COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT No. 126

Geology of the Northeastern part of the Hughenden 1:250,000 Sheet Area, Queensland

BY

A. G. L. PAINE and R. R. HARDING (Bureau of Mineral Resources) and
D. E. CLARKE (Geological Survey of Queensland)

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SUMMARY

Igneous and metamorphic rocks crop out in a triangular region in the northeastern part of the Hughenden 1:250,000 Sheet area; a region of hills and ranges bordered by plains in the north and southeast, ranging from 360 to 1000 m above sea level.

The Cape River Beds, which consist mainly of schist, gneiss, and quartzite in the map area, are probably Cambrian to Ordovician. They form a belt along the southwestern side of the area of crystalline rocks. Foliated and gneissic granodiorite, adamellite, and granite in the east are correlated with the mainly Middle Ordovician Ravenswood Granodiorite Complex of the Charters Towers, Townsville, and Bowen Sheet areas. The Cape River Beds and the Ravenswood Granodiorite Complex are intruded by a large post-tectonic batholith, the Lolworth Igneous Complex, which is late Silurian or early Devonian in age. Another batholith, the Dumbano Granite, intrudes the Cape River Beds in the northwest; for the present it is regarded as coeval with the Lolworth Igneous Complex.

The isolated outcrops of acid volcanics and associated sediments which overlie the granite and metamorphics are probably Upper Permian. A subvolcanic intrusive complex, the Mundic Igneous Complex, which intrudes the Lolworth Igneous Complex in the northeast, is possibly also Upper Permian. Two stocks of adamellite and granite, whose ages are unknown, intrude the Cape River Beds and the Ravenswood Granodiorite Complex.

A Pliocene age is assigned to the Campaspe Beds, a thin piedmont deposit which was derived mainly from the granite of the Lolworth Range. The veneer of ferricrete overlying the Campaspe Beds south of the Cape River indicates a period of minor lateritization. Widespread outpourings of plateau olivine basalt (Nulla Basalt) occurred in the late Pliocene and Pleistocene; the youngest flow, the Toomba Basalt, has no soil cover and is probably Recent in age.

The regional strike of the foliation in the Cape River Beds and Ravenswood Granodiorite Complex is consistently to the northwest, and has determined the orientation of the Great Dividing Range. Most faults strike east-northeast or northeast, and are apparently transcurrent.

Some of the widespread gold and minor sulphide mineralization in the area is almost certainly related to the Upper Permian(?) igneous activity, but some may be early Palaeozoic.

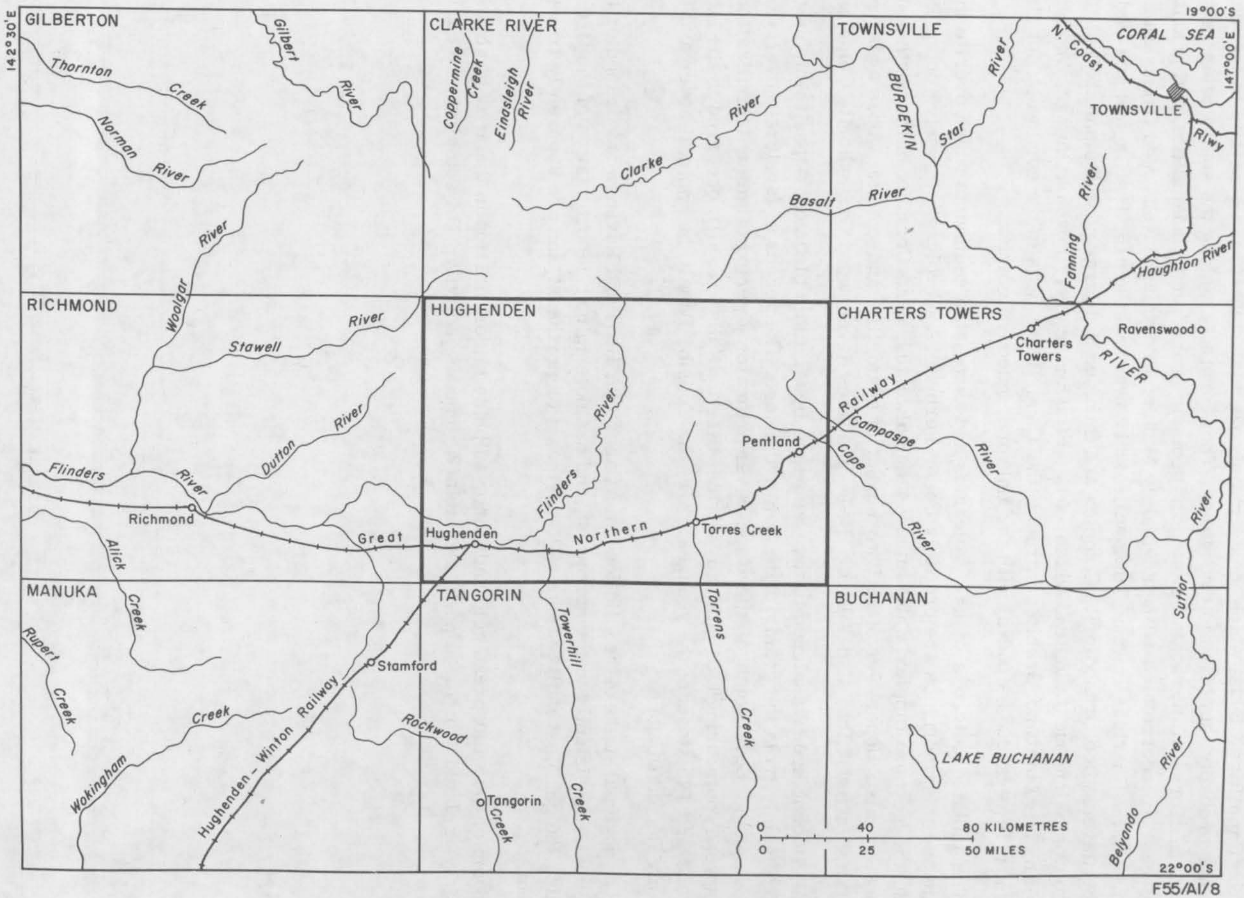

Fig. 1. Locality map and Sheet index.

INTRODUCTION

The Hughenden Sheet area is in north-central Queensland, between latitude 20°S and 21°S and longitude 144°E and $145^\circ30'$E (Fig. 1).

The northeastern part of the Sheet area, described in this Report (see map), comprises Palaeozoic igneous and metamorphic rocks and superficial Cainozoic basalt. It was mapped in 1963 by a combined field party of the Commonwealth Bureau of Mineral Resources and the Geological Survey of Queensland. During 1962 and 1963 another party mapped the rest of the Sheet area, which mainly comprises the Permian to Cretaceous sedimentary rocks of the Eromanga and Galilee Basins (Vine, Bastian, & Casey, 1963, unpubl.; Vine, Casey, & Johnson, 1964, unpubl.). Neither these strata nor the Cainozoic basalt west of the Flinders River were studied by the northeast Hughenden field party, although they extend on to the geological map which accompanies this Report.

The average annual rainfall is between 500 and 600 mm. The rains are monsoonal and the wet seasons generally extend from December or January until March or April. Rare thunderstorms occur between April and November, especially in October and November. January is the hottest month, with a normal daily maximum of 35°C and a mean temperature of 28°C, and July the coldest, with a normal minimum of 9°C and a mean of 17°C. Frosts are rare.

Pentland, the only sizable settlement in the map area, has a population of about 350, and is situated on the Flinders Highway and Great Northern Railway. Pentland has several shops, a hotel, a railway station, and a garage. Both Charters Towers (110 km northeast of Pentland by road) and Hughenden (150 km southwest of Pentland by road) are served by regular air flights. The railway (Queensland Government Railways) is a single narrow gauge (106 cm) track. The transport of cattle and base metal concentrates and smelter products from Mount Isa to Townsville, and of coal from Colinsville to Mount Isa, constitutes the main traffic.

The Flinders Highway is sealed with bitumen between Townsville and Hughenden. The main access roads from Pentland to Lolworth and Cargoon homesteads and from Charters Towers to Glencoe homestead have a gravel surface. In the north and southeast numerous minor roads and vehicle tracks provide access to the basalt plains and low-lying country around Pentland. In the Great Dividing Range and Lolworth Range, access by vehicle at the time of the survey was restricted to two tracks; one turns west off the Pentland-Lolworth road at Gypsy Pocket, and leads to a coal deposit at Oxley Creek; the other branches northwest from the Flinders Highway, east of the Cape River, follows the Campaspe River upstream, climbs the Lolworth Range, and ends at the Brilliant Brumby gold mine.

The most important industry in the area is beef cattle raising. A meat works at Cape River employs a small number of men. A few men work on the railway and still fewer gain seasonal employment at timber getting and gouging for minerals. There are several citrus orchards and vineyards on the alluvial flats of the Cape River between Capeville and Kiora homesteads, but some of them have been abandoned.

The vegetation is mainly open savannah woodland, but dense scrub grows on the Toomba Basalt in the north, and on parts of the Lolworth Range.

The geological time scale used in this Report is that of Harland, Smith, & Wilcock (1964).

Previous and Contemporary Investigations

Until the present survey in 1963, geological investigations were closely concerned with gold discoveries. In 1868 Daintree reported on the first discoveries near Pentland, and in 1870 he prepared a general report on the geology of north Queensland. Rands

(1891) briefly described the geology of all mines then operating, and in 1894 gave a detailed account of the Cape River Deep Lead. Between 1910 and 1963 Marks, Cameron, Russell, Morton, Shepherd, Ball, Cribb, and Anthony reported on other gold and silver occurrences. Many of these reports contained short geological descriptions.

Twidale (1956) gave a general account of the Cainozoic basalts in north Queensland. The geology of the area as known in the late 1950's was summarized by Brooks (in Hill & Denmead, eds, 1960), and some observations on the crystalline rocks were made by Vine et al. (1963, unpubl.). A helicopter gravity survey covering the Hughenden Sheet area was carried out by the Bureau of Mineral Resources in 1963 (Gibb, 1969).

Reports and Explanatory Notes on the adjoining Sheet areas are as follows: Clarke River - White (1961, 1962, 1965); Townsville - Wyatt (1968), Wyatt, Paine, Harding, & Clarke (1970); Charters Towers - Wyatt, Paine, Clarke, Gregory, & Harding (1971), Clarke & Paine (1970).

Acknowledgments

Miss B.R. Houston of the Geological Survey of Queensland examined many thin sections and the results of her work have been incorporated in the text.

In 1964 D.J. Casey of the Geological Survey of Queensland compiled information on the history and production of the mines, and K.R. Levingstone, District Geologist of the Survey at Charters Towers, has provided additional information on the economic geology of the area.

Physiography

The main topographic divisions are plains, dissected hilly terrain, ranges and a feature which is called here the 'Lolworth Range plateau residual' (Fig. 2).

Much of the area is over 600 m above sea level; it rises to over 1000 m at Mount Stewart in the east, and to about 900 m in the headwaters of Range Creek in the northwest.

The streams belong to three main systems: the Flinders River system, which drains the western part of the area, and flows into the Gulf of Carpentaria; the Lolworth Creek system, which drains the northern part of the area; and the Cape-Campaspe River system draining the southeastern part. Lolworth Creek and the Cape and Campaspe Rivers drain towards the Pacific Ocean via the Burdekin River.

In Figure 2 the term 'ranges' denotes high areas of rugged relief which are not necessarily surrounded on all sides by country of markedly lower elevation. For instance the average elevation of the Cargoon high plain and much of the dissected hilly terrain in the northwest is about the same as the elevation of part of the ranges.

The ranges comprise the west-southwesterly trending Lolworth Range, which is the dominant physical feature of the area, and a narrow northwesterly belt of rugged metamorphic strike ridges (referred to as the 'quartzite belt'), which forms part of the Great Dividing Range. The term Great Dividing Range is used for the main divide between streams flowing east to the Pacific and those flowing west to the Gulf of Carpentaria and the interior of the continent. In places the divide has a low relief.

The highest part of the Lolworth Range is an undulating elongate plateau. Towards the northeast it culminates in Mount Stewart, the highest peak in the area. Mount Stewart rises abruptly 450 m above the plain, but it rises only 180 to 200 m above the general summit level of other hills in the Lolworth Range. To the north, the Lolworth Range falls gradually away to the basalt plain. The southern slopes of the range are steeper, and consist of a succession of rounded spurs, separated by narrow valleys and gorges, with a relief of 150 to 250 m.

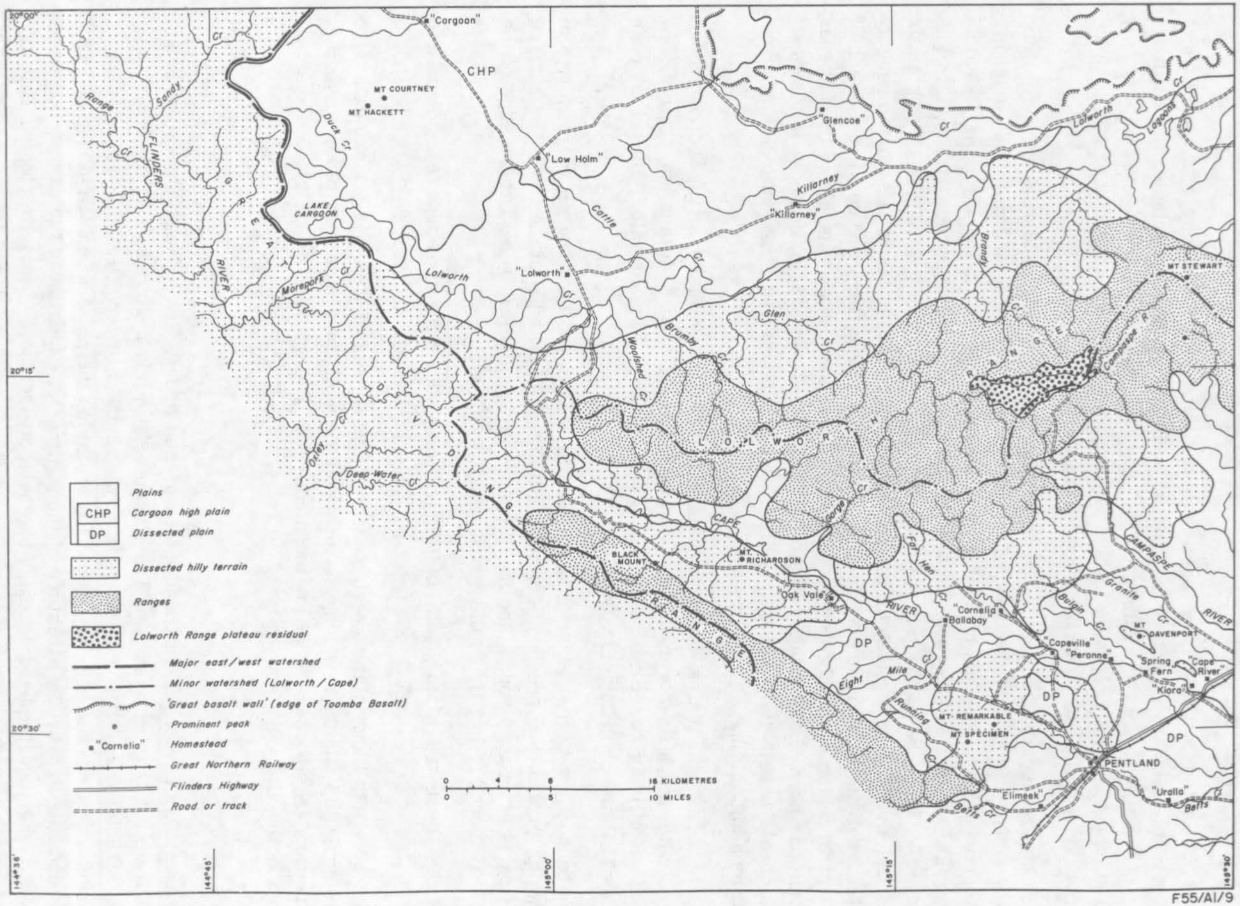

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Fig. 2. Physiography

The 'quartzite belt' has a general local relief of 200 to 250 m (up to 300 m opposite Gorge Creek); in places the ridges rise to 840 m above sea level. The northeastern margin of the belt rises abruptly from the plain, but to the southwest the summits of the ridges are only slightly higher than the neighbouring country. The ridges become gradually less distinct towards the northwest, and eventually merge into hilly country with irregular drainage; to the southeast the ridges gradually lose height, although their relief remains constant. They end rather abruptly near Betts Creek.

The dissected hilly terrain forms a broad zone in the headwaters of the Flinders River and its tributaries, and discontinuous zones bordering the ranges. The drainage pattern is close, and hills are numerous. Although the hills are steep, local relief is only 75 to 100 m and is commonly much less. A few prominent monadnocks, for example Mount Davenport, rise to 200 m above the surrounding country.

North of the Lolworth Range the plains form a flat or gently undulating surface which slopes gradually from 750 m above sea level in the northwest to 450 m in the northeast. The western edge of the plains forms a plateau with respect to the adjoining dissected hilly terrain and for this reason the western part of the plains has been distinguished as a separate subunit, the Cargoon high plain. The western edge of the Cargoon high plain is part of the Great Dividing Range. To the west, the summits of the hills coincide roughly with the level of the Cargoon high plain, and the hills have been formed by dissection of this feature, which formerly extended farther west. The eastern margin of the Cargoon high plain has been drawn arbitrarily at the 2250-foot (about 675-m) contour. In the west, two Cainozoic basalt vents, Mount Courtney and Mount Hackett, rise 60 to 100 m above the Cargoon high plain.

Farther east, the plains, owing to their gradual decrease in elevation, contrast more strongly with the hills bordering the Lolworth Range. Near Lolworth homestead a few small steep hills of basement rocks rise from the plain. Two low shield-like rises near Leonidas Mill are probably old volcanic vents.

In the northeast, the Recent Toomba Basalt is bordered by a broken scarp, 3 to 5 m high, which probably corresponds closely with the original edge of the flow. The surface of the flow is extremely rough, and it is impassable to vehicles. The southern edge of the basalt is referred to locally as the 'great basalt wall'.

In the dissected plain south of the Lolworth Range the streams are incised 10 to 15 m.

The Lolworth Range plateau residual is the only remnant of a formerly more extensive gently undulating plateau, which was probably part of the Miocene or older surface of lateritization. It is bordered by a low indented scarp. The drainage on the plateau residual is poorly defined.

Drainage

Present Day Drainage. The headwaters of the Flinders River (Range Creek and Sandy Creek) drain the Dumbano Granite. The streams are fairly closely spaced and there is no obvious structural control. Farther south, where the Flinders River and its tributaries drain country underlain by the Cape River Beds, the pattern is even closer and still largely uncontrolled by the structure of the sediments, except near the narrow quartzite belt, where the superimposed drainage has been obstructed by quartzite ridges. This has resulted in the formation of incised meanders in Morepork and Oxley Creeks to the northeast of this belt.

Where Lolworth Creek rises (as Duck Creek), it forms part of the poorly developed consequent drainage on the Nulla Basalt. Lake Cargoon probably occupies an original depression in the surface of the basalt. In the northeast, some of the southern tributaries of Lolworth Creek have been impounded by the basalt to form a group of small lagoons. The middle reaches of Lolworth Creek are deeply incised in the basalt.

The Campaspe-Cape River system is broadly controlled by the structure of the underlying beds. The Cape River has eroded a wide tapering valley in the less resistant schists and gneisses of the Cape River Beds and Ravenswood Granodiorite Complex. The general course of the Cape River has been controlled by the trends in the underlying basement. The drainage pattern of the tributaries is open, and is not strongly oriented.

History of the Drainage Pattern. Part of the drainage pattern has been inherited from Tertiary erosion cycles. The earliest recognizable cycle is represented by a gently undulating surface of which a remnant can be recognized on top of the Lolworth Range. This surface is believed to be related to a period of lateritization in the Oligocene or early Miocene (Wyatt et al., 1970). The drainage pattern in the Lolworth Range shows that Brandy Creek and the Campaspe River, which now join the east-flowing drainage, have successively beheaded a major west-flowing stream, the ancestral Glen Creek, which rose near Mount Stewart. In Oligocene-Miocene(?) times the major divide probably lay much farther east than at present. Probably an ancient peneplain, coinciding with the summits of the Lolworth Range, the Great Dividing Range, and the White Mountains (immediately southwest of the map area), sloped gently to the southwest. River capture by easterly flowing streams caused the old divide to migrate about 80 km to the west during the dissection of the old peneplain. During the migration of the divide, which possibly extended from Miocene to early Pliocene times, the Cape River eroded a wide valley and, together with Lolworth Creek, the Campaspe River, and Betts Creek, captured streams which formerly flowed west to join the Flinders River. During this period the Lolworth Range and the quartzite strike ridges emerged.

By the time the Campaspe Beds were being deposited, probably in the Pliocene, the present regional drainage pattern had emerged. Outpourings of basalt began on the plains north of the Lolworth Range, and in places modified the course of Lolworth Creek. Later, small consequent streams developed on the Nulla Basalt.

CAMBRIAN TO ORDOVICIAN

The Palaeozoic stratigraphy and igneous intrusions are summarized in Table 1.

Cape River Beds

The oldest rocks in the area are schist, gneiss, and quartzite which crop out in a belt extending for 100 km to the northwest of Pentland. In 1868 Daintree described them, and in 1870 referred to them as the Cape River Series. Rands (1891, 1894) and Marks (1910a) summarized the occurrence and lithology of some of the rocks.

In 1963 the metasediments were renamed the Cape River Metamorphics, but mapping of the Charters Towers Sheet in 1964 (Wyatt et al., 1971) indicated the presence of extensive labile arenite and siliceous siltstone which are believed to be the non-metamorphosed equivalents of the metamorphics. The name was therefore revised to Cape River Beds to include both the metamorphics and sediments.

Daintree included all the metamorphic rocks in the Pentland area in his Cape River Series, but we have mapped the orthogneiss between Gorge Creek and Pentland as part of the Ravenswood Granodiorite Complex, rather than Cape River Beds. Small pods and sheets of granite and some metamorphosed dykes and sills have been mapped with the Cape River Beds because they are too small to separate at the 1:250,000 scale.

Daintree recognized a threefold division in his Cape River Series: basal schist and gneiss in the northeast, followed by mica schist and subordinate hornblende schist, and an upper subdivision of quartzite and subordinate schist in the Great Dividing Range to the

TABLE 1. PALAEOZOIC STRATIGRAPHY AND IGNEOUS INTRUSIONS

Age		Rock Unit	Lithology	Topography	Remarks
U. PERMIAN(?)	Mundic Igneous Complex	Pum_4	Pink porphyritic leucocratic microgranite	Rugged hills up to 1000 m above sea level (Mt Stewart)	See Table 3. Probably related to gold and minor base metal mineralization at Lolworth diggings and Mt Stewart
		Pum_2	Porphyritic micro-adamellite(?) (photo-interpretation only)	Rugged crater-like depression in Lolworth Igneous Complex	
		Pum_1	Vent breccia	Depression among hills in Lolworth Igneous Complex	
		Puv	Conglomerate, rhyolite, acid pyroclastics, tuffaceous sandstone and siltstone	Rugged to undulating near Range Cr Hills, cappings and low rises near Betts Cr	Terrestrial. About 60 m thick. Nonconformable on SDd and older rock units; probably equivalent to Betts Cr Beds (Vine et al., 1963, 1964, both unpubl.). Gold reported in agglomerate at Golden Mt (Rands, 1891)
		Pzg	Adamellite, leucogranite, quartz diorite	Low undulating rises	Stocks of uncertain age. Stock in NW intrudes COc; SE stock intrudes Ravenswood Granodiorite Complex
U. SILURIAN OR L. DEVONIAN		Dumbano Granite SDd	Adamellite and muscovite granite, strongly foliated in places; massive pink garnetiferous muscovite granite	Uneven low hills and rises	Intrudes COc; nonconformably overlain by Puv. Pink massive granite cuts foliated adamellite and granite. L. Devonian isotopic dates obtained in Clarke R Sheet area, but in Hughenden Sheet area, some parts may be equivalent to Ravenswood Granodiorite Complex. Silver, gold, and minor base metals near Mt Emu Plains
		Lolworth Igneous Complex SDl	Biotite adamellite and granodiorite; banded, pegmatitic, and aplitic garnet-muscovite granite and adamellite; minor quartz diorite	Rugged broken country of Lolworth Ra ; outlying hills and rises	Apparently massive throughout; post-tectonic. Intrudes COc and Ravenswood Granodiorite Complex; intruded by Mundic Igneous Complex. Reliable isotopic age of 395-400 m.y. Gold at Mt Clearview possibly related. Garnet-muscovite granite also occurs as sheets and dykes cutting all rock types of complex and country rocks around margin

Age		Rock Unit	Lithology	Topography	Remarks
M. ORDOVICIAN (?)	Ravenswood Granodiorite Complex	ODa	Strongly foliated red and pink biotite granite and microgranite	Low rises; minor hills	Mainly syntectonic. Intrudes COc; intruded by Lolworth Igneous Complex and Pzg near Pentland; nonconformably overlain by Puv. ODa intrudes ODn; relationships between ODr and other phases unknown. Host for some gold mineralization
		ODr	Moderately foliated biotite granodiorite	Low undulating rises	
		ODn range	Strongly foliated adamellite and granodiorite, grading into orthogneiss, commonly rich in biotite; rare migmatite	High strike ridges near Gorge Cr, with relief up to 300 m. Undulating low rises elsewhere	
CAMBRIAN TO ORDOVICIAN		Cape River Beds COc	Schist and gneiss, calcareous in places; amphibolite, quartzite, minor granofels, marble, hornfels, and meta-greywacke	Steep hills with close drainage pattern in NW; low rises with rare steep hills in SE	Oldest rocks in map area. Mainly greenschist facies of regional metamorphism, but higher grade in places. Thickness unknown but probably great. Host for much of the gold mineralization. Possible isotopic age of 483 $\pm$ 25 m.y. obtained from metamorphics, but see text; unmetamorphosed equivalents crop out in Charters Towers and Bowen Sheet areas, where Rb/Sr isochron of 510 $\pm$ 100 m.y. has been obtained from interbedded rhyolite
		COq	Mainly quartzite; interbeds of schist and amphibolite	Quartzite forms high rugged strike ridges with relief up to 300 m	

west. The foliation and schistosity in the metamorphics commonly dip southwest, but we have been unable to establish the general sedimentary succession (see also Rands, 1894). A belt consisting mainly of quartzite in the Great Dividing Range has been mapped as a separate subunit (COq), but its stratigraphic relationships to the rest of the Cape River Beds is unknown.

Some observations on inliers of metamorphics in the northwest of the Hughenden Sheet area were made by Vine et al. (1963, unpubl.).

Distribution and Topography

The Cape River Beds occupy an area of 1000 sq km, and extend for 100 km along a northwesterly belt from Pentland to Oaky Creek. Around Pentland they occur as separate roof pendants on the Ravenswood Granodiorite Complex. There are also small outcrops at the head of Inkerman Creek and southeast of the Lolworth Range, and small inliers in the basalt plain northwest of Lolworth homestead.

In the northwest, the Cape River Beds form dissected hills. The summits of the hills are broadly coincident because the beds have only recently been exhumed from beneath the basalt. In the southeast, where the base-level of the creeks is controlled by the level of the Cape River, exhumation from beneath the Campaspe Beds is less advanced, and dissection is not so well developed. Here, and in the intervening country occupied by the valley of the Cape River, the surface is uneven; steep hills, for example Mount Richardson and Mount Davenport, rise above the undulating low hills and plains. The quartzite subunit (COq) forms rugged strike ridges and has a relief of about 300 m in the southeast. Along much of the eastern boundary between the quartzite and the remainder of the Cape River Beds there is a pronounced escarpment, which is one of the most striking physical features of the area.

Lithology

Main Part of Unit (COc). In the northwest the Cape River Beds (excluding the quartzite subunit COq) range from phyllite and quartzite of the greenschist facies to amphibolite and garnet-biotite gneiss. The higher-grade rocks are generally found along the northeastern edge of the belt.

South and southeast of Lake Cargoon, scattered outcrops of biotite-quartz-feldspar gneiss (too small to map at the 1:250,000 scale) are surrounded by alluvium. In places, dark red garnet is present in zones parallel to the northwesterly foliation; elsewhere the gneiss has been shattered, and the fragments rotated and cemented by quartz and tourmaline. The gneiss has a granodioritic composition, and quartz and biotite are associated in lenticular segregations. Veins and sheets of aplitic and pegmatitic garnet-biotite-muscovite granite cut the gneiss in varying attitudes; the garnet in the granite is much lighter in colour than that in the gneiss.

Amphibolites occur in Range Creek, near the Mount Emu diggings. They are similar to amphibolites in the Ewan Metamorphics (Wyatt et al., 1970) in the Townsville Sheet area, and are composed of hornblende and plagioclase with some sphene and epidote. They are cut by coarse hornblende-plagioclase pegmatites, quartz-alkali feldspar veins, and quartz-epidote veins. Although the folioation is broadly parallel to the regional trend, the amphibolites may slightly transgress the mica schists which surround them.

In the Morepork Creek area the dissected country consists of mica schists and metamorphosed arenites, some of which are calcareous. They are crenulated and extensively veined by quartz. Quartzose bands in the sequence highlight the crenulations. The rocks are dark grey-green and fine-grained. The mica content ranges from about 5 percent in the arenites to about 70 percent in the pelitic bands; muscovite and biotite are generally equally abundant.

Near the Dumbano Granite, lenses of mica schist are interbanded with white muscovite granite and biotite adamellite, all of which may grade into each other. The schist is composed mainly of mica and quartz with only a little feldspar.

Vine et al. (1963, unpubl.) record abundant post-metamorphic rhyolite sills in inliers of metamorphics west of the map area.

In the central part of the belt quartz-feldspar-biotite gneiss (Fig. 3) and schist, garnet-muscovite-biotite-quartz gneiss, tremolite-epidote-quartz-feldspar gneiss, augen gneiss, and metamorphosed feldspathic greywacke have been recorded. The altered feldspathic greywacke, beside the road 3.5 km east-southeast of Mount Richardson, appears to be of lower metamorphic grade than the biotite schist with which it is interlayered. It contains clastic fragments of mica schist.

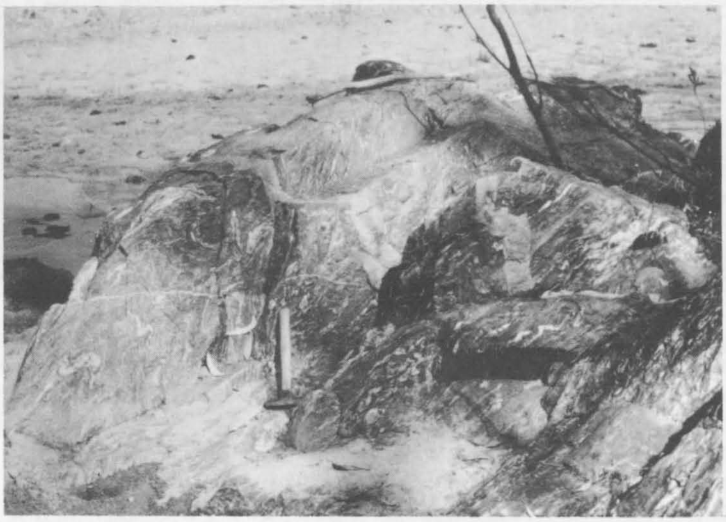

Fig. 3. Intricately folded biotite gneiss, Cape River Beds, north bank of Cape River, 2.5 km northwest of Oak Vale homestead. The gneiss is cut by a narrow rectilinear dyke of biotite adamellite, probably related to the Lolworth Igneous Complex.

In the central part of the belt muscovite is usually subordinate to biotite. Lenses of quartz up to 25 cm long, with scattered large crystals of epidote and hornblende, are common in the gneisses, and irregular sheets of quartz are common parallel to the foliation, although they locally transgress it. Concordant lenses of quartz-feldspar-epidote pegmatite, sometimes containing hornblende and tourmaline, intrude some of the gneisses (Fig. 4). The augen gneiss consists of quartz, feldspar, tremolite-actinolite, sphene, and altered hornblende. It crops out as a narrow band in the biotite schist 1.5 km south of where Oxley Creek crosses the western boundary of the quartzite belt. It is similar in composition to the massive fine-grained green and white laminated tremolite-epidote quartzofeldspathic gneiss. The gneiss generally forms bands, about 30 cm thick, which are interbedded with fine-grained biotite gneiss. Although the bands are generally parallel to the foliation of the enclosing gneiss, they locally transgress it, and in places lens out suddenly. Near Black Gin Creek a band of tremolite gneiss cuts across the foliation of the host gneiss, and has been shear-folded by movements in the foliation plane of the host gneiss. It is possible that the tremolite gneiss represents small intrusive bodies. In general, in the central part of the belt, the metamorphic foliation appears to be parallel with the bedding.

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In the southeast the Cape River Beds crop out as roof pendants in the Ravenswood Granodiorite Complex. Biotite-muscovite schist predominates. In places, it grades into foliated granodiorite, and small areas of migmatite have been found in the transition zones, which abound with xenoliths of schist in all stages of assimilation.

Fig. 4. Finely banded biotite gneiss, Cape River Beds, with concordant lenses of quartz-feldspar-epidote pegmatite, in creek bed near road crossing 3.5 km west-northwest of Oak Vale homestead. In places the pegmatite lenses contain hornblende and tourmaline.

The large roof pendant forming Mount Davenport and its foothills consists chiefly of muscovite schist containing no biotite, but amphibolite, muscovite quartzite, and hornfelsed feldspathic sediments crop out at the southern foot of the mountain. The muscovite schist is commonly ironstained to a lustrous brownish red, and is intruded by thin sills of metamorphosed biotite microgranite and microgranodiorite. The muscovite schist contains microcline and other alkali feldspar.

Hematite-muscovite schist (Fig. 5) and hematitic muscovite-cordierite schist form low ridges about 1.5 km northwest of Kiora homestead, but about 100 m to the southwest diopside granofels (Fig. 6) crops out. Marble and calcareous hornfels form a small roof pendant on the Ravenswood Granodiorite Complex beside the road 1.5 km north of Mount Remarkable.

A small outcrop beside the Campaspe River, 7 km north of Mount Davenport, consists of finely banded pink granitic gneiss; it is intruded by folded and boudinaged biotite pegmatite and by later rectilinear veins of muscovite pegmatite. Much of the biotite pegmatite, which is locally garnetiferous, is believed to be related to the granitic phase (ODa) of the Ravenswood Granodiorite Complex; the muscovite pegmatite is normally garnetiferous and is related to the Lolworth Igneous Complex.

Garnet-biotite-muscovite schist and gneiss, with some amphibolite, crop out in one of the eastern tributaries of Fat Hen Creek, 5 km northwest of Cornelia homestead. Low linear outcrops of dark green coarse tremolite-chlorite rock (possibly an altered ultramafic rock) occur 2.5 km east-southeast of Cornelia homestead.

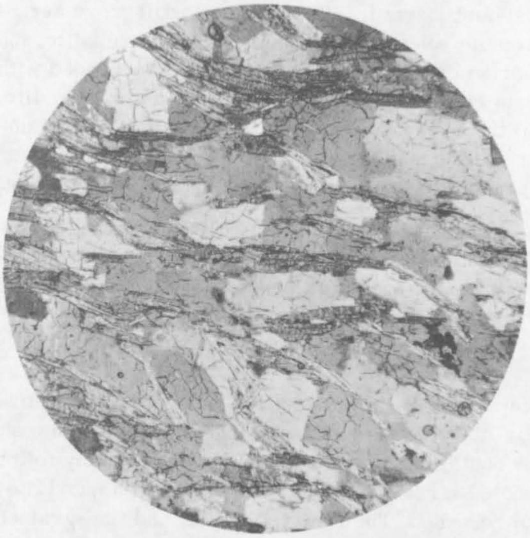

Fig. 5. Hematite-muscovite-quartz schist, Cape River Beds, 1.5 km northwest of Kiora homestead. The schist is composed mainly of quartz and muscovite, and a little hematite. Crossed nicols, X 45. (GSQ TS15003).

One kilometre southeast of Capeville homestead a possible cataclasite crops out where Lea Creek meets the southern margin of the Cape River alluvial flat. It consists of scattered elliptical fragments of altered feldspar and microcline-quartz-biotite rock up to 1 cm long, set in a fine-grained greenish purple matrix of chlorite and sericite. Cleavage is strongly developed in the groundmass, and flakes of chlorite and sericite are bent around the fragments. The rock is either a mylonitized granite or a pyroclastic rock containing fragments of granite. It is apparently of much lower metamorphic grade than the schists and gneisses. No contacts were seen in the field. Similar rock forms a steep ridge beside Cornelia Creek, 2.5 km southeast of Cornelia homestead. It is possible that these rocks, together with the metamorphosed feldspathic greywacke mentioned above, are remnants of a younger, and only slightly metamorphosed, sequence infolded in the Cape River Beds.

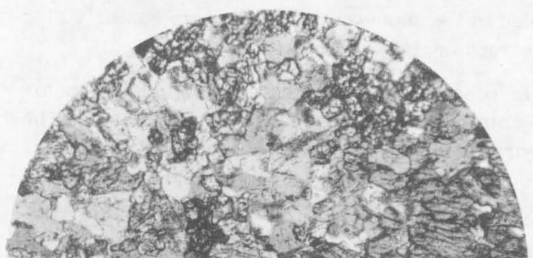

Fig. 6. Diopside granofels, Cape River Beds, 1.5 km northwest of Kiora homestead. The granofels consists of diopside, quartz, actinolite, albite-oligoclase, and epidote. Crossed nicols, X 45. (GSQ TS15019).

Belt of Quartzites (COq). The central belt of the Cape River Beds consists of prominent strike ridges composed of thin bands of resistant quartzite interbedded with soft grey quartz-mica schist and subordinate quartz-muscovite schist, quartzofeldspathic amphibolite, and rare andalusite(?)-mica schist. The quartzofeldspathic amphibolite is interbedded with quartzite in Black Gin Creek; it consists largely of colourless or pale green tremolite. Epidote-quartz hornfels occurs close to the Gypsy Pocket granitic intrusion (Pzg). Concordant sheets of felsite of unknown age intrude the quartzite near Gypsy Pocket, and lenses of quartz, up to 25 cm long, occur parallel to the foliation in the quartz-mica schist.

The bedding in the quartzite belt is apparently parallel to the foliation. In the northwest, the beds of quartzite commonly range from 1 to 2 m thick and are separated by beds of mica schist of similar width. The quartzite beds appear to thicken towards the southeast at the expense of the schist. Individual beds of quartzite range up to 30 m thick.

Structure

The general structural trend of the Cape River Beds is remarkably constant; the foliation strikes northwest, and dips vertically or at steep to moderate angles to the southwest. In the quartzite belt, particularly in the south, the foliation generally dips steeply to the northeast. Low dips to the northeast were noted in relatively competent bands of a quartzite-schist sequence but the location was not recorded. The schist, phyllite, and fine-grained quartzose rocks near Mount Cracknell show large-scale structures, but folds have not been positively identified on the air-photographs, except in the quartzite belt, which displays the tectonic style better than the other rocks. Two possible folds have been photo-interpreted in the schists in the northwest, but the easterly one, immediately west of Lake Cargoon, is not entirely in accordance with field observations. Possible synclinal closures occur at both ends of the quartzite belt, which may therefore constitute the youngest part of the sequence. The sudden changes in width of the belt (for example, south of Gypsy Pocket) are tentatively attributed to fold closures which are otherwise not apparent. The sequence has been isoclinally folded. Gently dipping foliation in some areas probably indicates near-recumbent folding. The lineation, as expressed by the axes of small dragfolds, plunges southeast at 10^{o} to 30^{o}. In the northwest, the plunge of the lineations is believed to be parallel to the axes of the major structures, which are mainly synclinal. The possible synclinal closure at the southeastern end of the quartzite belt indicates a reversal of plunge.

The structure of the schists at Mount Davenport does not conform with the regional pattern. The dip of the schistosity at the summit is 10^{o} north, and at the base of the hill, moderate southwesterly dips were recorded in the southwest and moderate easterly dips in the east. North of Pentland the foliation trends north-northwest.

In the northwest, a few northwesterly possible faults can be seen on the air-photographs, and faults with a similar trend occur a few kilometres northwest of Pentland. The quartzite belt is cut by faults, trending north of east, with apparent horizontal displacements of up to 1 km. Farther south, transcurrent faults trend northeast; the movement is mainly sinistral, but two faults near Black Gin Creek show apparent dextral displacement.

The deformation was probably caused by northeast-southwest compression. The east-northeasterly faults are probably wrench faults, and the northwesterly strike faults are possibly dip-slip faults with a high-angle reverse movement.

Thickness

The alternations in lithology in the belt of quartzites may represent the original sedimentary succession, but transposition of beds may have occurred in places. The folding is apparently isoclinal; the scarcity of recognizable closures and the problem of tracing individual beds makes it difficult to estimate the thickness. Elsewhere, the structure of the deeply eroded schists and gneisses is unknown. All that can be stated is that the original thickness of the Cape River Beds was almost certainly great.

Metamorphism

Most of the Cape River Beds probably fall within the quartz-albite-epidote-biotite subfacies of the greenschist facies of regional metamorphism (Turner & Verhoogen, 1960). Some of the rocks, for instance in the extreme northwest, are lower in grade, and others probably belong to the almandine-amphibolite facies. Staurolite, kyanite, and sillimanite have not been recorded, but andalusite may be present (R.R. Vine, pers. comm.). The Lolworth Igneous Complex and Ravenswood Granodiorite Complex probably controlled the degree of recrystallization.

Original Lithology

The Cape River Beds were laid down as a thick sequence of shale, siltstone, and sandstone. Amphibolite, tremolite schist and gneiss, marble, and pyroxene hornfels probably represent calcareous and dolomitic sediments. Volcanic rocks cannot be ruled out as possible progenitors of some of the strongly recrystallized schists and gneisses.

Age and Relationships

The Cape River Beds are intruded by the Ravenswood Granodiorite Complex, the Lolworth Igneous Complex, and the Dumbano Granite, and are unconformably overlain by the Upper Permian Betts Creek Beds. The Ravenswood Granodiorite Complex crops out mainly in the Charters Towers Sheet area, where it consists of a Middle Ordovician phase (455 m.y.) and an Upper Silurian/Lower Devonian phase (395 m.y.) (Wyatt et al., 1971; Clarke, 1969, unpubl.; Webb, 1969). Isotopic dates obtained from the Lolworth Igneous Complex (Webb, in Appendix 1 of this Report) and the Dumbano Granite (Richards, White, Webb, & Branch, 1966) lie close to the Silurian-Devonian boundary (380-400 m.y.).

Seven specimens of schist and gneiss (Table 2) from the Cape River Beds in the Hughenden Sheet area were analysed by A.W. Webb and Miss R. Bennett by the Rb/Sr whole rock method. When plotted on a graph (Fig. 7) the ^{87}Sr/^{86}/Sr: ^{87}Rb/^{86}Sr ratios of four of the specimens lie close to a straight line. The line may represent an isochron, although the number of specimens analysed is too few to give a reliable result. Furthermore the scatter about the line of best fit is slightly greater than would be expected from experimental error alone, indicating that there were differences in the initial ^{87}Sr/^{86}Sr ratios of the four specimens. The remaining three specimens lie well away on either side of the possible isochron and have therefore been disregarded. The age defined by the possible isochron is 483$\pm$25 m.y. (Lower Ordovician), but because it is uncertain whether the rocks remained closed systems during metamorphism (indicated initial ^{87}Sr/^{86}Sr ratio 0.729), it is not possible to decide whether this figure represents a sedimentary or metamorphic age (J.A. Cooper, pers. comm.).

A Rb/Sr isochron of 510$\pm$100 m.y. (Upper Cambrian) has been obtained from unmetamorphosed acid volcanics of the Cape River Beds in the Bowen Sheet area (Paine, Clarke & Gregory, 1970, unpubl.). It is mainly on account of this that the Cape River Beds are regarded broadly as Cambrian to Ordovician in age. As the Ravenswood Granodiorite Complex (445 m.y.) appears to be largely syntectonic in the map area, the figure of 483 m.y. may represent the age of deposition. However, the correlation between the dated areas of the complex and the areas of foliated granodiorite in the Hughenden Sheet area is tenuous.

TABLE 2. Rb/Sr WHOLE ROCK ANALYSES, CAPE RIVER BEDS

ANU No.	BMR No.	Rock Type	Military Grid Reference E	Military Grid Reference N	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ (calc.)
GA5783	F55/1/2	Biotite gneiss	306000	2447200	124.6	155.4	2.323	0.7435
GA5784	F55/1/4	Biotite gneiss	308900	2448100	239.3	113.6	6.119	0.7724
GA5785	F55/1/7	Biotite schist	284800	2452400	137.6	54.43	7.369	0.8024
GA5786	F55/1/8	Biotite-muscovite schist	282900	2458200	302.6	47.04	18.85	0.8610
GA5787	F55/1/23	Biotite schist	301000	2447200	295.5	59.08	14.43	0.8287
GA5788	F55/1/25	Granitic biotite gneiss	334200	2450500	104.4	55.85	5.420	0.7457
GA5789	F55/1/30	Biotite-muscovite schist	335200	2442100	128.2	27.96	13.35	0.7989

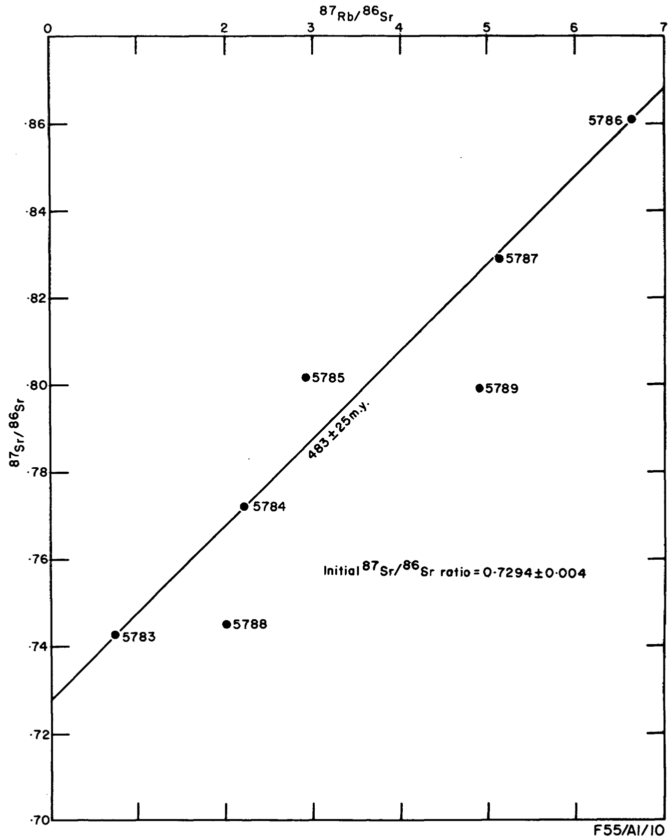

Fig. 7. Possible Rb/Sr whole rock isochron for metamorphics of the Cape River Beds.

MIDDLE ORDOVICIAN(?)

Ravenswood Granodiorite Complex

The extensive outcrops of foliated granitoid rocks in the Pentland district are considered to form an extension of the Ravenswood Granodiorite Complex (Wyatt et al., 1971; Clarke, 1969, unpubl.), which covers 8000 sq km in the Charters Towers, Townsville, and Bowen Sheet areas.

Much of the complex is foliated parallel to the trend of the metamorphics, and it is essentially syntectonic. Both the Cape River Beds and the Ravenswood Granodiorite Complex have been intruded by a post-orogenic batholith, the Lolworth Igneous Complex.

The Ravenswood Granodiorite Complex has been subdivided into a gneissic granodiorite and adamellite phase (ODn), and less strongly foliated granodiorite (ODr) and granite (ODa) phases.

Distribution and Topography

The unit extends from northwest of Gorge Creek southeastwards in a broad belt which widens to include most of the basement rocks between the Campaspe River and the Great Dividing Range. A smaller area occurs in the headwaters of Davey Creek, 8 km southwest of Lolworth homestead. In all, the unit covers about 300 sq km within the Sheet area. Around Gorge Creek, the gneisses crop out as resistant strike ridges which rise 300 m above the

Cape River, and form the southwestern part of the Lolworth Range. Along strike to the southeast, the ridges give way abruptly to gently undulating low-lying country, which is typical of the complex as a whole, where exposures are found only in small creeks and gullies. Here the only hill of note is a short steep pink granite ridge, which rises about 100 m, 2.5 km east of Cornelia homestead.

Lithology

The gneisses (ODn) consist chiefly of plutonic rocks which have been sheared and recrystallized to varying degrees. They are generally coarsely banded, and range from dark to pale grey. They consist of alternating dark biotite-rich bands and light quartzofeldspathic bands. In places, the feldspar has a pink tinge, and it may form prominent megacrysts. Most of the rocks are orthogneisses, but in the hills around Gorge Creek some paragneiss is interfoliated with the orthogneiss. Some of the orthogneisses contain numerous xenoliths of schist and gneiss (Fig. 8). In places complex folds are developed in the foliation.

Most of the orthogneisses are rich in biotite. The following rock types have been recorded from the Gorge Creek area, where outcrops are fresh and plentiful: dark grey uneven-grained gneissic adamellite; dark grey fine-grained crudely foliated blastoporphyritic gneiss; grey fine to medium-grained foliated adamellite; dark grey uneven-grained schistose garnetiferous augen gneiss; dark grey uneven-grained mica-quartz-feldspar gneiss; and rare black lustrous fine-grained foliated melanocratic quartz diorite. The gneisses commonly contain about 20 percent biotite, but one rock contains about 35 percent biotite and muscovite and 25 percent completely sericitized alkali feldspar. The plagioclase (15-30%) is mainly oligoclase, and quartz ranges from 25 to 40 percent, with 50 percent in the paragneiss. The quartz diorite was found at the head of Gorge Creek; it contains 45 percent andesine, 45 percent hornblende, and 10 percent quartz. The augen in the augen gneiss consist of alkali feldspar partly replaced by quartz, micropegmatite, and sieve-textured garnet, which is partly replaced by biotite. The flow lines of biotite around the garnet crystals indicate that crystallization of garnet was succeeded by at least one stress episode. In most of the rocks, however, the effects of stress have been largely obliterated by recrystallization.

In the low-lying country to the south and east the rocks are usually weathered and friable. The main rock type is foliated dark to pale grey 'granodiorite', which is locally rich in biotite, and crowded with xenoliths of biotite schist. In places the foliated granodiorite appears to grade into schist of the Cape River Beds. Biotite-rich knots occur in places in the granodiorite, and a few migmatitic zones are also present.

Southwest of Lolworth homestead gneissic adamellite predominates.

The poorly exposed area between the Cape River and Granite Creek is underlain by moderately foliated biotite granodiorite (ODr) similar to the main part of the complex in the Charters Towers Sheet area. The outcrops in the left bank of the Cape River, at the Flinders Highway crossing, consist of weathered pinkish white coarse biotite granodiorite. The rock is slightly porphyritic and moderately foliated. It is intruded by numerous veins of coarse biotite pegmatite. The boundary between this subunit and the orthogneiss is largely arbitrary.

The main area of pink biotite granite (ODa) crops out northeast of Pentland. The granite is a strongly foliated and crudely banded rock composed of quartz (40%), which is sheared and partly recrystallized; microperthite (35%), which is bent and slightly altered; plagioclase (15%), which is highly fractured; and biotite (10%), which is generally associated with recrystallized quartz. The outcrops east of Cornelia homestead and at Fat Hen Creek consist of weakly foliated pink biotite leucogranite. Xenoliths of pink to buff leucocratic foliated biotite microgranite and granite occur in the Lolworth Igneous Complex just north of Cornelia homestead (Fig. 9). The biotite pegmatite dykes in the area are probably associated with the granites; they are commonly folded and boudinaged, and some of them are garnetiferous.

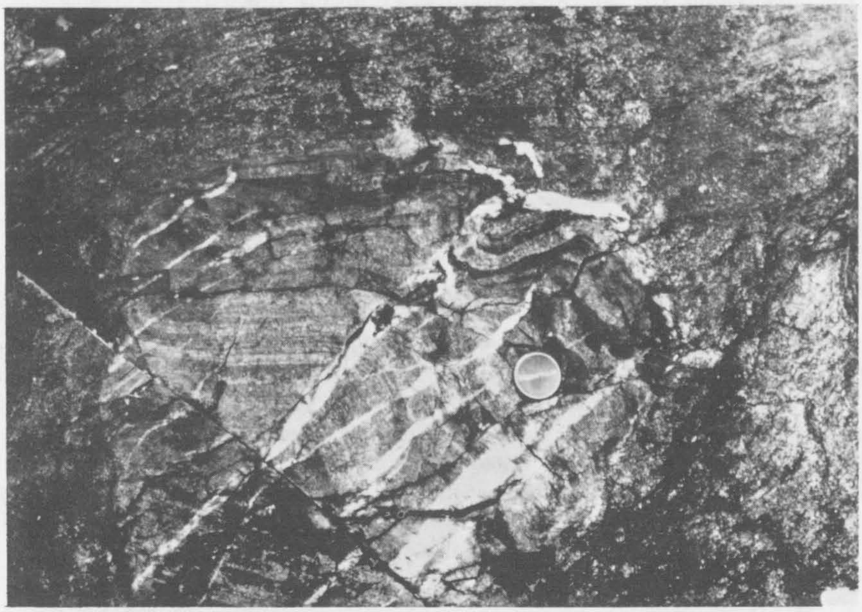

Fig. 8. Rounded xenolith of contorted gneiss with quartz veins, in gneissic adamellite of the Ravenswood Granodiorite Complex, in creek bed east of Gorge Creek, 6 km north-northwest of Oak Vale homestead. The xenolith is about 80 cm in diameter.

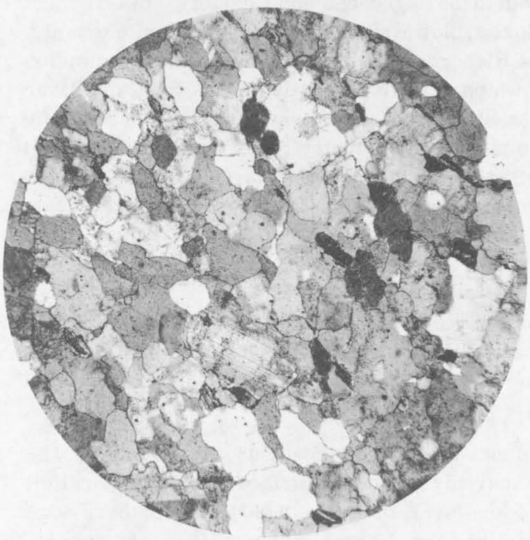

Fig. 9. Xenolith of slightly foliated leucocratic microadamellite in the Lolworth Igneous Complex, 6.5 km north of Cornelia homestead. The xenolith probably represents the granite phase (ODa) of the Ravenswood Granodiorite Complex. Crossed nicols, X 45. (GSQ TS15018).

Structure and Tectonic Environment

The foliation dips regionally to the southwest at moderate to steep angles. In parts of the granite (ODa) near Pentland the foliation is almost horizontal. The degree of foliation varies considerably, and is greatest in the northwest. The contact with the Cape River Beds is regionally discordant, but is nearly concordant in the northwest. South of Ballabay homestead and southeast towards Pentland the contact is subhorizontal and close to the surface. The contact is gradational and can only be mapped approximately.

The Ravenswood Granodiorite Complex was probably affected by the closing stages of the orogeny which folded and metamorphosed the Cape River Beds.

Order of Emplacement

The granite phase (ODa) intrudes the gneissic granodiorite and adamellite phase (ODn), but the relationship between the granodiorite (ODr) and the other two phases is unknown.

Age and Relationships

Isotopic dating by the Rb/Sr whole rock method (Webb, 1969) has shown that the Ravenswood Granodiorite Complex in its type area around Ravenswood in the Charters Towers Sheet area is mainly Middle Ordovician (454$\pm$30 m.y.). However, some phases of the complex were emplaced at the same time as the Lolworth Igneous Complex, close to the Silurian-Devonian boundary (394$\pm$30 m.y.). Since Ravenswood is 160 km northeast of Pentland, any correlation between the foliated rocks in the Hughenden Sheet area and the Ravenswood Granodiorite Complex can only be tentative. Nevertheless, in view of the clear difference in age between the foliated granitoid rocks and the massive cross-cutting Lolworth Igneous Complex in the Hughenden Sheet area, it seems reasonable at this stage to regard the foliated rocks as Middle Ordovician, and to correlate them with the main part of the Ravenswood Granodiorite Complex.

UPPER SILURIAN OR LOWER DEVONIAN

Lolworth Igneous Complex

The Lolworth Igneous Complex crops out in the Hughenden and Charters Towers Sheet areas. It comprises massive biotite granodiorite, biotite adamellite, and muscovite granite. A small body of quartz diorite north of Mount Richardson has been included in the complex. The complex is a post-orogenic batholith which cuts discordantly across the Cape River Beds and Ravenswood Granodiorite Complex. A thermal metamorphic aureole is probably present, but its extent is not known. The complex and its country rocks have been intruded by pegmatite and granite dykes associated with the complex. The Lolworth Igneous Complex was intruded 400 m.y. ago, at about the Silurian-Devonian boundary.

Distribution and Topography

The Lolworth Igneous Complex crops out over about 1000 sq km in the mapped area. In the south the contact is well exposed, but the northern boundary is concealed by Cainozoic basalt and sediments. Mount Specimen and Mount Remarkable, 10 km south of the main batholith, may represent outlying cupolas.

The Lolworth Range is the predominant topographic feature of the complex. The summits of the range emerge from a broad unevenly dissected surface of moderate relief; they rise to an elevation of over 800 m above sea level. In the southeast, the southern edge of the range is defined by a broken escarpment of rugged spurs, steep valleys, and gorges, but the Lolworth Igneous Complex extends into the undulating dissected country to the southeast. In the southwest, the boundary of the complex lies considerably to the north of the Lolworth Range escarpment, but northwest of Mount Richardson the escarpment generally coincides with the southern boundary of the complex until it merges, still farther west, into the hills underlain by the Cape River Beds. North of the Lolworth Range, the complex forms hills which gradually descend to the basalt plain.

Mount Specimen is a steep conical hill rising 200 m above the surrounding plain, and Mount Remarkable is a northeast-trending ridge 100 m high.

Lithology

Large areas towards the centre of the complex have not been examined, but most of the complex probably consists of massive pale grey to pink medium to coarse-grained biotite adamellite and granodiorite. A little muscovite is invariably present, and large poikiloblasts of microperthite, enclosing quartz and biotite, are commonly developed. The biotite tends to occur in well defined clots.

Pegmatitic garnet-muscovite granite or adamellite is also common, particularly in the east, and extends into the Charters Towers Sheet area. It is usually pale salmon-pink, but both red and white varieties also occur. Most outcrops are noticeably banded. The bands appear to be primary; their texture ranges from aplitic to graphic or pegmatitic, and the grainsize varies widely. Feldspar crystals range up to about 30 cm long. The bands are commonly a few millimetres to 10 cm or more thick, but range up to more than 1 m. They contain variable proportions of quartz, feldspar, and small euhedral crystals of pink to red garnet. The garnet is particularly abundant in some of the aplitic bands. A little biotite is also present. In the Hughenden Sheet area the garnet-muscovite granite forms the undulating hilly country north of Mount Stewart and east of the Niggers Bounce, and a belt of country southeast of the Lolworth Range. Where the southern edge of the Lolworth Range trends northeast from near Cornelia homestead to Mount Stewart, it coincides roughly with a transition zone between biotite adamellite to the northwest and muscovite granite to the southeast. The zone is several kilometres wide, and consists of adamellite and granite in which biotite may predominate over muscovite. Large pink zoned porphyroblasts(?) of plagioclase are common.

Massive fine to medium-grained light grey quartz diorite forms a narrow extension of the complex among the gneisses of the Ravenswood Granodiorite Complex, 7 km northwest of Gorge Creek. The quartz diorite may be the result of contamination by mafic-rich gneiss. It forms a belt of low-lying country among rugged ridges of gneiss.

At Mount Specimen and Mount Remarkable the granite has been deeply weathered, probably due to lateritization, but some of the alteration may have been due to hydrothermal effects associated with the numerous small gold deposits which have been worked in the immediate area. The abundance of muscovite in this granite suggests that it may belong to the Lolworth Igneous Complex. Mount Remarkable appears to consist of a thick dyke of altered muscovite granite, which bifurcates and lenses out towards the southwest.

Dykes of pink and white garnetiferous muscovite pegmatite, aplite, and granite are abundant in the Lolworth Igneous Complex and in the country rocks around the margin. The dykes are similar in texture and composition to the muscovite granite in the eastern part of the complex, where they sharply transgress the primary banding. The dykes range in thickness from 10 cm to several metres, but are commonly a metre or so wide. They dip at steep to moderate angles. Northeast of Cornelia homestead, where banded muscovite granite intrudes the Ravenswood Granodiorite Complex, frequent ridges of pegmatitic muscovite granite occur among sparse outcrops of weathered granodiorite. Towards the contact it is difficult to establish whether certain ridges are dykes or merely resistant bands in the main body of the complex, and the position of the contact on the map is only approximate. The muscovite pegmatite, aplite, and granite dykes are equally abundant in the central and western parts of the complex where biotite-bearing rocks predominate. The coarser-grained and thicker dykes tend to occur in the country rock close to the margin of the complex. The aplitic dykes towards the centre of the complex are adamellitic in composition and consist of quartz, equal proportions of oligoclase and potash feldspar (orthoclase and microperthite), muscovite, and a little garnet. Around Gorge Creek, north of Oak Vale homestead, numerous greyish white fine to medium-grained muscovite-biotite adamellite dykes intrude coarse gneiss of the Ravenswood Granodiorite Complex. Thin dykes of biotite adamellite (Fig. 3), probably related to the complex, intrude gneiss of the Cape River Beds 2.5 km northwest of Oak Vale homestead.

Structure

In the east, the southern contact of the complex transgresses the regional foliation of the country rocks, and probably dips steeply. Roof pendants of country rock are unknown in this area, although Mount Specimen and Mount Remarkable probably represent outlying cupolas. In the west, the contact is not clearly transgressive, and its sinuous form suggests that it dips at a low angle.

The primary banding in the eastern part of the complex dips at moderate to low (rarely steep) angles, and open sinuous folds can be seen in some outcrops.

Most of the faults in the Lolworth Igneous Complex trend northeast. In the east, similarly trending fractures have been filled by dykes of the Mundic Igneous Complex.

The Lolworth Igneous Complex does not appear to have undergone any major tectonic deformation, but some of the quartz is slightly strained. The complex is regarded as post-orogenic. It has discordant contacts with the country rock, and is not foliated.

Order of Emplacement

The relative ages of the different phases of the complex have not been established. Although the pegmatitic garnet-muscovite granite appears to form an envelope enclosing the eastern half of the main body of biotite adamellite and biotite granodiorite, the numerous garnet-muscovite pegmatite dykes, which are similar in composition and texture to the pegmatitic granite, intrude the main part of the complex. It is possible that the different phases are essentially coeval, and the variations in composition and texture may be due to assimilation of country rock rather than to magmatic differentiation.

Age and Relationships

The Lolworth Igneous Complex intrudes the Cape River Beds and the Ravenswood Granodiorite Complex, and is intruded by the Mundic Igneous Complex. K/Ar mineral ages averaging 395 m.y. and a Rb/Sr isochron of 401± 7 m.y. have been obtained from the complex (Appendix), showing that it was intruded in the late Silurian or early Devonian.

Dumbano Granite

The Dumbano Granite of the Clarke River Sheet area (White, 1962; Richards et al., 1966) extends south into the Hughenden Sheet area, where it intrudes the Cape River Beds. It crops out over about 300 sq km in the northwest of the map area.

The outcrop is bisected by an irregular meridional strip of Upper Permian(?) volcanics and Cainozoic basalt, which form the watershed between Galah Creek and the Flinders River. The part drained by the Flinders River was traversed during the present survey; the only known observations on the western area are those of Vine et al. (1963, unpubl.). The eastern area consists of unevenly dissected undulating rises and low hills.

Lithology

The Dumbano Granite comprises grey even-grained adamellite, grey adamellite with relatively large pink feldspar phenocrysts, and pink garnetiferous muscovite granite. The adamellites are commonly strongly foliated. The porphyritic adamellite consists of feldspar phenocrysts or porphyroblasts, up to 2.5 cm across, set in a medium-grained groundmass of quartz, alkali feldspar, plagioclase, biotite, and a little muscovite. The phenocrysts show no preferred orientation, and in places are zoned.

At the northern margin of the map area, at about longitude 144°40'E, adamellite with phenocrysts of pink feldspar is predominant, but patches of even-grained adamellite crop out in lenticular masses elongated northwest. The even-grained adamellite grades into the porphyritic variety and their age relationship is uncertain; both varieties are cut by sheets of aplitic or pegmatitic pink garnetiferous muscovite granite. Grey adamellite at Cargoon homestead crops out below a thin sheet of basalt. East of Range Creek and near the Flinders River the even-grained adamellite is foliated and contains parallel inclusions of schist. A white muscovite granite, with lenses of muscovite parallel to the foliation, is intimately associated with the schists in this area. The granite is different from the pink muscovite granite, and possibly represents an earlier intrusive (synorogenic?) episode.

Pink muscovite granite, with or without small pale red garnets, is common in the northeast; it is cut by sheets of aplite and pegmatite similar in composition to the granite, and similar to the sheets in the adamellite and schist to the southwest. This granite resembles the eastern part of the Lolworth Igneous Complex.

Structure, Relationships, and Age

Both types of adamellite are foliated to varying degrees in a west-northwesterly direction. The pink muscovite granite is not foliated. The few easterly and northeasterly lineaments identified by photo-interpretation are probably small faults. In the west, the granite is faulted against and underlies Upper Permian(?) sediments and volcanics. In the southwest and east it is overlain by Cainozoic basalt, and in the south it intrudes the Cape River Beds. Here the contact consists of interlayered white muscovite granite, biotite adamellite, and mica schist which grade into each other, and the boundary of the granite has only been mapped approximately.

Except for the muscovite granite, the lithology of the Dumbano Granite in the Hughenden Sheet area corresponds broadly with that noted by White (1962, 1965) in the Clarke River Sheet area. The pegmatitic garnet-muscovite granite, which is evidently the youngest component of the Dumbano Granite, resembles part of the Lolworth Igneous Complex, and may be related to it. The strong foliation and interlayering with schist recorded near the Flinders River suggest that parts of the Dumbano Granite may be syntectonic and possibly similar in age to the Ravenswood Granodiorite Complex.

Five K/Ar mineral ages were determined from four specimens in the Clarke River Sheet area (Richards et al., 1966). The ages range from 375 to 390 m.y., and their average is given as 380 ± 8 m.y. (Lower Devonian). In the absence of Rb/Sr dating, this age should be regarded as a minimum. In the Hughenden Sheet area the presence of massive garnet-muscovite granite cutting foliated biotite adamellite indicates more than one phase of intrusion. White (1962, 1965) did not note separate phases in the Clarke River Sheet area, and the relevance of the isotopic dates to the granite in the Hughenden Sheet area is therefore uncertain. Until more work is done, it is probably best to regard the Dumbano Granite as essentially the same age as the Lolworth Igneous Complex, that is Upper Silurian or Lower Devonian, bearing in mind that it may include some older phases, which are possibly equivalent to the Ravenswood Granodiorite Complex.

UPPER PERMIAN (?)

Sediments and Volcanics (Puv)

Sediments, pyroclastics, and acid lavas crop out in isolated areas in the northwest and southeast of the map area. They have a probable maximum thickness of about 60 m. Near Range Creek the area of outcrop is about 30 sq km; other outcrops occur a few kilometres west and southwest of Pentland.

In the northwest, the sequence forms rugged to undulating country, 800 to 925 m above sea level, which contrasts strongly with the plateau underlain by the Sturgeon Basalt to the west. The sediments and volcanics are drained by the headwaters of Range Creek. To the east the Dumbano Granite forms more gentle slopes in which the creeks are less deeply incised.

Near Pentland the sequence is poorly preserved. Near the railway line the beds form low rises; southwest of Golden Mount a few small hills and cappings occur among strike ridges of the Cape River Beds.

Lithology

At Range Creek acid volcanics rest nonconformably on the Dumbano Granite (Vine et al., 1963).

West of a prominent northeast-trending fault, the basal part of the sequence consists of conglomerate containing rounded and subangular pebbles of granite, porphyry, and flow-banded rhyolite. This passes upwards into conglomerate with angular fragments, and into sandstone and tuffaceous beds. Next to the fault, the sediments are strongly sheared and altered. The sequence dips gently to the west. East of the fault, a conglomerate about 30 m thick composed of granite cobbles and boulders, lies directly on granite and local areas of schist. This conglomerate is overlain by 15 m of a different conglomerate containing subangular pebbles of rhyolite, some of which are flow-banded, set in a sandy matrix; a few fragments of chert and epidote are present. The conglomerates are overlain by 10 to 15 m of acid tuff and interbedded sandstone, followed by up to 10 m of porphyritic rhyolite. The rhyolite is composed of irregular phenocrysts of quartz and feldspar set in a blue-grey fine-grained matrix. The basal beds dip off the granite at about 30^{o} to the south, but in a short distance the dip flattens out.

West and southwest of Pentland there are two outcrops, which may be connected. Acid volcanics crop out over an area of 4 sq km, southwest of Golden Mount. The chief rock type is altered reddish yellow porphyritic rhyolite containing rare angular fragments of quartz up to 8 cm across. Felsite dykes intrude the Cape River Beds nearby. Rands (1891) recorded tuffs containing numerous fragments of schist and quartzite. He described the tuff as grading into coarse agglomerate, and suggested that they mark the site of a former volcanic neck. In a rail cutting south of Betts Creek, thin-bedded pink to buff tuffaceous siltstone underlain by a thin basal conglomerate dips gently to the southwest off migmatite of the Ravenswood Granodiorite Complex. A sill of porphyritic rhyolite and a feeder dyke intrude the tuffaceous siltstone. The country immediately north and west of the railway cutting is covered in places by quartzite pebbles which have possibly been weathered out of conglomerates of similar age.

An oval area of andesite and andesitic fragmental rocks about 0.5 km across was mapped by Morton (1937a) on the left bank of the Cape River, about 1 km upstream from Oak Vale homestead.

Structure and Thickness

In the Range Creek area the sequence dips gently to the west and south. At the northeast-trending fault the beds are probably downthrown to the northwest. No folding was observed in the sequence.

At Betts Creek the sequence dips gently southwest, but the structure of the volcanics at Golden Mount is unknown.

At Range Creek the sequence is probably no more than 60 m thick. At Betts Creek about 10 to 15 m of tuffaceous siltstone are exposed.

Age and Relationships

At Range Creek the sediments rest nonconformably on the Dumbano Granite and are unconformably overlain by the Sturgeon Basalt. At Betts Creek the tuffaceous siltstone rests unconformably on the Cape River Beds and Ravenswood Granodiorite Complex. The Upper Permian Betts Creek Beds (Vine et al., 1963, unpubl.), which in places contain fine volcanic detritus, crop out a few kilometres west of the tuffaceous siltstone. The Betts Creek Beds have a similar strike and dip to the tuffaceous siltstone in the railway cutting, and also rest unconformably on the Cape River Beds.

The tuffaceous siltstone sequence is possibly a facies equivalent of the Betts Creek Beds which was deposited nearer to a volcanic centre.

The sediments and associated volcanics are regarded provisionally as Upper Permian in age.

Mundic Igneous Complex

The Mundic Igneous Complex mainly comprises a group of small stocks, bosses, and other bodies aligned in a northwesterly direction in the country drained by the headwaters and tributaries of Mundic Creek. The boundary between the Hughenden and Charters Towers Sheet area bisects the complex. The main intrusions form the Pentland Hills in the Charters Towers Sheet area and Mount Stewart in the Hughenden Sheet area; smaller isolated bodies crop out between the main intrusions. Dykes extend out from the main centres for more than 30 km into the country rocks.

The intrusions are epizonal and subvolcanic, although most of the volcanics have been removed by erosion. The intrusions were emplaced into the early Palaeozoic craton of granite and metamorphics. The features of the complex are summarized in Table 3, and the probable order of emplacement of the different phases is shown in Figure 10.

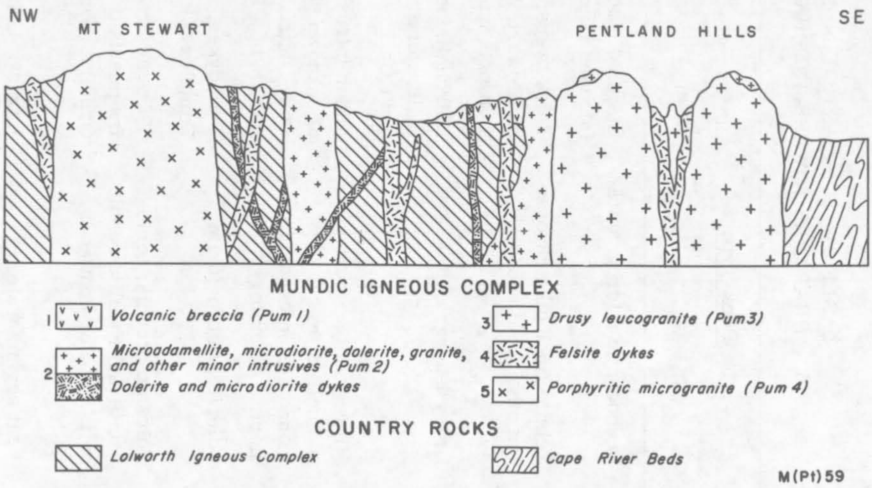

Fig. 10. Probable order of emplacement of the different phases of the Mundic Igneous Complex.

Distribution and Topography

The complex appears to comprise five discrete intrusive bodies (excluding the associated dykes), with a total area of 65 sq km. Three of the bodies occur in the map area. They include an oval microgranite stock covering about 25 sq km which forms Mount Stewart and the surrounding peaks. The stock forms rugged country which protrudes more than 200 m above the general level of the Lolworth Range in the southwest, and rises 450 m above the plain in the northeast. The summit of Mount Stewart is just over 1000 m above

TABLE 3 - SUMMARY OF MUNDIC IGNEOUS COMPLEX, CHARTERS TOWERS AND HUGHENDEN SHEET AREAS

Order of Emplacement	Map Symbol	Rock Type	Remarks	Distribution: Hughenden Sheet area	Distribution: Charters Towers Sheet area
5	Pum$_4$	Leucocratic microgranite	Epizonal stock. Forms rugged Mt Stewart. Intrudes Lolworth Igneous Complex	X	-
4	f	Felsite (including rhyolite and other acid rocks)	Thick dykes. Some cone sheets(?) near Mt Stewart. Flow-banded. Intrude Lolworth Igneous Complex.	X	X
3	Pum$_3$	Drusy leucogranite	Epizonal stock. Forms rugged Pentland Hills. Intrudes Lolworth Igneous Complex and COc	-	X
2	Pum$_2$	Microgranite, micro-adamellite, micro-monzonite, microdiorite, diorite, dolerite	Minor intrusives. Small bosses and bodies of unknown shape. Also roof pendants on Pum$_3$. Intrude Lolworth Igneous Complex. Intruded by Pum$_3$	X	X
	d	Dolerite, microdiorite	Thin dykes. Intrude Lolworth Igneous Complex		
1 (oldest)	Pum$_1$	Volcanic breccia; some dacite and rhyolite rubble on E slope of Pentland Hills	Volcanic breccia crudely bedded; contains fragments of Lolworth Igneous Complex. Overlies Lolworth Igneous Complex	-	X
		Vent agglomerate	Intrudes Lolworth Igneous Complex	X	-

sea level. Two smaller plug-like bodies occur northwest and southeast of Mount Stewart. Both crop out in dissected depressions each about a square kilometre in area. The acid dykes in places form resistant ridges in the Lolworth Igneous Complex. These are the only dykes in the map area which have a strong topographic expression.

Lithology

Volcanic Vent (Pum_1). One and a half kilometres northwest of the Mount Stewart stock (Pum_4) an oval depression in the Lolworth Igneous Complex is occupied by vent breccia. The breccia is composed of blocks of coarse muscovite granite (Lolworth Igneous Complex) and flow-banded rhyolite, set in a groundmass of comminuted granite fragments.

Microadamellite Boss(?) (Pum_2). Three and a half kilometres southeast of the Mount Stewart stock a small boss has been photo-interpreted in a dissected depression. It is thought to be formed from one of the less acidic rock types of the complex, by analogy with a similar body nearby in the Charters Towers Sheet area, which consists of porphyritic hornblende microadamellite (hand-specimen description). These minor intrusives contain a higher proportion of mafic minerals than the main part of the complex, and are best developed around the northern flanks of the Pentland Hills, a short distance to the southeast in the Charters Towers Sheet area. They range from dolerite (?) to microgranite, and are thought to have been emplaced early in the history of the complex. The photo-interpreted body noted here is the only representative in the map area of this subunit.

Microgranite Stock (Pum_4). Mount Stewart consists of red leucocratic porphyritic microgranite composed of medium-sized phenocrysts of quartz and kaolinized red feldspar set in a fine mosaic of similar composition. It includes small scattered patches of mottled dark and pale green material which may be altered dolerite xenoliths. No other mafic minerals are present. The Lolworth Igneous Complex, which forms the northeastern foothills, has been intruded by a sheet of brown granophyre, 100 m or so thick, which dips at a moderate angle towards the microgranite stock.

Dykes. The dykes associated with the Mundic Igneous Complex fall into two groups - dolerite/microdiorite and felsite. The felsites are invariably younger than the dolerites and microdiorites. Both groups are well exposed in the headwaters of Mundic Creek (Figs 11 & 12). The dolerite/microdiorite dykes are less numerous and thinner than the felsites.

Fig. 11. Faulted felsite dyke, Mundic Igneous Complex, in the bed of Mundic Creek 7 km south of Mount Stewart. The dyke intrudes massive coarse muscovite-biotite adamellite of the Lolworth Igneous Complex.

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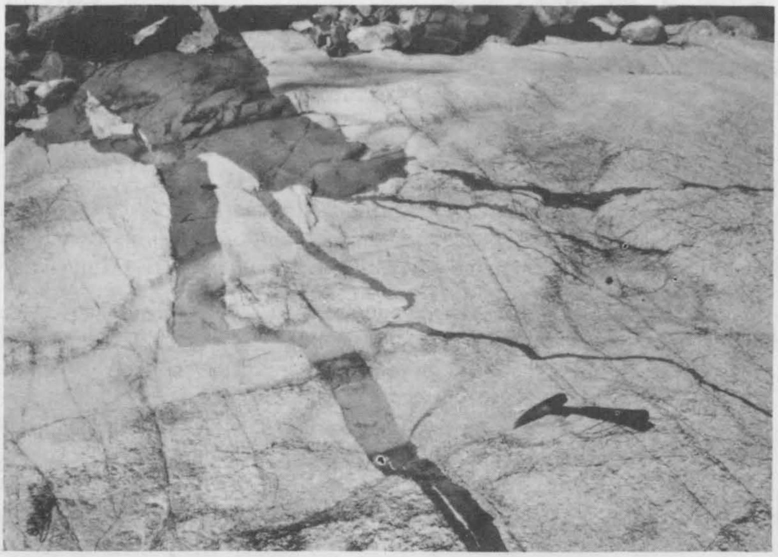

Fig. 12. Terminal apophyses of a basic dyke, Mundic Igneous Complex, intruding coarse adamellite of the Lolworth Igneous Complex, near head of Mundic Creek 6.5 km south of Mount Stewart.

The dolerite/microdiorite dykes were seen to intrude the Lolworth Igneous Complex only. They are generally between 0.5 and 1 m thick, with a maximum of 2 m. Dolerites and microdiorites appear to be equally abundant. Calcite is a common alteration product. They have the typical dark blue-grey colour of basic dykes, but are locally mauve to dark brown, and tend to develop a bright orange crust. Some of the dykes are markedly porphyritic.

Pale buff to pinkish buff felsite dykes cut the Lolworth Igneous Complex and the dolerite/microdiorite dykes. They are commonly flow-banded, either parallel to their margins or in sinuous plications. The felsites generally contain only rare quartz phenocrysts, but some dykes are crowded with phenocrysts of red feldspar and quartz, while others contain only feldspar phenocrysts (Fig. 13). The dykes include porphyritic rhyolite and spherulitic porphyritic rhyolite.

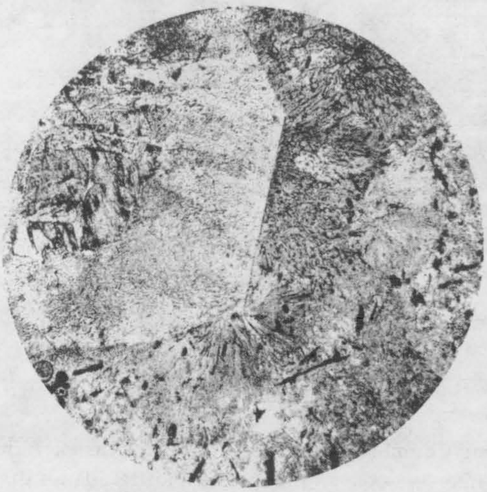

Fig. 13. Porphyritic spherulitic felsite dyke, Mundic Igneous Complex. The dyke intrudes adamellite of the Lolworth Igneous Complex 5 km south-southeast of Mount Stewart. Centres of spherulitic growth occur on the border of a large feldspar phenocryst, which has been recrystallized to a micrographic intergrowth of quartz and feldspar. Acicular crystals of iron oxide are abundant. Crossed nicols, X 45. (GSQ TS15030).

In places the felsites and dolerites or microdiorites form composite and multiple dykes. At one locality a flow-banded porphyritic felsite dyke, 2 m thick, is flanked on both sides by a half-metre band of amygdaloidal dolerite. There is a gradual colour transition between the two rocks over a width of 15 cm. There may not be much difference in age, although the felsite is apparently younger. At another locality, pink felsite 10 m thick forms the core of a multiple dyke. The felsite is flanked by dolerite/microdiorite dykes 30 to 50 cm thick. Blocks of dolerite are included in the felsite; the contacts are sharp, but the colour of one of the dolerite dykes becomes paler towards the felsite contact. It appears that a dolerite/microdiorite dyke was split down the centre and intruded by acidic magma which expanded it to ten times its former width. At another locality a thick felsite dyke was seen to truncate a dolerite/microdiorite dyke.

Structure, Age, and Relationships

The probable order of emplacement in the Mundic Igneous Complex is summarized in Table 2 (see also Fig. 12).

All rocks of the complex intrude the Lolworth Igneous Complex. The complex is nonconformably overlain by the Campaspe Beds.

Pyroclastics and tuffaceous sediments (Puv) occur near Betts Creek, southwest of Pentland. Their age is not known, but they are tentatively correlated with the Upper Permian Betts Creek Beds a short distance to the west. They are intruded by a felsite sill and dyke similar to the felsite dykes in the Mundic Igneous Complex. For this reason the Mundic Igneous Complex is regarded provisionally as Upper Permian.

PALAEOZOIC

Adamellite, Leucogranite, and Quartz Diorite (Pzg)

There are two granitic intrusions in the map area whose ages are unknown.

An adamellite intrusion occupies an irregular depression, known as Gypsy Pocket, which is surrounded by hills of quartzite and schist of the Cape River Beds. The intrusion is situated near the head of the Cape River, about 55 km northwest of Pentland, and is about 8 sq km in area.

A subcircular intrusion of coarse leucogranite, 3.5 km in diameter, crops out a few kilometres south of Pentland. It forms low spurs which to the north emerge from alluvium, and to the south merge into the low-lying and gently undulating or flat surface underlain by the Ravenswood Granodiorite Complex and Campaspe Beds.

The Gypsy Pocket intrusion consists chiefly of massive fine to medium-grained light grey adamellite. The rock has a granitic texture, and is composed of oligoclase, microperthite, quartz, biotite, and hornblende. The main body is intruded by hornblende microdiorite and aplite dykes, and an arm of fine-grained quartz diorite trends southwest from the main mass. The quartz diorite is composed of andesine, quartz, hornblende, biotite, epidote, and sphene.

Quartz diorite at Gypsy Pocket appears to truncate a rhyodacite dyke which intrudes the Cape River Beds nearby. In the map area such dykes are a feature of the late Palaeozoic igneous activity, and are apparently unrelated to the large early Palaeozoic batholiths.

The stock near Pentland intrudes gneissic granodiorite of the Ravenswood Granodiorite Complex, and is nonconformably overlain by the Campaspe Beds.

Dykes and Sills

Although many of the dykes and related igneous intrusions have already been described (felsite and dolerite/microdiorite dykes related to the Mundic Igneous Complex, muscovite pegmatite and muscovite-biotite adamellite dykes related to the Lolworth Igneous Complex, biotite pegmatite dykes related to the Ravenswood Granodiorite Complex, and hornblende microdiorite dykes in the Gypsy Pocket stock), numerous dykes of unknown affinities crop out in the map area.

Dykes of tourmaline pegmatite, white adamellite, and tourmaline-muscovite pegmatite intrude the Ravenswood Granodiorite Complex near Gorge Creek. Thin muscovite-biotite-tourmaline pegmatite dykes intrude the Cape River Beds east of Oak Vale homestead (Fig. 14). Microdiorite, pink muscovite-tourmaline pegmatite, and cream dacite(?) dykes intrude the Ravenswood Granodiorite Complex (ODn) south of the Cape River. Altered andesites intrude the Cape River Beds near Black Gin Creek, and the Ravenswood Granodiorite Complex in several places; some of them cut adamellite dykes related to the Lolworth Igneous Complex.

Sills of metamorphosed microgranodiorite and microgranite intrude schists of the Cape River Beds at Mount Davenport, and similar dykes (Fig. 15) intrude the Cape River Beds and Ravenswood Granodiorite Complex north of Ballabay homestead. Some of the latter are intruded by garnet-biotite pegmatite dykes, which in places appear to be related to the granite phase of the Ravenswood Granodiorite Complex.

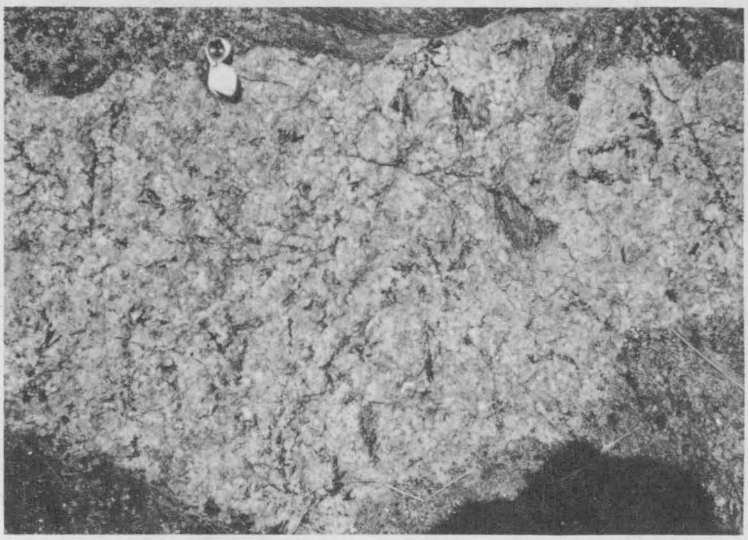

Fig. 14. Tourmaline clusters in muscovite-biotite-tourmaline pegmatite intruding the Cape River Beds, bed of Cape River 3.5 km east of Oak Vale homestead.

Porphyry dykes were reported by Daintree (1868) to be closely related to the gold mineralization at Gorge Creek and Mount Remarkable, but no such dykes were seen during the present survey.

In the Mount Remarkable gold mining area, mainly south of Mount Specimen, Rands (1891, p. 5) observed dykes of quartz felsite, dolerite, gabbro, and graphic granite flanked by coarse tourmaline granite. In the Upper Cape gold mining area he described (1891, p. 8) a dyke consisting of hypersthene (?), quartz, brown mica, and leucoxene; the gold-bearing veins were enriched where in contact with this dyke.

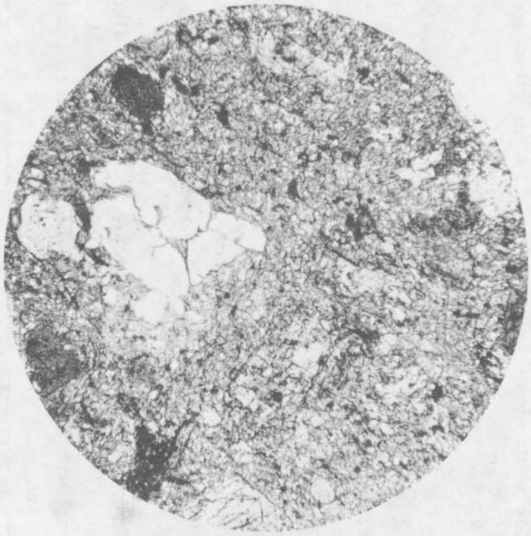

Fig. 15. Metamorphosed microgranodiorite dyke, which intrudes garnetiferous gneiss of the Cape River Beds 4 km north of Ballabay homestead. Phenocrysts of biotite (top left), embayed quartz (centre left), and plagioclase (bottom centre), set in a granular groundmass of quartz, feldspar, biotite, and muscovite. Crossed nicols, X 45. (GSQ T15022).

Dykes of porphyritic hornblende andesite, metasomatized in places, were observed at Lolworth diggings (Fig. 18) by personnel of the Aerial, Geological, and Geophysical Survey of Northern Australia, and their petrography is described in CSIRO Mineragraphic Report No. 211 (CSIRO, 1941b, unpubl.).

CAINOZOIC

The Cainozoic stratigraphy is summarized in Table 4.

Campaspe Beds and Ferricrete (Tf)

The Campaspe Beds (Wyatt et al., 1970, 1971) extend into the eastern part of the map area. They include most of the auriferous sediments of the Pentland district which were referred to as 'older alluvium' by Rands (1891), and cover much of the area mapped as 'Pliocene Tertiary boulder drift' by Daintree (1868). The beds were derived from the granite of the Lolworth Range. They are probably Pliocene in age.

The Campaspe Beds underlie most of the plains in the southeast; remnants have also been preserved among the foothills of the Lolworth Range. The beds have been extensively dissected; they generally crop out in small scarps bordering streams in the plains, and underlie the flat interfluves. At the foot of the Lolworth Range, hills of granite emerge from the interfluvial areas. Many outcrops occur at various levels on the Lolworth Range, but only a few are large enough to be shown at the 1:250,000 scale.

Lithology

The Campaspe Beds comprise argillaceous gritty sandstone, conglomerate, and minor siltstone. Conglomerate predominates near the Lolworth Range, and fine to medium-grained sandstone and local siltstone elsewhere. Quartz and feldspar are the chief constituents, but muscovite is commonly abundant, and grains of garnet are present in places. The beds are generally poorly sorted and bedded. Rare cross-bedded lenses occur. In interfluvial areas the sediments are usually covered by a veneer of residual sand and soil.

TABLE 4. CAINOZOIC STRATIGRAPHY

Age	Rock Unit	Lithology	Topography	Remarks
QUATERNARY	Qa	Sand, silt, gravel	Flat	Alluvial. Superficial. Possibly up to 15 m thick in places. Gold; groundwater
	Q	Undifferentiated colluvial and residual black soil, sandy soil, sand, rare gravel	Flat	Superficial. Colluvial and residual. Black soil derived from underlying basalt. Thickness unknown, but small
	Toomba Basalt Qt	Vesicular olivine basalt	Regionally flat, in detail very rough	Terrestrial; probably one flow only. Possibly up to 30 m thick near vent. Overlies Czn. No soil. Original surface preserved. Lava tunnels
PLIOCENE TO PLEISTOCENE	Czb	Olivine basalt, scoriaceous and weathered in places	Conical hills (Mts Courtney, Hackett, and Black); small mesa on Great Dividing Ra	Mainly vents. Probably same age as Czn. Intrude or overlie Czn and older rock units
	Nulla Basalt Czn	Olivine basalt	Plains, transitional to plateau in W	Terrestrial; several flows. Generally probably 7-10 m thick; possibly up to 30 m thick near vents. Overlies Tc and older rock units. Equivalent to Sturgeon Basalt (Vine et al., 1964, unpubl.), Chudleigh Basalt (White, 1965), McBride Basalt (White, 1965)
PLIOCENE	Tf	Nodular to pisolitic ferricrete; ferruginous buckshot gravel	Plains and low mesas	Product of lateritic weathering. Generally less than 1 m thick. Preserved on Tc S of Cape R
	Campaspe Beds Tc	Clayey gritty sandstone, conglomerate, siltstone	Plains and low mesas	Piedmont deposit derived mainly from Lolworth Ra. Up to 15 m thick. Overlies Palaeozoic crystalline rocks; overlain by Czn. Gold in Cape R Deep Lead (Fig. 18). Some groundwater

South of the Cape River the Campaspe Beds are overlain by a horizon of pisolitic to nodular dark brownish red ferricrete, which is usually about 1 m thick. There is generally an abrupt change from the ferricrete to the mottled zone below. Where overlain by ferricrete the Campaspe Beds are stained red, but most of the outcrops north of the Cape River are pale buff or white.

Thickness, Origin, and Relationships

The Campaspe Beds are mainly horizontal, but depositional dips of up to 10^{o} occur in the source areas. The maximum thickness of sediments seen in any one section was 6 m. Although Daintree (1868) recorded a thickness of 18 m a few kilometres west of Pentland, the beds are probably generally less than 15 m thick.

The Campaspe Beds were derived from the Lolworth Igneous Complex, and form a broad piedmont around the foot of the Lolworth Range. The lack of sorting, poorly developed bedding, random orientation of mica flakes, and the persistence of coarse sand and pebbles far from the source area all indicate that the Campaspe Beds were laid down under torrential conditions. An arid climate, with occasional heavy downpours, combined with a sparse cover of vegetation, would provide such conditions.

The Campaspe Beds rest unconformably on the Cape River Beds, Ravenswood Granodiorite Complex, Lolworth Igneous Complex, and Mundic Igneous Complex. In Betts Creek, 10 km southwest of Pentland, they disconformably overlie a laterite surface which is probably equivalent to the laterite in the Charters Towers Sheet area (Miocene or older). North of the Lolworth Range the Campaspe Beds are overlain by the Nulla Basalt of Plio-Pleistocene age. The Campaspe Beds are therefore considered to be Pliocene in age.

Nulla Basalt

Twidale (1956) applied the name Nulla Basalt to the older of the two basalts of the Nulla Basalt Province, which extends over 5000 sq km in the Clarke River and Townsville Sheet areas. In the Hughenden Sheet area the province includes all basalt in the Lolworth Creek drainage basin to the northeast of the Great Dividing Range.

The Nulla Basalt covers 1000 sq km in the north of the map area. I. forms an almost featureless plain which slopes gradually from about 750 m above sea level in the west to less than 450 m in the east. Along part of its southern edge the basalt has been dissected by Lolworth Creek.

No thin sections were made of the basalt in the Hughenden Sheet area. The basalt is blue-grey and contains abundant phenocrysts of yellow-green olivine up to 2 mm across. It weathers dark brown, and where vesicles are present it has a pitted surface. In the Charters Towers and Townsville Sheet areas the lava consists of olivine basalt containing abundant altered olivine phenocrysts in a groundmass of plagioclase and titanaugite.

Local residents have reported that interbedded lenses of sand have been encountered in the basalt. Morton (1932) has reported blocks of diatomite, which were probably derived from a seam sandwiched between the Nulla and Toomba Basalts.

The Nulla Basalt includes a number of separate flows, some of which are vesicular near the top. The presence of more than one flow is indicated by an indistinct stepped appearance on air-photographs. The basalt, where seen at the edge, appears to be up to 6 m thick in places, but the maximum thickness in the map area is probably considerably greater. The low uneven rise with a central crater-like depression 2.5 km east of Leonidas Mill is probably an old vent.

The Nulla Basalt rests unconformably on early Palaeozoic granite and metamorphics, and overlies the Campaspe Beds. Its correlative to the west of the Great Dividing Range, the Sturgeon Basalt (Vine et al., 1963, 1964), unconformably overlies Lower Cretaceous sediments. In the Townsville Sheet area the Nulla Basalt has been confirmed by isotopic dating as Plio-Pleistocene in age (Webb, in Wyatt et al., 1970).

Unnamed Basalt (Czb)

Areas of unnamed basalt, probably of the same age as the Nulla and Sturgeon Basalts, occur at Mount Hackett, Mount Courtney, Black Mount, and in the Great Dividing Range 20 km west of Pentland.

Mount Courtney and Mount Hackett are formed from basalt which has weathered to a rusty brown crumbly material. The hills are strewn with pieces of ropy lava and bombs up to 40 cm long. The bombs have chilled margins and highly vesicular cores. Olivine phenocrysts appear to be absent. The degree of weathering suggests that these basalts are appreciably older than the Toomba Basalt. The hills probably represent scoria cones built up after the extrusion of the Nulla Basalt.

Black Mount is an isolated flat-topped cone (Fig. 16) covered with boulders of slightly vesicular basalt. It too is possibly an old vent, for it is located at the intersection of a fault and a boundary between competent and incompetent rocks of the metamorphic basement. However, neither bombs nor scoriaceous lava occur on its slopes, and Rands' description (1891, p. 9) suggests that it may be an isolated remnant of a flow.

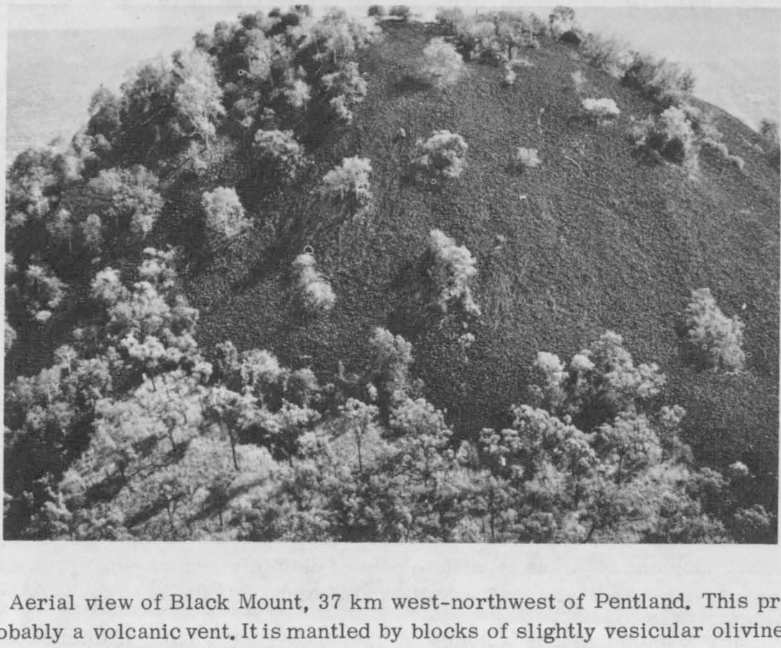

Fig. 16. Aerial view of Black Mount, 37 km west-northwest of Pentland. This prominent hill is probably a volcanic vent. It is mantled by blocks of slightly vesicular olivine basalt. Photograph by R.R. Vine.

An isolated mesa of basalt 1 km across rests on the Cape River Beds 20 km west of Pentland. It resembles the Nulla and Sturgeon Basalts in photo-pattern. A circular outcrop of basalt about 100 m across was mapped by Morton (1937a) on the left bank of the Cape River 3.5 km west of Ballabay homestead. This outcrop is evidently in about the same place as a northeast-striking olivine basalt dyke which was noted by Rands (1891, p. 7) on the north side of the Cape River about 5.5 km below the Upper Cape gold mining area.

Toomba Basalt

The Recent(?) Toomba Basalt (Twidale, 1956; Wyatt et al., 1970) overlies the Nulla Basalt in the northeast of the map area. Together with the similar Kinrara Basalt (White, 1965) in the Einasleigh Sheet area, it represents the youngest volcanic episode in north Queensland.

The Toomba Basalt in the Hughenden Sheet area was not visited during the present survey.

Near Myola homestead, to the east of the Sheet area, it is a porphyritic olivine basalt with almost fresh olivine. The basalt is fine-grained and highly vesicular. It has no soil, and is not weathered, in contrast to the Nulla Basalt.

The boundary of the Toomba Basalt can be readily photo-interpreted from its dense black photo-pattern. Its surface is flat, but there is a domal eruption centre with a lighter photo-pattern near the western end of the basalt. In the east there are several inliers of the Nulla Basalt, the largest of which has an area of 25 sq km. The broken scarp along the edge of the Toomba Basalt averages about 3 to 5 m in height, and is an impassable obstacle to vehicles, being known locally as the 'great basalt wall'. Although regionally horizontal the Toomba Basalt has a highly irregular surface which consists of a chaotic maze of fissures and collapse pits. A collapsed lava tunnel trends in a southwesterly direction for 8 km near Glencoe homestead.

The Toomba Basalt is probably a single flow which was erupted from a vent close to the western edge of the outcrop area. The flow extends to the east-northeast for 90 km. The maximum observed thickness near the edge of the flow is about 5 m, but around the vent it is possibly up to 30 m thick.

The Toomba Basalt appears to be preserved essentially in the state in which it was extruded. Twidale (1956) regarded it as late Pleistocene to Recent in age, and White (1965) mapped it as Recent.

Sediments (Q, Qa)

Areas of colluvial and residual black soil, sandy soil, sand, and rare gravel (Q) occur on the Nulla Basalt around and to the north of Lake Cargoon. The black soil has been derived from the underlying basalt, and the remaining sediments have evidently been derived from the Cape River Beds and Dumbano Granite.

Alluvium occurs extensively in the beds and banks of streams in the low country in the southern and northeastern parts of the area. It is being deposited and reworked at the present day. Some of the gold of the Cape River goldfield was won from Quaternary alluvium.

STRUCTURE

The main rock units and their structure are shown in Figure 17. Apart from the superficial Cainozoic basalt and the Permo-Triassic sediments of the Galilee Basin, the map area has four main structural components, the Cape River Beds, Ravenswood Granodiorite Complex, Lolworth Igneous Complex, and Dumbano Granite. Except for the strong dyke trends associated with the Mundic Igneous Complex, the other rock units in the map area are of limited structural significance.

The major structural feature is the persistent northwesterly trend of the foliation of the Cape River Beds and most of the Ravenswood Granodiorite Complex. Most of the faults trend east-northeast to northeast. The east-northeast faults are largely confined to the Cape River Beds between Morepork Creek and Gypsy Pocket, and are generally sinistral wrench

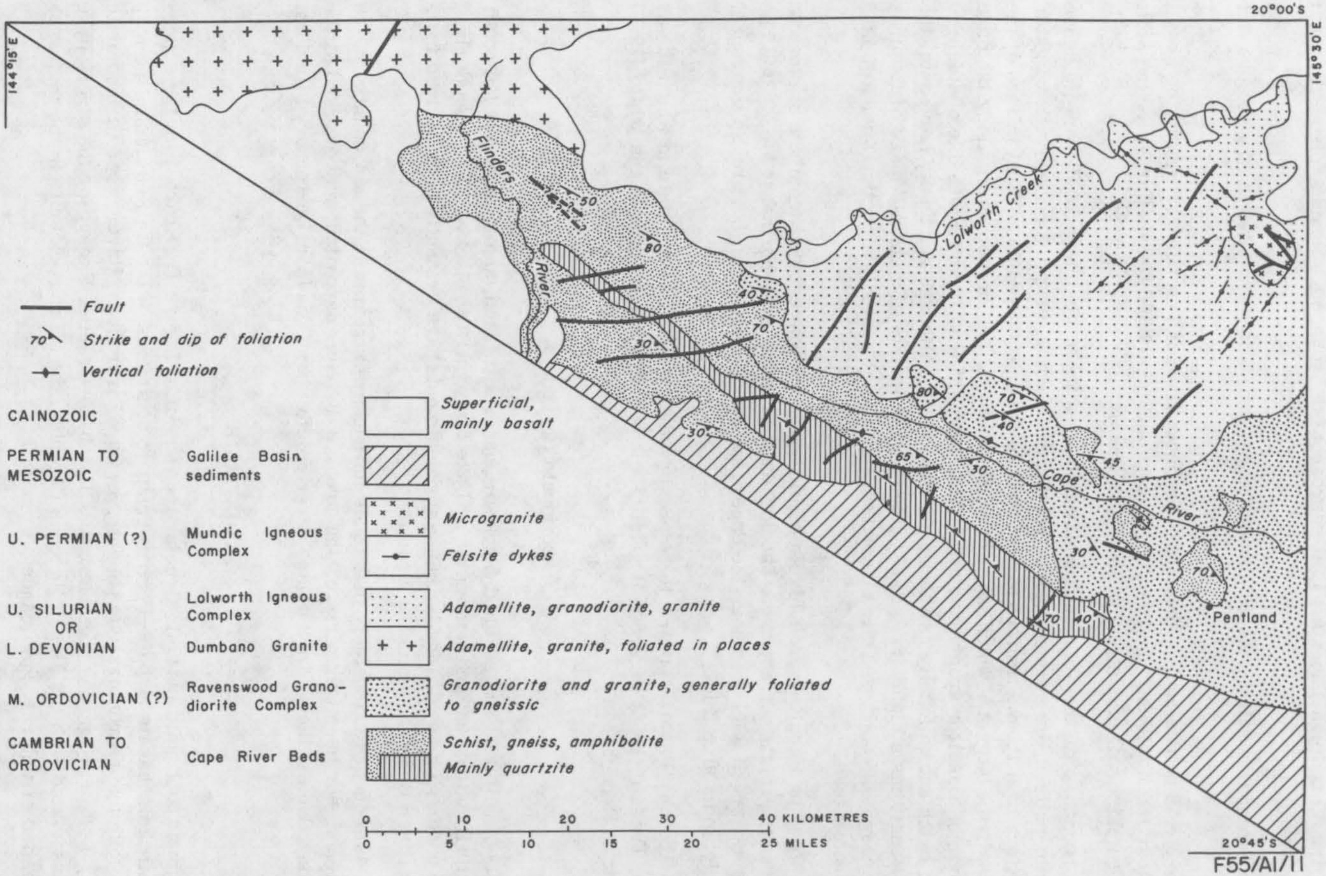

Fig. 17. Structure and major geological units.

faults with displacements of up to 1 km. They probably originated during the period of northeast-southwest compression in which the Cape River Beds were folded. The absence of a complementary set of meridional wrench faults suggests that the compression had an anticlockwise rotational component.

Northeasterly faults are present in the Lolworth Igneous Complex and the quartzites of the Cape River Beds; they are not apparent in the intervening schists. Where they cut the quartzites these faults also seem to be transcurrent, with both sinistral and dextral movements. They were possibly formed as a result of weak senile compression, in the same direction as before, after the Lolworth Igneous Complex was emplaced. Northwesterly fractures were also formed or reopened in Upper Permian (?) time in the eastern part of the Lolworth Range, and were filled by felsite dykes of the Mundic Igneous Complex.

Minor northwesterly faults occur in the Cape River Beds, but their sense of movement is unknown. The felsite dykes of the Mundic Igneous Complex in the northeastern part of the Lolworth Range have a similar trend.

GEOLOGICAL HISTORY

In Upper Cambrian to Ordovician (?) times pelitic, arenaceous, and minor calcareous sediments, and possibly also volcanics (Cape River Beds) were laid down, probably in a trough aligned northwest. The sediments were folded and metamorphosed to the high greenschist and low almandine-amphibolite facies of regional metamorphism. While compression was still active, the metasediments were intruded by a granodiorite batholith, the Ravenswood Granodiorite Complex.

After the major stresses had ceased, both the Cape River Beds and the Ravenswood Granodiorite Complex were intruded by another batholith, the Lolworth Igneous Complex. The Dumbano Granite may include correlatives of both batholiths, but most of it was probably intruded at the same time as the Lolworth Igneous Complex.

There is no record in the area of any further geological events until the Upper Permian, 150 million years later, but to the north and east there is evidence that the northeastern part of the Hughenden Sheet area is part of a stable cratonic zone, the Lolworth-Ravenswood Block, which had formed by Lower Devonian time (Wyatt et al., 1970; Paine, in press). The area underwent major uplift and erosion, and from the Devonian to the Lower Permian it was a source area for sediments which were laid down well outside the map area to the north, south, and east.

In Upper Permian (?) time acid magma invaded the upper levels of the crust. Some reached the surface, and in the northwest and south of the map area, lavas were interbedded with freshwater sediments (Puv). In the northeast much of the magma was emplaced beneath a shallow cover to form the stocks, bosses, and dykes of the Mundic Igneous Complex. Other intrusions (Pzg) were possibly emplaced during this period.

In the map area there follows another long gap in the geological record. In Tertiary time, before or in the Miocene, a thick lateritic weathering profile was developed on an undulating surface of low relief. Probable remnants of the surface are preserved on the Lolworth Range (Fig. 3), and in Betts Creek 10 km west of Pentland. In the Pliocene the laterite was almost entirely eroded away, and the detritus was deposited to form the Campaspe Beds. A suitable climate for the development of a lateritic profile again ensued, but was probably much shorter lived than earlier in the Tertiary. The ferricrete thus produced had begun to be eroded before the extrusion of floods of olivine basalt (Nulla Basalt) over thousands of square kilometres in Plio-Pleistocene times. The youngest basalt (Toomba Basalt) was probably erupted in Recent time.

ECONOMIC GEOLOGY

Of metals, only gold and minor silver have been produced in commercial quantities. The discovery of alluvial and primary gold along the Cape River in 1867 heralded a long period of spasmodic prospecting which resulted in a total recorded production of nearly 55,000 oz (1710.5 kg) of gold. In 1910 gold and minor silver-lead were discovered 18 km east of Mount Emu Plains homestead, and the total recorded production of silver is 4500 oz (140 kg). Base metals occur in small quantities in the gold and silver ores, but apart from a small amount of copper obtained from the Crystal Oak mine (Lolworth field), no commercial production has been recorded.

Groundwater is obtained for stock from shallow bores in the Nulla Basalt, Quaternary alluvium, and Campaspe Beds. In the Capeville district water has been drawn from the alluvium along the Cape River for irrigation of pastures and orchards.

Gold and Silver

The metalliferous deposits in the map area and the publications and reports relating to them are recorded on Figure 18.

The chief gold-producing area was the Cape River Gold and Mineral Field, which included all of the gold deposits in the map area south of the Lolworth Range, and also those at Mount Clearview and Mount Stewart. The field has a total recorded production of 45,000 oz (1399.5 kg). The actual production was considerably greater, because there is no record of the quantity won by the Chinese miners, who were almost as numerous as the Europeans during the productive years of the field, and because the small production in later years was included with that from Charters Towers.

Other producing areas were Lolworth (8363 oz, 260.1 kg, of gold) and Mount Emu Plains (4500 oz, 140 kg, of silver, and 400 oz, 12.4 kg, of gold).

Pentland District (Lower Cape)

The most important single occurrence of gold in the Pentland or 'Lower Cape' district was in the basal conglomerate of the Campaspe Beds, in a strip known as the Cape River Deep Lead. Gold was also won from other deep leads, from quartz veins, and from Recent alluvium. The deposits in Recent alluvium were quickly exhausted. Many of the gullies were extremely rich (Rands, 1891), but the output was not recorded.

The Cape River Deep Lead consisted of auriferous conglomerate, about 30 to 50 cm thick, resting on schist; the overlying finer-grained sediments were virtually barren. The lead began just south of Capeville homestead, where it was shallow, narrow, and rich. To the south it became progressively deeper, wider, and poorer. About 4 km south of Capeville the grade fell off abruptly where a large aplite dyke forms a high bar in the bedrock. South of the bar, only small disconnected areas were rich enough to be mined, and the cost of sinking below a depth of 30 m made further exploration prohibitive. Morton (1937a) traced the lead at the surface for a further 4 km, and concluded that, although rich patches are probably present, they are too small and scattered to repay exploration.

Another gold lead, evidently also in the Campaspe Beds, was worked along Sandy Creek (Chinamans Gully) near Cornelia homestead.

The position of the Sarah Houston (Howson), Mystery, Hayward, Hughes Leader, Just-in-time, and Big lodes is not clear, but they were probably located about 4 km northeast of Pentland. The lodes, which were reported to occur in 'granitoid schist', trend northeast. The Golden Hill and Springs reefs, southwest of Pentland, were other small producers. The hand-sorted ore from the Pentland lodes yielded up to 2 oz (62.2 g) of gold per ton, and the deepest shaft was 30 m deep.

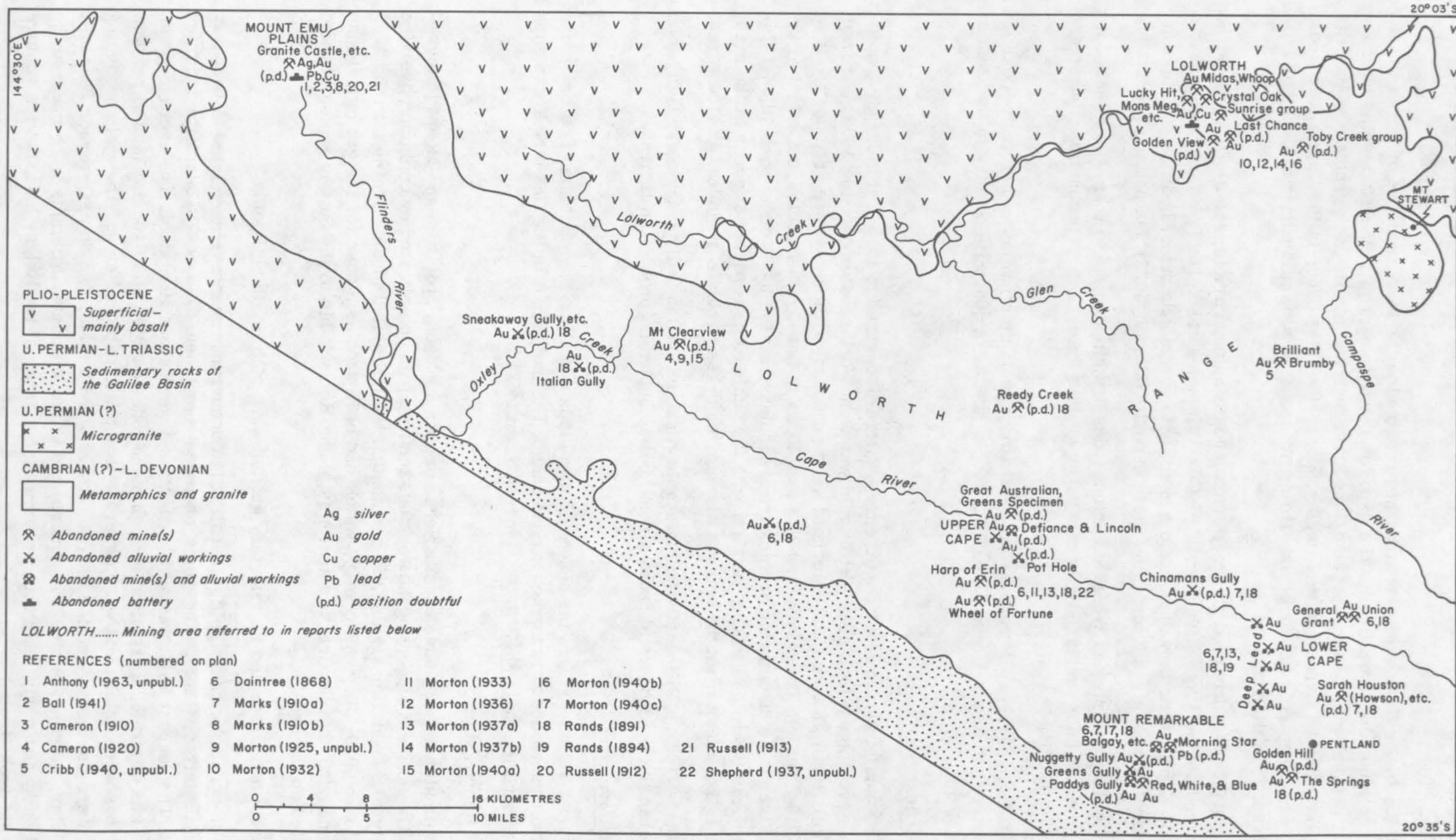

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Fig. 18. Mettaliferous deposits.

Upper Cape

In the Upper Cape area, workings were centred on the lower reaches of Gorge Creek, where it joins the Cape River. The deposits occur in narrow rich quartz veins near the contact between metasediments of the Cape River Beds and biotite-rich gneissic adamellite of the Ravenswood Granodiorite Complex. Most of the lodes occur in the Cape River Beds. Some were reported to originate from, or occur within, acid porphyry dykes or sills (Daintree, 1868; Rands, 1891).

Alluvial gold occurred in small rich leads (Canton, Pothole, and Bluff) along Gorge Creek and in the Cape River north of Oak Vale homestead. The leads carried gold to a depth of 12 m, where they died out in contact with hornblende schist bedrock. At one time consideration was given to dredging these deposits (Morton, 1933), but nothing eventuated.

The Harp of Erin and Wheel of Fortune lodes are situated 3.5 to 5 km southwest of the main group, in mica schist and quartzite cut by granite dykes, but no production figures are available (Rands, 1891).

Rands (1891, p. 9) reports on gold workings in small veins and alluvium near the headwaters of Reedy Creek (Fig. 18), and in gullies in quartzite country to the west of Black Mount.

Mount Clearview

The auriferous lodes at Mount Clearview were discovered in 1915, but although considerable development took place, little gold was won. Work recommenced in 1933, and from then until 1938, 1700 oz (52.9 kg) of gold were produced, with an average grade of about 14 dwt (21.8 g) per ton. The gold occurred in four lodes in fine-grained gneiss and schist of the Cape River Beds. The metamorphics trend northeast, but the lodes occupy meridional fissures. Granitic dykes striking parallel with the schists are reported to occur in the area, but it is not clear from the reports whether the dykes postdate the lodes, or vice versa.

Rands (1891, p. 9) describes alluvial gold workings (Italian Gully, Sneakaway Gully, and others) in the headwaters of Oxley Creek, but he quoted no production figures.

Mount Davenport

Mount Davenport was the centre of some lode and alluvial production. The Union and General Grant lodes were worked in mica schist. The main shaft in the Union reef was sunk to 55 m, and the main shaft in the General Grant to 34 m.

Mount Remarkable

Both alluvial and lode deposits were worked near Mount Specimen and Mount Remarkable. The problem of locating the workings accurately is complicated by confusion over the identity of Mount Remarkable. It seems that the hill called Mount Specimen on the 1959 RASC 1:250,000 topographic map, which has been used as a base for the geological map accompanying this Report, was known as Mount Remarkable to the Survey geologists who reported on the area.

Specimen Creek and its tributary gullies were rich in alluvial gold.

The erratic primary gold mineralization occurred in quartz veins related to porphyry dykes (Daintree, 1868). The veins occupied meridional fissures in quartzite and mica schist. The deepest shaft was 49.5 m, but most were about 10 m deep. The average grade of ore was 40 dwt (62.2 g) per ton, though some lodes carried up to 400 dwt (622 g) per ton. Crushings were small, and were generally composed of picked stone. The main producing lodes were the Balgay and the Barcoo; others were the Morning Star, Governor Blackall, Lone Star, Martins, Albions, Mariners, and Commissioners. Attempts were made in the late 1930's and early 1940's to recommence mining of the Balgay lode, but the venture failed (Morton, 1940c).

At least some of the gold in the Mount Remarkable district appears to have occurred in quartz veinlets in the Upper Permian(?) volcanics (Puv) southwest of Golden Mount (Rands, 1891, p. 6).

Two quartz veins containing considerable amounts of silver-poor galena and cerussite were reported by Rands (1891, pp. 5-6) on the northern side of Specimen Creek. The veins occur in mica schist; a gabbro dyke crops out nearby.

Mount Emu Plains

The Mount Emu Plains area was worked from 1910 to 1915 and from 1939 to 1942. The mines are in the Dumbano Granite near its contact with the Cape River Beds. The granite here commonly contains muscovite instead of the more typical biotite. The orebodies consist of quartz veins or greisen with quartz lenses; extraction of the gold was hampered by the content of galena, pyrite, arsenopyrite, and sphalerite. The most important lode is the Granite Castle, which has been explored for about 400 m on the surface. It consists of greisen and lenses of quartz in a well marked fissure which trends east and dips steeply to the north. It ranges up to 1.5 m in width. The quartz veins, which average about 25 cm wide, contain most of the gold. The lode has been worked to a depth of 30 m in the Granite Castle and 27 m in the Granite Castle West. Recoveries from hand-picked shipments were over 20 dwt (31.1 g) of gold per ton, 20 oz (622 g) of silver per ton, 8 percent lead, and nearly 1 percent copper (Ball, 1941). Most of the silver was presumably derived from the galena.

A small but rich producer was the Diecan, sunk on a narrow quartz vein showing free gold. The vein was followed to a depth of 18 m (Russell, 1912).

Near the surface some of the lodes were rich in lead, and unsuccessful attempts were made to work them for silver and lead.

Lolworth

Several mines situated between Brandy and Toby Creeks were together known as the Lolworth diggings. Gold was discovered in 1926, and mining effectively ceased in 1953, although attempts are still made from time to time to reopen the mines on a small scale. There was very little alluvial production.

The deposits occur in biotite adamellite of the Lolworth Igneous Complex. The adamellite has been intruded by various dykes which may be related to the Mundic Igneous Complex. The orebodies were probably formed at relatively high temperatures. They consist of small veins, with greisenized aureoles, which contain pyrite, arsenopyrite, chalcopyrite, and sphalerite; greisen pipes containing small amounts of the same sulphides; and pegmatitic quartz veins. Other high-temperature minerals present in small amounts are wolframite, scheelite, molybdenite, bismuth, and tourmaline. Torbernite has also been recorded. The occurrence of gold in bournonite from the 115-foot (35-m) level of the New Venture mine is described in CSIRO Mineragraphic Report No. 211 (CSIRO, 1941b, unpubl.).

The Crystal Oak mine was the site of the original discovery. The deposit consists of a stockwork of gold and copper-bearing quartz veins. A small amount of copper and about 350 oz (10.9 kg) of gold were produced between 1928 and 1939. The grade averaged about 20 dwt (31.1 g) of gold per ton from picked ore. The workings are less than 30 m deep.

The Midas mine was the biggest producer at Lolworth; 3550 oz (110.4 kg) of gold were taken from it between 1934 and 1950. The ore occurs in a pipe of greisenized granite. Besides gold, a little sphalerite and chalcopyrite are present. The main shaft is 40 m deep, and the average grade was 28 dwt (43.5 g) per ton. The mineragraphy of some specimens of ore from the Midas mine is described in CSIRO Mineragraphic Report No. 205 (CSIRO, 1941a, unpubl.).

At the Sunrise and Big Shine mines the ore occurs in small pegmatitic quartz veins occupying fissures in the granite. The Sunrise produced about 800 oz (24.9 kg) and the Big Shine 250 oz (7.8 kg). The ore averaged about 100 dwt (155.5 g) per ton at the Sunrise, and 40 dwt (62.2 g) at the Big Shine.

The Mons Meg lode was discovered in 1934 and was worked until 1953. The orebody is a greisen pipe containing gold and small amounts of galena, sphalerite, and chalcopyrite. The ore averaged 17 dwt (26.4 g) per ton, and was enriched where the orebody intersected a diorite dyke (Mundic Igneous Complex?), which probably acted as a barrier to the ore-bearing fluids. The main shaft is 59 m deep, and the total production was 2700 oz (84 kg).

Mount Stewart Area

No geological work has been done on most of the mines near Mount Stewart, and their locations are not known, but over 60 of them are mentioned in Wardens' and other reports. Most of the lodes on and around Mount Stewart trend north to northeast, and dip to the east, and their average thickness is about 30 cm. The maximum recorded depth of workings is 34 m at the Surprise. The distribution of the gold appears to have been erratic. The total recorded production is 1650 oz (51.3 kg) of gold from 2300 tons of ore.

The Brilliant Brumby mine, which is still being worked from time to time, lies to the west of the main group. It has been described by Cribb (1940, unpubl.). The main lode trends at 350° and is almost vertical; there are several smaller parallel lodes. The average thickness of the veins is about 30 cm and the maximum thickness about 1 m. The outcrop can be traced for 300 m, and surface workings extend for over 200 m; the main workings, which are at the northern end, are about 120 m long and up to 24 m deep. The total recorded production is 790 oz (24.6 kg) from 950 tons of ore.

Mode of Occurrence and Origin

There are several kinds of primary mineralization in the map area: quartz veins associated with porphyry dykes into which they merge in places (Upper Cape and Mt Remarkable); greisen and pegmatitic quartz veins (Lolworth diggings); quartz veins and greisen (Mt Emu Plains); simple quartz veins (Mt Remarkable, Mt Clearview, and Brilliant Brumby); and erratic pods in barren rock (Pentland district).

It is almost certain that more than one period of mineralization is represented in the area. The primary structural control seems to have been fractures trending between north and northeast.

Daintree (1868) emphasized that the mineralization at the Upper Cape and Mount Remarkable mines is often closely associated with acid porphyry dykes (or 'elvans'*), for example near Gorge Creek (Upper Cape district), where the quartz veins appeared to him to be almost 'a continuation to the surface of the elvan veins themselves' (p. 611). Rands (1891, p. 8) describes Greens Specimen reef at the Upper Cape as a kaolinized feldspathic rock resembling quartzite, which is transected by auriferous quartz veinlets. Unfortunately such dykes were not sighted in the Gorge Creek area during the 1963 regional survey, and their affinities and relationships are unknown. However, throughout northeast Queensland they appear to be characteristic of a high level of intrusion, and are commonly associated with epizonal granites. Therefore the acid porphyry dykes at Gorge Creek and Mount Remarkable are unlikely to be related to the Lolworth Igneous Complex, which is not a high-level intrusion, and whose associated dykes have granitic, pegmatitic, and aplitic textures. The difference in association is epitomized by the contrast between the Lolworth Igneous

* The word 'elvan' is used by authors on the geology of Cornwall (for example Stone, 1968) for quartz-feldspar porphyry and felsite dykes which intrude the Cornish granites and surrounding slates.

Complex, on the one hand, and the epizonal subvolcanic Mundic Igneous Complex, on the other, which intrudes it. Clearly it is important that any future study of the gold mineralization in the Cape River district must solve the problem of the identity, age, and relationships of the porphyry dykes.

Morton (1936) reports that the Mons Meg lode at Lolworth diggings appears to postdate a diorite dyke cutting across the granite of the Lolworth Igneous Complex. It is thought that this dyke and the mineralization are more likely to be related to the Mundic Igneous Complex than to the Lolworth Igneous Complex. On the air-photographs a prominent swarm of intermediate to basic dykes of the Mundic Igneous Complex can be seen trending northwest through the mineralized area. Such dykes are nowhere known to be related to the Lolworth Igneous Complex. Dykes of porphyritic hornblende andesite, metasomatized and slightly mineralized in places, are described petrographically in CSIRO Mineragraphic Report No. 211 (CSIRO 1941b, unpubl.). It seems reasonable to relate these dykes to the dyke swarm of the Mundic Igneous Complex that transects the Lolworth diggings.

Nothing is known of the location or geology of the 60 or so separate workings in the Mount Stewart area which are mentioned in Wardens' and other reports, but it is likely that at least some of them are related to the Mundic Igneous Complex, which forms Mount Stewart itself.

Alluvial gold derived directly from coarse disseminations in a porphyry dyke was recorded by Daintree (1868, p. 612) near Mount Remarkable or Mount Specimen (see below). It is possible that this has a genetic connexion with the gold occurring in veins of quartz and felsite in volcanics (Puv) southwest of Golden Mount (Rands, 1891, p. 6).

The most likely source of the mineralization at Mount Emu Plains and Mount Clearview are respectively the Dumbano Granite and the Lolworth Igneous Complex. Although dykes are mentioned in the reports on Mount Clearview, their relationship with the mineralization is not clear.

The source of the gold-bearing veins in the Pentland district and at Mount Davenport is unknown. Rands (1891, p. 2) reports that the Union reef is 'crossed' (presumably cut) by dykes of coarse muscovite(?) granite, which suggests that these reefs may be related to or older than the Lolworth Igneous Complex.

Many creeks, which were often used as reference points in the old reports, such as Sandy Creek, Reedy Creek, and Specimen Creek, are not marked on the RASC topographic map which was used as a base for the geological map. However, in most cases they can be identified by perusing the air-photographs while reading the descriptions in the reports.

In view of the occurrence of coarse waterworn alluvial gold at the base of the Campaspe Beds in the Cape River Deep Lead, and the similar occurrence at Chinamans Gully, the Campaspe Beds should be regarded as a prospective target if any further exploration for gold is carried out in the area.

On geological grounds it seems reasonable to suggest the existence of potentially auriferous deep leads beneath the basalt which all but encircles the Lolworth diggings.

The possibility of fossil gold placers occurring in the sedimentary rocks along the present northeastern edge of the Galilee and Eromanga Basins was first pointed out by Daintree (1868), and should also be considered in the course of further exploration.

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APPENDIX

ISOTOPIC DATING OF THE LOLWORTH IGNEOUS COMPLEX,

HUGHENDEN AND CHARTERS TOWERS SHEET AREAS

by A.W. WEBB*

K/Ar mineral dates on specimens of the Lolworth Igneous Complex from the Hughenden and Charters Towers 1:250,000 Sheet areas are given in Table A. The average age is 395 m.y., identical to that proposed by Bottino & Fullagar (1966) for the Silurian-Devonian boundary (recalculating their data to $\lambda = 1.47 \times 10^{-11} yr^{-1}$ for the ^{87}Rb decay constant). There is no detectable difference between the ages measured on the specimen of the biotite-muscovite phase (GA5590) and those measured on the muscovite-bearing phase (GA5596, GA5285).

TABLE A. K/Ar ANALYSES, LOLWORTH IGNEOUS COMPLEX

ANU No.	Mineral	K (%)	$^{40}Ar^{*}/^{40}K$	^{40}Ar atm	Age+ (m.y.)
GA5590	Biotite	6.254) 6.224) 6.24	0.02547	1.3	392
	Muscovite	8.853) 8.848) 8.85	0.02577	1.2	396
GA5596	Muscovite	8.755) 8.736) 8.75	0.02533	1.5	390
GA5285	Muscovite	8.893) 8.895) 8.89	0.02613	2.3	401

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

* Radiogenic

\+ Individual K/Ar ages are accurate to $\pm$ 3 percent

Rb/Sr whole-rock analyses of these and other specimens from the complex are given in Table B. The regression of those data by the method described by McIntyre, Brooks, Compston, & Turek (1966) gives an age of 401 $\pm$ 7 m.y. for these specimens. The regression also suggests that redistribution of Rb and/or Sr, as well as variations in initial $^{87}Sr/^{86}Sr$, has taken place. The limits of this age are the 95 percent confidence limits of the analytical precision. The value of $\lambda = 1.47 \times 10^{-11} yr^{-1}$ for the decay constant of ^{87}Rb was used in the calculation of the age, and the Sr isotope ratios were normalized to a value of $^{88}Sr/^{86}Sr = 8.3752$. The initial $^{87}Sr/^{86}Sr$ ratio of this suite of samples was 0.7097. This high value suggests that anatexis or partial assimilation of older rocks occurred during the formation of the magma which produced the rocks of the Lolworth Igneous Complex.

* Formerly of the Bureau of Mineral Resources

TABLE B. Rb/Sr WHOLE ROCK ANALYSES, LOLWORTH IGNEOUS COMPLEX

ANU No.	BMR No.	Rock Type	Military Grid Reference E	Military Grid Reference N	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ (calc.)
GA5285	F55/2/10	Garnet-muscovite granite	355600	2473000	229.7	7.8	89.9376	1.2414
GA5590	F55/1/6	Adamellite	296300	2456300	122.4	262.4	1.3482	0.7168
GA5592	F55/1/13	Biotite granite	285800	2461100	94.4	308.4	0.8842	0.7151
GA5595	F55/1/27	Muscovite-biotite granite	327700	2459100	143.4	225.4	1.8402	0.7220
GA5596	F55/1/31	Garnet-muscovite granite	340000	2487500	270.1	68.0	11.5392	0.7762
GA5598	F55/2/9	Garnet-muscovite	356200	2470800	207.6	41.6	14.5513	0.7968

The age of 395 to 400 m.y. is similar to that measured on the younger phase of the Ravenswood Granodiorite Complex (Webb, 1969).

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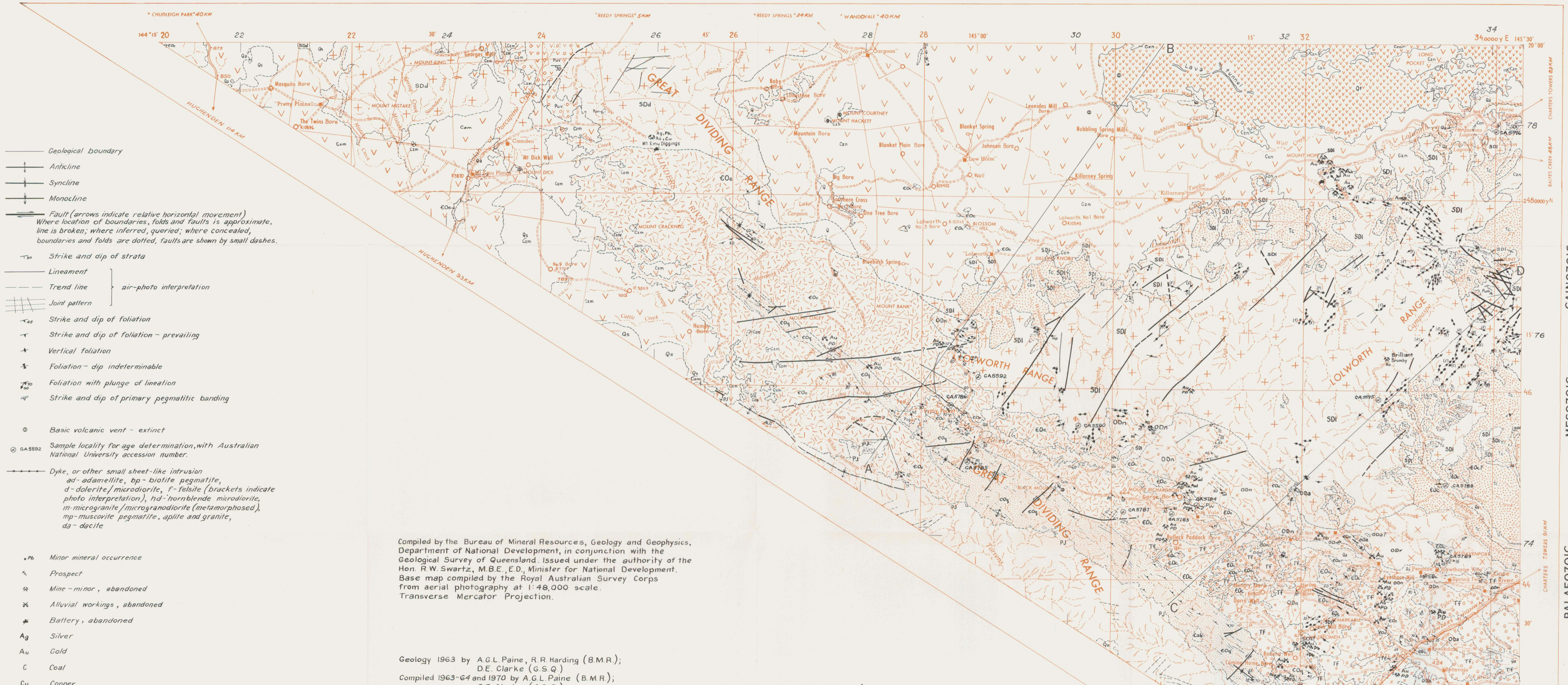
12445/71—L (R70/2182)

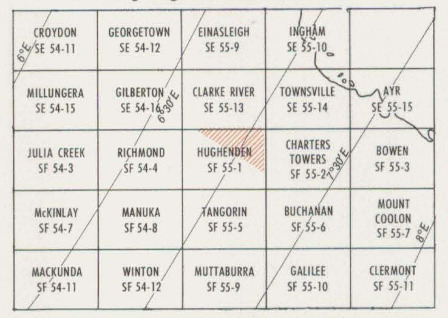


- Geological boundary
- Anticline
- Syncline
- Monocline
- Fault (arrows indicate relative horizontal movement)
  Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by small dashes.
- Strike and dip of strata
- Lineament
- Trend line } air-photo interpretation
- Joint pattern
- Strike and dip of foliation
- Strike and dip of foliation – prevailing
- Vertical foliation
- Foliation – dip indeterminable
- Foliation with plunge of lineation
- Strike and dip of primary pegmatitic banding
- Basic volcanic vent – extinct
- GA5592 Sample locality for age determination, with Australian National University accession number.
- Dyke, or other small sheet-like intrusion
  ad – adamellite, bp – biotite pegmatite,
  d – dolerite/microdiorite, f – felsite (brackets indicate photo interpretation), hd – hornblende microdiorite,
  m – microgranite/microgranodiorite (metamorphosed),
  mp – muscovite pegmatite, aplite and granite,
  da – dacite
- Pb Minor mineral occurrence
- Prospect
- Mine – minor, abandoned
- Alluvial workings, abandoned
- Battery, abandoned
- Ag Silver
- Au Gold
- C Coal
- Cu Copper
- Pb Lead
- R10304 Water bore { Number refers to bore registration number of the Queensland Irrigation and Water Supply Commission records.
- Dam on stream
- Spring
- Waterhole on stream
- Road
- Vehicle track
- Railway with station
- "Elimeek" Homestead
- Building
- Yard
- Fence
- Trigonometrical station
- Astronomical station
- ·263 Elevation in metres – approximate
- PD Position doubtful

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjunction with the Geological Survey of Queensland. Issued under the authority of the Hon. R.W. Swartz, M.B.E., E.D., Minister for National Development.
Base map compiled by the Royal Australian Survey Corps from aerial photography at 1:48,000 scale.
Transverse Mercator Projection.

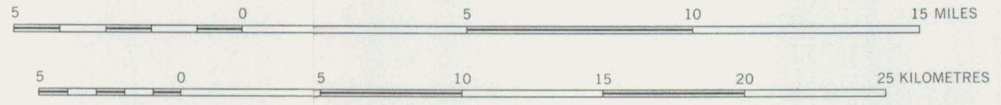
Geology 1963 by A.G.L. Paine, R.R. Harding (B.M.R.); D.E. Clarke (G.S.Q.)
Compiled 1963-64 and 1970 by A.G.L. Paine (B.M.R.); D.E. Clarke (G.S.Q.)
Drawn by I. Chertok, R. Hammill, M. Little

INDEX TO ADJOINING SHEETS
Showing Magnetic Declination 1970



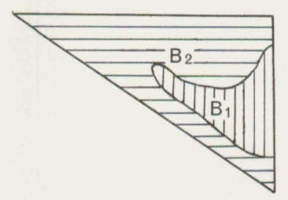
ANNUAL CHANGE 0°57'E

Scale 1:250,000



BROWN NUMBERED LINES ARE THE 20,000 YARD TRANSVERSE MERCATOR GRID, ZONE 7 (AUSTRALIA SERIES)
BLACK NUMBERED TICKS INDICATE THE 20,000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID (ZONE 55)

GEOLOGICAL RELIABILITY DIAGRAM

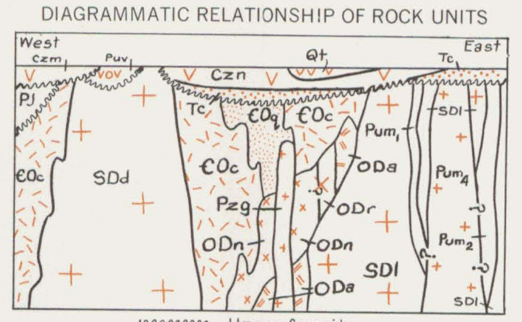


B1 Detailed reconnaissance: numerous traverses and air-photo interpretation
B2 Reconnaissance: traverses and air-photo interpretation

Reference

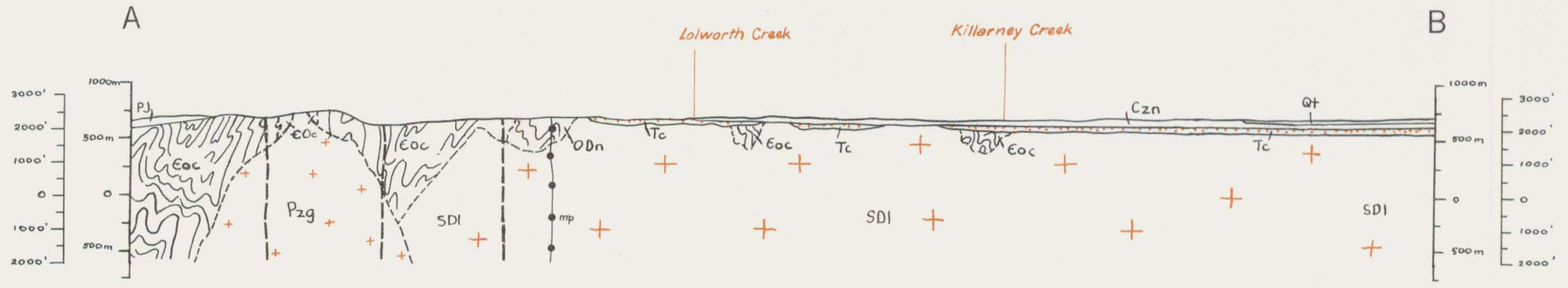
CAINOZOIC	QUATERNARY		Qa	Alluvial sand, silt, gravel
			Q	Undifferentiated colluvial and residual black soil, sandy soil, sand, rare gravel
			Qs	Sand, gravel, rubble, sandy soil
		Toomba Basalt	Qt	Vesicular olivine basalt
	PLIOCENE TO PLEISTOCENE		Czb	Olivine basalt, scoriaceous and weathered in places
		Sturgeon Basalt	Czm	Olivine basalt
		Nulla Basalt	Czn	Olivine basalt
TERTIARY	PLIOCENE	Campaspe Beds	Tf	Nodular to pisolitic ferricrete; ferruginous buckshot gravel
			Tc	Clayey gritty sandstone, conglomerate, siltstone
MESOZOIC	UPPER PERMIAN TO JURASSIC	Sediments of Galilee and Eromanga Basins	PJ	Sandstone, siltstone, mudstone, coal, conglomerate
PALAEOZOIC	UPPER PERMIAN?		Pzg	Leucogranite, adamellite, quartz diorite
		Mundic Igneous Complex	Pum_4	Pink, porphyritic, leucocratic microgranite
			Pum_2	Porphyritic microadamellite ? (air-photo interpretation only)
			Pum_1	Vent breccia
			Puv	Conglomerate, rhyolite, acid pyroclastics, tuffaceous sandstone and siltstone
	UPPER SILURIAN OR LOWER DEVONIAN	Dumbano Granite	SDd	Adamellite, muscovite granite, strongly foliated in places; massive pink garnetiferous muscovite granite
		Lolworth Igneous Complex	SDl	Biotite adamellite and granodiorite; banded pegmatitic and aplitic garnet-muscovite granite and adamellite, minor quartz diorite
	MIDDLE ORDOVICIAN ?	Ravenswood Granodiorite Complex	ODa	Strongly foliated red and pink biotite granite and microgranite
			ODr	Moderately foliated biotite granodiorite
			ODn	Strongly foliated adamellite and granodiorite, grading into orthogneiss, commonly rich in biotite; rare migmatite
	CAMBRIAN TO ORDOVICIAN	Cape River Beds	€Oc	Schist and gneiss, calcareous in places; amphibolite, quartzite, minor granofels, marble, hornfels, metagreywacke
			€Oq	Mainly quartzite; interbeds of schist and amphibolite

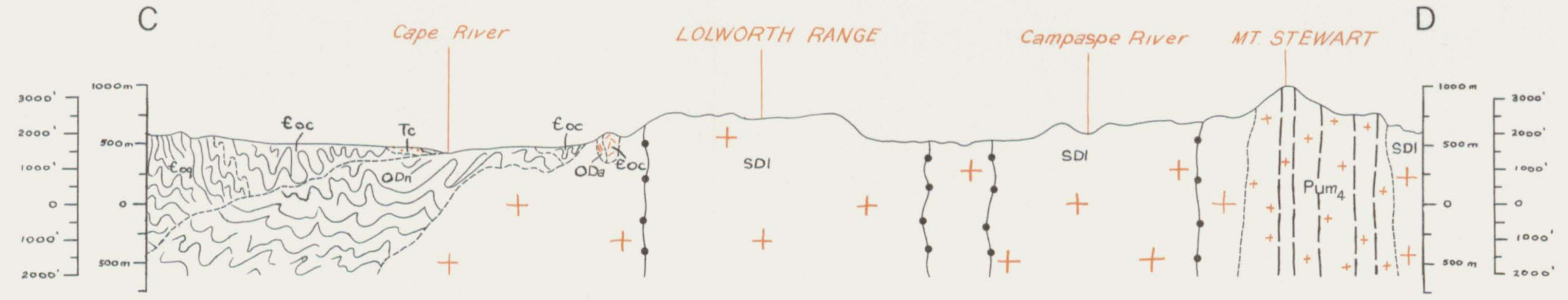
DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



Sections

Thickness of Cainozoic units exaggerated
Folding schematic
Scale V/H ≃ 4





HUGHENDEN
(NORTHEAST PART)

Part Sheet SF 55-1