western end of the ridge.

The southeastern slopes of Mount Curlewis, an inselberg which rises 700 feet above sea level on the coast 7 miles east of Guthalungra, consist of weakly foliated inequigranular leucocratic aplitic biotite granite. Quartz forms xenoblastic grains 0.3 mm across in aggregates 1 mm across. Sodic plagioclase and microcline are roughly tabular, but much of the feldspar has been recrystallized into fine-grained aggregates. Biotite is also recrystallized as strings of small flakes.

Medium-grained biotite leucogranite (C-Pg, shown in error on the map as C-Pd) is well exposed in a railway ballast quarry on the western side of Mount Carew, a small inselberg $1\frac{1}{2}$ miles west by south of Wilmington railway siding. The leucogranite is intruded by pyritiferous basic to intermediate dykes. A quarry worker reported that he had found masses of pyrite several inches across in the leucogranite.

North of Mount Roundback the granitic rocks crop out mainly as undulating rises with scattered small outcrops and bare expanses of rock up to 100 yards across. The granitic rocks form most of Mount Roundback, but they are masked in places by scree from dioritic roof pendants.

The white hornblende-biotite adamellite, beside a railway level-crossing 2 miles east of Wilmington siding, is massive and coarse-grained. It is composed of zoned oligoclase, perthite, quartz, biotite, and chloritized green amphibole; the mafic clusters include sphene, apatite, zircon, iron oxides, and allanite.

Massive boulders of coarse white granite occur beside the track near Kalli Valley homestead; quartz-hornblende latite porphyry crops out nearby, but its relationship to the granite is unknown.

The northeastern foothills of Mount Roundback are composed of hornblende-biotite adamellite.

A narrow belt of granite or granodiorite intrudes gabbro on the seaward side of Mount Luce. The outcrop is about 50 feet wide and at least 300 feet long, and the contact dips at about 50° to the south. The granite has been contaminated by the gabbro, and contains numerous basic xenoliths and schlieren elongated parallel to the contact. Flow-banded microgranite intrudes both granite and gabbro along the contact, and both rocks have also been intruded by two swarms of microdiorite and dolerite dykes - an earlier swarm trending at 290° and a later at 015°. The dykes and country rocks have been severely epidotized in zones up to 6 inches wide along the contacts. Numerous pegmatite veins intrude both the granite and gabbro.

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The massive white to grey chloritized granite, which crops out at several places at Bowen, is believed to underlie much of the town. Massive leucoadamellite crops out on the eastern side of a low hill on the northern outskirts of Bowen (half a mile north of the Bowen Shire Council Rugby Football ground), just within the Bowen Sheet area. It contains phenocrysts of strongly zoned oligoclase surrounded by coarse microcline antiperthite which is intergrown with quartz in places. The granite intrudes intermediate volcanics which are probably Lower Permian in age. As at Mount Luce, the granite is intruded by two swarms of intermediate to basic dykes; the earlier trends northwest and the later has a northerly trend.

Age and Relationships

The acid plutonic rocks generally intrude the basic to intermediate rocks (C-Pd). The only younger intrusions are abundant dykes and scattered epizonal granites (P-Mg).

No isotopic ages are available for the acid plutonic rocks (C-Pg) in the Ayr Sheet area. In the western part of the Bowen Sheet area the extensive granite which intrudes Upper Carboniferous volcanics has been dated isotopically at about 285 m.y. by the K/Ar method (uppermost Carboniferous). A few miles north of the known limit of these Upper Carboniferous granites is a group of oval epizonal stocks from which a single isotopic age of 270 m.y. (Lower Permian) has been obtained. In the north-central part of the Bowen Sheet area, deeply weathered and altered granitic rocks are overlain nonconformably by the Lizzie Creek Volcanics (Lower Permian), and from their fresher parts two isotopic ages of 270 m.y. have been obtained by the K/Ar method. However, detailed mapping is required to determine whether the fresh and weathered rocks are part of the same body. Granite at Bowen intrudes volcanics mapped with the Lower Permian Carmila Beds just south of the Ayr Sheet area. The Thunderbolt Granite near Collinsville (Bowen Sheet area) has yielded isotopic ages which average 265 to 270 m.y.; it is believed to be younger than the Lizzie Creek Volcanics. Until greater resolution can be obtained by further age determinations and detailed mapping it seems best to regard the granites grouped in this unit (C-Pg) as Upper Carboniferous to Lower Permian in age.

ACID VOLCANIC PLUG (C-Ph)

Mount Louisa is a plug-like mass of intrusive rhyolite and related rocks 20 miles south-southwest of Home Hill. It forms a high steep hill with cliffs in places near its summit.

Mount Louisa consists mainly of strongly flow-banded rhyolite and felsite, with subordinate trachyte and trachyandesite. The rocks are generally slightly porphyritic, green to white, and highly jointed; some of them are vitric. The flow banding is usually steep and commonly contorted. The cliff faces exhibit strong vertical joints. The plug is intruded by dykes of microdiorite and microadamellite, similar to those to the east in the diorite and granodiorite (C-Pd). Dykes of felsite and trachyandesite, similar to parts of the Mount Louisa plug, intrude the adamellite (C-Pg) to the east.

The acid intrusives are composed of microlites of feldspar, ironstained clay, and quartz. Quartz probably forms a high proportion of the groundmass. Small patches of penninite and epidote are scattered through the rock. Granular quartz occurs in irregular aggregates and the feldspar phenocrysts are completely altered to clay and epidote.

The Mount Louisa plug probably intrudes the Carboniferous to Permian granitic rocks (C-Pg). The plug is intruded by microdiorite dykes.

INTERMEDIATE TO ACID VOLCANICS (C-Pv)

Intermediate and acid volcanics, correlated with Carboniferous to Permian volcanics near Townsville, form the foothills of Saddle Mountain and Mount Elliot and the northern part of the Cape Cleveland peninsula. The maximum thickness at Cape Cleveland is 4000 feet.

Topography

At Cape Cleveland the volcanics form a narrow steep headland rising in places to 300 feet above sea level. Across the granite contact to the south, the headland becomes higher and broadens to form the main mass of the Cape Cleveland peninsula. West of Giru, the volcanics form a fringe of foothills east and southeast of Saddle Mountain and Mount Elliot. Uneven hills of volcanics, rising to 800 feet above sea level, extend for several miles southeast of Mount Elliot.

Lithology

Well bedded dark to pale brownish grey acid welded crystal tuff crops out at Cape Cleveland; one specimen has a dacitic composition. Some thin flows of acid lava were also noted.

In the southeastern foothills of Saddle Mountain, massive dark greenish grey andesite agglomerate and lapilli tuff, with small disseminated cubes of pyrite, predominate. Pale pinkish brown feldspar porphyry crops out on the western side of the road due east of the summit of Saddle Mountain.

Massive porphyritic greenish grey andesite or dacite and some dark blue finely porphyritic andesite crop out three-quarters of a mile southwest of where the Bruce Highway crosses Palm Creek.

Southeast of Mount Elliot, in the Walkers Creek/Black Gully district, purple and greenish purple porphyritic and aphanitic andesites(?) crop out. They are commonly amygdaloidal and strongly epidotized. The abundant boulders of fine-grained basic rocks are probably derived from dykes.

Structure and Thickness

At Cape Cleveland the volcanics are well bedded, with a fairly constant dip to the southeast. Northwesterly lineaments, probably faults, appear in places on the air-photographs. Dips of 50^{o} were recorded at two points about a mile apart. If there is no repetition of the sequence by faulting, the preserved thickness is about 4000 feet.

The thickness and structure of the volcanics elsewhere are unknown. In a road cutting on the main road to the west of Black Gully, the andesite appears to dip northwest at 5^{o}, and the andesite half a mile southwest of where the Bruce Highway crosses Palm Creek seems to dip west at a moderate angle. No structure was visible in the other outcrops.

Age and Relationships

The volcanic rocks around Mount Elliot and Saddle Mountain are continuous with similar rocks near Townsville which have been dated as late Carboniferous to Permian because they contain sedimentary interbeds with Glossopteris sp. (Wyatt et al.,1970a). The volcanics at Cape Cleveland, however, are somewhat different in lithology from the volcanics near Townsville. They are included in this group for lack of evidence that they are of any other age. They are intruded by the Cape Cleveland adamellite (P-Mg).

PERMIAN TO MESOZOIC

(TABLE 1)

VOLCANICS (P-Mv)

Nares Rock is an islet about 200 feet square which rises 15 to 20 feet out of the sea 3 miles south of Holbourne Island. The rock consists of strongly jointed dark grey hornfelsed tuff or tuffaceous sediments. It is mainly uniformly dark grey, but in places is finely banded and light grey. The bands dip vertically and strike northwest; they are slumped in places and probably represent bedding. The rocks do not part along the bands.

The hornfels contains 10 to 20 percent angular to subangular grains of quartz and poikiloblastic albite, which suggests that it is a recrystallized sediment. The grains are enclosed in a matrix of poikiloblastic to granophyric intergrowths of quartz and alkali feldspar.

Some volcanics in the Proserpine Sheet area have been found to be Cretaceous, and Nares Rock could possibly be of the same age.

GRANITES, ETC. (P-Mg and P-Md)

Some granitic plutons (P-Mg) in the Ayr Sheet area are mapped collectively as Permian to Mesozoic. The plutons are typically subcircular in plan and rise abruptly from the coastal plain as high rugged ranges. Leucocratic adamellites predominate over true granites. Rare small outcrops of diorite and dolerite (P-Md) occur around the margins of the acid stocks, and on Holbourne Island. The presence of net-veined complexes in places suggests that the more basic rocks are genetically related to the granitic rocks. The only known younger intrusive rocks are rare acid and microdiorite dykes of unknown age.*

Topography

Mount Elliot, Saddle Mountain, Gloucester Island, and the Cape Cleveland and Cape Upstart peninsulas are mantled by dense scrub. Mount Elliot rises abruptly to about 4000 feet above sea level and dominates the landscape in the western part of the Sheet area. Saddle Mountain and the Cape Upstart peninsula rise 2800 feet and 2500 feet respectively; Gloucester Island and the Cape Cleveland peninsula reach just under 2000 feet above sea level. The granites at Cape Edgecumbe and in the saddle between Mount Little and Sprole Castle have also been mapped with this group. Cape Edgecumbe is the northern tip of a rocky headland which consists largely of bare outcrops and tors of granite. The granite northeast of Mount Louisa forms rough bouldery hills.

Lithology

The adamellite (P-Mg) on the southern margin of the Cape Cleveland peninsula is a coarse massive white and pink porphyritic biotite adamellite, containing a little hornblende. The rock is composed mainly of quartz, perthite, and plagioclase which is diffusely zoned from andesine to albite. The accessories are sphene, magnetite, and apatite.

One and a half miles southeast of Cape Cleveland, thick granophyre dykes, which are probably offshoots of the adamellite, intrude the volcanics (C-Pv).

The southwestern margin of Saddle Mountain, which lies within the Townsville Sheet area, is composed of leucogranite and adamellite. The leucogranite is a massive red

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* Recent K/Ar isotopic dating of biotites from the Mount Elliot and Cape Cleveland granite stocks has shown them to be Lower Permian (see Appendix 5).

medium-grained rock which contains no plagioclase. The groundmass is locally granophyric, and some muscovite occurs in places. The rare mafic minerals have been entirely epidotized and chloritized. One and a half miles to the southeast the rock grades into adamellite. Some cobbles of fine-grained quartz-hornblende gabbro were found in a creek near the southern margin of Saddle Mountain.

Feltham Cone and the smaller inselbergs nearby have a similar air-photo pattern to that of Saddle Mountain.

The granite at Mount Elliot in the Townsville Sheet area is a massive pink-brown coarse porphyritic biotite-hornblende granite (P-Mg). It is composed of potash feldspar, zoned plagioclase (andesine to albite), green hornblende, biotite, magnetite, apatite, zircon, epidote, and allanite.

The stock north of The Gap, 5 miles east-northeast of Mount Louisa, consists of massive medium-grained biotite adamellite. No dykes were seen.

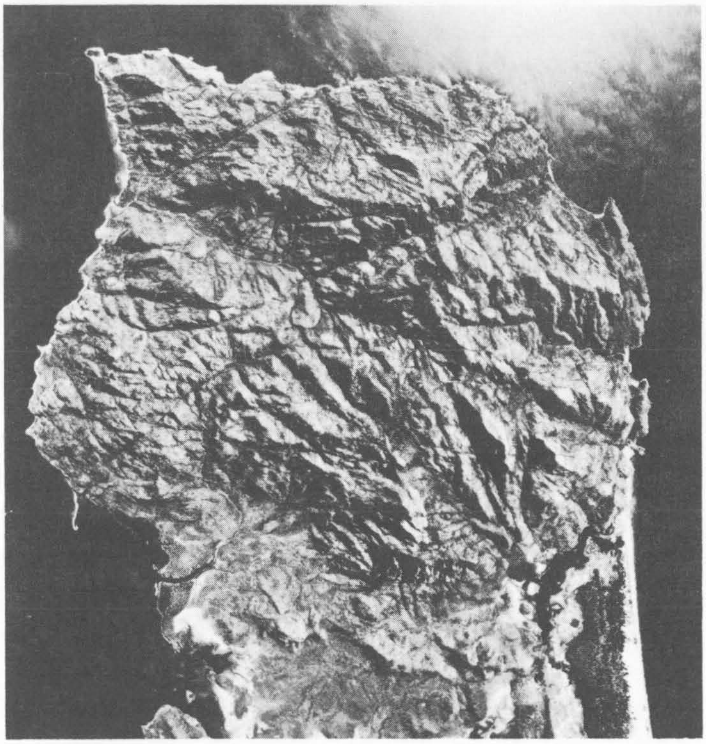

Fig. 9: Vertical air-photograph of Cape Upstart peninsula, an epizonal stock or ring complex of Permian or Mesozoic age. Approximate scale, 1:100,000. Reproduced by courtesy of Division of National Mapping, Department of National Development.

Most of the Cape Upstart peninsula consists of a subcircular stock of adamellite (P-Mg) with some low hills at its southern end (Fig. 9). The southeastern margin of the stock consists of massive leucocratic pinkish brown porphyritic medium-grained hornblende-biotite adamellite; it is composed of oligoclase-andesine (40%), potash feldspar (30%), and a little biotite, hornblende, and iron oxide. Massive coarse leucocratic biotite adamellite, containing recrystallized quartz, chloritized biotite, and microfractured oligoclase, crops out on the northern coast, and possibly represents a remnant of the country rock which surrounded the main stock.

Small outcrops of diorite, microdiorite, and quartz diorite (P-Md) crop out in places around the eastern and northern margins of the Cape Upstart stock. Their size has been exaggerated on the geological map.

Two miles north-northeast of The Cape homestead there is an excellent exposure of a net-veined complex of basic to intermediate intrusive rocks (P-Md) in intimate association with granite (P-Mg). The melanocratic rocks form a sliver, several hundred yards long and 30 to 50 feet wide, along the margin of the granite. The granite contains numerous basic to intermediate xenoliths, some of which show orbicular structures (P.J. Stephenson, pers. comm.). The melanocratic rocks range from augite-diorite to porphyritic biotite microdiorite.

Quartz diorite, biotite-quartz diorite, and biotite diorite also crop out along the margin of the adamellite in a bay on the northeastern coast of the Cape Upstart peninsula. The adamellite veins the diorites, but in places, the diorite becomes finer in grain near the contact, and has a crude foliation which may be a type of flow structure. Dioritic xenoliths with crenulate margins occur in the adamellite in places. Thin horizontal veins of adamellite permeate the diorite and meandering anastomosing pegmatitic apophyses commonly extend upwards from them. Similar features have been described by Blake et al. (1965), where basic and acid magma have been intruded simultaneously, or where basic magma has intruded acid rock. In the first case, the basic magma is chilled against the acid magma in which it is trapped, and may crystallize as xenoliths with crenulate margins; in the second case, the basic magma has intruded and remelted the granitic rock, which has then 'back-veined' the basic rock.

The adamellite (P-Mg) forming the saddle between Sprole Castle and Mount Little is a northerly continuation of the intrusion at Mount Pring in the Bowen Sheet area. The Mount Pring mass consists of coarse inequigranular massive white biotite adamellite composed of perthite, zoned oligoclase, quartz, and biotite, with a little zircon, apatite, sphene, and euhedral allanite.

The Cape Edgecumbe promontory consists of massive pink medium-grained drusy leucocratic alkali granite composed of perthite (40%), quartz (40%), albite (15-20%), and some biotite and zircon. Euhedral quartz crystals occur in rare druses.

The southeastern tip of Holbourne Island consists of coarse, medium, and fine-grained intermediate and basic plutonic rocks (P-Md). Thick melanocratic and paler layers dip at a low angle to the north-northwest. The rocks include leucocratic hornblende gabbro, augite diorite, and diorite; a more leucocratic rock which is locally pegmatitic, occurs as horizontal veins from which apophyses extend upwards, as at Cape Upstart. Some of the veins contain feldspar, hornblende, quartz, and epidote.

The granophyre and hornblende-quartz alkali syenite (P-Mg) on the northeast coast of Holbourne Island are faulted against the diorites (P-Md). The granophyre close to the fault is strongly sheared and intruded by abundant basic to intermediate dykes. The hornblende-quartz alkali syenite crops out 200 yards farther northwest. The northwestern tip of the island consists of leucogranite intruded by a swarm of dark dykes.

Middle Island also consists of leucocratic granitic rocks. A coarse biotite alkali rhyolite porphyry crops out on the northwest coast; it is intruded by numerous dykes of similar porphyry, up to 20 feet thick, and by thinner dykes of dolerite or microdiorite.

Fig. 10: Dolerite or microdiorite dykes intruding the complex marginal zone of the Gloucester Island leucogranite stock (Permian or Mesozoic). The stock forms the main mass of the island, but large marginal slivers of dark dioritic rocks, banded in places, crop out along the northeast shore. Photograph by J.E. Zawartko.

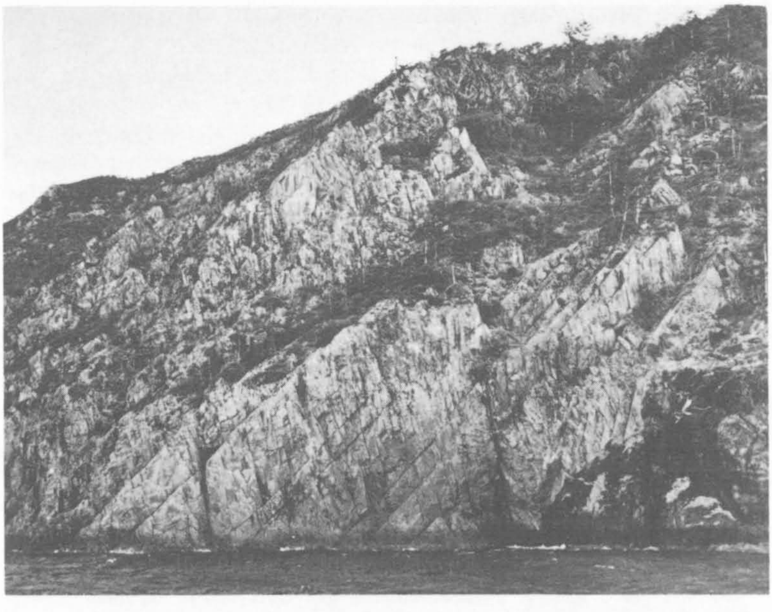

Fig. 11: Jointing in leucogranite, northeast shore of Gloucester Island. A complex zone of mixed dioritic and granitic rocks is visible on the right of the picture. Photograph by J.E. Zawartko.

Gloucester Island consists mainly of uniform medium to fine-grained leucocratic biotite granite (P-Mg). Dioritic slivers (P-Md) crop out at sea level in places (Figs 10, 11).

At the extreme northern tip of the island a net-veined complex (Figs 12, 13), similar to that on the Cape Upstart peninsula, is well exposed at sea level. The oldest rocks in the complex are hard siliceous mottled pale grey, pink, and green hornfelsed volcanics which occur as xenoliths, up to 6 feet across, in diorite and granodiorite. The volcanics are commonly banded, and in places amygdaloidal. Xenoliths and blocks of diorite (which themselves contain xenoliths of the volcanic rocks) occur in granodiorite, and the xenoliths are cut by an irregular permeating network of granodiorite veins. The leucocratic granite, which appears to form most of the island, cuts across the net-veined complex. The contact is rectilinear, but apophyses are present in places. Finally, the complex was intruded by basic to intermediate dykes.

Structure

The Mount Elliot, Saddle Mountain, and Cape Upstart plutons are well defined subcircular stocks. The outline of the Cape Cleveland mass is irregular but roughly equidimensional and may be circular at depth. The granite outcrops between Sprole Castle and Mount Little represent the partly unroofed northern extension of a circular stock which forms Mount Pring in the Bowen Sheet area. All these granites are evidently high-level epizonal intrusions, and further mapping may show that some of them (e.g., Cape Upstart) are ring complexes.

The deep straight V-shaped valleys, which are common in most of the granites, are almost certainly the result of erosion along faults. The faults have a preferred northwesterly trend, and are therefore probably the result of regional rather than local stresses.

Age and Relationships

Although these granitic intrusions are not necessarily all of the same age, they are collectively regarded as the youngest in the Sheet area. The Cape Cleveland peninsula adamellite intrudes volcanics which may be equivalent to the Upper Carboniferous to Permian volcanics near Townsville. It is intruded by rare microdiorite dykes. The Saddle Mountain and Mount Elliot stocks both intrude volcanics which are continuous with the Upper Carboniferous to Permian volcanics near Townsville. The granite at Cape Edgecumbe is probably continuous at depth with the granite at North Head (within the Bowen Sheet area), which intrudes abundant Permian microdiorite and dolerite dykes. Only rare acid dykes are known in the granite at Cape Edgecumbe. The Cape Upstart adamellite and the Gloucester Island mass are included with the group because they are probably epizonal intrusions, and because they are only rarely intruded by dykes.

The age of the few dykes which intrude the granites and adamellites is unknown. The granites in the Whitsunday and Cumberland Islands are regarded as Cretaceous (Clarke et al., 1968, unpubl., and in prep.). A large Lower Cretaceous granite has been delineated recently by mapping and isotopic dating in the northeastern part of the Bowen Sheet area (Paine et al., in prep.; see also Webb & McDougall, 1964). This suggests that some of the youngest granites in the Ayr Sheet area, especially in the east, may also be Cretaceous.

DYKES

Dykes with a wide range in composition are common in all rock units except the younger granites. Microdiorite and dolerite dykes are the most widespread. They are commonly between 2 and 5 feet thick, but range up to 20 feet. There are no known early Palaeozoic dykes; the vast majority are believed to be late Palaeozoic (probably Permian), but some are probably Mesozoic. Epidotization is widespread and typical of the dark dykes.

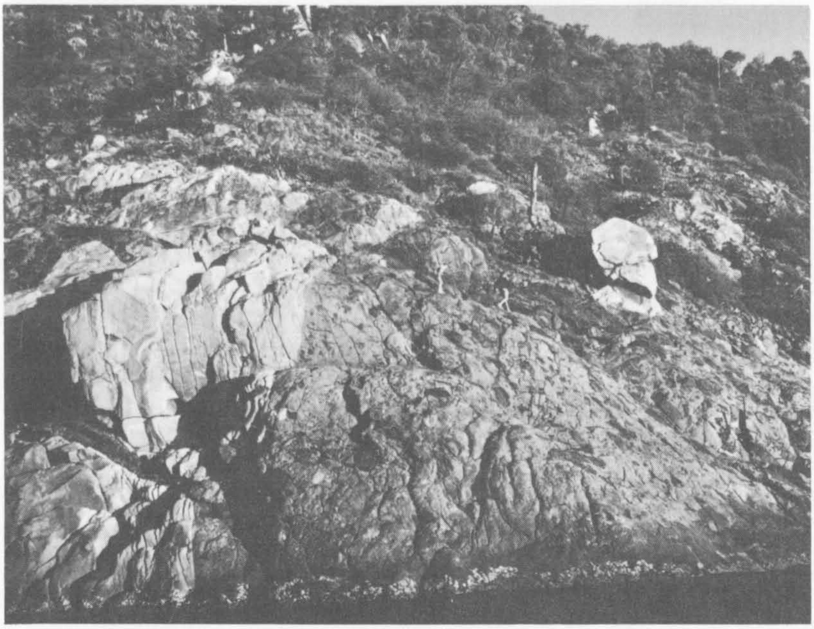

Fig. 12: Leucogranite (left) intruding net-veined complex, northern point of Gloucester Island. The leucogranite is probably magmatically related to the net-veined complex. The resistant stack of light-coloured rock to the right of the figures is a pipe-like body of leucogranite which is probably an offshoot of the main mass. Photograph by J.E. Zawartko.

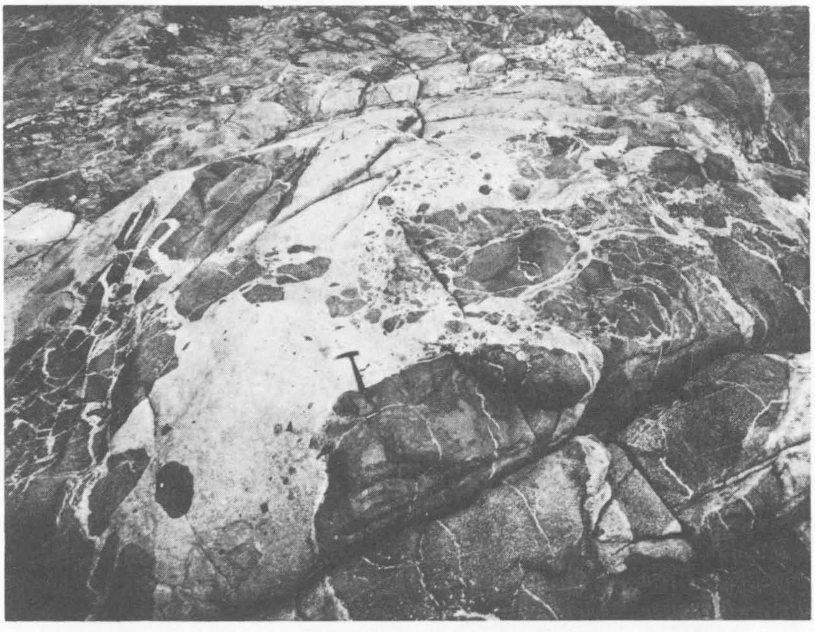

Fig. 13: Close-up of part of the net-veined complex in Figure 12. Photograph by J.E. Zawartko.

The acid felsite, microgranite, granophyre, and porphyry dykes can be related in places to the Permian to Mesozoic igneous centres (P-Mg), near some of which they are very abundant. They are usually thicker than the basic to intermediate dykes. In the central and northwestern parts of the Sheet area, most of the dykes trend between north-northwest and west-northwest, except for some east-northeasterly dykes in the Inkerman Shear Zone. The dykes in the southwest and east appear to have no preferred orientation.

Southeastern Part of Sheet Area

Both the intermediate to basic and the acid dykes are well exposed in and around the town of Bowen, which lies just south of the Sheet area. Easily accessible outcrops are found on North Head, in an old quarry west of Magazine Creek, and on the eastern slopes of a low hill just west of the turn-off to Flagstaff Hill. The outcrops reveal the following chronological sequence of events: (1) acid and intermediate volcanics (probably Lower Permian), (2) adamellite (C-Pg), (3) northwesterly swarm of basic to intermediate dykes, (4) northerly swarm of basic to intermediate dykes, (5) leucogranite (P-Mg), and (6) northerly microgranite dykes.

Some of the basic to intermediate dykes at Bowen have been albitized, and the mafic minerals are almost invariably uralitized, epidotized, or chloritized. The dykes are generally fine-grained and equigranular, but some contain plagioclase phenocrysts. In the dykes which have not been albitized the plagioclase ranges from labradorite to andesine. Some contain primary hornblende, with or without quartz, and no pyroxene. They include dolerite and microdiorite and some augite microdiorite and hornblende dolerite, some of which contain quartz. There is no significant difference in composition between northwesterly and northerly dykes.

The basic to intermediate dykes near Bowen are intersected by thicker microgranite dykes, some of which are probably offshoots from, and others intrude, the leucogranite (P-Mg) of Cape Edgecumbe.

An albitized dolerite dyke intrudes diorite at the eastern end of Holbourne Island, and a swarm of albitized microdiorite dykes intrudes the granite (C-Pg, see p. 27) at Mount Carew west of Salisbury Plains homestead.

A weakly banded microtonalite dyke intrudes granite (C-Pg) 1 mile east of Salisbury Plains homestead. It is composed of phenocrysts of andesine set in a groundmass of hornblende, plagioclase, and appreciable amounts of interstitial quartz and alkali feldspar. A different type of microtonalite dyke intrudes the granite (C-Pg) 4 miles west-northwest of The Cape homestead. It contains 60 percent of zoned plagioclase phenocrysts (An_{80}-An_{55}) set in a groundmass of quartz (15%), hornblende (10%), and biotite (10%).

The granite (P-Mg) 1½ miles east of Cape Upstart is intruded by a multiple dyke of microdiorite and felsite. The margins of the dyke consist of albitized hornblende microdiorite and the core is a thin lenticular intrusion of porphyritic felsite. A rhyolite dyke intrudes the granite (P-Mg) on the northeastern coast of the Cape Upstart peninsula (Fig. 14). It is composed of phenocrysts of oligoclase-andesine, potash feldspar, embayed quartz, and epidotized hornblende set in a groundmass of alkali feldspar laths, interstitial quartz, some plagioclase, epidote, and acicular apatite.

Fig. 14: Five-foot porphyritic rhyolite dyke intruding adamellite (P-Mg) on the north-eastern coast of the Cape Upstart peninsula.

Central Part of Sheet Area

Partly amphibolitized dolerite dykes, composed of calcic labradorite and augite, intrude the granite (C-Pg) southwest of Kellys Mount.

Dyke swarms intrude the intermediate to basic plutonic rocks (C-Pd). They include two large north-northwesterly swarms and an east-northeasterly swarm along the Inkerman Shear Zone. The dykes include rhyolite, rhyodacite, microgranite, microadamellite, microgranodiorite, acid porphyries, and microdiorite. The microgranodiorite dykes were probably intruded soon after the emplacement of the granodiorite and diorite country rock; they are cut by the acid dykes. Fine-grained dark green microdiorite dykes, believed to be no older than late Palaeozoic, are common in the central part of the Sheet area; at least three intrusive episodes have been recognized at The Rocks in the Burdekin River.

Microgranite, microadamellite, and rhyodacite, with or without phenocrysts, are next in abundance. Dacite is comparatively rare. Rhyolite dykes were found near Beaks Mountain and Mount Louisa. At Beaks Mountain they appear to be related to Edinburgh Castle (an intrusive centre 4 miles south of the margin of the Sheet area), which resembles the Upper Permian or Lower Triassic plugs between the Bogie and Bowen Rivers. One of the rhyolite dykes contains concentric spheroidal flow structures, compressed in the plane of the dyke.

The width of the dykes generally ranges from 1 to 10 feet, but some are much wider. A microadamellite dyke up to 300 feet wide crops out in the Burdekin River, near its junction with Landers Creek. The dyke has a weak east-west foliation and is closely jointed. The jointing is probably due to the Millaroo Fault, which is close by to the west.

Rhyolite dykes associated with the Mount Louisa rhyolite plug intrude adamellite (C-Pg) east of the plug.

TABLE 2. CAINOZOIC STRATIGRAPHY

Period or Epoch	Rock Unit and Map Symbol	Lithology	Topography	Relationships	Structural/Depositional Environment	Remarks
QUATERNARY	(Qm)	Mud, silt; minor salt	Littoral flats and pans	Superficial; complementary to coastal dunes	Deposited in calm water from high tides and floods	Intermittent deposition continuing in lee of coastal dunes
	(Qr)	Sand; some interbedded silt	Low linear dunes up to 25 ft high	Superficial	Ancient and present shore dunes; perhaps some submerged offshore bars	Includes some old blowout dunes; local concentrations of heavy minerals
	(Qu)	Scree, gravel, sand; semiconsolidated in places	Scree slopes	Superficial; merges with alluvium (Cza) and residual soil (Czs)	Outwash fans, essentially stable at present; therefore thought to have been deposited in a wetter climate	Dissected by present streams; probably Pleistocene
UNDIVIDED	(Cza)	Sand, silt, mud, gravel; semiconsolidated in places	Flat to gently undulating	Superficial; merges with residual soil (Czs) and outwash fans (Qu)	Levees, floor plains, and deltas	Up to 270 ft thick in Burdekin R Delta; elsewhere much thinner; mostly Quaternary
	(Czs)	Soil, sand, rubble; semiconsolidated in places	Gently undulating	Superficial; mainly closely related to bedrock	Mainly residual soil developed on deeply weathered granitic rocks; some colluvium	Generally less than 10 ft thick
	(Czc)	White powdery material rich in calcium carbonate	Flat	Isolated deposits interfingering with residual soil (Czs)	Superficial; derived from weathered coarse diorite	Two small isolated deposits; thickness of 50 ft claimed by lessees; worked for local agricultural use

Western Part of Sheet Area

Felsite, quartz porphyry, and feldspar porphyry dykes intrude the low-grade metamorphics (Pzu) southwest of Mount Woodhouse. Leucocratic microgranite dykes intrude sheared volcanics (Cuv) at the northeastern end of the Mount Dalrymple range. Four miles west of Mount Benjonney a complex swarm of blue-grey feldspar-hornblende porphyry, feldspar-hornblende-quartz porphyry, andesite, and aplitic quartz porphyry dykes intrudes the Ravenswood Granodiorite; the swarm is truncated by an arcuate body of microgranite (C-Pg). Some of the feldspar-hornblende porphyry dykes intrude dark-blue andesite dykes, and both are cut by flow-banded microdiorite dykes.

A swarm of flow-banded felsite, andesite, and microdiorite dykes intrudes the granodiorite in the Burdekin River east of Clare. The dykes are parallel, and their relative ages are unknown. The swarm is parallel to the north-northwesterly swarm in the Stokes Range, 6 miles to the east.

Two miles southeast of the confluence of Deep Creek and the Burdekin River west-trending microdiorite dykes intrude granite rocks. They are cut by thin tourmaline pegmatite. Dykes of red granite and biotite adamellite also intrude the plutonic rocks, but their relationship to the microdiorite and pegmatite is unknown.

Northerly trending pyroxene microdiorite dykes containing oligoclase-andesine intrude the porphyritic microgranite (C-Pg) in the northeastern foothills of Major Creek Mountain; they are severely epidotized. Similar epidotized dykes, including some dolerites, are abundant in the Upper Carboniferous to Permian Volcanics (C-Pv). They are generally absent in the younger granites (P-Mg), but strongly altered microdiorite(?) dykes intrude granite (P-Mg) near Cape Ferguson.

CAINOZOIC

(Table 2)

Earth Lime (Czc)

The small superficial deposits of unconsolidated white 'earth lime' occur 10 miles to the southwest and 8 miles to the south of Inkerman homestead. The earth lime deposits are covered by several feet of soil, and were probably formed by leaching and concentration of calcium carbonate in the dioritic rocks. In places the colluvium overlying the diorite has also been calcified. Connah (1958) regarded the deposits as the products of Quaternary mound springs (see p. 45).

Residual and Colluvial Soil (Cza)

Residual and colluvial soils form a discontinuous broad zone between the hills and the coastal plain. The soil-covered areas are higher than the coastal plain; they are gently undulating and are interrupted by a few low rounded hills. Scattered cobbles and angular blocks of weathered rock are found in a few areas, and patches of gravel are not uncommon at shallow depth in creek sections. The soils range from pale sand to black loam, depending on the parent rocks, and are at least 10 feet thick in places. They are probably largely residual, but colluvial material is also present.

Alluvial and Deltaic Deposits (Cza)

Most of the Sheet area is underlain by superficial Cainozoic alluvial and deltaic sediments. They are believed to be mainly Quaternary, but some may be Tertiary.

Near the mouth of the Burdekin River the entire sugar crop on the Burdekin River Delta (valued at about $30 m. in 1963, Wiebenga et al., 1966, unpubl.) depends on underground water pumped from the Quaternary sediments. The sediments were studied in 1964 by a group of geologists from Louisiana State University and detailed geophysical surveys were carried out by the Bureau of Mineral Resources in 1962-65.

Many waterbores have been drilled in the delta. Those which reached bedrock are plotted on the map in Appendix 4. The maximum thickness of the sediments recorded in a bore is 271 feet near Plantation Creek, 5 miles northeast of the centre of Ayr, but seismic work has indicated a thickness of at least 500 feet near Lynchs Beach (Wiebenga et al., 1966, unpubl.).

Some colluvial and outwash deposits which underlie gently sloping country close to the hills and ranges have been mapped in places with this unit. The deposits merge imperceptibly with the alluvium laid down in the flat-lying country by overflow from the larger streams during floods. Both the colluvium and alluvium merge and interfinger with the deltaic deposits.

The sediments of the Burdekin River Delta consist of interbedded lenses of sand, silt, and gravel, with lenses of mud near the coast. Recent erosion of the Quaternary deposits, due to slight coastal emergence, can be seen at Lynchs Beach (Alva), where a 10 foot cliff has been cut in interbedded deltaic sand and mud (Fig. 15). A C^{14} age of 3870$\pm$50 years b.p. was obtained on carbonized wood embedded in the sand near the top of this cliff (Institute of Nuclear Sciences, DSIR, New Zealand), which sets a maximum age limit on both the uppermost sediments and the emergence.

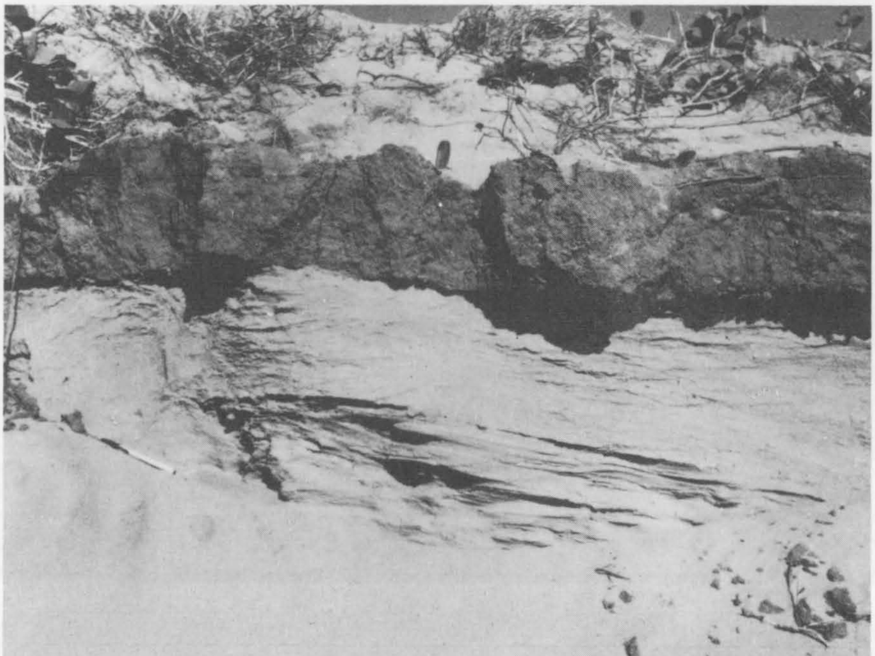

Fig. 15: Quaternary deltaic sediments of the Burdekin River Delta at Lynchs Beach (Alva), 10 miles northeast of Ayr. The sediments consist of fine sand and interbedded lenses of silty mud, and are now being eroded owing to a recent slight fall in sea level.

QUATERNARY

Outwash and Scree (Qu)

Wedge-like deposits of angular rubble and sand form an outwash apron around the Mount Dalrymple range. At the foot of the range the rubble is consolidated scree, but the finer-grained material farther away is unconsolidated. The apron is up to $2\frac{1}{2}$ miles wide; it thins gradually outwards from the range and merges with the alluvium. The maximum thickness of rubble is estimated at about 50 feet. A crude radial system of small streams dissects the outwash apron. The rubble is an accumulation of angular fragments of fine-grained acid volcanics up to 2 feet in diameter.

Kellys Mount, and the two hills 3 miles southwest, are surrounded by a similar outwash apron.

Thick tongues of scree, which coalesce to form outwash fans, occur around the slopes of Mount Roundback and Mount Little in the southeast.

The scree and outwash deposits are now being dissected. They are the products of a former period of active denudation, probably a pluvial period during the Pleistocene.

Coastal Sand Dunes (Qr)

Sand dunes, some of them several miles inland, occur along much of the coast. They consist of material deposited by wave action, and later redistributed by winds. Most are fixed by vegetation, but some of the present-day active beach dunes and offshore sand bars are included in this unit. The highest dunes (e.g., that extending southeast from The Cape homestead) are about 25 feet high, but most of them are less than 15 feet above sea level.

The dunes indicate former strandlines. Their distribution and trends are controlled by the predominant northwesterly longshore currents. In places, they have advanced out to sea by growth at their distal ends and bridged the gaps between former islands (Cape Cleveland and Cape Upstart peninsula) and the mainland; extensive mud flats have been developed in their lee. Cape Bowling Green is a complex of dunes which is currently growing to the northwest by the addition of material from the Burdekin River.

Thin remnants of pale brown hard cemented beach detritus ('beach rock') occur between tide-marks along the beaches as, for example, at Dingo Beach. They are too small to map.

Some of the beach sands along the coast between Bowen and Cape Bowling Green contain high concentrations of heavy minerals. Three samples of the sands have been analysed and the results are tabulated in Appendices 2 and 3. A body of heavy mineral sand at Dingo Beach is about 3000 feet long, 30 feet wide, and about 18 inches thick in the centre. The analysed sample contains 87 percent iron and titanium oxides (see p.). The heavy minerals have been derived from the gabbro at Abbot Point.

A pumice beach occurs on the northeastern side of Cape Cleveland.

Coastal Mud Flats (Qm)

Much of the low-lying country fringing the coast consists of mud flats which are periodically inundated by high tides and floods. In places the mud flats are covered by a thin layer of salt. The flats are most extensively developed in the lee of the large ancient coastal dunes, as for example at Abbot Point, Cape Upstart, and Cape Bowling Green.

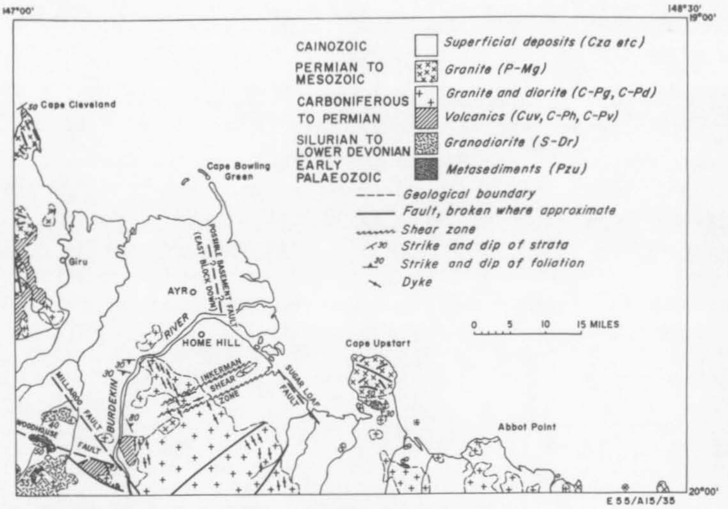

Fig. 16:

STRUCTURE

The major structural units are outlined in Figure 16.

The Inkerman Shear Zone is at least 2 miles wide at its widest part. The rocks within it have been intensely metamorphosed by shearing and recrystallization, and in places by metasomatic activity (with which some traces of copper mineralization are associated). In the Townsville Sheet area, just west of Horse Camp Hill, phyllonite, mylonite, schist, and gneiss have been developed from granite and granodiorite within the similar Alex Hill Shear Zone, which lies on strike with the westerly projection of the Inkerman Shear Zone. Outcrops are not abundant in the intervening area, but the existing outcrops show no evidence of shearing along this east-northeasterly zone. The foliation within the shear zone is vertical, but the direction of movement is unknown.

The Woodhouse Fault, in the southwest, can be traced for 16 miles within the Ayr Sheet area. It continues northwest into the Townsville Sheet area as a fault system extending west-northwest up the valley of the Reid River. The total length of the fault is about 65 miles. In the Ayr Sheet area, the Woodhouse Fault in the metamorphic rocks (Pzu) is marked by dip reversals, fault breccia, and zones of silicification and shearing. The distribution of the Upper Carboniferous volcanics (Cuv) suggests that the Woodhouse Fault may have partly controlled their extrusion. The major component of movement is apparently vertical. In the Townsville Sheet area the movement is north block down. Pyritic silicified rhyolite occurs along the fault near Mount Dalrymple.

A major northwesterly fault, here named the Millaroo Fault, is believed to extend northwards into the Ayr Sheet area. In the Bowen Sheet area, this fault has downthrown Lower Permian Volcanics in the east against Upper Carboniferous granite in the west. The granite near the confluence of the Bogie and Burdekin Rivers, to the south of the Ayr Sheet area, is strongly brecciated on the projection of the Millaroo Fault, and the fault is believed to have controlled the direction of the Burdekin River near here. The Millaroo Fault may extend farther northwest beneath the alluvium, and the brecciated microgranite at the confluence of Seven Mile and Major Creeks may possibly be an indication of it.

There is evidence of strong faulting (Sugar Loaf Fault) parallel to the coast between Beach Hill and Green Hill. Mylonite is present in places. The shearing is stronger at Sugar Loaf in the northwest than at Green Hill in the southeast. The Sugar Loaf Fault is normal to the Inkerman Shear Zone and roughly parallel to the Millaroo Fault.

Numerous dyke swarms intrude the plutonic rocks (C-Pd and C-Pg) parallel to the Sugar Loaf and Millaroo Faults. East of Stockyard Creek the dykes trend north-south, possibly because of rotation by two northeasterly faults. The northwesterly dykes persist through and are therefore younger than the Inkerman Shear Zone. They may be genetically related to, the Lower Permian volcanics (Lizzie Creek Volcanics, Bowen Sheet area) and Upper Carboniferous to Permian volcanics (C-Pv).

Numerous other faults have been mapped in the southwest. Most of them appear to be of local significance only. The strong faults on the border of the Upper Carboniferous volcanics of Mount Dalrymple may have developed as a result of subsidence of the massive pile of volcanics, together with vertical movement along the Woodhouse Fault. The fault along the southwestern side of Mount Dalrymple may be a branch of the Woodhouse Fault.

Detailed gravity surveys in the Burdekin River Delta have revealed a sharp north-northwesterly gravity gradient a few miles east of Ayr. The gradient is interpreted as a hinge-fault (east block down) in the pre-Cainozoic basement, the throw being greater in the north than in the south (Wiebenga et al., 1966, unpubl.).

A strong negative gravity anomaly, roughly circular in plan, is centered $1\frac{1}{2}$ miles south of the Burdekin River bridge. It is possibly due to a relatively low density intrusion (Wiebenga et al., 1966, unpubl.).

GEOLOGICAL HISTORY

The oldest rocks known are isolated remnants of metamorphics (Pzu) which crop out in the southwest. They represent altered impure arenites and siltstones which were probably deposited in the early Palaeozoic, and are intruded by the Ravenswood Granodiorite. Similar rocks occur in the southern part of the Cape Upstart peninsula and near Guthalungra, but it is not known whether they are the same age. They are older than the plutonic rocks mapped as Upper Carboniferous to Lower Permian.

Two isotopic dates of 420 m.y. (Silurian) have been obtained on the earlier (granodioritic) phase of the Ravenswood Granodiorite in the Townsville Sheet area.

The calcareous hornfels at Charlies Hill is the only record of sedimentation between Silurian and Carboniferous times. The beds were probably deposited in a shallow near-shore environment, with basement rocks cropping out nearby.

The late Palaeozoic (late Carboniferous and early Permian) was a time of widespread igneous activity and tectonic unrest in eastern Queensland. Most of the plutonic rocks are believed to have been emplaced in this late Palaeozoic period of recurrent mobilization of magma. The acid volcanics in the southwest (Cuv) were extruded in the Upper Carboniferous; their distribution was probably partly controlled by the Woodhouse Fault. Intrusion of diorite-granodiorite (C-Pd) and granite-adamellite (C-Pg) was accompanied and closely followed by faulting, shearing, and by the intrusion of dykes. The intermediate volcanics (C-Pv) were probably erupted between separate Upper Carboniferous and Lower Permian intrusive epochs, and acid vulcanism (C-Ph) is believed to have recurred at that time. High-level granites (P-Mg), accompanied by minor dyke intrusion, were emplaced in the Permian or Mesozoic.

There is no record of sedimentation during the Mesozoic, although there are remnants of possible Mesozoic sediments in the southeastern part of the Townsville Sheet area (Wyatt et al., 1970a). During this era the environment was chiefly erosional.

The development of the coastal plain during the Cainozoic led to the deposition of superficial alluvial, deltaic, and littoral deposits. In the Ayr Sheet area, it is not known to what extent the formation of the coastal plain was due to faulting, but the development of a Tertiary graben in the Proserpine Sheet area (White & Brown, 1963, unpubl.; Clarke et al., 1968, unpubl., and in prep.) indicates that faults may also have been active at the same time in the Ayr Sheet area.

ECONOMIC GEOLOGY

Apart from minor molybdenum mineralization at Kellys Mount, no metalliferous deposits are known in the Ayr Sheet area. Minor occurrences of phosphate rock (Holbourne Island), vermiculite (Stokes Range area), and graphite (Cape Upstart peninsula) have been recorded. The groundwater in the Burdekin River Delta and the water in the Burdekin River are of major economic importance.

Groundwater

Groundwater is used extensively in the Burdekin Delta for irrigation. Intensive hydrological and geophysical investigations have been carried out in the past few years, and the results have been summarized in an unpublished 'Progress Report on the Water Resources of the Burdekin Delta' submitted to the Queensland Irrigation and Water Supply Commission in June 1964. The Bureau of Mineral Resources has since carried out further geophysical work to define the structure of the delta (Andrew & Wainwright, 1964, unpubl.; Andrew et al., 1965; Wiebenga et al., 1966, unpubl.).

Metals

There is no recorded production of metals. Workings in pyritiferous metarhyolite at the eastern end of the Mount Dalrymple range are possibly old gold prospects.

During the regional mapping, minor occurrences of the copper minerals malachite, azurite, and chalcopyrite were found in altered rocks 4 miles southwest of Mount Inkerman in the Inkerman Shear Zone, and in volcanics in the Burdekin River near Millaroo. A little finely disseminated chalcopyrite has been noted in gabbro near Abbot Point (see Appendix 3).

Three of the five specimens analysed spectrochemically (see Appendix 1) contain interesting metal values: a greisen from a costeaned area on the northeastern slope of Kellys Mount contains 300 ppm molybdenum; the epidote rock from the Inkerman Shear Zone (Ar9/7/37(K)) contains 1000 ppm nickel and 50 ppm cobalt; and the magnetite rock from the Inkerman Shear Zone contains 200 ppm copper and 40 ppm cobalt.

Morton (GSQ file 30/609M, 7 Oct. 1930) has reported on an area held by the Ayr Exploration Syndicate at Kellys Mount. The costeaned area mentioned in the previous paragraph is believed to represent part of the Syndicate's workings. Morton reported that 'greisenisation of the granite on a grand scale, and to every degree of intensity, is in evidence .... The numerous veins and veinlets of barren quartz in evidence within the altered zone were apparently introduced during the process of greisenisation, as they do not occur in the surrounding unaltered granite'.

Pyrite, or its oxidation products, was reported to be widespread, and traces of gold and silver were reported in part of the workings. Occasional vugs carrying lead carbonates with an appreciable silver content and traces of bismuthinite accompanying pyrite were reported from elsewhere in the workings. A sample from one of the shafts assayed 1 dwt 14 gr of gold and 60 dwt of silver. Morton concluded that the low values encountered did not justify further prospecting. However, he stressed the large extent of the greisen, and the possibility of economic mineralization at depth cannot be entirely discounted.

In 1966-67 Australian Selection Pty Ltd located molybdenum anomalies in the greisen by geochemical sampling, and drilled shallow percussion holes (up to 200 ft) on some of the anomalies. However, the molybdenum values intersected were uneconomic (Australian Selection Pty Ltd, 1967, unpubl.).

A number of samples of beach sand have been mineralogically examined (see Appendices 2, 3). The most interesting mineral sand occurs at Dingo Beach, just west of Abbot Point, where a thin blanket of dark blue-black ilmenite-magnetite sand has been concentrated from gabbro which crops out nearby. The analysed sample contains 87 percent iron and titanium oxides. It is estimated that about 3000 tons of ilmenite are present in 10,000 tons of sand over a length of 3000 feet, an average width of 30 feet, a maximum thickness of about 18 inches in the centre, and a grade of 30 percent ilmenite, but it is difficult to assess the proportion of ilmenite in the complex oxides (see Appendices 2, 3). The old beach dune inland from the present beach contains a considerable proportion of dark minerals; the grade is much lower than in the sands on the beach, but the deposit is much larger.

Rock Phosphate

A small low-grade deposit of phosphatized coralline beach conglomerate occurs at Holbourne Island. Production from the island was:

	Tons	
1918	450	
1919	650	
1920	850	
1921	450	
Total	2400	(averaging about 18% P_2O_5)

Saint-Smith (1919), Reid (1944), and Young (1944, unpubl.) have reported on the deposit. The coralline material has been phosphatized by leaching from guano, and is not suitable for the production of superphosphate because of wide variations in grade and a high content of iron and calcite.

Earth Lime

Two small deposits of 'earth lime' (see p. 39) are being worked for local use.

Eight Miles South of Inkerman Homestead. It was claimed by the operator that 16 acres of workable lime have been proved in this deposit. One drill hole is reported to have penetrated 50 feet of earth lime without reaching the bottom of the deposit. From the surface the section is: black soil (2 ft); grey soil (3-4ft); white earth lime. The deposit consists of zones of uniform earth lime (probably derived from diorite), and zones of partly calcified colluvium where the earth lime contains up to 50 percent of cobbles and pebbles of microdiorite and microgranite which have not been calcified. In one place a 2-foot microdiorite dyke, which has not been calcified, forms a bar through a zone of almost pure earth lime. The deposits were probably formed by selective calcification of the coarse plutonic rocks and the matrix of the unconsolidated colluvium; the fine-grained igneous rocks are not visibly affected.

Ten Miles Southwest of Inkerman Homestead. The deposit 10 miles southwest of Inkerman homestead is a bed from 4 to 12 feet thick which covers only a few acres. Much of the lime appears to be pure, and little rubble is associated with it, but some zones are probably low in grade. The deposit is poorly exposed owing to an extensive blanket of black soil.

Graphite

Jack (1888) recorded the presence of graphite near Cape Upstart, and Dunstan (1921) wrote: 'At Cape Upstart, a seam of graphite 4 to 8 feet thick occurs in coal measure strata, the alteration of coal to graphite being caused by a massive igneous intrusion. No particulars are available, however, concerning the character or quality of the graphite'.

The occurrence is situated 2.5 miles west-northwest of the The Cape homestead, low on the eastern slope of a granite spur. The old shaft is surrounded by mullock of black chiastolite hornfels, some specimens of which are soft, friable, and sooty, whereas others are hard and dense. Some micronodular vermiform aggregates of calcite are also present. The hornfels crops out sporadically around the foot of the spur.

Material from this shaft is reported to have been shipped to Germany for treatment in the early part of this century (W. Hickmott, pers. comm.). The graphite content of the lip of the old shaft was estimated at 30 to 40 percent (I.R. Pontifex, pers. comm.).

Vermiculite, Asbestos, and Garnet

Low-grade vermiculite and asbestiform tremolite occur in the Inkerman Shear Zone and Stokes Range (Carruthers, 1954). The vermiculite is closely associated with weathered biotite in altered granodiorite gneiss. Monomineralic garnet rocks also occur in the Inkerman Shear Zone. No production of these minerals is recorded, but a local resident reported that they had been worked.

Road Metal and Railway Ballast

Granite is quarried for road metal in a hill to the north of The Rocks, 10 miles south-west of Ayr, and for railway ballast at Mount Carew.

Future Prospects

The areas believed to have most promise of economic mineralization are the Inkerman Shear Zone and the area immediately east of Mount Dalrymple.

The Inkerman Shear Zone is a fundamental structure which has been the locus of major metasomatic activity (monomineralic and skarn-type rocks; anomalous nickel, copper, and cobalt values), and warrants detailed examination.

The area east of Mount Dalrymple is intersected by at least two major faults, the Woodhouse and Millaroo Faults, and pyritic rocks and possible old workings have been noted in the area.

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APPENDIX 1

SPECTROCHEMICAL ANALYSES

by

A.D. Haldane

Semiquantitative spectrochemical analyses of five rock specimens from the Ayr Sheet area, Queensland, are tabulated. All values are expressed in parts per million.

Field Specimen Number	Ar 3/5/51(P)	Ar 9/7/37(K)	Ar 9/7/37(M)	Ar 10/7/37	Ar 6/7/39
Ni	a	1000	5-	10	10
Co	a	50	7	40	12
Cu	10	2-	2-	200	2
V	15	15	30	5-	60
Mo	300	a	a	10	a
Military Grid Ref.	551537	558521	558521	558521	564520
Rock type	Greisen	Epidote rock	Epidote-garnet rock	Magnetite rock with no visible copper	Unmineralized portion of specimen of epidote-garnet-magnetite rock

In addition, P, W, Zn, Sn, Be, Ag, and Bi were sought but not detected in any specimen.

a, sought but not detected
5-, less than 5 ppm; 2-, less than 2 ppm

APPENDIX 2

MINERALOGICAL COMPOSITION OF THREE SAMPLES OF HEAVY MINERAL SAND FROM BEACHES NEAR BOWEN

by

I.R. Pontifex

A polished section and a thin section of a random sample of each sand were examined. The percentages of the minerals present were calculated from a grain count of each section.

Sample 1

Locality: Air-photo: Ayr, run 8, No. 5061, point 14. Dingo Beach, 15 miles northwest of Bowen.

Opaque minerals:

	Percent
Ilmenite with exsolution intergrowths of hematite, rutile, and magnetite	26
Titaniferous magnetite	23
Hematite containing exsolution intergrowths of ilmenite	10
Ilmenite	11
Ilmenite-magnetite (grains having the properties of both minerals)	9
Magnetite partly oxidized to hematite	8

Non-opaque minerals:

	Percent
Zircon	6
Amphibole	3
Augite	2
Epidote	2
Rutile	1
Quartz	1
Plagioclase	1

The average grainsize is 0.15 mm. Generally the grains are angular or subangular; some of the opaque grains are well rounded.

The proportions of iron and titanium oxides vary from grain to grain, and it is difficult to determine the abundance of grains containing specific mixtures of these oxides. The percentages of opaque minerals given above are, therefore, accurate to within about 10 percent. It is apparent that all these grains have a common source. The opaque minerals commonly form composite grains with amphibole. Zircon occurs as stumpy euhedral crystals. The most common amphibole is hornblende. Two types of epidote are present; one is pale green-yellow, the other deep sea-green.

Sample 2

Locality: Air-photo: Ayr, run 3, No. 5037, Point 1. Lynchs Beach, 10 miles north of Ayr.

Opaque minerals:

	Percent
Ilmenite with exsolution intergrowths of hematite, rutile, and titaniferous magnetite	18
Titaniferous magnetite	12
Ilmenite	10

Non-opaque minerals:

	Percent
Amphibole	10
Quartz	19
Epidote	6
Plagioclase	6
Augite	4
Zircon	3
Rutile	2
Orthoclase	4
Volcanic groundmass fragments	2
Organic fragments	2
Biotite	1
Tourmaline	1
Garnet	1

The average grainsize is 0.15 mm. Generally the grains are angular or subangular. Many have well preserved cleavage faces and crystal form.

The comments regarding the iron-titanium oxide minerals given for Sample 1 also apply to this sample. In Sample 2, however, accessory amounts of chalcopyrite and pyrite are associated with some of the iron-titanium oxide grains. The sulphides fill fractures in the oxides, and form masses up to 0.05 mm.

Hornblende is the dominant amphibole. Two different types of epidote are present in about equal abundance. One is light green-yellow, the other is deep sea-green. The plagioclase was found to range from oligoclase to andesine. Most of the orthoclase grains are fresh but some are partly altered to sericite.

The grains which appear to be derived from a volcanic groundmass are microcrystalline; the dominant component is quartz; subordinate minerals are feldspar and sericite.

Sample 3

Locality: Air-photo: Ayr, run 9, No. 5045, point 4A. Kings Beach, 1 mile northeast of Bowen (just south of Ayr 1:250,000 Sheet area).

Opaque minerals:

	Percent
Ilmenite with exsolution intergrowths of hematite, rutile, and titaniferous magnetite	7
Titaniferous magnetite	7
Ilmenite	6

Non-opaque minerals:

	Percent
Amphibole	25
Quartz	14
Plagioclase	10
Epidote	7
Orthoclase	5
Augite	4
Rutile	4
Organic fragments	4
Calcite	4
Zircon	2
Biotite	2
Chlorite	2
Hypersthene	±1
Spinel	±1
Apatite	±1

The grainsize ranges between 0.05 and 0.3 mm. The grains are angular and subangular.

The comments regarding the opaque minerals given for Sample 1 also apply to Sample 3. The dominant amphibole is hornblende, and some fragments of this mineral have small iron oxide inclusions oriented along cleavage planes. The plagioclase is generally unaltered. Most of the grains range from andesine to oligoclase, but about 25 percent of them range from labradorite to andesine.

Two types of epidote are present: the most abundant is a light green yellowish type, which usually occurs in anhedral grains; the other is deep green, and commonly has a broken prismatic form.

The identification of the hypersthene is not certain.

APPENDIX 3

MINERALOGICAL COMPARISON OF ILMENITE SAND AND GABBRO FROM NEAR ABBOT POINT

by

I.R. Pontifex

1. Ilmenite sand

Field occurrence: This is a beach sand specimen from Dingo Beach, 1 mile west of Abbot Point. Gabbro crops out east and west of Dingo Beach.

Mineralogy: In the field, the grains which were attracted to a hand magnet were removed. These were presumably mostly magnetite. The remaining sand was separated in the laboratory into 3 fractions on a Frantz isodynamic separator, and each of these was examined microscopically. A thin section and a polished section of a random sample of the original material were also examined.

The following components (excluding the constituent removed by magnet) were identified, and their approximate volume percentages were estimated:

	Percent
Ilmenite containing hematite inclusions	55
Titaniferous hematite	15
Ilmenite	10
Titaniferous magnetite	5
Zircon	8
Hornblende	2

Minor amounts of epidote, olivine, rutile, tourmaline, leucoxene, and pyrite are also present. The average grainsize is 0.15 mm. The opaque grains are angular and subangular.

The main constituent of the sample, ilmenite, almost invariably contains needle and bleb-like inclusions of titanhematite oriented along certain morphological directions. This variety of hematite by definition contains a maximum of 10 percent TiO_2. The exsolution intergrowth relationship of titanhematite and ilmenite indicates that the Fe_2O_3 content in the ilmenite exceeds 6 percent. The grains in which titanhematite is the dominant mineral commonly contain abundant inclusions of ilmenite discs, which indicates that the TiO_2 content in the hematite exceeds 10 percent.

Some homogeneous opaque grains have optical properties intermediate between magnetite and ilmenite; others consist of titaniferous magnetite which contains exsolution blades of ilmenite 0.01 mm wide. All these grains are derived from a solid solution of iron and titanium oxides. Ilmenite is the dominant component as no suggestion of the spinel structure is evident in any of the grains.

Zircon and hornblende generally have a euhedral form. Commonly hornblende is associated with ilmenite. Epidote, olivine, and leucoxene occur as irregular, generally angular, fractured grains; some are subrounded. Rutile and tourmaline grains are relatively well rounded.

2. Gabbro (BMR TS14349)

Field occurrence: A sample of a gabbro from 2 miles west of Abbot Point.

Description of thin section: The rock consists chiefly of an ophitic aggregate of plagioclase, hornblende, and augite. The average grainsize of the plagioclase laths and ferromagnesian grains is 1 mm and 0.6 mm respectively.

Euhedral crystals of plagioclase consist mainly of labradorite, and form about 55 percent of the rock. Some plagioclase is slightly altered to sericite and epidote.

Hornblende forms about 20 percent of the section; it occurs as anhedral grains and as alteration rims around augite. The hornblende generally contains fine opaque inclusions and is commonly intergrown with small opaque masses. Some hornblende shows minor alteration to chlorite.

About 15 percent of the rock consists of anhedral grains of augite, generally as remnant cores surrounded by irregular coronas of hornblende.

Description of polished section: The opaque mineral grains have an average size of 0.2 mm, and form the following approximate proportions of the rock:

	Percent
Ilmenite containing hematite inclusions	3
Titaniferous hematite and magnetite	2
Pyrite	2
Chalcopyrite	0.5

The ilmenite containing hematite inclusions forms anhedral grains which are associated with hornblende; it has the same mineralogical composition as the ilmenite-hematite grains in the ilmenite sand previously described. The hematite is the variety titanhematite, and is localized as blebs and needles along morphological directions of the ilmenite host. In some grains hematite is the dominant mineral, and these generally contain ilmenite blebs.

Grains which have a composition intermediate between magnetite and ilmenite are almost as common as the ilmenite-hematite grains. Pyrite occurs as discrete anhedral grains, and is also associated with the iron and titanium oxides.

Chalcopyrite grains up to 0.01 mm are disseminated through the rock; these are not associated with the other opaque minerals.

Conclusions

The mineralogical composition of the opaque minerals in the beach sand and in the gabbro is similar; in both the dominant heavy mineral is ilmenite which contains exsolution intergrowths of titanium-rich hematite. Grains containing various proportions of iron and titanium oxides are also characteristic of both samples; such grains are commonly associated with hornblende.

The angular nature of the grains, and the presence of unaltered hornblende and olivine in the sand, suggest that it is relatively near its source.

These relationships indicate that the gabbro is the source rock for the detrital iron and titanium oxides, hornblende, and epidote on the adjacent beach.

A minor contribution of detrital minerals from a second provenance is indicated by the presence of zircon and tourmaline in the sand. These minerals were no doubt derived from the acid igneous intrusives of the area.

APPENDIX 4

WATER BORES DRILLED TO BEDROCK IN THE BURDEKIN RIVER DELTA

Information supplied by Queensland Irrigation and Water Supply Commission

Irrigation Commission Bore Number	R.L. Natural Surface (State Datum) (N/R - not recorded)	Depth to Bedrock (ft)	Driller's Description of Bedrock
B3S1	18	252	Porphyry
L3B8	25	178	Decomposed rock
L3B7	27	189	Granite
CD4	26	185	Granite
CD7A	17	204	Granite
B3S2	N/R	271	Rock
E2.5	N/R	110	Decomposed granite
E3	42	100	Decomposed granite
D2.5	N/R	158	Basalt
DE3	N/R/	170	Rock
E3A	37	114	Decomposed granite
L3B5	45	128	Diorite
L3B4	N/R	101	Decomposed granite
F4A	47	98	Decomposed granite
FG4.2	N/R	103	Decomposed granite
F4.5	N/R	104	Granite
FG4.7	N/R	60	Porphyry
FG4.9	N/R	81	Granite
EF5.2	N/R	144	Granite
EF5.4	N/R	143,151	Granite, porphyry
E5A	41	188	Weathered rock. Quartz
D6A	29	202	Weathered granite
E6B	N/R	210	Diorite
B1S3	N/R	250	Granite
FG3A	53	64	Quartz
FG4	N/R	86	Quartz
FG4.8	N/R	103	Granite
H4	61	71	Decomposed granite
GH4.2	N/R	103	Granite
GH4.6	N/R	104	Weathered granite
GH4A	60	115	Weathered granite
G4.9	N/R	85	Granite
G50	46	79	Decomposed granite
H6	39	62	Granite
GH5A	41	139	Granite
FG5.2	N/R	94	Granite
F5	N/R	120	Granite
GH7A	18	87	Decomposed granite
G8	23	112	Rock
JO.8	65	79	Granite
J1.3	70	66	Granite

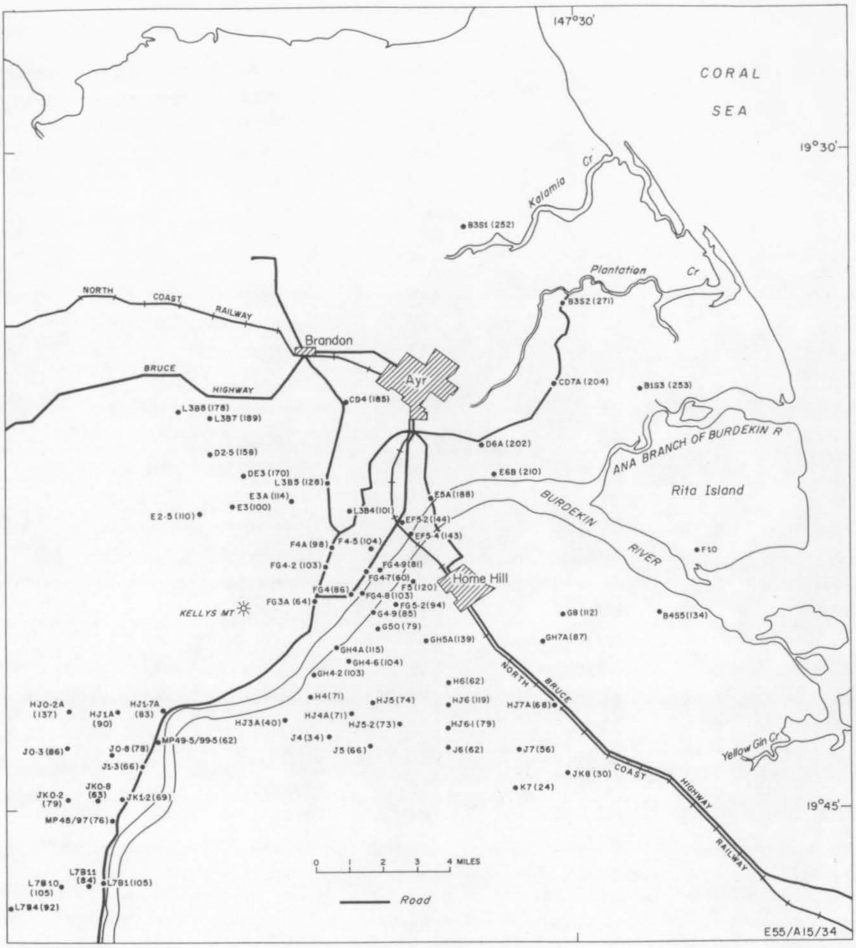


Fig. 17: Location of water bores which reached bedrock in the Burdekin River Delta.

Irrigation Commission Bore Number	R.L. Natural Surface (State Datum) (N/R - not recorded)	Depth to Bedrock (ft)	Driller's Description of Bedrock
HJ3A	N/R	40	Diorite
J4	N/R	34	Weathered granite
HJ4A	55	71	Fractured rock
J5	N/R	66	Decomposed granite
HJ5	N/R	74	Decomposed granite and quartz
HJ5.2	N/R	73	Decomposed granite
HJ6	N/R	119	Decomposed granite
HJ6.1	N/R	79	Decomposed granite
J6	41	62	Decomposed granite
J7	29	56	Decomposed granite
K7	27	24	Decomposed granite
HJ7A	26	68	Decomposed granite
JK8	N/R	30	Decomposed granite and quartz
B4S5	N/R	134	Decomposed granite
F10	18	30-43 (bottom)	Black sand
HJO.2A	60	137	Basalt
HJ1A	60	90	Granite
HJ1.7A	82	83	Granite
MP49.5/99.5	81	62	Granite
J0.3	64	86	Granite
J0.8	65	78	Granite
J1.3	70	66	Granite
MP49/98	77	46	Granite
JK0.2	69	79	Granite
JK0.8	71	63	Basalt, granite
JK1.2	79	69	Limestone, basalt, granite
MP48/97	81	76	Granite
L7B4	76	92	Hard rock
L7B10	76	105	Granite
L7B11	84	84	Granite
L7B1	90	105	Stone

Note: Bore F10 did not bottom in bedrock; it has been included here because of the interesting 13-foot intersection of black sand.

APPENDIX 5

ISOTOPIC AGE DETERMINATIONS

By A.W. WEBB

Rock Unit/ Map Symbol	Sheet Area Specimen No.	ANU Accession No.	Military Grid Reference E	N	Rock Type	Mineral Analysed	Method	Age (m. y.)
P-Mg	E55/15/5	GA5733	518000	2582000	Adamellite	Biotite	K/Ar	267
P-Mg	6	GA5579	516000	2557000	Granite	Biotite	K/Ar	269
C-Pd	1	GA5275	548500	2531300	Granodiorite	Biotite	K/Ar	266
C-Pd	2	GA5276	558000	2520700	Diorite-gneiss	Hornblende	K/Ar	264
C-Pd	3	GA5277	558000	2520700	Green amphibole rock	Amphibole	K/Ar	245
C-Pd	4	GA5319	558000	2520700	Diorite-gneiss	Hornblende	K/Ar	275
C-Pd	13	GA5580	567600	2512300	Granodiorite	Biotite	K/Ar	269
C-Pd	13	GA5580	567600	2512300	Granodiorite	Hornblende	K/Ar	281

K/Ar Analyses

No.	K (%)		$^{40}Ar^*/^{40}K$	$Ar^{40}/Ar^{atm.}$ (%)
E55/15/1	7.270) 7.246)	7.26	0.0167	8.0
2	0.4209) 0.4185)	0.420	0.01653	25.6
3	0.1998) 0.2019)	0.201	0.01528	15.6
4	0.3369) 0.3384)	0.338	0.01727	18.9
5	7.014) 7.005)	7.01	0.01675	4.3
6	7.064) 7.117)	7.09	0.01687	3.5
13 Biotite	7.177) 7.206)	7.19	0.01691	1.6
13 Hornblende	0.5456) 0.5446)	0.545	0.01773	14.4

* radiogenic

$\lambda\epsilon = 0.584 \times 10^{-10} yr^{-1}$; $\lambda\beta = 4.72 \times 10^{-10} yr^{-1}$; $^{40}K = 1.22 \times 10^{-4} g/g$ K

Note: the analytical error in individual K/Ar determinations is ± 3 percent, unless otherwise stated

Three groups of specimens were dated:

(1) Numbers 2, 3, and 4, from the Inkerman Shear Zone

(2) Numbers 5 and 6, late Palaeozoic granitic intrusions

(3) Numbers 1 and 13, which are possibly unrelated to the other two groups.

The shear zone specimens contain two foliated diorite-gneisses (2,4) and an amphibole rock (3). The approximate age of 270 m.y. for 2 and 4 is one which is common to the south in the Bowen area. It may relate to movements in the shear zone and is unlikely to be the actual age of emplacement of the rocks. The date measured on specimen 3 may indicate later movements along the shear zone producing recrystallization and the formation of a rock composed of almost 100 percent amphibole.

Specimens 5 and 6 were from Cape Cleveland and Mount Elliot respectively, and the age of 265-270 m.y. is similar to that obtained from the Thunderbolt Granite in the Bowen Sheet area.

Specimen 1, from The Rocks, is intruded by several younger igneous rocks and the date of 266 m.y. possibly reflects this later activity. The discordance between the biotite and hornblende dates of specimen 13 also suggests argon leakage.

W. G. Murray, Government Printer, Canberra

18563/69—L 21

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

AYR
QUEENSLAND

SHEET SE 55-15

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
FIRST EDITION 1968

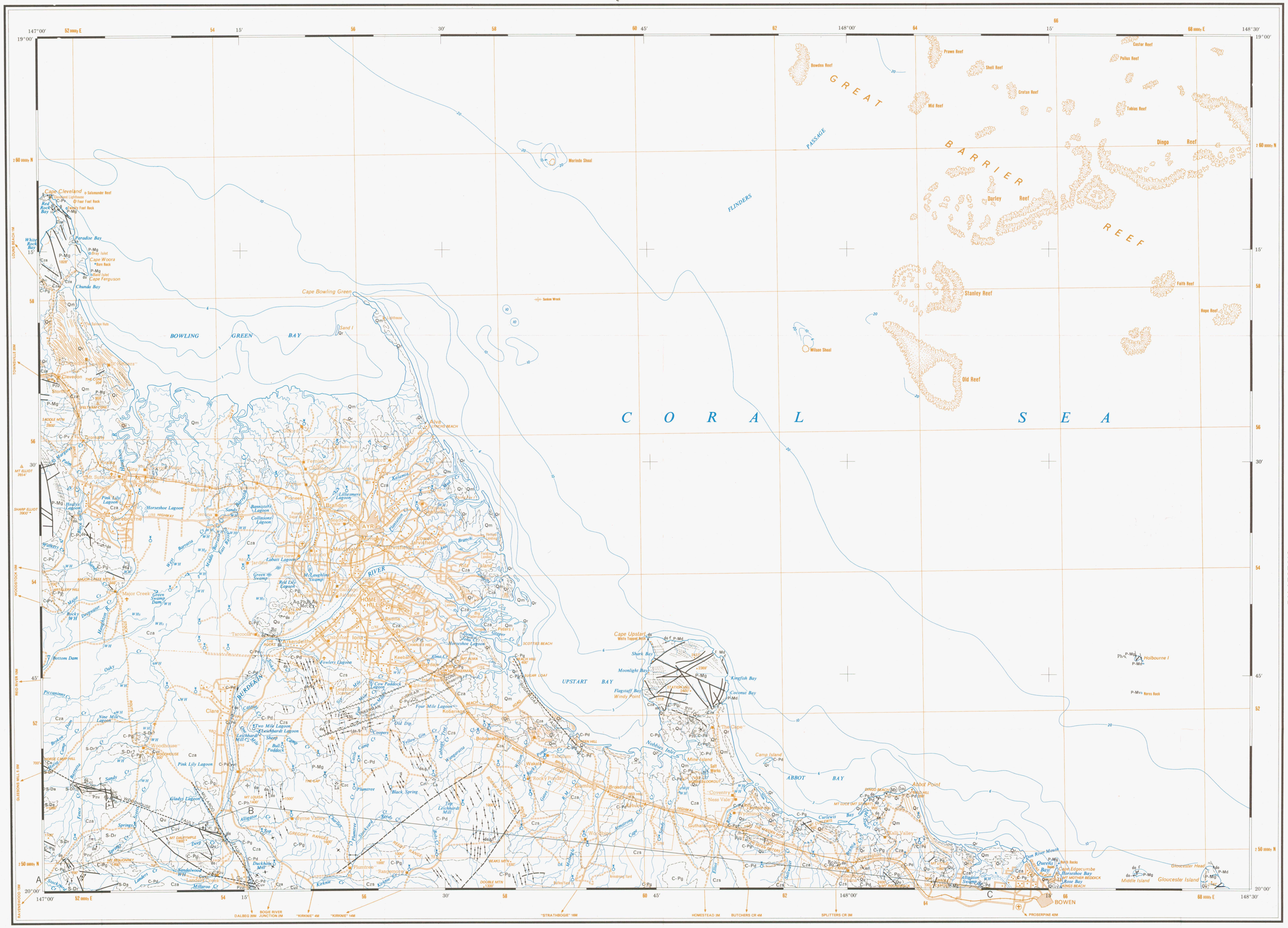
Reference

- Geological boundary
- Fault, showing relative horizontal movement
- Boundary of major shear zone
- Where location of boundaries and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries are dotted, and faults are shown by short dashes
- Joint pattern } air-photo interpretation
- Trend of coastal sand dunes } air-photo interpretation
- Strike and dip of strata
- Strike and dip of cleavage
- Strike and dip of foliation
- Vertical foliation
- Foliation, dip indeterminable
- Strike and dip of platy flow
- Vertical platy flow
- Strike and dip of primary banding in gabbro
- Primary banding in gabbro, dip indeterminable
- Sample locality for age determination
- Dyke
  - do = dolerite, andesite, microdiorite
  - f = felsite (including rhyolite and acid porphyry)
  - g = granophyre, granite
  - mt = microtonalite

- Mineral prospect, little or no production
- Quarry
- (Mt) Unexploited mineral deposit
- Minor mineral occurrence
- Ag Silver
- Au Gold
- Bi Bismuth
- Cu Copper
- Gt Graphite
- Im Ilmenite
- Ls Limestone ('earth lime')
- Mo Molybdenum
- Mt Magnetite
- Ni Nickel
- Pb Lead
- Ph Phosphate Rock
- Py Pyrite
- Rc Crushed rock aggregate

- Bore
- Windpump
- Spring
- E Dam
- WH Waterhole on stream
- Bank of major watercourse
- Swamp
- 10 Depth in fathoms

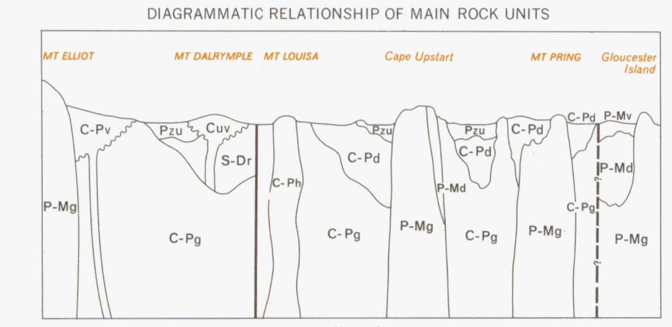
- Road
- Vehicle track
- Railway with siding
- Tramway (sugar cane)
- Fence
- Power transmission line
- Telephone line
- Town
- "Lisgar" Homestead
- House or building
- Pump Pumping station
- Yd Yard
- Airfield
- Landing ground
- Trigonometrical station
- 1900′ Elevation in feet, derived from military maps
- MW Microwave repeater station



Reference

CAINOZOIC	QUATERNARY		Qm	Coastal mud flats
			Qr	Coastal sand dunes
			Qu	Outwash and talus
			Cza	Alluvial and deltaic deposits
			Czs	Residual soil, sand and rubble; some semi-consolidated material
			Czc	Earth lime'
	PERMIAN TO MESOZOIC		P-Mg	Epizonal leucocratic adamellite and granite, minor granophyre, syenite, rhyolite-porphyry, rare diorite and gabbro
			P-Md	Dolerite, microdiorite, gabbro
			P-Mv	Hornfelsed tuff
PALAEOZOIC	UPPER CARBONIFEROUS TO LOWER PERMIAN		C-Pv	Intermediate lavas and pyroclastics, minor acid volcanics
			C-Ph	Rhyolite, trachyte, trachyandesite; mainly intrusive
			C-Pg	Adamellite, granite, some granodiorite; minor fine-grained variants
			C-Pd	Diorite, quartz diorite, tonalite, gabbro, norite; minor granodiorite, adamellite and granite
	UPPER CARBONIFEROUS		Cuv	Flow-banded rhyolite and massive welded tuff; andesite and andesitic tuff
		Ellenvale Beds	Ce	Flow-banded rhyolite, rhyolite-breccia, andesite
	UPPER DEVONIAN ?		Pzj	Hornfelsed calcareous conglomerate, with calcareous quartzite interbeds
	SILURIAN TO LOWER DEVONIAN	Ravenswood Granodiorite	S-Da	Biotite granite, leucocratic adamellite
			S-Dr	Deeply weathered hornblende-biotite granodiorite; minor adamellite, quartz diorite, diorite, alkali granite
	EARLY PALAEOZOIC		Pzu	Schist, phyllite, quartzite, hornfels

DIAGRAMMATIC RELATIONSHIP OF MAIN ROCK UNITS



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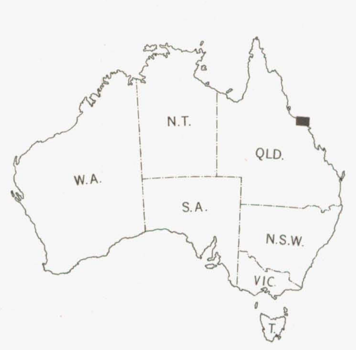
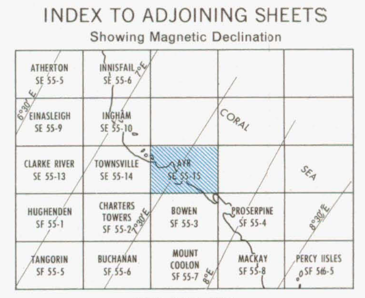
Vertical aerial photography at 1 : 85,000 scale by Adastra Airways Pty. Ltd., 1961.
Transverse Mercator Projection.



INDEX TO ADJOINING SHEETS
Showing Magnetic Declination



Scale 1:250,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

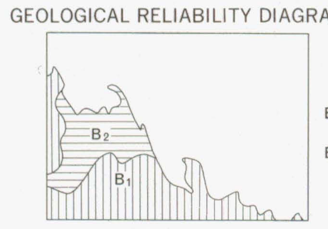
GREY NUMBERED LINES INDICATE THE 20,000 YARD TRANSVERSE MERCATOR GRID, ZONE 7 (AUSTRALIA SERIES)

Section

Scale: $\frac{V}{H} = 4$

Cainozoic sediments omitted from section; attitude of faults not known

GEOLOGICAL RELIABILITY DIAGRAM



B_1 Detailed reconnaissance with air-photo interpretation

B_2 Mainly air-photo interpretation

Geology, 1964, by: A. G. L. Paine, C. M. Gregory (B.M.R.), D. E. Clarke (G.S.Q.)
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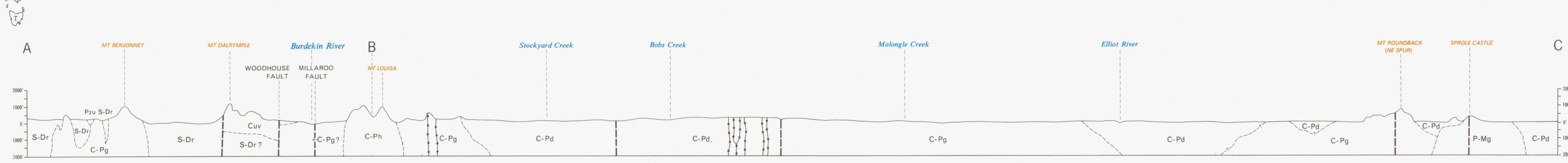
Drawn by: Austral Cartographic Service, Canberra, A.C.T.



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SHEET SE 55-15

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