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BULLETIN 84

GEOLOGY OF THE HODGKINSON AND LAURA BASINS, NORTH QUEENSLAND

by

F. de Keyser and K. G. Lucas



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CORRIGENDA

p. 9, para. 8, last line: for 'scrap' read 'scarp'.

p. 35: The samples in figure 6 are from: 1. 3m. SE of Mt Mulligan township (typical greywacke); 2. & 3. Mt Mulligan Ck; 4. Caledonia Ck, near Southern Cross mine; 5. Northcote track; 6. & 7. Mt Holmes area; 8. & 9. Upper Palmer R.; 10. Spear Ck, Upper Palmer R.; 11. St Georges R./Mitchell R. divide; 12. Mitchell R., just below St Georges R. junction; 13. Big Watson Ck.; 14. 2m. N of Desailley Ra.; 15. W of King Pin Yard; 16. NE of limestone pinnacle on Jestah track; 17. Jestah track, N of Kum Kum Ra. (Mt Garnet Form.); 18. Between O.K. road and Wrotham Pk road (Mt Garnet Form.); 19. Wrotham Pk road (Chillagoe Form.); 20. W. of Koorboora (Mt Garnet Form.).

p. 52, para 3, last line: Add '31'.

p. 64: Heading should read 'Upper Permian Depositional Environment'.

p. 100, para 5, line 3: for 'Avalena' read 'Wolena'.

p. 132, para 6, line 4: Add '147'.

p. 148, last sentence: for 'Such' read 'Sink'.

Plate 7: is printed upside down.

Table 4: Analysis 39 is of 'Puckley Granite', ½m S of old Palmer road crossing of Cooktown-Laura Rlwy. Analyst, AMDL. D55/13/7.

Analysis 40 is of the hornblende microgranodiorite cited as Analysis 39.

The analysis of the dyke cited as '40' is omitted. It should be '41', and is:

SiO_2	76.70
Al_2O_3	12.10
Fe_2O_3	0.19
FeO	1.34
MgO	0.23
CaO	0.90
Na_2O	3.15
K_2O	4.50
H_2O+	0.40
$H_2O—$	0.06
CO_2	0.11
TiO_2	0.19
P_2O_5	0.09
MnO	0.04
Total	100.00

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SUMMARY

This Bulletin presents the results of systematic geological mapping in north Queensland by joint field parties of the Bureau of Mineral Resources and the Geological Survey of Queensland, during the period 1958 to 1963. The area investigated is more than 36,000 square miles, and extends from Princess Charlotte Bay in the north to the township of Ingham in the south, and from 142°30′E, to the shores of the South Pacific Ocean. It is the site of a Palaeozoic geosyncline — the Hodgkinson Basin — and includes part of the western Precambrian borderland, which is separated from the geosyncline by the Palmerville Fault, a large fundamental structure.

The Precambrian borderland consists of metamorphosed and granite-intruded gneiss, schist, and amphibolite. The Palaeozoic geosyncline was probably initiated during the late Silurian, when the Palmerville Fault system developed as a hinge zone east of which the eroded Precambrian surface gradually subsided. The earlier, near-shore, formations — with clastic and mixed clastic-carbonate facies — were deposited in a littoral to neritic unstable shelf environment. They are represented by the Upper Silurian to Lower Devonian Chillagoe and Mount Garnet Formations. When subsidence accelerated, from about the Middle Devonian, the thick turbidite sequence of greywacke and siltstone of the Hodgkinson Formation was deposited. These successive geosynclinal periods of sedimentation were accompanied by volcanic outbursts mainly of basic affinity.

During a major orogeny in the Carboniferous, the geosynclinal deposits were folded and faulted, and in the southeast were regionally metamorphosed to form the Barron River and Barnard Metamorphics.

Gradually the region emerged above sea level; while folding continued the sea contracted to a much smaller area in which the Carboniferous Silver Valley Conglomerate (and possibly also the Montalbion Sandstone and Ringrose Formation) were deposited — formations cleaner, more quartzose, and coarser than the earlier geosynclinal deposits.

The orogeny was accompanied by intrusions of various granites, and by extrusions of (mainly acid) volcanics, mostly in ring complexes and cauldron subsidence areas. This igneous activity probably continued into the Permian and perhaps even the Triassic.

After a period of denudation to about sea level, isolated and shallow basins during the Upper Permian were filled with lacustrine and paralic sediments and intercalated volcanics, to be subsequently broken up into narrow segments by rifting and block-faulting.

The Laura Basin was initiated when this old land surface started to sag in the north, during the Jurassic and continuing into the Cretaceous, and received freshwater quartz sandstone and conglomerate, and later also shallow-marine shale.

During the Cainozoic, the Palaeozoic outcrop area rose higher, and the sediments of the Laura Basin, too, emerged above sea level. The uplift took place in steps and stages, progressively stronger from north to south, and probably most actively during the Plio-Pleistocene. Faulting and basaltic vulcanism accompanied these movements, while the coastal plain obtained its present position by coastal scrap retreat and alluviation.

The Hodgkinson Basin and its adjoining borderland have produced a wide variety of metallic and nonmetallic minerals and materials, including gold, tin, tungsten, molybdenum, copper, lead, silver, fluorspar, coal, and limestone. Gold gave the impetus to the development of north Queensland, not only in mining, but indirectly also in agriculture and the cattle industry. The most active and prosperous mining period extended from the end of the 19th century to the early 'twenties, and the area has been Queensland's greatest producer of tungsten, fluorspar and alluvial gold.

After World War II mining dwindled to negligible proportions, except for alluvial tin dredging in the Mount Garnet area. Favourable market conditions, however, have from time to time led to the temporary re-opening of old workings, and the mid-sixties have been characterized by a strong resurgence of exploration and prospecting activities by a great number of Australian and overseas companies.

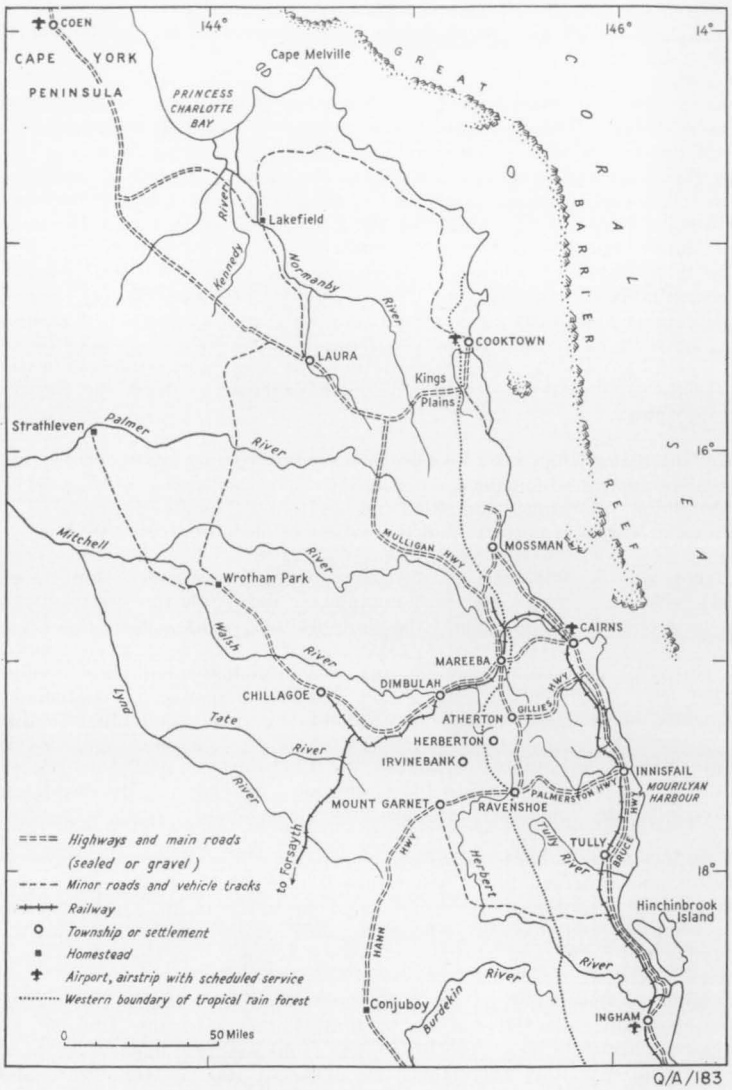


Fig. 1. Communications, main settlements, and streams.

INTRODUCTION

Situation and Access (Fig. 1)

The area investigated — about 36,000 square miles — extends from Princess Charlotte Bay in the north to the township of Ingham in the south, and from longitude 142°30′E. in the west to the shores of the Pacific Ocean in the east. It represents the site of a Palaeozoic geosyncline — here called the Hodgkinson Basin — and adjoining western borderland, and also includes the Mesozoic Laura Basin which was superimposed on the northern section of the Hodgkinson Basin.

The most important and fastest growing city is Cairns, whose population by the end of 1965 was estimated as 28,000. The only other substantial townships are Innisfail (7000), Mareeba (5000), and Ingham (5000).

Since World War II, accessibility to and within the area has been improved and extended by a growing transport system in order to keep up with the increasing agricultural development (sugar, tobacco) and tourist trade. The emphasis has shifted from railroad and sea traffic to air and road transport. The coastal Bruce Highway is now a bitumen road all the way from the Daintree River south to Brisbane, and the three arteries that provide access from the coast to the tablelands have been sealed as far west as Mount Garnet and Dimbulah, and are still being improved. A wide gravel road, the Mulligan Highway, now stretches from Mareeba to Cooktown, and is being extended towards Coen on Cape York Peninsula as a beef road project with Commonwealth Government assistance. However, local inland roads still tend to become impassable during the wet season, so that many cattle stations are isolated for several months each year.

Air transport improved rapidly immediately after the war, and includes services by a small air charter and mail company located in Cairns. An air-ambulance service based on Cairns also transmits telegrams by radio on daily schedules. Most cattle stations have small landing strips able to accommodate the small charter and ambulance planes.

Authorship

Author responsibility for the various chapters and sections is indicated by the initials in the list of contents. In general, de Keyser is responsible for most of the information pertaining to the southern part of the Hodgkinson Basin, and for the compilation of the economic geology, whereas Lucas is responsible for the information on the northern part of the basin, and on the Laura Basin and Mount Garnet district.

Several sections are based partly or almost entirely on the work of others. Thus the structural geology of the Hodgkinson Formation is mainly a result of studies by B. J. Amos (1968); the Permo-Carboniferous igneous rocks have been studied in detail by C. D. Branch (1966) and many petrological data have been obtained from reports by W. R. Morgan.

Field Investigations

The field work was carried out in the period 1958-63 by combined geological parties of the Bureau of Mineral Resources and the Geological Survey of Queens-

land; the results have been set out in various unpublished reports (BMR Record Series), and have been summarized in Explanatory Notes accompanying the coloured 1 : 250,000 geological maps.

The area is represented by six complete 1 : 250,000 Geological Sheets and parts of another four Sheets, all of which are completely covered by air-photographs at scales of 1 : 24,000, 1 : 50,000, and lately 1 : 80,000. The air-photographs were indispensable to the investigation: in the absence of reliable and accurate topographical maps they were the only means of navigation; they served as a base on which to plot the geology, and were invaluable for photo-interpretation of the geology and geomorphology. The final maps were compiled on planimetric bases provided by the Division of National Mapping, and were then reduced to the required scale.

Geochemical sampling was done during the later years, but on a reconnaissance scale only.

The regional mapping schedule was as follows:

1958 — Atherton 1 : 250,000 Sheet (leader: J. G. Best),
Chillagoe district (leader: F. de Keyser).

1959 — Atherton 1 : 250,000 Sheet (J. G. Best).

1960 — Mossman 1 : 250,000 Sheet (F. de Keyser).

1961 — Cooktown 1 : 250,000 Sheet (K. G. Lucas).

1962 — Cairns-Innisfail-Ingham 1 : 250,000 Sheets (F. de Keyser);
Cape Melville and Cooktown 1 : 250,000 Sheets (K. G. Lucas).

1963 — Ingham 1 : 250,000 Sheet (R.S.H. Fardon).

The various Federal and State Government geologists who have contributed to this work are listed on the geological map (Pl. 24).

Physiography

The map area embraces the Western Plain, the Uplands, the Coastal Plain and bounding slope, and the Continental Shelf and Great Barrier Reef (Pl. 25). These units are described more fully on pages 134-147.

The Western Plain becomes progressively flatter and more alluviated to the west, and merges with the floodplain that extends to the Gulf of Carpentaria about 100 miles west. The Palmerville Fault separates this gently west-sloping land from the higher, hilly, densely incised Uplands which constitute the greater part of the map area. They comprise a variety of granite monadnocks; dendritically incised uplands with remnants of several peneplains or pediplains on folded Palaeozoic formations; ruggedly eroded tablelands of late Palaeozoic volcanics and granite; plateaux of late Cainozoic basalt and Mesozoic sandstone; and granitic highlands along the eastern margin of the Uplands, where Mount Bartle Frere and the Bellenden Ker Range are the highest mountains in Queensland.

The Coastal Plain, and its steep bounding slope towards the Uplands, are generally contiguous features all along the coast. In some places, particularly between Cairns and Cooktown, the Upland bounding slope or scarp plunges straight into the sea, but generally the Coastal Plain is from 1 to 10 miles wide; it attains

30 miles in the south, and even more in the Normanby drainage basin south of Princess Charlotte Bay. It is a flat thickly alluviated plain with a sprinkling of monadnocks.

The scarp is commonly not a vertical face, but more a sharp break of slope generally steeper than 35°. The steepest slopes are along the re-entrants of the main river gorges and, farther north, round the tablelands of Mesozoic sandstone. The scarp is generally flanked by talus and piedmont deposits.

The Continental Shelf forms a coastal seaway between the coast and the outer Great Barrier Reef, and widens from 20 miles in the north to 80 miles east of Ingham. Its depth ranges from very shallow near the coast to 20 or 30 fathoms near the outer barrier, and in a few places, where the barrier reef is low or indistinct, as in the south, to as much as 60 fathoms. Beyond the barrier the shelf slopes away steeply to about 1000 fathoms. The inter-barrier seaway is studded with large and small reefs and shoals and with steep, rugged, hard-rock islands, the largest of which are Hinchinbrook Island and Dunk Island.

Climate, Vegetation, and Soils

The climate ranges from humid tropical in the eastern zone between Cooktown and Ingham, to dry seasonal tropical farther inland. The east coast and tableland receive the highest rainfall on the Australian continent, ranging from about 80 inches per annum near Cooktown and Ingham to 179 inches near Tully, at the foot of the Bellenden Ker Range. The coastal belt is covered with dense tropical rain forest, the approximate western limit of which is shown on Figure 1.

Inland, the rainfall decreases sharply to about 30 inches per annum along the western margin of the map area, and the vegetation changes from rain forest to open eucalyptus forest or savannah woodlands, and to open savannah grasslands on the river plains south of Princess Charlotte Bay, on the clayey Blackdown and Wolena Formations, and on some basalt flows in the drier regions.

In the west the rainfall is seasonal, but in the east it is more evenly distributed (Fig. 2) owing to the prevailing southeasterly trade winds. In the extreme northwest the rainfall is monsoonal, and the early rains are accompanied by light northwesterly winds. Most of the rain falls from January to the end of March, when cyclones and hurricanes may bring downpours of 20 inches or more in 24 hours.

Daily mean temperatures range from 55°F (average minimum) to 85°F (average maximum) in July, and from 70°F to 90°F in January.

Most of the dense rain forest has been cleared for agriculture on the coastal plain and the richer parts of the Atherton Tableland.

In many places, the coastal fringes are occupied by mangrove swamps, muddy salt flats, intertidal flats, small estuaries, sand dunes, and beach sand. Mangroves and beach forests (casuarina, calophyllum, and pandanus) are the common type of vegetation, and dense low woody vegetation is found in dune areas.

The poorly drained grey soils and coastal freshwater swamps are usually covered with ti-tree, and the peaks and crests of the mountainous highlands are matted by dense, mossy, low scrub (high-mountain scrub).

The distribution of the various types of soil depends on the climate and composition of the parent rock (Brass, 1953). Leached grey podsolic soils are found over most of the area. Deep loose sandy loam and sand are predominant from Laura northwards, and cover most of the Mesozoic sandstone areas; they become red in the drier regions.

Laterite occurs as gravels and as ferruginous crusts on which the roads and tracks are passable even during the wet season. Deep red loams are common in the humid rain forest, and small tracts of heavy black soil are scattered patchily throughout the map area.

Weathering is deep and intensive in the rain forest. At China Camp, for example, the granite is decomposed down to 210 feet, and at the Koombooloomba Dam site to 130 feet. In the hot humid regions, the rocks weather to red, yellow, and brown clays: basalts are characterized by a deep rich chocolate to purple-brown crumbly soil; the granitic soils are a more vivid red or pink, and are grittier; and the soils on slates and greywackes are usually yellow, brown, or red. In the dry inland areas, weathering is more superficial, soil cover is thinner, and the rocks are generally hardened by surface silicification, rather than decomposed to clay.

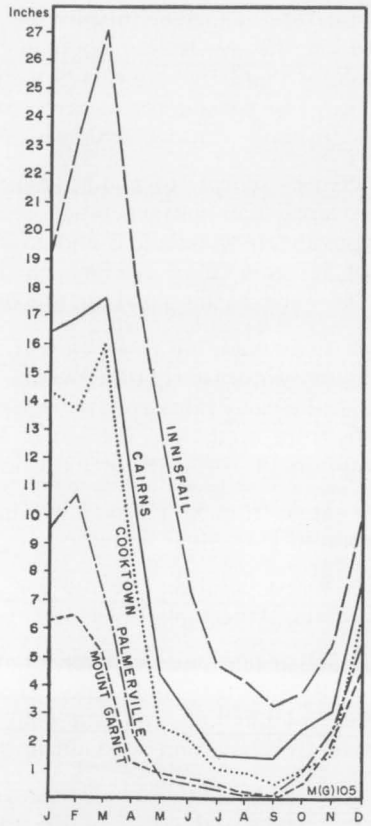


Fig. 2. Rainfall chart.

Cultural and Industrial Geography

The pattern of human activities is closely related to the physiographic units and the climate. Culturally a division can be made between the well developed eastern coastal zone, and the poorly developed inland areas farther west. The general trend at present is one of increasing development and prosperity in the eastern zone (sugar, tobacco), and of a gradual decline in the west, where mining used to be an important industry at the beginning of the century. Subdivisions according to land-use and population density coincide fairly closely with the broad physiographic divisions.

Most of the area is very sparsely populated, but the Atherton Tableland and eastern coastal belt between Cairns and Ingham have a density of 5 to 15 persons per square mile, and are the most northerly area in Australia with a population density of more than 1 per square mile. The total population in the map area is probably about 100,000.

The main industries are primary, and are concentrated in the richer coastal belt — cane growing, mixed farming, and some cattle fattening on the coastal plains, timber-getting in the forests of the coastal scarp, highland, and Atherton Tableland, dairying, pig, and crop raising (maize, peanuts, potatoes) on the Atherton Tableland, and tobacco growing on the poorer soils around Dimbulah and in the Mareeba/Mount Garnet plain. The Tinaroo Falls irrigation scheme on the upper Barron River was constructed largely to develop the tobacco industry to the west and northwest.

Elsewhere, in a few parts of the uplands and on all the western and southern slopes and plains, the raising of beef cattle is virtually the sole industry. Most of the uplands, occupied by the folded Palaeozoic formations, are too rugged for grazing. Most of the cattle properties are poorly developed, particularly in the northwest, and transport and communications are poor.

Mining has decreased gradually, and the only metal still being produced in quantity is tin, mainly from two dredges near Mount Garnet. Small-scale production from elsewhere in the Herberton/Mount Garnet district and from the Annan River Tinfield, south of Cooktown, is dwindling. Limestone for agricultural purposes is quarried south of Almaden, and brick clay is produced at the Clohesy River and at Silkwood.

Sugar milling and refining is an important secondary industry on the coast, and there are a meat works, a brewery, and light service industries around Cairns. A bulk-sugar handling installation has been built recently at Mourilyan Harbour, south of Innisfail. Hydro-electric power stations have been constructed at Tully Falls (Koombooloomba Dam) and at the Barron Falls, at the eastern margin of the Atherton Tableland, and possible sites for other schemes are being investigated.

Previous Investigations and Explorations

Although the northern and western coasts of Cape York Peninsula were among the first parts of Australia to be sighted and reconnoitred by Spanish, Portuguese, and Dutch navigators during the 17th and 18th centuries (Jack, 1921), the first exploration in the map area was carried out by Captain James Cook,

who, in 1770, charted, described, and named sections of the east coast, and made landings at Trinity Bay (Cairns), the mouth of the Endeavour River (Cooktown), Lookout Point, Lizard Island, and a few coral cays farther north.

Between 1815 and 1870, several Royal Navy surveys were conducted along the coast, usually with scientific observers aboard. Captain King in HMS *Mermaid* probably recorded the first geological observation in 1819 when he noted quantities of pumice above the high-tide level on the Palm Island beaches (King, 1827). Geological specimens collected on King's voyages were described by Fitton (App. C *in* King, 1827). Other naturalists were Jukes (1847), who accompanied HMS *Fly* on its voyage, and MacGillvray (1852) and Huxley, who in 1848 sailed on HMS *Rattlesnake*. Rattray (1869) made observations on the physiography of the region, and discussed the relations and ages of the hard-rock axis of the Cape York Peninsula, and the superficial ferruginous duricrust. The last of these nautical naturalists were Coppinger (1883) and Agassiz (1898), the latter being of interest for his views on the origin of the Great Barrier Reef. Jones (1961) relates how Leichhardt, the first of the land explorers, in 1845 skirted the southwestern part of the map area, and reported enthusiastically on the fine pastures he found in the Valley of Lagoons along the upper Burdekin River (in the adjoining Einasleigh Sheet area to the south). His impressions were later confirmed by Gregory in 1856, and when Dalrymple also praised the qualities of the region in an official report in 1860, the land was thrown open to settlement. To provide the new country with shorter communications, Dalrymple searched and found a way to Rockingham Bay, where he established Cardwell as a port in 1864, the first centre of habitation in the map area.

Three years after Leichhardt's expedition, another expedition under the leadership of Kennedy had crossed the area from Rockingham Bay to Princess Charlotte Bay. After a great deal of initial trouble, Kennedy had succeeded in getting access to the jungle-covered Atherton Tableland via the valley of the Tully River, and had then travelled northwest down the Hodgkinson and Mitchell Rivers, north on the easier country west of Mount Mulgrave, and north down the Hann River to the west of Princess Charlotte Bay and along the eastern side of Cape York Peninsula proper, where he was speared to death, together with most of his party.

More successful was Hann's expedition, in 1872. Hann crossed the Tate, Walsh, Mitchell, and Palmer Rivers west of the Palmerville Fault, keeping a respectful distance from the rough greywacke and slate country to the east, which he described as '.....the most dreadful country that anyone could desire to travel over,.....painfully and laborious to get over', and '.....a wretched country of bare slate ridges'. Upon reaching Princess Charlotte Bay, he turned south to the Endeavour and Bloomfield Rivers, but was forced by impenetrable rain forest to turn west and retrace his steps southwards, along the western side of the Palmerville Fault. The results of his expedition (Hann, 1874) were of great importance to north Queensland, for his discovery of traces of gold in the Palmer River sparked off numerous rushes and prospecting expeditions, and led to the opening up and development of the country.

It was during Hann's expedition also that the first geological study was made. Norman Taylor (*in* Hann, 1874), the expedition's geologist, recorded the agate

basalts (Nychum Volcanics) southeast of Mount Mulgrave, and the mica schist country (Dargalong Metamorphics) between the Mitchell and Palmer Rivers. Because of the find of a *Glossopteris* specimen, the sandstone-capped tableland south of the Mitchell River near Mulgrave homestead was named 'Taylor's Carboniferous Range': apparently Taylor did not recognize the unconformity between the fossiliferous formation and the overlying Mesozoic sandstone. Taylor also collected Cretaceous fossils, including Ichthyosaurian vertebrae, from a 'limestone formation similar to that on the Barcoo and Upper Flinders', on the Walsh River. He found coal and *Glossopteris* north of the Palmer River (Little River Coal Measures), and marine Cretaceous fossils later identified as *Ostraea* and *Hinnites* (Jack & Etheridge, 1892) in a conglomerate of the Battle Camp Range, west of Cooktown — a site which later geologists have been unable to locate.

The discovery of gold in the Palmer River and subsequently in the Hodgkinson River aroused widespread interest in north Queensland, and geologists of the Geological Survey of Queensland spent much time there in geological reconnaissance and exploration. Among the first geologists were Jack and Daintree, who were also well known explorers.

In the first geological map of the colony, Daintree (1872) showed only the southern coastal part, which he mapped as mainly granitic in the east and volcanic in the west.

Jack, in many papers written between 1879 and 1907, reported his visits to nearly every mining centre in the map area. His most important papers were on the Palmer, Hodgkinson, and Russell River Goldfields (Jack, 1883-99), the coal deposits of the Cooktown hinterland (1879-95), the tin and other deposits of the Herberton and Chillagoe districts (1881-1907), and the Annan River Tinfield (1891a). He mapped and described the Hodgkinson Formation in its type area, mentioning the discovery of *Lepidodendron australe* and small coralline limestone bodies. Later, he correlated the rocks of the Palmer River Goldfield with those of the Hodgkinson district, and investigated the relations of the Permian coal formations of the Cook district to the surrounding older rocks and the overlying coal-bearing Mesozoic strata.

Tenison Woods (1880b) presented a general description of the geology of north Queensland, attaching the names Normanby Shales to the Permian coal measures at Oaky Creek west of Cooktown, and Dalrymple Sandstones to the flat overlying coal-bearing formation. He also considered that the granite of the Hann Tableland, northwest of Mareeba, was formed by 'altering' of the slates, which were seen to 'pass gradually into schist, gneiss, and finally granite'. The coarse greywacke at Port Douglas he thought to be a volcanic rock. In 1888 Tenison Woods reviewed the status and knowledge of the Desert Sandstone, a term first used by Daintree (1872).

Maitland (1891a,c, 1892) described coal prospects in the Desert Sandstone north and west of Cooktown, reported *Maccoyella* sp. and *Rhynchonella* sp. from northeast of Deighton siding, noted the amount of topographic relief beneath the Desert Sandstone, and described thin sections of some volcanic rocks.

Twenty years after Daintree's partly blank and very generalized map was published, the wealth of new information was embodied in *The geology and*

palaeontology of Queensland and New Guinea (Jack & Etheridge, 1892). The main outcrop areas of igneous rocks and Mesozoic sediments (Desert Sandstone and Rolling Downs Formation) were fairly accurately sketched on the map. Taylor's error in the interpretation of his *Glossopteris* find in 'Taylor's Carboniferous Range' was still not corrected, so that there was some confusion in Jack & Etheridge's work (pp. 176, 519, 520, 528). The pre-Permian sediments were all included in the Permo-Carboniferous Gympie Formation despite the identification of Devonian corals from limestone lenses in the Hodgkinson Goldfield. Knowledge of the Mesozoic sediments of the Laura Basin was reviewed, but the basin was not recognized as such.

Between 1880 and 1920, numerous reports were prepared on the mining areas by officers of the Geological Survey (Ball, Cameron, Dunstan, Gibb, Jack, Jackson, Jensen, Maitland, Marks, Rands, Russell, Saint-Smith, Skertchly, Stirling, Warde, and others). The Chillagoe, Herberton, Wolfram Camp, and Hodgkinson Goldfield areas continued to receive attention after 1920. A few new small centres sprang up in the 'twenties and 'thirties, and there was a revival of mining and prospecting after 1945 (Broadhurst, Connah, Cribb, Denmead, Fleischman, Levingston, Morton, Reid, Ridgway). Some of the mining reports were accompanied by geological maps and descriptions of the surrounding districts (Ringrose, Skertchly, Stirling, Ball, and Saint-Smith).

Since the first investigations by early explorers of the Great Barrier Reef — Jukes in 1847 and Agassiz in 1898 — the origin of the continental shelf, coastal plain and corridors, scarps, ranges, and plateau of north Queensland, and their relationships, have been discussed in many geomorphological papers, by Andrews (1910), Bryan (1928a), David (1911), Davis (1917), Hedley (1925a,b), Jensen (1911), Marks (1924), Poole (1909), Süssmilch (1938), Griffith Taylor (1911), and Whitehouse (1940, 1951). All, except Agassiz (and with the abstention of Marks), agreed that the features were due to late-Tertiary vertical movements. Most thought that differential faulting had been the main factor, but others sought the solution in warping (Davis, 1917; King, 1962). Bryan (1925) allowed the possibility of faulting, though he believed that most of the landforms of east Queensland can be ascribed to differential erosion.

In 1923, another comprehensive study of the geology of the region was published by Jensen. His work was a great improvement on the outdated volume by Jack & Etheridge, though naturally some of Jensen's maps and conclusions have since been revised. He correctly correlated the rocks around Cairns with those of the Hodgkinson/Palmer River belt, a point of view that was later obscured and replaced by the theory that the low-grade metamorphic coastal rocks were older than the Hodgkinson sediments, and had formed tectonic land during the Palaeozoic geosynclinal sedimentation (Hill, 1951; White, 1961). Jensen's original idea was taken up again by de Keyser (1965).

Bryan touched on aspects of physiography, palaeogeography, and earth movements in north Queensland, in a series of papers published between 1925 and 1930. Reid (1930) discussed the Palaeozoic stratigraphy and concluded that the Hodgkinson Formation is Upper Devonian (possibly Middle Devonian to Lower Carboniferous, as his Star Series); he reviewed the relations between the various

formations, and found that little was certain except that the Silver Valley beds unconformably overlie the Chillagoe Formation.

In 1930, Whitehouse named the sediments in the Barron River gorge, northwest of Cairns, the Barron River Series; these were later greatly extended along the coast and shown on the Geological Map of Queensland (1953) as the Barron River Metamorphics. They were regarded as the oldest Palaeozoic sediments in the area (White, 1961), and even by some as possibly Precambrian (Hill, 1951), but recently de Keyser (1965) has suggested that they are mainly the low-grade metamorphic equivalents of the Hodgkinson Formation.

In 1931, David compiled a geological map of Australia, and explanatory notes were published the next year. The later edition of his map (1950) showed little change, but the accompanying text gave accurate accounts of the age and relationships of the fossiliferous strata in the region. The Geological Map of Queensland (1953) contained certain corrections in the Mesozoic and Permian stratigraphy, and included the Barron River Metamorphics.

From time to time, papers were published on certain aspects of the geology of the continent, which also referred to the north Queensland region, e.g. by David (1911), and Hills (1955, fig. 4).

The first systematic attempt to elucidate the regional geology of north Queensland was undertaken between 1937 and 1942 as part of the Aerial, Geological and Geophysical Survey of Northern Australia (AGGSNA); Jensen and Clappison were the principal writers on the Hodgkinson Basin. Air-photographs were used for the first time, but were generally limited to known mineralized areas. Jensen's detailed AGGSNA Reports (1939-41) remained unpublished owing to the advent of World War II, but much of the information contained in them, though to a large extent outdated, was included in a paper on the geology and physiography of Cape York (Jensen, 1964).

In 1946, the high-grade metamorphic rocks along parts of the southern coast and on some of the islands were grouped as the Coastal Series (Bryan & Jones, 1946), and were later renamed Barnard Metamorphics (Jones & Jones, 1956). They were regarded as Precambrian, possibly Archaean, until 1965, when de Keyser suggested that they might be the higher-grade metamorphic equivalents of the Palaeozoic geosynclinal deposits of the Hodgkinson Basin.

The Great Barrier Reef attracted early interest (Agassiz, 1898; Davis, 1917; Hedley & Taylor, 1907; and others). From the 'twenties onwards the Great Barrier Reef Committee published many descriptions of the coastal and offshore deposits and morphology. A bore was sunk about 600 feet on Michaelmas Cay, northeast of Cairns, and penetrated several hundred feet of Holocene coralline limestone above Pleistocene(?) detrital sediments (Richards & Hill, 1942). Fairbridge (1950) has contributed the most detailed and comprehensive study of the reef and the continental shelf, and Hill (*in* Hill & Denmead, 1960, pp. 412-13) has written the most recent review.

Since World War II, there have been many unpublished reports by geologists of mining companies (Broadhurst, Clark, Dixon, Knight, O'Mara, Mott, Sturmfels, Swindon, and others). Mineragraphic reports on ores and drill cores from several

mining districts in the southern part of the map area have been issued by the CSIRO (e.g. Edwards, 1950-58, and Stillwell, 1936-50). Local detailed geological investigations have been made in connexion with the development of hydroelectric power schemes and irrigation projects (see, e.g., Calvert, 1959; Carter, 1959; Dunlop, 1956; Gipps & Britton, 1960; Gloe, 1950; Wolff, 1962).

In 1956 systematic regional geological mapping in north Queensland was initiated by joint field parties of the Bureau of Mineral Resources and the Geological Survey of Queensland. After the mapping of the Gilberton, Clarke River, and Einasleigh 1 : 250,000 Sheet areas to the southwest, the Hodgkinson Basin was mapped during the period 1958 to 1963. The results of the survey of the Hodgkinson Basin were incorporated in a series of unpublished reports by Best, de Keyser, Lucas, Fardon, and White, and in the published explanatory notes on the individual 1 : 250,000 Sheets. White (1961) has summarized the geological knowledge of the Cairns hinterland up to 1960. The petrological work was done mainly by Morgan (1961-65), and the fossils have been described by Mary White (1959-61, unpubl.), Woods (1961-63, unpubl.), and Dorothy Hill (unpubl. notes). Amos (1968) elucidated the complex structure of the geosynclinal formations. Other regional studies include the investigation of the late Palaeozoic acid igneous rocks in north Queensland by Branch (1962, 1963, 1965), and isotopic dating in the Geochronology Laboratory of the Australian National University (Richards, White, Branch & Webb, 1966). The important mining districts of Chillagoe and Herberton have been described in detail by de Keyser & Wolff (1964) and Blake (1968, unpubl.). The Bureau of Mineral Resources has also carried out gravity surveys of the Great Barrier Reef and the adjacent coast (Dooley, 1964), and local geophysical surveys in certain mineral fields (Langron, 1957, unpubl.; Horvath, 1959, unpubl.; Hussin, 1964, unpubl.).

PRECAMBRIAN

The Precambrian basement and source rocks of the sediments in the northern part of the Tasman Geosyncline formed a vast landmass along the western shores of the geosyncline. Various parts of the massif are known as the Georgetown Inlier (White, 1961) or Georgetown Massif (Hill, 1951), Carpentaria Block (Andrews, 1937), and Northern Massif (Bryan, 1932). The massif is composed of several metamorphic rock units which have been briefly described by White (1961, 1965). The units in the map area (Pl. 24) include the Dargalong Metamorphics and the McDevitt Metamorphics, both of which are intruded by Precambrian basic dykes, granite, and a little serpentinite, and by late Palaeozoic igneous rocks.

Dargalong Metamorphics

Derivation of name: the abandoned mining camp of Dargalong, longitude 144°26′E., latitude 17°14′S.

Type area: the metamorphic terrain around Muldiva Creek and its tributaries, between Dargalong and the Walsh River.

The name Dargalong Beds was introduced by Skertchly (1899) to describe '. . . a series of highly metamorphosed rocks, chiefly mica and hornblende schist and gneiss.' Whitehouse (1930) used the term Dargalong Gneiss, and de Keyser & Wolff (1960) chose the name Dargalong Metamorphics because of the hetero-

geneous composition of the various members. Jensen (1923) included the rocks in his Etheridge (or Etheridgean) Series. Similar, and probably equivalent, metamorphic rocks in the Palmerville area, which were grouped in the Frome Series by Jensen in 1940, are here included with the Dargalong Metamorphics. The Dargalong Metamorphics crop out west of the Palmerville Fault, which separates them from the Palaeozoic sedimentary formations. They have been mapped in the Cooktown and Atherton Sheet areas, but their distribution farther north, in the Ebagoola and Hann River Sheet areas, has been mainly photo-interpreted. The lithological descriptions of the northern areas are based on the work of Ball (1901), Cameron (1907), and C. W. Ball (1943). In the south the Dargalong Metamorphics are bounded by the McDevitt Metamorphics and Palaeozoic igneous complexes.

The main rock types have been described by Ball (1917b), and more recently by de Keyser & Wolff (1964). Quartzite, quartz-mica schist, gneiss, augen-gneiss, granulite*, muscovite pegmatite, migmatite, muscovite granite, and amphibolite are the types of rock normally exposed. The various rock types (amphibolite excepted) grade into each other, as observed by Ball (1901a). Some of the granulite and gneiss strongly resemble the muscovite granite, which was probably formed by granitization: its contacts are ill defined and gradational. The largest outcrop of muscovite granite is at Dargalong, where the boundary is fairly well defined on the air-photographs. The biotite granites from the Ebagoola region farther north (Ball, 1901a) are probably much younger and may belong to the late Palaeozoic intrusive period.

Where the metamorphics are strongly interlayered and veined with quartzo-feldspathic material, either by injection or by metamorphic differentiation, the term migmatite has been employed. Augen gneiss is common in such areas (Pl. 1, Fig. 2); it contains large augen of untwinned potash feldspar, 1 to 3 inches across, set in a micaceous quartz-plagioclase groundmass. Some quartzo-feldspathic veins are rimmed by a thin border of biotite.

Coarse pegmatites are abundant where granitic and granulitic rocks predominate. The pegmatite veins are generally parallel to the foliation of the host rocks, but cross-cutting relationships are fairly common. Books of muscovite up to a foot across are known from the Mount Kitchin mica prospects, about 32 miles west of Chillagoe.

The quartzites are generally slabby and thoroughly recrystallized white to grey or, more rarely, dark grey rocks. Ripple marks are preserved in a few places, and possible traces of cross-bedding have been noted. Ball (1901a) has recorded graphitic quartzite in the Ebagoola area.

The mica schist is a silvery grey commonly plicated rock. The amplitude of the minor folds ranges from a few millimetres to several feet. Muscovite is generally more common than biotite, though biotite-rich rocks poor in muscovite are locally abundant. Garnet and sillimanite schists have been reported from around Ebagoola (Ball, 1901a).

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* The term granulite as used here refers to non-foliated metamorphic rocks composed predominantly of equidimensional mineral grains and formed by metamorphism.

The mica schist grades into gneiss with a decrease in the proportion of mica and an increase in grainsize. These schists and gneisses are evidently metamorphosed sediments. Some of the gneiss is orthogneiss, as for example at Fox Creek near Palmerville, where the gneiss contains inclusions of amphibolite which have been partly digested or granitized around the borders (Pl. 1, Fig. 1).

The amphibolites in the Dargalong Metamorphics are sharply defined bodies which occur as uniform sheets in the schist and gneiss, or as irregular masses. They do not grade into the other rock types, and most of them were probably of basic igneous origin. A few of the amphibolites which contain appreciable amounts of quartz and impure armoured calcite relics may have been derived from calcareous sediments.

A recrystallized limestone with sandy impurities was found about 10 miles south of Palmerville. The rock is highly deformed, and the origin of the carbonate is uncertain.

Although the depositional environment of the Dargalong Metamorphics can no longer be recognized with certainty, the limited extent of some of the quartzite beds, and their apparently rather quartz-rich composition (in places leaning towards that of an arkose), may suggest a shallow-water environment.

Mineralogical Composition, Metasomatism, and Metamorphism

The gneiss and schist are composed of quartz, potash feldspar, plagioclase (oligoclase to calcic andesine), biotite, muscovite, and minor amounts of garnet, zircon, tourmaline, epidote, apatite, and iron oxides; sillimanite is known from the Ebagoola area. The muscovite granite, granulite, and gneiss differ only in structure and texture. The amphibolite is composed mainly of andesine and fawn-brown to green-brown hornblende, with some quartz and a little muscovite, sphene, iron oxide, and apatite. Many of the amphibolite bodies are garnetiferous.

In many of the rocks, the feldspars are altered to sericite and saussurite, and the red-brown biotite to pale green chlorite. In places the feldspars are so altered that their composition cannot be determined, and the biotite has been almost completely replaced by pale green chlorite. Other alteration products observed include carbonate minerals and hydrated iron oxide.

The degree of metamorphism seems to change gradually from place to place. The high-grade zones are characterized by their coarse grainsize, gneissose textures, and association with migmatites; the hornblende in the amphibolite is usually greenish brown rather than green and the plagioclase is a calcic andesine. These two features suggest that the grade of metamorphism is high in the almandine-amphibolite facies. The lower grade rocks are finer-grained, more schistose, and are not associated with migmatites; their metamorphic facies is uncertain. The few thin sections cut contain quartz, oligoclase, muscovite, and biotite (usually chloritized). Albite has been reported by Jensen (1941), but none was found in the thin sections examined.

In the augen gneiss, the augen are of metasomatic origin. They consist of untwinned potash feldspar up to $1\frac{1}{2}$ inches across, enclosing irregular, ragged, and corroded remnants and shreds of muscovite, chloritized biotite, and quartz, which are considered to be relics of the original mineral assemblage. Metasomatism may also have been important in the formation of the muscovite granites: they grade into gneiss and granulite, and the plagioclase has been partly replaced by potash feldspar and quartz.

The Dargalong Metamorphics have been subjected to postmetamorphic stresses: the quartz is granulated and shows strain shadows, and the muscovite and biotite flakes are bent and warped: these effects are probably related to the Carboniferous orogeny which folded the sediments in the Tasman Geosyncline. The chloritization of the biotite and intense alteration of the feldspar are the result of retrogressive metamorphism, probably also arising from the Carboniferous orogeny.

Age of the Dargalong Metamorphics

Jack (1891) considered the Dargalong Metamorphics to be the metamorphosed counterparts of the sediments in the Chillagoe, Palmer River, Hodgkinson, and Montalbion districts, which he lumped together in the Carboniferous. Skertchly (1899) regarded them as older than his Devonian Herberton Beds (see p.32), and placed them in the Silurian. Jensen (1923) called them pre-Silurian, and later workers considered them to be Precambrian (Whitehouse, 1930) or even Archaean (AGGSNA, 1940; White, 1961, 1964), because of the high degree of metamorphism. The occurrence of pebbles of high-grade gneiss and amphibolite in the unmetamorphosed Silurian conglomerate of the Chillagoe Formation indicates that the metamorphic rocks are pre-Silurian and probably much older.

The age of the muscovite granite about 7 miles southwest of Chillagoe has been determined as 1044 m.y. by the K/Ar method (Richards, White, Branch & Webb, 1968). It is assumed that the granite is metasomatic-metamorphic in origin and that this is roughly the age of the metamorphism.

Postmetamorphic Intrusions

The Dargalong Metamorphics are intruded by acid and basic dykes, dyke swarms, stocks, and batholiths. Most of the stocks are adamellites and granodiorites resembling the Permo-Carboniferous granitoid rocks farther east. They include muscovite-biotite granite, grey biotite granite, coarse pink biotite granite, and dark green hornblende diorite; hypersthene-bearing diorite and quartz diorite are also known, e.g. from west of Chillagoe (de Keyser & Wolff, 1964), and from the Hamilton Goldfield (Ball, 1901a). The innumerable dykes of unmetamorphosed quartz-feldspar porphyry, felsite, andesite, and dolerite are possibly also penecontemporaneous with the Permo-Carboniferous volcanic rocks and dykes farther east, and may represent feeder channels for similar volcanic deposits now removed by erosion. On the air-photographs the acid dykes stand out as thin white ribs, whereas the basic dykes form dark lines and grooves.

McDevitt Metamorphics

Derivation of name: Mount McDevitt, longitude 144°17′E., latitude 17°34′S.

Type area: along the Tate River from Bolwarra homestead to the junction with the Rocky Tate River.

The name was used by Best (1962) for metamorphic rocks exposed over 300 square miles around the old mining camp of Fischerton.

The McDevitt Metamorphics have not been studied in detail. They include quartz-mica schist, andalusite schist, quartzite, garnet-mica schist, and quartz-muscovite-cordierite-garnet schist. According to Best (1962) the grade of metamorphism is less than that of the Dargalong Metamorphics, and they may therefore be younger. The relationships, however, have not been clearly established, and

it is possible that the McDevitt Metamorphics are the less intensely metamorphosed equivalents of the Dargalong Metamorphics.

The McDevitt Metamorphics contain bodies of dolerite and amphibolite which Best (1962) equates with the Cobbold Dolerite (White, 1959, 1965) on the Einasleigh Sheet area. Unmetamorphosed, probably Permo-Carboniferous dolerite sills and dykes are numerous, especially in a swarm northwest of Fischerton, and intrusions of later granite are common. Most of the granites are probably Permo-Carboniferous, but some have been mapped as the Proterozoic Forsayth Granite (Best, 1962).

The McDevitt Metamorphics are bounded in the north and east by the Dargalong Metamorphics, in the south and east by Palaeozoic igneous complexes, and in the south by undifferentiated Precambrian. In the west they are uncomformably overlain by Mesozoic sandstones. The boundaries with the Dargalong Metamorphics and the undifferentiated Precambrian are vague and arbitrary, and are based largely on the metamorphic grade. No information is available about the boundary in the south.

Undifferentiated Precambrian

The metamorphic rocks in most of the southwest quadrant of the Atherton Sheet area have been grouped together as undifferentiated Precambrian because it has not been possible to define separate formations (Best, 1962). Some are similar to the Dargalong Metamorphics, others resemble the McDevitt Metamorphics and the Forsayth Granite.

Inliers of metamorphic rocks have been mapped in the Cainozoic alluvial deposits on the eastern side of the Atherton Sheet area as far as Mount Garnet and Sunday Creek. Most of them are gneissic, and may be Archaean (Best, 1962); muscovite-quartz schist and interbedded quartzite, albite-muscovite-quartz schist, and gneissic albite granite have been recorded by Yates (Blake, 1968, unpubl.; Zimmerman, Yates & Amos, 1963, unpubl.).

Forsayth Granite (White, Best, & Branch, 1959)

Derivation of name: the township of Forsayth, longitude 143°32′E., latitude 18°31′S.

The Forsayth Granite is a grey coarse-grained massive to porphyritic biotite granite which intrudes the Precambrian metamorphic rocks, and is unconformably overlain by Permo-Carboniferous volcanics and Mesozoic formations. On the map (Pl. 24) four bodies are shown west and southwest of Fischerton; Best (1962) also included the muscovite granite at Dargalong, but the mineralogical composition makes this doubtful. There are probably other unmapped masses of Forsayth Granite in the area shown as undifferentiated Precambrian.

White, Best, & Branch (1959, unpubl.) give the age of the granite as late Proterozoic or early Palaeozoic, but subsequent isotopic age determinations indicate that it ranges from Precambrian to Siluro-Devonian (Richards et al., 1966).

Cobbold Dolerite

Bodies of dolerite and amphibolite in the McDevitt Metamorphics have been equated by Best (1962) with the Cobbold Dolerite (White, 1965) in the Einasleigh Sheet area.

Sandalwood Serpentinite

The lenticular body of serpentinite near Gunnawarra homestead probably lies along the faulted eastern edge of the Precambrian basement, and is similar to the Sandalwood Serpentinite in the Einasleigh Sheet area (Best, 1962).

Structure of the Precambrian Formations

The Precambrian formations are characterized by pronounced foliation, schistosity, or gneissic structure; the foliation planes are normally steep, but in some areas dips are moderate to low. The foliation is usually but not always parallel to the original bedding. Minor folding and crenulation, boudinage, plastic folding, shearing, and possible mylonitization have been observed, but the structure of the Precambrian rocks has not been studied in detail.

Boundary between the Precambrian Shield and the Palaeozoic Geosyncline

The Precambrian shield is separated from the Palaeozoic geosynclinal formations by the Palmerville Fault (de Keyser, 1963), which runs from Princess Charlotte Bay in the north to Halifax Bay in the southeast. The fault is sharply defined from near Almaden northwards, but around Mount Garnet it is obscured and the structure more complicated.

Jack (1891) found the boundary in the Chillagoe district 'transitional and intergrading', whereas Ball (1918) called it abrupt. Jensen (1941) regarded it as a fault, and Broadhurst (1952) saw only a normal unconformable relationship. The evidence accumulated during this investigation indicates that the boundary is faulted.

PALAEOZOIC

The oldest known sediments in the Hodgkinson Basin are the Chillagoe and Mount Garnet Formations, which have much in common and are penecontemporaneous in part at least. The Chillagoe Formation may be described as a mixed-type shelf facies, the Mount Garnet Formation as a clastic-type shelf(?) facies. Where the two units are associated, the Mount Garnet facies is the younger one, but along the old Tasman shoreline the proportions of the two formations vary and one unit may even disappear completely (Fig. 3). Both formations are equally well developed in the Chillagoe/Walsh River area, but the Chillagoe Formation thins out towards the Mount Garnet area, and the Mount Garnet Formation, after an initial increase north of the Walsh River, thins out rapidly and finally disappears north of the Mitchell River.

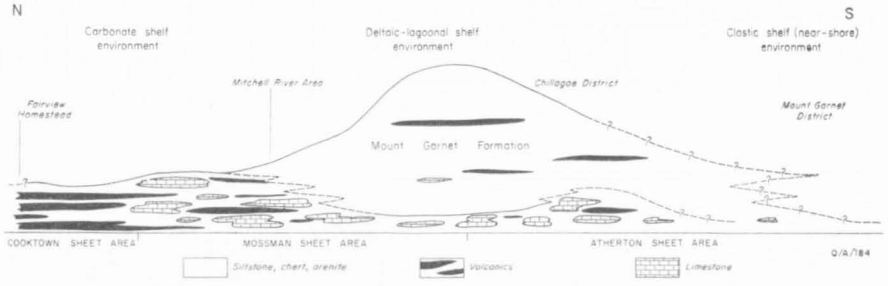


Fig. 3. Relationship between the Chillagoe and Mount Garnet Formations.

The lithology of the two formations is given in Table 1.

TABLE 1: LITHOLOGY OF THE CHILLAGOE AND MOUNT GARNET FORMATIONS

Lithological Description	*Outcrop and Air-photo Characteristics*
LIMESTONES *(typical of Chillagoe Formation)*	
1. Massive and dense limestone; very rarely thin-bedded (1-1½ in.). Dark grey, weathers to light grey; some very dark members fetid when broken. Recrystallized to coarse white marble in contact aureoles around granite intrusions. Some beds contain chert nodules which in places coalesce into nodular lenses, and finally into beds by interfingering. Other facies changes include: interfingering with sandy limestone-conglomerate, transition into sandy chert breccia, and vertical intergrading from calcareous sandstone to pure crinoidal limestone. Outwash channels in limestone filled with sandstone, thin-bedded limestone, or sandy limestone or marl. Fossils very common: crinoids, brachiopods, gastropods, corals.	Conspicuous jagged bare bluffs, 300 ft high, showing fluted karren erosion, and containing many caves, easily recognizable on air-photos by their karren erosion and dark tones. Other limestone exposures form low smoothly worn pavements.
2. Limestone breccia-conglomerate — subangular fragments of limestone (several inches across, with rare boulders several feet in diameter) in little calcareous sandy matrix. Occasional fragments of chert, gneiss, and granite.	As for massive limestone, but generally without karren erosion. Usually underlain by local unconformity (Fig. 4), and therefore probably represent wave-platform breccia.
3. Sandy limestone, and calcirudite with sandy matrix, mingled with lenses of limestone or chert.	
CHERTS *(mostly in Chillagoe Formation)*	
1. Regularly bedded chert, beds generally 1-3 in. thick and separated by shaly partings. Light grey to black, creamy, yellow, pink to red and green. Well jointed and breaks into parallelopipeda. Interfingers with limestone, and commonly includes limestone lenses. Weathered surfaces in places resemble weathered limestone. Some fossils: *Heliolites, Demospongia, Radiolaria.*	Smooth rounded rubble-covered ridges, contrasting with jagged bare limestone bluffs and with lower and less regular ridges of greywacke and siltstone.
2. Chert breccia, commonly as pipe-like bodies in limestone. Origin uncertain, but here thought to be hydrothermal breccias.	
ARENITES	Ridges that are generally lower and less regular or smooth than chert ridges.
1. Massive moderately to poorly sorted coarse to medium-grained grey (quartz) greywacke with vague conglomerate and pebbly zones and irregular patches of siltstone or fine sandstone. Forms large lenses in well bedded finer-grained greywacke or siltstone sequences. Pebbles or fragments include quartz, chert, slate, schist, quartzite, basic and acid volcanics, microgranite, and limestone. Subangular to subrounded grains of quartz (60-80 percent), feldspar (10-20 percent), muscovite, rock fragments, in fine-grained matrix (up to 15 percent) of quartz, sericite, and chlorite.	
2. Bedded fine to medium-grained quartz greywacke and greywacke with shaly intercalations. In places beds range from 1½-6 in. thick, or 6 in.-1½ ft. Bedding structures include: scour-and-fill, lensing, intraformational breccias, cross-lamination, convolute lamination, graded bedding, load casts, and slump structures(?).	
3. Thick-bedded graded quartzite or quartz sandstone; white porous fine to medium-grained quartz sandstone (mainly in Mount Garnet Formation). Not common.	

TABLE 1 (continued)

Lithological Description	*Outcrop and Air-photo Characteristics*
4. Fine-grained calcareous, micaceous greywacke or impure sandstone with fine cross-lamination. Uncommon. 5. 'Ashy' greywacke: a soft very dark grey thick-bedded medium-grained micaceous and feldspathic arenite with abundant dark fine-grained matrix. Contains beds, 2-5 ft thick, of green silica-cemented fine conglomerate or grit. (Mount Garnet Formation only.) 6. Fine-grained sericitic and feldspathic sandstone or sandy siltstone, pink-yellow to greenish. Commonly contains small lenses of conglomerate, chert, limestone, basalt, shale, or quartz greywacke. In places grades into chert or quartz greywacke. Basal member of Chillagoe Formation.	
LUTITES 1. Well bedded sequences of alternating pepper-coloured siltstone (fine sandstone) and dark grey to black fine-grained siltstone (Pl. 15, fig. 1). Beds ½-2 in. thick. Commonly somewhat calcareous. Graded bedding, fine cross-lamination, and small-scale scour-and-fill structures very common. 2. Shaly siltstone, dark grey to grey-green, weathering to yellow or brown. Finely sericitic. Average grainsize 0.05 mm. Contains thin beds of grey sericitic quartzite. 3. Well bedded green marly siltstone intercalated with finely cross-laminated fine-grained calcareous sandstone. 4. Massive siltstone and claystone with non-bedded or poorly bedded appearance. 5. Well bedded black cherty or siliceous siltstone, with shaly partings. Appears to grade into bedded black impure chert.	Lutites poorly exposed, and underlie many alluvial areas. Outcrops mainly in creek beds.
CONGLOMERATES 1. Greywacke conglomerate, with pebbles (about 1 in. across) of chert, quartz, schist, siltstone, basalt, rhyolite, limestone (generally dissolved), and other rock types, in much greywacke matrix. Grades into pebbly greywacke with which it has no sharply defined contacts. Common in Mount Garnet Formation. 2. Basalt conglomerate (one locality in Chillagoe Formation): basalt pebbles in calcareous sandy matrix. 3. Coarse conglomerate occurring as small lenses mostly in basal portions of Chillagoe Formation. Polymict, poorly sorted; consists of subangular to rounded pebbles and boulders of Dargalong Metamorphics (gneiss, schist, granite, amphibolite), up to about 6 in. across on average, with observed maximum of 2 ft, in much sandy matrix. Streaks and lenses of sand with faint small-scale cross-lamination.	Large bodies of conglomerate form firm ridges somewhat higher than surrounding arenite and lutite country.
BASALT Lavas intercalated in sedimentary sequence, and especially abundant near the Palmer River. Some albitized and chloritized. Amygdaloidal basalts have cavity fillings of calcite and chorite; may be pseudo-amygdaloidal in places.	On air-photographs basalt flows can be recognized by their darker colour.

Chillagoe Formation

Derivation of name: the old mining township of Chillagoe, longitude 144°32'E., latitude 17°07'S.

Type area: the region between Chillagoe and Mungana.

The name Chillagoe Beds was coined by Jack & Etheridge (1892). Skertchly (1899) restricted his Chillagoe Limestone to the limestone members of the association, but Dunstan in 1913 and 1916 included the whole sedimentary sequence in his Chillagoe/Cloncurry Series and Chillagoe Series. The AGGSNA Report (1940) refers the limestone-bearing zone near the Palmer River to the Palmerville Series, although it was recognized as a probable extension of the Chillagoe Beds. David (1932) used the term Halysites Limestones. On the Geological Map of Queensland (1953) the formation is shown as the Chillagoe Group. De Keyser et al. (1960) described the unit as the Chillagoe Formation.

The Chillagoe Formation occupies a belt, up to 9 miles wide, which extends from Almaden northwards to west of Laura, where it disappears underneath Mesozoic beds. Farther north, the formation was penetrated at a depth of 3785 feet in the Cabot/Blueberry Marina No. 1 well, and at Saltwater Creek near Princess Charlotte Bay. The sheared and contact-metamorphosed sediments at Cape Sidmouth on the eastern coast of Cape York Peninsula, and the reported outcrops of recrystallized limestone farther north still, probably also belong to the Chillagoe Formation. In the south, the Chillagoe Formation crops out near Mount Garnet with the Mount Garnet Formation.

The characteristic rock types of the Chillagoe Formation are fossiliferous limestone and chert, interbedded with arenite, lutite, and basalt. The lithology is summarized in Table 1 and has been described in greater detail by Jensen (1941c, unpubl.), Broadhurst (1952, 1953a), and de Keyser & Wolff (1964).

The basal unit is mainly a fine-grained sericitic quartz sandstone or siltstone, which differs in appearance from the other arenites and lutites (de Keyser & Wolff, 1964). The unit is only found along the Palmerville Fault, and it has been suggested that the deposition of the sandstone was associated with the faulting (de Keyser & Wolff, 1964, p. 18).

The basic volcanics in the Chillagoe Formation are widespread, but are most abundant in the north, in the region of the Palmer River. The feldspar in the volcanics is either calcic plagioclase or albite, and they generally contain much chlorite, calcite, epidote, sphene, and iron oxide dust. In some basalts, fresh augite is present, but the mafic minerals are generally completely chloritized, perhaps as a result of absorption of water during extrusion (Rösler, 1960; Hentschel, 1960; Zavaritsky, 1960). These authors are not agreed about what happens to the elements which are excluded from the chlorite lattice, but it has been suggested that sodium is taken up in the albitization of the feldspars (spilitization), and that the silica liberated may give rise to primary or secondary cherts, which are common in the Chillagoe Formation.

Amygdaloidal basalt is especially well developed north of the Palmer River. The amygdules generally consist of calcite and chlorite. It is possible that many of the big and well rounded amygdules are pseudo-amygdules formed by limestone assimilation, as described by Rösler (1960).

The genesis of some of the rock types is uncertain. For example, Broadhurst (1952) has interpreted the limestone conglomerates and chert breccias near Redcap and Mungana as volcanic breccias associated with diatremes. Jensen (1941c, unpubl.) considers that the breccias at Mungana were formed chiefly by faulting and fracturing, while de Keyser (de Keyser & Wolff, 1964) has concluded that they include hydrothermal breccias, wave-platform breccias, and normal conglomerates. The cherts have been interpreted as silicified calcareous shale (Jensen, 1941c, unpubl.), silicified tuff (Broadhurst, 1952), silicified calcareous ooze, or primary silica.

Granites intruding the Chillagoe Formation have transformed many of the calcareous sediments in the contact zones into calc-silicate rocks, bleached and recrystallized the limestone, and recrystallized the chert to fine-grained quartzite. In places it is difficult to distinguish between certain types of calc-silicate rocks and basalt.

Age of the Chillagoe Formation

Fossils are almost entirely confined to the limestone, in which they are locally extremely plentiful and commonly segregated in layers. They are poorly preserved, and silicification makes it difficult to determine the species. A few fossils are found in the chert.

The fauna (Appendix) indicates a Silurian age (*Halysites*), but the presence of *Stringocephalus* sp.(?), 2 miles east of Rookwood homestead, suggests that sedimentation may have continued into the Devonian. Hill (1943a) found late Silurian (Wenlock or Ludlow) affinities in some corals from the Chillagoe/Mungana area, and early or middle Devonian traits in others. The age of the Chillagoe Formation is therefore tentatively given as Upper Silurian to Lower Devonian.

Previously, Jack (*in* Jack & Etheridge, 1892) had equated the formation with the Permo-Carboniferous Gympie Series. Skertchly (1899), repudiating his earlier findings, concluded that the Chillagoe Limestone rests unconformably as 'a much denuded cake' on the associated cherts and clastic sediments (which he included in the Herberton Beds), and was of Upper Carboniferous or Lower Permian age. Dunstan (1913b) referred the limestone to the Silurian, and four years later included the limestone and the associated sediments in the Silurian Chillagoe Series. David (1932) also considered the formation to be Silurian.

Mount Garnet Formation

Derivation of name: the township of Mount Garnet, longitude, 145°08′E., latitude, 17°39′S.
Type area: around Mount Garnet.

The name was proposed by Best (1962) for a rock unit consisting dominantly of siltstone and greywacke. Previously the sediments had been included with the Herberton Beds (Skertchly, 1899; Jensen, 1923 in part; Levingston, 1960b), but that name has now been abandoned. The sediments of the Mount Garnet Formation have been described by de Keyser & Wolff (1964).

The Mount Garnet Formation crops out intermittently in an arcuate belt extending from north of the Mitchell River to southeast of Mount Garnet. It is

flanked to the west by the Chillagoe Formation (or by Precambrian rocks southeast of Mount Garnet), and to the east and north by the Hodgkinson Formation. The outcrops are isolated by intrusive granites and outliers of Permo-Carboniferous volcanics; northeast of Mount Garnet the formation borders the Ringrose Formation.

The types of sediment in the Mount Garnet Formation are virtually identical with those in the Chillagoe Formation, but the relative proportions are different: arenite and siltstone predominate with only small scattered lenses of limestone and chert. There is no sharp boundary between the two formations.

The Mount Garnet Formation comprises quartz greywacke, greywacke, quartzite, sandstone, sericitic siltstone, and shale, with subordinate chert, conglomerate, intraformational breccia, basalt, and lenses of limestone and limestone conglomerate (Table 1). Throughout the succession, the massive members alternate with well bedded rocks, and the limestone and quartz greywacke occur as lenses in siltstone. The greywacke and quartz greywacke grade into fine conglomerate containing pebbles of quartz, chert, siltstone, and limestone (the latter commonly dissolved). In places, the greywacke includes lenses of fairly clean quartz sandstone. Green chloritic shale is common in the Koorboora and Petford/Emuford areas. It was considered by both Jack and Skertchly to represent altered basic dykes, but Jensen (1923) considered it to be of volcanic or tuffaceous origin.

Subordinate soft, dark grey, 'graphitic' schist, and soft, ash-coloured, grey to black, micaceous arenite with an abundant dark fine-grained matrix are typical of the Mount Garnet Formation, and have not yet been found in the Chillagoe Formation.

The rock types may show considerable variation in weathering: some of the siltstones are grey-green and fairly soft in creekbed exposures, but are pink or red and much more indurated on the adjoining hill slopes. The massive greywackes commonly show spheroidal weathering and in places they were mistaken for igneous rocks by Jensen.

The boundary of the Mount Garnet Formation with the younger Hodgkinson Formation is difficult to map because the lithological differences are almost imperceptible (see also Blake, 1968, unpubl.). The arenites of the Mount Garnet Formation have a wider range in lithology, and include more of the cleaner quartz greywacke. The arenites of the Hodgkinson Formation are commonly feldspathic and many beds seem to contain more matrix. The bedding in the Hodgkinson Formation is generally more regular than in the Mount Garnet Formation, in which the lithology changes more frequently. The difference can be seen more clearly in weathered exposures, but the formations can rarely be differentiated in single outcrops. The Mount Garnet arenites generally weather either light grey or very drab, and have a rough granular surface; the Hodgkinson arenites are usually more blocky, brown, smoother, and speckled with feldspars. In places the formations can be differentiated by photo-interpretation, as for example north of the Palmer River, where the uniform lithology of the Hodgkinson Formation contrasts with the varied lithology of the Mount Garnet Formation.

Depositional Environment and Relationships of the Chillagoe and Mount Garnet Formations

The Chillagoe and Mount Garnet Formations may be regarded as two facies of roughly the same age. They comprise the same set of rock types, but in different proportions. Figure 3 shows diagrammatically the facies changes from north to south, and the changes in the relative thicknesses of the two formations.

The Chillagoe Formation and, to a lesser degree, the Mount Garnet Formation are characterized by rapid local changes of facies; by lensing, intertonguing, and intergrading; by small local unconformities and disconformities (Fig. 4), washouts (Fig. 5), scour-and-fill structures, etc. (de Keyser & Wolff, 1964). Some thin-bedded sequences of alternating siltstone and fine-grained pepper-coloured sandstone and their associated bedding structures strongly resemble recent littoral sediments in tidal channels (van Straaten, 1959, fig. 4). The lenses of coarse conglomerate contain well rounded pebbles and boulders of metamorphosed rocks from the Precambrian shield. Siliceous sponges such as found in the Chillagoe Formation rarely live at depths greater than 225 feet, and at present most colony-forming corals live at depths of less than 150 feet.

All these features point to a near-shore, shallow-water, mixed clastic and reef environment (shelf), with frequent oscillations of sea level, rapid facies changes, and the entry of clastic material from the west and south. The absence of a very coarse basal sequence in the Chillagoe Formation suggests that the sediments were derived from a mature continent with low relief near its coastline. Rapid deposition of the clastic sediments is indicated by the presence of diffuse lenses of conglomerate and pebbles in the arenites, the presence of fresh feldspars, the poor rounding of the detrital grains, and the presence of some convolute bedding lamination. The rapid deposition may have been the result of rapid subsidence coupled with a copious supply of detritus.

White (1961) considered the Mount Garnet area to have been a shelf with an irregular floor and steep shoreline, and Best (1962) thought that '. . . the wide

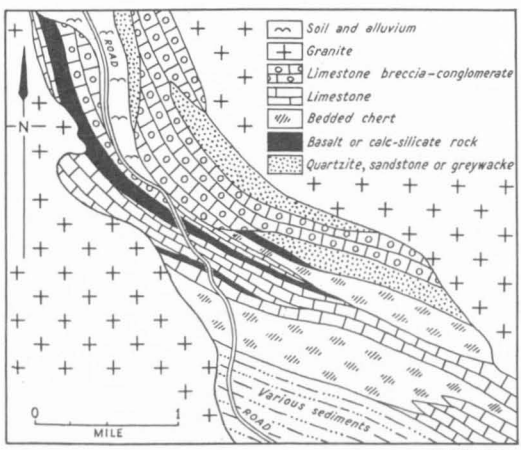


Fig. 4. Chillagoe Formation: local unconformity.

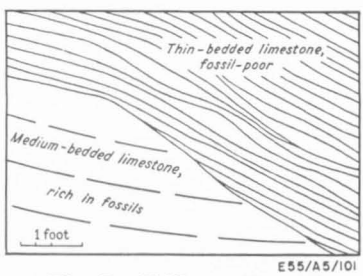


Fig. 5. Chillagoe Formation: outwash in limestone.

shelf was missing probably because of a steep coastline'. Zimmerman et al. (1963, unpubl.) concluded that the beds were deposited '. . . in the unstable zone between the edge of a stable shelf and a subsiding basin.' De Keyser & Wolff (1964) have suggested that the Chillagoe Formation is a mixed-type shelf association, and that the Mount Garnet Formation is its clastic-type shelf counterpart. The Mount Garnet Formation was probably laid down in water of about the same depth as the Chillagoe sequence, and the differences are probably due to the relief of the hinterland or the relative volumes of detritus available. Where there was strong erosion in the source area, or where big rivers entered the sea, the supply of clastic material was plentiful, and coral reefs were not likely to flourish. This environment corresponds to the clastic Mount Garnet facies. Where, on the other hand, the source land lacked pronounced relief, or the streams were insignificant, the supply of clastic material would decrease and coral reefs would flourish. Under these conditions the Chillagoe facies would prevail. This hypothesis is compatible with the concept of tectonic land in the south, as proposed by White (1961), which also explains the disappearance of the Mount Garnet facies towards the north, and the thinning of the Chillagoe facies to the south.

It is probable that the Mount Garnet seas in the south were divided by tongues of land: this would explain the observed directions of sediment transport in the Almaden area, where both a western and eastern source of supply are indicated by the attitude of the cross-bedding.

The easterly extent of the Chillagoe and Mount Garnet Formations beneath the Hodgkinson Formation is unknown. It seems unlikely that the Upper Silurian/Lower Devonian seas were restricted to a long narrow arm in which the reef deposits could be formed. The sea was probably much more extensive, but it is doubtful whether the Chillagoe and Mount Garnet facies types as such would have persisted much farther out from the coastline. It is assumed that fine-grained pelitic sediments were deposited in deeper water beyond the shelf area, and they are probably indistinguishable from the fine-grained slate and the siltstone of the overlying Hodgkinson Formation. It is possible, therefore, that some of the phyllites of the Hodgkinson and Barron River Formations to the east represent sediments of the same age as the Chillagoe and Mount Garnet Formations.

The Term 'Herberton Beds'

Although the term Herberton Beds has been abandoned (Best, 1962), the name was widely used as recently as 1960 (Levingston, 1960; de Keyser et al., 1960).

The term was introduced by Skertchly (1899) to include all the slate, shale, conglomerate, sandstone, and greywacke (but not the limestone) exposed between Herberton and Cardross and as far north as the Palmer River and Cooktown. He regarded them as Devonian. It is now known that the beds may include five formations ranging from Silurian to Carboniferous.

In 1904, Stirling separated out the Silver Valley Beds as Carboniferous. Jensen (1923), aware of the lithological differences between the greywackes in the Herberton and Hodgkinson Goldfield areas, restricted the name Herberton Series (Ordovician) to the greywacke, arkose, quartzite, and interbedded chlorite schist in the Herberton, Irvinebank, Koorboora, and Emuford districts. He also included the basal sandstone member of the Chillagoe Formation in the Chillagoe/Almaden

district. To the Silurian, he assigned the main body of what is now the Chillagoe Formation, as well as the sediments south-southeast of Petford.

Even after much later mapping (AGGSNA, 1939), the relationships and ages of the sedimentary sequences in the Herberton/Mount Garnet area were not completely understood because of the very slight differences and obscure relationships. Certain fallacies, such as the 'basal' position of the Ringrose Conglomerate, and wrong ages and relations of the overlying volcanics, were retained in Levingston's summary (1960) of the Herberton/Mount Garnet area, which is largely based on the 1939 AGGSNA Report; while de Keyser et al. (1960) still used the term Herberton Beds for the sediments in the Koorboora/Petford area.

Best (1962) concluded that the Herberton Series as defined by Jensen represents several stratigraphical units: the greywacke-siltstone sequences belong either to the Mount Garnet Formation (in the south) or to the Hodgkinson Formation (in the north), certain arkoses form part of the Carboniferous(?) Montalbion Sandstone, and many of the quartzites belong to the Carboniferous(?) Ringrose Formation. Subsequent detailed mapping by Smith and Yates and by Blake (1968, unpubl.) indicates that the so-called Carboniferous formations may be different facies types of the Mount Garnet and Hodgkinson Formations (see p.58).

Hodgkinson Formation

Derivation of name: the Hodgkinson River, which runs through the Hodgkinson Goldfield, 50 to 60 miles west of Cairns.

Type area: the Hodgkinson Goldfield.

Jack (1884) first described the folded sediments in the goldfield as the Hodgkinson Beds, and correlated them with the Upper Devonian Star Beds and Reid Beds west of Townsville. Later he extended the Hodgkinson beds to the Palmer River and Limestone districts (Jack, 1887c, 1888d). Dunstan (1916) included them in the Herberton Series. Jensen (1920) introduced the name Hodgkinson Series, and in 1939 (AGGSNA Report) he extended the series farther to the north, east, and southeast. In the AGGSNA Report the term Maytown Series was used for the exposures in the Palmer River district, although they were recognized to be the same as the Hodgkinson Series. The Geological Map of Queensland (1953) shows the Hodgkinson Formation as Carboniferous-Devonian.

The Hodgkinson Formation is the most extensive unit in the map area: it crops out continuously for over 200 miles from Irvinebank, just north of latitude 17°30'S., northwards to latitude 14°15'S., near Cape Melville. Its outcrop area is about 15,000 square miles, and it probably underlies an area of about 5000 square miles in the Laura Basin. To the southeast, the Hodgkinson Formation grades into the Barron River Metamorphics (its metamorphic equivalent), which occupy another 2000 square miles. The western boundary of the Hodgkinson Formation is exposed, but the position of the northern and eastern boundaries is uncertain as they are concealed beneath the South Pacific Ocean. The Hodgkinson Formation, and its metamorphic equivalent, is an extensive geosynclinal unit which may be compared, for example, with the Neranleigh-Fernvale Group of southeast Queensland (Hill & Denmead, eds, 1960, pp. 131-40). The term 'basin' is used in this Bulletin although most of its boundaries cannot be even approximately defined.

Stratigraphy

The Hodgkinson Formation is a highly folded, thick, fairly uniform, geosynclinal deposit of rhythmically alternating arenite and slate, with intercalated beds of chert, volcanics, and some limestone. The formation is probably several tens of thousands of feet thick, but few thick sections can be measured because of the complex structure. Cribb (1960) has summarized the information available prior to the recent regional survey by the Commonwealth and State Governments. More recently, the formation has been briefly discussed by de Keyser & Wolff (1964).

Bryan (1925) observed that the sediments of the Hodgkinson Formation are generally not metamorphosed (the metamorphosed equivalents are known as the Barron River Metamorphics), although many of the earlier writers used rock terms that would suggest a moderately high metamorphic grade.

Two incomplete sections of about 10,000 feet have been measured: one in the McLeod Hills, 10 miles northeast of Dimbulah, and the other north of Big Watson Creek, near the western boundary of the formation to the south of the Mitchell River. The lower parts of both sections are generally fine-grained, and the McLeod Hills section includes radiolarian chert near the base. The upper part of each section is fairly rich in gritty and pebbly arenite, which may correspond to the thick-bedded* coarse sediments in the type area. The estimated thickness of 21,000 feet in the type area (Jack, 1884) may be approximately correct, although the effect of repetition by folding and faulting is uncertain.

In the southwest, to the north of the Featherbed Range, a 14-mile section across the strike is exposed: most of the steeply dipping, medium-bedded to thin-bedded, graded arenite within the slate sequences faces westwards, but the section is probably complicated by structural repetition.

The thickest section measured is 25,000 to 30,000 feet in the eastern limb of the large steeply plunging syncline in the Desailly Range, 35 miles west of Mossman (Fig. 20). The succession is composed of typical thin-bedded and medium-bedded turbidite and lutite sequences, with abundant thick to massive arenites, some of which are pebbly and conglomeratic. Keratophyres are interbedded with the sediments near the base of the section. The top and bottom of the section are not known, but to the east, structurally below its local base, is a more disturbed, generally fine-grained sequence which may represent the finer-grained lower part of the succession.

Lithology

Lutites are the predominant rock type: they generally include micaceous quartz siltstone, slaty mudstone, and black phyllite. In the type area the lutite is olive-weathered, dark grey, silty, slaty mudstone. Lutite is most common in the east, and southeast of Maytown. The soft dark slate along the Mulligan Highway south of the Palmer River is possibly graphitic. The lutites contain very few macrofossils, but flattened radiolarites have been found in a siltstone from South Cape Bedford, north of Cooktown. The arenites and coarser rocks fall into two main categories:

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* In this Bulletin, beds are described as massive where over 5 feet thick; thick-bedded, 1 to 5 feet thick; medium-bedded, 4 to 12 inches thick; and thin-bedded, 1 to 4 inches thick.

relatively thick-bedded pale clean greywacke, greywacke-conglomerate, and impure sandstone, mostly without internal structures; and thinner-bedded coarse to fine (especially fine) arenites which commonly display turbidite structures and grade into thin siltstones. The thick beds generally range from 5 to 100 feet thick, and the turbidites are generally less than 5 feet. The thick beds may show some turbidite structures, but grading and other characteristic structures of turbidites are poorly developed. Not all the thin-bedded arenites are turbidites.

The modal composition of 15 arenite specimens from the Hodgkinson Formation is given in Figure 6. They include arkose, feldspathic sandstone, and greywacke according to van Andel's classification (van Andel, 1958). However, the sedimentary structures indicate that the rocks belong to the greywacke suite of Packham (1954), and according to Crook's classification, they may be described as litho-feldspathic to feldspatho-lithic greywackes (Crook, 1960). In the 15 rocks examined, quartz ranges from 38 to 73 percent; feldspar from 16 to 46 percent; and rock fragments from 13 to 32 percent.

The thick-bedded or massive arenites are generally pale grey or blue-green feldspathic or lithic sandstones. They range from even fine-grained sandstone to pebbly, gritty, coarse or medium-grained sandstone and grit transitional to greywacke-conglomerate. The only internal structures are laminae of pebbly grit, grit, or gritty sand, from half an inch to 12 inches thick, which are especially common around the Hodgkinson Goldfield.

A thick but darker even medium-grained greywacke is fairly common west and south of the type area. It is commonly slightly calcareous, and has a red-brown flecked, or salt-and-pepper appearance on slightly weathered surfaces.

In most of the greywackes the grains are subangular, and consist of quartz, alkali feldspar (albite, microcline, orthoclase, perthite, and less commonly oligoclase), muscovite, and biotite, in decreasing order of abundance. Tourmaline, zircon,

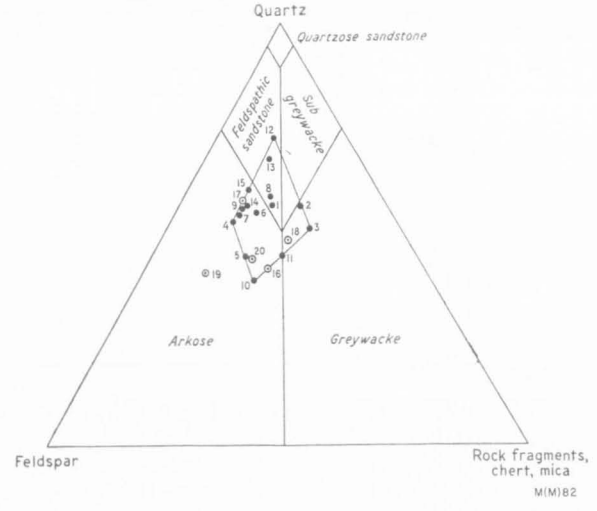


Fig. 6. Modal composition of arenites mainly of the Hodgkinson Formation.

black iron oxide, sphene, leucoxene, epidote, garnet, and apatite are common accessory minerals. Rock fragments include chert, calcareous quartzite or sandstone, basic volcanics, fine-grained acid and intermediate volcanic rocks, slate, gneiss, muscovite granite, siltstone, sericite schist, and quartz with sillimanite needles. The intergranular matrix generally forms less than 15 percent of the rock, but ranges up to 25 percent. The most common cementing minerals are quartz, chlorite, and sericite, and, in places, calcite. Variable amounts of the epidote minerals or alkali feldspar and zeolite may be present. The matrix in the darker thinner-bedded turbidites consists mainly of chlorite and fine intergranular detritus.

The sorting in the arenites is generally poor to moderate, and the mineral grains are angular to subrounded. Crushing, granulation, undulose extinction in quartz, and bending and rupturing of the micas can be observed in almost all thin sections.

Some of the subordinate quartz sandstones contain small white quartzite pebbles, and these are common in parts of the belt along and just south of the Palmer River west of Uhrstown to the formation boundary. They are pale green, even-grained, and range from coarse to fine-grained, but most of them are probably turbidites.

Many of the gritty sandstones, especially in the type area and in the Desailly Range, contain numerous conspicuous slivers of grey shale from 1 to 2 inches long. The slivers are much larger in some of the massive sandstones and greywacke-conglomerates into which this type of rock grades with an increase in the number and size of the pebbles.

Jensen (1923) considered that the greywackes resembled trachyte tuff and might have been derived from trachyte.

Greywacke-conglomerate is commonly found in association with abundant thick sandstones in the type area northwards to the upper St Georges River and Desailly Range, and still farther north, with some coarse conglomerate, and subordinate sandstone, to the Palmer River. Greywacke-conglomerate has also been recorded from Cape Bowen in the far north. It commonly grades into and is interbedded with the gritty and pebbly greywackes and contains both intraformational and exotic fragments. The intraformational fragments include angular slivers of shale, slightly less angular pebbles, cobbles, and boulders of greywacke, and more rounded pebbles of limestone, especially in the type area and around the St Georges River. Some of the limestone-bearing conglomerate in the type area is slightly calcareous.

The exotic fragments are generally better rounded and more evenly distributed; they consist mainly of small pebbles of quartzite and granite, with subordinate quartz, hornfels, schist, and dolerite(?). The dolerite is possibly intraformational, but the others have been derived from the basement.

The rounded pebbles of blue limestone containing *Heliolites* in the greywacke-conglomerate 2 miles below the St Georges/Mitchell River junction (Jack, 1884) have probably been derived from the Chillagoe Formation.

In the west, from south of Mount Mulligan Creek to the Mitchell River, pebbles of chert are common, and in some of the conglomerates they are abundant and angular; limestone and porphyritic rhyolite(?) are less common. The chert has probably been derived from the Chillagoe Formation, and the other rock types may also have been derived from the same source.

The thick greywacke-conglomerate in the Desailly Range contains abundant small rounded pebbles of white granular quartzite, and pebbles of granite are also common. The conglomerates of the Palmer River and the Cannibal Creek track are usually coarse, but they are not associated with thick arenites. They contain coarse intraformational detritus, and rounded pebbles, cobbles, and boulders of granular quartzite and leucocratic granite. One of them has an unusual matrix of clay-rich sand. In the quartzose sandstones to the west of these conglomerates only quartzite pebbles are common.

The conglomerate to the west of Cape Bowen contains rounded pebbles of sheared dark quartzite, micaceous metaquartzite, and silicified rhyolite (Morgan 1964, unpubl.) amongst other rock types.

Intercalations of volcanic rocks are most common near the western boundary and also to the north of the Daintree River, and southwest of Cooktown. They are associated with red and green lutite, and are mostly basic volcanics, which have been transformed into greenschist in the east. The rocks are generally massive to slightly foliated, tough, and green or purple. Some are calcareous, and one pyritic dolerite was noted northwest of the lower Mitchell River crossing. The rock near Cannibal Creek has a chemical composition close to spilite (Table 2). Within a radius of 20 miles southwest of Cooktown, pale green intermediate volcanics are more common than the basic lavas. The volcanics near the base of the section in the Desailly Range are altered keratophyres or quartz keratophyres, and quartz keratophyres and rhyolites have been described from the northern part of the Cape Melville Sheet area (Morgan, 1964, unpubl.).

Chert and less commonly limestone are generally associated with the volcanics, and also occur independently. Where there is only slight metamorphism and internal deformation, thin-bedded radiolarian jasper and grey and green chert, and shaly jasper and chert, can be found. A few manganiferous cherts and black pyritic cherts occur near Wolfram Camp and elsewhere. In the east, mostly in the upper Palmer River valley, jasper is absent and the cherts are thick and microcrystalline rather than cryptocrystalline. This may be due to the higher grade of metamorphism or diagenesis, but the beds also appear to be more silty. Near the Mulligan Highway crossing on the Palmer River, some of the chert contains subradial aggregates of tremolite-actinolite.

Jensen, and others, have described the cherts as silicified limestone or calcareous slate, but their close association with volcanic rocks, and the presence of radiolaria, suggest that they may be organic or inorganic deposits of siliceous material.

Some of the siliceous rocks in the Hodgkinson district which have previously been described as quartz veins (Jack, 1884) are now believed to be recrystallized bedded chert.

Limestone is known from only a few localities. Two fairly large lenses occur about 20 miles southwest of Cooktown, a third body is located near the confluence of the Mitchell and St Georges Rivers, another one 10 miles southeast of the latter, and one outcrop of limestone occurs 16 miles north of Mareba. There are small lenses of limestone in the Hodgkinson Goldfield, and intraformational fragments in the conglomerates. The limestone is white or light grey, microcrystalline, and massive, and commonly contains a few fossils. It is probably a biohermal rock.

Minor amounts of very dark grey clay-rich arenites, and sandy and silty mudstones with an ash-like appearance are found in many parts of the formation, particularly in the east. They comprise beds from 3 inches to at least 10 feet thick, but are commonly from 1 to 2 feet. In some, the sand fraction (which may be quartzose, e.g. near Maytown) is dominant, with a subordinate clay matrix in the pore spaces. In most, however, especially in the east, dark clay is predominant, with scattered grains of silt, sand and pebbles.

A little completely unstratified sediment is also present. The faint internal structures and the texture indicate a violent mode of formation rather than deposition by grain settling. In the east, this rock type commonly contains horizontally aligned or disoriented and bent intraformational slivers of shale and balls or swirl structures of coarse detritus; deformed lamination was noted in one outcrop at Nob Point, north of Cooktown. Pull-aparts were noticed in thin beds near this rock type 20 miles northwest of Mareeba. Mica flakes are prominent among its sand-sized detritus (biotite is more common than in other arenites), and are commonly not parallel to the main stratification, but may have no preferred orientation. Very commonly this unsorted sediment contains strap-like plant remains, including *Leptophloeum australe* and cf. *Protolepidodendropsis*, in many places carbonized. Similar plants are found in the unsorted sediments at the top of many of the turbidites. An analysis of an 18-inch bed from south of the Mitchell River appears in Table 2. It does not contain plant remains, but is notably rich in potassium, water, and carbon. Its microtexture corresponds to that of greywacke as described by Fischer (1933). The structures, texture, and setting indicate that it is a slide deposit, but there is no field evidence of affinity with the turbidites. It is the only direct field evidence, in the Hodgkinson Formation, of large-scale mixing of mud with moderately coarse detritus.

TABLE 2: CHEMICAL ANALYSES, HODGKINSON FORMATION, NORTH QUEENSLAND

	1	*2*	*3*
SiO_2	65.80	74.80	49.90
Al_2O_3	15.60	12.60	15.40
Fe_2O_3	1.08	0.36	1.75
FeO	4.11	2.66	9.39
MgO	1.65	0.93	6.29
CaO	1.24	0.97	7.47
Na_2O	1.25	3.75	4.25
K_2O	3.50	1.70	0.13
H_2O-	0.50	—	0.04
H_2O+	3.50	1.38	3.10
CO_2	0.51	0.05	0.04
TiO_2	0.59	0.40	1.93
P_2O_5	0.12	0.07	0.18
MnO	0.05	0.05	0.15
C	0.31	—	—
Total	99.81	99.72	100.02

1. Unsorted arenite with muddy matrix. Nychum Creek, a tributary of Big Watson Creek, 15 miles north of Nychum homestead. Analyst, AMDL. M11.
2. Massive micaceous greywacke, Mount Holmes area, Desailly Range. Analyst, AMDL. M244b.
3. Green metavolcanic rock, probably spilite, Cannibal Creek area. Analyst, AMDL. 1995.

Other rare sediments include a 2-inch (slaty) silty mudstone, containing dark pelite flakes, and, in the type area, a blocky hackly mudstone rich in small subcylindrical to nodular pieces of white limestone, which probably represent solitary corals in situ.

A magnetite-tremolite quartzite was found along the Palmer River east of Byerstown, and magnetite-bearing quartzite has been described by Morgan (1964, unpubl.) from the Byerstown Range. In the magnetite-tremolite rock, the arrangement of the iron oxide dust suggests replacement of an unknown mineral by quartz. The rock is a fine-grained mosaic of quartz, with idiomorphic magnetite crystals, fine iron oxide, and clustered needles of light green tremolite.

The Turbidites in the Hodgkinson Formation

Turbidites are defined as beds possessing a combination of structures that can be ascribed to deposition from a sediment-laden density current (Kuenen, 1957a). Such rocks are common in the Hodgkinson Formation, and comprise a variety of sedimentological types. Most are thin-bedded and medium-bedded greywackes; others are partly gritty and pebbly, and many of the thin beds are largely silty. Many of the thick sandstone beds are fairly well sorted, homogeneous, and unstratified, but in good exposures they show slight grading with distinctly coarser bands at the base, and wavy, cross, and convolute laminations at the top. However, not all of the thin, medium, or thick-bedded sediments are turbidites, and some of the thin fine-grained sandstone and siltstone sequences resemble the tidal and other littoral and neritic deposits figured by van Straaten (1959). The greywacke-conglomerate (which is rarely graded), intraformational breccia, and massive sandstone appear to occupy a fringing relationship to the turbidites.

Turbidite structures are best developed in the thin and medium-bedded fine to coarse-grained greywackes; they include grading, bottom structures, cross-lamination, convolute lamination, and other bedding structures.

Grading is commonly well developed in the thin and medium-bedded turbidites, in which it is nearly continuous throughout each bed. Very thin laminae (less than half an inch thick) are apparently too thin to show grading, and the thick beds are generally ungraded in their bulky middle sections, if graded at all. Sharply discontinuous grading at the base is common, however, even in the thin and medium-bedded turbidites: the basal unit consists of a thin, usually lenticular or even discontinuous layer of clean coarse gritty or pebbly sand, in places occupying only the depressions, probably scour channels, in the substratum. The thin basal unit is overlain by the more gently graded, usually darker, and more muddy sediment, with a sharp decrease in grainsize.

Truncation of tops is common, but double grading is rare.

Bottom structures include sole markings, ripple marks, loadcasts, and the like. Sole markings are generally found in medium and thick-bedded turbidites; they are not common in the Hodgkinson Formation, and consist almost exclusively of flute casts and groove casts (Pl. 2, fig. 2), and some slightly fluted groove casts. The markings are subparallel within small vertical intervals. In most places between Stannary Hills and the St Georges River where the sequence is fairly coarse, the sole markings indicate sediment transport oblique to the trend of the basin; and,

along the western margin of the formation south of the Mitchell River, the direction indicated is commonly roughly northeast, away from the probable margin of the basin. Elsewhere they may indicate the location of rising areas within the basin, from which detritus was being shed.

Ripple marks are not common, but some were seen along the St Georges River. Observed amplitudes range from a quarter of an inch to 1 inch, and the wavelength from 2 to 6 inches. Most are of the current-ripple type (Fig. 7d), but an oscillatory ripple mark was also observed (Fig. 7c).

Load casts are common, though not well developed: the lutite 'matrix' of the formation seems to have been fairly strong and coherent at or near its depositional surface (Fig. 7b). Discontinuous layers of lenses or muddy balls of grit or sand are a conspicuous feature of the lutite within a quarter of an inch of the base of some of the thin turbidite beds. In places, only a few grains are entrained in the substratum, which may be locally disturbed on a small scale. There is clear evidence in places of penetration and incipient stripping of the thin uppermost layer of the clayey top of the substratum below some of the thin sandy turbidites (Fig. 7a), but the preservation of large angular fragments of shale in the breccias and greywackes in Mount Mulligan Creek and elsewhere demonstrates that much of the lutitic substratum was relatively strong and coherent.

Cross-lamination is generally best developed in the thin and medium-bedded turbidites, in which it is usually restricted to the fine sandy and silty upper middle parts (Fig. 7b). In a few outcrops, horizontal lamination or coarse cross-lamination is preserved in the body of a thick fairly clean arenite, for example in some of the thicker turbidites of the Desailly Range, and in the quartzose turbidites south of the confluence of the Palmer and South Palmer Rivers. In the Palmer River locality it is generally confined to the upper, fairly clean, medium-grained parts of the beds, and comprises sets up to 4 feet long and from 6 to 12 inches thick.

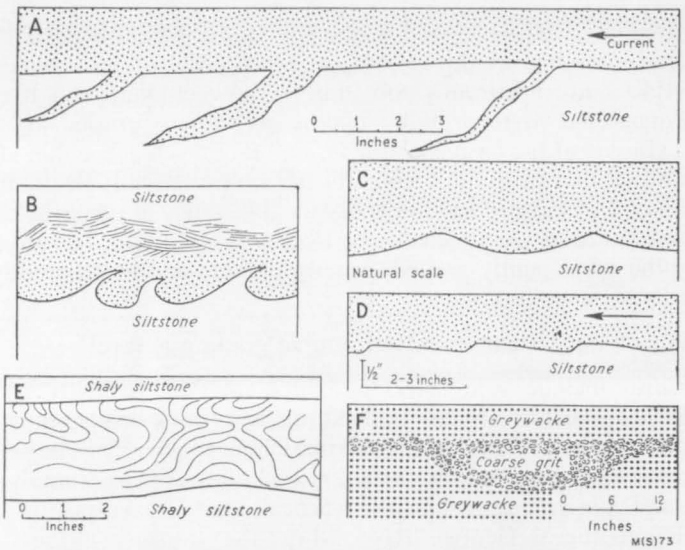


Fig. 7. Hodgkinson Formation: bedding structures.

The lamination in the thin fine-grained turbidites and doubtful turbidites is mostly wavy and subhorizontal, but there is considerable regular cross-lamination, and some convolution. The cross-laminated sets generally range from a quarter to half an inch thick and are usually lenticular; they are commonly enclosed between wavy laminations. The complete cross-laminae are seldom preserved: most of them are truncated at the top, and the topsets and part of the foresets are missing. This facilitates determination of the facing of the beds. The preservation of complete cross-laminae only in the lutitic parts of the sequence, where thick turbidites are absent, indicates that the lutite was deposited in relatively quiet conditions, probably on a nearly flat seabed.

The truncated sets of cross-laminae are usually overlain by finer deposits at the top of the turbidite bed, which in places are also cross-laminated. Near Maytown, however, some truncated sets appear to be directly overlain by normal (non-turbidite) lutite. These slightly different features indicate different degrees of current competence depending on the load and slope.

Convolute lamination (ten Haaf, 1956) was seen only in medium and fine-grained turbidites between 2 inches and 3 feet thick (Fig. 7e). Some exposures exhibit asymmetric over-steepening of the ridges, and in most examples the inferred slope or current direction could be confirmed by the orientation of cross-laminae in the same turbidite, or in an adjacent bed.

Miscellaneous Bedding Structures. The presence of shale slivers in the turbidites and thick greywackes probably indicates a fairly coherent muddy sea floor. The few calcareous turbidites in and near the type area commonly contain small rounded clay pellets, but elsewhere the turbidites and other greywackes contain angular shale fragments, up to 6 inches long. In the St Georges River, one of the intraformational breccias is so crowded with large blocky fragments of shale that the gritty and pebbly matrix is in places merely interstitial, and was apparently injected between the blocks and slivers of shale as the substratum broke up. In the Desailly Range, the margins of large shale fragments in one of the conglomeratic greywackes are studded with rounded pieces of quartzite and other pebbles and granules, which have evidently been pressed into the plastic surface of the inclusions during the brief but violent process of its incorporation in the coarser sediment.

Slump structures, mostly fairly small-scale, are moderately common. Beds from 2 to 4 feet thick, displaying chaotic slump structures in thin-bedded turbidite/lutite sequences, and truncated at the top of the bed, were seen in the type area. The irregular minor folding in many of the bedded cherts is probably also a slump effect (cf.p. 124).

Notes on Some Turbidite Current-directional Structures

In areas where the Hodgkinson Formation consists predominantly of lutitic sediments the cross-laminae in the thin turbidite beds usually provide the only means of determining palaeocurrent directions. Where the turbidites are all very thin and fine-grained, the current directions tend to vary considerably from bed to bed, whereas in sequences of slightly thicker and coarser turbidites, from 1 to 4 inches thick, the current directions tend to be constant in successive beds. This has already been noticed in other parts of the world (Kuenen, 1958).

In several bedded sequences, directional sole markings are also present. In several localities, the current direction indicated by the sole markings tends to be oblique to the regional trend of the basin, whereas the current direction indicated by cross-lamination is more commonly parallel to the trend. This contrast has been discussed by Knill (1959), and Kuenen (1957b, 1958) has pointed out the preponderance of longitudinal transport in flysch basins.

However, exceptions to the longitudinal transport direction are known (e.g. in Portugal, MacGillavry, 1961), and in the Hodgkinson Basin the sole markings and coarse cross-lamination in the relatively thick turbidites indicate appreciable transport normal or oblique to the trend of the basin, probably from the source of the detritus. In the St Georges River area (Fig. 7f) a scour channel normal to the trend of the basin was also noted. The directions indicated by the sole markings and coarse cross-lamination probably indicate the most important current directions, which in this case were chiefly away from the southwestern margin of the basin and from the rising centres south of Uhrstown and in the upper St Georges River and Desailly Range area. The strong heavily laden curents entering the basin would have lost much of their force and load by the time they reached the deeper or distal parts of the basin, and would turn parallel to the regional trend, along the already established troughs (e.g. along the McLeod Hills). In the thinner deposits in the

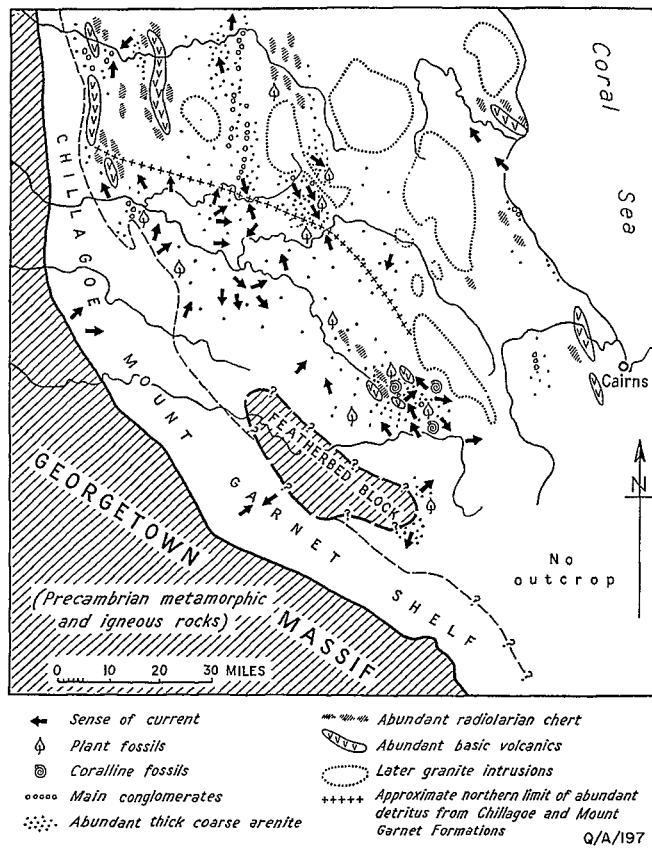


Fig. 8. Sedimentation features in part of the Hodgkinson Basin.

deeper and distal parts of the basin there are no sole markings, but only the more delicate cross-laminated structures.

The palaeocurrent directions shown on Figure 8 have been obtained by 'unwinding' the folded beds about their present strike only. This reconstruction is approximate only, and in many cases may be unreliable because of the complicated structures due to successive phases of folding (cf. pp 119 et seq.). The local sequence is generally not known, and in most cases the apparent conflicts in current directions may be due to non-contemporaneity. Where currents flowed along an intrabasin trough, slight earth movements might have been sufficient to reverse the current directions. Where the sea floor was almost level, the direction of weak currents may have varied, and such conditions appear to have prevailed in some of the very thin-bedded parts of the sequence, e.g. in the west, north of the Mitchell River, and south of Mount Mulligan (where complete untruncated sets of cross-laminate are preserved).

Notes on the Composition of the Turbidites

The turbidites generally consist of the same type of detritus as the other arenites (p. 35), but the proportions may be different. The cement, where present, is probably chloritic rather than quartzose, except in the coarser cleaner types, or in the basal parts of the beds. In the quartzose turbidites south of Uhrstown, on the Palmer River, and around Maytown and Cape Bedford both the detritus and cement are exceptionally rich in quartz.

A small proportion of the turbidites is calcareous. In the south, particularly, it is common to find a single thin calcareous bed (which weathers a conspicuous orange-red) among a series of normal non-calcareous beds. The calcareous beds are commonly ill defined and any shale fragments present tend to be darker and more rounded than usual. The thicker calcareous beds, some of which are turbidites, are usually slightly darker and more clayey than the normal clean arenite, and the carbonate tends to be concentrated in ellipsoidal bodies, up to a foot long, in the upper parts of the beds. The thin-bedded medium-grained turbidites around Molloy and near the Mitchell River north of Mount Mulligan contain numerous scattered euhedral cubes of pyrite up to half an inch across.

Many of the plant-bearing horizons occur in the finer-grained silty unsorted tops of the turbidites, particularly around the type area.

Palaeontology and Age of the Hodgkinson Formation

Plant remains (generally carbonized) and impressions are the most common fossils in the formation. Unidentifiable stem fragments are particularly abundant to the north of Wolfram Camp. The most common identifiable species is *Leptophloeum australe* (M'Coy) (White, 1961b, unpubl.; Woods, 1961a, unpubl.) found to the west of Stannary Hills, north-northwest of Dimbulah, in Desailly Creek, and on the Mulligan Highway in the Desailly Range. White (1959, unpubl.) has also identified a psilophyte stem from 12 miles northwest of Dimbulah, and Woods (1961a, unpubl.) has compared one form in a collection of indeterminate lycopod fragments from Carroll Creek, 18 miles northwest of Cooktown, with *Protolepidodendropsis* or a related genus found in 'presumably Upper Devonian sediments of

the Dotswood area' several hundred miles farther south. Both White and Woods consider that the plants are probably Upper Devonian, and do not range into the Carboniferous.

Limestone lenses and intraformational fragments containing corals have been mostly found in and around the type area, but a useful collection has also been made from the smaller limestone outcrop 22 miles southwest of Cooktown. Some brachiopod valves were also found. The fossils have been described by Jack (1884), Etheridge (*in* Jack & Etheridge, 1892), and in recent unpublished reports by Hill (1961a,b, and pers. comm.); they are listed in the Appendix. The limestone lens near the confluence of the Mitchell and St Georges Rivers contains crinoids, rugose corals, and *Alveolites*(?) sp., unfortunately rather crystallized.

Reid (1930) has suggested that Etheridge's determinations indicate a Devonian rather than a Carboniferous age, and Hill (1961a,b) considers that the fossils in the Cooktown locality indicate affinities with late Eifelian Stages in Europe.

A spiriferid brachiopod (J. J. Veevers, pers. comm.) was found in slate 12 miles northwest of Dimbulah, and various tracks and trails have been found in slate at four localities near the southwest margin of the basin between Stannary Hills and the Mitchell River. The best preserved is the open-planispiral form cf. *Spirodesmos* Andree, 1920, found in Eureka Creek 150 yards upstream of the derelict Stannary Hills railway station; a coarser, ornamented form was noted at the junction of the Mitchell and St Georges Rivers.

The presence of Middle Devonian corals and Upper Devonian plants in the same coarse parts of the formation, which Lucas considers to represent the upper part of the section, has not yet been explained. The coralline limestone fragments may have been derived from earlier sediments and some of the big limestone lenses may represent exotic blocks that glided bodily down the slopes in the Upper Devonian sediments. It is also possible that the range of the fossils is greater than indicated. Jack (1884) placed the age of the Hodgkinson Formation between the Star beds and Reid beds, which occur west of Townsville. He therefore considered them to be Carboniferous, but in 1892 he correlated the Hodgkinson Formation with the Permo-Carboniferous Gympie beds. Ball (1917a) concluded that they could not be younger than Carboniferous because they are unconformable under the Permian Mount Mulligan Coal Measures, and Jensen (1920) considered them to be Devonian. Subsequent investigators have confirmed the Devonian age (Reid, 1930; Mary White, 1960, 1961a,b, unpubl.; Hill, 1961a,b, unpubl.). It is possible that *Leptophloeum australe* (M'Coy) ranged into the Carboniferous, but according to Mary White (pers. comm.) the Upper Devonian age of all the eastern Australian and most of the western Australian occurrences has now been established.

Sedimentation and Palaeogeography of the Hodgkinson Basin

The Hodgkinson Formation has the characteristics of a flysch deposit (Tercier, 1948): it is a thick and relatively extensive, monotonously uniform, poorly fossiliferous, geosynclinal accumulation of rhythmically bedded arenites and lutites which were subjected to orogenic deformation soon after deposition, and perhaps in part during deposition. The arenites are dark grey and commonly graded, and show other turbidite structures. Subordinate rock types include chert and siliceous shale, commonly associated with basic volcanics and greenschist; limestone is rare. Sub-

division of the flysch sediments is almost impossible because of the lack of fossils and marker beds.

The Hodgkinson Formation is a sequence of marine sediments laid down in a varying depositional environment. Much of the sandy detritus was deposited by turbidity currents, and the thick greywackes, greywacke-conglomerates, and intraformational shale-pebble conglomerates may be fluxo-turbidites, which are transitional between turbidites and slump deposits; they are commonly found at the base of the marginal slope.

Turbidites are generally considered to be infraneritic or bathyal deposits (e.g. Kuenen, 1958b). A few authors consider that some flysch deposits were formed in shallow water (Mangin, 1962, 1964; Wassojewitsch, 1959), but, although the existence of shallow-water fluviomarine turbidites is now accepted, some authors claim that they do not resemble flysch deposits (Bouma & Brouwer, 1964). In other words all flysch deposits are turbidites, but not all turbidites are flysch deposits (Nesteroff & Heezen, 1963; and others). According to Lucas, the current-directional turbidites in the Hodgkinson Formation show that there was generally an appreciable bottom slope throughout the basin, which indicates that it was of considerable depth in places. Evidence of shallow depth of deposition is very scarce, and includes the oscillatory ripple marks in the St Georges River, a scour channel in the same river (Fig. 7f), and the corallogene limestone southwest of Cooktown and in the Hodgkinson Goldfield. Some of the limestone, however, such as the lens at the confluence of the Mitchell and St Georges River, may be 'olistostromes' or 'olistoliths' — huge exotic blocks which have moved down the continental slope by gravitational sliding (cf. Kuendig, 1959; ten Haaf, 1957). Such blocks may reach a size of several square miles.

The depth of deposition of the shale, siliceous shale, radiolarian chert, and associated basic volcanics is uncertain. They are commonly thought to be deep-water deposits, but there is little supporting evidence. In the Chillagoe shelf deposits, chert and basic volcanics occur in association with biothermal limestone, and the association may be controlled by geochemical conditions rather than depth of deposition (Routhier, 1964); a scarcity of detritus due to the great distance from the source, and perhaps to the elevated position on the geanticline may be contributory factors.

The presence of shale and chert suggests slow deposition, under pelagic conditions, but rapid deposition is indicated by the turbidite structures such as convolute lamination and load casts, and the presence of fresh detrital feldspar and of conglomerate bands with no sharply defined top and bottom planes. Well developed current-directional turbidite structures on the southern and southwestern margins of the Hodgkinson Formation demonstrate the existence of heavily laden currents flowing away from the margin of the basin (Fig. 8). This feature, and the lack of outcrops to the west of the main boundary, suggest that the present southwestern boundary corresponds roughly to the original boundary of the Hodgkinson Basin. The nearness to the coast and the shallow depth of the sea are indicated by the presence of lenses of coralline limestone and intraformational limestone fragments, the abundance of coarse sediment and fluxo-turbidites, and the abundance of plant remains. The composition of the coarse detritus also suggests the presence of a nearby landmass to the south and west; the greywackes and

conglomerates contain appreciable amounts of rock and mineral fragments including chert and rounded pebbles of limestone containing *Heliolites* sp., derived from the Chillagoe and Mount Garnet Formations to the south and west, or fragments of quartzite, quartz with sillimanite needles, muscovite, granite, mica schist, tourmaline, and garnet, derived from the Precambrian basement.

In the northeast, towards the centre of the geosyncline, there generally appears to be a slight decrease in the ratio of coarse sediments to lutites from west to east. This feature is most noticeable in a zone extending from the Hann Tableland to the north-northwest along the regional strike, but fading out southwest of Cooktown.

In the coarse greywackes and greywacke-conglomerates farther west (e.g. in the area between the Palmer and St Georges Rivers, and in the Desailly Range) the pebbles and mineral fragments consist mostly of muscovite granite, quartzite, vein quartz, schist, and other rocks that were probably derived from the Precambrian basement; pebbles and fragments from the Chillagoe and Mount Garnet Formations are scarce. No Precambrian rocks are exposed in the area, and the source of the pebbles and mineral fragments is uncertain, unless the material was transported by strong currents from the Precambrian shield far to the west, but the absence of fragments from the Chillagoe Formation suggests that this is unlikely. Perhaps the Precambrian basement was exposed temporarily in geanticlines which later subsided and were covered by flysch sediments.

The presence of numerous plant fossils in the Desailly Range, and the distribution and composition of coarse conglomerate beds between the Palmer and St Georges Rivers east of the Cannibal Creek granite, suggest that a tectonic ridge of Precambrian basement was present at one stage. This is a common feature in geosynclinal basins, where '. . . flysch cordilleres have a disconcerting tendency to vanish into thin air' (Trumpy, 1960, p. 891). It is possible that such basement ridges were formed along great fault zones.

Lucas considers that the coarse-grained sediments occur higher in the succession than the lutites, whereas de Keyser feels that the distribution of the coarse and fine-grained deposits varied from place to place as well as in time; it is difficult to correlate the beds in different parts of a geosyncline, as the 'incidence of coarse units (turbidites) may vary greatly spatially' (Crook, 1959). There probably are lutitic sequences at the base of the succession, but they may be of the same age as the older Chillagoe and Mount Garnet Formations (see p. 52).

Stratigraphic Relations of Hodgkinson Formation to Adjoining Older Formations

The inclusion of Precambrian metamorphic rocks and mineral fragments in the greywackes and conglomerates of the Hodgkinson Formation indicates the presence of an unconformity, but it is nowhere exposed.

The presence, in these same coarse sediments, of fragments of chert and limestone from the Chillagoe and Mount Garnet Formations suggest that they may be unconformable or disconformable with the Hodgkinson Formation, at least in the south and southwest; farther out in the geosyncline the Upper Silurian to Upper Devonian sediments are probably conformable (F. de K.). White (1961) has established an unconformity between the Silurian and Devonian units farther south, in the Kangaroo Hills and Wairuna districts outside the map area. It would

be difficult to prove this unconformity in the Hodgkinson Basin, where the boundary between the Mount Garnet and Hodgkinson Formations is not sharply defined (see also Blake, 1968, unpubl.), and is mostly overlain and penetrated by Permo-Carboniferous igneous rocks.

It seems likely that even if an unconformity exists in the south, the formations become disconformable and finally conformable farther north, where fragments of the Chillagoe and Mount Garnet Formations become scarce in the Hodgkinson Formation. Moreover, the Mount Garnet facies, which is a predominantly clastic shelf facies, disappears towards the north, and this is regarded as supporting evidence for the gradual change from the postulated unconformity in the south to the conformable relationships in the north.

The area now occupied by the Featherbed Volcanics may have been the site of an elongated faulted inlier of crystalline Precambrian rocks separating the Chillagoe and Mount Garnet shelf in the southwest from the Hodgkinson Basin in the northeast (Fig. 8). The evidence for his hypothesis is as follows:

1. The presence of a faulted inlier of Precambrian rocks at Stannery Hills (K.G.L.). However J. W. Smith and K. Yates (pers. comm.) consider that the Precambrian age of the outcrop is doubtful.

2. In the Mount Garnet Formation near Almaden there is evidence of sediment transport from the Featherbed block.

3. The presence of Permo-Carboniferous granites (Herbert River and Elizabeth Creek Granites), acid volcanics (Featherbed Volcanics), and cauldron subsidence structures, all of which are generally confined to the Precambrian shield to the south (Branch, 1966).

4. The curvature of the regional strike around the southeastern end of the Featherbed Volcanics. As the volcanics are later than the Hodgkinson Formation, the curved structure was most likely due to the presence of some pre-Devonian bastion underlying the Featherbed Volcanics.

5. The coarseness of the sediments and the abundance of plant remains in the Hodgkinson Goldfield and north of Wolfram Camp indicates the presence of a nearby source area, and the composition of the greywackes indicates a predominantly metamorphic derivation.

Barron River Metamorphics

Derivation of the name: the Barron River at Cairns.

Type area: the environs of Cairns.

Whitehouse (1930) first used the term Barron River Series for the low-grade metamorphic arenites and lutites in the Cairns area. They were subsequently designated the Barron River Metamorphics on the Geological Map of Queensland (1953), on which they are shown as a strip, about 20 miles wide, extending along the coast from Cape Melville in the north to Ingham in the south. Recent mapping has shown that their areal extent is considerably less than shown on the 1953 map.

The Barron River Metamorphics consist of slate, phyllite, sericite schist, recrystallized arenites (mainly greywacke), thin-bedded weakly metamorphosed siltstone, and subordinate bedded chert and greenschist; there are rare lenses of

recrystallized limestone, ultrabasic rocks (talc schist, tremolite-chlorite schist, etc.), and a few greywacke-conglomerates. Thin sections of some of the rock types are shown in Plates 4 and 5.

The clastic rocks are grey to dark bluish grey when fresh, weathering to rusty brown, yellow, and pink. Bedding structures are difficult to detect because of the strong deformation and deep weathering. Some of the thin-bedded siltstone and fine-grained sandstone shows graded bedding (Plate 3, fig. 1). Quartz veining is common, particularly in the postmetamorphic belts of shearing at Etty Bay and Mourilyan Harbour (p. 125), where older quartz veins parallel to the original schistosity have been granulated and transposed by the later shear folding, and a younger group of undeformed quartz veins cuts across the folded and sheared rocks.

The grade of metamorphism is nowhere higher than the quartz-albite-epidote-biotite subfacies of the greenschist facies, and in places is lower still. The phyllite and sericite schist are composed of quartz and sericite with small amounts of chlorite, biotite, and feldspar, and a little tourmaline, apatite, zircon, iron oxides, and leucoxene. The arenites consist of quartz, potash feldspar, plagioclase, muscovite, biotite, and rock fragments. Recrystallization of the quartz-mica matrix has caused some crenulation of the clastic grain boundaries, but in hand specimen the arenites are the least metamorphosed in appearance. The greenschists consist of combinations of albite, chlorite, epidote, actinolite, sphene, and magnetite. Greywacke-conglomerate is exposed along the Cook Highway north of Cairns, and at Port Douglas. It contains the same kind of detritus as the Hodgkinson conglomerates; granitic and quartzose granules derived from the Precambrian basement, intraformational(?) fragments and pebbles of limestone containing crinoid fragments, and shale.

The outcrops of the Barron River Metamorphics are generally deeply weathered, and fresh exposures are found only in the rejuvenated sections of the streams running off the tablelands to the coast, and along the coast.

Relationship between Barron River Metamorphics and Hodgkinson Formation

Before 1960, the contact zone between the Barron River Metamorphics and the Hodgkinson Formation had not been mapped owing to the rugged topography and dense tropical vegetation. The boundary of the Geological Map of Queensland (1953) is arbitrary and largely coincides with alluvium boundaries and the western edge of the tropical rain forest. In the forested eastern zone the rocks are deeply weathered and decomposed to soft clay, which contrasts strongly with the oxidized and indurated exposures in the drier inland areas. The differences in type and intensity of weathering explains why the eastern and western sequences have been considered as separate units, probably of different age. Thus the idea prevailed that the region shown as Barron River Metamorphics on the Geological Map of Queensland formed a highland area during the Devonian sedimentation. Hill (1951) defined the North Coastal High as a structural eminence on the eastern side of the Hodgkinson Trough, and White (1961) suggested that the 'Early Palaeozoic' Barron River sediments 'were folded to form a major geanticline and finally emerged as land' before or during the Hodgkinson sedimentation. Finally, Brooks (1960) correlated the Barron River Metamorphics with the early Palaeozoic Neranleigh-

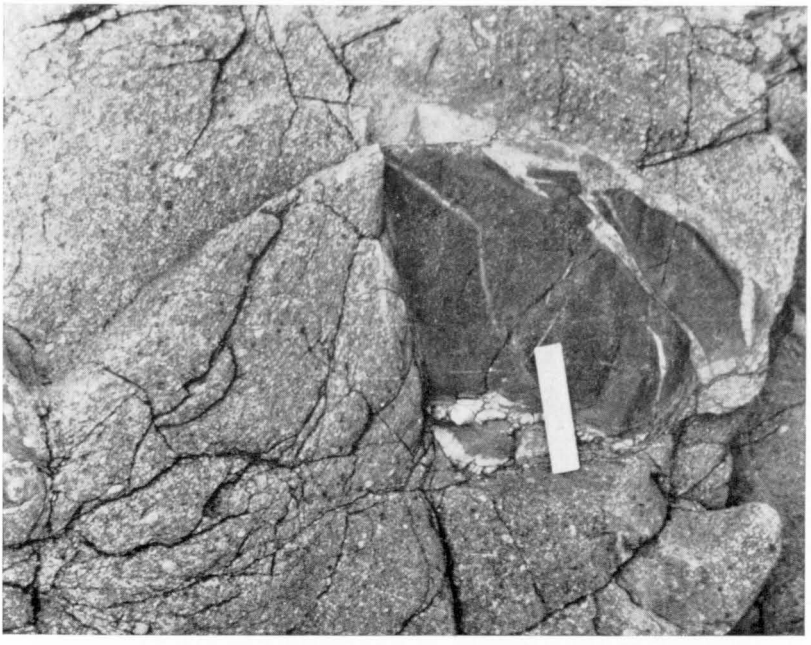


Fig. 1. Dargalong Metamorphics. Inclusion of amphibolite (dark grey) in orthogneiss which shows various stages of contamination. Fox Creek, near Palmerville.

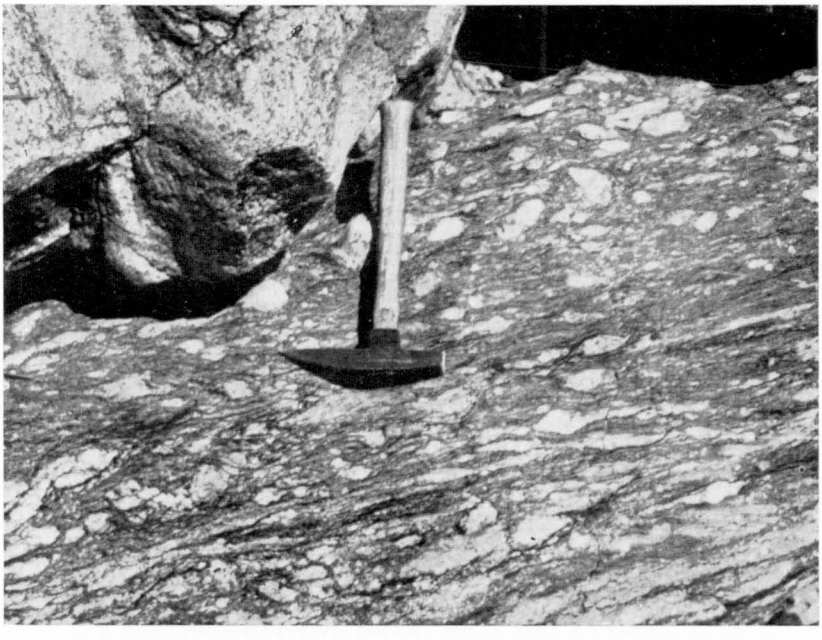


Fig. 2. Dargalong Metamorphics. Augen gneiss, Muldiva Creek.

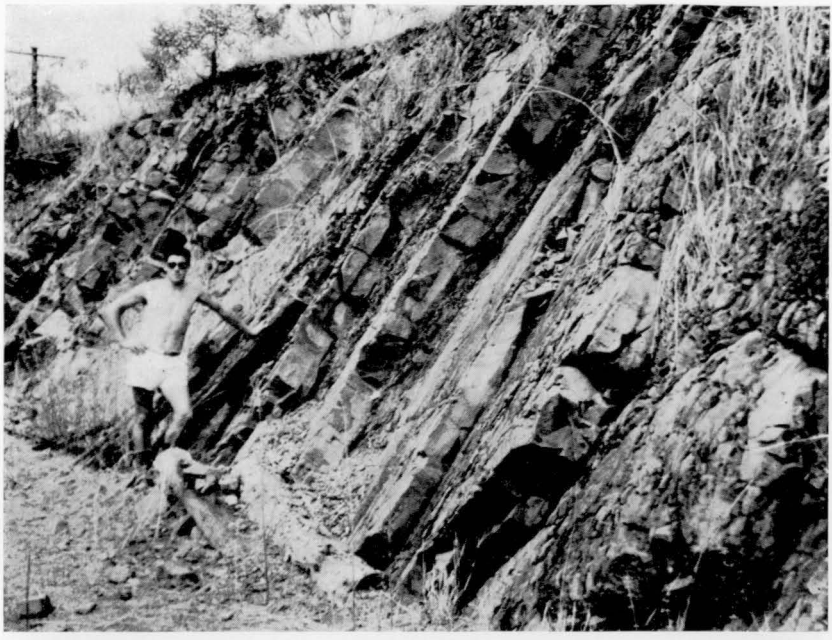


Fig. 1. Hodgkinson Formation. Typical section of bedded greywacke and siltstone. Sense of graded bedding shows strata to be overturned. Railway cutting at Mount Mulligan.

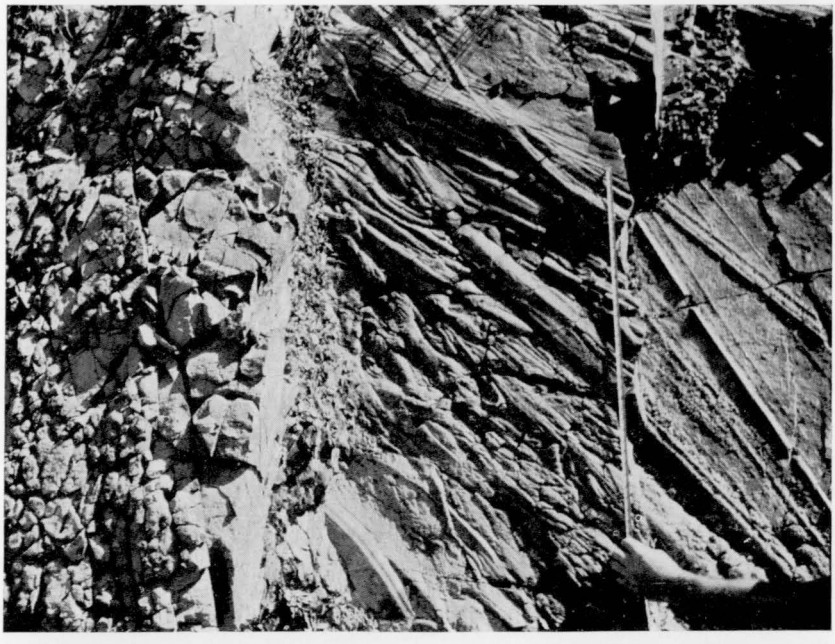


Fig. 2. Hodgkinson Formation, same locality as Fig. 1. Frontal view showing the overturned bases of three different beds, with groove casts and flute (?) casts.

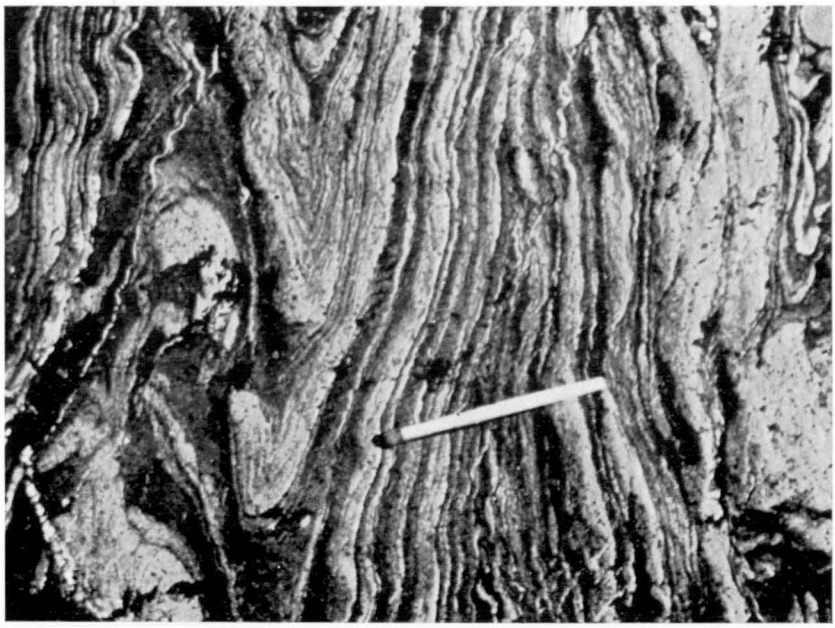


Fig. 1. Barron River Metamorphics. Folded graded thin-bedded sandstone-siltstone sequence, Mulgrave River area. B_2(?) folding incongruously transected by S_3 cleavage (parallel to the match).

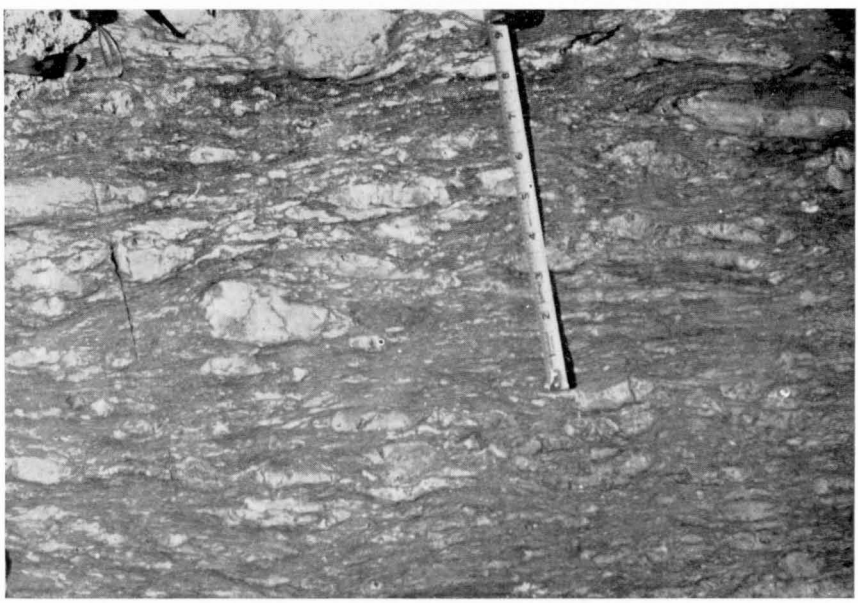


Fig. 2. Hodgkinson Formation. Pseudo-conglomerate formed by incomplete transposition along S_3 cleavage. Daintree River.



Fig. 1. Barron River Metamorphics: microplicated schist, Etty Bay.

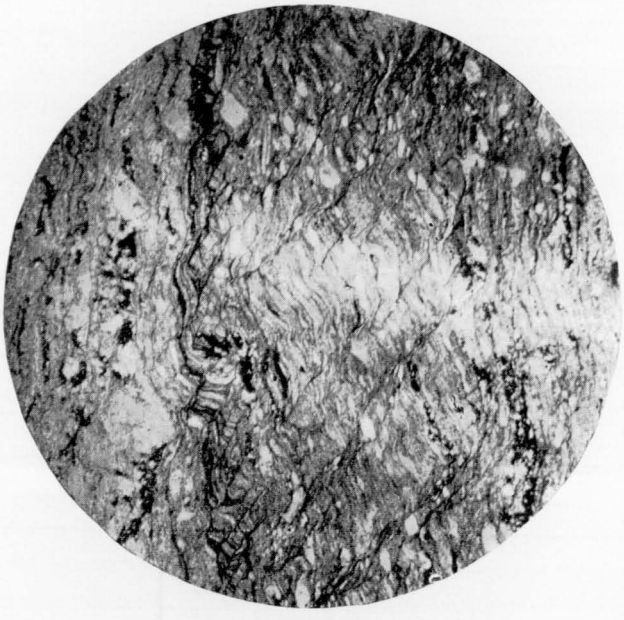


Fig. 2. Barron River Metamorphics(?) — phyllite showing strain-slip cleavage across the original bedding cleavage. Daintree River.



Fig. 1. Barron River Metamorphics: siltstone showing a new schistosity developing across the original bedding-plane schistosity. Clam Shell Falls area, Gordonvale.

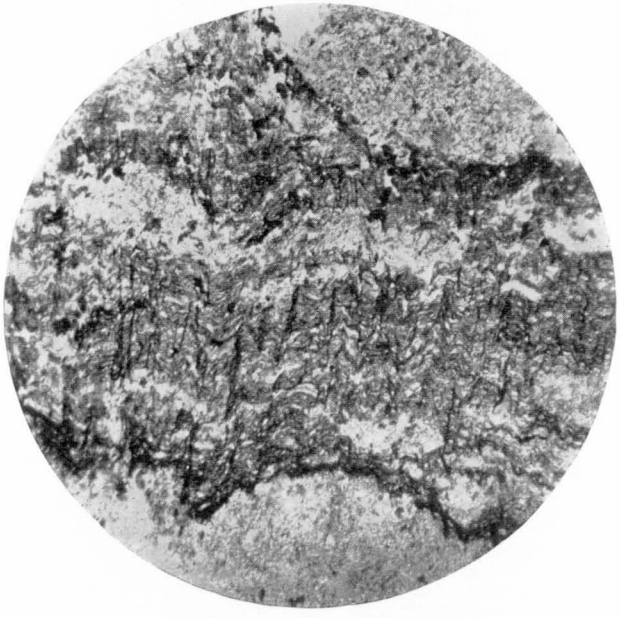


Fig. 2. Barron River Metamorphics: phyllitic siltstone showing strain-slip cleavage across the original bedding-plane cleavage. Mulgrave River area.

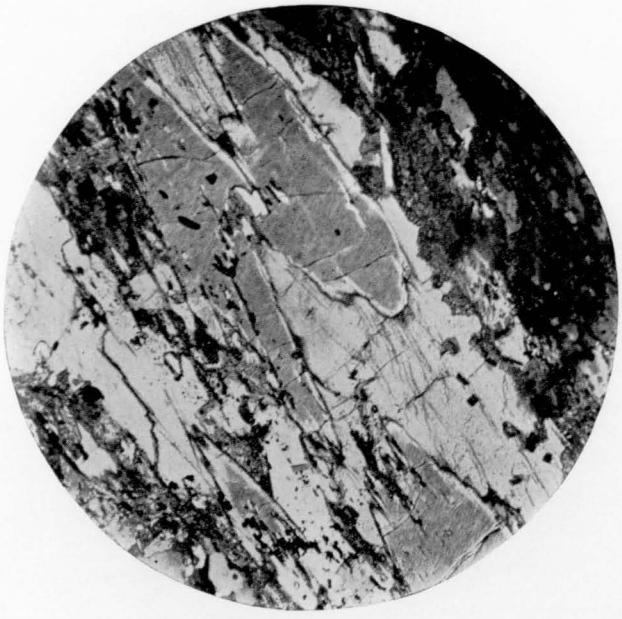


Fig. 1. Barnard Metamorphics. Sillimanite-andalusite intergrowth. Andalusite probably replacing sillimanite. Russell Island.

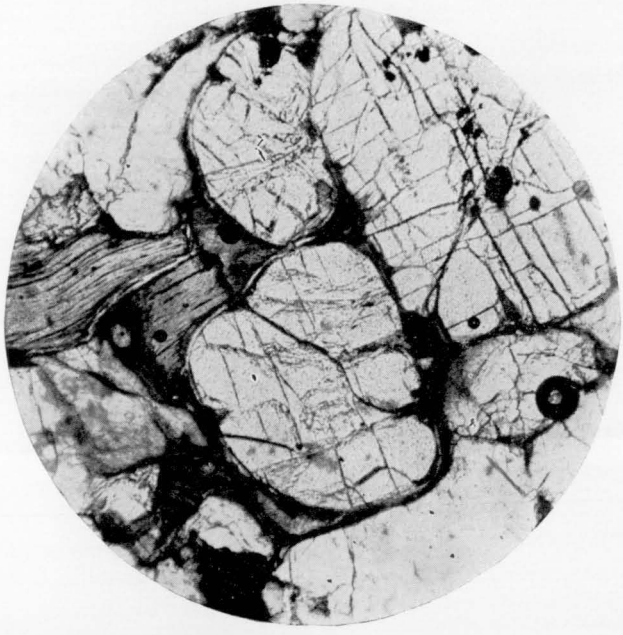


Fig. 2. Barnard Metamorphics: Andalusite with fuzzy rim of fibrolitic sillimanite. High Island.



Babalangee Amphibolite

(a) Undeformed, normal specimen, composed of hornblende (H) and altered plagioclase (P).
(b) Somewhat sheared specimen. Note granulation of hornblende, formation of actinolite (A), and development of oriented texture.
(c) Strongly sheared specimen transformed into actinolite-quartz schist with remnants of green hornblende.



Fig. 1. Amygdaloidal basalt, Nychum Volcanics, southeast of Mulgrave homestead.



Fig. 2. Sheared and crushed granite at Babinda. Note broken plagioclase crystal, drawn-out biotite, and laminated flows of crushed granulated rock.

Fernvale Group of southeastern Queensland because of lithological similarities and the coincidence of the regional strike.

The mapping carried out since 1960 has shown no fundamental differences between the Hodgkinson and Barron River rocks, and de Keyser (1965) concluded that the Barron River Metamorphics are the weakly metamorphosed equivalents of the unmetamorphosed Hodgkinson Formation (probably with the inclusion of late Silurian to early Devonian sediments), and hence are largely of Devonian age. Both units consist mainly of greywacke and lutite with subordinate bedded chert, basic volcanics, and rare lenses of limestone, in about the same proportions in each formation. No angular unconformity has been detected in the field, and there are no changes in lithology or occurrences of basal conglomerate which could indicate the presence of an unconformity. Furthermore, there appears to be a gradual transition from unmetamorphosed Hodgkinson sediments in the west to low-grade Barron River Metamorphics in the east, and the metamorphic boundary cuts across the regional trend-lines. The ill defined and arbitrary boundary between the Barron River Metamorphics and the Hodgkinson Formation represents a metamorphic isograd rather than a stratigraphical boundary; isolated patches of weakly metamorphosed rocks exist in the Hodgkinson Formation, especially along the coast, and zones of virtually unmetamorphosed rocks are present in the Barron River Metamorphics to the south and east.

The possibility that the two formations are of the same age was considered by Jack (1884), but he concluded that the western rocks 'unquestionably look newer' than the eastern rocks, and that 'if both existed side by side it is not easy to see how one escaped the metamorphism which the other underwent.' Jensen (1923) initially regarded the outcrops in the Cooktown/Molloy/Tinaroo/Herberton areas as older than his Hodgkinson Series, but thought that the rocks in the Cairns/Innisfail area 'undoubtedly belong to the Devonian belt' of the Hodgkinson beds. Later (*in* AGGSNA, 1939), he included the rocks in the Molloy/Tinaroo/Russell River area in his Hodgkinson Series, and concluded that they were deposited in a basin between the Featherbed Range and the 'metamorphic rocks in the east — the latter now represented sporadically in places of specially strong uplift in the coastal (Dividing) Range between Cairns and Cooktown'.

Barnard Metamorphics

Derivation of name: from the (North) Barnard Islands, 12 miles southwest of Innisfail.
Type area: as above.

The outcrops of high-grade metamorphic rocks along various parts of the Queensland coast were included by Bryan & Jones in 1946 in the Coastal Series, and were later renamed the Barnard Metamorphics by Jones & Jones (1956) after the Barnard Islands, where they had been first described by MacGillvray in 1852.

The Barnard Metamorphics, which are exposed along the coast from Tully to the Barnard Islands and on the Frankland Islands farther north, comprise mica schist, gneiss, migmatite, rare lenses of ultrabasic rock, and some gneissic granite, e.g. at South Mission Beach, 11 miles east of Tully.

The gneiss and migmatite on the Frankland Islands, 25 miles southeast of Cairns, show the highest grade of metamorphism (see p. 132); they are composed of quartz, orthoclase, microcline, biotite, muscovite, albite, oligoclase, andalusite, sillimanite, cordierite, and, according to Jones & Jones (1956), also kyanite. Chlorite is present as a retrogressive mineral, and tourmaline, apatite, iron oxides, zircon, and epidote are common accessory minerals. The biotite and muscovite are commonly intergrown, biotite being the later mineral. Sillimanite occurs as coarse crystals generally intergrown with (and perhaps replaced by) andalusite (Pl. 6, fig. 1), and as a fibrolitic felt. The cordierite is corroded and partly replaced by clusters of colourless and green micas. Andalusite is present as large, clear, equidimensional rounded porphyroblasts, and as intergrowths with sillimanite (Pl. 6, fig. 2).

Elsewhere, the gneiss and schist are generally composed of quartz, muscovite, red-brown biotite, some albite and more calcic plagioclase, and masses of sericite probably replacing the original feldspar. Zircon, apatite, iron oxides, garnet, and tourmaline are also present. In places the margins of the quartz grains are replaced by sericite and muscovite.

The intrusive gneissic granite at South Mission Beach consists of phenocrysts or porphyroblasts of quartz, twinned albite, mircocline, and an untwinned variety of potash feldspar, set in a granular quartz-feldspar mosaic. Brown biotite and a little dark green to blue-green sodic(?) amphibole are the mafic constituents; muscovite is associated with the biotite. The gneissic structure is due to granulation and recrystallization and is not a flow foliation. The schist intruded by the gneiss is composed mainly of masses of fine-grained pale green amphibole and pale brown biotite, with accessory quartz and pyrrhotite.

Jones & Jones (1956) have reported a talc-antigorite-carbonate rock on Kent Island (one of the North Barnard Islands), which probably represents a metamorphosed ultrabasic igneous rock.

Pegmatite veins containing quartz, muscovite, biotite, tourmaline, and feldspar are common on some of the islands and at South Mission Beach.

Thin sections of the schists and gneisses show that the Barnard Metamorphics have a complex tectonic/metamorphic history as indicated by rotated remnants of former S-surfaces, by granulation side by side with recrystallization, by the presence of minerals in more than one generation (andalusite, sillimanite), and by evidence of replacement. The unusual abundance of potash feldspar in some of the rocks is probably due to metasomatism.

The name Barnard Metamorphics has been applied to the schists, gneisses, and migmatites on many parts of the Queensland coast and island groups, from the Frankland Islands south to latitude about 26°S. (Jones & Jones, 1960), but the following discussion refers only to the outcrops in the Hodgkinson Basin.

Age and Relationships of the Barnard Metamorphics

The Barnard Metamorphics have generally been regarded as much older than the surrounding Barron River Metamorphics; they were considered to date from the Precambrian (possibly Archaean) because of their high grade of metamorphism,

which is much higher than that for example of the Precambrian Mount Isa Shale in northwest Queensland (Jones & Jones, 1956). De Keyser (1965) has argued that the Barnard Metamorphics are more probably the higher-grade metamorphic equivalents of the Barron River Metamorphics, because there is no evidence of an unconformity and no apparent differences in the original lithological composition, and because of the presence of a possible (though narrow) transitional zone from low-grade to high-grade metamorphic rocks in a road cutting about 10 miles north-east of Tully. Furthermore, the type of metamorphism (see p. 131) corresponds with one of Miyashiro's five classes of metamorphic facies series, in mineralogical composition, geological environment, and in the abrupt transition from the low-grade (Barron River) to the high-grade (Barnard) metamorphic rocks.

If the Barnard Metamorphics are the higher-grade metamorphic equivalents of the Barron River Metamorphics, they are largely Devonian (and possibly Upper Silurian) in age. A sample of the gneiss from South Mission Beach has been isotopically dated at 310 m.y. (Richards et al., 1966), or Carboniferous, which does not conflict with a Devonian age in view of the intrusive character of the gneiss, and the deformation of the rocks. It does not exclude a Precambrian age for the formation, but renders it less likely, as the intrusive gneiss and the metamorphism are probably roughly contemporaneous — Carboniferous — and therefore belong to the same orogenic period that affected the other deposits in the Hodgkinson Basin.

Babalangee Amphibolite

Derivation of name: after a small creek running off the Graham Range into the Russell River, east of Babinda.

Type area: the Graham Range, 4 miles east of Babinda.

The name was introduced by de Keyser (1964) for massive or schistose plagioclase amphibolite which probably intrudes the Barron River Metamorphics. It crops out over 9 square miles.

The Babalangee Amphibolite is intruded in the north by the Mareeba Granite, and is bounded by the Barron River Metamorphics in the south, but the contacts are concealed by alluvium.

The typical amphibolite is a massive plagioclase amphibolite with about 75 percent green hornblende, 23 percent calcic andesine, and 1 to 2 percent sphene, apatite, pyrite, and clinozoisite. The plagioclase shows polysynthetic twinning and some diffuse zoning, and is partly altered to clinozoisite and other minerals. The rock may be coarse or fine-grained, and has a nematoblastic even-grained texture in places. Where the rock is lineated, by parallel arrangement of the amphiboles, the lineation plunges at various angles to the northwest or southeast along the regional structural trend (cf. the Barron River Metamorphics at Etty Bay).

In many places the Babalangee Amphibolite is deformed, sheared, and altered along northwesterly zones (Pl. 7). During the initial shearing, the hornblende and plagioclase were granulated and the plagioclase lost its twinning; later, both minerals broke down and were replaced by actinolite, quartz, and clinozoisite. The ultimate product is a banded actinolite-quartz schist containing remnants of hornblende. Silicon-boron metasomatism during this alteration is indicated by the

abundance of quartz and the widespread distribution of tourmaline. Zoisite or clinozoisite is also common, and other minor minerals include sphene and pyrrhotite. The deformation and shearing apparently took place at a late and lower-grade stage of metamorphism during which the high-grade amphibolite assemblage was replaced by a low-grade mineral assemblage, accompanied by metasomatism. It is probable that the deformation is of the same age as that affecting the Barron River Metamorphics at Etty Bay (see p. 125), where the metamorphic stages, structural trends, and plunges of lineation are similar; both areas lie along the same zone of deformation.

The uniform massive non-bedded character and the simple original mineralogical composition suggest that the Babalangee Amphibolite is an altered basic intrusion, which was probably emplaced in the Barron River sequence before metamorphism had reached its peak.

Synopsis of the Palaeozoic Geosynclinal Sedimentation in the Hodgkinson Basin

During the late Silurian and early Devonian a shallow warm sea encroached over a slowly subsiding Precambrian basement, and in this shallow shelf environment the sediments of the Chillagoe Formation (a mixed carbonate and clastic shelf association) and the Mount Garnet Formation (clastic shelf association) were deposited. The relationships between these two formations have been discussed on page .

The western boundary of the Chillagoe/Mount Garnet shelf was probably formed by the Palmerville Fault: at the base of the Chillagoe Formation there is a persistent zone of a characteristic type of quartz siltstone or fine sandstone along the fault. This special rock type is not found elsewhere, and it forms a strongly diachronous lithostratigraphic formation which appears to be related to the fault. The Palmerville Fault acted as a hinge line between the subsiding shelf area and the positive Precambrian borderland, and vertical adjustments recurred from time to time (p. 126). Basil vulcanism may have been associated with the Palmerville Fault system.

The eastern boundary of the Chillagoe/Mount Garnet shelf is unknown. Lucas points out that there is no evidence that the Chillagoe or Mount Garnet Formation continues for any great distance beneath the Hodgkinson Formation, and that the proportion of detritus from the Chillagoe and Mount Garnet Formations in the Hodgkinson greywackes diminishes progressively from southwest to northeast, whereas the proportion of Precambrian detritus increases in that direction. He concludes therefore that the Hodgkinson Formation rests directly on the crystalline basement. De Keyser, however, considers it most unlikely that the Chillagoe reef environment could have existed in a very long and narrow sea, because detritus from all sides would probably have fouled the water. It is more probable, in his opinion, that the Chillagoe/Mount Garnet sea extended over most, if not all, of the Hodgkinson Basin, but that the marginal reef facies gave way to a shaly deeper-water facies of slow deposition farther offshore. This shaly facies would be hard to distinguish from the succeeding Devonian Hodgkinson shale and siltstone, and it is possible that the lower 'shaly' section which Lucas recognizes in the Hodgkinson Formation is but a different facies of the Chillagoe and Mount Garnet Formations.

Similarly, equivalent sediments may be represented among the Barron River and Barnard Metamorphics.

According to Lucas the earliest sediments of the Hodgkinson Formation were probably fine-grained chert and slate, accompanied by basic volcanics. The vulcanism probably continued from the Chillagoe period. The thick coarse arenites and conglomerates were mainly deposited during a second phase of sedimentation, when earth movements produced more relief of the basin floor and possibly elevated the bordering shelf area which supplied the detritus for the turbidites.

In the south, in the Mount Garnet region, the Hodgkinson Formation (in Lucas' opinion) may have been deposited unconformably on the Chillagoe and Mount Garnet Formations from which the detritus appears to have been partly derived. De Keyser suggests that the unconformity (if any) is not necessarily pronounced or of regional extent, as small oscillations of sea level were probably sufficient to cause temporary emergences of parts of the shelf area. In the northwest, little shelf detritus has been recognized in the Hodgkinson sediments (see northern boundary of shelf detritus on Fig. 8). It is possible that the shelf never emerged in the northwest, and that the Hodgkinson Formation conformably overlies the Chillagoe Formation; furthermore, the turbidity current directions in the northwest suggest that transport was mainly longitudinal, parallel to the old shoreline, and lateral currents were probably of secondary importance only. This may also explain the disappearance of the Mount Garnet facies to the north, if it is considered that the Mount Garnet Formation is a marginal facies derived mainly from the sides of the basin (Knill, 1959); the contention by most recent workers (Blake, 1968, unpubl.) that the Mount Garnet and Hodgkinson Formations are partly penecontemporaneous and interfingering facies units fits in well with this picture.

The deposition of the Hodgkinson Formation foreshadowed the Carboniferous orogeny: submarine troughs and ridges were formed, and in places the geanticlines probably reached sea level or even emerged. It is tempting to speculate that the formation of some of the geanticlines, the position of which is suggested by the concentration of coarse arenites, conglomerates, and fossils (see Fig. 8), was caused by the generation of magma, which eventually rose upwards during and after the main phase of the orogeny. In general, the rate of subsidence was greatest in the centre of the geosyncline, and turbidites were deposited in abundance in neritic to bathyal environments. They were built up to great thicknesses as subsidence continued strongly, while submarine ridges and troughs appeared and disappeared repeatedly. The unstable marginal zones of the geosyncline probably supplied much of the detritus, although part of the material was derived internally.

Finally, the oscillatory earth movements were succeeded by tectonic deformation, during which the contents of the geosyncline were folded and largely uplifted to form land; in a much restricted basin which remained in the south, in the Herberton district, the Ringrose Formation and Montalbion Sandstone may have been deposited (p. 58), being largely derived from the emerging Hodgkinson landmass. Lucas maintains that these two formations were laid down with angular unconformity on the Hodgkinson Formation, but later workers (Blake, 1968, unpubl.) consider that they are interstratified with the deposits of the Hodgkinson Formation. In either case, the compositional and structural characteristics of the

Ringrose and Montalbion sediments indicate that the palaeogeographic conditions were changing.

As the eastern margin of the Hodgkinson Basin is not exposed, it is not known whether the basin was an intracontinental geosyncline on the palaeocontinent of 'Austzealandia' (Gill, 1952), or a circumcontinental geosyncline opening to the Pacific Ocean in the east. The Hodgkinson Formation and the Barron River and Barnard Metamorphics in the central part of the basin have the characteristics of a eugeosyncline; the more stable, shallow-water, partly carbonate-type shelf characteristics of the marginal part have the properties of a miogeosyncline except for the presence of basic volcanics. Another term possibly applicable to the marginal part of the Hodgkinson Basin is 'parageosyncline', which has been defined by Beloussov (1962) as a structure situated within or next to an epigeosyncline, and which is intermediate in character between a typical geosyncline and a typical platform, and may contain extensive limestone deposits and also basic volcanics.

CARBONIFEROUS

Sediments of Carboniferous and possibly Carboniferous age are exposed in the Herberton/Mount Garnet/Koorboora district. They comprise the Montalbion Sandstone and the Ringrose Formation, whose ages are in doubt, and the Middle Carboniferous Silver Valley Conglomerate. Best (1962) and Lucas, who mapped the sediments in 1959, believe that the first two units rest unconformably on the Devonian Hodgkinson Formation, and are probably Carboniferous in age; J. W. Smith and K. Yates (pers. comm.), and Blake (1968, unpubl.), who mapped the sediments in more detail in 1963 and following years, consider that they interfinger with the Hodgkinson Formation, and are probably of Devonian age.

Montalbion Sandstone

Derivation of name: after Montalbion Hill, 16 miles west of Herberton.
Type area: as above.

The name Montalbion Beds was given by Skertchly (1899) to 'a series of comparatively unaltered shales and sandstones with calcareous seams and bands of nodular clay-ironstone', probably resting unconformably on the Devonian sediments. Best (1962) used the term Montalbion Sandstone.

The Montalbion Sandstone is exposed in many small scattered outcrops, with a total area of about 30 square miles, mostly around Irvinebank and Stannary Hills, and north of Dimbulah. The formation consists of several hundred feet of white or light grey quartz sandstone, conglomerate (generally at the base), and poorly exposed shale. The sandstone beds are from 1 to 30 feet thick, and the conglomerate beds from 6 inches to 6 feet. Most exposures are resistant to erosion, and consist of small gently dipping outliers from 50 to 200 feet thick. The formation is preserved on hill tops above the steeply dipping beds of the Hodgkinson Formation. Many of the outcrops have faulted boundaries, along which the sediments dip steeply, and are deformed, altered, and hardened.

The conglomerate is generally composed of fairly well rounded pebbles set in a sandy matrix, but cobbles and boulders up to a foot across were seen to the

north of Dimbulah. In places, the conglomerate grades into pebbly sandstone. The pebbles consist mostly of rocks from the Hodgkinson Formation and vein quartz; some quartzite pebbles in the northernmost outlier may have been derived from the Precambrian basement. The pink conglomerate sandstone south of Montalbion contains angular fragments of chert derived locally from the Hodgkinson or Mount Garnet Formations.

The most characteristic rock type is a medium-bedded to massive, locally pebbly or gritty, quartz sandstone, containing variable though minor amounts of feldspar and, in places, grey-green (intraformational?) shale flakes. The rock is well sorted, but the grains are fairly angular. It has no matrix, only a little siliceous and kaolinitic cement, and some residual porosity. The sandstone is well consolidated, though it is not as dense and indurated as the Hodgkinson arenites, except along the boundary faults. Faint coarse laminations and cross-laminations(?) are the only sedimentary structures visible.

In one of the most easterly outcrops, southeast of Stannary Hills, the sandstone is overlain by about 50 feet of ferruginous weathered sandy siltstone probably belonging to the Ringrose Formation, with which the Montalbion Sandstone interfingers farther to the south and east.

Ringrose Formation

Derivation of name: after R. G. Ringrose, who first described the conglomerate members of the formation.

Type area: the outcrops northwest of Herberton.

The conglomerate described by Ringrose (1897) was named Ringrose Conglomerate by Skertchly (1899), who considered that it probably marked an old shoreline at the base of the Devonian Herberton Beds. Best (1962) named the conglomerates and associated sediments the Ringrose Formation. Both Best and Lucas believe that the unit rests unconformably on the Hodgkinson Formation, but J. W. Smith and K. Yates (pers. comm.), and Blake (1968, unpubl.), regard the beds as a facies interfingering with the Hodgkinson Formation.

The Ringrose Formation covers about 70 square miles, mainly in the area between Irvinebank, Herberton, and Coolgarra. Its thickness is probably over 1000 feet.

The formation consists mainly of massive dark grey to black, blocky mudstone which is commonly rather silty, but in places cherty, with subordinate interbeds of turbidite, conglomerate, breccia, quartz sandstone, and radiolarian chert.

The mudstone is indurated but not generally cleaved. Very dark where fresh, it is usually pale grey-green to pink in slightly weathered outcrops, and disintegrates readily into small dice with subconchoidal surfaces. On hillsides it is commonly surface-silicified and deeply ironstained. There is little, if any, internal stratification. Some of the mudstone is visibly micaceous; some is slightly calcareous; and some grades into thin-bedded black radiolarian chert. In places, the flaggy cherty mudstone southeast of Irvinebank contains aligned shale fragments.

Most of the turbidites which are rhythmically interbedded with the mudstone at intervals ranging from several inches to about 3 feet, consist of very thin and fine-grained graded siltstone, silicified in part. Others are thicker (up to 3 feet) and coarser, especially near the eastern boundary of the formation. The turbidites commonly display wavy, convolute, and cross- laminations, mostly in the finer-grained, silty and micaceous, shaly upper parts of the beds.

East of Irvinebank there are some clean 6-inch beds of cross-laminated fine-grained ungraded or poorly graded quartz sandstone showing consistent current directions towards the southeast.

Massive to medium-bedded pebble to cobble conglomerate crops out mainly in the type area at Herberton. Conglomerate is also well exposed in a creek on the faulted and mineralized western boundary of an outlier southeast of Stannary Hills, where it probably forms the base of the formation; it consists of pebbles of quartzite, vein quartz, chert, and slate from the Hodgkinson Formation, Precambrian(?) granite, and basic volcanics, set in a dark fine-grained matrix. Near Stannary Hills, Herberton, and Gurrumba, the conglomerate is pale coloured and has a sandy matrix, similar to the conglomerate in the Montalbion Sandstone.

Thick and massive interbeds of white to pale grey quartz sandstone, similar to those in the Montalbion Sandstone, are common around Irvinebank, where the Ringrose Formation and Montalbion Sandstone appear to interfinger most extensively. They are also known in the Herberton inliers. The quartz sandstone is medium to coarse-grained, in places gritty and pebbly, and locally contains many fragments of green shale.

Other sandstone types include thin to medium-bedded coarse gritty quartz sandstone, and dark grey fine to medium-grained micaceous sandstone. North of Irvinebank, a gritty breccia fills a scour in fine-grained sediment, and a massive slightly chloritic quartz sandstone nearby contains beds of breccia, up to 6 inches thick, rich in fragments of shale and quartz pebbles. The contorted and slumped beds of mudstone (containing streaks and swirls rich in coarse sand) and breccia, exposed in Chinaman Creek, may represent the base of the formation.

The sandstone in places is micaceous and feldspathic; the feldspar is mainly plagioclase, but is usually altered. Some of the sandstone in the southern outcrops contains up to 20 percent subangular fragments of siltstone and quartz. Some of the quartz shows undulose extinction, whereas in the underlying Mount Garnet Formation all the quartz has undulose extinction.

Other Rocks of Possible Carboniferous Age

The outcrops north of Koorboora and in the Boxwood Ring Complex may belong to the Ringrose Formation or Montalbion Sandstone. They have been described by de Keyser & Wolff (1964) as white or pale grey or greenish, commonly purple-spotted, partly chloritic sericite-quartz sandstone and siltstone which are quite distinct from the rocks of the Mount Garnet Formation. Some of the beds may be tuffaceous, and there is commonly evidence of pneumatolytic alteration. A few beds of conglomerate are interspersed.

The sericitic quartz sandstone and siltstone in the Koorboora and Boxwood sediments are quite distinct from the rocks of the Mount Garnet Formation and resemble part of the Ringrose Formation or Montalbion Sandstone; the few dips observed are lower than those normally displayed by the Mount Garnet Formation, and commonly range from 20° to 30°. The sediments are restricted to the ring complexes, and have probably been preserved by downfaulting.

The Koorboora and Boxwood sediments probably rest unconformably on the Mount Garnet Formation, and are possibly of Lower(?) Carboniferous age.

Relationships and Age of the Ringrose Formation and Montalbion Sandstone

According to Best (1962) and Lucas, both the Ringrose Formation and the Montalbion Sandstone unconformably overlie the Mount Garnet and Hodgkinson Formations. The unconformity is usually not recognizable in the field, partly because of poor exposures, and partly because the Ringrose Formation dips almost as steeply (30°-70°) as the Mount Garnet and Hodgkinson Formations (50°-90°). The Montalbion Sandstone generally shows much lower dips, except along its faulted boundaries. The indirect evidence for the unconformity includes the differences in lithology, the much more limited distribution of the Ringrose Formation and Montalbion Sandstone, the lower degree of deformation, including the absence of slaty cleavage, and the restriction of the outcrops of the Montalbion Sandstone to the crests of hills and ridges.

According to Lucas, the Ringrose Formation and Montalbion Sandstone are younger than Devonian, and as the former is unconformably overlain by the Middle(?) Carboniferous Silver Valley Conglomerate, they are tentatively assigned to the Lower Carboniferous.

The coarser Montalbion Sandstone is considered to be a near-shore equivalent of Ringrose Formation, and the two units were laid down within a relatively small area on the southern margin of the Hodgkinson Basin after the main phase of the orogeny.

Lucas notes that the junction of the two formations cuts across the regional trend of the Hodgkinson Basin, and is remarkable for the abruptness of the lithological and structural transitions across it: it apparently marks the site of a hinge-line which was stable throughout the depositional and deformational periods of the formations. The Herberton/Mount Garnet district is an unusually complex and highly fractured zone of the Hodgkinson Basin, where there has been intense Permo-Carboniferous igneous activity, and where many northeasterly trends, fractures, and faulted boundaries cut across the northwesterly trend of the Hodgkinson Basin. Lucas considers that the significance of the Carboniferous(?) formations in the tectonic evolution of the region is revealed by the pattern of the regional, and even continent-wide, trends to the south: the formations lie athwart the south-western margin of the Hodgkinson Basin, in a zone where the north-northeasterly Burdekin River Fault zone (White, 1961) may be expected to intersect the margin of the basin. The north-northeasterly trends probably form a broad zone across the continent to the rift valleys of Spencer and St Vincent Gulfs: this zone has been a major structural feature since at least the Palaeozoic.

Thus the Montalbion Sandstone and the Ringrose Formation occur in a zone of weakness in the Hodgkinson geosyncline, located at the southeastern end of the hypothetical Precambrian Featherbed block, and at the intersection of the Burdekin River Fault zone with the southwestern margin of the geosyncline. The two formations have much in common with the paralic and marine folded Upper Devonian to Lower Carboniferous deposits at the southern end of the Broken River Embayment (White, 1961).

De Keyser considers that the trend of the two formations is not so much a straightforward regional feature, but rather forms a wrap-around structure abutting on the hypothetical Featherbed block. If the two formations rest unconformably on the Hodgkinson Formation, it is possible that they represent molasse-type synorogenic sediments deposited in a restricted trough during the emergence of the Hodgkinson Basin as a mountain chain. The trough would have bordered the southern and eastern ends of the Featherbed block, from which part of the detritus would have been derived. The trough is located roughly at the intersection of the Burdekin River Fault zone and the Palmerville Fault.

In marked contrast with the views of Lucas and Best, later workers (Blake, 1968, unpubl.) have concluded that the two formations represent different facies of the Hodgkinson and Mount Garnet Formations, with which they interfinger. They claim that there is no angular unconformity, and that the low dips are due to the competency of the sandstone beds. However, Lucas is convinced that there is an unconformity, and de Keyser considers that the beds in the Koorboora and Boxwood areas, at least, may be unconformable because the sediments have a different lithology, and lower dips which are unlikely to be due to differences in competency. This does not necessarily exclude the possibility of conformity in the Herberton/Mount Garnet area farther to the east, where the two formations mostly overlie the Hodgkinson Formation, or where the depositional area may have been farther away from the source area. That changes from unconformable to conformable relationships over a short distance are possible has been demonstrated in West Germany and on the island of Curacao (MacGillavry, 1961, p. 145).

Silver Valley Conglomerate

Derivation of name: Silver Valley, or Newellton, an abandoned old mining settlement on the Dry River, 9 miles southwest of Herberton.

Type area: same as the outcrop area, a 6-square mile depressed fault block about 8 miles southwest of Herberton.

The formation was first mapped and described by Stirling (1904) as the Silver Valley Beds, and was correlated by Dunstan (1916) with his Herberton Series, which he thought to be of Carboniferous age. Jensen (1923) referred to them as the *Rhacopteris* beds, and Reid (1930) as the *Aneimites* beds and the 'Silver Valley beds with *Aneimites ovata*'. Carey & Browne (1938) dated the formation as Middle Carboniferous on the fossil flora, and Hill (1951) considered the Newellton Beds (which she later called the Silver Valley Series) as mid-Carboniferous, possibly Moscovian.

The Silver Valley Conglomerate occupies a downfaulted block of 6 square miles, and the same beds may also be present farther south in a complex fault zone along the Dry River. The conglomerate forms an open syncline or basin, with

updrag mostly on the steep eastern and western boundary faults. Dips are very low in the central-southern part of the formation, and up to 20° elsewhere; steeper dips are found near the faulted boundaries.

The formation is a thin sequence (250 to 300 feet exposed) of conglomerate with subordinate sandstone, shale, and possibly acid volcanics. Pebble and cobble conglomerate predominates in all but the uppermost 50 feet of the exposed succession; it is thick-bedded to massive, and encloses minor lenses of cross-bedded sandstone. The clasts include pebbles of acid and intermediate volcanics of fair sphericity. Exposures are usually purple-brown, but in creek beds some of the beds are deep green and pyritic with an unstable cement of calcite and zeolite(?). In the lower part of the section pebbles of volcanic rock are less common, and there is an abundance of quartz sandstone pebbles derived from the Ringrose Formation or Montalbion Sandstone, and rock types from the Hodgkinson Formation.

The massive conglomerate contains minor lenses of torrentially cross-bedded sandstone and medium to thick interbeds of sandstone which are laminated in places. The sandstone is purple or green, medium to coarse-grained, lithic and feldspathic.

In the southwest the section is capped by about 10 feet of apple-green, floury, but siliceous shale which commonly contains a form of *Rhacopteris* sp. It was identified as *R. inequilatera* by Stirling, 1904, but has usually been described as *Aneimites* (*ovata*) by later writers, e.g. Reid (1930). It probably indicates a Middle Carboniferous age (Carey & Browne, 1938; Hill, 1951).

A steeply inclined sandstone dyke cuts the massive conglomerate near the road in the northeastern corner of the fault block.

The relationship between the Silver Valley Conglomerate and the volcanic rocks in the fault block is uncertain. Reid (1930) and Best (1962) mention interbedded rhyolites; the conglomerate is cut by a few fine-grained acid dykes, and some rhyolite flows were noted in the north. The thick green tuff capping the conglomerate at Breccia Hill, in the southwest, lies apparently at the top of the formation. However, the tuff is lithologically similar to parts of the Glen Gordon Volcanics 12 miles to the southeast, and, according to Morton (*in* Reid, 1930), some of the Featherbed Volcanics near Koorboora; it is possible therefore that the formation is overlain and intruded by appreciably younger acid volcanics.

Some authors consider that some of the 'varved' shales and conglomerates are glacial in origin, but no faceted pebbles or cobbles have been found. The massive conglomerate and torrentially cross-bedded sandstone lenses may possibly be fluvioglacial deposits.

UPPER PERMIAN

The Upper Permian rocks include both igneous and sedimentary units. The igneous rocks may include some of the Permo-Carboniferous ignimbrites and ring complexes that are discussed on pages 65-74. The sediments are usually associated with bedded volcanic rocks; they contain seams of coal, some of which have been mined. The Upper Permian rocks, with the possible exception of the Nychum

Volcanics, are preserved in small fault blocks scattered over the Cooktown, Mossman, and Atherton Sheet areas. Four main outcrop areas have been recognized, and as they are widely separated each unit has ben given a different name: Nychum Volcanics, Mount Mulligan Coal Measures, Little River Coal Measures, and Normanby Formation. Correlation between the units is uncertain as the Upper Permian fossil plants cannot be dated precisely. Coal was mined in the Mount Mulligan Coal Measures during the period 1914-57, and the stratigraphy is known in some detail.

Nychum Volcanics (in part; see also p. 71)

Derivation of name: from Nychum homestead, longitude 144°25′E., latitude 16°50′S.

Type area: all exposures in the area from Nychum homestead northwest to Mulgrave homestead, and southwest to the Walsh River.

The name was submitted by W. R. Morgan, and first published by Best (1962). The formation comprises a wide variety of volcanic rocks including tuff and interbedded sediments. Plant fossils indicate an Upper Permian age, but conflicting geological and isotopic evidence suggests that the Nychum Volcanics may have to be split up into two or more units of different age.

The Nychum Volcanics, which rest unconformably on the Precambrian and Siluro-Devonian formations (Pl. 9, fig. 2), are composed mainly of acid lavas and pyroclastic rocks, with subordinate intermediate and basic lavas. Sediments and tuff are interbedded in places, especially at or near the base of the formation. The volcanic members are described on page 71.

The sediments and tuffaceous rocks include conglomerate, arkose, current-bedded coarse micaceous sandstone, shale, coal seams, water-sorted tuffaceous sandstone, siltstone, and mudstone, and lithic tuff. They are well bedded, and range from 2 inches to 3 feet thick; they display cross-bedding, washouts, loadcasts, and possible slump structure. Extensive fossil channel systems have been observed in places, with individual channels up to 15 feet wide and several feet deep. The sedimentary structures, and the presence of coal seams and fossil plants indicate a shallow continental-lacustrine environment with broad valleys and low hills.

Where fresh, the tuffaceous sediments and lithic tuffs are white to pale cream and grey, commonly speckled with grey, green, pink, and brown grains. The arkose and sandstone are pink, grey, or white, and the shale is generally grey to black. Weathered surfaces are grey and roughly granular. Individual beds are fairly well sorted. The grains and fragments are angular to subangular, and consist of quartz, shale, quartzite, siltstone, chert, feldspar, greywacke, and plutonic(?) rocks. The lithic tuffs contain angular embayed grains of devitrified glass, and some sedimentary rock fragments, quartz, and feldspar, in a glassy matrix (Morgan, 1964b, unpubl.).

Plant fossils are common in the coaly shale and in some of the siltstone. Speciments collected in 1960 have been identified by Mary White (1961a, unpubl.); they include *Glossopteris indica* Sch., *G. angustifolia* Brong., a fragment of *Taeniopteris* cf. *T. elongata* Walk., a fragment of *Taeniopteris* cf. *T. Wianamattae*, small herbaceous equisetalean, and many seeds. Mary White suggests that the associations indicate an uppermost Permian or possibly Lower Triassic age.

The spores and pollen grains in specimens collected by the Broken Hill Pty Co. Ltd in 1957 have been assigned by Balme to genera such as *Lunatisporites, Striatopodocarpidites, Pityosporites,* etc. (B. E. Balme, Univ. of W. Aust., pers. comm.). A particularly abundant species is *Marsupipollenites triradiatus* Balme & Hennely. According to Balme, the microflora indicates an Upper Permian age, and closely compares with the microflora in the Newcastle Coal Measures, and the Upper Bowen Coal Measures and other formations in Queensland. P. R. Evans (BMR, pers. comm.) has examined material collected in 1960 and has confirmed the Upper Permian age.

Mount Mulligan Coal Measures

Derivation of name: Mount Mulligan, about longitude 144°50′E., latitude 16°50′S.
Type area: the Mount Mulligan coalfield.

Ball (1912b,c) used the names Mount Mulligan Beds and Mount Mulligan Coal Measures (1917a). Jensen (1920c) included the overlying Mesozoic sandstones in the term Mulligan Series, but this usage has not been followed by others.

Mount Mulligan is a steep-sided rift-block mountain of 20 square miles, 45 miles southwest of Mossman. It is largely composed of Mesozoic sandstone and conglomerate, with the Mount Mulligan Coal Measures at the base. The coal measures comprise conglomerate, arkose, pebbly beds, siltstone, sandstone, shale, fireclay, and coal. They attain a thickness of possibly 800 feet in the north, but thin out rapidly to the south, and ultimately wedge out completely about 700 yards south of the King Cole colliery. The thickness is about 50 feet at the Mount Mulligan State mine, 150 feet at Gorge Creek (Ball, 1912b,c), and at least 300 feet 2½ miles northwest of the State mine.

In the type area around the State mine the base of the Coal Measures is composed of blue-grey sandy conglomerate about 16 feet thick, which is usually referred to as 'puddingstone'. It consists chiefly of fragments of the underlying Hodgkinson Formation and some rhyolite pebbles. At the King Cole colliery, the basal beds are composed of fragmental volcanic material (Morton, 1945c); similar rocks were encountered in drill holes north of the State mine (Connah, 1953a), and gritty and pebbly beds containing much volcanic material are exposed farther to the northwest. All these beds are probably reworked local deposits.

On the extreme northern flank of Mount Mulligan, the basal beds consist of massive or thick-bedded conglomerate, arkose, and pebbly beds up to several hundred feet thick. Over half the pebbles in the conglomerate consist of rhyolite; vein quartz and chert are subordinate, and fragments of Hodgkinson sediments are uncommon. The pebbles and boulders are well rounded, and although their size varies in different beds, the average diameter is commonly 1 to 3 inches.

The basal beds are overlain by the productive coal measures composed of thinly bedded and laminated sequences of coal, clay, and fine sandstone. The beds generally show considerable lateral changes. Ball (1917a) has described detailed sections in the type area, where the thickest seams of payable coal occur. There are four composite coal seams (Shepherd, 1945), three of which have been worked. The seams range from 3 inches to 3 feet thick, and are interbedded with alternating shale and clay with occasional interbeds of sandstone and siltstone.

The thickness of the productive measures is about 20 feet at the King Cole colliery, but it increases to 114 feet in the State mine. The thickness of the coal seams in the State mine remains fairly constant, but the intercalated sediments thin out uniformly from east to west; to the south, the number of seams decreases, and at the King Cole colliery only one seam, which thins out rapidly to the west and southwest, is present. In the drill holes half a mile to a mile northwest of the State mine (Connah, 1953a) the succession is quite different from that in the type area; the thickness of the coal measures is over 200 feet, and only one band of poor-quality coal, near the base of the measures, was found. At the northernmost point of Mount Mulligan, thin layers of impure coal are found in thinly bedded and laminated grey shale, siltstone, and fine-grained sandstone. The bedding in the sediments is irregular, with much swelling and pinching and fine cross-lamination.

The coal measures are overlain by conglomerate and sandstone forming the vertical cliffs of Mount Mulligan. They are generally regarded as Mesozoic, but it is suggested that the lowermost conglomerate directly overlying the coal measures is probably Permian. This conglomerate ranges from 30 to 70 feet thick, and resembles the basal conglomerate of the Permian sequence; it is a coarse structureless rock and the pebbles consist mainly of rhyolite. The conglomerate is green or yellow-green when seen from a distance. The overlying Mesozoic conglomerate is red or white, and commonly cross-bedded; rhyolite pebbles are extremely rare.

The abundance of rhyolite pebbles derived from the Featherbed Volcanics west of Mount Mulligan, the thinning and converging of the coal seams to the southwest, and the orientation of occasional cross-beds in the basal conglomerate indicate that the Mount Mulligan Coal Measures were derived from a source area to the west and southwest. The cross-bedding and the scarcity of rhyolite pebbles in the overlying Mesozoic strata indicate that they were derived from the east or southeast.

The plant fossils collected in 1960 from the coaly and shaly interbeds (Appendix) indicate an Upper Permian age, which is confirmed by the microflora in the coaly sediments (de Jersey, 1947, 1949; P. R. Evans, pers. comm.). David (1932) correlated the Mount Mulligan Coal Measures with the Collinsville Coal Measures of the Middle Bowen, and considered them to be upper Lower Permian; Bryan & Jones (1946) accepted this correlation. Later, the Mount Mulligan Coal Measures were considered to be Upper Permian (David, 1950), and Mary White (1961a, unpubl.) even considered the possibility of a Lower Triassic age.

The dip of the Mount Mulligan Coal Measures is generally less than 20°, except along the faulted edges of Mount Mulligan, where the dip suddenly steepens, and the beds may be locally overturned. The general structure is a broad flat asymmetrical syncline, formed by drag associated with the downfaulting of the Mount Mulligan fault block.

Little River Coal Measures

Derivation of name: Little (Kennedy) River, one of the headwater branches of the Kennedy River, 15 miles north of Palmerville.

Type area: a narrow 12-mile long fault block along the Palmerville Fault.

Taylor discovered the coal in 1872. Jack (1882) described the coal measures, which he considered to be Permo-Carboniferous, but later (*in* Jack & Etheridge,

1892) he correlated them with the Upper Bowen Formation. They were named the Little River Coal Measures by Bryan (1928b).

The Little River Coal Measures are poorly exposed in an alluviated north-south depression which is flanked by hilly outcrops of the Chillagoe Formation on the east and by cliffs of Mesozoic sandstone on the west. The depression, which is about 12 miles long and 1 mile wide, represents a downfaulted block along the Palmerville Fault system; it is flanked by Precambrian rocks (covered with Mesozoic strata) in the west, and by Siluro-Devonian sediments in the east.

The outcrops consist of pale grey thick-bedded medium to coarse-grained feldspathic and lithic sandstone, grey silty shale containing plant fossils, and interbeds of medium-bedded slightly lenticular dark impure limestone, thin-bedded fine-grained sandstone, and fairly thick impure coal. Calcareous veinlets and limonite are common in the fault zones.

The coal was of potential importance because of its location on the proposed railway route from Cooktown to Palmerville. The seams are up to 20 feet thick, but are steeply dipping and faulted.

Mary White (1916c, unpubl.) examined specimens of shale collected in 1961, and identified *Schizoneura australis*, *Glossopteris indica*, *G. angustifolia*, *Vertebraria indica*, and indeterminate seeds and rootlets. She states that *S. australis* has been rarely found in Australian collections, and appears to indicate an Upper Permian age. *Glossopteris browniana* has been reported by David (1950). The *Glossopteris* flora was already known to Jack (1882), and Jensen (1964) mentions the presence of a *Rhacopteris* species.

The Little River Coal Measures are strongly folded and faulted as a result of the rifting, and are poorly exposed; the thickness is unknown.

Normanby Formation

Derivation of name: the Normanby River, about 5 miles west of the nearest outcrops.

Type area: three small, elongated, faulted outliers in a north-south line 18 miles west of Cooktown.

Jack (1879a,b) found *Glossopteris*-bearing shale and coal, and Tenison Woods (1880b) named the formation the Normanby shales, though most later writers have referred to them as the Oaky Creek Coal Measures, a term introduced by Maitland (1891a). Lucas & de Keyser (1965) renamed them the Normanby Formation. The formation probably comprises several thousand feet of thin-bedded micaceous sandstone, thick-bedded coarse to fine-grained feldspathic sandstone, dark silty calcareous shale, thick beds of pebble conglomerate, and thin bands of impure limestone. In the southern outlier at least 100 feet of massive laminated impure coal occurs in the western (upper?) part of the formation. In the central or eastern (lower?) part of the northern and southern outliers, thick flows of fine-grained rhyolite, thin beds of lapilli tuff, and volcanic breccia are common.

Glossopteris indica has been obtained from several localities above the rhyolites east and northeast of The Brothers (Woods, 1962d, unpubl.), and very small moulds of *Thamnopora* sp. have been found in the dark clay matrix of the basal(?) calcareous breccia or conglomerate on the western boundary of the forma-

tion 1 mile south of The Brothers. The identification of the *Thamnopora* sp. has been confirmed by Professor Dorothy Hill (pers. comm.). There is a remote possibility that the *Thamnopora* was derived from the Devonian limestone a few miles to the west, but only the *Thamnopora* moulds have been seen, and the more robust skeletons of *Fasciphyllum* or *Favosites* which accompany the *Thamnopora* in the Devonian limestone have not been noted. Furthermore, the moulds appear to be individually set in the matrix of the breccia, and are not found in the enclosed fragments.

Jack (1879a,b) appraised the coal prospects of the formation, but the coals have never been worked, and are only briefly mentioned in the Powell Duffryn Report of 1949. The coal is folded, crushed, and faulted. A specimen collected by Lucas was found to contain 34.72 percent fixed carbon, 41.76 percent ash, 16.00 percent volatiles, and 7.52 percent moisture.

The formation is folded, but not cleaved; the folds plunge gently or moderately steeply. The formation is bounded by well defined faults against the Hodgkinson Formation, and is overlain by unfaulted Jurassic sandstone. The beds are cut by numerous steep strike faults and several steep northeasterly cross-faults. The pattern and style of the folds are consistent with deformation during downfaulting along the boundary faults; the cross-faults are younger than the strike faults (Amos, 1962, unpubl.).

The thickness of the formation is probably between 2000 and 5000 feet; the succession in the southern outlier includes 600 to 1000 feet of rhyolite and possibly more in the central outlier. In the southern outlier, the rhyolite occurs between an upper freshwater or brackish coal-bearing sequence and a lower brackish or shallow-marine sequence.

Permian Strata Beneath the Laura Basin

The Cabot-Blueberry Marina No. 1 well, 10 miles south of Princess Charlotte Bay, penetrated 220 feet of Permian rocks, dipping at about 30°, at a depth of 3566 to 3766 feet (Mines Administration Pty Ltd, 1962, unpubl.). The beds consist mostly of grey, black, and brown silty and carbonaceous shale with some coal laminae, with subordinate pale grey-green fine-grained microfractured silicified crystal(?) tuff, fine-grained pale grey sandstone, and various siltstones. *Glossopteris indica* is present in the basal part of the sequence (Woods, app. 2a, *in* Mines Administration Pty Ltd, 1962, unpubl.). The shale and sandstone are reported to be slightly glauconitic.

Seismic exploration over the area around and south of the well has since indicated the possibility of the presence of thicker sequences of relatively unaltered strata (including Permian rocks at the base). The beds occur in zones striking north-northwest (Marathon Petroleum, 1964, unpubl.). The extensive Permian rocks, which may occur beneath the Laura Basin, may form the link between the marine beds, rhyolite, and coal of Normanby Formation, and the continental Little River Coal Measures.

Upper Depositional Environment

Coal seams, fossil plants, washouts, channel systems, current-bedding, rapid lateral facies changes, and local abundance of conglomerate and basal breccia

indicate that the Upper Permian deposits were laid down in a flat or mature continental-lacustrine environment, probably under warm humid conditions. The presence of the marine form *Thamnopora* sp. indicates that parts of the Permian section were deposited in a paralic environment, and that in places the sea encroached probably from the north. Sedimentation was accompanied by active vulcanism, and the rise of the magma was facilitated by the extensive faulting. The continent was eventually broken up by faults, and the Permian sediments have been preserved in narrow meridional rift valleys.

PERMO-CARBONIFEROUS IGNEOUS ROCKS

After the major Lower(?) Carboniferous orogeny (p. 133) the folded geosynclinal sediments in the Hodgkinson Basin and their borderland were invaded by granitic magma, and large volumes of acid and intermediate volcanic rocks were extruded. Locally, the volcanic deposits are interbedded with freshwater sediments and tuffs.

The igneous rocks are concentrated along the southern margin of the basin and in the borderlands (Fig. 9). Farther north, volcanic deposits are lacking, except for isolated occurrences in the Upper Permian rift blocks, and the granite batholiths are smaller and more disconnected.

The igneous rocks form most of the prominent topographic features such as the granitic tablelands and monadnocks, the rugged Featherbed Range, the Bartle Frere and Bellenden Ker Ranges, and Hinchinbrook Island. On the air-photographs the igneous rocks can be distinguished by their positive relief, light tonal values, jointing, massive structures, and, in places, their bouldery and tor-like outcrops. As recognition on the photographs is far more difficult in the tropical rain forest, the geological boundaries in the eastern and southeastern parts of the geological map are approximate only.

Many of the volcanic rocks occur in large downfaulted surface cauldrons and ring complexes (Fig. 23), in association with granites. The structure, evolution, and genetic relationships of the volcanics and granites in the southern part of the Hodgkinson Basin and adjacent borderland have been described in detail by Branch (1966), and these rocks are only briefly discussed here.

The chemical analyses of igneous rocks are listed in Tables 3 and 4. Most of the analyses were made by the Australian Minerals Development Laboratories (AMDL) in Adelaide, and by the Bureau of Mineral Resources (BMR). Some analyses of granites outside the map area are included. The norms and Niggli values have been calculated by F. de Keyser, and the chemical data have been incorporated in a series of variation diagrams (Figs 11-14).

The relationships between the various granite types on the one hand, and between granites and volcanics on the other hand, have long been the subject of much speculation, and still are to some extent, but the regional mapping, Branch's detailed studies, and the isotopic age determinations have greatly increased our knowledge of these rocks. Previously, difficulties have arisen by trying to fit all the granite into one episode, and all the volcanics into another. The emplacement of the various units appears to have overlapped, and to have taken place over a long period starting from about the Middle Carboniferous and extending into the late Permian; maximum igneous activity occurred during the late Carboniferous and early Permian.

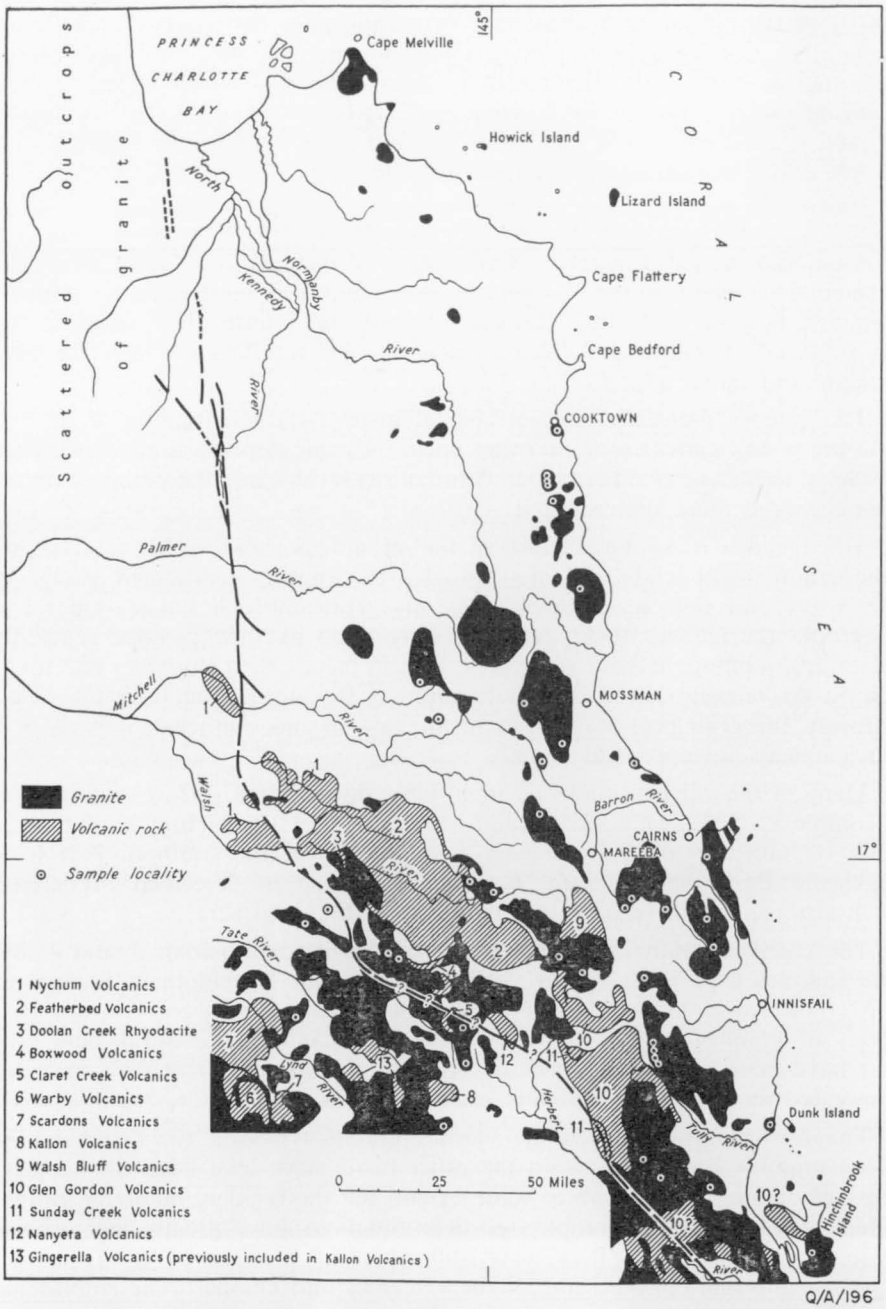


Fig. 9. Distribution of Permo-Carboniferous igneous rocks, and location of samples taken for isotopic dating.

The nomenclature proposed by D. W. Peterson (1961) has been followed: the classification is based largely on that of Nockolds (1954). The term 'granite' is used to include all granitoid rocks that make up a given 'granite' body, such as granodiorite, adamellite, alaskite, quartz diorite, and granite (sensu stricto).

The Volcanics

A dozen volcanic units have been formally named in the map area. They generally occur in disconnected cauldron subsidence areas and ring complexes. Many of them are similar in lithology, correlation is difficult, and their relative positions in the stratigraphical column are uncertain.

Nanyeta Volcanics

Derivation of name: Nanyeta Creek, or Return Creek, which flows through Mount Garnet. The name was submitted by Branch, and first published by Best (1962).

Type section: headwaters of the east branch of Smiths Creek, 5 miles northwest of Mount Garnet.

The Nanyeta Volcanics cover 10 square miles north of Mount Garnet; they consist mainly of purple, pink, grey, white, or creamy dellenite or rhyodacite tuffs and flows, massive or flow banded, and subordinate trachyandesite, andesite, and agglomerate. The maximum thickness measured is 550 feet, and the average about 150 feet. In places, silicified shale and siltstone are associated with the volcanics. Branch has correlated an isolated outcrop near Silver Valley with the Nanyeta Volcanics, and regards them as mid-Carboniferous, but Blake (1968, unpubl.) includes this outcrop with the Glen Gordon Volcanics. Branch equates the Nanyeta Volcanics with the Sunday Creek Volcanics (see below) because of the similarity in the lithological succession, and considers that both the Sunday Creek and Nanyeta Volcanics are overlain, possibly unconformably, by the Glen Gordon Volcanics. Blake (1968, unpubl.), however, correlates the Nanyeta Volcanics with both the Glen Gordon and Featherbed Volcanics.

The Nanyeta Volcanics dip at 20° to 50° to the northeast.

Sunday Creek Volcanics

Derivation of name: Sunday Creek, a tributary joining the Herbert River at longitude 145°16′30″E., latitude 18°0′10″S. Named by Best (1962).

Type area: headwaters of Sunday Creek.

The main outcrops of the Sunday Creek Volcanics are in the headwaters of Sunday Creek, and in a small area on the south side of the Millstream, 8 miles southwest of Ravenshoe (Branch, 1966). The volcanics include dacite, dellenite, rhyodacite, some rhyolite, and subordinate quartz andesite and quartz trachyandesite. In one locality the base is exposed, with thinly bedded quartz sandstone and grit resting unconformably on Precambrian gneiss. The maximum thickness exposed is about 650 feet. The volcanics appear to be gently folded, with dips up to 35°. According to Branch they are unconformably overlain by the Glen Gordon Volcanics, but J. W. Smith and K. Yates (pers. comm.) and Blake (1968, unpubl.) consider that this conclusion is doubtful.

The Sunday Creek Volcanics appear to have been recrystallized, probably owing to the intrusion of Herbert River Granite.

Glen Gordon Volcanics

Derivation of name: Glen Gordon, a ridge at longitude 145°22′E., latitude 17°42′S., about 10 miles southwest of Ravenshoe. Named by Best (1962).

The Glen Gordon Volcanics crop out in a belt, 10 to 15 miles wide, trending south-southeast from Herberton to Kirrama homestead; the volcanics farther south, along the Herbert River, may also belong to the formation. Branch has correlated the 10 square miles of volcanics to the north of Mount Garnet with the Glen Gordon Volcanics, but Blake (1968, unpubl.) includes them with the Nanyeta Volcanics. The volcanics at the northwestern end of Hinchinbrook Island have been mapped as possible Glen Gordon Volcanics by de Keyser et al. (1965).

The Glen Gordon Volcanics include pink to grey dellenite, rhyodacite, dacite, and rhyolite, a few sheets of trachyandesite, and occasional pyroclastics. Interbeds of silicified mudstone, shale, quartz greywacke, and siltstone are found in a few localities. The maximum thickness of the formation is about 1500 feet, with an average of 800 to 1000 feet.

Dips range from 10° to 30°, except near faults, where the volcanics may be vertical; Branch (1966) considers that the Glen Gordon Volcanics rest unconformably on the Sunday Creek Volcanics, and correlates them with the Featherbed Volcanics. However, Blake (1968, unpubl.) includes the Sunday Creek Volcanics with the Glen Gordon Volcanics. The formation is intruded by Elizabeth Creek Granite, and by pink leucocratic alaskite (Cgb.).

Walsh Bluff Volcanics

Derivation of name: from Walsh Bluff, at longitude 145°21′E., latitude 17°9′S., 11 miles northwest of Atherton. The name, proposed by Lucas, was first published by Best (1962).

The volcanics crop out over 90 square miles in a triangular area west of Atherton, and consist of grey and pink dellenite, rhyodacite, and about 65 feet of interbedded quartz sandstone. The rhyodacite includes about 1000 feet of welded tuff sheets overlying thinner lower flows. The total thickness is about 1200 feet.

Branch (1966) compares the quartz sandstone below the main welded tuff unit with the similar sequence in the Glen Gordon Volcanics, and suggests that the two formations occur in the same structural depression. The prominent zone of columnar jointing near the top of the succession may also indicate a correlation with a similar welded tuff sheet in the Featherbed Volcanics.

The dip of the volcanics ranges up to 30°, and the eastern and western margins are mainly bounded by faults. The southern boundary against the granites in the Herberton area has not been mapped; Branch states that the Walsh Bluff Volcanics rest unconformably on the Herbert River Granite, but Lucas considers that this is doubtful as there are no granite fragments in the volcanics, whereas sedimentary fragments are abundant. According to Branch (1966), the formation is intruded by Elizabeth Creek Granite, and is probably of Middle to Upper Carboniferous age. Blake (1968, unpubl.), on the other hand, found that the Walsh Bluff Volcanics unconformably overlie Elizabeth Creek Granite, and are probably Lower Permian.

Kallon Volcanics

Derivation of name: from Mount Kallon, at longitude 144°56′E., latitude 17°52′S. The name was published by Best (1962).

Branch (1962, unpubl.) originally included four occurrences of volcanics, with a total area of 75 square miles in this formation (as shown on Pl. 24), but in 1966 he restricted the name Kallon Volcanics to the exposures around Mount Kallon, and grouped the three outcrop areas farther west, between Sundown homestead and Bullock Creek siding, in a new formation, the *Gingerella Volcanics* named after Gingerella homestead. In the Mount Kallon area, about 200 feet of dellenite or rhyodacite and some trachyandesite are exposed; the volcanics near Gingerella include breccia and agglomerate, dellenite, rhyodacite, rhyolite, and trachyandesite, overlying some 5 feet of green shale. The maximum thickness is about 400 feet.

The volcanics are faulted against the Herbert River Granite, and intruded by Elizabeth Creek Granite.

Scardons Volcanics

Derivation of name: from Scardons Waterhole, in Rocky Creek, at longitude 144°6′E., latitude 17°35′S. The name was introduced by Best (1962).

The Scardons Volcanics crop out over 300 square miles, partly to the west of the map area. The main body of 250 square miles lies along the Lynd River, northeast of Bulleringer homestead, and a smaller area has been mapped at the head of Fulford Creek, on the eastern side of the Warby Ring Complex. The volcanics comprise pink, purple, and grey dellenite, rhyodacite, rhyolite, and volcanic agglomerate, with a total thickness of at least 1300 feet. Andesitic xenoliths and pumice blocks are common. According to Branch, the volcanics were extruded in a number of basins bounded by ring fractures, in which various levels of the succession are exposed. They are intruded by Elizabeth Creek Granite, and the generalized section is similar to that in the Newcastle Range Volcanics to the southwest of the map area; there is also a lithological resemblance to the Featherbed Volcanics.

Warby Volcanics

Derivation of name: from Warby Creek, which joins Fulford Creek at longitude 144°12′E., latitude 17°48′S. The name was introduced by Best (1962).

The formation crops out over 60 square miles in the Warby Ring Complex, 15 to 25 miles west of Lyndbrook homestead. A thickness of 350 feet of dellenite, rhyodacite, rhyolite, and volcanic breccia is exposed, and the formation is intruded by Elizabeth Creek Granite. Branch correlates the formation with the adjoining Scardons Volcanics.

Claret Creek Volcanics

Derivation of name: from Claret Creek, a tributary of Packsaddle Creek which flows into California Creek. The name was introduced by Best (1962).

The Claret Creek Volcanics cover an area of 12 square miles in the Claret Creek Ring Complex, about 15 miles west-northwest of Mount Garnet. They

consist of dellenite, rhyodacite, and rhyodacite crystal-lithic breccia with from 25 to 75 percent sedimentary rock fragments. The volcanics are probably 200 to 300 feet thick, and are intruded by Elizabeth Creek Granite. The xenoliths of pink leucocratic granite are probably not derived from the Elizabeth Creek Granite, but may be of deeper crustal origin.

Two volcanic necks were mapped by Branch. The formation is correlated structurally with the Boxwood Volcanics.

Boxwood Volcanics

Derivation of name: from Boxwood homestead, at longitude 144°53′E., latitude 17°26′S. The name was first published by Best (1962).

The Boxwood Volcanics occupy about 12 square miles in the Boxwood Ring Complex, and consist mainly of massive porphyritic dellenite or rhyodacite. The total thickness exposed is about 200 to 300 feet. The volcanics are intruded by Elizabeth Creek Granite, but the xenoliths of fine-grained pink leucocratic granite found in some of the rocks are probably not related to the Elizabeth Creek Granite.

Branch (1966) tentatively equates the Boxwood Volcanics with the adjoining Featherbed Volcanics. However, the Boxwood Ring Complex is cut by the Tennyson Ring Dyke which is probably genetically associated with the Featherbed Volcanics, and the Boxwood Volcanics may therefore be older.

Doolan Creek Rhyodacite

Derivation of name: after Doolan Creek, a tributary joining Walsh River at longitude 144°29′E., latitude 17°01′S. The name was introduced by de Keyser (de Keyser & Wolff, 1964).

The Doolan Creek Rhyodacite forms the outer zone of the Doolan Creek Ring Complex, in which it occupies about 7 square miles. The 15 square miles of volcanics at Mount Redcap, 3 miles southwest of the ring complex, may be of the same age as the Doolan Creek Rhyodacite because of the strong lithological similarity.

The formation consists of massive rhyodacite or dellenite; in the north, the structure is terminated by the boundary fault of the Featherbed Volcanics. It may be equivalent to part at least of the Nychum Volcanics. The rocks at Mount Redcap are recrystallized and intruded by Almaden Granite; a similar granite, as well as pink biotite granites, intrude the formation in the Doolan Creek Ring Complex.

Featherbed Volcanics

Derivation of name: from the Featherbed Range, a rugged incised tableland 60 miles west of Cairns. The volcanics were originally called Featherbed Porphyries by Jensen (1920), who thought they were Silurian. Ball (1915) considered the volcanics to be Permo-Carboniferous. Whitehouse (1930) stated that they probably represent more than one series of volcanics, of different ages.

The Featherbed Volcanics are the thickest and most extensive volcanic formation in the map area. According to Branch (1966) they cover an area of over 950 square miles, and extend from Nychum homestead in the northwest to Stannary Hills in the southeast. De Keyser restricts the name Featherbed Vol-

canics to the volcanics forming the Featherbed Range, from Nychum homestead to Emu Creek, and considers the volcanics to the southeast as a separate unit, possibly representing the lower part of the Featherbed Volcanics (de Keyser & Wolff, 1964).

The formation comprises dellenite, rhyodacite, rhyolite, volcanic breccia and agglomerate, and rare dacite. Orbicular structures are common in some localities, e.g. along the Walsh River, and in the Tennyson Ring Dyke (p. 74). Coal bearing sediments of local extent are found at or near the base of the volcanics 3 miles northeast of Koorboora. The formation is intruded by pink leucocratic granite. The maximum thickness is about 2000 feet.

Branch compares the Featherbed Volcanics to the Newcastle Range Volcanics to the southwest, and to the Glen Gordon Volcanics.

Nychum Volcanics (in part, see also p. 60)

Derivation of name: from Nychum homestead, at longitude 144°25′E., latitude 16°50′S. The name was introduced by Best (1962).

The Nychum Volcanics cover a total area of 235 square miles; they include several outcrop areas between the Walsh and Mitchell Rivers, between Chillagoe and Mulgrave homestead. Sediments are commonly interbedded with the volcanics see p. 60). The volcanics include dellenite, rhyodacite, rhyolite, dacite, subordinate andesite (generally hypersthene-bearing) and basalt, and pyroclastics (including autobrecciated lavas, tuff, and welded tuff), and have been described by Morgan (1961, unpubl.; 1964, unpubl.). Stratification is better developed than in most of the other volcanic units, and lateral variations are so common that no two sections are alike. The basalt and andesite flows occur near the base of the formation. In the type area, around Nychum homestead, the total thickness is about 500 feet. About a dozen andesitic and two or three rhyolitic eroded volcanic vents have been recognized by Morgan.

It is possible that the various outcrops grouped together as the Nychum Volcanics include two or more separate units, in spite of the similarity in lithology, stratification, and the presence of intercalated sediments.

Near Nychum homestead, the formation is truncated by the boundary fault of the Featherbed cauldron.

Undifferentiated Volcanic Rocks

This group comprises various igneous rocks of uncertain age. The group includes a number of large explosion vents, miscellaneous volcanics, and a large dyke southwest of Mount Mulligan.

The explosion vents have been described by Branch (1966). The *Barwidgi Volcanic Fissure* is 7 miles long and up to 1000 feet wide, and is associated with the Gingerella Volcanics; a number of vents have also been mapped in the Claret Creek, Nychum, Featherbed, Scardons, and Warby Volcanics, and along the boundary fault of the Glen Gordon Volcanics near Silver Valley.

The *Gurrumba Volcanic Neck* 12 miles northwest of Mount Garnet, and the *Crystalbrook Volcanic Neck* 3 miles southwest of Crystalbrook homestead,

represent large isolated vents. The Gurrumba Neck is 3 miles long and $1\frac{3}{4}$ miles wide, and the Crystalbrook Neck has a diameter of 4000 feet. The vents are generally filled with dellenite or rhyodacite volcanic breccia, and usually contain numerous fragments of country rock. The Crystalbrook Neck consists of microgranodiorite.

The volcanics of limited extent to the northwest and south of Mount Mulligan have been tentatively correlated with the Nychum Volcanics by de Keyser (Amos & de Keyser, 1964). They consist of flow-banded rhyolite, amygdaloidal lavas, and volcanic breccia; the volcanics are cut by associated dykes and faults. As the correlation with Nychum Volcanics is uncertain the rocks have been shown as 'undifferentiated' on the geological map.

The large composite dyke to the southwest of Mount Mulligan is 10 miles long and up to half a mile wide; the wider northern end consists of fine-grained mottled hornblende-biotite adamellite, but in the south, where the dyke narrows and finally passes into a fault, it consists of rhyolite or dellenite. Morgan (1964, unpubl.) considers that the inclusions of leucocratic micrographic aplite and granite present in the rhyolite have been formed by partial fusion of xenoliths in depth.

General Remarks on the Volcanics

The composition of the volcanic rocks ranges from rhyolite to andesite and basalt, but the predominant type is dellenite or quartz latite (rhyodacite according to Branch's nomenclature) with subordinate rhyodacite and rhyolite. The names given are based on the composition of the groundmass and phenocrysts, but it is difficult to classify some of the rocks in which the phenocrysts include only quartz and plagioclase, whereas the groundmass is composed exclusively of a mixture of quartz and alkali feldspar.

The colour of the volcanics ranges from pink, grey, black, cream, and purple to green. Most of the more acid rhyolites are pink or cream, whereas the massive welded-tuff sheets are generally grey.

The structure, texture, and field relationships of most of the dellenites and rhyodacites indicate that they are welded ashflow tuffs; they have been described in detail by Branch (1966). They form thick massive unstratified sheets of great areal extent, and are composed of crystals or fragments of quartz, plagioclase, and potash feldspar, set in a dense usually devitrified and commonly recrystallized matrix composed mainly of quartz and alkali feldspar. The welded tuffs contain from 25 to 60 percent of angular crystal fragments and rounded embayed phenocrysts, compared with a much smaller proportion in the typical lava flows. Mafic minerals are scarce, and commonly include remnants of biotite and hornblende, usually much altered to chlorite, accompanied locally by epidote, calcite, and magnetite or hematite. Some of the rocks contain a little clinopyroxene or occasional flakes of muscovite.

Branch concluded that the cauldron subsidence structures and ring complexes, with which most of the volcanic deposits are associated, were formed under tension, mainly by the subsidence of large crustal blocks and the uprising of volatile-rich acid magma derived by fractional melting in the lower crust. On the other hand, Rittman (1962) believes that such structures are due to diapiric rise of viscous

TABLE 3: CHEMICAL ANALYSES — PERMO-CARBONIFEROUS VOLCANIC ROCKS

	1	2	3	4	5	6	7	8
SiO_2	71.30	51.30	60.20	62.10	63.90	70.10	64.40	73.30
Al_2O_3	14.60	16.60	14.70	15.30	15.10	12.30	15.10	13.30
Fe_2O_3	1.13	2.90	1.70	1.39	1.66	0.70	2.63	0.81
FeO	1.34	5.65	5.20	4.80	3.55	1.82	2.59	1.55
MgO	0.34	5.50	2.35	1.38	0.99	0.26	1.41	0.19
CaO	1.61	9.60	5.50	4.70	4.40	1.44	2.75	0.98
Na_2O	3.25	3.10	3.35	3.80	4.10	3.80	3.85	4.55
K_2O	4.15	0.58	2.10	2.10	2.10	3.30	3.20	3.40
H_2O+	1.30	1.37	0.45	0.43	0.73	1.17	1.83	0.91
H_2O-	0.07	1.37	2.60	2.20	1.91	4.75	0.45	0.15
CO_2	0.49	0.31	0.05	0.07	0.06	0.03	0.12	0.37
TiO_2	0.27	1.31	1.45	1.18	0.80	0.26	1.05	0.23
P_2O_5	0.05	0.18	0.29	0.25	0.29	0.04	0.22	0.07
MnO	0.04	0.13	0.11	0.10	0.08	0.05	0.06	0.06
Total	99.90	100.50	100.10	99.80	99.70	100.00	99.66	100.90

Nanyeta Volcanics

1. Dacite welded tuff, 3 miles north-northeast of Nymbool. Analyst, H. W. Sears, AMDL. A1033.

Nychum Volcanics

2. Basalt, 8 miles west of Nychum homestead. Analysts, C. R. Edmond and H. W. Sears, AMDL. R10381.
3. Andesite, 9 miles southeast of Wrotham Park homestead. Analysts, C. R. Edmond and H. W. Sears. R10795.
4. Hypersthene-augite andesite, 9 miles southwest of Nychum homestead. Analysts, C. R. Edmond and H. W. Sears. R10368.
5. Hypersthene andesite, 16 miles southwest of Nychum homestead. Analysts, C. R. Edmond and H. W. Sears. R10366.
6. Rhyodacite welded tuff, 3 miles southwest of Nychum homestead. Analysts, C. R. Edmond and H. W. Sears. R10388.
7. Porphyritic dacite, 6 miles southwest of Mount Mulgrave homestead. Analysts, C. R. Edmond and H. W. Sears. M621(C_4).

Scardons Volcanics

8. Rhyodacite incipiently welded tuff, 3 miles west of True Blue fluorite mine. Analyst, H. W. Sears. C103.

anatectic magma, followed by a de-gassing process which in viscous magmas does not reach the explosive stage until the magma is very close to the surface. At this level, the proportion of phenocrysts is high, and there is relatively little exploding gas, so that the gaseous tuff cloud is not shot into the air, but rather wells out. The rise of the magma is finally followed by caldera-collapse and the extrusion of voluminous hot tuff sheets, which are compacted and welded.

In contrast to the welded tuffs, the acid lava flows contain fewer phenocrysts, and commonly display excellent flow banding. This banding is generally steep and inconsistent notwithstanding the regular low dip of the flows themselves. This may be due to the high viscosity of the rhyolite flows, which were pushed forward rather than flowing forward passively.

Along the Walsh River on the west side of the Featherbed Volcanics, some of the flow-banded rhyolites grade into orbicular lavas near the top of the flow sheets, and similar structures, up to several inches across, were also found locally in the Tennyson Ring Dyke. The globules are commonly made up of dense material similar to that of the enclosing lava; elsewhere they are only partly filled, or are filled with opaline silica, chalcedony, or quartz. Liquid immiscibility may have been responsible for their formation, as has been suggested recently by various authors (e.g. Brajnikov, 1964). The process was probably late magmatic, and was probably initiated by the drop in pressure due to extrusion.

The volcanic products include subordinate glass-rich rocks, welded pumice beds, crystal-lithic breccias, agglomerates, and water-laid reworked tuffs. Most of the glassy rocks have been devitrified. Many of the volcanics contain xenoliths of other volcanic rocks, but inclusions of granite and sedimentary rocks may also be present. In places the volcanics contain amygdules, which may be filled with prochlorite, chalcedony, quartz, and calcite (Pl. 8, fig. 1). Agate nodules, derived from the amygdaloidal members of the Nychum Volcanics, are plentiful along the Mitchell River.

The volcanics are commonly intruded by granite, and although the intrusive contacts are rarely exposed, the volcanics near the intrusions have usually been recrystallized, granulated, and devitrified; their hornblende has been converted into aggregates of fine biotite, and numerous quartz veins are present. Where recrystallization is very pronounced, the contact between the volcanics and intruding granite is gradational, as in the Burdekin River area.

The Granites

Before the regional mapping programme, only a few of the granites in the Hodgkinson Basin had been described, and little was known about their age and origin.

The more recent data on the southern part of the area have been collated mainly by Branch (1966), and in the north by Morgan (1961, 1964, 1965, unpubl.). Branch has made a special study of the structure and evolution of the late Palaeozoic granites and volcanics of the Georgetown Inlier and part of the margin of the southern part of the Hodgkinson Basin (Branch, 1966).

This Bulletin includes brief descriptions only of the granite units together with chemical data and the results of isotopic age determinations. The subdivision into units is based on lithology and geographical distribution. The large granite bodies have been mapped as single units, but some of them may consist of several phases differing in composition and age. In places, one rock type grades into another. These points are illustrated in the variation diagrams (Figs 12-14) and by the range in age of the intrusions.

Ixe Microgranodiorite

Derivation of name: from Ixe Mountain, at longitude 144°24′E., latitude 17°45′S. Formerly known as Ixe Monzonite (Best, 1962); the new name was introduced by Branch (1966).

The rock crops out in two areas on the northern side of the Lynd River, north of Fossilbrook, with an area of about 20 square miles. It is a fine-grained

dark greenish grey rock with white feldspar phenocrysts, and comprises microgranodiorite and some adamellite; they contain biotite and rare hornblende which is generally altered to chlorite and epidote. In the area northeast of Burlington homestead the microgranodiorite grades into a coarser-grained rock similar to the Herbert River Granite. The microgranodiorite is intruded by Elizabeth Creek Granite, and is considered by Branch to be of the same age as the Herbert River Granite.

Almaden Granite

Derivation of name: from Almaden, at longitude 144°40′E., latitude 17°20′S. Name introduced by Best (1962).

The Almaden Granite is generally a grey biotite-hornblende adamellite or granodiorite, which was first mapped in the Almaden/Chillagoe area. The texture ranges from coarse to fine-grained, and is commonly porphyritic. The rock is composed of quartz (15-30%), plagioclase (30-45%), potash feldspar (7-25%), and subordinate biotite and hornblende. De Keyser subsequently included some intrusions of pyroxene-hornblende-biotite-quartz diorite and quartz gabbro, which occasionally contain hypersthene (de Keyser & Wolff, 1964). The outcrops of grey biotite-hornblende granodiorite in the Ingham Sheet area probably also belong to the Almaden Granite, as they are similar in lithology, and comparable in age to the type Almaden Granite.

Branch considers the Almaden Granite to be a variety of the Herbert River Granite.

Herbert River Granite

Derivation of name: from the Herbert River in the Herbert River Falls area, at longitude 145°21′E., latitude 18°18′S. The name was first published by Best (1962).

Type area: Herbert River Falls.

The Herbert River Granite crops out almost exclusively in the Atherton Sheet area, along the southern margin of the Hodgkinson Basin and in the adjoining borderland. The granite probably continues into the Ingham Sheet area, but the intrusions could not be mapped because of the dense cover of rain forest and the deep weathering, and most of them have been included in an undifferentiated unit (Cgb). The total known outcrop area of Herbert River Granite is about 1000 to 1300 square miles.

The typical Herbert River Granite is medium-grained and light grey, and commonly contains pale pink phenocrysts of feldspar. The composition ranges from adamellite to granodiorite. The rock consists of quartz (30-50%), alkali feldspar (10-45%), plagioclase (10-50%), and biotite (up to 10%). Hornblende appears only in the more basic varieties which grade into Almaden Granite; muscovite is rare.

Elizabeth Creek Granite

Derivation of name: from Elizabeth Creek, which flows into the Einasleigh River at longitude 143°54′E., latitude 18°5′S. This name was first published by Best (1962).

The total outcrop area of the many scattered exposures of Elizabeth Creek Granite is roughly 2000 square miles, mainly in the Atherton Sheet area. Both

the Elizabeth Creek and Herbert River Granites are confined to the southern margin of the Hodgkinson Basin and the adjoining borderland.

The typical Elizabeth Creek Granite is orange-red to salmon-pink, and has very few mafic minerals. The granite is normally equigranular and medium-grained, but in places it grades into porphyritic microgranite, or coarse pegmatitic granite. It consists of quartz (30-40%), potash feldspar (30-35%), plagioclase (20-30%), and a little biotite (1-5%). Muscovite is rare, and the presence of amphibole in a few localities is due to contamination, according to Branch (1966). Most of the Elizabeth Creek Granite is adamellite, which usually contains more potash feldspar than the adamellites of the Herbert River Granite; a little is true granite.

In places, two or more phases of Elizabeth Creek Granite can be mapped, e.g. in the Doolan Creek and Warby Ring Complexes and in the Petford/Ootann/Nymbool area. South of Petford, the boundary between the coarse pegmatitic pink or red granite and the fine-grained pink granite is sharply defined. The rugged granite south of Lappa Junction is distinguished by the presence of hornblende-bearing biotite microgranodiorite which invariably contains a little accessory allanite (de Keyser & Wolff, 1964).

In many areas, the Elizabeth Creek Granite is greisenized, and the feldspars are pseudomorphed by biotite or sericite. In places, tin, tungsten, copper, and bismuth minerals occur in association with the greisens. The greisens may form large diffuse areas, or may be limited to sharply defined granite dykes, or to narrow zones along joints.

Tully Granite Complex

Derivation of name: after the township of Tully, on the Bruce Highway 30 miles south of Innisfail. The name was introduced by de Keyser (1964).

The Tully Granite Complex, 45 miles long by 15 miles wide, extends from near Tully in the south to about Malanda in the north. It is a heterogeneous mass ranging from quartz gabbro, through tonalite, granodiorite, and adamellite, to acid micrographic granite. Granodiorite and adamellite are predominant. The rocks contain varying proportions of hornblende and biotite, but hypersthene and clinopyroxene appear in some of the more basic types. The texture ranges from fine to coarse, from aphyric and uneven-grained to seriate-porphyritic, and is generally xenomorphic-granular. Micrographic textures are common in the acid, leucocratic, and alkaline members. The plagioclase ranges from labradorite in the more basic rocks, to oligoclase or albite-oligoclase in the most acid varieties.

Mareeba Granite

Derivation of name: from the township of Mareeba, 24 miles west of Cairns. The name was first used by Jensen (1923) for the granite on Hann Tableland, northwest of Mareeba, and was published by Best (1962).

The Mareeba Granite comprises several large intrusions (including the Hann, Mount Carbine, and Windsor Tablelands) and a number of smaller stocks in the geosyncline region of the Hodgkinson Basin between Innisfail in the south and the Bloomfield River in the north. The intrusions are mainly oval and elongated north-northwest.

The Mareeba Granite consists mainly of adamellite, but ranges from granodiorite to granite. The rock is generally grey, porphyritic, medium to coarse-grained, and contains both biotite and subordinate muscovite. Tourmaline is common in many places, especially along the coast to the north and south of Cairns, and garnet is not uncommon.

The rock is composed of quartz (10-70%), potash feldspar (5-55%), plagioclase (10-45%), biotite, and muscovite. The large crystals of creamy white microcline perthite are probably late-stage porphyroblasts rather than true phenocrysts; they generally enclose small crystals of biotite, corroded grains of plagioclase, and quartz, and their margins commonly merge with the groundmass. The porphyroblastic origin is most apparent in some contact zones (Fig. 10).

The composition and texture of the Mareeba Granite varies considerably, particularly in the marginal zones of the intrusions; the variations include coarse-grained rocks with oriented 'phenocrysts', coarse-grained aphyric rocks, fine-grained white tourmaline-bearing aplogranite and muscovite microgranite, and leucocratic diorite. The outcrop at Hartleys Creek, along the coast north of Cairns, ranges from biotite to muscovite granite; in places the granite has been tourmalinized and greisenized or silicified, and small veins of aplite and pegmatite are also present. Two outcrops of diorite, 20 miles west of Mount Carbine, have also been included with the Mareeba Granite.

Isotopic age determination (Richards et al., 1966) indicate that the Mareeba Granite is younger than the Herbert River and Elizabeth Creek Granites.

Cannibal Creek Granite

Derivation of name: from Cannibal Creek, 4 miles west of the northwestern tip of the granite outcrop. The name was introduced by Amos & de Keyser (1964).

The Cannibal Creek Granite includes one intrusion of 45 square miles and a small intrusion 8 miles east of the main body. The granite consists normally of

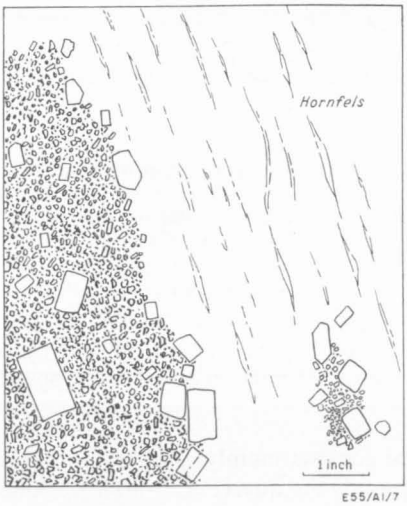


Fig. 10. Contact between granite and hornfels, showing metasomatic formation of feldspar porphyroblasts

medium to coarse-grained biotite-muscovite adamellite. The rock is somewhat foliated, sparsely porphyritic, and cream-grey. It has a chilled margin of micro-adamellite with pronounced flow structure; the low dip of the flow structure in the northeast suggests that the granite contact also dips at a low angle under the adjacent sediments.

Finlayson Granite

Derivation of name: from Mount Finlayson Range, 23 miles south of Cooktown. The name was proposed by Morgan and first published by Lucas & de Keyser (1965a).

The Finlayson Granite forms most of the high mountains in the Annan River Tinfield, south of Cooktown. It generally consists of medium or coarse-grained porphyritic adamellite composed of quartz (30-50%), potash feldspar (20-45%), plagioclase (10-40%), biotite, and muscovite. A chilled margin is usually present, and it commonly contains tourmaline. The tin mineralization in the Annan River Tinfield is associated with this granite.

Trevethan Granite

Derivation of name: from Trevethan Creek, 15 miles south of Cooktown The name was proposed by Morgan, and first published by Lucas & de Keyser (1965a).

The main body of the Trevethan Granite crops out 12 to 15 miles south of Cooktown, where it forms the bare, bouldery Black Mountain. The granite is speckled pale grey, medium to coarse-grained, and commonly porphyritic. It is similar to the Almaden Granite, but isotopic age determinations show that the Trevethan Granite is younger; the granites do tend to become younger towards the north and east. Granodiorite and quartz diorite predominate. They are composed of quartz (13-36%), plagioclase (38-57%), potash feldspar (up to 7%), biotite (11-25%), and actinolithic hornblende and clinopyroxene (up to 25%). In some specimens the hornblende has thin rims of fine-grained biotite. The more basic quartz diorites appear to have been emplaced before the main intrusion.

Puckley Granite

Derivation of name: from Puckley Creek, 30 miles west-northwest of Cooktown. The name was introduced by Lucas (Lucas & de Keyser, 1965a).

The outcrops of the Puckley Granite cover a total area of roughly 50 square miles, but the extent of the granite is unknown, as it is largely concealed by Mesozoic sandstone. It is well exposed along the old railway line in the Puckley Creek area, and the exposure 10 miles west of the upper McIvor River probably also belongs to it.

The Puckley Granite consists mainly of coarse to medium-grained porphyritic biotite adamellite composed of quartz (25-40%), potash feldspar (20-40%), plagioclase (28-38%), and biotite (up to 12%). In places small amounts of muscovite are present. Compared with the Finlayson Granite the plagioclase in

the Puckley Granite is generally more calcic, and the potash feldspar is orthoclase rather than microcline. It appears to be richer in lime and soda, and poorer in potash.

Altanmoui Granite

Derivation of name: from the Altanmoui Range, at longitude 144°38′E., latitude 14°32′S. The name was introduced by Lucas (Lucas & de Keyser, 1965b).

The name Altanmoui Granite has been given provisionally to all granite outcrops along the coast, north of latitude 14°40′S. The large outcrop at Cape Melville consists of grey medium-grained porphyritic biotite adamellite with a fairly uniform texture. It is composed of roughly equal proportions of quartz and oligoclase (35% each), and lesser microcline perthite (25%). The southeastern margin of the intrusion is more varied and includes porphyritic biotite microgranite, aplitic granite, tourmaline-muscovite pegmatite, and some hornblende-bearing rocks. At Barrow Point the rocks consists of porphyritic biotite microadamellite. In the Altanmoui Range the suite includes porphyritic biotite microgranite, foliated muscovite-biotite granite, and pegmatitic aplite.

Other Granites

The geological map (Pl. 24) includes two unnamed granite units (Cgb and Cgc). Blake (1968, unpubl.), after detailed work in the Herberton/Mount Garnet area, added seven new granite names to intrusive bodies that had previously been mapped as Herbert River and Elizabeth Creek Granites by Branch (1966).

One of them (Cgb), in the Ingham and Innisfail Sheet areas, includes a range of granitic rocks which could not be adequately mapped owing to the dense cover of rain forest, the deep weathering, and the rugged terrain. Some of the rocks resemble the Elizabeth Creek and Herbert River Granites, but in many places it is impossible to correlate them with one of the named granite units, and gradation appears to be common (de Keyser et al., 1965). The common rock types include pink leucocratic even-grained coarse, medium, or fine-grained alaskite; grey to pink biotite granite and adamellite; grey hornblende-biotite adamellite; cream arfvedsonite granite or alaskite; microgranite, microadamellite, aplite, and pegmatite. Muscovite-biotite granite was noted in one place only. The alaskites resemble the Elizabeth Creek Granite, and are widespread south of the Herbert River gorge. Many of the grey to pink biotite adamellites and hornblende-biotite adamellites are related to the Herbert River Granite; they occur mainly north of the Herbert River gorge. The arfvedsonite granite on Hinchinbrook Island has been described by de Keyser (1966). Many of the rocks are porphyritic, and chilled margins are fairly common.

The other unnamed granite (Cgc) forms the Gorge Range along the southern side of the Herbert River gorge. The rock is a pink, leucocratic, somewhat vuggy microgranite, containing tourmaline and rare arfvedsonite(?). To the south, the

outcrop tapers into a dyke, and finally passes into a fault. The granite intrudes the surrounding Glen Gordon Volcanics(?), and is probably also younger than most of the other granites (Cgb). The fault, into which the granite (Cbc) tails off to the south, transects the other granite (Cgb), and the intense tourmalinization of this granite along the Palmerville Fault in some of the tributaries of the Herbert River directly to the north is probably associated with the younger granite (Cgc).

Blake (1968, unpubl.), after detailed work in the Herberton/Mount Garnet area, added seven new granite names to intrusive bodies that had previously been mapped as Herbert River and Elizabeth Creek Granites by Branch (1966).

Mineralogical Composition

The granitic rocks range from quartz gabbro and quartz diorite through granodiorite and adamellite to granite and alaskite. Quartz forms more than 10 percent in all the rocks, except in a few of the most basic members. The uncommon rock types include trondhjemite and albite granite. Adamellite is the most common rock type.

In the quartz diorite and granodiorite, hornblende is generally one of the main mafic constituents, but it is absent from the true granite and alaskite. Clinopyroxene and hypersthene are restricted to a few of the quartz diorites and gabbros. Biotite is ubiquitous, although very little is present in some of the acid leucocratic granites and alaskites. Where biotite, hornblende, and pyroxene are found together, the order of crystallization is: clinopyroxene and hypersthene, hornblende, and finally biotite.

Optical data on the feldspars have been given by Branch (1966), who notes that the plagioclase has a particularly wide range in composition and optic axial angle. The potash feldspar is commonly microperthite or cryptoperthite. Microcline and microcline perthite are the normal potash feldspars in the Mareeba and Finlayson Granites and are also common in the Tully Granite Complex; they are much less common in the Elizabeth Creek Granite, and rare in the Herbert River and Almaden Granites, which contain orthoclase or orthoclase perthite. In the alaskites of the Herbert River area, the potash feldspar may be an untwinned microcline showing only faint and rare patchy microcline twinning. The large microcline crystals in the Mareeba Granite are thought to be porphyroblasts (see p. 77 and Fig. 10) formed at a late-magmatic stage, when the granite was already partly crystallized.

The accessory minerals include apatite, zircon, tourmaline, epidote, iron oxide, garnet, allanite(?), fluorite, and cassiterite. Their relative proportion varies: garnet is common in the Mareeba Granite and Tully Granite Complex; fluorite and cassiterite are found in Elizabeth Creek Granite; and allanite is a persistent accessory around Lappa Junction and farther south.

Chemical Composition

Chemical analyses, norms, and Niggli values of many of the granites are given in Table 4.

TABLE 4: CHEMICAL ANALYSES, NORMS, AND NIGGLI VALUES— PERMO-CARBONIFEROUS GRANITIC ROCKS

	1	2	3	4	5	6	7	8	9
SiO_2	77.40	71.20	75.20	75.56	68.30	76.70	73.84	65.42	72.34
Al_2O_3	11.40	14.10	12.73	12.89	15.20	12.00	13.72	16.70	13.84
Fe_2O_3	0.46	0.86	0.07	0.37	1.07	0.23	0.83	1.80	0.82
FeO	1.21	1.79	1.48	1.60	2.30	1.27	1.49	2.50	2.29
MgO	0.25	0.73	0.60	0.29	1.43	0.19	0.56	1.97	0.71
CaO	0.98	2.25	1.34	0.88	4.00	1.15	1.58	3.00	2.02
Na_2O	3.25	3.35	3.39	2.76	3.85	3.10	3.50	4.50	3.33
K_2O	4.10	4.05	4.42	4.95	2.20	4.75	4.26	3.26	3.69
H_2O+	0.49	0.24	0.44	0.53	1.00	0.11	0.32	0.50	0.62
H_2O-	0.08	0.56	0.05	0.19	0.26	0.28	0.11	nil	0.05
CO_2	0.03	0.16	n.d.	n.d.	0.04	0.05	n.d.	n.d.	n.d.
TiO_2	0.14	0.29	0.05	0.12	0.38	0.11	0.15	0.08	0.24
P_2O_5	0.05	0.07	0.10	0.07	0.11	0.04	0.14	0.05	0.03
MnO	0.04	0.06	0.04	0.01	0.03	0.02	0.06	0.10	0.06
Total	99.90	99.71	99.91	100.22	100.17	100.00	100.56	99.88	100.03
Q		29.02	31.69	35.42	24.66	35.08	30.31	15.08	30.34
or		23.45	26.60	30.00	13.25	28.65	25.45	19.35	22.25
ab		30.90	31.00	25.40	35.15	28.35	31.70	40.45	30.45
an		10.95	6.40	3.95	18.05	4.75	6.95	14.60	10.10
C		0.55	0.07	1.77	—	—	0.83	0.40	0.82
di		—	—	—	1.12	0.72	—	—	—
hy		3.98	3.98	2.92	5.84	1.92	3.24	8.00	4.80
mg		0.93	0.07	0.39	1.14	0.24	0.87	1.87	0.87
il		0.42	0.06	0.18	0.54	0.14	0.22	0.12	0.34
ap		0.16	0.21	0.16	0.24	0.07	0.29	0.11	0.05
Total		100.36	100.08	100.19	99.99	99.92	99.86	99.98	100.02
al		41.90	43.40	46.20	38.50	44.50	43.30	37.90	41.70
fm		16.60	12.90	12.50	21.00	9.60	14.80	24.80	18.60
c		12.20	8.30	5.70	18.40	7.70	9.10	12.40	11.10
alk		29.40	35.40	35.50	21.10	38.10	32.80	24.90	28.60
si		359.60	436.00	460.40	293.80	484.00	396.50	252.70	370.60
k		0.44	0.46	0.54	0.27	0.50	0.44	0.32	0.42
mg		0.33	0.40	0.21	0.44	0.19	0.31	0.46	0.29
ti		2.00	0.20	0.50	1.23	0.50	0.60	0.23	0.92
p		0.15	0.24	0.18	0.20	0.13	0.30	0.08	0.06
qz		142.00	194.00	202.30	105.40	232.00	165.00	53.10	156.20

Herbert River Granite

1. Biotite adamellite, Herbert River falls. Analyst, H. W. Sears, AMDL. GSQ.R/555.
2. Biotite-hornblende adamellite, 12 miles southwest of Chillagoe. Analysts, C. R. Edmond and H. W. Sears, AMDL. E55/5/8.
3. Biotite adamellite, 8 miles west of Herberton. Analysts, A. McClure and S. Baker, BMR. E55/5/12.
4. Biotite granite, 1 mile south of Herberton. Analysts, A. McClure and S. Baker. E55/5/13.
5. Hornblende-biotite granodiorite from Claret Creek Ring Complex. Analyst, H. W. Sears. E55/5/22.
6. Biotite microadamellite, 5 miles west of Dimbulah. Analysts, C. R. Edmond and H. W. Sears. E55/5/39.
7. Hornblende-biotite microgranite (assimilated Herbert River Granite?), 5 miles northwest of Almaden. Analyst, A. McClure. E55/5/7.
8. Biotite granodiorite, 17 miles west of Camel Creek homestead. Analysts, A. McClure and S. Baker. E55/9/9.
9. Biotite granodiorite, 15 miles northwest of Camel Creek homestead. Analysts, A. McClure and S. Baker. E55/9/10.

TABLE 4 (continued)

	10	*11*	*12*	*13*	*14*	*15*	*16*	*17*
SiO_2	67.50	66.76	65.30	77.00	74.50	78.36	77.47	78.18
Al_2O_3	15.30	15.32	15.40	12.20	13.10	12.18	12.38	12.74
Fe_2O_3	1.50	1.36	0.57	0.82	0.36	0.60	0.92	0.51
FeO	2.40	2.92	3.65	0.54	1.33	0.37	0.67	0.27
MgO	1.75	2.02	2.07	0.07	0.23	nil	0.03	0.03
CaO	4.05	4.23	4.75	0.67	1.59	0.44	0.36	0.38
Na_2O	3.10	3.11	2.80	4.30	3.40	2.95	3.25	3.52
K_2O	3.20	3.22	3.15	3.80	4.80	4.92	4.61	4.40
H_2O+	0.14	0.80	1.20	0.28	0.29	0.62	0.52	0.52
$H_2O—$	0.87	0.11	0.19	0.14	0.14	0.13	0.09	0.07
CO_2	0.03	n.d.	0.04	0.07	0.12	n.d.	n.d.	n.d.
TiO_2	0.05	0.29	0.05	0.07	0.19	0.02	0.03	0.04
P_2O_5	0.09	0.17	0.08	0.01	0.05	0.06	0.03	0.05
MnO	0.04	0.10	0.02	0.02	0.02	0.07	0.02	0.02
Total	100.02	100.41	99.70	99.99	100.12	100.72	100.38	100.38
Q	23.78	20.96	20.79	33.79	30.29	39.17	37.72	37.60
or	19.25	18.95	19.20	22.75	28.85	29.60	27.75	26.30
ab	28.35	27.75	25.90	39.10	30.95	26.90	29.70	31.90
an	18.70	19.90	20.70	2.82	6.35	1.75	1.65	1.55
C	—	1.05	—	—	—	1.50	1.55	1.84
di	0.60	—	2.48	0.36	1.04	—	—	—
hy	7.36	8.92	10.06	0.18	1.74	0.26	0.50	0.12
mg	1.59	1.41	0.62	0.87	0.37	0.63	0.97	0.54
il	0.08	0.40	0.08	0.10	0.26	0.02	0.04	0.06
ap	0.19	0.34	0.16	0.03	0.11	0.16	0.05	0.11
Total	99.90	99.68	99.99	100.00	99.96	99.99	99.93	100.02
al	37.20	36.00	35.60	45.80	44.00	49.60	48.30	50.80
fm	23.90	26.40	25.90	7.60	9.90	5.70	8.70	4.50
c	17.90	18.10	20.00	4.60	9.70	3.30	2.60	2.80
alk	20.90	19.70	18.50	42.00	36.30	41.50	40.40	42.00
si	279.40	265.00	259.20	491.40	425.60	542.30	514.40	527.90
k	**0.40**	**0.34**	**0.43**	0.37	0.48	0.52	0.48	0.44
mg	0.45	0.46	0.47	0.09	0.20	—	0.03	0.07
ti	0.15	0.90	0.15	0.34	0.80	0.10	0.15	0.20
p	0.16	0.30	0.13	0.03	0.11	0.21	0.08	0.14
qz	95.80	86.00	85.20	123.40	180.40	276.30	252.80	426.20

Almaden Granite

10. Hornblende-biotite granodiorite, 10 miles north-northwest of Rookwood homestead. Analyst, H. W. Sears. E55/1/16.
11. Hornblende-biotite granodiorite, 1 mile west of Almaden. Analysts, A. McClure and S. Baker. E55/5/6.
12. Granodiorite, 5 miles east of Rookwood homestead. Analyst, C. R. Edmond. E55/1/4.

Elizabeth Creek Granite

13. Biotite adamellite, 15 miles south of turnoff to Sundown homestead, Hann Highway. Analyst, C. R. Edmond. E55/5/24.
14. Biotite adamellite, 16 miles southwest of Mount Garnet. Analyst, H. W. Sears. E55/5/25.
15. Biotite granite, Bamford Hill, 2 miles north of Petford. Analyst, A. McClure. E55/5/1.
16. Biotite granite, Elizabeth Creek at Cumbana homestead. Analyst, A. McClure. E55/9/3.
17. Biotite adamellite, 8 miles east of Glen Anne homestead. Analyst, A. McClure. E55/9/11.

TABLE 4 (continued)

	18	19	20	21	22	23	24
SiO_2	77.40	77.60	76.40	76.00	74.70	74.40	73.02
Al_2O_3	11.60	11.80	12.50	12.70	13.50	13.60	14.32
Fe_2O_3	0.23	0.39	0.53	0.50	0.17	0.22	0.41
FeO	1.18	0.58	0.63	0.99	1.31	1.28	1.81
MgO	0.10	0.11	0.06	0.20	0.23	0.23	0.80
CaO	0.84	0.82	0.65	0.71	1.00	1.46	2.02
Na_2O	3.20	3.62	3.60	4.10	3.40	3.65	2.76
K_2O	4.65	4.10	4.70	4.25	4.95	4.10	3.92
H_2O+	0.33	0.73	0.64	0.24	0.35	0.70	0.67
H_2O-	0.10	0.17	0.15	0.13	0.11	0.15	—
CO_2	0.09	0.04	0.10	0.13	0.09	0.10	—
TiO_2	0.12	0.08	0.05	0.07	0.11	0.10	0.11
P_2O_5	0.03	0.02	0.02	0.03	0.09	0.05	0.07
MnO	0.01	0.01	0.01	0.03	0.04	0.04	0.08
Total	100.00	100.07	100.10	100.07	100.10	100.08	99.99
Q	36.44	36.72	33.81	31.40	30.89	31.35	33.40
or	28.15	24.80	28.35	25.45	29.70	24.70	23.70
ab	29.35	33.20	32.90	37.20	30.95	33.35	25.30
an	3.50	3.75	3.15	3.40	4.45	7.00	9.75
C	—	—	0.39	0.11	0.99	0.59	2.20
di	0.48	0.20	—	—	—	—	—
hy	1.64	0.76	0.76	1.70	2.48	2.44	4.80
mg	0.24	0.42	0.55	0.52	0.18	0.22	0.44
il	0.16	0.12	0.06	0.10	0.16	0.14	0.16
ap	0.05	0.05	0.05	0.05	0.19	0.11	0.16
Total	100.01	100.02	100.02	99.93	99.99	100.00	99.91
al	45.50	46.50	47.30	45.50	46.60	46.20	44.70
fm	8.40	6.40	6.60	9.30	9.40	9.30	16.40
c	6.00	5.90	4.50	4.60	6.30	9.00	11.50
alk	40.50	41.20	41.70	40.60	37.80	35.50	27.50
si	516.70	522.30	491.30	462.40	437.90	429.50	387.60
k	0.49	0.43	0.46	0.41	0.49	0.43	0.48
mg	0.12	0.17	0.09	0.20	0.22	0.21	0.39
ti	0.60	0.40	0.24	0.32	0.48	0.43	0.45
p	0.79	0.06	0.05	0.08	0.22	0.12	0.15
qz	254.70	275.50	224.50	200.00	186.70	187.50	177.60

Elizabeth Creek Granite (Contin.)

18. Biotite adamellite, 8 miles south of Burlington homestead. Analyst, E55/5/47.
19. Biotite adamellite, Stannary Hills. Analyst, H. W. Sears. E55/5/23.
20. Biotite adamellite, 3 miles southwest of Crystalbrook homestead. Analyst, C. R. Edmond. E55/5/28.
21. Biotite adamellite, 3 miles east of Whitechalk homestead. Analyst, H. W. Sears. E55/9/17.
22. Grey granite, 5 miles northeast of Whitechalk homestead. Analyst, H. W. Sears. E55/9/19.

Mareeba Granite

23. Biotite granodiorite, Gillies Highway, 9 miles southwest of Gordonvale. Analyst, H. W. Sears. E55/6/2.
24. Biotite granodiorite, Granite Creek, Mareeba. Analyst, S. Baker.

TABLE 4 (continued)

	25	26	27	28	29	30	31	32
SiO_2	75.40	74.80	72.70	73.64	71.40	71.90	73.90	77.00
Al_2O_3	13.50	13.80	14.00	14.40	13.90	13.90	15.10	11.80
Fe_2O_3	0.23	0.34	0.21	0.48	0.32	0.20	0.19	0.30
FeO	0.01	0.97	1.81	0.40	2.70	2.45	0.82	1.41
MgO	0.12	0.33	0.57	0.90	0.65	0.54	0.08	0.30
CaO	1.09	1.05	1.74	0.45	2.50	2.65	0.65	0.73
Na_2O	3.35	3.50	3.35	4.56	3.00	2.85	4.15	2.90
K_2O	4.20	4.55	4.30	3.79	3.85	3.95	4.25	4.55
H_2O+	0.60	0.08	0.16	—	0.85	0.49	0.55	0.34
H_2O-	0.16	0.35	0.68	0.84	0.17	0.10	0.05	0.07
CO_2	0.03	0.03	0.05	—	0.08	0.18	0.04	0.07
TiO_2	0.10	0.12	0.25	0.03	0.37	0.33	0.03	0.20
P_2O_5	0.20	0.11	0.13	0.07	0.12	0.10	0.13	0.15
MnO	0.05	0.03	0.05	0.10	0.05	0.04	0.04	0.02
Total	100.04	100.06	100.00	99.66	99.96	99.70	99.98	99.84
Q	35.17	31.91	29.57	29.86	29.87	30.87	29.46	38.21
or	25.35	27.25	25.95	22.90	23.40	24.00	25.40	27.60
ab	30.65	31.80	30.60	41.75	27.65	26.30	37.60	26.70
an	4.20	4.55	7.95	1.80	11.90	12.55	2.85	2.70
C	3.12	1.57	1.11	2.35	0.63	0.52	2.86	1.26
hy	1.70	2.08	4.04	0.66	5.48	4.86	1.40	2.66
mg	0.24	0.36	0.22	0.51	0.34	0.21	0.19	0.31
il	0.14	0.16	0.36	0.04	0.52	0.48	0.04	0.28
ap	0.43	0.24	0.27	0.16	0.27	0.21	0.13	0.32
Total	100.00	99.92	100.07	100.03	100.06	100.00	99.93	100.04
al	48.80	47.40	40.10	50.70	41.50	42.40	51.40	45.20
fm	7.60	9.26	21.6	5.50	17.80	15.70	5.60	12.60
c	7.20	6.60	9.10	2.90	13.60	14.40	4.00	5.10
alk	36.40	36.70	29.20	40.90	27.20	27.40	38.90	37.10
si	463.50	437.00	354.40	441.00	362.00	373.20	427.50	500.80
k	0.45	0.46	0.46	0.35	0.46	0.48	0.40	0.51
mg	0.15	0.31	0.19	0.15	0.28	0.27	0.12	0.23
ti	0.50	0.50	0.90	0.13	1.40	1.29	0.13	1.00
p	0.52	0.27	0.27	0.18	0.25	0.22	0.32	0.41
qz	217.90	190.00	137.60	177.40	153.20	163.60	171.90	252.40

Mareeba Granite (contin.)

25. Muscovite-biotite granite, ½ mile south of Southedge homestead. Analyst, H. W. Sears. E55/1/5.
26. Biotite-muscovite adamellite, Lighthouse Mountain. Analyst, H. W. Sears. E55/1/7.
27. Biotite adamellite, Mount Lewis forestry road, 16°36'., 145°16'E. Analyst, H. W. Sears. E55/1/6.
28. Biotite adamellite, Mount Carbine. Analyst, S. Baker. E55/1/6.
29. Biotite adamellite, Mount Spurgeon, 16°27'S., 145°10'E. Analyst, H. W. Sears. E55/1/9.
30. Porphyritic microadamellite, McLeod River, 16°30'S., 145°02'E. Analyst, C. R. Edmond. E55/1/8.
31. Biotite-muscovite adamellite, 2 miles east of Spring Hill homestead. Analyst, H. W. Sears. E55/1/12.
32. Biotite adamellite, Roaring Meg falls. Analyst, H. W. Sears. E55/1/15.

TABLE 4 (continued)

	33	34	35	36	37	38	39	40
SiO_2	72.30	69.20	65.90	66.60	75.40	75.10	73.50	70.40
Al_2O_3	14.20	14.80	14.60	14.90	12.80	12.70	13.90	12.70
Fe_2O_3	0.20	0.44	0.50	0.35	0.18	0.36	0.21	0.25
FeO	2.20	2.85	3.95	3.75	1.56	1.45	1.89	4.01
MgO	0.66	1.69	2.95	2.45	0.40	0.29	0.41	0.46
CaO	1.86	2.95	4.60	4.65	1.11	0.91	2.46	1.51
Na_2O	4.20	2.90	3.00	3.10	2.90	3.20	3.90	3.00
K_2O	2.80	3.40	2.70	2.70	4.70	4.95	2.95	4.85
H_2O+	0.61	0.19	9.65	0.08	0.64	0.64	0.12	1.47
H_2O-	0.07	0.87	0.09	0.59	0.59	0.05	0.31	0.03
CO_2	0.04	0.08	0.04	0.08	0.01	0.03	0.05	0.46
TiO_2	0.33	0.46	0.63	0.59	0.24	0.10	0.23	0.48
P_2O_5	0.18	0.17	0.18	0.18	0.17	0.20	0.08	0.13
MnO	0.04	0.06	0.05	0.07	0.03	0.05	0.03	0.04
Total	99.70	100.06	99.84	100.19	100.17	100.07	100.04	99.79
Q	29.32	27.54	20.16	21.88	34.82	33.30	32.63	
or	16.85	20.55	16.25	16.20	28.45	29.50	17.82	
ab	38.30	26.60	27.45	28.20	26.55	28.50	33.05	
an	8.25	13.85	18.65	19.05	4.45	4.00	11.65	
di	—	—	2.80	2.56	—	—	3.98	
hy	4.78	8.44	12.02	10.56	3.20	2.60	—	
mg	0.21	0.46	0.52	0.36	0.18	0.39	0.31	
il	0.46	0.66	0.90	0.84	0.34	0.34	0.44	
ap	0.37	0.37	0.37	0.37	0.37	0.21	0.21	
Total	99.91	100.00	100.12	100.02	99.81	99.69	100.37	
al	43.20	39.50	32.70	34.20	45.40	44.80		
fm	15.70	23.70	31.00	27.80	12.40	11.70		
c	10.40	14.30	18.80	19.50	7.20	5.90		
alk	30.50	22.50	17.60	18.50	35.00	37.60		
si	376.50	313.40	250.80	260.50	454.70	450.90		
k	0.30	0.44	0.37	0.36	0.52	0.51		
mg	0.33	0.49	0.54	0.52	0.28	0.22		
ti	1.33	1.60	1.80	1.73	1.10	1.10		
p	0.40	0.32	0.30	0.30	0.40	0.26		
qz	154.40	123.40	80.40	86.50	214.70	200.50		

Mareeba Granite (contin.)

33. 'Granite', 6 miles west of Mulligan Highway/McLeod River crossing. Analyst, C. R. Edmond. E55/1/10.
34. Muscovite-biotite microgranodiorite, 9 miles west-southwest of Curraghmore homestead. Analyst, H. W. Sears. E55/1/11.

Trevethan Granite

35. Actinolite-biotite granodiorite, Mulligan Highway, 15°41′S., 145°11′S. Analyst, AMDL. D55/13/1.
36. Actinolite-biotite granodiorite, Mulligan Highway, 15°38′S., 145°11′E. Analyst, AMDL. D55/13/3.
37. 'Granite', Cooktown. Analyst, AMDL. D55/13/4.

Finlayson Granite

38. 'Granite', Rossville, 15°44′S., 145°13′E. Analyst, AMDL. D55/13/5.

Dykes

39. Hornblende microgranodiorite, 3 miles southwest of Mount Mulligan. Contaminated Herbert River Granite(?). Analyst, D. K. Rowley, AMDL. M.674.
40. Acid porphyry dyke, traversing Trevethan Granite, 3 miles north of Mulligan Highway/Annan River crossing. Analyst, AMDL. D55/13/2.

The granites fall into the calcic division of Peacock's classification of the igneous rock series, with an alkali-lime index of 64 (Fig. 11). This class is generally found in orogenic belts.

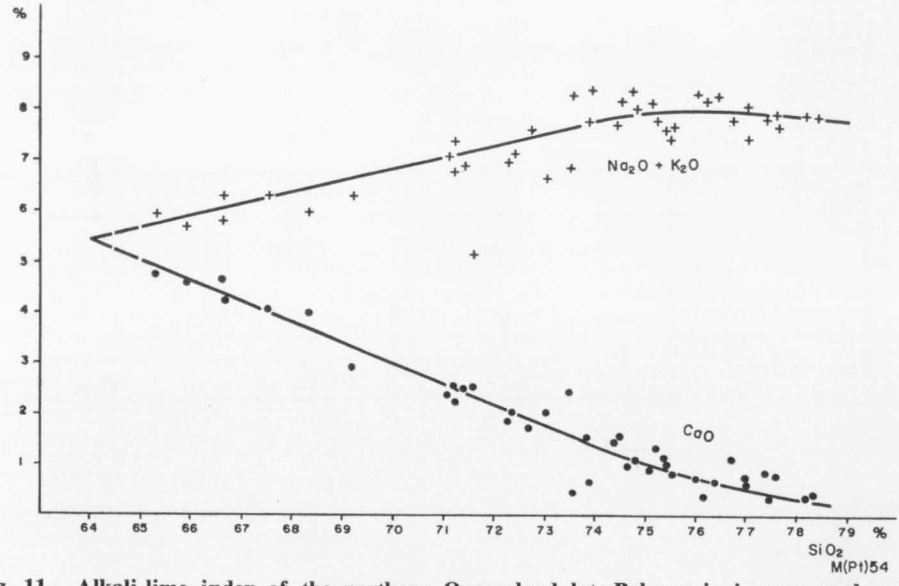


Fig. 11. Alkali-lime index of the northern Queensland late-Palaeozoic igneous rock suite.

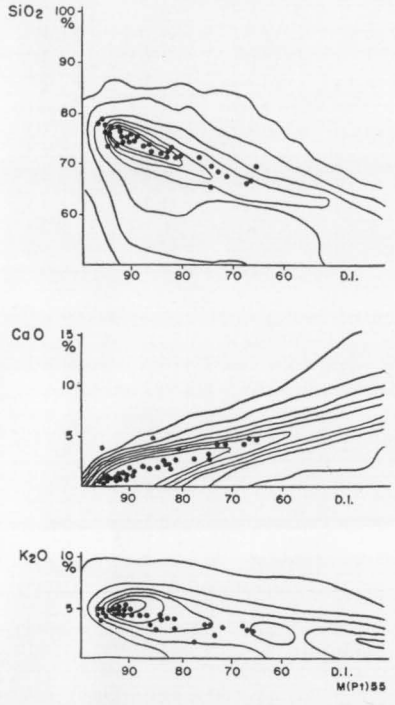


Fig. 12. Oxide/Differentiation Index diagrams.

In Figure 12 the percentages of SiO_2, CaO, and K_2O are plotted against the differentiation index (D.I.) on a contoured background representing the frequency density of 2000 analysed rock samples from all over the world (Thornton & Tuttle, 1960). The result shows that the north Queensland granites form a normal series which falls along the frequency maxima on the diagram.

Other diagrams include a ternary diagram following Larson's method (Fig. 13), and another diagram after Larsen (Fig. 14). All the diagrams show an apparently continuous and gradual compositional variation between the late Palaeozoic granites. A decrease in MgO, FeO, CaO, An, and mafic minerals, is accompanied by an increase in K_2O, Or, Q, and alkali/lime ratio, while Al_2O_3 is constant at first, decreases later. Na_2O or Ab as well as total feldspar remain approximately constant. Hornblende is common in rocks rich in mafic minerals, whereas muscovite appears in rocks poor in mafic minerals.

Although variation diagrams reveal gradual changes in the chemical composition of a suite of rock types, the interpretation of their possible significance is not absolutely certain. Bowen warned that such diagrams may illustrate evolution trends only when glassy or uniformly fine-grained volcanic rocks are used, and Chayes (1964) states that Harker diagrams do not prove fractional crystallization, but may illustrate a multitude of processes such as hybridization, contamination, gas transfer, etc. Tuominen (1964) even considered that the trends shown on diagrams tend to camouflage rather than show up relationships of genetic importance.

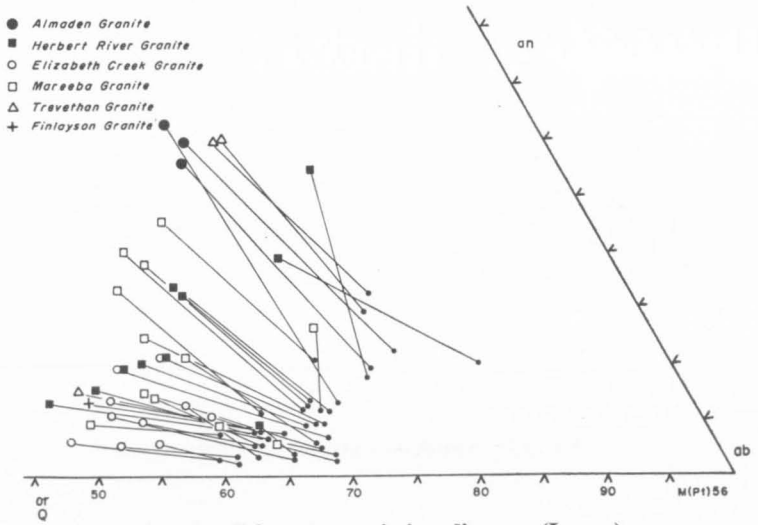


Fig. 13. Triangular variation diagram (Larsen).

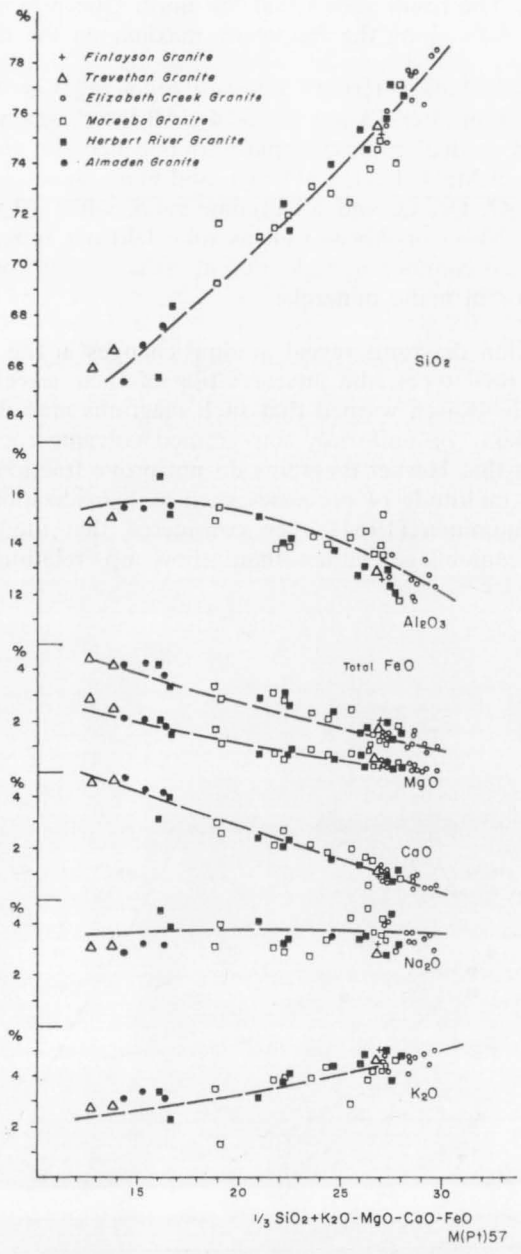


Fig. 14. Variation diagrams (Larsen).

Contact Effects

In general, the contact thermal effects of the late Palaeozoic granites are relatively small, except where the sediments include limestone and other calcareous rocks, especially next to the intermediate granodiorites. The greywacke is only slightly recrystallized, and the slate and siltstone are locally transformed to biotite-quartz hornfels which commonly contains some andalusite and remnants of cordierite. The andalusite is usually altered to fine sericite; the cordierite is crowded with inclusions and largely pinitized. Tourmaline is fairly abundant in some of the hornfelses. In places large porphyroblasts of microcline and sodic plagioclase have been found in the contact zone.

The contact metamorphic effects in the calcareous sediments include recrystallization, decoloration, and the formation of calc-silicate minerals such as grossularite, vesuvianite, diopside, epidote, scapolite, prehnite, wollastonite, tremolite, hornblende, and hedenbergite. The metamorphism was commonly accompanied by metasomatism, and in places contact-metasomatic ore deposits were formed.

Tourmalinization and silicification represent more hypothermal effects. In the group of hills about 25 miles northwest of Chillagoe, near the Nolan Creek crossing, the original sediments have been completely replaced by a quartz-tourmaline rock, probably as a result of magma intrusion close to the surface (but not exposed).

Where the volcanic rocks have been intruded by granite, recrystallization is a prominent feature, and in places there appears to be a gradational contact between the granite and volcanics, as in the Burdekin River area.

Emplacement

The granites are epi-mesozonal intrusions in the classification of Buddington, emplaced at shallow depth. They belong to the group of subvolcanic granites recognized by A. J. R. White, B. Chappell, and C. D. Branch (pers. comm.), which are characterized by narrow contact aureoles, intimate association with volcanic rocks (usually calc-alkaline), graphic intergrowths, feldspar zoning, and complex twinning. The granites are roughly elliptical or oval in plan, with the long axes subparallel to the regional strike of the folded sediments, although cross-cutting relationships are seen in details. The contacts are sharp and clean, and are generally steep. There is little evidence of forceful intrusion. Some of the granites appear to have been emplaced along fault zones.

These features indicate a fairly rapid and mostly passive form of emplacement of the magma at the higher levels now exposed. The oval shape of the intrusions, and the abundance of ring fractures and cauldron subsidence areas along the southern margin of the Hodgkinson Basin and in the adjoining borderland, suggest that the granites were emplaced by major ring-fracture stoping or cauldron subsidence.

It is interesting to note the difference in contact relationships at different levels of a granite body. On the western margin of the Mount Spurgeon Tableland, the granite contact is smooth and clearcut, and there is little disturbance of the wall rock. On the eastern margin of the same granite, in the Mossman River, about

1000 feet below the level of the western outcrop, feldspar porphyroblasts have been found in the wall rocks (Fig. 10), and the surrounding sediments have been more plastically and intricately deformed than those in the western outcrop, and seem to have been forcibly pushed aside by the intruding magma.

Dykes

Numerous dykes occur in all areas of igneous activity. Most of the dykes are acid, but basic dykes are common in places, as for example, along the Tate River southwest of Chillagoe.

Most of the dykes have been plotted from the air-photographs; the basic dykes usually appear as dark lines and grooves, and the acid dykes stand out as white lines and ribs. In places, the trace of the dyke is indicated by the distribution of the vegetation.

Most of the dykes range from a few feet to about 40 feet wide, but in many areas where the dykes occur in dense swarms, the aggregate dilatation of the country rock must have been considerable.

The localization of the dyke swarms is probably structurally determined. Doming may have been a important factor, as in the area south of the Herbert River Gorge where the Palmerville Fault may have acted as a hinge line. Elsewhere, dyke swarms are located along the projected extensions of faults where these change direction abruptly; as for example, west and south of the Palmerville Fault near Ootann, where it shows a nick-point.

The acid dykes include quartz-feldspar porphyry, felsite, rhyolite, granophyre, aplite, trachyte, quartz trachyte, microgranite, alkali microgranite, and keratophyre. In one locality on the Burdekin River, an arfvedsonite microgranite dyke was found (de Keyser, 1966). The acid dykes are similar to the extrusive volcanic rocks in texture and mineralogical composition; in the rain forest belt, where the rocks are poorly exposed, it is usually difficult to distinguish between the volcanics and the dykes. Most of the dykes are weathered pink or mauve, but the groundmass in the fresh rocks ranges from light to dark grey, black, mauve, cream, pink, or green, and the texture from finely crystalline to dense and flinty. Spherulitic textures are not uncommon, and generally occur in narrow rims around quartz grains. Flow banding, where present, may show drag effects along the wall rock. Xenoliths are found locally, and include pink leucocratic granites. Many of the dykes are aligned in the direction of the regional strike, but cross-cutting dykes are also common.

Basic dykes are far less numerous than acid, except in some areas, and show a wider range of deviation from the regional trend. Most of the dykes consist of dolerite or quartz dolerite containing hornblende, actinolite, augite, or olivine, and in places some biotite. Andesite and andesite porphyry dykes also occur. In some of the dolerites the feldspar is albite. Many of the dykes are chloritized, silicified, calcified, or sericitized, or the original pyroxene has been altered to actinolite at a late-magmatic stage.

The dykes are of several ages. Precambrian or early Palaeozoic dykes are probably present in the Precambrian borderland; fragments of rhyolite are found

in the Silurian Chillagoe Formation. Some of the olivine dolerites may be related to the Cainozoic vulcanism: the olivine basalt dykes on Stevens Island (South Barnard group) and at Bones Knob near Atherton are known to be Cainozoic; but most of the dykes were probably intruded during and shortly after the late Palaeozoic period of igneous activity. The granites are intruded by the acid and basic dykes. The basic intrusions are generally later than the acid dykes, but there were probably several overlapping phases of intrusion.

One type of dyke rock is easily distinguished by its abundant euhedral pink or cream feldspar phenocrysts, from 1 to 2 cm across, and rounded quartz phenocrysts, set in a dense fine-grained groundmass. The feldspar is commonly pink orthoclase rimmed by white albite or oligoclase. One of these dykes in the Boxwood Ring Complex passes laterally into a normal fine-grained acid dyke. A similar rock type occurs 10 miles south-southeast of Cardwell (de Keyser et al., 1964, unpubl.), but as its origin as a dyke rock is not certain here it has been included with the granite (Cgb) on Plate 24.

The large granodiorite or adamellite dyke southwest of Mount Mulligan has been included with the undifferentiated rock types (Pzu), and has been described on page 72, and by Morgan (1946b, unpubl.).

Age and Relationships of the Granites and Volcanics

The ages and relationships of the granites and volcanics in north Queensland are complex, and the stratigraphic order of the igneous units as shown on the geological map (Pl. 24) is subject to revision as more data become available.

Early writers tended to assign one age to all the granites, and a different age to all the volcanic rocks, but later it was found necessary to distinguish between pre-granite and post-granite volcanics or porphyries (e.g. Ball, 1914c). In the Herberton district, other volcanics were not recognized as late Palaeozoic and were placed in the Lower Tertiary (AGGSNA, 1939; Levingston, 1960b). The unconformable contact between the volcanics and the underlying folded Palaeozoic formations is not generally exposed, and Jensen (1939a, unpubl.), for example, considered the Featherbed Volcanics to be older than the Hodgkinson Formation, and the Nychum Volcanics to be interbedded with Chillagoe Formation. As late as 1964, he defended this view, which is based mainly on the presence of rhyolite grains and fragments in the greywackes of the Hodgkinson Formation. However, early Palaeozoic or even Precambrian volcanics, similar to the Permo-Carboniferous volcanics, were probably widespread on the Precambrian borderland; for example, isotopic age determinations suggest a Proterozoic age for the Croydon Felsite about 150 miles to the southwest of the Hodgkinson Basin. The greywacke-conglomerate at the base of the Chillagoe Formation also contains rhyolite fragments which consequently must be older than the Silurian. Photo-interpretation, geological mapping, and the isotopic ages clearly indicate that the Featherbed Volcanics are younger than the Hodgkinson Formation.

The complexity of the problem is illustrated by the continuing change in ideas during the last decade. De Keyser et al. (1959, unpubl.) originally regarded the granites in the Chillagoe/Petford district as modifications of a single batholith. Branch at first recognized two distinct epochs of granite intrusion — an older

Herbert River Granite, and a younger Elizabeth Creek Granite — and likewise subdivided the volcanics into two different time groups. De Keyser & Wolff (1964) then distinguished at least six granite variants, with a general order of intrusion from basic to acid. They regarded the named granite units as lithological types only, without attaching too definite age limits to them. Lately, Blake (1968, unpubl.) has further subdivided the granites in the Herberton/Mount Garnet district into 10 units of different intrusive age, and found that the order of intrusion did not follow any trend from basic to acid. Branch (1966) modified his original views to the extent that he now considers the Elizabeth Creek Granite and the Herbert River Granite to have two distinct origins: the former would have been derived from fractionated sima magma and be related to the upper Palaeozoic volcanic rocks, whereas the Herbert River Granite would have been formed from anatectic magma.

Further regional mapping, and isotopic age determinations, have shown that the intrusive age ranges of the Elizabeth Creek and Herbert River Granites cover approximately the same time span, and that there is a general tendency for all granites in the Hodgkinson Basin to become younger towards the east and north. Basic granite varieties furthermore may be younger than acid varieties. The results of the isotopic datings have been summarized by Richards et al. (1966). It should be noted that the ages of the Herbert River and Elizabeth Creek Granites span a period of about 60 million years, compared with 30 million years for the emplacement of the Mareeba Granite, which is generally more uniform, lithologically, than the others. The wide range is possibly a result of contamination and re-heating processes between the Herbert River and Elizabeth Creek Granite types, which commonly occur in close association.

Before the advent of isotopic dating techniques, the estimated ages of the granites ranged from Silurian to lower Triassic. One as yet not satisfactorily explained anomaly concerns the Nychum Volcanics: these are considered to be Upper Permian on fossil evidence, whereas isotopic age determinations suggest that both the Featherbed Volcanics and the Nychum Volcanics are Lower Carboniferous (L. Black and J. R. Richards, pers. comm.). Both datings appear to be firmly established and reliable, and no definite answer to the problem has yet been found. Possibly the outcrops along the Mitchell River (where the fossils have been found) belong to a unit unrelated to the volcanics in the type area around Nychum homestead and west of the Palmerville Fault (which yielded the samples for the isotopic work). However, plant fossils have recently been found by W. R. Morgan from the type area also, from near the base of the succession, and they are being investigated by Mary White, whose report may shed some light on the problem.

The granites in north Queensland appear to be satisfactorily dated by isotopic age determinations, but the relative ages of the volcanics are less firmly established, except where they are interbedded with fossiliferous sediments. The isolated outcrops of volcanics are lithologically similar, and correlation is based mainly on their relations to adjoining granites, and on structural considerations. The uncertainty of such correlations is shown by the differences of opinion between Branch (1966) and Blake (1968, unpubl.) regarding correlation of the Glen Gordon, Walsh Bluff, and Nanyeta Volcanics in the Mount Garnet/Herberton district. Using the different types of granite as datum pegs is not warranted, as their ages may extend over long periods and are found to overlap, while the volcanic complexes were formed in much

shorter time spans. A certain granite type can therefore be older or younger than a given volcanic complex.

Branch (1966) made use of rock sequences and structural and mineralogical characteristics. Thus, he provisionally correlated the Boxwood Volcanics with the Featherbed Volcanics because of the similarity in lithology and the presence of both hornblende and allanite, minerals that are not common elsewhere. However, the Boxwood Volcanics are probably slightly older than the Featherbed Volcanics as they are cut by the Tennyson Ring Dyke, which is genetically associated with the Featherbed Volcanics. The Featherbed Volcanics are also younger than the Doolan Creek Rhyodacite and the Nychum Volcanics, both of which are cut by the boundary fault of the Featherbed cauldron subsidence area. The internal subdivision of the Featherbed Volcanics is also uncertain (de Keyser & Wolff, 1964, p. 36; Branch, 1966, p. 29).

Although the general pattern of igneous activity in north Queensland has been established, the relative ages and detailed correlation of some of the volcanic units are still uncertain. It is possible that the various ring complexes, each containing a similar sequence of volcanics and granites, were formed one after another, and although the cycle of igneous activity is similar in each ring complex the ages can differ considerably. In some of the Nigerian ring complexes the same sequence of events has been repeated several times (Turner, 1963).

MESOZOIC

Mesozoic sediments occur in the Laura Basin in the Cape Melville and Cooktown Sheet areas, and along the western margin of the map area, on the eastern edge of the Carpentaria Basin. They were formerly much more extensive, but only small residuals remain towards the more central parts of the map area. The Mesozoic rocks include Jurassic sediments (in the Laura Basin) and Lower Cretaceous deposits; the Pepper Pot Sandstone at Mount Mulligan may be Triassic.

Pepper Pot Sandstone

Derivation of name: the Pepper Pot, which forms the southernmost tip of the Mount Mulligan block mountain.

Type area: Mount Mulligan (Pl. 9, fig. 1). The formation was named by de Keyser (Amos & de Keyser, 1964).

The Pepper Pot Sandstone is composed of current-bedded massive red micaceous and arkosic sandstone, pebbly sandstone, and conglomerate near the base, which grade into more flaggy white argillaceous sandstone and siltstone at the top. The section includes thin red tuff-shales (Ball, 1912b,c), one of which is a foot thick, and forms the base of the Mesozoic succession resting on the Mount Mulligan Coal Measures.

The conglomerate contains well rounded pebbles of quartz and chert, and some quartzite and greywacke of the Hodgkinson Formation; rhyolite pebbles are extremely rare compared with the underlying Permian conglomerates. Bedding and cross-bedding are well developed, especially in the sandstone and pebbly sandstone. The presence of lenses of conglomerate and grit filling stream channels and washouts, the coarse torrential type of current-bedding, and the plant fossils (Ball, 1917a)

indicate a terrestrial environment of deposition, with transport from the east and southeast. The sandstone at the top of the succession is finer-grained, more thinly bedded and flaggy, and more friable, silty, argillaceous, and micaceous than the lower sandstones. Ripple marks are present in places. Conglomerate is uncommon in the upper part of the section.

The Pepper Pot Sandstone rests on the Mount Mulligan Coal Measures with a slight unconformity according to Ball (1917a), but Morton (1945) considers that the formations are conformable, and Dixon (1957b, unpubl.) suggests they are separated by a marked angular unconformity. Although the formations appear to be conformable, the wedging out of the Permian strata to the south indicates a slight unconformity.

Dixon (1957b) estimated the thickness at 1000 feet, and this is confirmed by measurement on the air-photographs.

The Mount Mulligan sandstones and conglomerates were originally considered to belong to the Desert Sandstone, but in 1917 Ball recorded the presence of *Taeniopteris*, *Odontopteris*, *Phyllotheca*, and *Ginkgo*, which suggested that the formation was Triassic. Dixon (1957b) was impressed by the resemblance to the Cretaceous Blythesdale Sandstone (now Wrotham Park Sandstone) in the west, and Whitehouse (1952) correlated the formation with the Mesozoic sediments in the Laura Basin, which he regarded as wholly Cretaceous at the time. Others, recognizing that part at least of the Mesozoic sediments in the Laura Basin are Jurassic, correlated the sandstones at Mount Mulligan with the Lower Jurassic or Triassic Bundamba Series (David, 1950). Triassic arenaceous beds with red tuff-shales have been found in numerous localities near the base of the Artesian and Bowen Basins and it seems likely that the Pepper Pot Sandstone may also be Triassic.

The Mesozoic strata at Mount Mulligan generally dip at less than 20°, but steep dips are encountered along the faulted boundaries (Pl. 26).

Wrotham Park Sandstone

Derivation of name: Wrotham Park homestead, longitude 144°00′E., latitude 16°40′S.

Type area: the Mesozoic sandstone outcrops in the Wrotham Park/Walsh River area. The name was introduced by Laing & Power (1959).

The Wrotham Park Sandstone rests unconformably on the folded Precambrian and Palaeozoic formations along the western borders of the Mossman and Atherton Sheet areas; it forms the Red Plateau with a regional dip of less than 5° to the west (Pl. 9, fig. 2).

The formation comprises pebble conglomerate and basal breccia, pebbly sandstone, feldspathic quartz sandstone, and some thin intercalations of shale. The ratio of conglomerate to sandstone increases eastwards towards the old shoreline. In many places, fine glauconitic sandstone of uneven texture forms the top layer (Houston, *in* Woods, 1961). Where the unconformity at the base is exposed, a basal breccia 3 to 5 feet thick is usually present; it is composed of angular fragments of the underlying Precambrian or Palaeozoic formations.

The well rounded pebbles in the conglomerate range up to about 5 inches in diameter, and consist mainly of vein quartz, quartzite, rhyolite, chert, and metamorphic rocks.

The sandstone is texturally and mineralogically fairly mature; the grains are well rounded and sorted, and the grainsize is 0.5 to 1.0 mm. The sandstone is usually feldspathic, red or white, and mostly thick-bedded or massive; flaggy sandstone is less common. Lenses and intercalations of pebbly sandstone and conglomerate are numerous. Cross-bedding is usually well developed, and generally indicates transport from the east. Mud cracks and ripple marks occur locally.

The shale interbeds are generally light grey, and weather rusty red. The enclosed sandy laminae occasionally contain worm tracks.

Fossils are scarce. In 1960, terebratulid brachiopods were found at the top of a small mesa 3 miles southeast of where the road crosses Nolan Creek, and *Maccoyella barklyi* (Moore) was identified from the same outcrop by Woods (1961). Rare impressions of indeterminate plant stems and some fossil wood were noted in other outcrops. Woods assigned a Neocomian age to the formation, because it underlies the Blackdown Formation, which he regards as Aptian. Laing & Power (1960) correlated the Wrotham Park Sandstone with the Gilbert River Formation to the southwest of the Atherton Sheet area. They regard the Gilbert River Formation as lower Aptian on the basis of the fossils in the top of the formation, which is probably continuous with the Wrotham Park Sandstone.

The Wrotham Park Sandstone probably extended at least as far east as Mungana, where remnants of sandy valley-fill deposits strongly resemble the Cretaceous beds (de Keyser & Wolff, 1964). The northern extension of the formation is unknown, and the boundary with the lithologically very similar Battle Camp Formation has been drawn arbitrarily.

The pre-Cretaceous surface was uneven, showing relief of several hundred feet (Dixon, 1957a, unpubl.). The thickness of the formation is therefore variable, with a possible maximum of 400 feet along Elizabeth Creek in the type area. The base of the formation was probably deposited mainly in brackish or freshwater environments, which were succeeded by littoral-marine facies.

The formation is well exposed in steep-sided mesas and buttes, but in many places the sandstone in the larger outcrops has disintegrated into a blanket of thick loose white quartz sand, with local outcrops of tough 'billy' composed of quartz sand grains embedded in a dense pale grey or creamy siliceous matrix.

Blackdown Formation

Derivation of name: Blackdown homestead, longitude 143°55′E., latitude 17°02′S., outside the map area.

Type area: Elizabeth Creek and Walsh River areas, between Wrotham Park and Blackdown homesteads. The name was introduced by Laing & Power (1959). The fossils have been described by Woods (1961).

The Blackdown Formation rests conformably on the Wrotham Park Sandstone and consists mainly of grey to black shale, siltstone, and sandy shale, with intercalations of grey, olive, and buff lenticular sandstone which may be glauconitic in part. Discoidal calcareous concretions are common in certain bedding planes in both the shale and sandstone; they range up to 8 feet across and are thought to be syngenetic (Woods, 1961). Veins of gypsum in joints and bedding planes have been reported by Laing & Power (1960).

The Blackdown Formation is considered to be lower Aptian by Laing & Power (1960); Woods suggests an Aptian age, and has correlated the beds with part at least of the Roma Formation. Dr Irene Crespin has examined foraminifera and some radiolaria and ostracoda in a specimen from Elizabeth Creek, 3.3 miles from the Walsh River Telegraph Office on the road to Wrotham Park, and dated them initially as Aptian, but later she suggested that an Albian age is more probable (pers. comm.). However, the specimen was collected from beds which may be a continuation of the Cretaceous sediments along the Walsh River near its junction with Louisa Creek, for which Woods (1961) proposed the name Trimble Formation, and which he believes to be of Albian age because of the presence of *Aucellina hughendenensis* (Etheridge) and *Inoceramus etheridgei* Etheridge fil.

These outcrops are small and scattered, and their relationship with the Blackdown Formation is unknown. Woods (1961) estimates that the maximum thickness of the Blackdown Formation is about 200 feet.

THE LAURA BASIN

Dalrymple Sandstone

Derivation of name: Dalrymple Range, 10 miles northwest of Cooktown.

Type area: Eastern margin of continuous outcrops west of Normanby River, from Battle Camp Range (long. 144°45'E., lat. 15°18'S.) southeast for 10 miles to Cone Mountain (Stacks Creek), 29 miles west-northwest of Cooktown.

Outliers of the formation were called Dalrymple sandstones by Tenison Woods (1880), but other names have been in general use since then (Denmead *in* Hill & Denmead, 1960), one of the most recent being Laura Sandstone. The name Dalrymple Sandstone was endorsed by Lucas (Lucas & de Keyser, 1965).

The Dalrymple Sandstone is the basal unit of the Mesozoic sequence in the Laura Basin. It is well exposed round the elevated southern and eastern margins of the basin, and inwards towards the axis of the basin almost as far as Laura township, where it dips beneath the Cretaceous Battle Camp Formation and Cainozoic terrestrial deposits. It rests unconformably upon the uneven basement of folded Palaeozoic sediments and granite. The buried granite stocks formed inselbergs, up to 1000 feet high, and some of them in the northeast were never completely covered by the Dalrymple Sandstone.

The top of the formation appears to have been nearly planar, and its thickness therefore varies considerably according to the configuration of the basement. In and around the Battle Camp Range the formation rests with local steep initial dips upon a very uneven granite basement. In places the relief of the basement is probably more than 1000 feet over a distance of 1 to 2 miles, but the formation appears to be at least 2000 feet thick in most of the type area. Wedges and lenses of sandstone, shale, and conglomerate, up to 300 feet thick, are exposed in the Dalrymple Range and in many other sections around the margin of the basin. On Flinders Island in the north, however, the formation consists of at least 800 feet of coarse conglomerate with minor sandstone and shale. Most of the 1200 feet of sandstone and shale reported in the Deighton Bore, northeast of Laura, probably belongs to the Dalrymple Sandstone, and at least 1800 feet of Dalrymple sandstone and shale were found in Cabot-Blueberry Marina No. 1, near Princess Charlotte Bay.

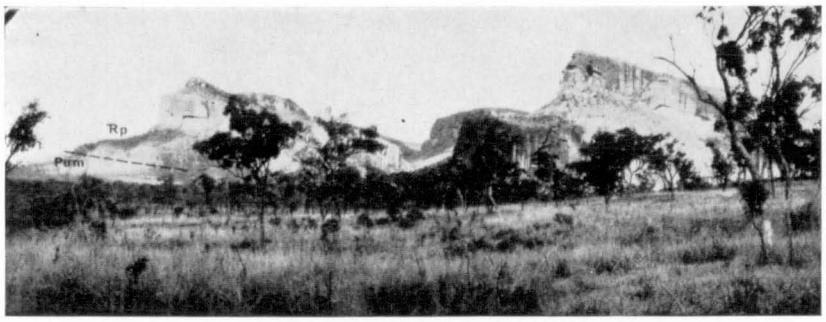


Fig. 1. Mount Mulligan, from the northwest.

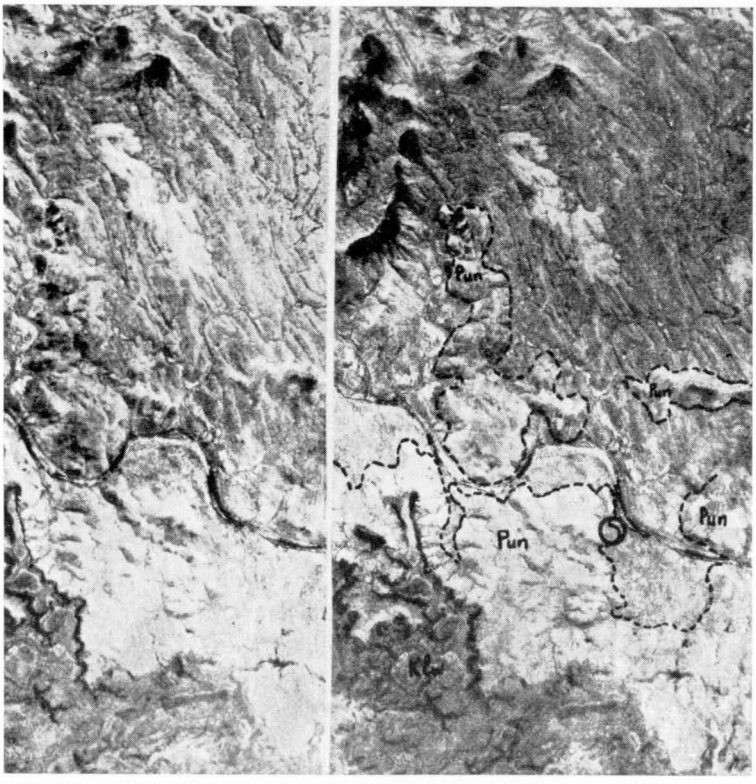


Fig. 2. Horizontal Wrotham Park Sandstone (Klw; dark vegetation), overlying Nychum Volcanics (Pun; sparsely vegetated, light tones) and folded strata of the Chillagoe and Mount Garnet Formation (grey; showing north-northwestern trend-lines). Elizabeth Creek area, east rim of Red Plateau. Scale 1 : 80,000 approximately.

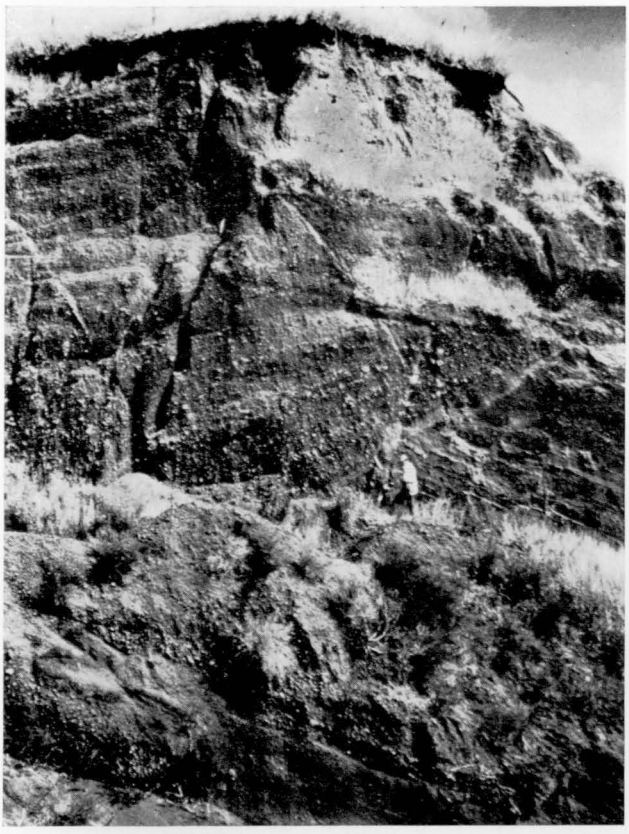


Fig. 1. Bedded cinder deposits in quarry in the flank of one of the Seven Sisters cones. Note cross-stratification and small settling faults (near person).

Fig. 2 (Below). The Seven Sisters, a group of Quaternary basaltic cinder cones between Atherton and Yungaburra.



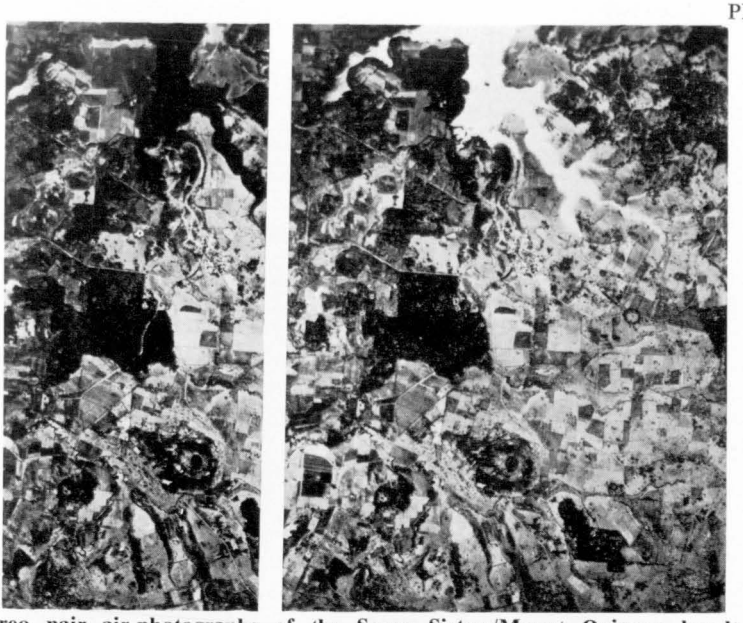


Fig. 1. Stereo pair air-photographs of the Seven Sisters/Mount Quincan basalt area, at Yungaburra.

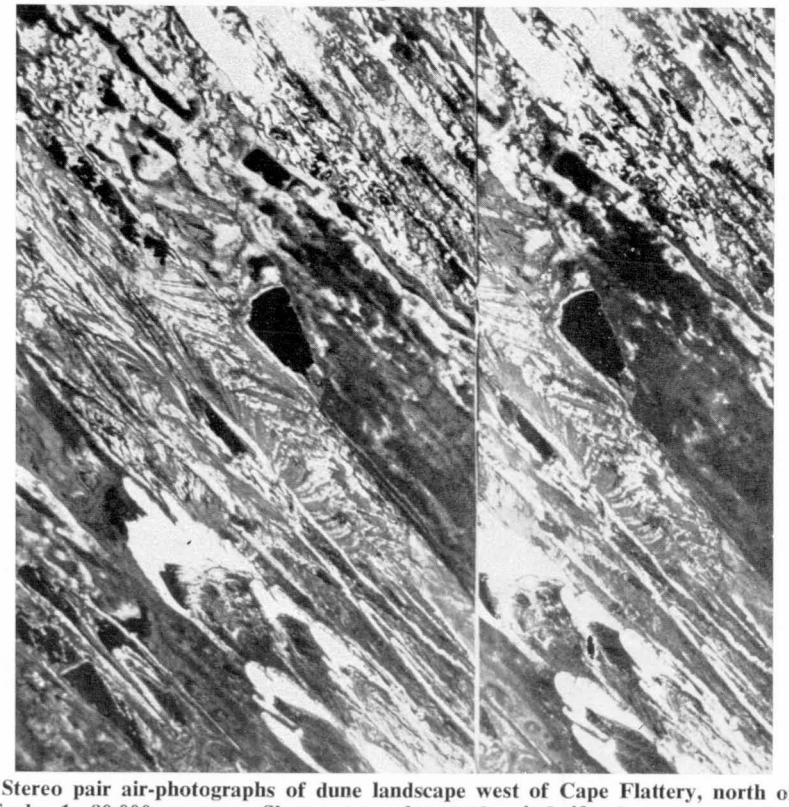


Fig. 2. Stereo pair air-photographs of dune landscape west of Cape Flattery, north of Cooktown. Scale 1 : 80,000 approx. Shown are elongated wind-rift dunes, parabolic dunes, blow-outs, sand marks, and lakes.



Fig. 1. Graded-bedded siltstone and fine-grained sandstone of the Mount Garnet Formation.



Fig. 2. Slightly metamorphosed siltstone and fine-grained sandstone sequence of the Hodgkinson Formation. Daintree River.



Fig. 1. Folded Barron River Metamorphics, Mulgrave River. B_2(?) folds incongruously transected by S_3 cleavage (parallel pencil).
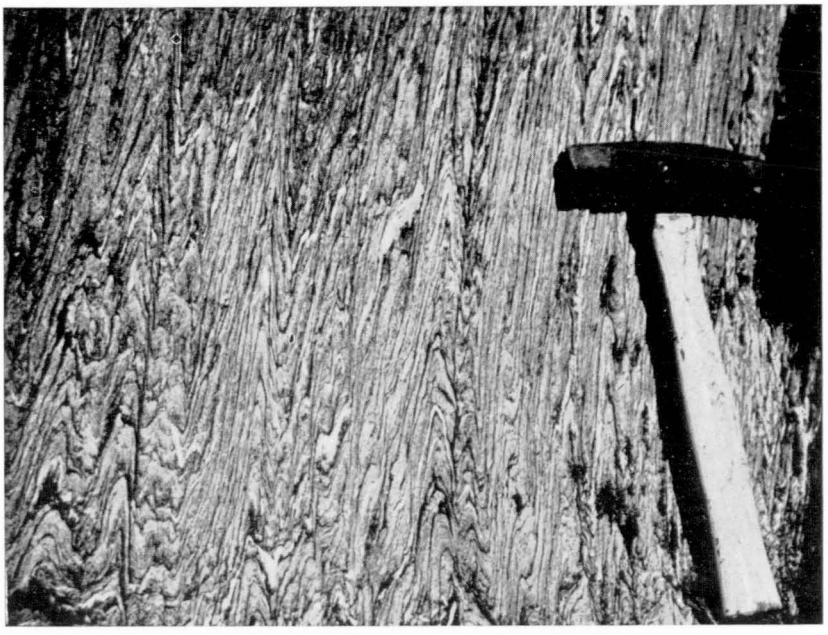


Fig. 2. Shear-folded and transposed Barron River Metamorphics, Etty Bay.



Fig. 1. Mourilyan Harbour area, showing old beach sands and strand-lines, separated by swamps of tidal flats and lagoonal deposits.

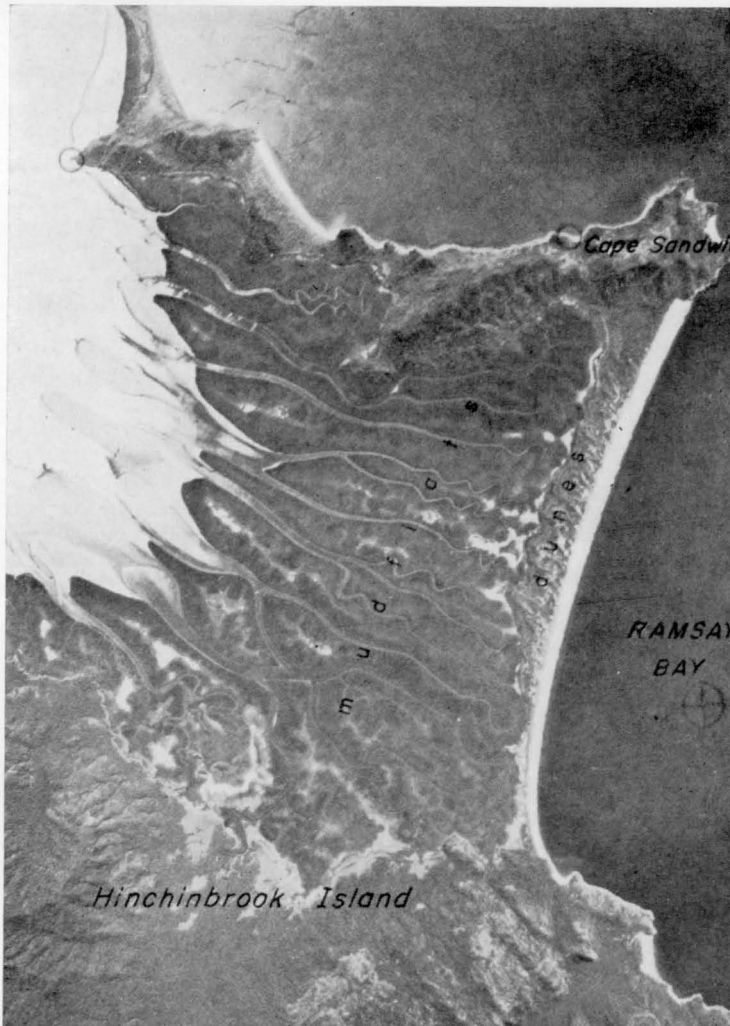


Fig. 2. Northeastern part of Hinchinbrook Island, showing a headland (Cape Sandwich) tied to the main body of Hinchinbrook Island by mud flats and a strip of dunes.



Fig. 1. Black Mountain, with Mt Simon in the background. Example of bouldery granite outcrop, 16 miles south of Cooktown. Looking northwest from aircraft.

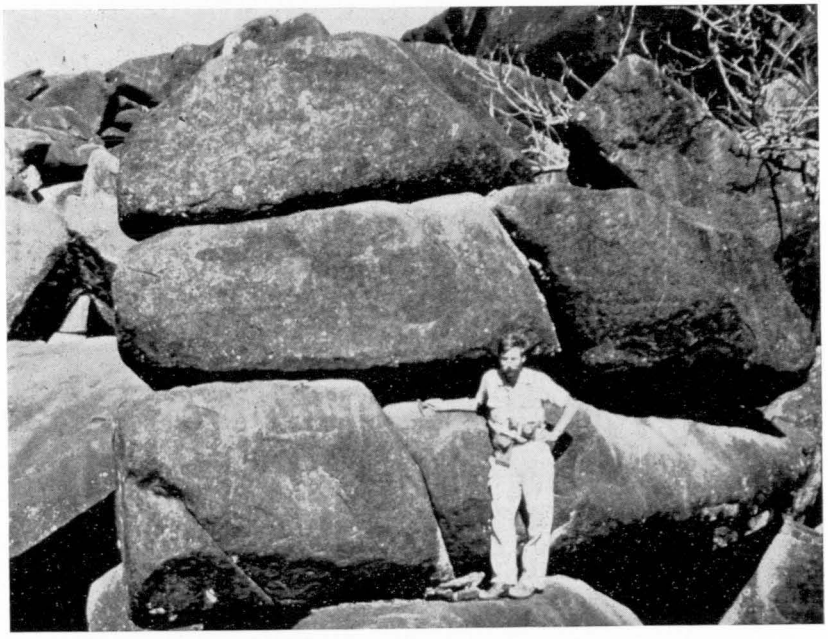


Fig. 2. Large granite boulder broken in situ along joint planes. Flank of Mount Simon.

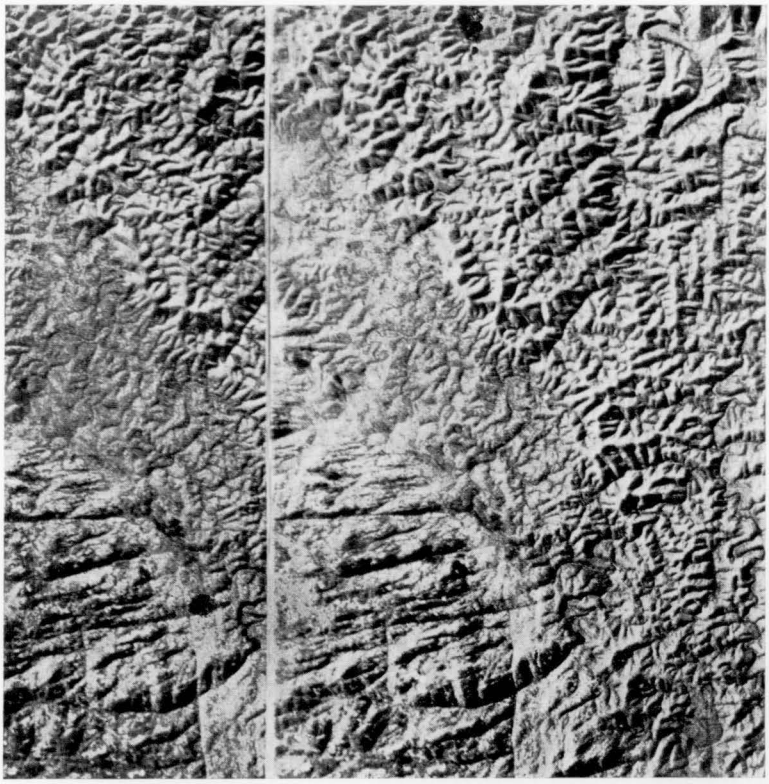


Fig. 1. Stereo pair of air-photo showing the dendritic drainage p in the monotonous rock sequer the Hodgkinson Formation, ar jointed pattern of the Cannibal Granite (southwestern part of graphs). Scale 1 : 80,000 ap mately.

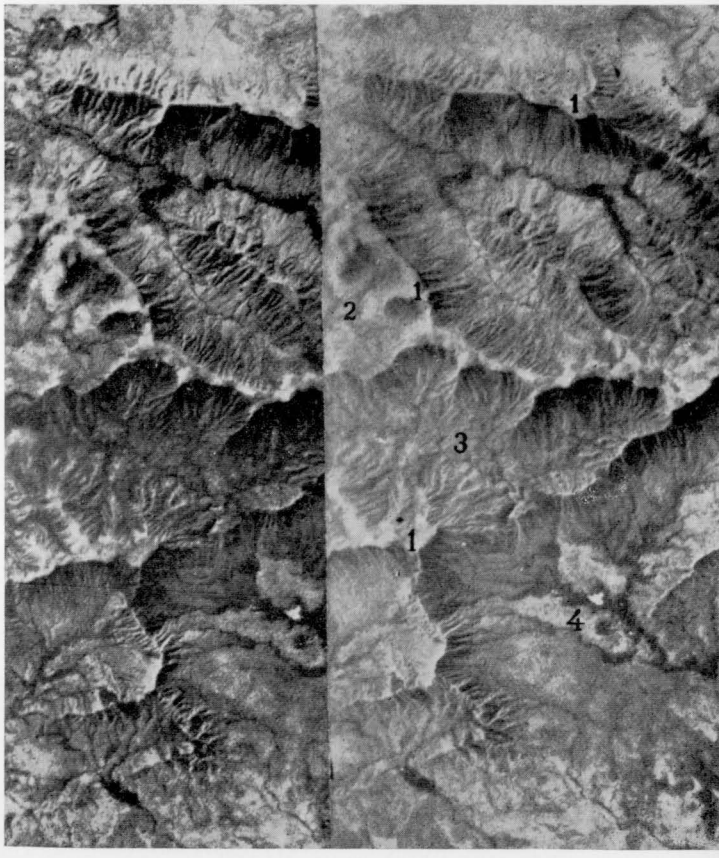


Fig. 2. Remnants of four different levels of erosion (1-4) in the Dalrymple Range about 10 miles northwest of Cooktown. Level 1 forms the skeletal top remnants of the tableland; Levels 2 and 3 form perched valleys; Level 4 is the local base level grading into the coastal plain. Stereo pair of air-photographs.



Fig. 1. Bloomfield Terrace, 700 feet above sea level. Bloomfield River mouth to the right.



Fig. 2. Bloomfield Terrace, seen from the northeast. Mount Amos in the background.

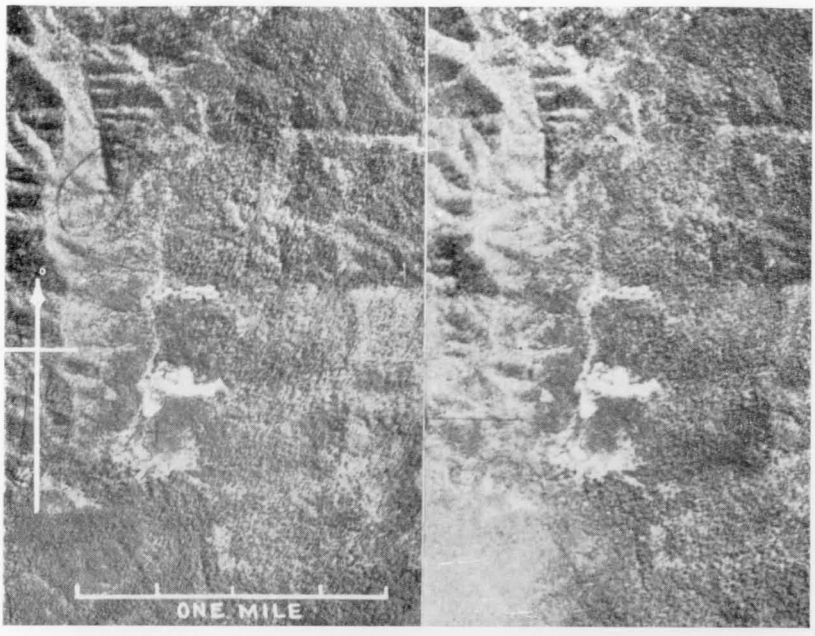


Fig. 1. Perched valley, Mount Poverty. Stereo pair of air-photographs.

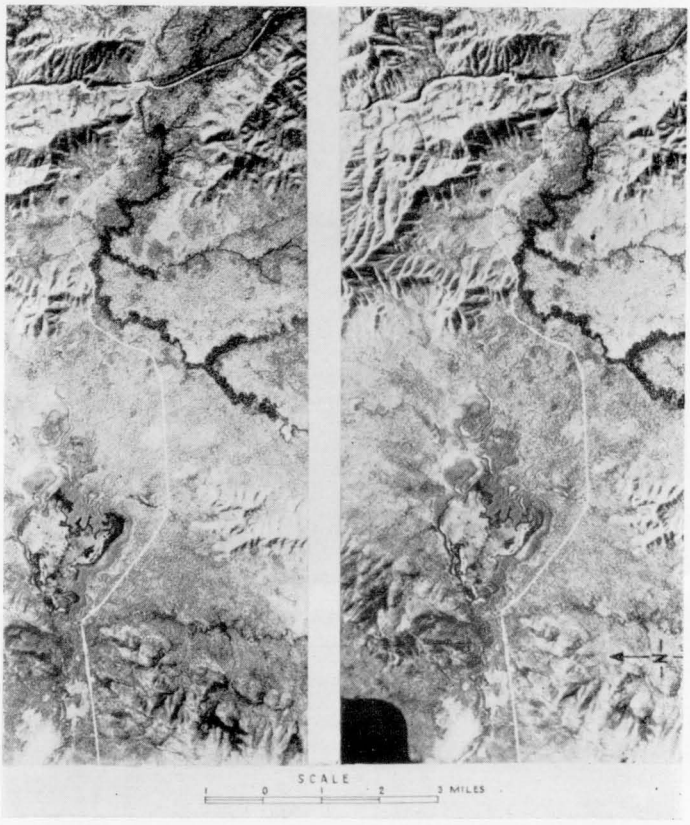


Fig. 2. Kings Plains, and the captured Annan River. North is to the left. Stereo pair of air-photographs.

The main outcrops consist of the thick sandstone that constitutes most of the top half of the formation, and the sandstones which form the prominent cliffs and benches round the margin of the basin. The sandstone is thick-bedded, unstratified, and cross-bedded; it is medium to coarse-grained and gritty, off-white to grey, and contains small pebbles of quartz or chert locally. Similar sandstone and grit occur in the lower part of the succession, and where the basement rises the sandstone commonly overlaps onto it. The sandstone is generally composed of moderately well sorted, rounded to poorly rounded, subspherical grains of quartz, together with minor chert, metaquartzite, randomly oriented intergranular muscovite, and some aggregates of quartz and altered felspar which are probably of granitic origin. In most of the pale sandstones a near-white semi-opaque aphanitic material occupies a small part of the pore space, which has been slightly reduced by quartz outgrowth. The sandstones yield good supplies of water (Denmead, 1949a).

In several places there is up to 2 feet of pipe rock 100 to 200 feet above the base.

The exposed basal part of the Dalrymple Sandstone is more varied in extent, thickness, and lithology. It fills the depressions, and abuts against the buried hills in the pre-existing surface. The sequence consists mainly of coarse conglomerate and grey and brown shale, with minor dark grey clayey sandstone, sandy mudstone, coal, and clean sandstone.

Massive polymictic cobble conglomerate is predominant in the basal parts of some sections, and in the thin basal sequence on Flinders Island. The conglomerate contains a moderate proportion, and the basal breccia a high proportion, of slate and greywacke; greenstone and granite, derived from underlying basement, are present in places. Vein quartz, chert, quartzite, and rhyolite are the common stable fragments. The subspherical to oblate pebbles and cobbles are poorly packed, but may be imbricated in places; the matrix ranges from pale gritty sand to grey clayey sand. The massive conglomerate commonly contains lenses of plant-bearing shale up to a few feet thick. The shale is silty or sandy, brown or grey, and micaceous or carbonaceous.

The 1600-foot interval between cores 7 and 13 (inclusive) in Cabot-Blueberry Marine No. 1 yielded Jurassic microfossils (Evans, 1926, unpubl.) and macrofossils. The lithology in the well section is similar to that of the outcrops, but the sediments are slightly finer in grain as they are nearer the deeper part of the basin. Core 12 contains microplankton suggestive of a marine environment of deposition (Evans, 1962, unpubl.), but elsewhere plant fossils, lithology, and structures indicate that there the sediments were deposited in small piedmont lakes and swamps coalescing into extensive shallow lakes and flood plains on which sand was the dominant deposit.

The plant-bearing beds near the base of the formation appear to be Upper Jurassic (Woods, 1961b, unpubl.), but Evans (1962, unpubl.) thinks the spores in the lower part of the Mesozoic section in Cabot-Blueberry Marina No. 1 are Lower and Middle Jurassic. It is therefore probable that the depositional basin grew throughout the Jurassic from an early paralic environment along a meridional axis in the west, into a terrestrial environment, to the south and southeast.

Battle Camp Formation

Derivation of name: Battle Camp Range, 35 miles west-northwest of Cooktown (long. 144°45'E., lat. 15°18'S.). Name introduced by Lucas (Lucas & de Keyser, 1965a).

Type area: Northern and eastern scarps of Battle Camp Range, and thence 10 miles southeast to Cone Mountain, as for the underlying Dalrymple Sandstone.

Cretaceous shelly fossils were recorded by Hann (1874), Jack & Etheridge (1892), and Maitland (1891a), but no map of the Cretaceous formations had been published until 1965 (Lucas & de Keyser).

The Battle Camp Formation is the basal Cretaceous unit in the Laura Basin. It has almost the same distribution as the underlying Dalrymple Sandstone, and round the margins of the basin it is difficult to distinguish the two formations. In the east the base appears to be disconformable, and the boundary is marked by ferruginization of the underlying sandstone. There is an overstep in the northeast, and an angular unconformity of 5° to 10° on Flinders Island. Farther west, the boundary is seldom exposed, but appears to become conformable towards the axis of the basin. Along the Palmerville Fault, the boundary is difficult to identify but also appears to be conformable. Except where Jurassic sediments failed to bury the granitic summits in the uneven Palaeozoic basement, and at other places where there is overstep, the base of the formation is nearly plane, and the formation itself is more nearly tabular than the one beneath. Neverthless, the thickness ranges from almost nil to about 900 feet (in the Bathurst Range to the north), but is usually about 250 feet around the upraised margin of the basin, and has a known maximum of about 1250 feet in Cabot-Blueberry Marina No. 1, in the axis of the basin south of Princess Charlotte Bay. On the margins of the basin, the sequence has been largely eroded, and the remnants have undergone deep Cainozoic weathering and selective ferruginization. The altered sediments are difficult to distinguish from the Dalrymple Sandstone.

Plate 23 shows graphically the most important known sections of Mesozoic sediments in the Laura Basin.

At the northeast corner of the Battle Camp Range, about 500 feet of Cretaceous sediment overlies about 200 feet of Dalrymple Sandstone, and the boundary has been taken at a limonitic conglomerate bed. Above this sequence are over 400 feet of glauconite-rich sandstone, quartz sandstone, and conglomerate capped by remnants of leached and mottled siltstone up to 100 feet thick. This general sequence of sandstone and conglomerate overlain by siltstone is found all over the basin, except in the northeastern ranges, where the siltstone is missing and the top consists of massive sparkling quartz sandstone. The siltstone may have been eroded, and with the exception of the fresh olive siltstone in the bed of the Normanby River near Kalpowar homestead, all exposures of siltstone consist of small residuals of leached and variegated rock. The lower part of the formation, composed mainly of sandstone, diminishes in thickness to the west relative to the upper part of the formation, and on the borehole sections (see below) the upper silty part becomes predominant.

Glauconitic sandstone is common to subordinate in many sections except near the margin of the basin, where the glauconite has been weathered in places. The glauconite content ranges from accessory proportions to 30 percent in beds up to 10 feet thick.

In several sections in the north, about 100 feet of green fine-grained carbonaceous and calcareous clayey sandstone, soft and flaggy, and grey micaceous silty shale are present near the middle of the formation (Lucas, 1964, unpubl.). These impure sediments do not appear to contain glauconite. They have small-scale (including ripple-drift) cross-lamination and traces of small burrows. In the southern part of the basin, the only impure arenite is the thin sandy glauconitic mudstone or clayey sandstone (with *Rhyzocorallium* burrows) which forms the transitional zone between the main sandstone and shale at the top of the formation.

Apart from the one outcrop near Kalpowar homestead, the fresh olive siltstone of the upper part of the formation is known only from boreholes in the Fairview homestead area, northwest of Laura, and in Cabot-Blueberry Marine No. 1. In the Fairview homestead bore records it is difficult to distinguish from the overlying Albian claystone, but it may be about 400 feet thick here. It probably dominates the upper half (600 feet) of the formation's interval in Cabot-Blueberry Marine No. 1, including cores 3 and 4 (Woods, 1964, unpubl.).

In the Flinders Group of islands, the formation rests unconformably on the Dalrymple Sandstone. The lowermost few hundred feet includes thin seams of coal and plant-bearing brown sandy shale interbedded with glauconite-free sandstone and is apparently non-marine.

The Jurassic and Cretaceous quartz sandstones are rather similar. In the northeast (Lucas, 1964, unpubl., pp. 16-20) the cross-bedding in the Cretaceous sandstone is on a slightly smaller scale (sets up to 3 feet thick) and is more regularly planar in section and in plan than in the Jurassic sandstone; it is however contemporaneously oversteepened in places. The Cretaceous sandstones are slightly whiter, more porous, and more sparkling owing to quartz-grain outgrowth than the Jurassic sandstone. They also possess slight bedding foliation, possibly owing to the parallel orientation of the relatively few large flakes of muscovite on the bedding planes, especially in the Flinders Group. Muscovite may be more common in the massive Jurassic sandstone, but grains are smaller and more randomly oriented.

Small rich pockets of shelly microfossils and fragments of wood are fairly common in the sandstone and conglomerate at the base of the Battle Camp Formation where it overlaps basement in the northeast; sporadic fossils and fragments of wood are also present in the glauconite-bearing sandstones above the base nearer the axis of the basin. The fauna comprises mostly bivalves, and commonly includes species of *'Pseudomonotis'*, *Maccoyella*, *Ostea*, *Camptonectes*, and *Tatella* (Woods, 1964, unpubl.). Woods considers that several of the species are primitive compared with Australian Aptian species, and noted that the other genera lacked specific identity with the Aptian fossils elsewhere in Queensland. He compared the most common species of *'Pseudomonotis'* with forms described from the Neocomian of Western Australia and India. The strongest evidence of lowest Cretaceous age is the identification of *Hatchericeras lakefieldense* Woods from a glauconite-rich sandstone at the Normanby River crossing at Lakefield station (Woods, 1962). The genus was previously known only from the Hauterivien (upper Neocomian) of Patagonia. It is difficult to estimate the height of this horizon above the base of the formation, because the outcrop possibly lies on the upthrown edge of a fault block.

The fossil plants from the non-marine beds at the base of the formation in the Flinders Group have been determined by Woods (1964, unpubl.; 1962e, unpubl.) and de Jersey (1957, unpubl.).

The fresh and bleached outcrops of the upper siltstone yield small fragments of lamellibranchs, fish remains, and the belemnite *Peratobelus* sp. (Woods, 1964, unpubl.). An impression of the ammonite (?)*Australiceras* sp., and the remains of a starfish and a crinoid, were found at the base of the glauconitic *Rhizocorallium*-sandstone transition beds north of Laura; the bivalves *Thracia primula* and *Mytilus palmerensis* occur in the same beds at the Hann River road crossing to the north-west. All these fossils, according to Woods (1964, unpubl.) indicate an Aptian age for the upper fine-grained part of the Battle Camp Formation.

Wolena Claystone

Derivation of name: Parish of Wolena, near Fairview homestead, 6 miles northwest of Laura township. The formation was named by Lucas (Lucas & de Keyser, 1965a).

Type area: interfluve between Kennedy and Little Laura Rivers within 6 miles of Fairview homestead.

The formation is thinner and less extensive than the older formations of the Laura Basin; it consists entirely of soft marine clay and is poorly exposed. The main outcrops occur in the type area. There are smaller outcrops near the trace of the Palmerville Fault farther west, and a possible outcrop near Princess Charlotte Bay. The logs of the waterbores near Fairview homestead contain no information on the thickness of the formation, but the outcrop pattern and altitude data indicate that it is about 200 to 250 feet. A similar thickness seems to be present in the Cabot-Blueberry Marina No. 1 well (Pl. 23; palaeontological evidence *in* Woods, 1964, unpubl.; Evans, 1962, unpubl.).

The base of the formation has not been seen, but it appears to rest conformably on the siltstone of the Battle Camp Formation.

In the type area the Wolena Claystone is capped disconformably by the thin Fairview Gravel, which was presumably deposited in a Tertiary depression. The porous resistant gravel has protected the Avalena Claystone from further erosion, but the latter has been intensely bleached and kaolinized (?) to a depth of 1000 feet below the surface at Fairview homestead in places.

Fresh claystone, similar to that encountered in cores 1 and 2 in the Cabot-Blueberry Marina No. 1, is exposed in small gullies and depressions on the rolling downs along the Laura-Coen road. The claystone is massive to faintly laminated, unctuous, olive, and slightly calcareous; it contains fossiliferous calcareous concretions and minor micaceous, silty, and sandy lenses which are glauconitic at the base of the sequence in Cabot-Blueberry Marina No. 1 (Woods, app. 2b *in* Mines Admin., 1962, unpubl.). The concretions are between 3 inches and 2 feet across and are probably concentrated along certain horizons. They have yielded most of the fossils, partly because of the ready disintegration of the claystone, which does contain macrofossils as well as in places abundant *Inoceramus* prisms.

The fauna consists chiefly of *Aucellina hughendensis* and *Inoceramus* spp., both of which are typical of the Tambo Formation in the Great Artesian Basin.

Pseudavicula sp. nov. and *Myloceras* sp. confirm the Albian age (Woods, 1964, unpubl.).

Woods (1964, unpubl.) concluded that there is no strong faunal resemblance between the Laura Basin and the Carpentaria Basin to the west. The resemblance was strong in the Albian, but then the fauna was ubiquitous throughout eastern Australia and New Guinea, which implies a connexion of a different sort.

CAINOZOIC

The Cainozoic rocks include basalts, alluvium, residual sands and soils, talus and piedmont fans, laterite, dunes, beach sands, and a variety of coastal marine beds.

The precise age of most of the rocks is uncertain. The basalts range from mid-Tertiary(?) to Recent, and can be grouped in a number of provinces (Fig. 15). The alluvium and residual sands and soils are of various ages; they are most widespread in the north, in the south, and along parts of the coast. Laterite and lateritized sediments occur in a few places in the south and north. Coastal dunes are well developed from Cooktown northwards to Lookout Point, and to a lesser extent on Hinchinbrook Island. Marine sediments and fossil beach sands are common along the coast, and in places they extend up to 10 miles inland. Talus and piedmont fans have been distinguished only in the northern areas; elsewhere they are too small to be mapped.

Tertiary Sediments

The lateritized Tertiary sediments $\frac{Tl}{Cz}$ are probably the oldest Cainozoic deposits. They form the main part of the Lucy Tableland in the south, only a small part of which lies within the Ingham Sheet area. The sediments comprise pebble conglomerate, sandstone, quartzite, granite wash, clay, shale, and diatomite (de Keyser, Fardon, & Cuttler, 1965). They are commonly current-bedded, and generally not well sorted; they range from white to cream, brown or red. The total thickness in the Ingham Sheet area is about 150 feet, but owing to the undulating basement the beds lens out in many places. The sediments and the exposed part of the erosion surface below were subjected to prolonged weathering during the Tertiary with the formation of a deep lateritic soil. Six samples from a 16-foot soil section north of Oak Hills homestead, between the Burdekin and Herbert Rivers, were analysed by the Australian Mineral Development Laboratories. In the upper 2 or 3 feet the SiO_2 content decreases sharply downwards, whereas Al_2O_3 and K_2O and, to a lesser extent, Fe_2O_3 increase. Below this level, SiO_2 gradually increases again, and Al_2O_3 decreases slowly. Na_2O and FeO remain almost constant.

In the lateritic profile of the Lucy Tableland, red ferruginous grits and nodular ferruginous crusts are widespread; south and west of the map area, mammillar or broken ironstone and 'billy' crusts are also found.

Patches of *laterite* (Tl) have been mapped along the southern margin of the Atherton Sheet area. Both the Mesozoic and Cainozoic strata in the northern part of the Laura Basin and at the surface of the Normanby Plain are strongly ferruginized in many places (Lucas, 1964, unpubl.).

The isolated residuals of *gravel and billy* (Tf) in the Wrotham Park/Walsh River area have been described as the *Louisa Formation* by Woods (1961), and the more extensive sediments farther north, in the Laura/Fairview homestead area, have been referred to as the *Fairview Gravel* by Lucas (1962, 1964, unpubl.). The sediments consist of rounded quartz gravels with a sandy matrix, kaolinitic quartz gravel containing thin layers of white cemented sandstone, and grey billy. The sediments have been regarded by both Woods and Lucas as possibly Middle or Lower Tertiary (Woods, 1961), because boulders of ferruginous grit occasionally present are a possible indication of past lateritic processes, and the top of the residuals and low plateaux rises to 20 to 150 feet above the surrounding country.

The widespread more or less consolidated late Cainozoic *alluvial deposits* (Czx) in the northern part of the Laura Basin are referred to as the *Brixton Formation* by Lucas (1962, 1964, unpubl.). The formation blankets a large part of the intermontane depressions and valleys and the northern coastal plain, and in places forms gently dipping fans or washplains extending out from the valley-bounding slopes of the early(?) Tertiary landscape. The formation probably underlies much of the interfluvial sands and alluvials on the Normanby Plain, and is well exposed at the base of the scarp along the western margin of the Deighton Tableland, and in many streams draining the area. It rests disconformably on the leached Wolena Claystone, and is generally unconformable with the Mesozoic sediments of the Laura Basin. An erosional break separates the formation from the Fairview Gravel.

The formation can generally be divided into an older, mottled, dominantly clayey unit, and a younger, less consolidated, coarser, and better sorted unit which includes porous sand, pebbly sand, and gravel, cemented by limonite and manganese oxides. Basalt pebbles are locally present.

The age of the formation may be late Tertiary or Pleistocene, as it is overlain in several places by fossil piedmont deposits which are now being eroded.

In outcrop, the formation is generally only 5 to 50 feet thick, but the Marina No. 1 well penetrated 140 feet of ferruginous clayey sand and grit (Brixton Formation?) with 100 feet of fresh feldspathic sand and gravel below (Fairview Gravel?).

Tertiary to Recent Basalts

Flows of olivine basalt and associated pyroclastics are found on and around the Atherton Tableland (Atherton Basalt Province and Culgar Basalt); near Gunnawarra and Strathfield homesteads along the southern margin of the map area (McBride Basalt Province); about 40 miles southwest of Cooktown (McLean Basalt Province); and in some smaller areas 15 to 30 miles northwest of Cooktown (Piebald Basalt Province). The division into provinces is based on geographical associations, and each province may contain basalts which probably range from mid-Miocene to Recent.

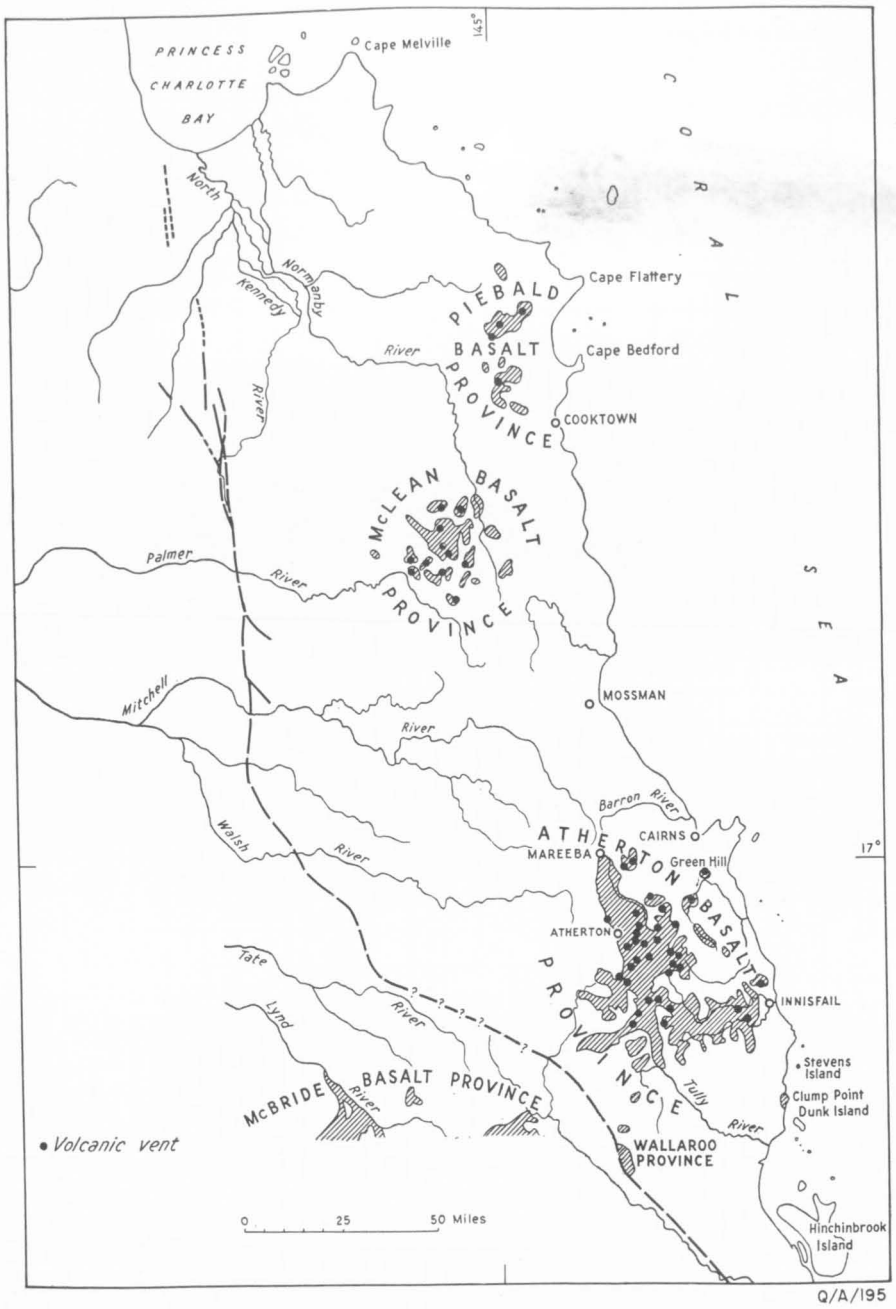


Fig. 15. The basalt provinces in northeastern Queensland.

General Petrography

Morgan (1968) concluded that the basalts in north Queensland belong to the alkali olivine basalt association of Yoder & Tilley (1962). The basalts are poor in silica and rich in alkalis, and many of them contain analcite or, less commonly, some nepheline (Table 5). Olivine basalts predominate; olivine nephelinite, nepheline basanite and olivine analcitite have also been recorded.

TABLE 5: CHEMICAL ANALYSES AND NORMS OF BASALTS FROM THE McLEAN, PIEBALD, AND ATHERTON PROVINCES

	1	2	3	4	5	6	7
SiO_2	44.20	49.50	43.30	41.20	49.90	42.10	47.87
Al_2O_3	11.10	12.90	12.30	11.20	13.20	12.40	17.89
Fe_2O_3	8.20	5.95	4.80	3.50	1.53	4.20	0.44
FeO	4.35	5.25	6.95	8.90	9.15	10.20	10.24
MgO	9.25	7.80	10.20	11.50	9.30	7.70	8.52
CaO	10.10	8.90	9.30	10.70	8.30	9.70	8.48
Na_2O	3.95	2.85	4.50	4.30	3.30	4.20	2.89
K_2O	1.06	1.30	0.91	1.13	1.66	2.35	1.75
H_2O+	2.25	1.23	2.25	2.85	0.96	2.20	0.77
H_2O-	1.49	1.22	1.66	1.03	0.24	0.61	0.26
CO_2	0.18	0.26	0.11	0.06	0.06	0.54	—
TiO_2	2.35	1.93	2.25	2.45	2.05	2.35	1.96
P_2O_5	1.05	0.47	0.98	1.16	0.45	1.04	0.38
MnO	0.19	0.16	0.18	0.20	0.14	0.28	0.21
Total	99.72	99.72	99.69	100.18	100.24	99.87	101.56
Q	—	3.00	—	—	—	—	—
or	6.29	7.78	5.56	6.67	10.07	10.90	10.56
ab	23.58	24.10	17.82	4.72	22.77	6.81	20.60
an	9.17	18.63	10.56	8.06	16.12	8.06	30.30
ne	5.40	—	11.08	17.04	—	15.62	2.13
di wo	13.46	8.47	11.08	15.54	8.82	12.64	3.94
di en	11.60	6.80	8.80	10.70	5.40	7.40	2.20
di fs	—	0.66	1.85	3.56	2.90	4.62	1.58
hy en	—	12.70	—	—	1.90	—	—
hy fs	—	1.06	—	—	1.06	—	—
ol fo	8.12	—	11.76	12.60	11.06	8.40	13.37
ol fa	—	—	2.65	4.90	6.32	5.71	10.20
mg	7.89	8.58	6.96	5.10	2.32	6.03	0.70
il	4.56	3.65	4.41	4.71	3.80	4.56	3.80
ap	2.69	1.34	2.35	2.69	1.34	2.35	1.01
cc	0.40	0.60	0.30	0.10	0.10	1.20	—
he	2.72	—	—	—	—	—	—

1. Olivine analcimite, 4 miles SW of Springvale homestead. Analysts, C. R. Edmonds and H. Sears, AMDL. R.10115.
2. Iddingsite-olivine basalt, 1½ miles SW of Springvale homestead. Analysts, *Ibid.* R.10116.
3. Olivine analcimite, Mulligan Highway, 2 miles N of Byerstown Range. *Ibid.* R.10119.
4. Olivine-nepheline analcimite, near the Jubilee tin workings, Annan River tinfield. Analysts, *Ibid.* R10130.
5. Porphyritic olivine basalt glass, 1¼ miles SW of Springvale homestead. R.11910.
6. Nepheline basanite, Starcke River. Analysts, *Ibid.* R.14530.
7. Olivine basalt from Lake Eacham. Analyst, V. E. G. Harris (Richard, 1924).

The basalts are generally porphyritic, and commonly vesicular or amygdaloidal. They range from fine to coarse-grained, and from black to dark blue-grey or green-grey. The most common phenocrysts are olivine and augite; plagioclase is less common. The rocks range from holocrystalline to hypocrystalline, and a few glasses also occur. The texture is mostly intergranular, but pilotaxitic, ophitic, subophitic, hyalo-ophitic, and intersertal textures have also been noted, especially in the coarser-grained basalts with abundant plagioclase and pyroxene. The seriate-glomeroporphyritic varieties contain clusters of olivine and intergrown augite up to 5 mm across. The amygdules may be partly or wholly filled with calcite, analcite, zeolites (nontronite, thomsonite?) and, more rarely, with chalcedony or chlorite.

Xenoliths of quartz, quartzite, schist, granite, quartz-albite granulite, peridotite, amphibolite, and gabbro(?) are common in places. Many of the quartz grains are surrounded by reaction rims of fine acicular diopsidic augite embedded in glass or alkali feldspar. Cognate inclusions of one variety of basalt in another have also been observed.

The essential minerals include plagioclase, olivine, clinopyroxene, and iron oxides; many of the basalts also contain varying proportions of interstitial potash feldspar, analcite, zeolites, nepheline, chlorite, or calcite. Apatite is a common accessory. Some of the basalts contain over 50 percent glass and palagonite.

In the older basalts the olivine is partly or almost completely altered to iddingsite and, less commonly, to bowlingite or hematite. In some rocks in the McLean Province, alterations to serpentine is not uncommon. The olivine (2V very large) forms from 5 to 20 percent of the rocks.

The composition of the plagioclase ranges from $Ab_{40}An_{60}$ to $Ab_{25}An_{75}$. The mineral is usually present as microlites in the groundmass, and the rare phenocrysts are generally twinned and embayed. The proportion of plagioclase ranges from 5 to 65 percent.

The common clinopyroxene is a colourless to pale green augite; pale purple titanaugite is less common. Some of the pyroxene shows twinning and oscillatory zoning. Pyroxene generally forms from 15 to 30 percent of the rocks, but ranges up to 50 percent.

Interstitial analcite is common in the McLean and the Atherton Province, where it usually forms several percent of the rock. One specimen of olivine-augite analcitite contains about 50 percent of analcite and other zeolites.

Interstitial nepheline is occasionally present in the Atherton and McLean Provinces. It forms tabular crystals partly enclosing augite and iron oxide in a glassy basanite or nephelinite from the Starcke River (Morgan, 1964, unpubl. and 1968a).

Peridotite nodules are extremely common in some flows and pyroclastic deposits, but are completely absent in other nearby outcrops. The inclusions are composed of olivine, enstatite, clinopyroxene, and some olive to brown-green spinel. Dr D. H. Green (Australian National University) has identified the clinopyroxene as chrome diopside, and he also found that the spinel is chromium-bearing. Peridotite inclusions in basalts are invariably composed of olivine, enstatite, chrome-diopside, and spinel; they are regarded by many petrologists as fragments

derived from the mantle, rather than deep-seated crystallization products of basaltic magma. Commonly the effects of postcrystalline stresses can be seen in peridotite inclusions, and in north Queensland the olivine is granulated and annealed, and the pyroxenes show bending, including some kink-bending (D.H. Green, pers. comm.).

McBride Basalt

The 75 square miles of McBride Basalt cropping out along the southern edge of the Atherton Sheet area represent only a fraction of the McBride Province, which occupies 2000 square miles in the adjoining Einasleigh Sheet area. The province was named by Twidale (1956a), and has also been described by Best (1959b, 1960, unpubl.). Over a hundred vents have been recognized in the Einasleigh Sheet area. Twidale (1956) distinguished an Older and a Newer McBride Basalt, and a more recent basalt which does not crop out in the map area. He suggested a late Pliocene to early Pleistocene age for the older group, and an early to middle Pleistocene age for the newer basalts. Best (1959b, unpubl.) revised the ages to late(?) Miocene or Pliocene, and mid-Pliocene to late Pliocene respectively, based on the relationships of the basalts to the Pliocene diatomites (White & Crespin, 1959).

Best (1959b, unpubl.) gave the basalt remnants along the Herbert River near Kirrama homestead the unofficial name of Wallaroo Basalt Province, which may be equivalent to the Older McBride Basalt. They are preserved on spurs which represent remnants of the old Tertiary erosion surface, and have been incised by the Herbert River gorge.

Atherton Basalt

The Atherton Basalt Province (Fig. 16) is the largest area of basalt in the Hodgkinson Basin. The province extends from Mareeba south to the Tully River, and east to Innisfail, and contains flows and pyroclastic deposits covering roughly 700 square miles. The buried flows in the alluviated plains of the Herbert River south of Mount Garnet may represent a link between the McBride and Atherton Provinces. Most of the basalts occur in the northern part of the Atherton Tableland (Best, 1960, unpubl.), but some flows descended down the valleys towards the coastal plain. The province also includes a few small basalts associated with eruptive centres in the coastal plain. The remnants of a basalt flow 8 miles northwest of Atherton, are separated from the Atherton Basalts by a range of hills, and have been named the *Culgar Basalt* by Best (1962).

The Atherton Basalt yields a rich brown soil which supports a population of over 10,000. The basalt is readily weathered in the wet tropical climate of the coastal belt, but in the dry climate prevailing in the McBride Province the basalt plains are very rough and stony.

About 50 vents have been recognized in the field or on the air-photographs (de Keyser, 1964). Several of them had been described by Jardine (1925), Ball (1931), and Best (1960, unpubl.), but many had not been previously recorded. They include shield volcanoes, composite volcanoes, cinder cones, maars, and one diatreme. Most of the lava vents are concentrated in the south and west of the

province, and the cinder cones in the north, whereas the maars occupy a central belt. In several localities, the topography and distribution of the basalts indicate the presence of eroded centres of eruption, as for example southeast of Ravenshoe, west of Babinda, and possibly on the Atherton Tableland.

The volcanic rocks include lava flows and coarse and fine-grained pyroclastic deposits, locally underlain by lacustrine or fluviatile sediments. On the Atherton Tableland the volcanics are deeply weathered, and it is difficult to distinguish between the flows and pyroclastics.

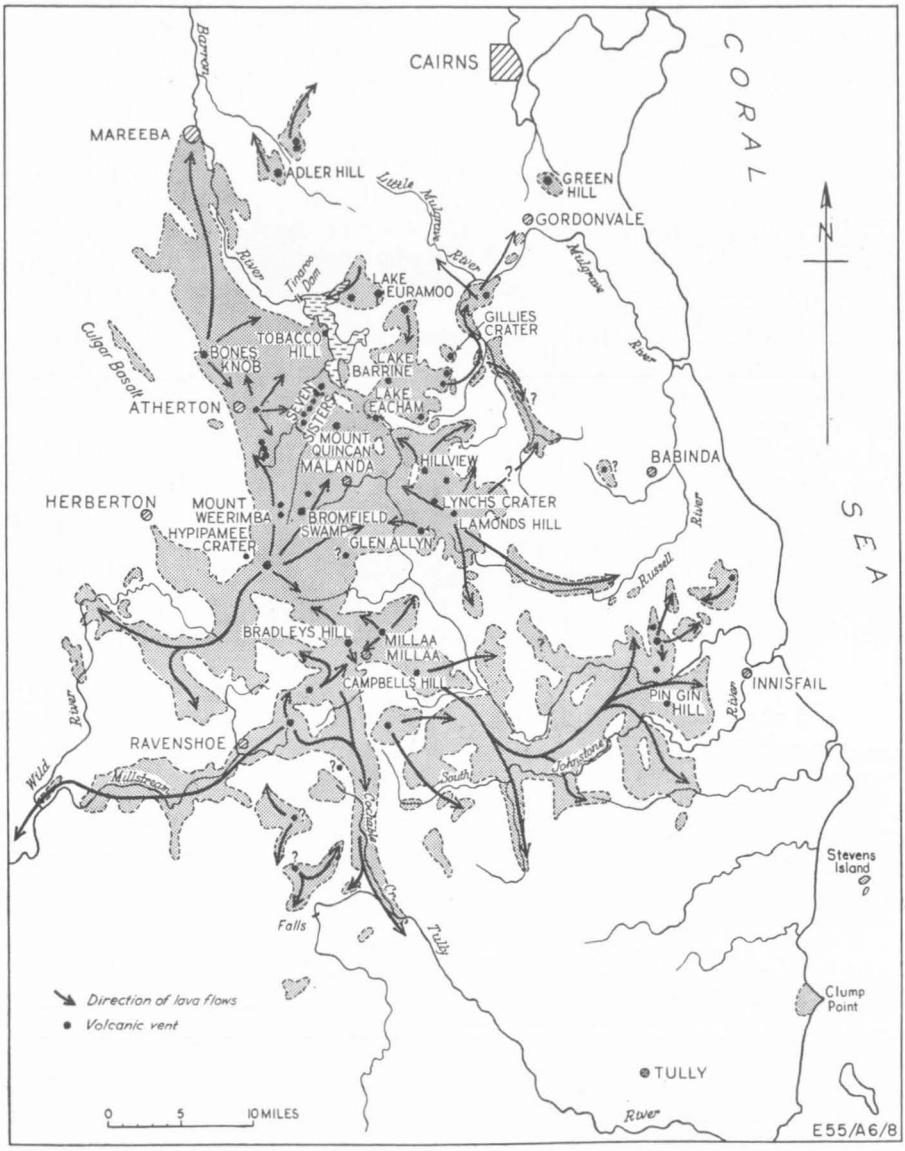


Fig. 16. The Atherton Basalt province.

The lavas are olivine-rich augite basalts, which may contain some interstitial analcite and possibly nepheline. Columnar jointing is very common, and good exposures can be observed in the many waterfalls. Peridotite inclusions are present in some of the flows. Spheroidal weathering is well developed in places (e.g. at Clump Point), and where the process is in an advanced stage only a few boulders remain in a grey clayey matrix which soon turns reddish brown on exposure to the atmosphere. Such outcrops are difficult to distinguish from weathered pyroclastics containing volcanic bombs (e.g. the pozzolan quarry northwest of Koomboo-loomba Dam; see Bush, 1960). However, the bomb-like fragments are dense and solid whereas the genuine bombs in the pyroclastic deposits are scoraceous and 'bread-crusted' (see also p. 228).

The pyroclastic deposits range from coarse to fine-grained, and are generally crudely bedded (Pl. 10, fig. 1). Around the cinder cones the material tends to be purely volcanic, but around the maars the deposits generally contain a considerable proportion of country rock derived from the explosion vents. The deposits around the maars are commonly composed of beds and laminae rich in volcanic material alternating with layers mainly composed of sedimentary fragments. On Stevens Island, in the South Barnard Islands, the angular fragments of country rock include amphibolite, greenschist, cherty schist, olivine nodules, and basalt.

The pyroclastic rocks show a considerable range in grainsize, but in individual layers sorting is fair to good. The cinder deposits consist of fragments of porous scoria and lapilli, and are completely unconsolidated. Bombs and nodules of peridotite are common in some deposits (e.g. Mount Quincan and Gillies Crater), but completely lacking in others (Seven Sisters Quarry). They range up to a foot across. The cross-cutting relationships of the pyroclastic rocks in the Seven Sisters road metal quarry west of Yungaburra (Pl. 10, fig. 1) suggest successive explosions from shifting vents. The smaller-scale cross-bedding in the pyroclastic deposits on Stevens Island and the vertical orientation of some of the elongated large fragments and boulders may indicate that they are a type of lahar or that they were formed by eruptions accompanied by heavy rain. Best (1960, unpubl.) also considered that some of the basaltic tuffs on the Atherton Tableland are lahars.

In places, the flows and pyroclastic deposits are cut by basalt dykes, as at Bones Knob near Atherton, and on Stevens Island.

The basalts are underlain in several places by Tertiary sediments, which are also intercalated with buried flows in the Mount Garnet/Herbert River area. In the Atherton/Russell River/Johnstone River area, the sub-basaltic sediments comprise auriferous gravel, grit, sand, silt, shale, clay, and some impure coal (Denmead, 1947b, unpubl.). The thickness locally exceeds 40 feet. Impressions of dicotyledonous leaves and fragments of wood are found in the Johnstone River gorge and near Peeramon, 14 miles east of Atherton. The fresh clay-shale is bluish or greenish grey, but is bleached and shaly where exposed at the surface. It contains thin, yellow-brown, ferruginous, or concretionary laminae. Some of the clay is pebbly. Angular quartz grit, which has a red clayey matrix in places, is common. The grit has been derived from nearby granite outcrops.

In a railway cutting at Yungaburra, cross-bedded layers of clay and angular quartz gravel, showing scour-and-fill structures, overlie the weathered Barron

River Schists. The gravels are overlain by red-brown basaltic soil apparently formed during the active period of the nearby Seven Sisters.

Description of the Vents

Most of the basalt has been erupted from the *shield volcanoes*; they do not form conspicuous features and have slopes of less than 10°. They are probably the oldest eruption centres as they are relatively deeply eroded. Some of them have adventive explosion craters on their flanks. The flows have coursed down some of the main streams, and along the Herbert River they probably extend into the McBride Province. Several of the shield volcanoes grade into composite volcanoes.

Bones Knob, 4 miles northwest of Atherton, has been described by Best (1960, unpubl.) as one of the oldest vents in the Atherton Province. The apical crater was reamed out at a late stage, and a dome of fine-grained pyroclastics was built up within it, lapping over the rim of the old crater on the southeastern side.

Another probable shield volcano lies across the main road 12 miles south of Atherton, east of Hypipamee Crater. The volcano is much more deeply dissected than Bones Knob, and is therefore considered to be older. The existence of the crater has been inferred by photo-interpretation: the basalt slopes away from the apex on all sides, and the drainage is strongly radial.

The shield volcanoes at Lamonds Hill, 8 miles east-southeast of Malanda; at Cambells Hill, near Millaa Millaa; and at an unnamed hill 1 mile northeast of Millaa Millaa are similar in general form. Glen Allyn, near Lamonds Hill, and the two hills between Ravenshoe and Milla Millaa, are volcano remnants with slightly steeper slopes, and grade into composite volcanoes.

Composite volcanoes appear to be rare in the Atherton Province, and many of them grade into shield volcanoes or cinder cones. They include Hillview, Braleys Hill, and several hills near Atherton, Babinda, Innisfail, in the valley of the Mulgrave River, and south of Millaa Millaa. The composite volcanoes are deeply dissected like the shield volcanoes, and are probably of the same age.

The *cinder cones* or scoria cones are steep-sided cones built up mainly of pyroclastic material; many of them grade into composite cones. The cinder cones are the most conspicuous volcanic forms in north Queensland.

Mount Quincan (Pl. 11, fig. 1) is one of the best examples. Situated 7 miles southeast of Atherton, it is about 600 feet high, and has a crater about half a mile wide and 300 feet below the top of the cone. The height of the crater rim on the northwestern side is almost 200 feet higher than on the southeastern flank. This phenomenon is due to the effect of the prevailing southeasterly winds (Jack & Etheridge, 1892, p. 587), and is a common feature of most of the scoria cones in north Queensland (Best, 1959, unpubl.). The outer slope of Mount Quincan is about 30°, the inner slope 45°. The floor of the crater is covered by a shallow lake or swamp. Nodules of peridotite and fragments of schist and granite are common in the scoria deposits.

The Seven Sisters (Pl. 10, fig. 2; Pl. 11, fig. 1) forms a conspicuous group of scoria cones, 150 to 250 feet high, 5 miles east of Atherton. They are aligned

in a direction N32°E. The outer slopes are about 30°. Bombs with olivine cores are found on the slopes of the southern cones, but peridotite or olivine fragments appear to be absent in the northern vents. Deep apical craters are not found in the Seven Sisters. The cross-cutting bedding relationships indicate shifting of the explosive channels (Pl. 11, fig. 1), and small settling faults are also present.

Pin Gin Hill is a scoria cone on a large lava flow 6 miles west-southwest of Innisfail. Breadcrust bombs and fragments of scoriaceous olivine basalt have been noted on the vegetated and weathered slopes.

Green Hill is a grass-covered cone, almost 350 feet high, 8 miles south of Cairns, and is composed of basaltic tuff or fine-grained pyroclastics with scoriaceous basalt bombs.

Other scoria cones are Adler Hill, Tobacco Hill, Mount Weerimba, and several other, unnamed hills.

Maars are explosion craters from which only very small amounts of pyroclastics were ejected, which may form low ring-walls around the crater. The pyroclastics commonly contain a considerable proportion of country rock, and where weathering is intense, the volcanic nature of the deposits can be inferred only from the red-brown colour of the soil, even where the only recognizable soil particles consist of slate, schist, or granite. In such areas, the boundaries between the basalt and country rock can be mapped only approximately.

Many of the maars contain a crater lake, but where the ring-wall has been breached by erosion, a swamp is generally all that remains (e.g. Bromfield Swamp). Where the breached maars are covered by tropical rain forest they are difficult to detect on the ground, but are recognizable on the air-photographs as circular flat-bottomed depressions (e.g. Gillies Crater).

Where the amount of ejectamenta becomes large, the maars grade into cinder cones.

Lake Barrine (Fig. 17B) and Lake Eacham (Fig. 17A) are the best known crater lakes in north Queensland. Lake Barrine, 8 miles east of Atherton, is a maar with a diameter of about 1300 yards. It has a small embayment which is possibly a smaller secondary vent. According to Best (1960, unpubl.) the lake is 400 feet deep. The retaining ring-wall is 90 feet above the surface, and consists of beds of coarse and fine-grained pyroclastics mixed with country rock, including fragments of mica schist up to 2 feet across. The cinder beds dip at about 15° outwards from the crater.

Lake Eacham has a diameter of about 1000 yards with a small embayment on the southeast side. Estimates of depth vary from 226 feet (measured, according to Jardine, 1925) to 360 feet (Ball, 1931) and 500 feet (Best, 1960, unpubl.). The ring-wall is 100 feet high and consists of pyroclastic beds dipping at 15° away from the crater.

Lake Euramoo (Fig. 17F), about 6 miles north of Lake Barrine, consists of two small overlapping craters. It is about 500 yards long and 150 yards wide, with walls up to 90 feet high.

Bromfield Swamp (Fig. 17E), 4 miles southwest of Malanda, is the largest maar in north Queensland, and has a diameter of about 1 mile. The crater is breached, and the lake has been reduced to a swamp. The crater is 150 to 200 feet deep, and so little material has been ejected that there is barely a ring-wall at all. The weathered basalt surrounding the crater was probably extruded from the big eroded and unobtrusive shield volcano whose apex lies $4\frac{1}{2}$ miles to the southwest,

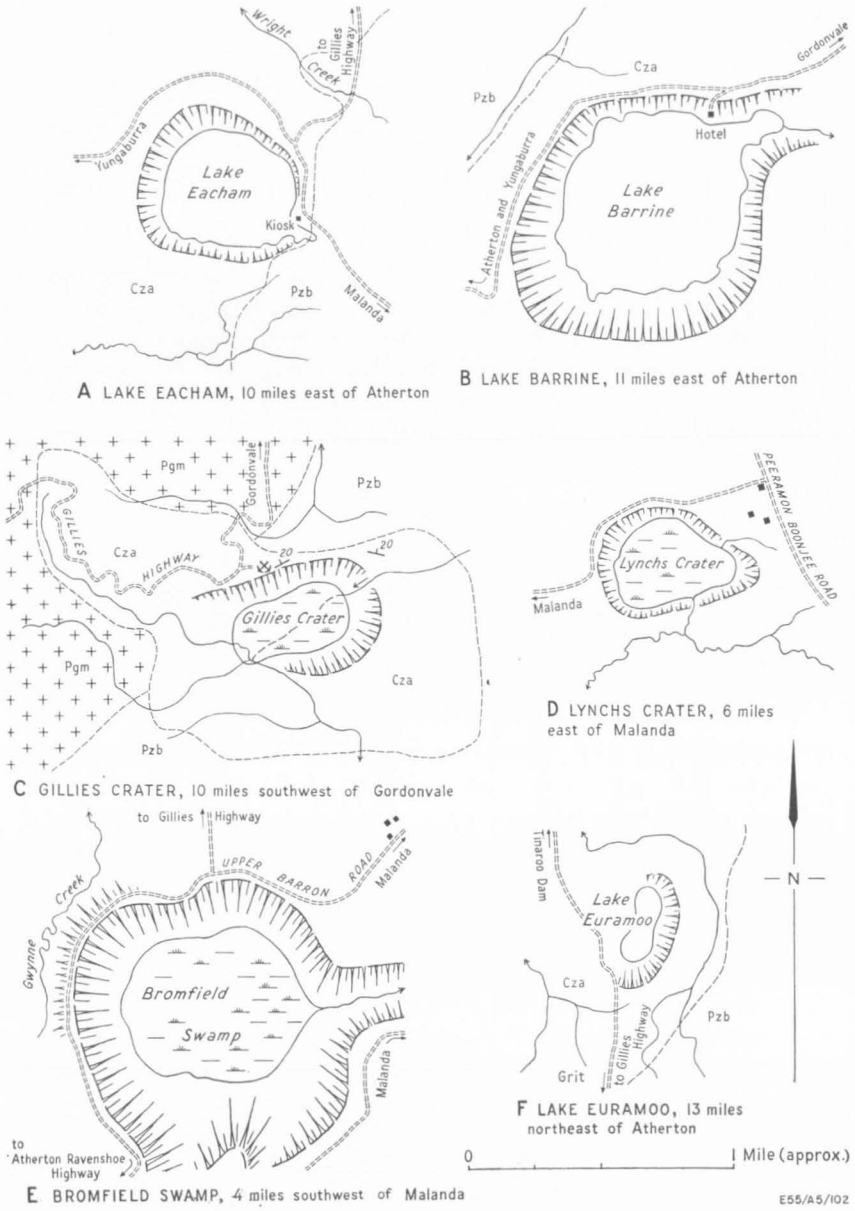


Fig. 17. Examples of maars and crater lakes on the Atherton Tableland.

and Bromfield Swamp is probably an adventive explosion vent on the northeastern flank of the shield volcano.

Lynchs Crater (Fig. 17D), 6 miles east of Malanda, is another breached crater without a real ring-wall. It is about 150 feet deep, has a diameter of 700 yards, and slopes inwards at 25°. Among the ejected bombs and fragments are boulders of schist up to a foot long.

Jardine (1925) thought that 'quiet lava flows' were extruded from both Bromfield Swamp and Lynchs Crater and that they are not explosive vents. He was probably confused by the vast amount of basalt around the vents, which was derived, however, from shield volcanoes nearby.

The name Gillies crater is here given to the breached maar on the southern side of the Gillies Highway near Heales Monument, 10 miles southwest of Gordonvale (Fig. 17C). The pyroclastic rocks are exposed along the highway and in a road-metal quarry; they consist of unconsolidated layers of well bedded ash and lapilli, and contain bombs and fragments of peridotite, olivine basalt (as breadcrust bombs up to a foot across), slate, schist, and other types of Barron River Metamorphics. An unusual leucocratic inclusion of hypersthene-augite-hornblende-plagioclase-rutile granulite or granular gabbro has been examined by Dr D. H. Green (Australian National University). It does not have the texture or the mineral assemblage of an igneous or metamorphic rock, and the fragment is probably of deep-seated origin. The proportion of country rock in the pyroclastics varies considerably from layer to layer, but in many layers country rock predominates. The beds dip at 15° to 20° away from the crater, which is a circular depression, roughly 600 yards wide, covered with rain forest. The exposures along the highway show the nonconformity with the granitic bedrock, and the alternation of fine-grained and coarse-grained beds of pyroclastics, including a 9-foot layer of red-brown to ochre-coloured tuff.

In the rain forest, 3 miles east of Lake Eacham, an unnamed breached maar with a diameter of a little over 1000 yards can be recognized on the air-photographs. It is a circular flat-bottomed grassy depression. A similar maar occurs 2 miles northeast of Lynchs Crater on the edge of the rain forest.

Hypipamee Crater, in the Atherton Province, is the only known example of an explosion pipe or diatreme, where there is practically no erupted material. The crater is a well known tourist attraction 10 miles south of Atherton. In Best's (1960, unpubl.) description 'explosive activity has blasted through granite a sheer-sided hole about 200 feet wide and 450 feet deep, now partly filled with water'. Basalt lapilli and small fragments of granite are scattered around the vent, which seems to have been formed by a single violent gas explosion.

Age of the Atherton Basalt

There is no direct evidence of the age of the basalts in the Atherton Province, but they have a considerable range: the earlier flows have been dissected to a depth of about 1300 feet by the North Johnstone River and Toohey Creek; later lavas flowed down these deep valleys and were subsequently dissected to a depth of 50 to 100 feet. Along several streams on the western side of the province, small weathered outliers of basalt crop out on the hillsides 200 to 300 feet above the basalt

on the floors of the valleys. The older shield volcanoes have been much more deeply eroded than the later well preserved cinder cones. Best (1959b, 1960, unpubl.) considers that the cinder cones have been protected from erosion by their greater resistance to channelling because of the greater permeability and porosity of cinder deposits. However, the high porosity and permeability would probably result in a faster rate of chemical weathering to clay, relative to the shield volcanoes, and the well preserved form of the cinder cones is therefore thought to be largely due to their later age.

Best (1960, unpubl.) observed that the basalts of the Atherton Province are lithologically similar to those of the McBride Province, and that in both provinces the olivine in the older flows is altered to iddingsite, whereas it is unaltered in the newer flows. The vents in both provinces also show a comparable range in their state of preservation. The age of the Atherton and McBride Basalts probably ranges from late(?) Miocene or Pliocene to Recent. Skertchly (1899) referred to the Atherton Basalt as Pliocene or younger, and Jardine (1925) considered the crater lakes and Mount Quincan to be post-Pleistocene. Jack & Etheridge (1892) distinguished two phases of vulcanism in the Atherton Province, the 'plugs' (cinder cones) belonging to the older, and the crater lakes to the younger group.

On the western side of the Atherton Province, in the Mount Garnet district, many of the older flows are buried under alluvial deposits up to a depth of 130 feet (Zimmerman et al., 1963, unpubl.). The presence of pebbles of Cainozoic basalt in the gravels underlying the lateritic duricrust in Return Creek indicate that the volcanic activity extends back to at least the mid-Tertiary.

In general, the vulcanism in the Atherton Province evolved from an initial lava-rich stage to an increasingly explosive gas-rich stage with few flows. The centres of activity shifted gradually from the southwest to the northeast, and Mount Quincan, the Seven Sisters, the crater lakes, and Green Hill probably represent the latest eruptions.

McLean Basalt

The McLean Basalt Province is named after Mount McLean, a modified cone a mile west of the main road about 40 miles southwest of Cooktown (Lucas and de Keyser, 1965). Most of the basalt crops out in the Butchers Hill Depression; remnants are also preserved as cappings on the spurs on the adjoining incised plateau.

The McLean Basalt, which covers a total area of about 130 square miles, has been described by Morgan (1965, unpubl., and 1968a). In places, the basalt rests on bouldery river gravel containing some granite fragments. Near Springvale homestead, the basalt is underlain by a few feet of pale siltstone containing dicotyledonous plant remains. In the Annan River Tinfield the stanniferous gravel and siltstone are overlain by remnants of basalt. Lithic and lapilli tuff is exposed at or near the base of the lavas in a few localities.

The main body of the McLean Basalt consists of one flow about 100 feet thick, and there is at least one (less extensive) later flow which was probably erupted from Mount McLean. The 180-foot section 1 mile south of Springvale homestead

consists of four flows, with thicknesses of 45, 30, 70, and 6 feet. The first and second flows are separated by 30 feet of gravel.

About 18 vents could be recognized (Morgan, 1968a). Several of the vents lie on known or inferred faults. The vents examined were found to be composite lava and cinder cones; they contain flows and bombs occasionally rich in peridotite inclusions, aggregates of pyroxene or spinel, and fragments of country rock. The circular depression on the eastern side of the Mulligan Highway, 10 miles south-southwest of Butchers Hill homestead, may be a maar.

The basalt is generally a fine to medium-grained alkaline olivine basalt. Olivine analcitite and analcitite tuff have also been recorded, and one of the analcitites contains small crystals of nepheline (Morgan, 1968a). Some of the flows have a glassy groundmass containing small phenocrysts of olivine and, less commonly, pyroxene. Chemical analyses of the basalts are listed in Table 5.

Little is known about the age of the McLean Basalt, but it probably has a wide range. Some of the cones seem to be relatively recent compared with the basalt cappings on the spurs and tableland.

Piebald Basalt

The Piebald Basalt Province includes a number of separate outcrops scattered over an area of about 55 square miles, mainly in the plain around the McIvor River, between 8 and 35 miles to the northwest and north-northwest of Cooktown. The name is derived from Mount Piebald, one of the old cones in the province (Lucas & de Keyser, 1965). About 14 vents have been identified (Morgan, 1968a); some of them are cinder cones, others are probably composite, and one at least is possibly a pit crater. Mount Piebald is a fairly large modified cone from which a flow descended to the north.

The Piebald Basalt is similar to the McLean Basalt, but no analcitites have been recorded. Some of the flows are rich in inclusions, mostly of Mesozoic sandstone, but also of coarse basic igneous rocks, diopside, and spinel. One of the flows at the Starcke River is a nepheline basanite (Table 6).

The age of the Piebald Basalt is unknown. Volcanic activity probably continued until almost historical times, as a spring at Boiling Springs homestead, on the northeastern edge of the Mount Piebald flow, is reported to have been hot until about 1912.

Late Cainozoic Sediments

Fossil earthy *talus and piedmont fans* (Czt) have been mapped in intermontane depressions and valleys, and along the main scarps bounding the coastal plains. In the north, where they are large enough to be mapped as a separate unit, they are found almost exclusively at the foot of Mesozoic sandstone scarps. Most of the coarse material in the sediments consists of fragments of sandstone, but a high proportion of the earthy ferruginous matrix was probably derived from the Hodgkinson Formation where it crops out on the lower slopes.

An older and a younger talus can be distinguished (Fig. 26C). The older forms perched remnants up to a mile from their related bounding slopes, and the

younger forms more continuous blankets on the present valley slopes. The older, more ferruginized talus may be perched up to 100 feet above the surrounding plain, and there is evidence of considerable scarp retreat. The younger talus grades into fossil piedmont fans.

Dune Sand

Extensive deposits of dune sand occur along the coast north of Cooktown, between Cape Bedford and Lookout Point; smaller deposits are found along Ramsay Bay on Hinchinbrook Island, and near the mouth of the Jeannie River.

The main outcrop to the north of Cooktown has an area of about 225 square miles; it extends for over 45 miles along the coast, and is up to 10 miles wide in places (Pl. 11, fig. 2; see also Bird, 1965). About 5 to 10 percent of the area is occupied by numerous freshwater lakes. The dunes range up to 250 feet high; many of them are anchored by vegetation, but where this has been destroyed, the dunes are on the move. Most are longitudinal dunes or modified remnants of such dunes, and are aligned parallel to the prevailing southeasterly trade winds. They are the elongate blow-out and wind-rift dunes of Melton (1940). Lucas distinguishes between the older dunes, which are characterized by ferruginous staining and partly re-exposed in the Cape Flattery deposit, and the unstained white younger dunes which form the bulk of the exposed sand bodies.

The numerous freshwater lakes occur where the sand has been deflated about groundwater level. Sand marks anchored by the humid underground show the pattern of dune removal and the way the dunes advanced towards the northwest (Pl. 11, fig. 2). The older dunes may retain small lakes at higher levels, probably owing to the presence of impermeable peaty lenses.

The elongate blow-out dunes (also called parabolic dunes, or U-dunes) are associated with sand deposits of appreciable thickness, and were formed under conditions of moderate winds of constant direction. The wind-rift dunes, which are similar in shape but much longer, range up to 5 miles long, and were formed by strong winds of constant direction. The sand migrated downwind in a straight line, and a typical gap or rift is usually present at the tip of the hairpin-shaped rim. The air-photographs clearly show the shifting pattern of the dunes, where traces of the former frontal lobes have been fixed by the groundwater table.

To the northwest, where the supply of sand diminishes, clusters of small dunes have been formed that represent remnants of U-dunes and fragments of the limbs of parabolic dunes, anchored by the shallower groundwater level.

On the fixed dunes, where the vegetation has been locally destroyed, blow-holes may develop and gradually grow into parabolic dunes. Where these merge together they form a tooth-comb pattern. Such dunes form a strip 5 miles long and about 1700 feet wide along Ramsay Bay on Hinchinbrook Island. The sand forming the dunes on the island has apparently been transported from the south by longshore currents, and has banked up on the eastern side of the mud flats exposed when the level of the sea fell in the shallow channel between the former island now called Cape Sandwich and the main body of Hinchinbrook Island (Pl. 14, fig. 2).

In the extensive Cape Bedford deposits, the sand was apparently derived from the Mesozoic sandstone which formerly extended to the east over part of the area now under the sea.

The best exposure of the older dune sand is found on the northern side of the isthmus about 4 miles west of Cape Bedford. The outcrop is 220 feet high and is deeply dissected by gullies and cliffs. It consists of poorly consolidated, orange, yellow, and white sands in which aeolian cross-bedded sets, ranging from 10 to 140 feet thick, are common; they are separated by white kaolinitic sands from 4 inches to 2 feet thick. The section has a thin, pisolitic, iron-enriched capping. Similar deposits, which are overlapped by the younger dune sands north of the Morgan River, contain thin horizontal beds of sandstone cemented by limonite. According to Lucas (1962, unpubl.), the sediments resemble the Teewah Sands east of Gympie, which Coaldrake (1960) considers to date from before the Pleistocene and to have been modified during the Pleistocene.

The older dune sands are generally firmly anchored by their cappings and the vegetation, but they have supplied much of the material for the younger dunes, for once the protective cover is destroyed locally in a blow-out they disintegrate rapidly.

Residual Sand

Loose residual sands (Qs) cover interfluves in all the low gently undulating tracts around the Mesozoic sandstones, especially on the Jack Peneplain. They have apparently been derived from the disintegration of the Mesozoic sandstones, or in places from the superficial Brixton Formation.

Alluvial Deposits (Qa)

Pleistocene to Recent alluvial deposits are extensive in the Normanby Plain in the north, in the Mount Garnet alluvial basin in the south, and in several places along the coast where they form most of the coastal plains. Smaller expanses occur inland.

In the Normanby Plain the alluvial deposits consist of unconsolidated silty and fine sandy clay, and are probably up to 100 feet thick; they rest on the older mottled alluvials (Brixton Formation) and Cretaceous sediments with cut-and-fill relationships. The clay is generally a dark grey, dense, swelling, calcareous variety, but is commonly modified near the surface by soil-forming processes.

The alluvial deposits in the Mount Garnet area, which date back to the Tertiary, consist of sediments showing different degrees of consolidation, interbedded with basalt flows. They comprise alluvial and colluvial clay, silt, sand, and gravel. Five phases of sedimentation have been recognized by M. J. Bik (pers. comm.), who studied the area in 1962 (Zimmerman et al., 1963, unpubl.). The oldest sediments are capped by a hard mottled lateritic duricrust. The second phase is represented by deeply weathered sediments containing layers with iron and manganese nodules; they overlie the duricrust zone with cut-and-fill relationships, and are usually red-brown or yellow. The second phase was followed by at least another two phases, probably of Pleistocene age in Bik's opinion, because of the lack of weathering effects. However, the isotopic age of carbonized wood from a depth of 60 to 70 feet in a drillhole about half a mile south of the dredged area in Smiths Creek, near Mount Garnet, was found to be 36,600 $\pm$ 1900 to 2400 years (Zimmerman et al., 1963, unpubl.). The sediments of both phases are characterized by yellow or yellow-brown soil profiles and their unweathered appearance. They also form cut-

and-fill deposits in the earlier sediments. The youngest sediments, of Recent age, consist of sandy channel deposits, and heavy-textured back-swamp deposits found along the larger stream channels.

The maximum thickness of the Cainozoic succession, including the interbedded basalt flows, is over 210 feet.

The alluvial deposits on the coastal plains and deltas of the main rivers are composed of coarse and fine sand, gravel, sandy clay, silt, and a few beds of conglomerate. Lensing and cross-bedding are common. The thickness varies according to the locality and size of the streams. In the Herbert River delta, for example, the water bores near Ingham penetrated 312 to 316 feet of sediment (Calvert, 1959, unpubl.). A bore at Gordonvale, in alluvials of the Mulgrave River, penetrated 110 feet of clay and silt with layers of gravel, without reaching bedrock (Jardine, 1925). There is a higher terrace above the borehole, and the total thickness of sediment is estimated to be over 150 feet.

The presence of mangrove remains in the borings at Gordonvale and of mangrove mud in the borings near Ingham indicate that the coastal alluvials interfinger with lagoonal-marine strata.

Smaller, scattered alluvial plains occur inland, especially in the Dimbulah/Mareeba/Molloy/Mount Carbine region west of Cairns. The indicated thickness just north of Mareeba is over 60 feet, and over 75 feet along Station Creek, between Molloy and Mount Carbine. In the Kings Plains area, 15 miles west of Cooktown, drillholes put down to test alluvial tin prospects (see p. 193) penetrated up to 167 feet of alluvium, the upper 40 to 60 feet of which consisted of ferruginous mottled sandy clay, overlying 80 to 120 feet of dominantly coarse sediments and some dark pyritic clay.

An unusual *travertinous limestone* of Recent age crops out in the valley of the Little Mulgrave River within a mile of the Gillies Highway (Reid, 1926). The limestone lies 40 feet above the bed of the gully, and is about 30 feet thick. It contains plant remains and some gastropods, and was probably deposited in a freshwater lake formed by the damming of the Mulgrave River by basalt.

Marine deposits

The coastal marine deposits and the sediments on the continental shelf include sandy and muddy salt flats, mangrove swamps, lagoonal deposits, fossil beach sands and strandlines, raised fringing reefs and pumice berms, beach rock, and unexposed shelf deposits. The most extensive outcrops occur around Princess Charlotte Bay, with smaller deposits fringing the coastal plains in many places, as at the mouths of the Starcke and Daintree Rivers at Cairns, Mourilyan Harbour, and alongside the Hinchinbrook Channel. Some of the fossil beach sands and strandlines extend for 5 to 6 miles inland, and even up to 10 miles along Princess Charlotte Bay. The pattern of the old strandlines is clearly visible on the air-photographs (Pl. 14, fig. 1). In places the coast originally consisted of sand spits and bars enclosing lagoons which have been silted up. In general, the coastal deposits were gradually growing and shifting northwards under the influence of the longshore currents created by the prevailing southeasterly winds. Some of the sands are coarse and angular, and were derived from local granulated quartz veins.

Eight miles from the mouth of the Normanby River a slightly porcellanized coquina, containing oysters, barnacles, and a *Pecten* has been found in a sandy marl under 3 feet of grey clay. The deposit probably represents a Pleistocene strandline (Woods, 1963, unpubl.).

Deposits of fine silt and mud have completely filled former lagoons in a number of places along the coast, and are separated from the sea by sand spits and barriers. The general effect is the straightening of the coastline by the silting up of bays and coves. The deposits at the mouths of the larger rivers grade into tidal flats interwoven with a network of tidal channels fringed with mangrove.

Little is known of the offshore reef deposits and associated sediments. They consist of the outer barrier reef, platform reefs, and coral sand cays, with fringing reefs around rocky islands in the sheltered shallow sea behind the outer reef. The boreholes on Michaelmas Cay (some 25 miles northeast of Cairns), and on Heron Island and Wreck Island in the Capricorn Group (lat. 23°16′S.) penetrated 378 to 506 feet of coralline limestone and reef sand, followed by about 225 feet of only slightly consolidated foraminiferal and glauconitic quartz sand, the bottom of which was not reached. Richards & Hill (1942) consider the upper section to be post-Pleistocene. Older foraminiferal sands and Miocene detrital reef limestone have been recognized in the Wreck Island Bore (Hill, 1960b).

Assuming that the average depth of the sea is 100 to 200 feet, the bores indicate a thickness of at least 400 to 500 feet of Quaternary and possibly Upper Tertiary marine sediments, consisting mainly of terrigenous material with lenses and tongues of reef detritus and limestone, the proportion of which increases markedly in the reef zone (Fairbridge, 1950).

A hard beach gravel with a calcareous cement is found a few feet above sea level on many of the rocky islands. Russell (1962) and Boekschoten (1963) consider that beach rock is formed where seeping fresh groundwater mixes with sea water, especially where the average temperatures are high, and organic material is not abundant, as on small tropical islands.

On many of the islands pumice can be found several feet above high-water level. The deposits on the Palm Islands (east of Ingham) were recorded by King in 1819 during a voyage in the *Mermaid*.

STRUCTURE

Both the Precambrian units forming the shield area in the west, and the Palaeozoic geosynclinal formations of the Hodgkinson Basin, have undergone intense orogenic deformation. The Permian and Mesozoic strata have been only slightly affected by tectonic movements, and most of their deformation was the result of faulting which continued into the Cainozoic.

The Precambrian orogeny has not been studied in detail, but the main structural elements of the Precambrian rocks are outlined on page 25.

The Hodgkinson Formation and Barron River Metamorphics, and to a lesser extent the Chillagoe and Mount Garnet Formations, were intensely folded and faulted probably during the early Carboniferous. Jense (1939a, 1940, unpubl.) and others (AGGSNA, 1939, 1940a) have recorded scattered observations on local

structural features such as folding, cleavage, crush conglomerate, faulting, and the regional strike.

Folding and Cleavage in the Hodgkinson Basin

In 1960-61, Amos (1968) made a detailed study of the tectonic history of the Hodgkinson Basin in the Mossman and Cooktown Sheet areas. He established the main sequence of events during the folding of the Palaeozoic sediments. The following account of the folding and its structural characteristics is based mainly on the two unpublished reports by Amos.

Amos recognized four fold systems, B_1, B_2, B_3, and B_4. In this Bulletin, the axial-plane cleavages associated with the folds are designated S_1, S_2, etc., the original bedding is called S_0*, and the lineations associated with these systems are indicated as L_1, L_2, etc.

The oldest folds, B_1, are generally large tightly compressed folds with approximately horizontal axes trending north (in the northern areas) to northwest (more to the south). The limbs have a consistent steep dip and the hinge areas are narrow, so that the folds are difficult to recognize, especially where they have been deformed by later folds. Smaller, mesoscopic B_1 folds are rare. An axial-plane cleavage, S_1, may be developed in the core of the B_1 folds, but is rarely visible on the limbs, nor is there any evident lineation.

The B_1 folds are responsible for the regional north-northwesterly strike and steep dips in the Hodgkinson Basin, and have also influenced the orientation of the later folds. Though they are largely obscured by the later folds their ubiquity is indicated by the steep bedding attitudes that antedate the B_2 and B_3 folds (Fig. 18), and by the repeated reversals of facing in the greywackes (Fig. 18d).

The B_2 folds are large open folds with a broad hinge area, superimposed on the steeply dipping limbs of the B_1 folds (Fig. 18). The axial planes are vertical and trend east, northeast, or north. The fold axes plunge steeply at 50° to 90°; the angle and direction of plunge are controlled by the intersection of the B_2 axial planes and the steeply dipping B_1 limbs (Fig. 18b,c). No cleavage or lineation is associated with the B_2 folds. The wide range in the trend of the axial planes suggests that the B_2 folds include more than one fold system.

In the central-west of the Mossman Sheet area, the B_2 folds have an amplitude of several miles, but in the Cooktown Sheet area they are less common, and are represented by smaller mesoscopic structures which are cut incongruently by the S_3 cleavage of the well developed B_3 fold system.

The B_3 folds are large, generally tight, similar folds (shear folds) with relatively small hinge areas. The axial planes strike north-northwest, north, or north-northeast, and the fold axes usually plunge at 50° to 90°. A pronounced axial-plane slaty cleavage, S_3, is associated with the B_3 folds, and dips at 75° to 90° to the west or east. A lineation, L_3, is developed parallel to the intersection of the S_3 cleavage

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* Amos (1968) used S_1 for the original bedding planes, S_2 for cleavage associated with B_1, etc, but it seems preferable to avoid confusion and indicate all structural elements of a given folding phase by the same suffix.

and the original bedding S_0, and is therefore parallel to the fold axes. Partial transposition of the bedding along the S_3 cleavage is common.

The B_3 folds and the associated S_3 cleavage are among the most conspicuous structures in most of the Hodgkinson Formation. They are clearly visible on the air-photographs as large steeply plunging folds with amplitudes ranging up to 4 miles wide. Towards the east the folds become less obvious, but the S_3 cleavage gradually becomes more pronounced and more uniformly distributed, until it is the dominant structural element. The cleavage shows a wide variation in trend, which is particularly evident in outcrops along the coast.

Mesoscopic B_3 folds are not common in association with the larger B_3 folds, but they are more numerous in the east, where the S_3 cleavage is more intense.

In many places the bedding is transposed by the S_3 cleavage, whereby the sandy beds have been divided into lenticular fragments which have been drawn

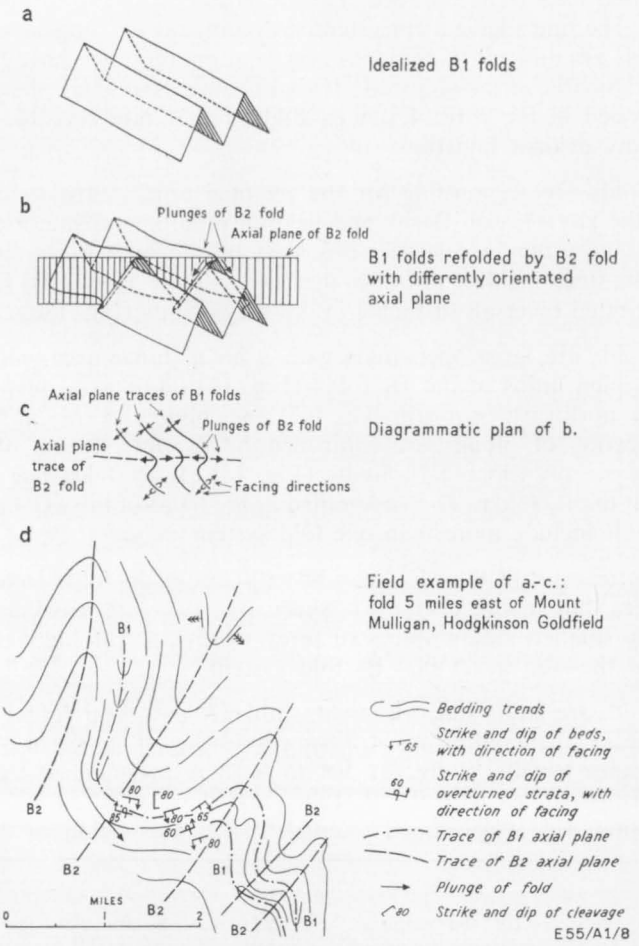


Fig. 18. Relationship between B_1 and B_2 folding.

out along the cleavage planes. The bedding has also been transposed by extremely tight folding and subsequent shearing out of the limbs. In some slaty beds, the original slaty cleavage is transected by a strain-slip cleavage that gradually develops into a new slaty cleavage S_3. In many places, usually farther inland, where the rocks were more brittle, probably because they were less deeply buried, the transposition by the S_3 cleavage was less complete: instead of suffering continuous deformation and elongation the fragments have largely retained their ellipsoidal outlines and form a tectonic pseudo-conglomerate (Pl. 3, fig. 2). These zones have been mapped as shear zones, and are up to 5 miles wide and 15 to 20 miles long. They represent zones of intense flattening rather than simple shear zones.

The B_4 folds have a limited distribution. They are open right-angled folds in the S_3 cleavage, with subhorizontal axes trending northwest. They are macroscopic and mesoscopic kink folds, with one gently dipping limb and one steeply dipping limb with the same regional orientation as the unfolded S_3 cleavage. The limbs are generally planar, and the hinge areas are narrow and angular, but not fractured. There is poorly developed strain-slip cleavage, S_4, parallel to the axial planes, which have a slightly variable orientation. The weak lineation, L_4, is defined by the intersection of the S_3 and S_4 cleavages and is parallel to the fold axes which trend northwest. At the Daintree River the fold axes are nearly horizontal, but farther north the plunge steepens to about 30° to the northwest at Sporing Creek. Bedding is preserved in some places, but is completely transposed elsewhere.

Distribution of the Fold Systems

The sediments in the Hodgkinson Basin have generally been deformed by more than one of the fold systems described above. In the west, however, B_1 folds only are present, probably because of the stabilizing influence of the resistant basement block along the western border of the basin, and because the sediments are thinner in the marginal zone. A few fold closures can be seen on the air-photographs, but in general the beds dip steeply to the east without much direct evidence of folding as the folds have narrow hinge areas, steeply dipping limbs, generally horizontal axes, and few associated minor folds or lineations.

The B_2 folds reached their maximum development in the west and south of the Mossman Sheet area, where they are easily recognized on the air-photographs. They may be also represented as mesoscopic open folds with east-trending vertical axial planes in coastal exposures south of Cooktown, and in the Barron River Metamorphics in the Cairns and Innisfail Sheet areas (Fig. 19; Pl. 3, fig. 1).

The B_3 folds and their S_3 cleavage are equally well discernible on the air-photographs, and are most widely distributed in the central and eastern parts of the Hodgkinson Basin, though some prominent S_3 cleavage zones (shear zones) have been mapped in the west, e.g. at the Mitchell River northeast of Belleview homestead (Fig. 20).

The macroscopic (concentric) B_2 folds in the west give way to B_3 similar folds (shear folds) in the east, and they are thought to be contemporaneous in part, although the mesoscopic B_2 folds in the east are older than the S_3 cleavage, which transects them incongruously (Fig. 19). In the intermediate areas the B_2 and B_3 folds appear to grade into each other. A good example is the fold across the Mulligan Highway at the head of the St Georges River (Fig. 21), where both con-

centric and similar folds appear to be present: there is considerable bedding-plane slip in some horizons, and a lack of cleavage in the thick arenitic beds, compared with the pronounced thickening of beds in the trough of the fold, conspicuous slaty cleavage in the pelitic layers, and constant amplitude.

The B_4 system was found only in an area of uncertain extent between the Daintree River and Sporing Creek (a tributary of the Granite Normanby River); it may extend for some distance to the north and south beyond the streams, and the deformation at Etty Bay and Mourilyan Harbour southeast of Innisfail, may be the chronological equivalent of the B_4 system, although its style is different (p. 125).

Outcrops are much scarcer in the southern parts of the Hodgkinson Basin, and photo-interpretation is hampered by the tropical rain forest, but the sequence of folding and cleavage is similar to that in the northern part of the basin.

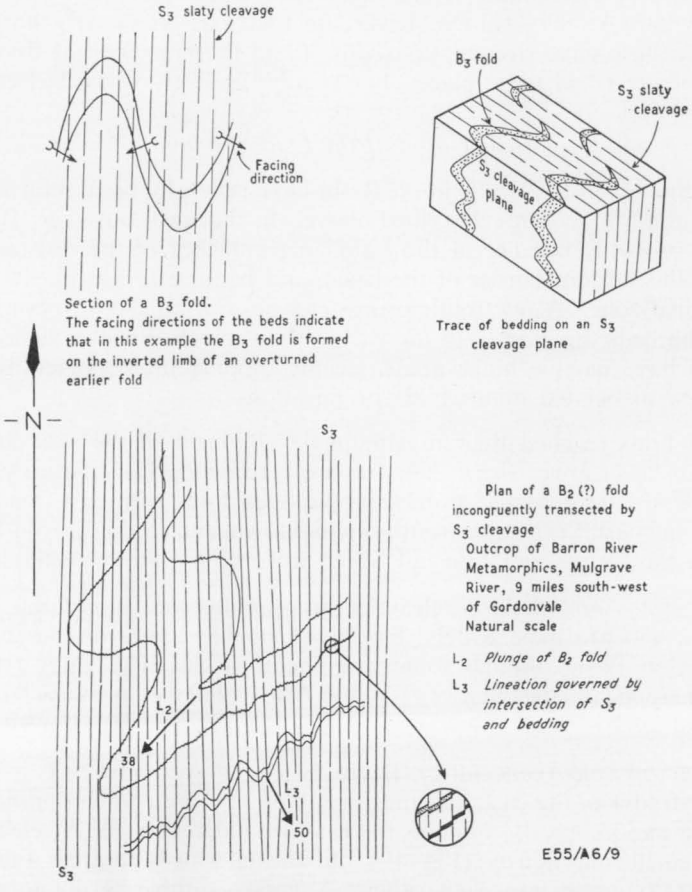


Fig. 19. Structures of the B_3 fold system.

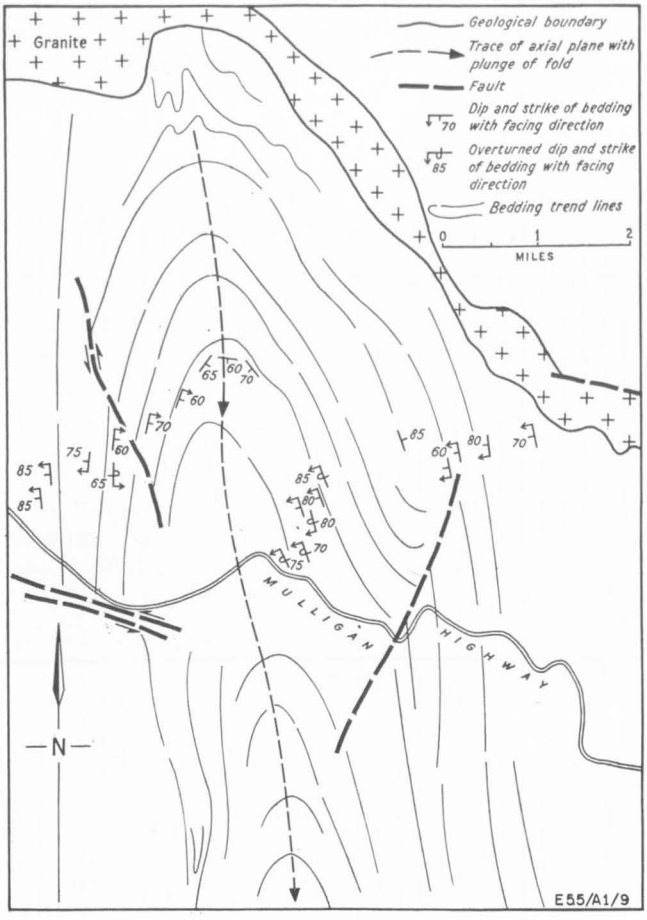


Fig. 20. Fold on the headwaters of the St Georges River.

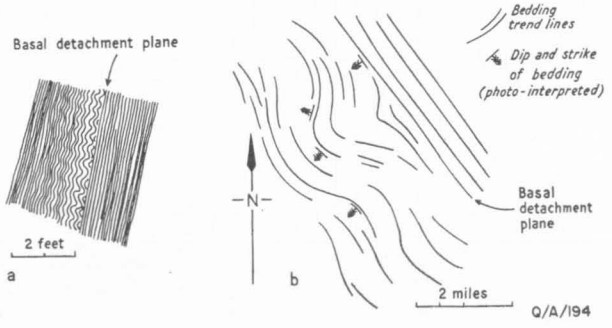


Fig. 21. a. Folded phyllite, Bruce Highway.
b. Fold north of the St Georges River.

Other Folds

In addition to the four main fold systems, there are local deformations produced as a result of sedimentological peculiarities, local faulting, or higher temperature and pressure conditions.

The bedded cherts in the Palaeozoic formations commonly show incompetent disharmonic mesoscopic folding with axial plunges in various directions. This type of irregular folding is found only in the bedded cherts which suggests that it is not of tectonic origin. Possibly the folds were formed by slumping before the beds were dehydrated and became hard and brittle.

A good example of local folding due to faulting can be seen on the Gillies Highway on the eastern slopes of the granitic Lamb Range, west of Gordonvale. The granite is in faulted contact against cleaved phyllite and schist of the Barron River Metamorphics, which contain minor folds with south-plunging, north-northeasterly to northerly axes. Towards the granite, the phyllite and schist gradually develop a cross-folding with north-northwesterly axes, which was probably produced by the drag along the fault. The cross-folds are commonly of the chevron type, and where they are closely spaced they give rise to a false-cleavage pattern which grades into minor faults. The plunge of the cross-folds cannot be measured because it is governed by the dips of the earlier folds.

Another example of purely local mesoscopic folding was observed in a road cutting on the Bruce Highway, 10 miles northwest of Innisfail. The 'fault' is a basal detachment plane parallel to the schistosity of the phyllite (Fig. 21A). A much larger basal detachment plane is present in a macroscopic B_2 fold north of the St Georges River, southwest of Cannibal Creek, where the fold is about 2 miles wide (Fig. 21B).

In the eastern part of the Hodgkinson Basin, examples of plastic flow folding (Fig. 22) are found around the granite batholiths, where the increase in temperature and the greater load pressures in the east apparently facilitated this type of deformation.

The phyllite, schist, and arenite of the Barron River Metamorphics along the coast to the north and south of Innisfail are intensely quartz-veined, sheared, and crumpled, and appear to have a higher grade of metamorphism than the same rocks elsewhere (de Keyser, 1964). The coastal rocks were previously regarded as

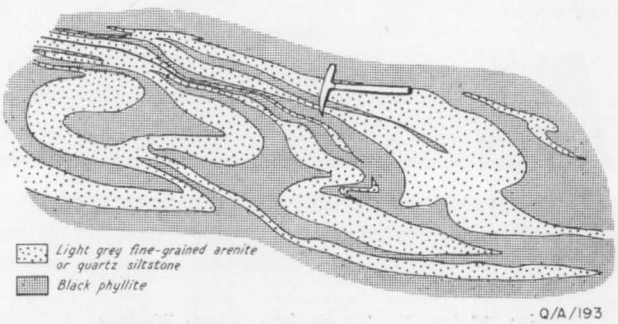


Fig. 22. Plastic deformation in siltstone, southeast of Mossman.

belonging to the higher-grade Barnard Metamorphics (Jones & Jones, 1956), but the mineral assemblage indicates a low-grade metamorphic facies. The deformation has been caused partly by post-metamorphic and post-granitic shearing and close faulting in a north-northwesterly zone, several miles wide, extending from the North Barnard Islands and probably beyond (see p. 48). The mesoscopic crumpling has an amplitude of 1 to 2 inches, but folds up to several yards wide (with crumpled limbs) are also common. Microscopic deformation is also apparent (Pl. 4, fig. 1). The plunge is generally steep to the southeast or northwest. The original cleavage and schistosity was included in the deformation, and in places it has been transposed by a later schistosity which developed from a strain-slip cleavage, probably during continuing slight metamorphism, when the mica and chlorite were recrystallized and reoriented. The sequence of events is shown diagrammatically in Fig. 24.

In general, the folding phases become more numerous and complex from west to east, and this tendency is illustrated in Plates 12 and 13, in which sediment sequences from different formations, but as closely similar in lithology as could be found, are shown in stages of increasing deformation.

Some northeasterly disruptive trends of post-cleavage age have been reported in the area between Cape Melville and Lookout Point (Lucas, 1964, unpubl.). The deformation consists of brittle minor folding and faulting, with gently plunging northeasterly fold axes. Lucas considers that the discordant trend of these folds may have prepared the way, by block fracturing on oblique lines, for the intrusion of granite.

Folding in the Permo-Carboniferous and Mesozoic Formations

The Permo-Carboniferous formations rest unconformably on the strongly folded geosynclinal sediments of the Hodgkinson Basin; they consist of interbedded volcanic and continental or littoral deposits, and are generally preserved in fault blocks. They are only gently folded, showing dips of less than 20°, except in the vicinity of faults; most of the folding appears to be due to drag along the confining faults.

The Silver Valley Conglomerate, 8 miles southwest of Herberton, is a Carboniferous formation preserved in a downfaulted block; the conglomerate forms an open syncline or basin with up-drag against the steep eastern and western boundary faults.

Permian sediments are preserved in two fault blocks at Oaky Creek west of Cooktown (Normanby Formation), and in a narrow fault block along the Palmerville Fault at the Little Kennedy River north of Palmerville (Little River Coal Measures). The Normanby Formation is strongly folded, but the beds are only slightly cleaved. The fold axes plunge at 5° to 20° to the south, and dips range from about 80° at the margins to horizontal in the centre of the outcrop. The major structural component is a macroscopic synclinal fold or folds parallel to the length of the fault block (Amos, 1962, unpubl.). The folding in the Little River Coal Measures is more complicated, and the bedding is not folded cylindrically about a single axis throughout the fault block (Amos, 1962, unpubl.). No clear picture could be obtained.

The Nychum Volcanics between the Walsh River and Mulgrave homestead are not restricted to a fault block. The folds are broad and open, and the dip, though mostly about 10° or less, ranges up to 35° in many places. Some of the steeper dips are probably due to the drag effect of the adjoining faults.

The Mesozoic strata are essentially horizontal, with dips of less than 5°. In a few places, dips up to 80° are found against fault planes, e.g. along the Palmerville Fault, and especially at Mount Mulligan where Permian and Mesozoic sandstone and conglomerate are synclinally folded in a fault block.

Faults, and Other Lines of Structural Weakness

Lines of structural weakness include faults, shear zones, dyke swarms, and ring fractures.

Faulting and shearing have been active throughout the life span of the Hodgkinson Basin, and have continued into the Mesozoic and Cainozoic eras. Most of them are straight and dip very steeply. Owing to the lack of marker beds the amount of displacement and sense of movement is uncertain.

The Palmerville Fault (de Keyser, 1963), which forms the western boundary of the geosyncline, is a major structure which extends for at least 400 miles from Princess Charlotte Bay in the north to Halifax Bay in the south (outside the map area). The same fault possibly extends along the eastern coast of Cape York Peninsula. The fault has not been located in a short section near Mount Garnet, but in the south (Herbert River) it is defined by tourmalinized crush and mylonite zones through the granite at Smoko Creek, one of the smaller tributaries of the Herbert River.

The Palmerville Fault coincides in part with the Tasman Line (Hill, 1951), and started its history as a boundary fault during the first stages in the downwarping of the Hodgkinson Basin during the late Silurian. Subsidiary fissures along the fault zone acted as feeder channels for the basalts and andesites of the Chillagoe Formation. During the Carboniferous orogeny, movements along the fault were probably reversed, and the structure acted as a thrust plane. After deposition of the Upper Permian formations (Little River Coal Measures), the Palmerville Fault resumed its role of a normal fault with the development of thin rift zones. Finally, in post-Mesozoic times, another inversion took place, and the Cretaceous and Jurassic strata east of the fault were raised 100 to 200 feet relative to the outcrops to the west. The present topography indicates that the last movements were quite recent: the west block is relatively flat and mature to old, whereas the east block has been recently elevated and its drainage system rejuvenated.

No evidence of lateral movements along the Palmerville Fault could be found

Another major fault, here called the Tully Fault (Fig. 23), has been inferred mainly on geomorphological grounds; the fault is poorly exposed and most of it is covered by basalt, rain forest, or alluvial deposits. It extends from Silver Valley, southwest of Herberton, to Hinchinbrook Channel, and separates the Tully Granite Complex from the Glen Gordon Volcanics. The granite along the fault in the Tully River valley is slightly foliated, and it appears to be sheared along the line of the fault to the west of the Bruce Highway.

A third major structure is the shear zone extending from the North Barnard Islands, Mourilyan Harbour, and Etty Bay in the southeast, to Cairns and very probably to the Daintree River and beyond, in the northwest. The shear zone is up to 5 miles wide, and has affected the Barron River Metamorphics (see p. 125),

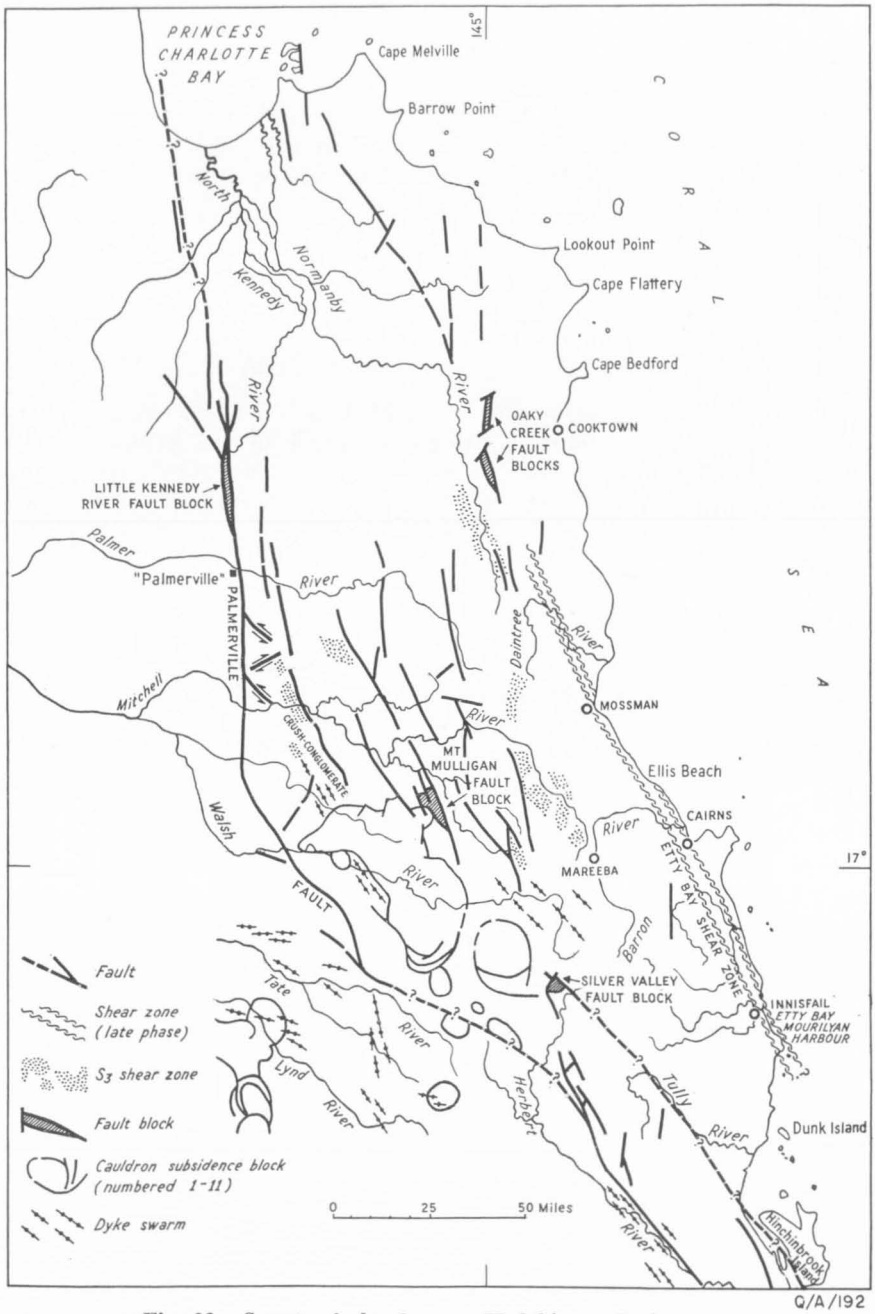


Fig. 23. Structural sketch map, Hodgkinson Basin area.

and also the margins of the granites along the Mulgrave River 'corridor' south of Cairns, and along the coast north of Cairns. The granites are crushed and foliated (Pl. 8, fig. 2) and in places strongly sheared; isotopic age determinations indicate that the granites are Permian (Richards et al., 1966), and the deformation is presumably later. Other evidence for this shear zone includes the presence of recrystallized mylonitic gneiss at Cairns, and strongly sheared greywacke and granite in the McAllister Range and Black Mountain area north of Cairns (Fardon & de Keyser, 1964). Amos' B_4 fold system may be a result of this late phase of deformation, and it is possible that the Oaky Creek fault blocks, which are in line with the shear zone (Fig. 23), may also be a related structure. Figure 23 suggests that the inferred fault, which delineates the Mesozoic sandstone scarp farther northwest, could belong to the same zone of structural weakness.

The Etty Bay shear zone, like the Palmerville Fault, was formed during several episodes of deformation, the oldest of which were influenced by the last stages of metamorphism, the youngest extending into the Tertiary, or perhaps even into historical times, if the location of earthquake epicentres in this zone (Jones, 1959) is of any significance.

Other faults, in the central part of the Hodgkinson Basin, mostly follow the regional northwesterly or north-northwesterly trend of the geosyncline. They originated during the Carboniferous orogeny and cycle of granite intrusion, but in places they show evidence of recurrent movements. One example is the fault that forms the eastern boundary of the Mount Mulligan rift block: it includes a post-Triassic(?) phase and a Cainozoic phase; the latter is reflected in the morphological contrast between the blocks of Hodgkinson Formation on either side of the fault.

Faulting along northeasterly lines, and in other directions, is much rarer. Those that terminate the Oaky Creek fault blocks to the west of Cooktown are clearly younger than the north-south boundary faults.

Faulting or fissuring during the Quaternary is indicated by the linear arrangement of some of the basalt cones (e.g. the Seven Sisters, east of Atherton), and the location of vents on known faults (Lucas, 1962, unpubl.). Best (1962) has described faults displacing Cainozoic basalt flows south of Mareeba and west of Ravenshoe, and has suggested that some of them are rejuvenated older structures.

Acid dykes, and to a lesser extent basic dykes, are extremely common in association with igneous intrusions in the Hodgkinson Basin. The dykes are locally concentrated in swarms. The fissures were formed in zones of structural weakness caused by up-doming of a block adjacent to a major fault (e.g. the Palmerville

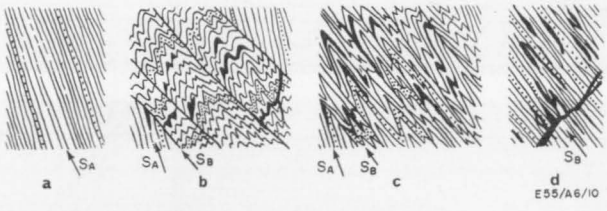


Fig. 24. Diagrammatic development of the deformation of the Barron River Metamorphics at Etty Bay and Mourilyan Harbour.

Fault), or by tension along cauldron subsidence areas (e.g. on the west side of the Featherbed Volcanics), or possibly by fracturing along the projected extensions of some faults where they suddenly change direction (e.g. both south and west of the bend in the Palmerville Fault to the southwest of Almaden).

The ring fractures enclosing the cauldron subsidence blocks in the southwestern part of the area (Fig. 23) have been described in detail by Branch (1962, unpubl., 1963, 1966). They range from the Carboniferous to the Permian, and are probably the result of postorogenic tensional stresses and passive collapse associated with magmatic processes in areas where large structural elements intersect or change direction. Most of the cauldrons are found in the Precambrian shield area, but the presence of several of them in the margin of the geosyncline suggests that the underlying basement lies at a relatively shallow depth beneath the Palaeozoic sediments.

Joints

Jointing is commonly well developed in the granites and volcanic rocks. The joints are clearly visible on the air-photographs. In places, the drainage is controlled by the joint systems. Many directions can be recognized, and dips, though commonly steep, range from vertical to low. A good example of low-dipping sheet joints may be observed in Elizabeth Creek Granite on the southeastern side of the Boxwood Ring Complex.

In places, the joints in the granites extend into the surrounding sediments. Even where no granite is exposed, the joint pattern in the sediments may indicate the presence of granite at shallow depth, as in the area to the west of the granite massif forming Thornton Peak and Mount Pieter Botte. Such areas deserve some attention in the search for ore deposits.

Tectonic Regimes in the Hodgkinson Basin (Fig. 25)

It is convenient to follow Harland & Bayly's nomenclature of tectonic regimes (1958) to describe the history and pattern of deformation in the Hodgkinson Basin during the Carboniferous orogeny.

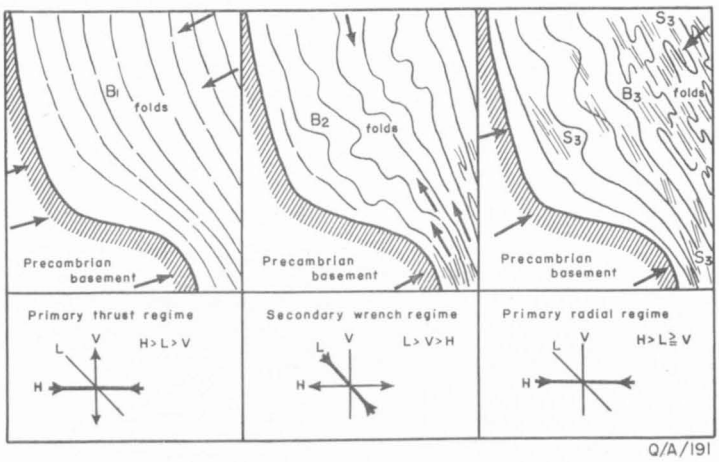


Fig. 25. Tectonic synthesis of the Hodgkinson Basin.

Harland & Bayly have distinguished thirteen types of tectonic regime depending on the orientation of the stress fields acting along the three principal stress axes: the primary horizontal stress axis H, the lateral axis L, and the gravity axis V.

The depositional area of the Hodgkinson Basin is bounded by a rigid block of Precambrian basement in the west, but the structure of the eastern side of the basin is unknown as it lies beneath the sea. In the south, the western margin protrudes into the geosyncline, and it appears therefore that the east-west compression generally had stronger immediate effects in the south than in the north.

At the onset of compression normal to the margin of the Hodgkinson Basin, the folds formed during this primary thrust regime ($H > L > V$) were tight and isoclinal with subhorizontal axes (B_1 fold system). Thrust faults were probably associated with them. At this stage the easiest direction of relief was upwards rather than lateral, and this was accomplished by the folding (vertical axial planes) and thrust faulting (Fig. 25A). Tectonic conditions were more or less uniform, and equally distributed; hence the B_1 folding was widespread and general.

In the south, where the basement protrudes into the Hodgkinson Basin, the basin was narrower and the B_1 folding tighter: the vertical piling up of the sediment packet was more pronounced, and proceeded faster, until relief of pressure became easier in a lateral direction. This first led to a general flattening (primary radial regime, $H > V = L$) which developed into a primary wrench regime ($H > V > L$). Material was squeezed laterally into the northern areas where there was still scope for modification and adaptation, and where B_2 folds were being formed partly as a result of this lateral flow, partly because the vertical loading there, too, became too great, and stress relief had to be sought laterally (secondary wrench folds, $L > V > H$; Fig. 25B). This was possible because of the greater width of the basin in the north, and because the protruding basement provided a protected corner where eddies could be formed. Diagonal wrench faults may have been formed during this period.

When resistance against further fold deformation increased because the slack had been taken out of the system, continuing pressure probably caused a return to the primary thrust regime in the upper levels, or the generation of a primary radial regime ($H > V = L$) at somewhat deeper levels; the deformation took the form of intense cleavage (S_3), shear folds (B_3), crush conglomerates, and shearing (Fig. 25C).

In general the main phases of folding succeeded each other in the order B_1, B_2, and B_3. However, B_3 and S_3 structures were probably formed very early in the the southern part of the basin, about the same time as the B_2 folds farther north; B_2 folds are also much less common in the south than in the north. Furthermore, the stresses at any particular point may have been modified by local conditions, such as differences in lithology, the presence of nearby stable blocks, different depths of burial, or the anisotropy of the earlier structures.

It is possible that the higher degree of metamorphism in the Barnard Metamorphics in the southern part of the basin is related to the greater stresses developed there because of the narrowness of the geosyncline.

Regional Metamorphism

Most of the formations in the Hodgkinson Basin have escaped regional metamorphism, and until recently the high-grade Barnard Metamorphics were considered to be Precambrian, and the low-grade Barron River Metamorphics Lower Palaeozoic; both, therefore, were believed to antedate the formations in the geosyncline, and to have formed tectonic land during the geosynclinal sedimentation.

De Keyser (1965) has recently suggested that the Barnard Metamorphics, Barron River Metamorphics, and Hodgkinson Formation are time-equivalent units, which have been subjected to different degrees of metamorphism. There is no evidence that these formations are unconformable, and the field and petrological relationships are in accordance with the descriptions of other areas where highly metamorphosed sediments exist side by side with their low-grade metamorphic and non-metamorphic equivalents. The regional metamorphism is usually of the andalusite-sillimanite type of metamorphic facies series (Miyashiro, 1961), which corresponds roughly with the 'Buchan' type of metamorphism in the Scottish Highlands. It corresponds with the low-pressure/high-temperature group in the classification of the metamorphic facies series recognized by Miyashiro.

The geological and petrological characteristics of the Hodgkinson Basin support this idea. The mineral assemblage of the Barnard Metamorphics (quartz, orthoclase, microcline, biotite, muscovite, albite, oligoclase, andalusite, sillimanite, cordierite, chlorite; see p. 50) appears at first glance to be anomalous and metastable, but according to Miyashiro (1961) it is the normal and typical assemblage for the amphibolite facies in the andalusite-sillimanite type of facies series. The rather abrupt transition from low-grade (Barron River) to high-grade (Barnard) metamorphic rocks is also characteristic of this type of metamorphism (Chinner, 1962). Other features of the andalusite-sillimanite type of metamorphism in the Hodgkinson Basin include the co-existence of andalusite and sillimanite, and the common presence of cordierite; the abundance of granites (including synkinematic granite in the higher-grade metamorphic region); the widespread extension of the granites beyond the limits of the regional metamorphic terrain; the scarcity of basic plutonic rocks, which, in addition, tend to be somewhat older than the granite; and the total absence of almandine garnet in the metamorphosed basic igneous rocks (see the Babalangee Amphibolite, p. 51).

The isotopic age of the migmatite (intruded by gneissic granite) at south Mission Beach, east of Tully, has been determined as 310 m.y. (Richards et al., 1966). This does not contradict the possibility of a Palaeozoic age for the Barnard Metamorphics.

The transition from the unmetamorphosed Hodgkinson Formation into the low-grade Barron River Metamorphics is very gradual. In the unmetamorphosed sediments, the matrix in the arenite and siltstone has been recrystallized into aggregates of chlorite, sericite, and quartz, and in places the quartz grains have been partly replaced by calcite, the rims have been corroded in 'chevaux-de-frise' fashion by sericite or muscovite. In some rocks the feldspars have been partly replaced by mica. The fine-grained lutite has been transformed into shale or, where dynamic metamorphism became stronger, into slate. Although older writers sometimes used a terminology that implied moderately high grades of metamorphism in the Hodg-

kinson Formation, the only metamorphism noticeable is low-grade dynamic (slate) or thermal (in contact outcrops), and is of local importance only.

Towards the east and southeast, the first signs of low-grade regional metamorphism are the conversion of the basic volcanics into greenschist composed of albite, chlorite, actinolite, epidote, sphene, and magnetite, followed by the recrystallization of the altered detrital biotite into flakes of clear idioblastic biotite, and by the formation of a new generation of biotite from the chlorite-sericite matrix. Mobilization of components is also apparent: a thin section of a greywacke-conglomerate at Port Douglas shows the concentration of small biotite flakes around the protected corners between pebbles, and thin quartz veinlets containing lateral secretions of biotite from the rock into the veinlets.

The grade of metamorphism in the Barron River Metamorphics is nowhere higher than the quartz-albite-epidote-biotite subfacies of the greenschist facies of Fyfe, Turner, & Verhoogen (1958), and is commonly lower still. The sedimentary structures have been preserved, and there is little sign of metamorphism in the coarse arenites, except in thin section.

In a few localities, the transition of the Hodgkinson Formation into the Barron River Metamorphics appears to be slightly more abrupt, usually near granite intrusions where there has been a local increase in temperature.

The Barnard Metamorphics were developed in the amphibolite facies of the andalusite-sillimanite type of metamorphic facies series, and the transition from the Barron River Metamorphics into the Barnard Metamorphics is abrupt, as is normal in this type of metamorphism. It has been suggested that this may be due to the telescoping of the metamorphic zones, or to the combined effects of two episodes of metamorphism.

The position of the metamorphic rock units in the Hodgkinson Basin relative to the Precambrian protrusion of the Mount Garnet region (see p. 130) suggests that the tighter and stronger deformation in the narrower part of the geosyncline may have been partly responsible for the higher grades of metamorphism found there.

GEOLOGICAL HISTORY

The probable sequence of the main geological events is illustrated diagrammatically in Plate 19. The sketches emphasize certain events only, and are not necessarily identical geographically. The post-Mesozoic history has been described more fully on page .

1. During the Precambrian, the arenites, lutites, and interbedded basic volcanics were folded, metamorphosed, and partly granitized, perhaps in two or more phases. This probably happened about 1050 million years ago. After isostatic uplift, a long period of denudation followed, and the mountainous region was reduced to a mature landscape. Late in the Precambrian and during the early Palaeozoic, there were repeated cycles of granite intrusion and the eruption of acid volcanics, which were also subjected to erosion and denudation.

2. Probably during the late Silurian and early Devonian, the worn Precambrian massif which now forms the basement of the Hodgkinson Basin began to subside

gradually. In the hinge zone, the Palmerville Fault system developed, along which there have been repeated movements. In the littoral to neritic environments of the unstable shelf clastic and mixed clastic-carbonate sediments (Chillagoe and Mount Garnet Formations) were deposited. The basalts and andesites interbedded with the sediments were possibly derived from parallel fissures associated with the Palmerville Fault. Barrier reefs were formed where the supply of detritus was small. On the outer side of the reefs, fine-grained lutites were probably the only sediments deposited.

3. From about mid-Devonian times, subsidence in the geosyncline accelerated, and the depth of deposition increased. Possibly the borderland was rising at the same time, especially in the south, where parts of the Chillagoe and Mount Garnet shelf emerged slightly. The thick monotonous turbidite sequences (Hodgkinson Formation) are interbedded with slate and chert. Basic volcanics, and some keratophyre, were extruded.

4. During a major orogeny in the early(?) Carboniferous, the Chillagoe and Mount Garnet Formations and the flysch deposits of the Hodgkinson Formation were strongly folded and faulted, and the southeastern part was regionally metamorphosed to form the Barron River and Barnard Metamorphics. While the region gradually emerged above sea level, the sea contracted to a much smaller area in the Koorboora/Mount Garnet/Herberton district, where the sediments are cleaner, more quartzose, and coarser (Montalbion Sandstone, Ringrose Formation). Their relationships to the Hodgkinson and Mount Garnet Formations are in dispute, and depend largely on the relative times of emergence and deformation. Granitic magmas were probably generated in depth and gradually worked their way upwards.

5. The Lower(?) Carboniferous sediments, too, were strongly folded during the continuing orogeny, but the relaxation of the compressional stresses was followed by another period of erosion and denudation during which continental sediments (Silver Valley Conglomerate) and acid volcanics were laid down on the mature landscape during the remainder of the Carboniferous and the early Permian. The sediments were fluviatile, and commonly tuffaceous. Many of the volcanics were erupted as welded tuffs and lavas in large cauldron subsidence depressions and ring complexes, formed as a result of the stress relief after the orogeny. Only the Precambrian basement and the southern margin of the Hodgkinson Basin were sufficiently rigid to support the formation of cylindrical ring fractures. The granites, which had probably been generated during the orogeny by differential melting and fusion, worked their way upwards and crystallized as high-level plutons, commonly in association with the volcanics in the cauldron subsidence areas and ring complexes. Assimilation, magmatic differentiation, and contamination with primary basic magma, produced a variety of granitic rocks, especially in the Precambrian shield area and along the margin of the geosyncline. In general, the granites appear to become younger towards the north and east.

The igneous activity spanned a long period extending from mid-Carboniferous or late Carboniferous to mid-Permian, with several overlapping episodes; the intrusions and extrusions were accompanied by the emplacement of acid and basic dykes which probably continued into the Triassic.

6. With continuing denudation, the landscape became flat and was lowered to about sea level during the late Permian. Sediments were deposited in lakes and in a paralic environment in the north, where swampy and shallow-water conditions prevailed. Acid vulcanism still continued in places. The climate was probably warm and humid.

Of these probably once widespread deposits, only remnants have been preserved in narrow rift blocks (Little River and Mount Mulligan Coal Measures, Normanby Formation).

7. The breaking up of the late Permian landscape by rifting and block faulting perhaps happened during the Triassic, and the Pepper Pot Sandstone at Mount Mulligan is a possible Triassic deposit of chaotic conglomerate which was rapidly laid down in one of the narrow rift valleys. The Triassic(?) sediments probably consisted of coarse valley-fill deposits of local extent only.

8. During the Jurassic, the old but still irregular surface started to sag in the north, especially along the Palmerville Fault, where renewed movements may have initiated the formation of the Laura Basin. Deposition of freshwater quartz sandstone and conglomerate kept pace with the subsidence, but in the northern part of the basin the sea may have encroached upon the land. Later, during the early Cretaceous, the tilting to the west became steeper, and subsidence more rapid. The resulting widespread shallow seas connected the Laura Basin with the adjoining Carpentaria Basin to the west.

Sediment transport was chiefly from the southeast and east, and the land presumably extended much farther east over the present continental shelf. However, this eastern land was probably soon submerged, largely as a result of faulting or warping; the beginnings of a continental shelf appeared, while the Laura Basin emerged, and the sea receded rapidly from the emerging shores.

9. During the Cainozoic, the Laura and Hodgkinson Basins rose in steps and stages, progressively more in the south than in the north, and probably mainly during the Plio-Pleistocene. The uplift was accompanied by faulting (e.g. along the Palmerville Fault) and by basalt vulcanism, while the coastal plain reached its present position by coastal scarp retreat and alluviation. Later Cainozoic sediments were deposited on the continuously subsiding shelf, while the Great Barrier Reef, initiated during the late Tertiary(?), has been growing rapidly since about the Pleistocene.

GEOMORPHOLOGY

The region has an asymmetrical east-west profile in which four elements can be distinguished (Pl. 9, fig. 2): a narrow coastal plain (1) rising via a steep bounding slope, scarp, or highland(2) to a heteromorphous upland axis(3) which falls gradually to the wide gently sloping western plain(4). In both the western plain and the more mature parts of the upland axis the drainage is to the west or northwest towards the Gulf of Carpentaria, but the eastern parts of the drainage system in the uplands have been captured by the more juvenile coastal stream system.

Little is known of the form and history of the continental shelf, but the apparent continuity of slope between the coastal plain and the shelf suggests that they may be closely connected in origin (Fig. 26B).

The *coastal plain* is a complex alluvial apron up to 25 miles wide in the south, and up to 80 miles wide around Princess Charlotte Bay, where it can be subdivided into the Jack Peneplain (which has affinities with the western plain) and the Normanby Sediplain (a Quaternary alluvial plain). The coastal plain rises to a height of 100 to 200 feet along the dissected landward margin.

The western margin of the coastal plain is clearly defined by the *bounding slope, scarp, or highland*, even in the Laura Basin where the bounding slope or scarp may be only a few tens of feet high. In places where the coastal plain is missing, the rocky slope plunges steeply into the sea; elsewhere, especially in the north, colluvial slope deposits may underlie at least the smoothly concave lower part of the slope.

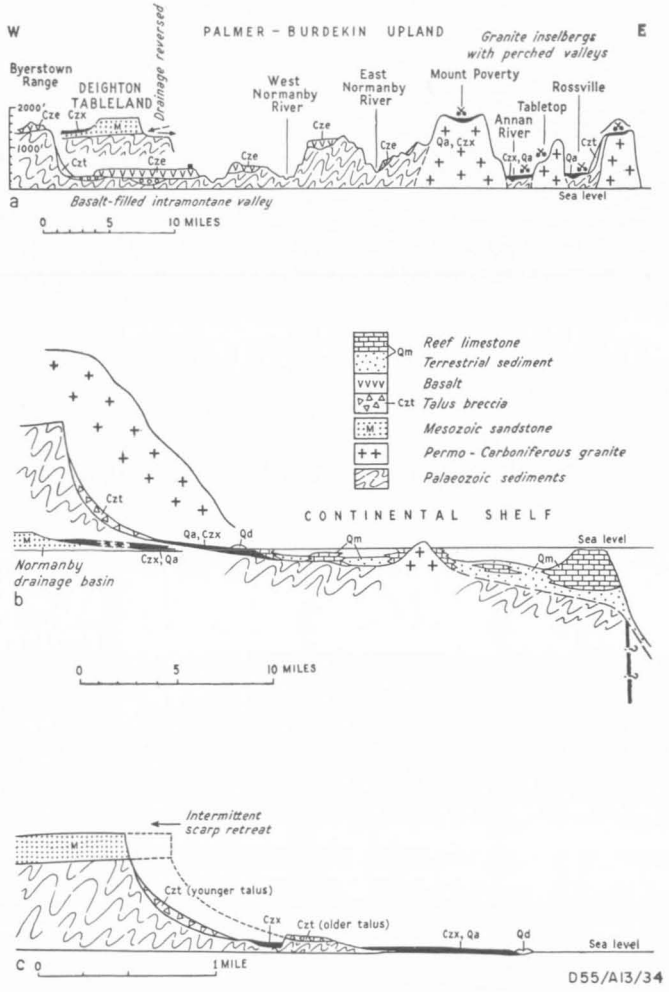


Fig. 26. **a. Generalized east-west section south of Cooktown.**
b. Generalized profile of coastal plain and continental shelf.
c. Relation between older and younger talus.

The *upland axis* is an irregular discontinuous belt of rugged mountains, plateaux, and dissected uplands, rising to heights of over 1500 feet in the east (Fig. 26A). The Great Divide meanders along the belt, which gradually falls to an elevation of about 500 feet in the west. The uplands comprise a complex system of mountains, inselbergs, tablelands, and other upland forms depending on the nature and structure of the underlying rocks — granite, rhyolite, sandstone, geosynclinal sediment, or basalt. Many of the present landforms probably date from the late Cretaceous, and some may be even older.

The *western plain* (Coleman Peneplain) represents the eastern margin of a mature and ancient surface which slopes gently to the west-northwest towards the Gulf of Carpentaria. It is a landscape of low relief except for occasional hogbacks or inselbergs up to about 500 feet high. Elsewhere the underlying rocks are covered by a stable mantle of colluvial sand and fine-grained alluvium. The plain is a slightly modified descendant of the late Cretaceous or early Tertiary lead-in surface to the Carpentaria Basin of that time.

Coastal Plain

The coastal plain is one of the most prominent and well defined physiographic units in north Queensland. To the west it is sharply defined by the steep uplands bounding slope or scarp of the coastal ranges and tablelands. The scarp rises 50 feet in the Laura and Normanby Basins and 2000 feet or more elsewhere. The coastal plain is up to 80 miles wide in the northwest, south of Princess Charlotte Bay, and up to 25 miles in the southeast, but in several places between Cairns and Cooktown the mountains rise straight from the sea, or are bordered only by a narrow piedmont depositional terrace.

The coastal plain probably extended to the east of the present coastline, and was probably formed when the Mesozoic basins to the west began to subside. It attained its present landward extent during the late Cretaceous or early Tertiary, with only local subsequent seaward or landward enlargement, subsidence and alluviation, or volcanic infillings. Its latest phase of landward growth was achieved by parallel scarp retreat, and it probably grew by this means throughout its history.

The main elements of the coastal plain include the flood-plain, the coastal saltwater swamps, the estuary, and the dunes, beaches, and fossil beach sands.

The *flood-plain* is an alluvial outwash apron which slopes more gently as it approaches the sea. Alluvial silt, sand, gravel, and lenses of clay have been deposited by meandering streams that form natural levees in places. Numerous old filled-in meanders can be seen on the air-photographs. Cross-bedding, lensing and tonguing, and cut-and-fill structures are common. Back-swamps, subject to periodic flooding, may be extensive, as in the Tully coastal plain; they are usually characterized by ti-tree vegetation. The alluvial deposits probably date from the Pleistocene or perhaps even late Tertiary: they are, except for the most recent deposits, commonly mottled and cemented, especially in the higher and steeper (4°-5°) landward parts, which are generally free of widespread Recent alluvium and show mottled older alluvium in numerous gullies. In the north, a few residuals of talus are perched slightly above the landward edge of the plain by the probably saltatory retreat of the coastal scarp. The more steeply inclined parts of the coastal plain, at the foot of the bounding slope, are generally deeply incised by numerous small streams

and gullies which, when in flood, debouch on to the modern* flat flood-plain slightly farther downstream. Cainozoic basalt was extruded on the coastal plain in the McIvor and Endeavour River Valleys, around Innisfail, and in the Mulgrave River Corridor near Gordonvale. The basalts or slight earth movements associated with the vulcanism diverted the Mulgrave River to the south, and the Russell River to the north. Eubenangee Swamp, southeast of Babinda, is probably the remnant of a lake formed behind the basalt flows that diverted the Russell River from its original southerly course to Innisfail. Jack (1888) and others have suggested that Trinity Bay at Cairns, formerly the mouth of the Mulgrave River, was cut off by the Green Hill basalts near Gordonvale which deflected the Mulgrave River.

The coastal plain sediments probably include terrestrial and marine Tertiary beds and Quaternary alluvial and marine deposits up to about 300 feet thick. The Cabot-Blueberry Marina No. 1 well penetrated 240 feet of Cainozoic sediment; a borehole near the Annan River estuary passed through 155 feet of fine-grained sediment without reaching basement; and bores in the Herbert River delta plain near Ingham went through up to 315 feet of clay, sand, gravel, some conglomerate, and mangrove mud. Over 600 feet of sediments were penetrated at Michaelmas Cay, 22 miles northeast of Cairns (cf. p. 118). It appears that the coastal plain and continental shelf have undergone differential downwarping and faulting, with increasing subsidence seawards.

The sloping coastal plain north of the Stewart River appears to be a true wash-plain, in which only a few of the creeks are deeply incised, even near the bounding slope. The plain is drained by numerous shallow anastomosing streamlets choked with sand. Many of them die out and spread their load in small deltas on the plain.

In the Normanby River drainage basin, the southern boundary of the coastal plain consists of a well defined bounding slope ranging from 50 to 300 feet high. The low flat flood-plain in the axis of the basin is called the Normanby Sediplain, and the slightly higher interfluvial subdivision (100-500 ft above sea level), which slopes or undulates from the bounding slope down to the sediplain, is known as the Jack Peneplain (Pl. 25).

The Normanby Sediplain extends for 50 miles inland from the marine deposits bordering Princess Charlotte Bay, and for another 30 miles as narrow strips along the stream valleys between the sand-covered interfluves of the Jack Peneplain, reaching the upland bounding slope along some of the major streams. The plain is covered by up to 20 feet of slow-moving floodwater at least once every good wet season, and road communications are often disrupted between December and June. The major watercourses are deep and run permanently, except for the sand-choked Morehead River in the southwest, which derives its copious load from the Mesozoic sandstone. Many of the watercourses are braided. Towards the sea, the alluvial deposits grade into, and probably interdigitate with, the marine sediments fringing Princess Charlotte Bay.

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* 'Modern' is used to distinguish those geological processes which are known to occur in historical time, from others for which there is only indirect evidence of their Recent age.

The Jack Peneplain consists of sand-covered and well vegetated interfluves; there are few streams except in the northeast, where the local drainage has been impounded by Quaternary earth movements which has resulted in the formation of alluvial flats with a rectilinear pattern. Elsewhere, the drainage is almost entirely subterranean. The sediments on the Jack Peneplain are older than the present surface of the Normanby Sediplain, whose deposits are probably encroaching upon the peneplain. The lateral streams along the boundary of the Normanby Sediplain and the Jack Peneplain are probably fed laterally for most of the time from the large shallow reservoir of the peneplain. The loose sand on the surface is probably residual sand derived from the slow disintegration of underlying slightly consolidated clayey alluvial sands, and in only a few places does the loose sand overlie weathered rock directly. The Jack Peneplain is a slowly wasting, little modified part of an ancient mature surface which is extensively underlain by pre-Recent alluvial deposits. It is as mature as the Coleman Peneplain to the west, with which it was probably coeval. In the south, the two peneplains were probably separated by a low divide which was destroyed by the inland retreat of the coastal plain bounding slope.

The *coastal saltwater swamps* are intertidal mangrove flats laced by an intricate system of tidal channels. It is a brackish to saltwater environment in which river silt and clay are deposited as black organic muds; deposits of sand are largely confined to the beds of the creeks. The swamps are well developed along Hinchinbrook Channel. In places, they represent silted-up lagoons.

The *estuaries* are generally flanked by mangrove swamps and mud flats which may grade into intertidal flats. Examples are the Annan River, Daintree River, and Mourilyan Harbour estuaries (Pl. 14, fig. 1).

The *beach and dune sands* can be readily distinguished on the air-photographs. The sand ridges are mostly vegetated, and are aligned parallel to the prevailing southeast trade wind; they are the elongate blow-out and wind-rift dunes of Milton (1940), formed by wind in conflict with the stabilizing influence of vegetation. Beaches are found along many stretches of the coast; they consist of well sorted and laminated deposits of clean sand, which is carried northwards by the longshore currents. The sands range from fine to coarse-grained, and usually consist of quartz, but at Etty Bay, for example, the beach sand contains a large proportion of epidote derived from greenschist a few miles to the south. The coarse sand at Rocky Point, 10 miles north of Innisfail, derived from the numerous strained and granulated quartz veins in the metamorphic rocks.

At the back of the beaches there is generally a low sand ridge or a series of low ridges representing old strandlines. They are clearly recognizable on the air-photographs (Pl. 14, fig. 1). The ridges are rounded and crescentic, with slight constrictions in places, and are from 5 to 10 feet high. They are generally subparallel to slightly radiate in groups or swarms, and are well developed south of Innisfail, where they extend 5 or 6 miles inland, and in places in the Cape Melville Sheet area, where they extend up to 12 miles inland from Princess Charlotte Bay. In the north, chiefly along Princess Charlotte Bay, individual strandlines are commonly partly or completely separated by marine salt flats or alluvium; in the south they are more tightly packed, though still separated by marine flats (Pl. 14, fig. 1). Near the mouths of some of the rivers the old strandlines become tortuous, and

near the Normanby River they grade into a cut-off meander pattern which marks the old river mouth. The strandlines also commonly form a slight barrier to the drainage.

On Hinchinbrook Island and the three headlands north of Cooktown the dune sands have tied a former hard-rock island to the mainland or main island (Pl. 14, fig. 2).

Bounding Slope, Scarp, and Highland

The bounding slope between the coastal plain and the uplands and, in the north, the western plain is continuous from one end of the map area to the other, and forms a scarp in places. The coastal plain was formed by the westward retreat of this scarp from the Jurassic onwards.

In places, the bounding slope is only 50 feet high, but elsewhere it forms a steep unbroken slope from 1500 to 2000 feet high. Locally, the steep slope can be termed a scarp, and in the Laura Basin the upper slopes are vertical sandstone cliffs. The steep slopes are maintained by headward erosion along the gorges of the major streams. Elsewhere, the foot-slopes merge into the coastal plain.

The most gradual lower break of slope is found where fossil talus and piedmont deposits are preserved along the scarps, mainly in sheltered valleys in the north. The slope of the talus surface decreases from about 50° to 10° or less within a mile of the 1000-foot scarp. In places, remnants of an older talus have been preserved about 50 feet above the distal ends of the younger talus fans (Fig. 26C). The coastal plain may have been formed by a cyclic process of talus formation, deep weathering, and fluviatile erosion (not necessarily in that order).

Some of the rugged convex granite hills along the margin of the bounding slope south of Cooktown are covered by a loose jumble of large boulders of fresh granite. The best known example is the Black Trevethan Range, over 1000 feet high, and 18 miles south of Cooktown (Pl. 15, fig. 1). The boulders range from 4 to 40 feet across. There are a few small patches of scrubby vegetation on the summits, but elsewhere there is no matrix between the boulders. The small subcircular depressions, up to 100 feet deep, on the summits are drained from below. Most of the boulders are equant to oblong, with some straight edges and rounded sides. Some boulders have been separated into several blocks by rectilinear joints (Pl. 15, fig. 2).

In the Black Trevethan Range, and in the smaller bouldery granite hills to the west of the Normanby River, south of the old Battle Camp siding, the bare bouldery hills pass abruptly into jungle-covered soil-clad slopes.

The most impressive example of bouldery granite outcrops is the Melville Range, a massive rugged inselberg, 12 miles long and 2000 feet high, fronting the sea in the north and a steeply sloping part of the coastal plain in the south. The range is convex and steep-sided, with only occasional trees and a little lichen. In places, the boulders are extremely large, and spire-like and blocky outcrops protrude locally from the jumble.

These bare bouldery hills resemble the 'metal hills' in the Chillagoe area, the development of which Jensen (1923) and others have ascribed to slight composi-

tional peculiarities. The hills are thought by others to represent plugs filling old vent holes. The bare bouldery hills occur only in granodiorites with appreciable amounts of mafic minerals, which initially may have facilitated the development of a deep soil profile. However, there is no difference in composition in the adjoining granitic rocks, and the formation of bouldery hills is probably due to a combination of steep slope and change in climate. They are probably a type of residual deposit of core boulders and joint blocks derived from below. A deeply weathered profile may have been developed on the early Tertiary landscape under humid conditions; a change to a drier and more seasonal climate may have killed the original lush vegetation and facilitated the removal of the soil by torrential downpours. In addition, the burning of the grass in historical times may have exposed the slopes to increased erosion and soil stripping. Once the soil has been removed, re-establishment of the vegetation would be a slow process on the bare slopes, under the present climatic conditions.

In the central and southern parts of the coastal area, the Bellenden Ker and Kirrama Ranges are more than 3000 feet high, Mount Bartle Frere being the highest peak with an altitude over 5000 feet. The transitional zone between the uplands and highland and the coastal plain in this region is characterized by waterfalls, knicked longitudinal stream profiles, and deep gorges and valleys. There is evidence that the uplift of the north Queensland plateaux and uplands has proceeded in stages: (a) the waterfalls in the Barron, Tully, Garrawalt, and Herbert Rivers show two clearly separated stages; (b) the longitudinal profiles of the rivers in the Innisfail Sheet area also show at least two main knick-points, and possibly more (Fig. 27); (c) the Russell River alluvial gold deposits occur in three main and three local minor terraces (Broadhurst, 1956, 1957, unpubl.). The waterfalls and knick-points occur in rocks of uniform composition, and their presence therefore probably indicates successive stages of uplift followed by the establishment of new local base-levels and new cycles of headward erosion.

The bounding slope may be regarded as the eastern limit of the upland axis, particularly where it forms a rugged highland; elsewhere it can be more properly regarded as the western limit of the coastal plain. The top of the bounding slope is sharply defined where the adjacent upland consists of tableland, but in the highland and inselberg region farther south the top is irregular and somewhat arbitrary.

Upland Axis

The upland axis comprises a complex system of tablelands, plateaux, mountains and monadnocks, alluvial plains and perched valleys, and dissected uplands (Fig. 26A), and includes the Great Divide. In the east it is separated from the coastal plain by the bounding slope and highland, and in the west it grades into the western plain (or Coleman Peneplain). It is the most complex region geologically, and has the most complex geomorphological history; it forms a buffer zone between the easterly and westerly drainage systems, where drainage reversals and modifications due to tilting and faulting have been most intense.

The upland axis can be divided into several geomorphological units:

1. the Palmer/Burdekin Upland
2. the Mesozoic plateaux and tablelands
3. the plateaux of Cainozoic basalt and the Tertiary pediments
4. the incised tablelands of Permo-Carboniferous volcanics
5. the granite massifs, forming highlands and monadnocks
6. alluvial valley plains and perched valleys.

The Palmer/Burdekin Upland is an extension of the Burdekin Upland of Twidale (1956b) and White (1962), and of the Palmer/Hodgkinson Uplands of Amos & de Keyser (1964). It constitutes the backbone of the upland axis and has been formed on the extensive Palaeozoic geosynclinal sediments. The steep intense folding in the Palaeozoic sediments, and the dominance of uniform slate and greywacke, have given rise to the dissected and undulating surface with its generally finely dendritic drainage pattern (Pl. 16, fig. 1). There are numerous accordant summit levels (gipfelfluhr) at altitudes between 1000 and 2000 feet. Hogbacks of resistant beds of chert or thick greywacke or conglomerate locally rise above the gipfelfluhr, which is highest in the southeast (e.g. Kirrama Range), and slopes generally to the west or northwest. The incised west-northwest drainage of the Palmer/Burdekin Upland is oblique to the regional strike of the formations, but is parallel to the gipfelfluhr slope. The incised drainage is therefore apparently resequent, after an earlier consequent system had been developed on a pre-Cretaceous erosion plain tilted to the west-northwest. This situation is complicated by local warping and swells, including one east-west swell along the southern margin of the Laura Basin, and one or more(?) roughly north-south warps in the east, which probably deflected the streams to the east (see pp. 147).

In the Palmer/Burdekin Upland, several dissected levels can be recognized at different heights (Pl. 16, fig. 2). Their origin and correlation are uncertain. A variety of processes may have contributed to the development of the different levels — cyclic regional uplifts, local differential movements along faults, local terrace forming, differential weathering and erosion, etc. Some of the levels may be large remnants of perched valleys (cf. p. 145).

An example of one of these levels is the marked but not very extensive rock-cut terrace (Bloomfield Terrace) or bevel at an altitude of 700 to 800 feet along the coast south of the Bloomfield River (Pl. 17). The terrace has a fine dendritic drainage pattern cutting down into fresh Devonian slate and greywacke. The relief is about 100 to 150 feet, and the accordant summits consist of weathered slate overlain by thin cappings of pisolitic ferricrete and gravel. The terrace is too low to be related to the Tertiary Normanby River headwater domain, and there are remnants of a low divide between the two drainage systems. The Bloomfield Terrace was probably a mature surface which drained to the east at least towards the end of its life, presumably before the development of the Bloomfield River gorge and concomitant rejuvenation and stripping. Remnants of the terrace are present in the joint or fault-controlled Gap Creek valley north of the Bloomfield River. The Wyalla Plain, a rectilinear depression between Gap Creek and the Bloomfield River, was possibly formed by block foundering rather than by scarp retreat; the faulting

may have caused the rejuvenation of the Bloomfield River and of the Bloomfield Terrace.

To the north of the Barron River gorge three levels can be recognized: the river valley plain at roughly 1200 feet; a plain at about 1500 feet in the Flaggy Creek area (a northern tributary of the Barron River); and the remnant of a plain at 1800 feet above Buchan Point.

The Deighton Tableland, one of the Mesozoic plateaux, is a dissected warped structural element which marks the exposed margin of the Laura Basin. It is a prominent feature carved out of resistant Mesozoic sandstone, and its boundaries are mostly sharp. The surface generally slopes gently towards the axis of the basin, which plunges to the north beneath Princess Charlotte Bay. The slope is locally modified by faulting or diverse initial dips in the underlying sandstone. The Deighton Tableland, forming part of the Great Divide, is an important watershed. It is also the main intake area for the Laura Basin aquifers.

In the west, where the Laura Basin grades into the Carpentaria Basin, the Deighton Tableland merges into the Coleman Peneplain in the Carpentaria drainage basin.

The surface of the tableland is dry, and is covered thickly with sand except where it is closely dissected, as in the higher parts near the coast, in the south, and in outliers. In the dissected areas, the drainage is controlled by joints, especially where the sandstone has been faulted as in the headwaters of the Endeavour River, and any sand cover has been largely stripped off. The Cretaceous shale has been extensively stripped from above the sandstone, but small residuals of hardened shale, up to 100 feet high, are common in the south and southeast. A thin veneer of loose, polished, ferruginous pellets is also common in the south.

The Red Plateau is a Mesozoic landform on the central-western or southwestern margin of the map area. The plateau, which is bounded to the east by an irregular cliff 100 to 400 feet high, slopes gently to the west until it merges with the western plain.

Mount Mulligan, a small tableland 60 miles west of Cairns, consists of Triassic(?) conglomerate and sandstone. It is an obsequent rift-block mountain: the wedge-shaped block, 10 miles long and about 3 miles wide, was originally downfaulted, but because of its resistance to erosion it now stands about 1000 feet above the level of the surrounding uplands composed of the softer Hodgkinson Formation.

The *Cainozoic basalt plateaux and sedimentary plateau and pediment residuals* include six areas.

The main basalt plateaux are the Atherton Tableland and the McBride Basalt Plateau (only the northeastern tip of which lies within the map area). Smaller basalt plateaux include those of Butchers Hill homestead and the Byerstown Range in the north, along latitude 16°S. The Mount Piebald Basalt farther north is too small to form a plateau.

The Atherton Basalt largely filled the ancestral Mitchell River headwater valley of early or mid-Tertiary(?) age, overlapped the then Great Divide, and flowed

down to the coast, deranging the drainage systems. The basalt at Butchers Hill homestead partly filled the depression at the head of the Laura River, and caused only minor modifications of the drainage. Both basalts have been partly eroded, with some reversal of topography in places, and the formation of new or modified drainage systems. The McBride Basalt completely buried the earlier landscape, and has been relatively little eroded.

Local deposits of fluviatile or lacustrine sediments and beds of diatomite are found below or interrelated with the lower sections of the basalts. Some of the gravels below the basalt contain basalt pebbles, which suggests that they are penecontemporaneous with the basalts. The early flows followed the original valleys and, in places, diverted and impounded the streams so that freshwater sediments could be deposited.

The topographic relationship of the basalts in the adjoining areas of the Byerstown Range, Butchers Hill depression, and eastern uplands indicate that the relief at the time of their eruption was about the same as it is now (Fig. 26A). Inversion of topography is demonstrated by the small basalt cappings on spurs in the upland, which originally must have been valley bottoms along which the basalt flows moved. The flows in the Byerstown Range apparently covered a high-level plain which has now been dissected beyond the margin of the basalt.

The type of drainage developed on the basalts depends on the rainfall, the extent and the initial dip of the flows, and the texture and structure of the basalt. The McBride Plateau contains few streams because of the relatively low rainfall (about 30 inches a year), thin soil, and close jointing of the basalt. The Atherton Tableland, by contrast, has a much higher rainfall, so that the flows and tuffs are deeply weathered and are covered by a thick mantle of soil. The soil and soft tuffs are susceptible to gullying and vertical erosion, and a moderately to fairly deeply incised dendritic drainage pattern has been developed, although it is much more open than in the Palaeozoic formations in the uplands. In the Millstream area, where the rainfall is lower, or along the bounding coastal slope, the thick flows have resisted vertical erosion and form flat stepped surfaces into which deep gorges have been cut by the larger streams, and along which only headward erosion takes place, along the waterfalls.

The pediments and sedimentary plateaux include the Fairview Plateau, the 'Louisa Formation', the Lucy Tableland, and other smaller pediments and plateaux.

The Fairview Plateau (Denmead, 1949a), west of Laura, is a small low plateau about 150 feet above the Jack Peneplain; it includes smaller outliers some of which merge with the peneplain. The edge of the main plateau is marked by an abrupt fall of 50 to 100 feet to a narrow belt of gently undulating, but dissected, country underlain by Cretaceous claystone, which forms a rich brown soil. The undulating belt slopes down to the Jack Peneplain within a few miles, or less, of the edge of the plateau.

The Fairview Plateau is sandy and well timbered, and only slightly undulating. There are some semicircular depressions, 100 to 400 yards across and 10 to 30 feet deep, some of which hold semipermanent water. Stable gravel and some partly silicified sand underlie the sandy surface, and there are only a few shallow streams. The residual deposits overlie a fairly level surface underlain by

claystone of the Cretaceous Wolena Formation, which is weathered to a depth of about 30 feet.

The Fairview Plateau represents the thickest accumulation of Tertiary residual gravel in the southern part of the Laura Basin. It occupies the axis of the basin, and overlies the softest formation in the Mesozoic succession.

Younger terrestrial deposits, equivalent to the Lynd Formation (Laing & Power, 1959), have been laid down around the lower flanks of the Fairview Plateau, and disappear beneath the Recent deposits on the Jack Peneplain.

The 'Louisa Formation' (Woods, 1961) is a thin superficial deposit of gravel and sand in the Wrotham Park/Walsh River area; it is similar to the gravels at Fairview homestead and gives rise to the same land forms: small sand-covered rounded residual hills, the slopes of which are covered by a mantle of quartz pebbles and sand. The residuals are underlain by the soft shale and siltstone of the Cretaceous Blackdown Formation.

On the western margin of the map area, an unbroken low plateau occupies the interfluve between the Walsh River and the old parallel valley 4 miles to the west. The plateau is underlain by at least 30 feet of fluviatile or lacustrine clayey sand and gravel which is slightly more consolidated, better sorted, and stratified than the Lynd Formation. The small dissected plateau, 100 feet high, to the north of the Mitchell River at Gamboola homestead is composed of similar sediments, and small residuals of the same terrace are distributed along the banks of the wide Mitchell River valley farther upstream, towards the outcrop area of the generally coarser but apparently equivalent 'Louisa Formation'. Remnants of gravel and sand terraces also flank the Palmer River flood-plain downstream from Palmerville, and are clearly abandoned river terraces.

The Lucy Tableland in the headwaters of the Burdekin River is the best example of a fossil pediment in the area. The plateau remnants and mesas are about 100 to 150 feet above the level of the dissected Palmer/Burdekin upland. The tableland consists of ferruginized Tertiary conglomerate, sandstone, clay, and diatomite, merging in places with the gently undulating or flat surfaces on the lateritized Palaeozoic formations. It is uncertain whether the Tertiary sediments are appreciably younger than their lateritized basement (and overlie it with a cut-and-fill relation), or whether they are about the same age and were lateritized at the same time.

The largest of the *Permo-Carboniferous volcanic tablelands* is the Featherbed Range, which covers an area of about 1000 square miles to the north of the Chillagoe/Mount Garnet region. The volcanics form a rugged, broadly flat-topped though deeply incised range rising 1000 to 2000 feet above the surrounding plains and uplands. The drainage pattern is incised and angular-dendritic, and is partly controlled by the joints. The Walsh River has cut a winding gorge through the centre of the range. It is uncertain whether the course of the Walsh River is a superimposed or an antecedent feature (see p. 148).

The Featherbed Volcanics originally occupied a large cauldron subsidence area (Branch, 1966). Their elevation above the older Nychum Volcanics in the lower Kum Kum Range at the northwestern end of the Featherbed Range is

probably due to differential erosion, and demonstrates a large-scale topographic inversion.

The Nychum Volcanics in the Kum Kum Range, a plateau up to 500 feet high, have been laid down on a landscape with some relief. Topographic inversion (locally of about 200 feet) has not been as pronounced as in the Featherbed Range.

Small rugged plateaux are preserved on the Permo-Carboniferous volcanics at Walsh Bluff, west of Atherton; south-southeast of Herberton; and north of Mount Garnet. Their topographic inversion (due to differential erosion) was pre-Cainozoic, for the plateaux rise 1000 feet or so above the Atherton Tableland, which is covered by Cainozoic basalt.

The Permo-Carboniferous *granite massifs and monadnocks* are being progressively isolated from the surrounding softer Palaeozoic sedimentary formations in the Hann, Windsor, and Mount Carbine Tablelands in the Palmer/Burdekin upland area; in the Bellenden Ker/Bartle Frere granite mountains, which are being detached from the Atherton Tableland by subsequent erosion by the encircling Mulgrave and Russell Rivers; and in the Melville Range, rising to 2000 feet above the sea. Granite also constitutes the only hard-rock islands at considerable distance from the mainland (Howick and Lizard Islands).

In the southeast, the rugged granites are covered in jungle, but elsewhere they form rounded, jointed, bare or tor-covered monadnocks or inselbergs. They rise up to 2000 feet above the Palmer/Burdekin Upland, commonly forming extensive tablelands (Windsor, Mount Carbine, Hann). Most of the granite inselbergs were probably formed before or early in the Mesozoic, as the Jurassic sediments in the Laura Basin apparently did not completely cover the granites. The inselbergs were modified according to the type of erosion (surface-lowering or scarp retreat) that predominated locally in the Tertiary. Those in the humid jungle-covered eastern ranges were deeply weathered during the late Cainozoic.

Alluvial Valley Plains and Perched Valleys. Small perched valleys are especially common on the granite inselbergs and scarps near the coast, and in the Deighton Tableland, where most of them are controlled by joints. The formation of the valleys in the granites was probably facilitated by the subhorizontal jointing or sheeting.

The much larger valley plains in the headwaters of the Mitchell and Laura Rivers were probably formed in the same way as the smaller perched valleys, but it is unlikely that all the valleys and valley plains belong to the same cycle of erosion. Most of them are partly filled with late Cainozoic mottled, fluviatile, clayey sands, and in places basalt.

The perched valleys are generally broad, with a flat aggraded bottom, and steep rocky or talus-covered sides (Pl. 16, fig. 2; Pl. 18, fig. 1). The hard-rock floors and the 10 to 30 feet of consolidated, mottled to heavily ferruginized clayey sand and gravel are commonly deeply weathered, evidently during the same period. The old alluvium has generally been slightly dissected and filled in along the median stream by Recent alluvium.

Many of the perched valleys are situated high in the scarps or mountains. In the Mesozoic Deighton Tableland they are joint-controlled, which accounts for their great length relative to their width (e.g. 5 miles long by ½ to 1 mile wide). Many of the valleys in the granites and Palaeozoic formation are not controlled by joints, but in a few (e.g. Tabletop, and Pl. 18, fig. 1) the chilled margin forms a resistant bar over which the stream cascades. Usually, however, the perched valleys appear to represent an arrested or embryonic stage of valley development by rapid scarp retreat, which is active at present only in the coastal gorges. According to Bik (pers. comm.), the deep weathering of the bounding slopes in the humid tropical climate may have assisted in their preservation, as no coarse detritus was available to erode and lower the beds of the streams. A change to a cooler or drier climate would provide abundant coarse detritus leading to down-cutting of the streams, as in the lower courses of some streams in the upper reaches of which perched valleys occur (e.g. Trevethan Creek and Wallaby Creek, south of Cooktown). The best examples of such rejuvenated streams are found at the northern end of the rain-forest belt near Cooktown, near the transition to drier country. This suggests that the formation and destruction of perched valleys is governed mainly by climate.

Big Tableland, 18 miles south of Cooktown, is an example of a level remnant that may have been a perched valley. It is a gently west-sloping, slightly rejuvenated surface remnant, 2 miles square, with an altitude from 2200 to 2600 feet, and it is deeply weathered on top. The western edge may be underlain by granite which probably formed a protective bar.

The Western Plain (mainly the *Coleman Peneplain*)

The Coleman Peneplain is a well preserved ancient surface in the headwaters of the Coleman River. The peneplain occupies the northwestern part of the map area and extends westwards for about 100 miles towards the Gulf of Carpentaria. It has a very low relief, except for narrow hogbacks of Precambrian rocks rising up to 500 feet above the plain. The peneplain slopes gently westwards, with an altitude of 500 to 1000 feet in the east and about 300 feet less in the west. In the northeast, it drops sharply to the coastal plain (Normanby Sediplain and Jack Peneplain), and in the southeast it merges with the Deighton Tableland across the streamless sand-covered tract known as 'the desert'. Farther south along the western side of the map area, the ancient surface has largely been stripped from the Precambrian and younger rocks, and the area is considered to be part of the upland axis.

The Coleman Peneplain is an area of low rainfall. The surface is covered with porous sand, and there are only a few sluggish streams. The stream heads, which are partly controlled by the joints in the underlying Precambrian rocks, are depressions which may contain shallow seasonal marshes. Downstream, some rejuvenation seems to have taken place, exposing a few terraces of older alluvium; farther down, near the boundary of the map area, Recent alluvium is spread over the original sandy Coleman Plain (cf. the Normanby Sediplain in relation to the Jack Peneplain).

The Coleman Peneplain has been cut on Precambrian metamorphic and igneous rocks, and, farther west, on Cretaceous sediments. It is probably equiva-

lent to the small remnants of pediments to the east and southeast (Fairview Plateau, etc.). The interfluves are covered by loose sand and a thin colluvial cap of ferricrete, overlying a zone, about 30 feet deep, of intense weathering.

The Coleman Peneplain was probably continuous, over a low divide, with the north-draining Jack Peneplain, the ancestral Normanby drainage basin.

Sketch of the Geormorphological History

It is assumed that the earliest surface of regional importance is represented by the flat-lying Mesozoic sediments which emerged in post-Lower Cretaceous times. The Mesozoic sediments formerly extended over a considerably larger area. Even where no Mesozoic strata were deposited in the southeast, the borderland is assumed to have had little relief, judging by the stable and mature composition of the Mesozoic sediments, and the long period of non-deposition in the east and southeast. Here and there, monadnocks of granite rose up from the plain.

The precise age of the post-Lower Cretaceous emergence and the ages of the later stages of uplift have not been established, nor is it known whether the vertical movements were due to faulting or flexuring. Many previous workers have described the morphology of the Great Barrier Reef, the continental shelf, the coastal plain (with its corridors), and the eastern plateau or highland landscape in the northern coast of Queensland. Most of them postulated differential faulting along north-northwesterly lines, block faulting, etc. (Andrews, 1910; Danes, 1911; Süssmilch, 1938; David, 1950; Twidale, 1956). Davis (1917) has suggested that the subsidence of the shelf and the rising of the plateau and highland was the result of several phases of flexure with continuously westward-shifting axes. His theory has much merit, especially in view of the north-south swell or warp, some distance inland from the coastal scarp, that has been postulated to account for the general and consistent stream deflection towards the east in the eastern margin of the upland axis, and which might be regarded as the latest of Davis' flexures. King (1962) also invoked flexure, and explained the formation of the coastal scarp by parallel retreat of a scarped hill-slope during pedimentation after warping. Warping is indicated by the gradual thickening of the Cainozoic sediments on the coastal plain and adjoining shelf from west to east, and faulting is indicated by the altitude of the peaks on Hinchinbrook Island, which rise to 3000 feet, and would be difficult to explain by regional flexuring. The faulting and flexuring were probably closely associated. The presence of knick-points in the rivers (Fig. 27), of interrupted waterfalls, and of terraces in the coastal plain, Russell River Goldfield, and Atherton Tableland

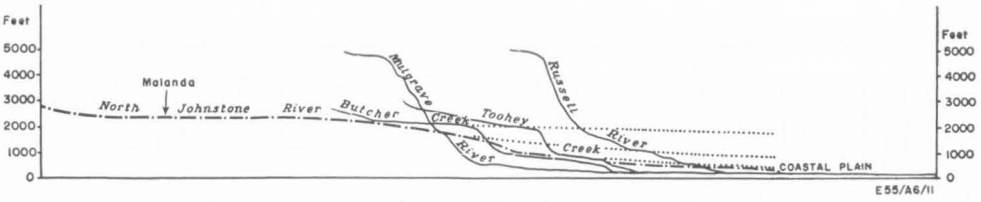


Fig. 27. Longitudinal profiles of some coastal streams.

indicate that the vertical movement took place in successive stages. The views of Agassiz (1898), who considered the shelf to be a marine-abraded platform, and of Gardiner (1898) and Vaughan (1915), both quoted in Davis (1917), who also rejected the possibility of considerable subsidence of the shelf, are disproved by the presence of hundreds of feet of Cainozoic sediments in the bores on Michaelmas Cay and Heron Island (Richards & Hill, 1942).

Some authors (e.g. Marks, 1924) consider that differential erosion was the major factor in the genesis of the marginal scarp, highland, and coastal corridors, but this certainly does not apply in the Ingham area and other places along the north Queensland coast and island groups, for there the 'physiographic units are constituted of many different types of rock, and they cut across geological boundaries' (Stanley, as quoted *in* Cotton, 1949). However, differential erosion undoubtedly has accentuated relief in many places.

It is assumed that the post-Lower Cretaceous emergence took place before the end of the Cretaceous or in the early Tertiary. Possibly, the edge of the continental shelf was defined by faulting during that period, and faulting or warping produced a regional tilt to the west, and submergence in the east. The formation of the coastal plain was initiated in the hinge area, to the east of the present coastline, and the plain was gradually extended westward by scarp retreat, while to the east it was repeatedly submerged.

The initial surface in the upland axis area was characterized by consequent drainage to the west and northwest. Incision of the Palaeozoic formations in the southeastern and eastern borderlands began, and the Mesozoic cover in the more elevated eastern regions began to be stripped and to recede towards the west by parallel scarp retreat. Inversion of relief started in areas underlain by Permo-Carboniferous volcanic rocks, but the major streams continued on their original courses and became superimposed. The Walsh River, which winds its way through a gorge in the Featherbed Range, is a fine example.

As well as topographic inversion, buried surfaces have been exhumed. The Nychum Volcanics are a good example: they form the low plateau of the Kum Kum Range where the protective cover of Mesozoic sandstone has been removed by erosion, and the level of the surrounding Palaeozoic sediments has been lowered by erosion.

In time, a new base level was established, possibly during the mid-Tertiary. The high, decomposed, flat remnants in the granitic highlands along the coastal plain, and among the high perched valleys in the east, probably represent the late Cretaceous or early Tertiary surface. The large valley plains, such as those in the Dimbulah/Mareeba/Mount Carbine region, the pediment of the Lucy Tableland, and the Mount Garnet Basin were possibly part of the new base level. During this period, lateritization was perhaps the predominant weathering process. The Great Divide was probably represented by the mountainous highland along the coastal plain in the east. In the west and north, the Mesozoic sandstone plateau was still receding by cliff-retreat, while a thin veneer of gravel and sand was being deposited on the surface farther west and north ('Fairview Gravel'). The drainage was approaching maturity and began to meander in places. Such holes were formed in the Chillagoe limestones, and they now form pipes from the caves to the surface of the limestone bluffs.

Before the cycle of mid-Tertiary denudation had been completed, movements along the Palmerville Fault and perhaps along the coast disrupted it. The region east of the Palmerville Fault was raised; the streams were rejuvenated and the meanders entrenched. The uplift was possibly dome-like or transverse, culminating in the area between the Mitchell and Palmer Rivers. The effect of this transverse swell can be seen in the intensive dissection and higher altitude of the Mitchell River/Palmer River area, and in the southward deflection of some streams away from the axis of the swell. The capture of the southern branch of Sandy Creek (draining into the Palmer River) by Fine Gold Creek (draining into the St Georges River) is a good example of stream piracy in that area.

The presence of remnants of different levels (Fig. 28), knick-points, terraces, and interrupted waterfalls suggests that uplift and warping took place in stages, although climatological changes may have been partly responsible. The estimated age of the main uplift varies: from Miocene to Pliocene (David, 1950), post-Miocene Süssmilch, 1938), mainly end of the Pliocene (Andrews, 1910), and Pleistocene (Bryan, 1925). This seems to fit in well with the major Plio-Pleistocene movements of the Gondwana continents, as described by King (1962, pp. 224-7). The Plio-Pleistocene was a time of unrest also in New Zealand, where vertical throws of thousands of feet have been reported along the Alpine Fault.

In north Queensland, the Plio-Pleistocene movements were accompanied and followed by modification of the streams and by basalt vulcanism, which extended into Recent and perhaps even historical times*.

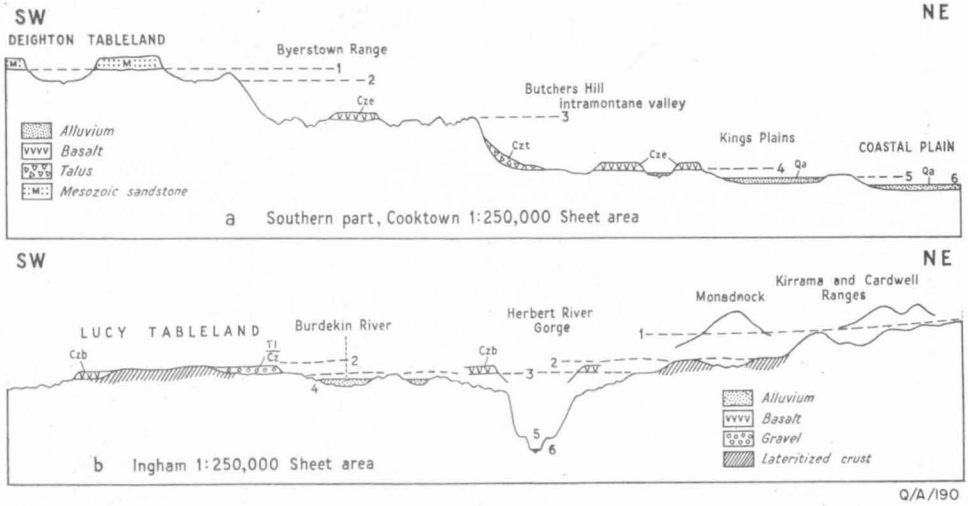


Fig. 28. Diagrammatic profiles showing several erosional and aggradational levels.

* The fear reportedly shown by past generations of aborigines for the crater lakes of Barrine and Eacham can, perhaps, be traced back to old legends originated by those who witnessed the last eruptive episodes.

Stream modifications included deflection of some west-bound rivers towards the east coast, and capture. The Annan River at Kings Plains (Pl. 18, fig. 2) is a fine example of river capture (Lucas, 1962, unpubl.). The Barron River was also deflected to the east: its upper course, with tributaries like the Clohesy River, originally flowed west (as indicated by the barbed junctions of its tributaries) and formed part of the headwater system of the Mitchell River. Best (pers. comm.) has suggested that the headwaters of the Walsh River formerly belonged to the Mitchell River system, but were diverted to the west by tilting and faulting to the southwest of Mareeba. As a result of the decapitation of its headwaters, the upper course of the present Mitchell River has become a typical misfit river insignificant compared with the width of its broad flood-plain.

The southerly diversion of the Mulgrave River near Gordonvale was directly or indirectly due to the basalt vulcanism at Green Hill; the easterly deflection

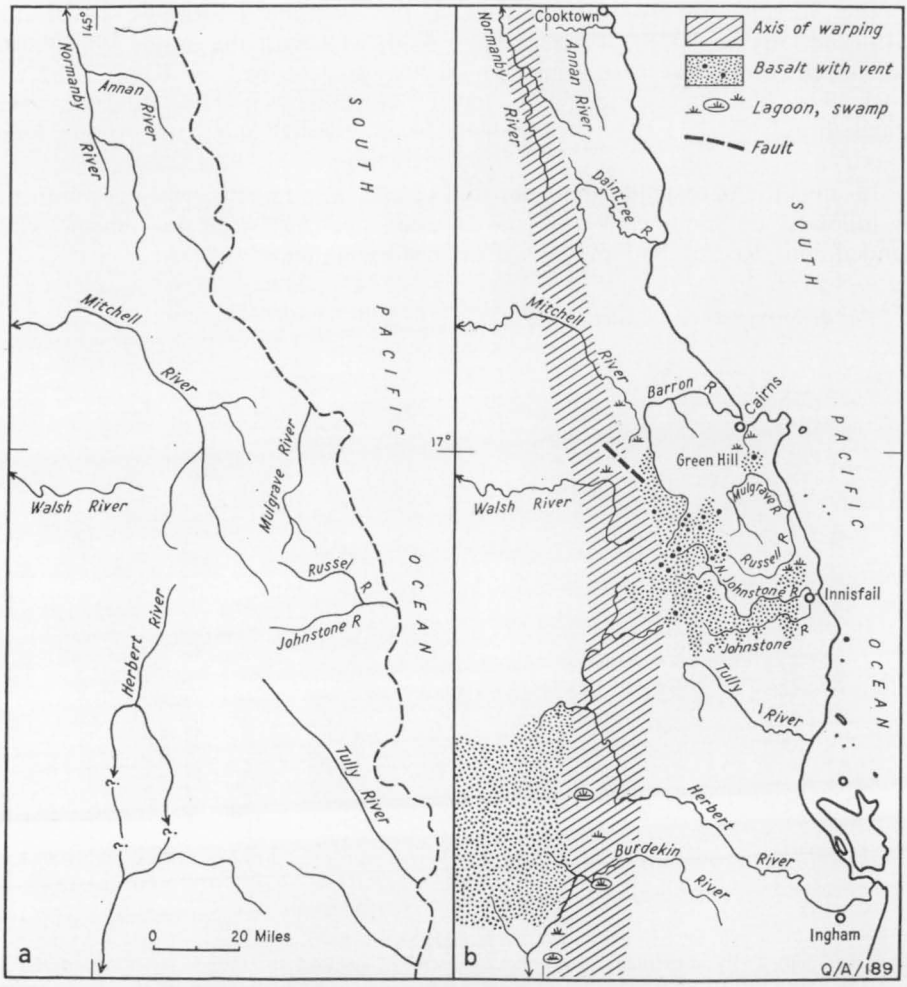


Fig. 29. Modification of drainage during the late Cainozoic.

of the North Johnstone River was also due to obstruction by basalt (Jardine, 1925); and Dr N. H. Monteith (Univ. of New England, pers. comm.) has suggested that the original flow of the Russell River into Glady Inlet at Innisfail was diverted to the north by basalts on the coastal plain. In the south, the Herbert and Burdekin Rivers formed part of the same system draining west or south (vide the widespread Tertiary gravels in the Lucy Tableland between the two rivers), but tilting and damming by basalt flows impounded the Herbert River, which ultimately escaped over the former divide to the east and drained into the Pacific Ocean.

In order to explain the consistent stream deflections, it is generally assumed that there was a slight north-northwesterly warp with its axis extending from the Normanby River area, 25 miles west of Cooktown, to west of Mareeba, and farther south to Gunnawarra homestead and beyond. In many places, damming of the streams by basalt flows assisted the deflections. The new divide is characterized by shallow lakes, lagoons, and swamps (Taylor, 1911).

Figure 29 shows some of the changes in drainage that have taken place as a result of the late Tertiary to early Quaternary earth movements.

Late Cainozoic climatological changes are also indicated. A change from a tropical wet to a dry or seasonal climate is suggested by the formation of the bouldery granite mountains (cf. p. 140), the presence of perched valley (cf. p. 145), and the formation of caves in the Chillagoe limestone. The karst development and the formation of the Chillagoe and Mungana caves probably originated during a wet climate, when the bottoms of the caves, which are below the level of the valley plain, were determined by the old groundwater level. With the drier conditions that followed, karst development almost ceased except for some superficial fluting, and the groundwater level was lowered until the caves became dry.

The main morphological processes operating at present are a continuation of those initiated during the late Cainozoic. They consist of marine sedimentation at the distal end of the ancient, mature, northwesterly draining system; continued extension of the coastal plain at the expense of the upland belt; continued dissection of the uplands; and reef sedimentation on the eastern coastal shelf. Earth movements are probably also continuing: the shelf area may be still subsiding, but sea-level oscillations, whose effects can be observed more directly, tend to camouflage this; and earth tremors in the coastal zone and eastern uplands (Jones, 1959) may be an indication of continued differential movements.

ECONOMIC GEOLOGY

The Hodgkinson Basin and its borderland have produced a wide range of minerals, including gold, tin, tungsten, molybdenum, copper, lead, silver, fluorspar, coal, and limestone. The most prosperous mining period extended from the end of the 19th century to the early twenties; some minerals (e.g. fluorspar and coal) reached their peak a little later. The Palmer Goldfield; the tungsten centres of Wolfram Camp, Bamford Hill, and Mount Carbine; and the fluorspar lodes, have been the biggest producers of alluvial gold, tungsten, and fluorspar in Queensland.

After World War II, regular mining died out, except for alluvial tin dredging in the Mount Garnet district, but when market conditions were favourable old workings such as the Gilmore and Dover Castle tin mines, have been temporarily reopened.

Development of Mining

Exploration for gold, and its mining, have been of the utmost importance in the exploration and development of north Queensland. A considerable amount of gold was won from the alluvial deposits on the Palmer River, and the search for gold led to the discovery of other minerals, which attracted many miners when the goldfields became exhausted; ports like Cairns and Cooktown were built to serve the mineral fields; cattle stations were founded to meet the needs of the increasing population; railways were constructed from Cairns to the mineral fields, and later, when mineral production started to dwindle, these helped to open up the fertile Atherton Tableland for dairy farming and the production of maize and peanuts; the expansion of the sugar cane industry in the humid coastal area between Ingham and the Daintree River was accelerated as a result of the development of the mineral deposits, and many miners from exhausted fields were absorbed in this new industry.

The first official search for minerals was conducted in 1872, when, prompted by the successful gold finds farther south in the Charters Towers and Etheridge fields, the Queensland Government sponsored an expedition to Cape York Peninsula, under the leadership of William Hann. Hann's party found a little gold in the Palmer River, which encouraged James Venture Mulligan to lead a prospecting party to the area, where they found rich alluvial deposits in 1873 near what became the township of Maytown. The first parcels of gold were taken to Georgetown and Cardwell, and a gold rush immediately followed. The Palmer Goldfield has been the most prolific alluvial producer in Queensland, and ranks fourth among the Queensland goldfields, with an estimated total production of 1,334,500 oz of fine gold. Peak production was reached in 1875, when 250,000 oz were recorded, and possibly some 50,000 people were living in the district (Dunstan, 1913b), half of whom where Chinese. By 1877, the Chinese outnumbered the Europeans. Uhrstown, Maytown, Byerstown, Palmerville, and Groganville mushroomed into mining townships, of which no vestiges now remain. The output of gold fell sharply during the next few years, apart from a temporary increase in 1888-89, when the newly discovered quartz reefs at Maytown were in full development. Later attempts at dredging, sluicing, and reopening of mines were unsuccessful and were soon abandoned, and only a few ounces per annum were produced up to World War II.

Encouraged by his Palmer River venture, Mulligan set out on five more expeditions, during which he reported gold and tin in several streams, including the Hodgkinson River. Payable gold was found during his last journey in 1876, and thousands of prospectors soon moved into the Hodgkinson district. Kingsborough and Thornborough became the chief settlements. Estimates of the total gold production vary considerably; the highest figure is about 300,000 oz up to 1951. The peak year was 1878, when about 44,000 oz were won. After that, production declined rapidly to 655 oz in 1891, when most of the mines were closed. Since then a fairly constant annual output of 2000 to 5000 oz was

maintained until World War II, when production virtually ceased. Sporadic development work is still being done by small parties from time to time.

Cairns and Cooktown both owe their existence to the gold rushes. Cooktown was built as a port for the Palmer Goldfield, and when the Hodgkinson field was discovered, Cairns was built on Trinity Bay. Immediately afterwards, in 1877, an easier though longer route was found slightly to the north, leading to the establishment of Port Douglas. Later, Cairns was chosen as the starting point for a railway to the Atherton Tableland and the Chillagoe field, and the importance of Port Douglas declined.

Meanwhile, fired by the Palmer and Hodgkinson discoveries, prospectors swarmed over most of Cape York Peninsula, but without spectacular results. A number of small goldfields were discovered over the years; the Mulgrave (1879), Russell (1887), Starcke (1890-92), Jordan (1898), Hamilton (1900), Tate (1896), Alice River or Philp (1904), Mount Peter (1915), and Bartle Frere (1937), but production was small compared with the Palmer and Hodgkinson fields.

Metals other than gold were discovered during these prospecting years. In 1875, Mulligan reported the presence of tin in the Wild River near Herberton, but as the locality was remote, and tin mining was much less rewarding than gold, the find at first stirred little interest, as did the discovery of tin on the Tate River three years later. During this period, however, Chinese prospectors were working the first tin shows on Granite Creek and Cannibal Creek in the Palmer River district, and by the end of 1884 had produced about 2375 tons of cassiterite concentrate. In 1878, a cattleman named John Atherton found tin in Tinaroo Creek and, a year later, in the Wild River, to which he directed a small party of interested miners. Their subsequent discovery of the Great Northern mine finally started the first rush for claims in the Herberton district, and drew prospectors from several goldfields. The intensive exploration during the following years in the Herberton/Mount Garnet area led to the discovery of many important lodes and alluvial deposits of tin (Vulcan and North Australian mines, and Herberton deep lead); and also of the silver-lead lodes at Silver Valley (1880) and Montalbion (1885), and the copper deposit at Mount Garnet (1883). Watsonville was founded 7 miles west of Herberton, and Irvinebank a year later. In 1886, new tin finds at Stannary Hills partly compensated for the cessation of work at Watsonville.

Less important deposits of tin were found outside the Herberton/Mount Garnet district. Between 1885 and 1887 alluvial and eluvial tin deposits were developed along the Annan and Bloomfield Rivers, south of Cooktown, and this was followed by lode mining at China Camp in 1908. Alluvial tin was worked in many of the creeks running off the granite tablelands to the north of Mareeba.

In 1888, tin was found near Koorboora, during the search for a dray road from the newly discovered Chillagoe copper workings to Cairns. Between 1900 and 1917 many of the lodes in the Koorboora area and, from 1908, in the adjoining Sunnymount area, were extensively worked, but production declined after 1912.

Interest in tin has been revived recently by the rise in the price of the metal. Private enterprise and the Federal and State Governments have explored and tested

old and new areas. A few old tin mines have been revived, but the bulk of the present-day production is furnished by the tin dredges of Ravenshoe Tin Dredging Ltd and Tableland Tin Dredging N.L.

The base-metal deposits, found in many places during the search for gold and tin, were originally worked only for their richest ores, and production remained low until the revival of metal prices in 1896. The Mount Garnet copper lode was discovered in 1883; it was opened up in 1896 by John Moffat, one of the best known mining pioneers in north Queensland, who also acquired mineral claims in the Chillagoe district after they had been pointed out to his men by William Atherton, on whose property they occurred. Soon numerous copper and silver-lead deposits were being developed in the Chillagoe district around Mungana, Redcap, Zillmanton, Chillagoe, Calcifer, Cardross, and Dargalong (de Keyser & Wolff, 1964). The ores were treated in local plants, but in 1906 a central mill capable of treating the lower-grade ores was opened by the Chillagoe Railways and Mines Co. Ltd. In the same year, the Cairns/Chillagoe railway was completed, and the district entered its most prosperous period, which lasted until about 1914 for the base metals. From 1900 to 1906, the district was the chief source of copper in Queensland.

Later, mining in the Chillagoe district suffered setbacks caused by political scandals, exhaustion of the richer ores, mismanagement, industrial unrest, lower metal prices, and fire and flooding in one of the biggest mines. In 1943, the smelters were closed for the last time, and finally were sold and dismantled in 1950.

In 1902, Mount Garnet also received the benefit of a railway connexion, which brought an influx of people and prosperity, even after the mine closed down in 1903 because of financial difficulties.

Other important copper producers in the Hodgkinson Basin were Mount Molloy, discovered in 1883 north of Mareeba, and the O.K. mines, developed after 1902 in remote dry country about 45 miles north-northwest of Chillagoe. By 1903, Mount Molloy was one of north Queensland's leading copper producers, but after 1905 production became erratic and intermittent, and the later history of the mine is somewhat nebulous. The O.K. mines were the main source of copper ore to the Chillagoe smelters from 1904 to 1910, but were then abandoned after an industrial strike.

The main centres of silver-lead mining were Mungana, Dargalong, and Muldiva in the Chillagoe district, and Montalbion, Silver Valley, and Orient Camp in the Herberton district.

The Chillagoe district has accounted for most of the tungsten and molybdenum produced in Queensland, and until 1920 was the world's largest producer of molybdenite. The main mining centres were Wolfram Camp and Bamford Hill in the Chillagoe district, and Mount Carbine, 36 miles north-northwest of Mareeba. Wolfram was found almost simultaneously in all three localities, and enjoyed its biggest boom period during World War I, when the price ranged from £100 to £200 per ton. After the war, production collapsed as the field could not compete against the large-scale wolfram mines developed in the USA, India, and China. Since then the intermittent production has been governed by fluctuating market prices. Minor recoveries took place in 1929-30 and from 1937 to about 1950.

Although molybdenite was discovered at the same time as wolfram, there was no demand for it until 1900; the price rose from £52 per ton in 1900 to almost £200 in 1902, was increased to £325 in 1913, and to over £500 in 1914. Production collapsed in 1920 and has since remained negligible.

Stibnite and some cervantite are generally found with the gold in the Hodgkinson and Starcke River fields, and along the Mitchell River. Cupriferous iron ore was used as flux in the Chillagoe copper smelters. Zinc and some cobalt are associated with the base-metal ores in the Chillagoe district, but have not been produced because of the difficulty of treating the complex ores, the lack of demand, the low grade of the ore, or the lack of adequate reserves. Outcrops of low-grade manganese ore are known mostly in the coastal ranges between the Daintree River and Gordonvale.

Among the non-metallic mineral deposits, only fluorspar, coal, limestone, and clay have been produced in quantity. The Chillagoe district, including the Tate River area, has been Queensland's largest source of fluorspar. Production started in 1917, when a parcel of 20 tons was shipped to New Caledonia. The main workings, west of Mungana, were opened up in 1924. The highly irregular output dwindled to almost nil in 1955, owing to low market prices.

Coal was eagerly sought after during the heyday of mining for the smelters, power plants, and railways. Several occurrences were tested, but the only find of importance was in 1907 at Mount Mulligan, where coal was steadily exploited from 1914 to 1957, when the mine closed down on completion of the Tully Falls hydroelectric scheme.

Limestone was used as flux in the mining industry, and later as a fertilizer. Limestone is abundant in the Chillagoe district and has been quarried at several localities. The sugar cane industry at Cairns and Innisfail consumes much limestone for chemical and agricultural purposes, and the quarry at Ootann, south of Almaden, has recently been expanded.

Road metal and building aggregate are produced from numerous local quarries in basalt, granite, and gravel, and clay is mined for the manufacture of bricks, pipes, and roofing tiles. Deposits of talc, mica, phosphate, quartz, pozzolan, and diatomite are also known, but they are generally too small or low-grade to be mined economically.

Mineral Exploration

In the early days prospectors combed the creeks and gullies for alluvial gold and tin, while the shoad deposits of wolfram and the ferruginous copper-stained outcrops of the base-metal deposits were obvious enough. Many of the copper deposits, including the O.K. and Mount Molloy lodes, owe their discovery to stockmen, teamsters, station owners, and others who accidentally stumbled across the conspicuous exposures.

In later years, when the superficial deposits were depleted, more systematic and sophisticated methods were employed. The major mineral fields and their numerous mines and prospects were described in detail by officers of the Aerial, Geological, and Geophysical Surveys of Northern Australia, but unfortunately

World War II intervened before their reports could be published (Jensen, 1939a,b, 1940, 1941a,b,c; Clappison, 1940a,b,c, 1941, unpubl.). After the war, many mining companies and syndicates, and the Commonwealth and State Governments, showed renewed interest in the Hodgkinson Basin. When the price of tin rose to record heights in the 'sixties, old tin mining areas were reinvestigated and the Dover Castle and Gilmore mines were successfully reopened.

Exploration was directed mainly towards the extension of old lodes and the search for new deposits in already established mining districts. Most of these activities were concentrated in the Chillagoe and Herberton/Mount Garnet districts, and were carried out by Alluvial Gold Ltd, the Broken Hill Co. Pty Ltd, Broken Hill South Ltd, the Bureau of Mineral Resources, Carpentaria Exploration Co. Pty Ltd, Clutha Development Ltd, Dominion Pty Ltd, Enterprise Exploration Pty Ltd, General Mining Corporation Pty Ltd, Loloma Mining Corporation N.L., Mareeba Mining & Exploration Pty Ltd, Metals Exploration N.L., Mineral Deposits Pty Ltd (Southport), Mount Isa Mines Ltd, New Consolidated Gold Fields (Australasia) Pty Ltd, Nippon Mining (Australia) Pty Ltd, Noranda Exploration Co. Ltd, North Broken Hill Ltd, Rio Tinto Australia Exploration Pty Ltd, Tableland Tin Dredging N.L., the Queensland Mines Department, Queensland Mines Ltd, United Exploration Pty Ltd, and others.

In the Annan River and Bloomfield River tin areas, the Broken Hill Co. Pty Ltd, New Consolidated Goldfields Pty Ltd, and the Annan Dredging Syndicate held Authorities to Prospect between 1956 and 1962. New Consolidated Gold Fields (Australasia) Pty Ltd took out Authorities to Prospect over large areas in north Queensland in 1957 (Clark, 1958, 1959, unpubl.).

The exploration techniques employed, apart from mapping and sampling, included various geophysical methods, churn and diamond drilling, and, in later years, geochemical sampling and geomorphological studies.

Geophysical methods were first used in 1930 in the Redcap and Mungana areas (Chillagoe district) by the Imperial Geophysical Experimental Survey (Broughton Edge & Laby, 1931), but were not successful (Ball, 1931). In 1938, AGGSNA tested tin orebodies in the Herberton district by potential ratio and electromagnetic methods (Thyer, 1939). In 1949, the Bureau of Mineral Resources carried out electromagnetic, magnetic and self-potential surveys in the Redcap, Mungana, and Zillmanton areas of the Chillagoe district (Langron, 1957, unpubl.), and an airborne scintillometer survey over a large area including the Chillagoe field in 1954 (Parkinson & Mulder, 1956, unpubl.). This was followed up by a closely spaced combined magnetometer and scintillometer aerial survey of the Chillagoe district in 1958, and the next year geophysical work was done at Ruddygore and Wolfram Camp (Horvath, 1959; Daly, 1959, both unpubl.). In later years the Bureau used refraction seismic and gravity surveys to evaluate alluvial tin prospects in the Mount Garnet area (Sedmik, 1963; Hussin & Horvath, 1963; Zimmerman et al., 1963, all unpubl.), and a gravity survey was used in the Kings Plains area west of Cooktown to test a new alluvial tin prospect (Best & Dallwitz, 1963, unpubl).

In 1961, Mineral Deposits Ltd (Southport) made magnetometer surveys of the iron deposits at Mount Lucy near Almanden, and the alluvial areas underlain

by basalt in the Mount Garnet area; Mount Isa Mines Ltd used a magnetometer on its copper prospect in the Watsonville area in 1962; and the Compagnie Générale de Géophysique applied refraction seismic methods in parts of the Mount Garnet Basin (Zimmerman et al., 1963, unpubl.). In the Laura Basin, the Compagnie Générale de Géophysique in 1963 completed a seismic survey for Marathon Petroleum. Application of geophysical methods, including induced polarization surveys, by exploration companies is now more commonplace.

Scout drilling was employed in several places, often in conjunction with the geophysical surveys. Churn and diamond drilling were used in the Redcap/Mungana area and at Ruddygore (de Keyser & Wolff, 1964); in the Mount Garnet Basin (Zimmerman et al., 1963, unpubl.); in the Herberton district; on the Kings Plains prospect (Best & Dallwitz, 1963, unpubl.); and at Station Creek between Mareeba and Mount Carbine (Clark, 1959b, unpubl.). In 1942, the Queensland Mines Department unsuccessfully attempted to locate, by drilling, payable tin deposits in the area indicated as favourable by the 1937 geophysical survey of the Herberton deep lead (Cribb, 1946).

Geochemical sampling techniques were introduced in 1961 by Enterprise Exploration Pty Ltd and by the Bureau of Mineral Resources in the Chillagoe and Herberton regions (Zimmerman & Howard, 1962; Zimmerman et al., 1963, both unpubl.), and geochemical prospecting is now commonly carried out by exploration companies. Some geochemical reconnaissance sampling was carried out in conjunction with the regional mapping in 1962 and 1963 in the Cairns, Innisfail, and Ingham Sheet areas.

Combined surveys using detailed mapping, geophysics, geochemistry and geomorphology will be required in future exploration, especially in alluvial or soil-covered areas. Improved methods that may be successfully applied include the determination of dispersion haloes (especially of mercury) around buried orebodies.

Distribution and Zoning
(Fig. 30)

With few exceptions the ore deposits are genetically associated with the late Palaeozoic intrusive rocks, even in areas far removed from the nearest outcrops of igneous rocks.

Gold is the most common and widespread type of mineralization: payable deposits have been found from Cardwell in the south to the Hamilton and Starcke fields in the north, and from the Tate and Alice River fields in the west to the Mulgrave River in the east. Antimony is associated with some of the gold lodes, especially in the Hodgkinson and Starcke fields.

Tin mineralization, though also widespread, is slightly more restricted than the gold in the map area, and does not appear to be present north of the latitude of Cooktown. The tin is usually associated with tungsten, molybdenum, and bismuth, but the main tungsten deposits contain little tin.

The base-metal deposits are concentrated along the southwestern margin of the Hodgkinson Basin and in the adjoining Precambrian shield. A notable exception

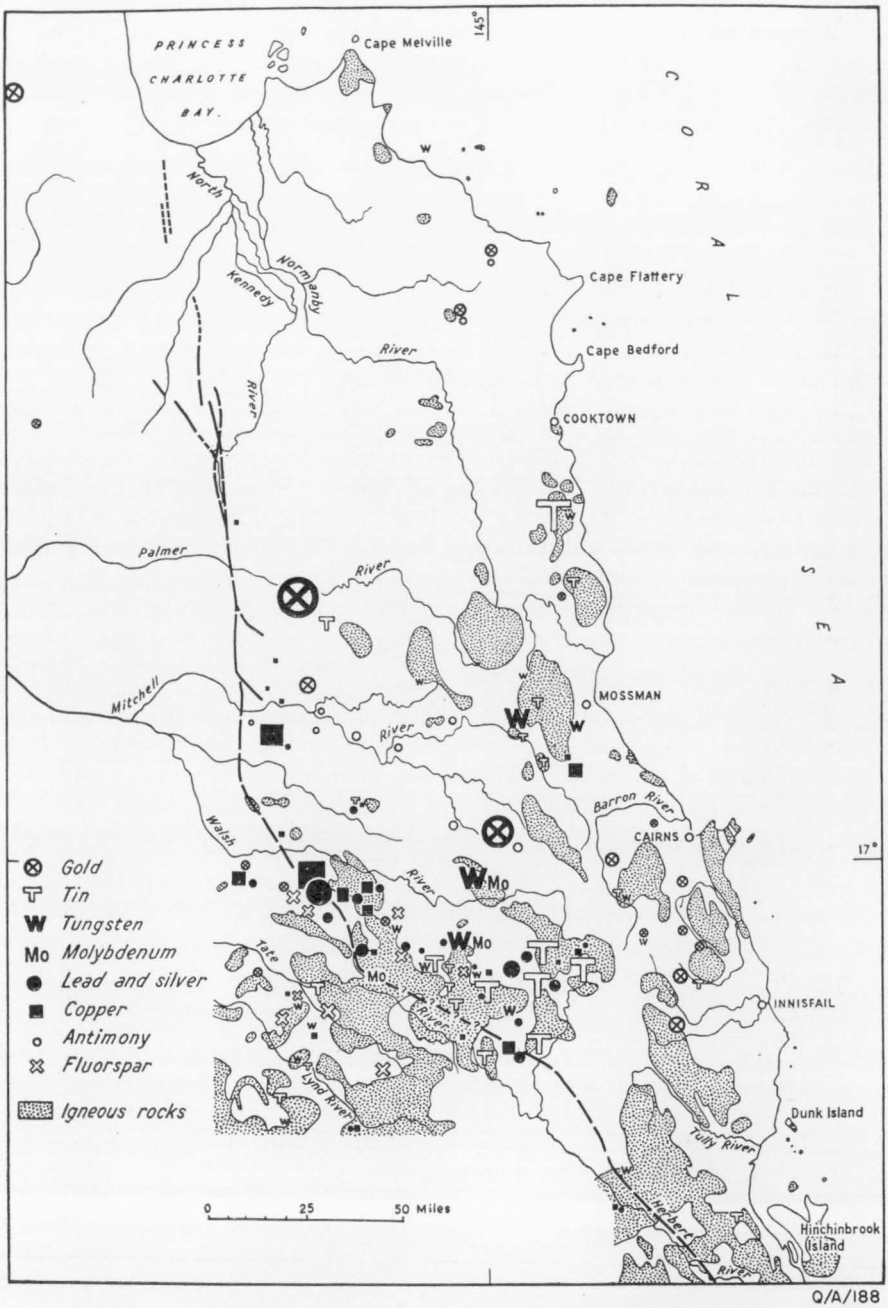


Fig. 30. Distribution of the mineralization.

is the Mount Molloy copper deposit, which is situated within the central part of the basin. The silver-lead lodes have a much more restricted distribution than the copper orebodies, and occur only in the Chillagoe and Herberton districts. Curiously, most of the silver-lead deposits occur within a radius of about 15 miles of the Featherbed Volcanics, and are the only type of metalliferous deposit known in the volcanics (Orient Camp, Lappa mines, Nightflower mine).

The fluorspar veins, associated with the late Palaeozoic granites, are limited to the Chillagoe field, where they are found mainly in the Precambrian shield.

Regional zoning can be recognized: the tin, tungsten, and molybdenum mineralization is always closely associated with nearby granite; the base-metal and gold lodes are farther removed; and the antimony, mercury, and some of the copper deposits are found even farther away. District zoning, shown by closely grouped mines, has been noted in the Herberton field (Blake, 1968, unpubl.), and also in the Chillagoe area (de Keyser & Wolff, 1964). Zoning in single orebodies is usually less evident, and in many deposits the normal zones are reversed. In the silver-lead lodes the sphalerite/galena ratio commonly increases in depth, and in the tin-tungsten lodes near Koorboora the wolfram/cassiterite ratio usually decreases in depth. In the complex cassiterite-sulphide lodes zoning is not consistent. Blanchard (1947) notes that sulphides give way to cassiterite in depth in some lodes, while the reverse is found in others. In many orebodies, the cassiterite and sulphides are intimately intergrown, and Blanchard considers that they were deposited simultaneously. Edwards (1951), however, concluded that the sulphides were later than the cassiterite, and that the complex ores are telescoped deposits (see p. 190).

Depth of Exploitation

Most of the copper and silver-lead in the Hodgkinson Basin has been won from the oxidized and secondary enriched zones. At greater depth, the primary ores were commonly not of economic grade, or required different treatment from the oxidized ores. Below groundwater level large quantities of water and the softness of the clayey wallrocks increase the difficulties of mining.

The base-metal mines were generally shallower than some of the gold and tin mines, in which there is little difference in the tenor of ore in the primary and oxidized zones.

The depth to groundwater generally ranges from about 50 to 100 feet in the Chillagoe district, but the zone of oxidation in places extends well below the water level, probably owing to free circulation in the cavernous limestone of the Chillagoe Formation.

Age of the Mineralization

The tin, tungsten, gold, fluorite, and base-metal deposits are probably all genetically associated with the Permo-Carboniferous instrusions.

The mica pegmatites at Mount Kitchin and on the Morehead River are Precambrian, the limestones are Upper Silurian to Devonian, the coal at Mount

Mulligan is Permian, and the pozzolan and diatomite deposits are associated with Cainozoic basalt. Unpayable seams of coal also occur in the Jurassic and Mesozoic formations of the Laura Basin.

Mineralization

Edwards (1951, etc.), Stillwell (1943, etc.), and Broadhurst & Edwards (1953) nave described the mineragraphy of some of the north Queensland orebodies; but most of the old workings are now inaccessible, and little is known about their paragenesis and conditions of crystallization.

De Keyser & Wolff (1964) have tentatively classified the main ore deposits in the Chillagoe district according to the temperature of formation and the type of lode. The scheme is approximate only, as many of the orebodies show a wide range in the temperature of formation and the high-temperature and low-temperature minerals appear to be telescoped. This is especially noticeable in the complex cassiterite-sulphide ores in the Herberton/Mount Garnet district, which ranges from high temperature minerals, such as topaz and tourmaline, to low-temperature minerals, such as marcasite, stibnite, and rare silver sulphosalts. In the Hodgkinson Goldfield the minerals range from scheelite and tourmaline to stibnite. The higher-temperature associations are found in the centre of the field, and the lower towards the edges. The parent granite is apparently situated below the centre of the field, and the deposits are not associated with the Mareeba Granite on the Hann Tableland to the east, as suggested by Jensen (1923).

The ore deposits in the Hodgkinson Basin range from high-temperature pneumatolytic-pegmatitic and hydrothermal deposits to low-temperature epithermal and perhaps telethermal veins. The high-temperature deposits include the tin and tungsten ores, and the contact-metasomatic copper and lead ores in the Chillagoe district (de Keyser & Wolff, 1964). Most of the gold lodes and some of the base-metal deposits (e.g. Ruddygore, Dargalong) are considered to be mesothermal; whereas the stibnite-(gold)-quartz lodes, the fluorspar veins, and some of the copper and lead ores are probably epithermal.

Cassiterite and wolfram are both high-temperature minerals, and the proportion of cassiterite (normally of somewhat higher-temperature origin) is generally higher in the granite and near its contact; the tungsten/tin ratio increases away from it. However, in some areas in the Herberton/Mount Garnet district the tin mineralization indicates a lower temperature of crystallization than in the wolfram-molybdenite pipes at Wolfram Camp and Bamford Hill (Blanchard, 1947), and Edmonds (1951) has compared these tin deposits with some of the Bolivian lodes formed at abnormally low temperatures.

In north Queensland the $MnWO_4/FeWO_4$ ratio is about 0.5 for the Bamford Hill wolfram (which occurs in high-temperature greisen-quartz pipes in granite), and only 0.3 for the Mount Carbine mineral (which is contained in lower-temperature quartz veins in sediments). This is in agreement with Leutwein's findings (1952).

There is little doubt that the high-temperature ore deposits are genetically associated with the granites in which, or around which, they occur. In areas where

the deposits are far removed from the nearest exposed intrusions the genetic relationships may be obscure. For example, it is possible that the copper occurrences in the Mitchell River area are related to the numerous flows of basalt or andesite interbedded with the cherts and other sediments of the Chillagoe formation, and that the syngenetic sulphides were subsequently concentrated in shear zones during orogeny. The regional mapping, however, has shown that it is more likely that they are epigenetic deposits associated with unexposed intrusions at shallow depth. The O.K./Mitchell River copper deposits were previously thought to be 'far removed from any granite bodies' (Edwards, 1943), but in 1960 a small outcrop of granite was found about 4 miles northeast of Belleview homestead; and a large outcrop of quartz-tourmaline rock near the road crossing at Nolan Creek, 8 miles west-southwest of Nychum homestead, indicates intense metasomatic action from a subsurface source. It is assumed that underlying granite was responsible for the hydrothermal alteration of the host rocks and for the precipitation of the ores in the O.K./Mitchell River copper deposits.

Control of Mineralization

The location and type of ore deposit in the Hodgkinson Basin were controlled by the following factors: (1) type of parent igneous rock; (2) type of host rock; (3) structural control (channelways, traps, fields of uneven stress distribution, etc.); (4) geological environment; (5) geomorphological history; and (6) climate (past and present).

Type of Parent Igneous Rock. The tin deposits are found only in association with the Elizabeth Creek, Mareeba, Cannibal Creek, and Finlayson Granites. According to Rattigan (1960), Serebryakov (1961), Gotman & Rub (1961), and others, tin-bearing granites are generally alkaline or moderately calc-alkaline (never peralkaline) rocks with a high K+Na/Ca+Mg ratio, and contain more potash feldspar (commonly microcline or microcline perthite) than plagioclase. They have a wide range of acidity, but are usually strongly acid and leucocratic. They generally contain biotite, and muscovite is also common, but pyroxene and sodic amphibole are never found. Accessory tourmaline, fluorite, and zircon are usually present. Greisenization, albitization, and quartz-metasomatism are common features in tin-bearing granites and many of them contain an unusually high content of tin, fluorine, boron, zirconium, barium, rubidium, beryllium, lithium, yttrium, gallium, lead, and the rare earths. The biotite tends to have a high content of beryllium.

These factors typify the tin-bearing granites in north Queensland (de Keyser, 1961, unpubl.; Zimmerman et al., 1963, unpubl.; Smith & Yates, pers. comm.). No tin mineralization is known in the alaskite on Hinchinbrook Island, which, although being acid and leucocratic, is a peralkaline rock containing sodic amphibole.

The contact-metasomatic base-metal deposits in the Chillagoe district appear to be associated with the granodiorites, quartz diorites, and adamellites of the Almaden and Herbert River Granites, which are less acid or leucocratic than the tin-bearing granites, and contain hornblende in addition to biotite. The host rocks are the calcareous beds of the Chillagoe Formation. Ovchinnikov (1959) found —

partly by experiment — that when a granitic melt is contaminated with calcium-rich rocks, iron and copper ores may be formed at the granite-limestone contact by means of some natural flotation process. The cupriferous iron contact deposits in the Chillagoe district appear to be an excellent example of the ideas expounded by Ovchinnikov.

The Ruddygore copper deposit is of the 'porphyry-copper' type and is associated with leucocratic microgranodiorite which intrudes several other varieties of granite (Broadhurst, 1949; Branch, 1960, unpubl.).

The fluorspar lodes are generally far removed from the nearest granite outcrops, but are probably genetically related to the Elizabeth Creek Granite, because fluorite is a common accessory in this granite and in the tin lodes associated with the granite.

Gold is found around the Mareeba Granite and in the Tully Granite Complex, but little is known about the parent rocks of the gold deposits farther north and west where the granites are not exposed.

Type of Host Rock. In the Chillagoe district most of the contact-metasomatic ore deposits occur in the limestone (de Keyser & Wolff, 1964), but elsewhere lithological control is far less obvious. There is some evidence of selective mineralization in the massive fine-grained arenite in the Herberton/Mount Garnet tinfield (Blanchard, 1947), and certain kaolinized or carbonaceous slates are reported to be the favoured host rocks for gold in some mines in the Hodgkinson field (Jensen, 1939a, unpubl.), but elsewhere the lithology of the host rock appears to have had very little influence.

Structural Control. Structural features have had a far greater influence on the deposition of the ores in north Queensland than the lithological composition of the host rock. Many of the lodes are associated with joints, faults, and shear zones which have provided channelways for the ore-transporting agencies and acted as the loci of precipitation. The intersection of joints and faults in particular have been cited as favourable structures for the location of ore shoots. The quartz-greisen pipes at Bamford Hill and Wolfram Camp were thought to be located along joint intersections (Cameron, 1904a; Ball, 1920; Jones, 1943), and the pipe-shaped ore shoots in many of the Herberton/Mount Garnet tin lodes may also have been controlled by intersecting joint planes, although Amos (1963, unpubl.) found no evidence for this in the one mine which has been studied in detail.

Bends and kinks in quartz veins are commonly mentioned as favourable structures for ore enrichment in the gold lodes (Jack, 1888a; Jensen, 1939a, unpubl.), and in the tungsten pipes at Wolfram Camp. At Wolfram Camp, enriched ore is generally also found at the contact of the pipes against abutting joints, faults, and barren quartz veins. In the contact-metasomatic base-metal deposits, knick-points along the irregular contact surfaces and embayments of limestone in granite appear to be favourable loci for ore concentration. Thickening and narrowing of the veins may influence the distribution of ore: in the Starcke Goldfields the tenor of the ore has been reported to be inversely proportional to the width of the reefs, but Rands (1893) found that most of the stibnite occurs in the bulging parts of the quartz veins at Cocoa Creek.

The breccia pipes in the Mungana and Redcap areas of the Chillagoe district may have been formed as a result of hydrothermal activity (de Keyser & Wolff, 1964), and the impregnated shatter zones at Ruddygore and, possibly, in some of the Tartana copper leases may be due to hydrothermal and igneous intrusive stresses. Granite intrusions may also be responsible for the mineralized steep open fractures dipping towards the granites in the Herberton/Mount Garnet tinfield.

The mineralized faults and fractures are generally parallel to the northwest to north regional strike, or roughly northeast, normal to the regional strike.

The fluorspar lodes west of Mungana are approximately parallel to the Palmerville Fault, and may be associated with secondary fissures related to this fault.

The Dover Castle tin mine northwest of Petford is probably situated on the northern extension of the ring fault along which the Tennyson Ring Dyke was emplaced.

In the Jordan Creek Goldfield, the northeasterly lodes in the Wyreema group are arranged in a north-northeasterly belt; they are arranged en echelon, and probably represent tension cracks resulting from a north-northeasterly dextral shear couple.

There are many other examples in the Hodgkinson Basin of structural control as a controlling factor in the formation of ore deposits.

Geological Environment. The Mount Mulligan coal and the Silurian limestones in the Chillagoe district were associated with specific geological environments.

Most of the copper deposits in the Hodgkinson Basin are concentrated on the western or southwestern margin of the basin, in shelf-type sediments with intercalated basic volcanics of the Chillagoe and Mount Garnet Formations. It is possible that the copper was originally precipitated syngenetically, and later was remobilized and concentrated in epigenetic veins. Such syngenetic precipitation could have been brought about by exhalative-volcanic processes, or by absorption of metals by micro-organisms on the shelf area.

Geomorphological History. In certain localities the location of the alluvial deposits is directly related to the sequence of geomorphological events. Best (1962, unpubl.) and Lucas (1962, unpubl.) have both delineated localities where payable alluvial deposits might be found in abandoned fossil stream valleys. The rich alluvial gold deposits in the Palmer River area could not have been concentrated without uplift and rejuvenation of the area east of the Palmerville Fault, and similar conditions apply to the tin deposits in the Russell River terraces.

The thicknesses of the oxidized zones and zones of secondary enrichment are also partly dependent on the geomorphological history.

Climate, commonly in conjunction with geomorphology and geological environment, is an essential factor in the formation of bauxite, coal, limestone, salt, and laterite. It also determines the depth of the oxidation zone. The tin deposits at Lode Hill and the tin greisens in the Annan River field could only be worked profitably because of the deep and intense decomposition of the granite under the influence of the wet tropical climate.

The factual data in the following descriptions were partly compiled by the geologists of the Geological Survey of Queensland who were members of the



Fig. 31. Gold and Mineral Fields, and the main gold mining centres.

combined survey parties from 1958 to 1963. The production figures (totalled to the end of 1966) are generally incomplete, occasionally grossly so, for the earlier returns were usually poorly recorded or not recorded at all. Well documented general historical reviews of the development of northern Queensland, including exploration and mining, are presented by Bolton (1963) and Mrs Jones (1961).

The two most important mineral districts, the Chillagoe and the Herberton/Mount Garnet areas, are only summarily described as they have been treated in detail by de Keyser & Wolff (1964) and Blake (1968, unpubl.).

The mineralized areas have been grouped into several Gold and Mineral Fields (Fig. 31) to facilitate administration. When new finds were made the mineral fields were rearranged or subdivided. The old Walsh and Tinaroo Mineral Field, for example, proclaimed in 1882, was divided into the Herberton Gold and Mineral Field and the Chillagoe Gold and Mineral Field in 1909, and the Mareeba Gold and Mineral Field was detached from the Chillagoe Field in 1949.

Gold
(Table 6)

The goldfields, in decreasing order of importance are the Palmer, Hodgkinson, Hamilton, Russell River, Starcke, Jordan Creek, Mareeba, and Mount Peter Goldfields, and a multitude of smaller production centres. Together they have yielded approximately 1,780,000 oz of fine gold, valued at about £7,565,000, of which 75 percent came from the Palmer and 17 percent from the Hodgkinson field (Table 6).

Palmer Goldfield

Gold rushes following the discovery of payable deposits on the Palmer River in 1873 soon brought up to 50,000 people to the field; Palmerville, Maytown, Uhrstown, Byerstown, and Groganville became booming though short-lived settlements that are now deserted or have disappeared completely. The total gold output was undoubtedly higher than the estimated 1,334,500 oz, because large numbers of Chinese miners are reputed to have commonly evaded the official channels for the sale of gold. More than 90 percent of the gold was obtained from the alluvials along the river and its tributaries, mainly between Fish Creek (5 miles east of Palmerville) and Byerstown (about 45 miles east of Palmerville), although gold was won over a distance of more than 100 miles, from near Strathleven west of Palmerville to Campbell Creek upstream of Byerstown.

The alluvial production soared to a peak of more than 250,000 oz in 1875, and then declined rapidly. In 1926 the Palmer River Gold-dredging Co. was formed to work the Strathleven, Glenroy, and Bonanza claims downstream from Palmerville, although the reported values of about 13d per cubic yard were not very encouraging. Work ceased in 1935 when the recovery grade declined to about 4d per cubic yard owing to the extreme minuteness of the gold and the abundance of heavy minerals which packed the riffles. Only 3600 oz of gold were obtained in four years of dredging. Between 1934 and 1938 hydraulic sluicing was unsuccessfully applied to a small area 6 miles upstream from Palmerville by the Commonwealth Preliminary Mining Syndicate.

TABLE 6. GOLDFIELDS IN ORDER OF DECREASING PRODUCTION
(See Fig. 31)

Name (Year of discovery)	*Location*	*Estimated Production* (fine oz)	*Description*	*Minerals*	*References*
Palmer Goldfield (1873)	Palmer R., about 110 miles WNW of Cairns	1,334,500	(a) Alluvial deposits, mainly between Fish Cr. junction and Byerstown. Provided over 90% of total production		Jack (1887)
	Maytown		(b) Quartz reefs, Maytown area — thin lenticular fissure veins in sheared phyllite and greywacke. Reefs strike NW and NNW, dip steeply SW. Main reef systems: Ida-Comet, Louisa, Queen, Alexander (Fig. 32). Average grade 1-2 oz per ton	Gold. Some pyrite, arsenopyrite, a little stibnite. Gangue: quartz	Clappison (1940a unpubl.), Jack (1888a, 1896b,c, 1897, 1899), Jackson (1913), Jensen (1940, unpubl.), Warde (1903)
	25 miles S of Maytown		(c) Quartz reefs, Limestone district. Main mine was Anglo-Saxon, on reef striking NE and worked to depth of 600 ft. This was biggest mine in Palmer Goldfield	Gold. Pyrite, arsenopyrite	Jack (1888d), etc
	North of Maytown		(d) Deep leads in basal conglomerate of Dalrymple Sandstone in headwaters of Mossman R. and Cradle Cr., N of Maytown. Prospected, but not brought into production because of low and erratic values		Clappison (1940b, unpubl.), Jack (1896a)
Hodgkinson Goldfield (1875)	Hodgkinson R., 50 miles W of Cairns	about 300,000	(a) Alluvial deposits. Yielded roughly 10% only of total production		AGGSNA (1937), Jack (1884, 1896e), Jensen (1939a, unpubl.), Morton (1944c), Tenison Woods (1880a)

TABLE 6 (continued)

Name (Year of discovery)	*Location*	*Estimated Production* (fine oz)	*Description*	*Minerals*	*References*
Hodgkinson Goldfield (continued)			(b) Quartz reefs; two main groups: *(a)* parallel to strike but cutting across dip; *(b)* across strike, and dipping to W Important lode systems: Tyrconnel, General Grant, Flying Pig. Average grade about 1 oz per ton. Maximum depth of workings 715 ft	Gold, stibnite. Some pyrite, arsenopyrite, chalcopyrite, sphalerite, galena. Locally rare molybdenite, some scheelite	
Hamilton Goldfield (1899)	Around Ebagoola, an old settlement 30 miles W of Princess Charlotte Bay	47,480	Mainly lode mining; very little alluvial (colluvial) gold. Most of gold-quartz reefs strike N or NNW and are located near granite contacts. Important centres: Yarraden, Ebagoola, and Potallah Cr	Gold. Some pyrite, arsenopyrite, galena, copper carbonates	Ball (1901b), Cameron (1906b)
Russell Goldfield (1887) (Also known as 'Russell Terraces', 'Topaz',' Boonjie'). In 1905 included in Russell Extended	Headwaters of Russell R., 10 miles ESE of Malanda. Lodes at Towalla, 13 miles SE of Malanda. (Fig. 33)	26,780	(a) Buried alluvial deposits in late Cainozoic terraces along sides of steep valleys. Auriferous basal gravels overlain by up to 20 ft of sand, silt, and clay, under cover of 40-100 ft of basalt. **Latest workings: Astronomer,** Marvel, Lady Olive	Gold, cassiterite	Broadhurst (1956-58, unpubl.), Jack (1888c, 1893), Morton (1937a)
			(b) Quartz reefs, striking NW generally less than 1 ft thick, dip almost vertical in decomposed Barron River Metamorphics. Grade 2-3 oz per ton, but shoots very small	Gold in quartz gangue. Some pyrite	Rands (1894)

TABLE 6 (continued)

Name (Year of discovery)	*Location*	*Estimated Production* (fine oz)	*Description*	*Minerals*	*References*
Jordan Creek Goldfield (1898)	1. Jordan Cr./Henrietta Cr. area, 10 miles SE of Millaa Millaa 2. Myee Cr. area, 7 miles SE of Millaa Millaa	12,780 (to end 1966)	(a) Recent creek alluvium, now exhausted (b) Quartz veins and leaders in decomposed granite, in places with slightly auriferous alteration haloes. Reefs generally trend NE, thickness 6 in.-1 ft. Values up to 2 oz per ton, but average grade much less. Biggest mine: Wyreema (J.B.J. mine or Two T's Lease) (c) Some deep leads under basalt. Prospect only	Gold. Manganese oxides, some pyrite, arsenopyrite	Ball (1944), Ball (1901a, 1913c), Morton (1934)
Starcke No. 1 Goldfield (1892)	Cocoa Cr., 30 miles NW of Cooktown	1100	Gold-stibnite-quartz veins. Main lode strikes WNW	Gold, stibnite	Ball (1909e), Cameron (1906b), Rands (1893)
Starcke No. 2 Goldfield (1890)	Starcke E, 45 miles NNW of Cooktown	13,000	(a) Alluvial deposits at Diggins Cr. and Munburra (b) Quartz reefs N and E of Munburra. Grade almost 1.9 oz per ton	Gold. Arsenopyrite, pyrite, stibnite	Ball (1909e), Beck (1935), Cameron (1906b)
Mareeba Goldfield (1893)	5 miles SE of Mareeba	11,850	Quartz lodes. Only important mine was Queen Constance in which lode trends NNW, and has flat dip	Gold. Some pyrite, rare sphalerite, stibnite	Rands (1894), Skertchly (1897)
Mount Peter Goldfield (1915)	3 miles W of Gordonvale on steep N slopes of Mt Peter	11,000	Irregular quartz reefs trending NE and ESE across regional strike of enclosing Barron River Metamorphics. Steep dips. Shoots small and widely spaced. Average grade: 1 oz 18 dwt per ton. Large lode: the Talisman	Gold. Little chalcopyrite, pyrite, arsenopyrite	Denmead (1947), Jensen (1919b), Reid (1931d), Saint-Smith (1915c)

TABLE 6 (continued)

Name (Year of discovery)	*Location*	*Estimated Production* (fine oz)	*Description*	*Minerals*	*References*
Mulgrave Goldfield (1879)	12-16 miles SSW of Gordonvale along spur at watershed between South Toohey Cr. and Butcher Cr., and along Mulgrave R	5580	(a) Recent alluvium, now exhausted		
			(b) Quartz reefs, 6 in.-1½ ft thick, with irregular ore shoots, and subparallel with, or diagonal to, strike of enclosing Barron River Metamorphics	Gold. Little pyrite, galena	Morton (1937a, unpubl.), Reid (1931c), Saint-Smith (1923)
			(c) Buried alluvial deposits similar to those of Russell Goldfield. Little information available		Ball (1941)
Fluorspar (1930)	10 miles SE of Chillagoe, on Crooked Cr	Unknown, but at least 5050 (mixed bullion) and fine gold)	Small, but commonly extremely rich shoots in thin leaders where these cut through greisenized gently dipping aplite veins in adamellite. Gold concentrated in kaolin-rich patches; values many ounces per ton	Gold. Gangue: kaolin, quartz, calcite, fluorite, zeolites, clay minerals	Denmead (1934c,d), Jensen (1941c, unpubl.), de Keyser & Wolff (1964), Reid (1933f,h)
Tate Goldfield (about 1895)	Tate R. area, about 30 miles SW of Chillagoe	At least 3370	Alluvial, and rich but extremely small quartz veins in Precambrian rocks	Gold. Gangue: quartz	Ann. Repts Dept of Mines, Skertchly (1897)
Alice River (or Philp Goldfield (1904)	Roughly 120-130 miles W of Cooktown, on Dickies Cr	2765	Two main lodes (Alice and St Aignan), ½ mile apart in N-S direction, and probably part of same N-S fault zone. Many parallel reefs and leaders. Reef 4-5 ft wide	Gold in quartz gangue	Cameron (1906b)

TABLE 6 (continued)

Name (Year of discovery)	*Location*	*Estimated Production* (fine oz)	*Description*	*Minerals*	*References*
Mount Wandoo (1901?)	17 miles W of Chillagoe on Wandoo Cr	Unknown; 2100 from 1933-37	Main workings within zone of altered ferruginous and micaceous gneiss, about 14 chains long, mineral impregnated. Mineralization concentrated in fissure deposits and in pipes formed at intersections of joints and fissures. Fissures much splayed, and sometimes referred to as stockworks. Maximum depth of workings 2 ft	Gold in arsenopyrite, pyrite, chalcopyrite. Gangue: ferruginous and kaolinized country rock	Ball (1918), de Keyser & Wolff (1964), Morton (1935, unpubl.), Reid (1932b), Rutledge & Morton (1933, unpubl.)
Bartle Frere workings (1937)	7 miles W of Babinda, at foot of Mt Bartle Frere	520	Quartz reefs subparallel with, or in places diagonal to, strike of surrounding Barron River Metamorphics. Shoots patchy and irregular	Gold in quartz gangue. Little pyrite, arsenopyrite, galena, sphalerite, chalcopyrite	Cribb (1940), Morton (1938a, 1939a), Redmond (1937)

Gold-bearing quartz reefs were found soon after the discovery of the alluvial deposits, and although their total yield was small compared with the output from the alluvials, many mines and workings were concentrated north and southeast of Maytown and at Limestone Creek, a tributary of the Mitchell River, 23 miles south of Maytown.

The biggest and most productive mine was the Anglo-Saxon in the Limestone (Creek) group, which yielded 30,892 oz of fine gold, or about a quarter of the total output from the reefs. The Anglo-Saxon lode, discovered in 1886, was worked to a depth of about 600 feet, had seven levels, and was sunk on a northeast-trending fissure vein with a maximum width of 6 feet. The ore shoot

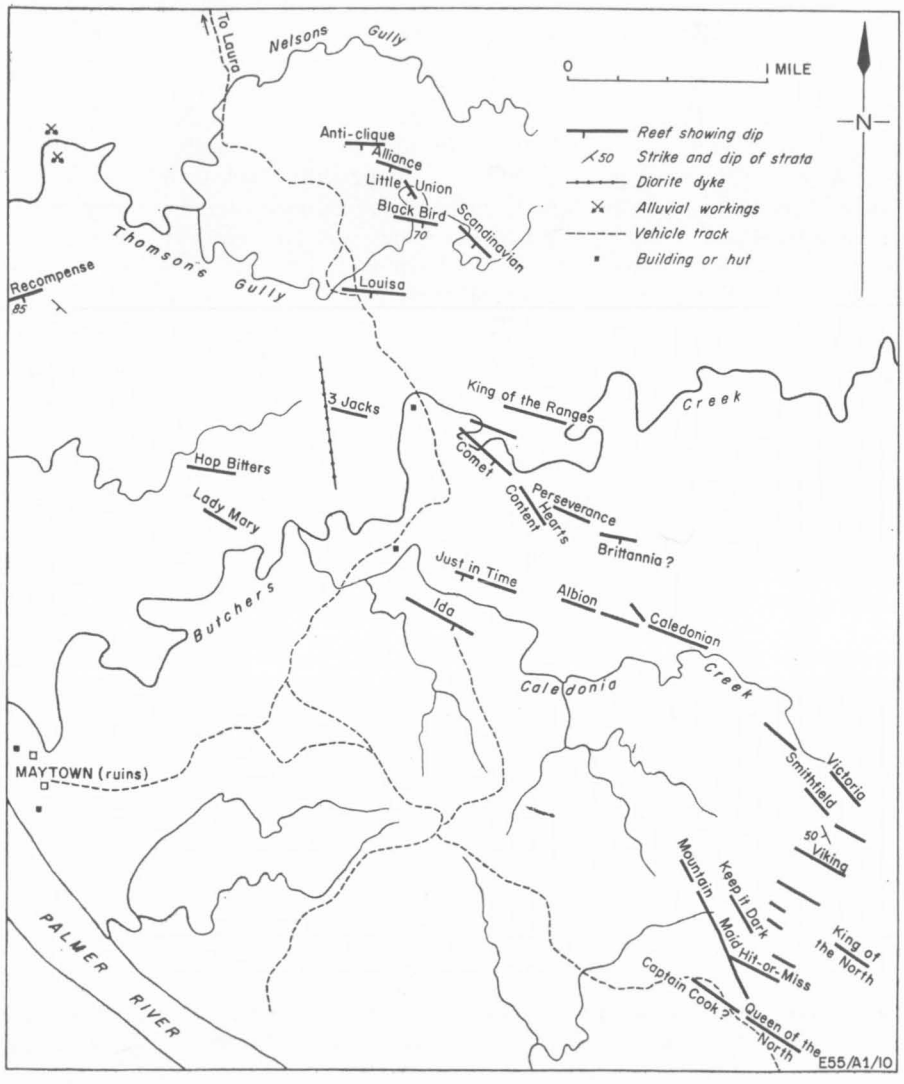


Fig. 32. The Maytown gold reefs.

was 300 to 400 feet long, but the ore became arsenical in the lower levels. The grade averaged 1.64 oz of gold per ton with rich patchs up to 78 oz per ton.

The Maytown reefs include several groups (Fig. 32), the largest of which were the Ida-Comet, Louisa, Queen, and Alexander groups. The first crushings were made in 1876, and when the mines closed down some 137,000 oz of fine gold had been obtained from 80,000 tons of ore, including the production from the Limestone (Creek) group. The grade ranged from 1 to 2 oz per ton. Most of the mines closed down after 1893 during a financial crisis, and were not reopened. An effort to revive the Louisa mine in 1939-40 was unsuccessful because of the troublesome quantities of mine water, and the large amounts of pyrite and arsenopyrite in the ore which made treatment difficult.

The mining operations on the Maytown lodes met with many difficulties. Timber was scarce and of poor quality, transport was very expensive, and the cost of living exorbitantly high (Jack, 1899). Mining was concentrated on the richest portions of the lodes, and little attention was paid to development work. The reefs were small, and though very rich on top were generally impoverished in depth. Water in the workings was difficult to cope with. Jackson (1913), contrary to most other opinions then current, concluded that most of the payable ore had been exhausted and that reopening of the mines was unwarranted, but that if the mines were reopened, more reefs should be mined simultaneously, using modern equipment, electric power, and cheap oil fuel.

The auriferous reefs are thin lenticular quartz-filled fissure veins within a belt of sheared dark phyllite and greywacke. The thickness ranged from a few inches to about 2 feet. In addition to the reefs mined, many thin unpayable leaders exist in the country rock. The reefs strike northwest or north-northwest, and dip steeply to the southwest. They are composed of milky vein quartz containing native gold, some pyrite, arsenopyrite, and a little stibnite. It is alleged that there were generally less base-metal sulphides in the Palmer reefs than in the lodes on the Hodgkinson Goldfield.

Jack (1888a) and others have noted that bends in the reefs were favourable loci for ore enrichment. It appears that the grade rapidly decreased in depth, especially in some of the Queen lodes, but it is uncertain whether the higher surface values were due to secondary enrichment.

Gold also occurs in the basal conglomerate of the Mesozoic Dalrymple Sandstone to the north of the Palmer River, in the headwater region of the Mosman River and Cradle Creek (Clappison, 1940a,b; 1896a). Jack reported the largest areas of auriferous leads above the unconformity along Chinky Creek, a tributary of the Mosman River. The conglomerate is up to 4 or 5 feet thick, and fills old stream courses running north on the pre-Mesozoic surface of erosion. The gold, where present, is concentrated near the bottom of the conglomerate; it is water-worn, and of high fineness. No production is known to have taken place, but a considerable amount of development work was done locally. The deposits were tested again in 1936-38, when diesel engines, a five-head stamp battery, and other machinery were available. Normal sampling showed traces of gold only, and the best grades found by test mining ranged from $2\frac{1}{2}$ to 5 dwt per ton. These values are considered unsatisfactory as the leads can be exploited

only by hard-rock mining methods, the volume of ore is small, the gold content erratic, and many of the leads ill defined. The conglomerate is probably the source of the small quantities of alluvial gold won by prospectors in Shephard Creek and the headwaters of the Mosman River.

Discussion. The alluvial deposits and most of the known reefs on the Palmer Goldfield can be considered to be exhausted, and the geomorphological history of the area indicates that there is little prospect of finding new alluvial deposits west of Palmerville: it is thought that the gold derived from erosion of the lodes on the pre-Mesozoic erosion surface was mainly dispersed towards the north originally, and that upwarp or tilting caused a change in the direction of drainage from north to west. Renewed movement along the Palmerville Fault resulted in rejuvenation of the topography of the Maytown block, and excellent traps were formed for the redistributed gold and for fresh supplies of gold from the rapidly eroding reefs and leaders. West of Palmerville, however, the topography remained old and flat, and there would be little concentration of the gold. The fine grainsize of the gold downstream from Palmerville indicates that it has been carried a long way from its source.

The source of the alluvial gold in the upper parts of the Palmer River, near the former sites of Uhrstown and Byerstown, is uncertain. No lodes have here been found, but there is a multitude of thin quartz leaders from which the gold may have been derived. It is possible, but less likely, that the metal was shed from the three granite tablelands to the south of the Palmer River.

Hodgkinson Goldfield

Estimates of the total output of gold from the Hogdkinson field vary: the highest figure quoted is about 300,000 oz, of which only 12,000 to 40,000 oz were obtained from alluvial sources, mostly in the year 1876. The Hodgkinson district, though a smaller gold-producing field than the Palmer Goldfield, was a richer lode-mining district (Pl. 26). In 1878, one year after the first lodes were opened up, there were 492 mines on 330 claims, and 12 crushing plants with a total of 121 stampheads. The main settlements were Kingsborough and Thornborough; others included Beaconsfield, Woodsville, Stewartstown, and Wellesley. Most claims were relinquished within a dozen years, and only a handful of mines remained in production intermittently until all activities stopped during World War II. In the postwar years there was some sporadic development work, but production was insignificant.

More than half of the total output was probably derived from the Tyrconnel and General Grant groups of lodes. The average grade was 17 to 18 dwt per ton for the General Grant, and 21.7 dwt for the Tyrconnel. The latter was the largest lode worked in the district, and was in almost continuous production until 1924; its bottom level is at 430 feet, where the grade became uneconomic. From 1933 to 1937 attempts were made to extract about 14,000 tons of available ore, but work was suspended as the grade of 4.17 dwt per ton turned out to be below expectation.

The General Grant was worked until 1910 for 23,120 oz of bullion. At a depth of 500 feet the orebody is 600 feet long, and sampling in 1934-37 indicated

reserves of 8000 tons averaging 8 dwt per ton. The grade was not considered to be economic, although there was slight improvement in the bottom level. The deepest workings were 715 feet below surface.

Prior to 1905, the Flying Pig was the most important producer, and yielded 14,930 oz of bullion from 8100 tons of ore.

One of the few persistent mines was the Minnie Moxham, later known as the New Minnie Moxham. It was the only producing mine after World War II, and yielded about 450 oz of fine gold in 1947-50.

Jack (1884) noted two main groups of lodes: those parallel to the strike of the sediments, but cutting across the dip; and those (mainly north-south) across the strike, and dipping to the west. The lodes, especially the first group, should not be confused with the conspicuous chert ridges which were commonly considered to be siliceous dykes or barren gold veins.

The lodes consist of sheared country rock interleaved with quartz stringers, or quartz veins ranging from a few inches to several feet wide. The best gold values seem to occur in white platy quartz with dark slaty seams, as in the Tyrconnel mine (and also found in the Maytown lodes of the Palmer field). The massive rubbly or blocky quartz appears to contain relatively little gold.

The veins contain native gold, varying amounts of stibnite, some pyrite, arsenopyrite, and small quantities of chalcopyrite, sphalerite, and galena. The stibnite appears to belong to a younger phase of hydrothermal activity. In some shoots both gold and antimony were mined, and in later years some of the mines changed production from gold to antimony, depending on market conditions. Galena and sphalerite were common in the Leviathan mine, and scheelite was found in a few mines, including the Southern Cross and Tyrconnel. In the Southern Cross, scheelite was first noticed at a depth of 90 feet, and below this level it was a constant constituent of the quartz gangue, especially in the gold-rich portions. Rare molybdenite is found in the Southern Cross, and barytes occurs in the gangue of the Minnie Moxham mine. Appreciable amounts of tourmaline are present in the Southern Cross lode.

There is little evidence of structural or stratigraphic control of the ore shoots. Jensen (1923) noted that the Tyrconnel shoot is located in a strong bend of the lode; occasionally a carbonaceous slate forms the favourable host rock, as in the Flying Pig workings, where the ore shoot pitches parallel to the lineation formed by the intersection of the lode with certain kaolinized or carbonaceous slates.

In places there is little surface indication of the presence of a reef. At the Tyrconnel, for example, the black shale contains thin quartz stringers which widen from a few inches at the surface to several feet in depth.

The available records indicate that the reefs have probably been worked out. The lodes are small and broken, the ore shoots commonly deeper than long, and the grade of the remaining ore at depth is apparently too low to be mined economically.

Production on the Hodgkinson field was mainly from lodes, and there was little alluvial gold compared with the Palmer district. The Hodgkinson lodes may

represent the upper zone of a mineralized vein system which has not been eroded sufficiently to provide a copious supply of free gold. The lack of surface indications supports this hypothesis.

Hamilton Goldfield

The Hamilton Goldfield, centred on the old settlement of Ebagoola, lies on the northwestern boundary of the map area, and extends farther west. It was the most important of the small gold-producing centres discovered in the course of the intensified prospecting that followed the establishment of the rich Palmer and Hodgkinson fields.

Gold was discovered at Ebagoola in 1899 by a prospector named John Dickie. Ebagoola developed as the main production centre, but the workings extended as far as Potallah Creek, 60 miles to the south-southwest beyond the map area. Production, which climbed to 8300 oz of fine gold in 1900, tapered off to less than 1000 oz per year after 1910, and the field was abandoned in 1941. A total output of 47,478 oz of fine gold has been recorded, mostly from lode mining; there was little alluvial or colluvial gold. Pyrite, arsenopyrite, galena, and copper carbonates were present in some of the lodes.

The country rocks consist of Precambrian schist intruded by small irregular bodies and dykes of granite and some diorite. Quartz reefs are common, but the auriferous shoots are concentrated near the boundaries of the intrusions, both in the granite and schist. Most of the reefs strike north-south or north-northwest.

Russell Goldfield (from 1905: *Russell Extended Goldfield*)

The Russell Extended Goldfield, one of a group of small fields in the jungle-covered mountain area between Cairns and Innisfail, has been intensely surveyed geologically (Broadhurst & Garth, 1957-58, unpubl.). The recorded production of 26,780 oz of fine gold was mostly obtained from alluvial deposits in the form of narrow terraces along the slopes of the steep-sided valleys of the Coopooroo Creek and Wairambah Creek drainage systems, which were buried by late Cainozoic basalt flows (Fig. 33). Recent rejuvenation has re-exposed some of the deposits.

The native gold is contained in gravel wash, generally a few feet thick, which is overlain by up to 20 feet of sand, silt, and clay, and 40 to 100 feet of basalt. The gravel has been worked by hydraulic sluicing and tunnelling. Development was hindered by the lack of accessible water (notwithstanding the copious rainfall), the rough and densely vegetated terrain, the soft decomposed ground, and the hardness of the gravel where cemented by iron hydroxides. Other adverse conditions included the low grade of the deposits, the extremely fine grain size of the gold, the scattered nature of the deposits, and the thick overburden.

Broadhurst & Garth (1957-58, unpubl.) investigated the area for Clutha Development Ltd and came to the conclusion that the remaining reserves could not be mined profitably.

For a short period, auriferous quartz lodes were mined in the vicinity of Towalla (now abandoned; see Fig. 33), some 2½ miles south of the Russell terraces. Production came from small shoots in northwest-trending lodes in the Coolamon

Creek area. The reported grade of 2 to 3 oz per ton (Rands, 1894) was insufficient to counterbalance the high cost of transport and the inadequacy of the reserves; and the lodes weer abandoned in 1905.

Jordan Creek Goldfield

The Jordan Creek Goldfield, situated in mountainous jungle country west of Innisfail, comprises two separate groups of workings: the original prospects in the Jordan Creek and Henrietta Creek area, 10 miles southeast of Millaa Millaa and 1 to 2 miles south of the Palmerston Highway; and a later group of workings in the Myee Creek area, north of the highway, 7 miles southeast of Millaa Millaa.

The gold is contained in small quartz veins and leaders in decomposed granite. In places there is a slightly auriferous altered zone up to 10 feet wide around the quartz veins. Assays are reported to have shown 1 to 2 oz of fine gold per ton, but the average recovery grade was much less. Many of the thin leaders are manganiferous, and a little pyrite and arsenopyrite are also present.

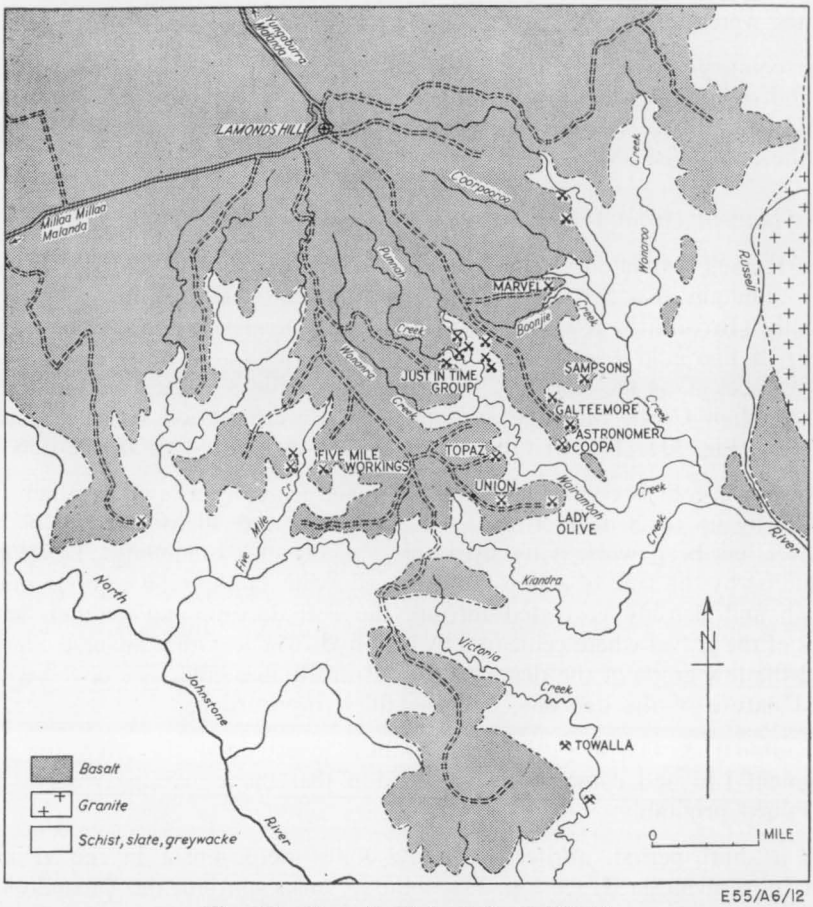


Fig. 33. Russell (Extended) Goldfield.

The Jordan Creek/Henrietta Creek lodes are arranged en echelon in a north-northeast-trending belt; they may have been formed in tension fissures caused by a dextral shear couple.

Much of the 12,750 oz of fine gold produced was won from alluvial deposits in creeks which have been worked out long ago; all recent production, amounting to several tens of ounces per year, has been derived from lodes mainly in the Myee Creek area.

Some prospecting has been done on a few deep leads under the basalt covering the granite, but the gold values are not high, and the tunnels need much timbering on account of the soft ground.

Starcke No. 1 and No. 2 Goldfields

In 1890 alluvial gold was discovered in Diggings (or Diggins) Creek, a branch of the Starcke River, 25 miles northwest of Cape Flattery; 2300 oz were recovered before the deposits were exhausted in 1895.

A smaller alluvial deposit was found in 1896 at Munburra, farther downstream, and this led to the discovery of the auriferous quartz reefs immediately to the north. Between 1898 and 1908 the reefs yielded 9190 oz of fine gold from 4858 tons of ore. The field (Starcke No. 2 Goldfield) was practically abandoned by 1909. The cessation of mining seems to have been brought about by poor management, the small scale of the operations, the high treatment costs and poor recovery from the battery, and the increased difficulties of mining below the water table. Few mines were worked below the water table at a depth of 50 to 100 feet, and the deepest workings were about 150 feet. Only high-grade ore, exceeding 1 to 2 oz per ton, could be treated economically, and there may remain fairly large orebodies carrying $\frac{1}{2}$ to 1 oz of gold per ton (Ball, 1909e). An attempt to develop one of the Munburra mines in later years is recorded by Beck (1935), but no further results have been reported.

The white quartz veins are commonly about a foot wide, and occur in the steeply dipping, north-striking greywacke and slate of the Hodgkinson Formation. The dip of the veins is variable, and the strike ranges from southwest to north-northwest. They are generally closely associated with oblique to subconcordant grey silicified quartz porphyry dykes (Morgan, 1964a, unpubl.), which postdate the development of cleavage in the Hodgkinson Formation. The veins are fissure and replacement veins with fragments and screens of brecciated country rock partly or wholly replaced by a mosaic of fine quartz. Other gangue minerals are arsenopyrite, pyrite, and sheets of calcite. Stibnite and cervantite were probably fairly common in the gold lodes, though they have not often been reported.

Mareeba Gold and Mineral Field

A small field, 5 miles southeast from the Mareeba railway station, produced 11,846 oz of fine gold, most of it from the Queen Constance lode, a north-northwest-trending, rather flatly dipping quartz reef standing out as the crest of a low hill. The country rock consists of slate and phyllite of the Barron River Metamorphics. After an initial production of 1770 oz in one year, the grade fell to less than 1 oz per ton, and after struggling on for another 8 or 9 years the field was abandoned.

Mount Peter Goldfield

Some 11,000 oz of fine gold were obtained from half a dozen irregular quartz lodes discovered in 1915 on the steep northern slope of Mount Peter, 3 miles west of Gordonvale. The lodes trend northeast and east-southeast across the regional strike of the Barron River Metamorphics, and contain shoots that are small and widely spaced. The average recovery grade was 1 oz 18 dwt per ton, though values of 4½ oz per ton were reported in some of the shoots. There was little activity after 1951.

Mulgrave Goldfield

Discovered in 1879, the Mulgrave Goldfield is the oldest of the smaller gold-producing areas, but its total recorded yield of 5580 oz is insignificant. Both alluvial and reef deposits were worked. Production was mainly alluvial, whereas lode mining was never successful because most of the reefs were low grade, and crushings showed poor returns notwithstanding promising assay results.

The lodes consist of narrow quartz reefs, generally ½ to 1½ feet thick, trending across and also subparallel to the strike of the enclosing Barron River Metamorphics. The workings, and the old mining township of Goldsborough on the west bank of the Mulgrave River, were deserted after 1905.

Alluvial deposits occur under the basalts on top of the spur separating South Toohey Creek from Butcher Creek, 8 miles east of Peeramon at the edge of the basalt-covered Atherton Tableland. At least three levels of wash were recognized by W. C. Ball (1941); the basalt cover is thin or absent in places. Little systematic geological work has been done in this area, although Ball believes that the wash forms a practically continuous sheet under the basalt.

Fluorspar Locality

The available information on the gold mining centre of Fluorspar, 10 miles southeast from Chillagoe, has been summarized by de Keyser & Wolff (1964). The lodes are in adamellite near its contact with the Featherbed Volcanics, and have produced some 5050 oz of mixed bullion and fine gold.

Tate Goldfield

The Tate Goldfield is mentioned in the Warden's reports and Annual Reports of the Department of Mines for the first few years of the 20th century. Prospecting for alluvial gold was carried out between Mount McDevitt and the Tate River, and Skertchly (1897) has described a rich but very small quartz vein in the Precambrian rocks 2 miles west of the Tate telegraph station, from which about 600 to 700 oz of gold were recovered. The best yield from the Tate area was 2000 oz in 1901; before and after that, the annual production was only several tens of ounces until about 1905.

Alice River (Philp) Goldfield

The reefs in the very short-lived Alice River Goldfield, roughly 120 to 130 miles west of Cooktown, form two main north-south lines about half a mile apart. They may be aligned along a fault zone. The country rock is reported to be granite. Discovered in 1904, the field produced about 2765 oz of fine gold mainly between 1904 and 1909, and was deserted soon afterwards.

Mount Wandoo

The available information on Mount Wandoo, 10 miles west from Mungana, has been summarized by de Keyser & Wolff (1964). Production figures are lacking, except for the years 1933-37 when 2100 oz were obtained. The workings occur in altered Precambrian ferruginous and micaceous gneiss and schist, and have been mined intermittently since 1901.

Bartle Frere Workings

The last field to be discovered, and one of the least successful, was the Bartle Frere field, 7 miles west of Babinda. The reefs occur in the Barron River Metamorphics at the northern foot of Mount Bartle Frere. The gold is contained in steeply dipping quartz reefs subparallel with, or in places transecting, the regional strike of the sediments. Assay values generally ranged from $\frac{1}{2}$ to 3 oz per ton, but the shoots were small, patchy, and irregular, and the cost of transport was high; the field was deserted after 1942, having yielded only 520 oz of fine gold.

Other Gold Prospects

Gold has been won in small quantities, or traces of gold have been reported, from many other localities.

In 1921, gold was discovered south of Six Mile Creek $4\frac{1}{4}$ miles southwest of Cooktown. The lodes strike west-northwest and north-south, and the grade of the ore ranged from 1 to $4\frac{1}{2}$ oz per ton (Moran, 1921).

Randalls mine, or the Freedom, is a quartz lode 8 miles southwest of Molloy. It was worked from 1939 to 1941 for a yield of about 650 oz of gold and 100 oz of silver from 230 tons of ore.

Three small quartz lodes have been reported from the Mitchell River area, south of Curraghmore homestead (Reid, 1932q). The quartz is ironstained in places, and contains free gold, pyrite, and galena.

Other small gold veins have been reported from the China Camp area (the Enterprise mine), 12 miles north of Daintree; from around Racecourse Mountain between Diggers Creek and the West Normanby River; and at Nolans Creek (Morton, 1939c), where some gold is associated with cobalt, bismuth, and arsenopyrite in low-grade pipe-like orebodies. Rich but small gold reefs have been

reported in diorite in the Gurrumba/Ord area, southwest of Emuford (Skertchly, 1897).

Between 1894 and 1898 attempts were made to work the low-grade quartz lodes at the Clohesy River, northeast of Mareeba. One shaft was sunk below 100 feet, but as the grade averaged only ½ oz per ton the prospect was abandoned. Another shaft was sunk to 135 feet at Kamerunga in 1933-34, but the prospect was soon closed down because of the irregular grade and the abundance of mine water.

At Mount Mascotte, 8 miles east-southeast of Atherton, about 200 oz of fine gold were mined from a quartz lode in a small inlier of chiastolite schist in the Atherton Basalt (Reid, 1931a).

Alluvial gold was won from the Tully River and from Culpa Creek, one of its tributaries, between 1894 and 1905; and from Sandy Creek, a tributary of the North Johnstone River. Small quantities of gold have been found in most of the streams draining the granite massifs west and southwest of Mossman; and in the St Georges River and its tributaries, Fine Gold Creek, and Hurricane Creek.

Sluicing prospects have been tested in the Russell River where it enters the coastal plain; in the North Johnstone River 8 miles west of Innisfail; and in creek alluvium at Eubanangee, 7 miles northwest of Innisfail (Reid, 1931b). Farther south, a little alluvial gold has been found in the headwaters of Yamanie Creek and Smoko Creek, tributaries of the Herbert River, and in the tin deposits on Broadwater Creek west of Cardwell. The Herbert River Gorge, west of the area mapped, has also been prospected for gold.

Traces of gold have been reported from a creek about 2 miles south of Ninian Bay (Downs, 1884); in association with native copper and silver in a thermal spring deposit on Noble Island (Cherry, 1908), and at White Rock south of Cairns.

Much gold was obtained as a by-product from the copper mines at Cardross, 20 miles west-northwest of Mungana, and in much smaller amounts from other copper mines in the Chillagoe area.

Tin

(Table 7, Fig. 34)

Gold was an important factor in the development of north Queensland, but the total value of the gold produced has been surpassed by that of cassiterite, which is the only mineral still being won in large quantities. It is estimated that, to the end of 1966, about 130,700 tons of cassiterite concentrate had been produced, valued at about £18,000,000. More than 80 percent of the tin was obtained from the Herberton Gold and Mineral Field: it represents slightly over half the total Queensland output, or 15 percent of the total Australian output. The production figures (Table 7) are very approximate only, as the output from numerous small scattered diggings has not been accurately recorded, and the figures for the alluvial deposits are incomplete.

TABLE 7: THE TINFIELDS OF NORTH QUEENSLAND
(See Fig. 34)

Name of District or Mining Centre (Date of discovery)	*Location*	*Estimated Production* (tons of concentrate)	*Description*	*Mineralogy*	*References*
Herberton/Mt Garnet district (1875) Centres: Herberton, Mt Garnet, Watsonville, Irvinebank, Stannary Hills, Coolgarra, Gurrumba, Glenlinedale, Nymbool, Brownville, Bakerville, Newellton, Emuford	Area between Herberton, Mt Garnet, and Petford; old Mt Garnet railway forms western boundary	107,685	(a) Lode tin. Mineralization genetically associated with Elizabeth Cr. granite which intrudes folded geosynclinal Devonian formations. Chlorite lodes (most important), greisen lodes, quartz lodes, biotite-quartz lodes, joint fillings, disseminations, and complex cassiterite-sulphide lodes Maximum depth worked: 1462 ft. Some important mines: Vulcan near Irvinebank, Great Northern near Herberton, and North Australian near Watsonville	Cassiterite; various amounts of stannite, wolframite, monazite, bismuth, bismuthinite, molybdenite, magnetite, arsenopyrite, pyrite, pyrrhotite, chalcopyrite, sphalerite, galena, stibnite, marcasite. Gangue minerals: quartz, chlorite, calcite, siderite, biotite, muscovite, kaolin, tourmaline; little topaz, fluorite, beryl	Broadhurst (1942, 1951), Cameron (1904b), Edwards (1951), Jack (1883a), Jensen (1939b, unpubl.), Munday (1895), Reid (numerous references), Skertchly (1897, 1899). See Blake (1968, unpubl.) for bibliography
1883	Old Wild R. valley S of Herberton		(b) Deep leads: sand and gravel, 5-25 ft thick, overlain by 50-100 ft of basalt	Cassiterite	Cribb (1946), Reid (1932m), Cuttler (*In:* Blake, 1968, unpubl.)
			(c) Alluvial deposits along many streams. Since 1939 large-scale dredging operations in Smiths Cr., Return Cr., and Battle Cr., by Tableland Tin Dredging N.L. and Ravenshoe Tin Dredging Ltd	Cassiterite	Zimmerman, Yates, & Amos (1963, unpubl.), Sedmik (1963, unpubl.), Horvath & Hussin (1966, unpubl.)

TABLE 7 (continued)

Name of District or Mining Centre (Date of discovery)	*Location*	*Estimated Production* (tons of concentrate)	*Description*	*Mineralogy*	*References*
Cooktown Mineral Field (1885)		13,000 (from all sources in both fields) (12,210)			
1. *Annan River Tinfield* Centres: Rossville, Helenvale, Shiptons Flat, Tabletop, Lower Tableland, Big Tableland, Mt Leswell, Mt Hartley, Mt Amos, Mt Romeo, Mt Poverty, Mt Finlayson	Area drained by Annan R., from about 10-30 miles S of Cooktown (Pl. 27)		(a) Recent and sub-Recent alluvial deposits	Cassiterite	Jack (1891a), Saint-Smith (1916e, detailed descriptions of all occurrences)
			(b) Deposits in older alluvial terraces (e.g., at Mt Poverty)	Cassiterite	
			(c) Lode deposits in granite: generally disseminations in decomposed greisenized granite traversed by stanniferous quartz-tourmaline veins. Worked by hydraulic sluicing methods		
			(d) Tin lodes near granite contact, but rarely in sediments. Irregular pipes and segregations of stanniferous quartz-tourmaline rock	Cassiterite; commonly accompanied by arsenopyrite, occasionally by wolframite. Little molybdenite, galena, native copper	
2. *Bloomfield River Tinfield* Centres: China Camp, Lode Hill, Alexander Cr	40 miles S of Cooktown	(700)	(a) Alluvial deposits on Baird Cr. and Alexandra Cr	Cassiterite.	
			(b) Lode Hill: disseminated cassiterite in decomposed greisenized granite traversed by stanniferous quartz-tourmaline veins. Worked by hydraulic sluicing	Cassiterite.	Saint-Smith (1916s)

TABLE 7 (continued)

Name of District or Mining Centre (Date of discovery)	*Location*	*Estimated Production* (tons of concentrate)	*Description*	*Mineralogy*	*References*
Chillagoe Gold and Mineral Field		Roughly 11,000 (from all localities)			
Gilmore mines	16 miles NW of Mt Garnet	3700	Mineralization in kaolinized fault zones within chert and chloritic beds, about 1 mile from nearest granite outcrop	Cassiterite; arsenopyrite, pyrite, chalcopyrite, some galena and wolfram	Dimmock & Cordwell (1959, unpubl.)
Koorboora/Petford area (1888)	About 70 miles SW of Cairns	(roughly 4450)	Production mainly from lodes: ill defined bodies of chloritized kaolinized sediments, containing ore shoots that tend to be irregularly pipe-like. Dover Castle mine, 4 miles NW of Petford, differs in that it is a well defined lode and is located in volcanics. Other mines: Two Jacks, Tennyson, Fair Play, Shakespeare	Cassiterite, with some wolfram especially near the surface. Complex cassiterite-sulphide ores at depth. Gangue: chlorite, kaolin, quartz, sericite	Blanchard (1947), Cameron (1904b), Jack (1891), de Keyser & Wolff (1964), Levingston (1960a)
Sunnymount area (1908)	5 miles ESE of Koorboora	(roughly 700)	Mineralization in chloritized, kaolinized sediments, at the intersection of fault-planes and joints. Mines: Tommy Burns, Prince Alfred. The Christmas Gift is a cassiterite-quartz vein	Cassiterite; some wolfram, a little galena and chalcopyrite. Gangue: chlorite, kaolin, quartz, tourmaline, garnet	Ball (1917), de Keyser & Wolff (1964), Levingston (1958b)
Tate R. area	Main centre at Fischerton, an abandoned settlement near junction of Tate and Rocky Tate Rs	(roughly 2000)	Mainly alluvial deposits, with cassiterite derived from minute seams in nearby granite. Little information available. Streams worked for tin in headwater region include: California, Spinifex, and Halpin Crs	Cassiterite	Ann. Repts, Dept of Mines

TABLE 7 (continued)

Name of District or Mining Centre (Date of discovery)	*Location*	*Estimated Production* (tons of concentrate)	*Description*	*Mineralogy*	*References*
Fossilbrook area	Area along Lynd R., 40 miles SW of Almaden	?	Mainly alluvial deposits, with cassiterite derived from quartz-muscovite-chlorite greisen lodes. No production figures known. Streams worked include: Fulford, Nuggety, Blackfellow, and Durbins Crs	Cassiterite	Zimmerman & Ruker (1962, unpubl.)
Big Watson Cr. area	25-30 miles N of Chillagoe	?	(a) Small alluvial creek deposits.	Cassiterite	Ann. Repts, Dept of Mines, for 1924-8
			(b) Pandora tin lode ('Watson tin mines'): a WNW shear zone, with tin mineralization genetically related to Elizabeth Creek Granite 2 miles to the E	Cassiterite	de Keyser (1961, unpubl.), Saint-Smith (1923a)
Palmer R. district and *Mossman hinterland*					
Cannibal Cr. lodes	20 miles SE of Maytown	?	Parallel, WNW quartz lodes in sediments of the Hodgkinson Formation	Cassiterite	Clappison (1940c, unpubl.), Jack (1888e)
Cannibal Cr., Granite Cr., and other branches of the Palmer R.		2375 (from 1879-84)	Small alluvial deposits, with cassiterite probably derived from thin quartz leaders and from Cannibal Cr. lodes	Cassiterite; gold	Jack (1888e)

TABLE 7 (continued)

Name of District or Mining Centre (Date of discovery)	*Location*	*Estimated Production* (tons of concentrate)	*Description*	*Mineralogy*	*References*
Mossman hinterland	Scattered localities in country W of Mossman	About 1180?	(a) Small scattered alluvial deposits in most creeks running off the granite tablelands west of Mossman: Mt Spurgeon, Mt Frazer, Mt Lewis, Mt Windsor, Mt Alto, Lighthouse Mountain. Source: thin quartz leaders	Cassiterite; locally some wolfram	Ball (1915), Clark (1959, unpubl.), Jensen (1927), Reid (1932i)
	6 miles S of Carbine	—	(b) Lode tin on Mt Holmes: thin quartz and pegmatite veins in roof contact zone of granite. No production. The Vera prospect, 1 mile NE of Mt Carbine, is another lode	Cassiterite; some wolfram	Ball (1912a), Morton (1931c)
Other localities Broadwater Cr. (1905)	5½ miles SW of Cardwell	?	Alluvial deposits in faults up to 2½ chains wide, along creeks on dissected jungle-covered granite plateau. First payable deposits found as late as 1939	Cassiterite; traces of gold and wolfram	Cribb (1940, unpubl.)
Tinaroo leases (1878)	6 miles NNE of Atherton	?	(a) A few small alluvial pockets in gullies along Barron R.	Cassiterite	
			(b) Unpayable lode deposits near granite contact	Cassiterite; tungsten and molybdenum minerals, and some chalcopyrite	Jensen (1920a), Saint-Smith (1913d)
Hartleys Cr.	20 miles NW of Cairns	?	Mineralized biotite - muscovite - tourmaline granite		Horsley (1912)

TABLE 7 (continued)

Name of District or Mining Centre (Date of discovery)	*Location*	*Estimated Production* (tons of concentrate)	*Description*	*Mineralogy*	*References*
Battle Camp siding	30 miles W of Cooktown	—	Traces only. No production	Cassiterite	Lucas (1962, unpubl.)
Barrow Point	15 miles SE of Cape Melville				Ball (1939, unpubl.)
Noble Is.	13 miles SE of Barrow Pt				Cherry (1908)



Fig. 34. Locality diagram of the tin, tungsten, molybdenum, and bismuth occurrences.

The main centres are the greater Herberton district (including the Mount Garnet area), the Cooktown district (with the Annan River and Bloomfield River tinfields), and the Chillagoe district (Koorboora, Sunnymount, and the Tate/Fossilbrook areas). Numerous smaller prospects are scattered over the map area, mainly around the granite tablelands west of Mareeba, and near Cardwell in the south (Fig. 34).

Herberton/Mount Garnet District

(see Blake, 1968, unpubl., for details and bibliography)

Mulligan first reported the presence of tin in the Wild River near Herberton in 1875, and in 1878 John Atherton showed prospectors tin-bearing localities at Tinaroo and, the following year, in the Wild River, but very little interest was aroused because of the remoteness of the deposits from the nearest settlements on the Palmer River. It was not until rumours were heard of a big discovery by the Chinese in 1880 that the first claim was filed and subsequently the Great Northern lode was discovered. Soon the township of Herberton was founded, and prospectors swarmed out to the west and south and discovered numerous lodes not only of tin, but also of silver, lead, copper, and tungsten ores. When the North Australian mine was opened the township of Watsonville was established, and other finds resulted in the establishment of Irvinebank, Stannery Hills, Coolgarra, Gurrumba, Glenlinedale, Nymbool, Brownville, Bakerville, etc., while Mount Garnet was built near the site of a big copper lode in 1883. In that same year the Herberton deep lead was found, and for a while it was the chief source of alluvial tin in the district. Other alluvial deposits were worked along the Tate River. In those days, 160 lode tin mines and 32 silver-lead mines were reported to be in operation. The number fell off rapidly after 1883, and most of the production became centred around Herberton and Irvinebank, mainly from the Vulcan mine, the greatest of all north Queensland tin mines.

Lode mining gradually lost its importance because of the rising cost of mining, increased transport costs when nearby batteries were abandoned, and decreasing grades. Industrial trouble in 1911 gave the coup-de-grace to many workings, and most of the batteries were taken over by the Queensland Government. Subsequent production was derived largely from the old dumps, although some of the lodes were mined successfully from time to time.

Skertchly (1897) lamented the wasteful greedy mining of the tin lodes in those early days. Because of the ready availability of good ore near the surface, and spurred by high prices, only the richest portions were taken out before the mines were abandoned, but '. . . the ore remaining was richer than any miner in Cornwall ever saw'. Development was not planned (except at the Great Northern mine), mining methods were primitive, shafts crooked, and technical knowledge wanting. Usually no plans or sections were made, nor were records kept. Skertchly also scorned the popular belief that the lodes petered out at a depth of a few hundred feet, and demonstrated that some of the tin lodes extended down to at least a thousand feet. He concluded that many of the mines abandoned were as rich as ever, and that pinching out of the lodes could be expected to be followed downward

by swelling again. This was recently confirmed in the Dover Castle mine, 4 miles northwest of Petford, where a lode long ago abandoned was successfully reopened (de Keyser & Wolff, 1964, p. 103).

Since about 1930 most of the tin has been won by dredging in Return Creek and Smiths Creek by Tableland Tin Dredging N.L. and, from 1957, in Battle Creek and later in Nettle Creek by Ravenshoe Tin Dredging Ltd. From 1939 to the end of 1966 inclusive the two dredges produced about 20,000 tons of cassiterite concentrate.

The total recorded output from the Herberton/Mount Garnet district (including the Emuford area) to the end of 1966 was 107,685 tons of 70 percent cassiterite concentrate, more than half of which was obtained from lodes, mainly in the Vulcan mine. Recovery grades ranged from about 1 to over 30 percent cassiterite, and in the early period grades up to 50 percent were not uncommon. The various mining centres around Herberton, Watsonville, Emuford, Ord, Irvinebank, etc., have been described in numerous papers by Jack (1883a), Munday (1895), Skertchly (1897, 1899), Cameron (1904b), Reid (many references), Jensen (1939b, unpubl.), Broadhurst (1942, 1951), and many others. A complete bibliography is given by Blake (1968, unpubl.).

The Herberton/Mount Garnet district consists of folded geosynclinal formations which are unconformably overlain by Permo-Carboniferous volcanics and intruded by the Permo-Carboniferous Herbert River and Elizabeth Creek Granites. The tin mineralization is genetically associated with the Elizabeth Creek Granite, which commonly consists of pink leucocratic biotite adamellite, and is more acid than the hornblende-biotite adamellite and granodiorite of the Herbert River Granite.

Tin Lodes. Cassiterite is widely distributed in various types of lodes in the granite and sedimentary formations. They include (see Blake, 1968, for details):

a. Disseminations in granite, but only within several feet of tin-bearing lodes.

b. Massive greisen, restricted to the roof zone of the granite. These deposits are large but low grade, and may have been the main source of the alluvial deposits. The deposits are too low-grade to be mined.

c. Greisen lodes, which crop out as steeply dipping veins ranging from less than an inch to several feet wide, and from a few feet to over a mile long. They consist mainly of quartz and lithium-bearing mica, and contain clusters of disseminated crystals of cassiterite. Small amounts of wolfram, topaz, and fluorite are commonly present. The greisen lodes are small and only the richer shoots have generally been worked. Most of the lodes occur in the granite, but a few are found in the sediments.

d. Cassiterite-quartz lodes, which consist of rich bunches of ore in barren quartz. They occur mainly in the sediments. Production has been small. Some of the lodes contain abundant tourmaline.

e. Cassiterite-biotite-quartz lodes, which occur only in granite; they are composed mainly of green biotite and quartz, with a little brown biotite.

f. Chlorite lodes. This type of lode, which occurs in the granites as well as in the intruded sediments, has accounted for most of the output from the lodes. They crop out as dark, iron-rich, siliceous, massive veins with thin stringers and knots of vein quartz. Kaolin is a common associate, and

calcite may also be present. The cassiterite is usually fine-grained (less than 0.1 mm), which makes the ore difficult to treat.

g. Lodes associated with aplites. Cassiterite occurs in joints in aplitic granite, or is associated with aplitic dykes. Greisen is usually present.

h. 'Streaky tin' lodes. Cassiterite fills fine joints in the country rock, caused by fracturing adjacent to faults. Though rich, these deposits are very small.

i. Complex sulphide-cassiterite lodes, common in many mines. The cassiterite is mainly associated with copper sulphide and with the sulphides of silver, lead, and zinc, and locally some bismuth. The complex lodes are generally gossanous at the surface.

The lodes are confined to zones of pneumatolytic and hydrothermal alteration along joints, faults, or fractures in the roof zone of the granites or in the country rock close to the granite contact. The intruded rocks include not only sediments, but also Herbert River Granite, and Permo-Carboniferous volcanics, forming roof pendants in the Elizabeth Creek Granite.

Structural control of the deposits is evident from the studies by Broadhurst (1951, 1953) and others. The mineralization occurs along steeply dipping tensional joints ('indicators'), but is often cut off or displaced by transecting flat joints or faults ('breaks') which nevertheless antedate the mineralization. Many of the orebodies form short irregular pipes which are possibly controlled by intersecting fractures or joint planes, though Amos (1963, unpubl.) found no evidence to support this view.

Lithological control is far less obvious, and has been observed in a few localities only; in one mine, for example, selective mineralization has occurred in four massive fine-grained arenites (Blanchard, 1947).

Most of the lodes were worked to a depth of a few hundred feet only, with the notable exception of the Vulcan mine, near Irvinebank, which went down to 1462 feet.

The minerals reported in lodes include cassiterite, stannite, wolfram, monazite, native bismuth, bismuthinite, molybdenite, magnetite, arsenopyrite, pyrrhotite, pyrite, chalcopyrite, sphalerite, galena, stibnite, and marcasite. Many occur in small amounts only, but in the complex lodes the sulphides are sufficiently abundant to be mined for copper and silver-lead.

Gangue minerals include quartz, chlorite, calcite, siderite, kaolin, biotite, muscovite, tourmaline, and a little fluorite, topaz, and beryl.

The minerals present in the complex ores indicate a wide range in the temperature of formation of the ore. The paragenesis has not been studied in detail, but Edwards (1951) has shown that the order of deposition is cassiterite, followed by arsenopyrite and pyrite, then pyrrhotite, and finally galena, sphalerite, chalcopyrite, and stannite. During further cooling pyrrhotite was replaced by marcasite, and carbonates were formed in the gangue.

The proportion of cassiterite in the complex orebodies may increase or decrease downwards (Blanchard, 1947).

The tin mineralization is associated with the Elizabeth Creek Granite, but initially it was thought that the cassiterite had been introduced by 'basic dykes' (the chlorite lodes) (Jack, 1883a; Maitland, 1891b). Munday (1895) disagreed, pointing out that in depth the 'dykes' resembled ordinary tin veins, and that '. . . the enclosed minerals (are) in a more banded form and parallel with the walls of the enclosing fissure'. Skertchly (1897) considered that the source of the lodes was deep-seated, and that they were mainly controlled by dykes and faults. Cameron (1904b) recognized the genetic relationship of the tin veins to the granite, and the hydrothermal alteration of the country rock. Ball, in a foreword to Reid (1933), suggested that there were probably two granites, and that aplite is associated with the lode 'injection' at Herberton. The regional mapping since 1958 has established the close association of the tin mineralization with the more acid and leucocratic of the granites.

Deep Leads. The deep leads at Herberton, discovered in 1883, are among the most important of the alluvial deposits. The leads consist of cassiterite-bearing sands and gravels, 5 to 25 feet thick, overlain by 50 to 100 feet of basalt, upon an uneven basement of granite. There are several buried channels over a width of at least half a mile in the pre-basaltic valleys of the Wild River and its tributaries, mainly between Wondecla and Kalunga. The leads were worked by means of numerous shafts and a number of adits, and values up to 40 lb per cubic yard have been reported (Reid, 1932m). A geophysical investigation by AGGSNA in 1938 suggested the existence of another lead: it was tested in 1942, but the values encountered were unpayable (Cribb, 1946). Probably more than 4000 tons of cassiterite concentrate have been won from the leads.

Recent Alluvial Deposits. The Recent sands and gravels along the streams have been worked extensively, but the production records are incomplete. The streams worked include the Wild River, Dry River, Emu Creek, California Creek, Return Creek, Smiths Creek, Battle Creek, Chinamans Creek, Eureka Creek, Nettle Creek, and many of their tributaries. Many of the smaller stream deposits have been exhausted, but since 1939 considerable amounts of tin have been obtained by dredging in Smiths Creek, Return Creek, and Battle Creek: from 1939 to the end of 1966, 20,000 tons of cassiterite concentrate were produced by Tableland Tin Dredging N.L. and Ravenshoe Tin Dredging Ltd (from 1957). Production in 1967 from these two dredges was 1442 tons of concentrate, about 20 percent of Australia's total output.

In 1962, the alluvial prospects in the Mount Garnet area, including the 'Ancestral Tate River prospect' and the 'Wurruma prospect' of Best (1962, unpubl.), were evaluated by detailed geological mapping, geomorphological studies, refraction seismic and gravity surveys, and scout boring, by the Bureau of Mineral Resources and the two dredging companies (Zimmerman et al., 1963; Sedmik, 1963; Hussin & Horvath, 1963). It was concluded that no further payable alluvial tin deposits are present in the Mount Garnet area. Nevertheless, Loloma Mining Corporation N.L. started dredging at Stannary Hills in 1965, and in almost two years produced 277 tons of cassiterite concentrate.

Cooktown Mineral Field

In 1885, alluvial cassiterite was discovered in Wallaby Creek and the upper Annan River valleys, and from 1885 to 1963 the total output of cassiterite concentrate from the Cooktown Mineral Field was 13,000 tons, almost all from alluvials. Peak production was reached in 1888 with 1051 tons; from 1896 to 1922 the average annual output ranged from 105 to 297 tons; and since then the yield has dwindled to a few tons per year.

The Cooktown district includes the Annan River tinfield (roughly the area drained by the Annan River from 10 to 30 miles south of Cooktown) and the much smaller Bloomfield River tinfield, which includes the workings at China Camp and the Roaring Meg area (the upper part of the Bloomfield River), some 40 miles south of Cooktown.

Centres in the Annan River field included Rossville, Helenvale, Shiptons Flat and Tabletop, Lower Tableland, Big Tableland, Mount Leswell, Mount Hartley, Mount Amos, Mount Finlayson, Mount Romeo, Mount Poverty, and Slatey and Granite Creeks (Pl. 27). The workings have been described in detail by Saint-Smith (1916).

Cassiterite occurs in Recent stream alluvium, older alluvial terraces, granite, and the contact zone around the granite.

Many of the deposits worked by sluicing consist of thoroughly decomposed greisenized granite containing disseminated cassiterite and stanniferous quartz-tourmaline veins and pockets. They are difficult to distinguish from the overlying alluvial and colluvial deposits. The disseminated deposits are enriched at the surface by leaching and removal of rock components, but the lower-grade decomposed rock is so soft that it can be worked economically by hydraulic sluicing.

Although most of the rich deposits worked in the early period consisted of Recent stream alluvium, some of the more extensive alluvial deposits occur high up in the relatively gently graded headwaters of the streams (Cameron, 1907), such as those at Big Tableland, Romeo, and Poverty. The high-level alluvials, especially at Poverty (Pl. 18, fig. 1), were deposited on an older and more mature erosion surface, possibly of Tertiary age. The deposits at Poverty, 1800 feet above sea level, consist of consolidated clay and mottled clayey grit and sand which are finer in grain than the Recent deposits.

Because of the mountainous terrain and the immaturity of the valleys, only small scale alluvial mining is possible. Suction-dredging was attempted in 1898 in Wallaby Creek, but the recovery plant was inefficient, and the dredge was lost in a flood (Cameron, 1907).

Mining of lode cassiterite began in 1887, but the small rich lodes at Mount Amos and Mount Leswell were soon worked out. The Lions Den mine near Mount Amos produced about 50 tons of cassiterite concentrate before closing down in 1891. The lodes occur mainly in granite, commonly at or near the contact with the intruded sediments; lodes in the sediments are extremely rare. The lodes are quartz-tourmaline segregations and irregular pipes (Jack, 1891a), possibly associated with joints (Cameron, 1907). Some of the quartz-tourmaline

veins are up to 6 feet wide; many are steep and can be traced for a hundred yards or more. The trend of the veins ranges from north-northwest to north-northeast.

Arsenopyrite is commonly associated with the cassiterite, or occurs alone in thin seams; wolfram is present in some mines. Small amounts of molybdenite, native copper, and galena have been reported from a few localities. According to Saint-Smith, the traces of gold in the alluvial sands were probably derived from thin quartz leaders in the sediments and not from the tin lodes.

The extensive areas of alluvium along the Annan River to the north and west of the alluvial workings have been considered as potential dredging prospects. Among the areas tested were the alluvial flats near Helenvale (Pl. 27) and on Mungumby Creek. Saint-Smith (1916e) quoted values of about 1 lb per cubic yard, but suspected that the values might be too high 'in view of the rather excessive amounts of black sand accompanying the tin'. In 1937, the Broken Hill Pty Co. Ltd tested the Helenvale flats again, and also an area along the lower part of the Annan River from Pooles Lagoon to the Annan bridge (QDM, 1937, p. 68). Values encountered in boreholes were less than $\frac{1}{2}$ lb per cubic yard and were considered to be unpayable. In 1961, a large potential dredging prospect was located at Kings Plains, 10 miles northwest of the Annan River tinfield, by the Bureau of Mineral Resources (Lucas, 1962, unpubl.). The prospect consists of 15 miles of an abandoned and alluviated river valley, the former east-west reach of a river (the upper part of the present Annan River) which drained north from the tinfield and then curved to the west to join the Normanby River. This ancestral Annan River was captured during the Quaternary by a tributary of Oaky Creek at the elbow at the eastern end of the alluviated section, which was left stranded and now forms the Kings Plains with its two lagoons (Pl. 18, fig. 2). The prospect was tested in 1962 by the Bureau of Mineral Resources by percussion drilling and gravity surveys (Best & Dallwitz, 1963, unpubl.). Fourteen gravity traverses, designed to outline the basement profile, were completed across the east-west valley from 6 miles west of the Annan River gorge. Fourteen holes were drilled with an aggregate footage of about 1900 feet; six holes reached basement. The drilling confirmed the presence of coarse alluvial sediments below the fine-grained alluvium at the surface. The depth of alluvium in the eastern holes ranged from 135 to 150 feet and in the western holes from 150 to 167 feet or more. The sections in all holes included 40 to 70 feet of ferruginous mottled sandy clay resting on 80 to 120 feet of coarse stream sediments with minor black or dark grey pyritic clay. The grade of the deposits was found to be uneconomic. Magnetic heavy minerals were abundant, with the greatest concentrations in the lowermost 20 to 40 feet. The cassiterite content ranged up to 13 oz of 72 percent concentrate per cubic yard for the interval below 100 feet in the eastern holes. Bulk values were less than 5 oz of cassiterite per cubic yard, with higher values generally in the east than in the west.

As a result of the investigation, it was suggested that the Mungumby Creek valley, which is continuous with the Kings Plain valley, is a likely prospect. The valley would have received none of the Annan River lode, but should have collected all the detritus from the steep western side of Big Tableland, which has

been one of the main producing centres of the tinfield in the past. Also, the rich Lions Den lode was worked on the western scarp overlooking the Mungumby Creek valley.

The Bloomfield River tinfield has been of much less significance than the Annan River field. Mining was centred around China Camp, now a deserted settlement about 40 miles south of Cooktown. Both alluvial and lode tin was mined, with a total recorded output of about 700 tons. Alluvial cassiterite was won on Baird Creek at China Camp, and on Alexandra Creek, a tributary of Roaring Meg Creek (which is the upper part of the Bloomfield River).

The 'lode' at China Camp (Lode Hill) was discovered in 1908. It consists of decomposed greisenized granite containing disseminated cassiterite and cassiterite-bearing quartz-tourmaline veins and ferruginous leaders. The decomposed granite is so soft that it could be worked to an average depth of 80 feet by hydraulic sluicing. Saint-Smith (1916e) had a high opinion of the locality because of the extent of greisenization, the depth and intensity of decomposition, and the satisfactory water supply.

In 1961-62, the Broken Hill Pty Co. Ltd investigated the potential of the deposits at China Camp and the Annan River field, with negative results.

Chillagoe Gold and Mineral Field

The total output of tin concentrates from the Chillagoe Gold and Mineral Field is estimated at 11,000 tons to the end of 1966. The tin has been obtained from widely scattered sources including the Sunnymount and Koorboora areas, the Tate River and Fossilbrook regions, and several other less important localities.

The workings in the Sunnymount and Koorboora areas have been described by de Keyser & Wolff (1964). Between 1900 and 1917, many of the lodes in the Koorboora area and, from 1908, in the Sunnymount area were extensively worked. After 1912 many mines were forced to close down owing to labour trouble. Between 1917 and 1920, production was practically restricted to the Two Jacks mine, 2 miles east-northeast of Koorboora siding, which had only recently been discovered. Since the cessation of mining at the Two Jacks in 1920, production has been small and intermittent. In 1959 a new rich ore shoot was developed in the old Dover Castle tin mine.

The mineralization in the Koorboora and Sunnymount areas is similar to that in the greater Herberton district: the lodes are ill defined bodies of chloritized, kaolinized, and altered Palaeozoic formations merging gradually into the unaltered sediments. They contain irregular pipe-like ore shoots which are reported to be located at the intersections of fissures and joints. The ore shoots grade into the barren lodes.

Blocks of granite have been found on the dumps of at least one of the mines so that the parent granite is probably present at no great depth.

Most of the lodes contain some wolfram in the upper zones, and several of the mines have been worked exclusively for wolfram. In the lower parts of the lodes there is commonly an increase in the proportion of base-metal sulphides as

in the Herberton district. The high cost of treating these complex ores usually led to the closing of the mines.

The Dover Castle lodes, 2 miles west of the wolfram mines at Bamford Hill northwest of Petford, differ from the other lodes in the district in that they are located, not in sediment, but in Featherbed Volcanics, and are well defined with definite hangingwall and footwall. Worked from 1906, and considered to be exhausted by the time the shaft was down to about 300 feet, the mine was sold in 1958. The new owner, on sinking a few more feet, uncovered a new ore shoot, and in 1962 the shaft had reached a depth of 600 feet. Up to the end of 1966 the mine had produced 615 tons of concentrate, of which over 63 percent was won after 1958.

The main alluvial workings in the Tate River area were centred around the former township of Fischerton (or Fisherton), near the junction of the Tate and Rocky Tate Rivers. Between 100 and 200 tons of cassiterite concentrate were produced annually from 1883 to 1903, but subsequently the yield fell to a few tons. The tin was derived from the nearby granite, which is reported to contain minute seams filled with cassiterite. Alluvial tin has been worked in California, Spinifex, and Halpin Creeks, which are tributaries of the Tate River. One of the sources of the California Creek deposits was probably the lodes of the Gilmore mines 9 miles southwest of Emuford. Geologically, these lodes belong to the Herberton/ Emuford district. The mineralization is located in kaolinized fault zones within chert and chloritic beds of the Mount Garnet Formation, about 1 mile from the nearest granite outcrop. Minerals associated with the cassiterite include wolfram, arsenopyrite, chalcopyrite, pyrite, and galena. According to Dimmick & Cordwell (1959, unpubl.) the output to 1957 was about 3215 tons of concentrate. The mine was revived in 1958, and subsequently produced about 480 tons of cassiterite to the end of 1966, mostly while held by Clutha Development Pty Ltd.

In 1961, the Bureau of Mineral Resources investigated the alluvial tin potential of the Fossilbrook area, of which little was known (Zimmerman & Ruker, 1962, unpubl.). The area lies along the Lynd River, 40 miles southwest of Almaden. Elizabeth Creek Granite intrudes Precambrian migmatite, gneiss, and schist; the granite contains quartz-muscovite-chlorite greisen lodes which are the source of the alluvial tin deposits. The valley of the Lynd is a broad alluviated plain, but the investigation showed that the alluvials are very thin and unsuitable for the large-scale exploitation. Among the streams that have been worked for alluvial cassiterite are Fulford, Nuggety, Blackfellow, and Durbins Creeks. No production figures are available.

Tin also occurs at Big Watson Creek to the north of Chillagoe. Saint-Smith (1923a) reported on the alluvial workings in Big Watson Creek, and also mentioned the 'Watson tin mines', which are probably the same as the ones known later as the Pandora workings. The Pandora lode is situated on a west-northwest-trending shear zone extending from the junction of the Almaden and Elizabeth Creek Granites about 2 miles east of the mine. The mineralization is undoubtedly related to the Elizabeth Creek Granite as in the Greater Herberton district and other areas. The main orebody is possibly pipe-shaped, and was formed at the intersection of the shear zone and the northerly continuation of the Nightflower line of faulting

(see p. 216). Production is unknown, but was probably small, although grades of 30 to 45 percent of cassiterite were reported, and a recovery grade of 10 percent is indicated.

Palmer River District, and the Mossman Hinterland

Small amounts of alluvial tin were won from many of the southern tributaries of the Palmer River east of Maytown, in many places in conjunction with the gold. About 2375 tons of alluvial cassiterite concentrate, valued at £102,300, were mined in Cannibal Creek and especially Granite Creek between 1879 and 1884. Subsequent production was small.

Lode tin was won from the Cannibal Creek tin workings (Jack, 1888a; Clappison, 1940c), 20 miles southeast of Maytown. The lodes are parallel and occur in a belt 200 feet wide. They trend west-northwest, dip steeply north, and consist of white to dark grey quartz, which is micaceous in places. The cassiterite is generally associated with the mica-rich zones, and is distributed erratically. The lodes are irregularly shaped, with repeated bulges and branches; the mineralization dies out to the east, and is cut off to the west by a chloritized shear zone trending north-northeast. In 1938 the lodes were tested by a company which suspended operations the following year. Production figures are not available.

Cassiterite is also widely distributed in the Mossman hinterland (Jensen, 1927). Alluvial cassiterite is present in virtually all creeks running off the granite tablelands to the north and west of Molloy, and has been worked in many places. The eastern slopes of the tablelands are reported to contain the richer accumulations. The known localities include Mount Spurgeon (Ball, 1915; Reid, 1932i), Mount Frazer, Mount Lewis, Lighthouse Mountain, Mount Windsor, and Mount Alto, and the headwaters of the Mossman and Daintree Rivers. At Mount Alto wolfram is found in association with the cassiterite. All the deposits are small, and the large alluviated areas extending from Molloy to Mount Carbine and beyond appear to be the best prospects for large companies. The Station Creek alluvial flats were tested by scout drilling in 1958 by New Consolidated Gold Fields Pty Ltd (Clark, 1959, unpubl.). The alluvium was found to be generally 40 to 60 feet thick, but the tin was not of economic grade.

The cassiterite is derived from numerous small stanniferous quartz veins and pegmatites and possibly patches of greisen around the granite tablelands. The veins are generally too small to be worked, and in most places are covered by tropical rain forest. Attempts were made to mine the tin veins at Mount Holmes (Ball, 1912a; Morton, 1931c), 6 miles south of Mount Carbine, where the roof of the granite has only recently been uncovered by erosion. In the roof zone of the granite and the overlying sediments, there are numerous small thin northeast-trending veins of cassiterite-bearing quartz and pegmatite which are cut by granite dykes intruded parallel to the regional north-northwest strike of the country rock. Slightly lower down, on the southeastern flank of the mountain, wolfram-quartz veins crop out.

Other Localities

Although the presence of cassiterite in the upper reaches of Broadwater Creek, high up on the mountainous tableland 5½ miles southwest of Cardwell, had been known since 1905, it was not until 1939 that payable deposits were found. The cassiterite occurs in Recent alluvial flats up to 50 yards wide, along the creeks on the dissected jungle-covered granite plateau (Cribb, 1940, unpubl.), and is accompanied by traces of gold and wolfram. The rough and inaccessible terrain is a major obstacle to mining.

Several prospects in the Tinaroo group of leases, 8 miles north-northeast of Atherton, contain tin in association with tungsten and molybdenum minerals and some chalcopyrite (Saint-Smith, 1913d; Jensen, 1920a). The veins are too low grade to be mined, but a few alluvial pockets in the gullies along the Barron River have yielded some concentrate.

Small amounts of cassiterite were recovered from Hartleys Creek, 20 miles northwest of Cairns (Horsley, 1912), where a small body of granite containing varying amounts of tourmaline, biotite, and muscovite is exposed along the coast.

A little cassiterite is also associated with the alluvial gold deposits in the Russell field, and traces of tin have been reported at White Rock, south of Cairns.

Alluvial cassiterite and tourmaline have been recorded south of Battle Camp siding, 30 miles west of Cooktown, and were probably derived from the nearby Puckley Granite (Lucas, 1962, unpubl.). Cassiterite is also known in the alluvials at Barrow Point, 15 miles southeast of Cape Melville, and a trace is reported from Noble Island (Cherry, 1908). The Barrow Point deposits were prospected by the Broken Hill Pty Co. Ltd in 1937 (Ball, 1939, unpubl.). The alleged occurrence of cassiterite on Howick Island (Idriess, 1938) probably refers to the cassiterite on Noble Island (Lucas, 1962, unpubl.).

Tungsten, Molybdenum, and Bismuth
(Table 8, Fig. 34)

Until 1920, Queensland mines were the most important producers in Australia of tungsten; and still provide more than half the Australian production of molybdenum.

The three major fields of Wolfram Camp, Bamford Hill, and Mount Carbine were discovered in 1893 and 1894. For the next twelve years most of the wolfram was derived from rich eluvial deposits, but when they were depleted, lode mining gradually increased during a period of rising wolfram prices. In 1900 a market was found for molybdenite, which increased the prosperity of the Wolfram Camp and Bamford Hill fields, and peak production was reached during World War I, when the price for wolfram rose from £100 to £200 per ton and molybdenite was sold for £325 to £500 per ton. In 1921 production almost ceased because of the large-scale postwar development of deposits in the USA, India, and China, stimulated by prices higher than those paid in Australia under the tariff fixed by the Commonwealth Government. Since then Australian production has been small and intermittent, governed largely by the erratic fluctuations in the price of wolfram. A minor boom occurred from 1938 to about 1945, and finally died out in 1958.

TABLE 8: TUNGSTEN, MOLYBDENUM, AND BISMUTH DEPOSITS
(See Fig. 34)

Name of Mining Centre (Date of discovery)	*Locality*	*Estimated Production* (tons of concentrate)	*Description*	*Mineralogy*	*References*
Wolfram Camp (1894)	15 miles NW of Dimbulah	5400 (wolframite) 1455 (mixed wolfram and bismuth) 1360 (molybdenite) 80 (bismuth)	(a) Eluvial shoad deposits, yielded most of initial output but became exhausted by 1906 (b) Lode deposits: situated in northern periphery of roof area of greisenized granite which has intruded Palaeozoic sediments and Permo-Carboniferous volcanics. Most important lode deposits are numerous (250) quartz pipes or chimneys, which are irregular and tortuous; flat lodes, disseminations, and segregations are other, unimportant types of lode deposits	Wolfram, molybdenite, native bismuth; some scheelite, bismuthinite, arsenopyrite, chalcopyrite, pyrrhotite, pyrite, sphalerite, galena, stibnite, tetrahedrite; little cassiterite. Gangue: quartz; some calcite, tourmaline, topaz	Ball (1911b, 1913a,d, 1919), Blanchard (1947), Cameron (1903, 1904a), Clappison (1941, unpubl.), Connah (1954), Dunstan (1905b), de Keyser & Wolff (1964), Morton (1945a), Morton & Ridgway (1944b), Dept of Mines (1953c); Ridgway (1946a)
Bamford Hill (1893)	2½ miles NNW of Petford	2050 (wolfram) 100 (mixed wolfram and bismuth) 175 (molybdenite) 21 (bismuth)	(a) Eluvial shoad deposits, exhausted by 1906 (b) Lode deposits: in southern periphery of roof area of greisenized granite which has intruded Featherbed Volcanics. Geological setting very similar to that at Wolfram Camp. About 70 quartz pipes worked	Wolfram, molybdenite, some bismuth; little sphalerite, pyrite, chalcopyrite, galena, magnetite, scheelite, powellite, bismuthinite. Gangue: quartz; little kaolin, fluorite	Ball (1911b, 1913a, 1914b,c), Blanchard (1947), Cameron (1904a), de Keyser & Wolff (1964), Levingston (1955), Morton (1940)

TABLE 8 (continued)

Name of Mining Centre (Date of discovery)	*Locality*	*Estimated Production* (tons of concentrate)	*Description*	*Mineralogy*	*References*
Mount Carbine (about 1894)	50 miles NW of Cairns	2800 (wolfram) about 100 (mixed wolfram and bismuth)	(a) Shoad deposits, soon exhausted (b) Quartz-feldspar veins through Palaeozoic sediments; veins are numerous, roughly parallel, branching and anastomosing. Commonly 2 ft wide or less	Wolfram; little scheelite, pyrite, cassiterite; traces of chalcopyrite, molybdenite. Gangue: quartz, feldspar, tourmaline, some muscovite, rare beryl	Ball (1911b, 1913a,b,e), Connah (1953c), Fleischman (1951a), Morton & Ridgway (1945), Ridgway (1946c)
Mt Perseverance	6 miles SSW of Mossman	About 115 (wolfram)	Quartz-feldspar veins, generally less than 2 ft thick, commonly branching and rejoining. Faulted, and irregular attitudes	Wolfram; some scheelite, tungstite; little cassiterite, pyrite, arsenopyrite; traces of chalcopyrite. Gangue: quartz, feldspar, some mica	Levingston & Carruthers (1953), Morton (1938b)
Koorboora area	50 miles SW of Mareeba	About 660 (wolfram)	Associated with tin lodes (see Table 7), mostly in upper parts. Neville mine (but rich shoot in spiralling pipe), Telegraph mine, and Mavis Bruce mine	Wolfram, cassiterite, sulphides, some bismuth. Gangue: quartz, chlorite, kaolin, limonite, some fluorite	Ball (1911b), Morton (1944e, 1946)
Tate/Lynd River region	25-55 miles S of Chillagoe	?	Many scattered quartz lodes in regions of tin-tungsten mineralization in greisenized granite. Some workings: Gralala (12 miles NW of Bullock Cr.), Four-mile Mountain, Eight-mile Mountain (NW of Fossilbrook), Desert Cr. (9 miles SSW of Fischerton), Garden Cr. (4 miles N of Fischerton)	Wolfram; little scheelite, molybdenite, bismuthinite, arsenopyrite, pyrite, cassiterite. Gangue: quartz; some fluorite, chlorite, muscovite	Little information available. See Ann. Repts Dept of Mines, Ridgway (1945a), Zimmerman & Ruker (1962, unpubl., map)

TABLE 8 (continued)

Name of Mining Centre (Date of discovery)	*Locality*	*Estimated Production* (tons of concentrate)	*Description*	*Mineralogy*	*References*
Herberton/Mt Garnet district	About 60 miles SW of Cairns	?	Several scattered localities around Coolgarra, Emuford, Glenlinedale, etc. Small deposits, in quartz-filled veins along joints and shear zones in granite, greisenized granite, and sediments. Also zoned greisen lodes in granite, and associated with cassiterite in tin lodes	Wolfram, molybdenite, bismuthinite; some sulphides, cassiterite, hematite. Gangue: quartz, topaz, fluorite; little tourmaline, beryl, monazite	Blake (1968, unpubl.); de Keyser & Wolff (1964) for some mines in Emuford area
Khartoum district (1914)	9 miles SW of Almaden	? (molybdenite)	Quartz reefs along margins of fine-grained acid biotite granite which intrudes medium-grained hornblende-biotite adamellite. Veins commonly gently dipping and have no preferred direction of strike. Largest mine: Kitchener	Molybdenite; at surface altered to powellite or molybdite. Rare wolfram, bismuth, cassiterite, sulphides	de Keyser & Wolff (1964), Saint-Smith (1917a,e)
Annan River Tinfield	S of Cooktown	?	Associated with cassiterite in quartz lodes. Mined for short periods at Mt Hartley and Mt Romeo	Wolfram, associated with cassiterite, arsenopyrite, in quartz gangue with tourmaline	Jack (1891a), Saint-Smith (1915d, 1916e)
Tinaroo	5 miles N of Almaden	?	In quartz veins controlled by joint systems in granite	Wolfram, molybdenite	Ball (1911b)
Scardons Camp	10 miles SE of Mareeba	?	In quartz veins at or near granite contact	Wolfram, scheelite, cassiterite, sulphides	Connah (1952), Morton (1943c)
Lake Eacham	3 miles SW of lake	?	Quartz lode	Wolfram	Ann. Rept, Dept of Mines, for 1909

TABLE 8 (continued)

Name of Mining Centre (Date of discovery)	*Locality*	*Estimated Production* (tons of concentrate)	*Description*	*Mineralogy*	*References*
Dingo Mountain	4 miles W of Kirrama homestead, W of Rockingham Bay	?	NW quartz vein in chloritized and greisenized granite	Wolfram.	Levingston (1957, unpubl.)
Noble Is.	30 miles SE of Cape Melville	?	Network of regular subconjugate quartz veinlets in sediments	Wolfram.	Lee-Bryce (1905), Cherry (1908)
Gurrumba/Ord area	15 miles NW of Mt Garnet	?	Reported occurrences from Gurrumba, Spinifex Cr., Gilmore mines	Wolfram.	Ball (1911b)

Bismuth has been mined as a by-product only. It is difficult to separate from wolfram, and was commonly sold in mixed wolfram-bismuth concentrates.

The Wolfram Camp, Bamford Hill, and Mount Carbine fields have yielded, to the end of 1963, an estimated total of 10,230 tons of wolfram concentrate, 1600 tons of wolfram-bismuth concentrate, 1530 tons of molybdenite concentrate, and 100 tons of bismuth concentrate, which probably represents about 85 percent of the total production from all sources in the map area. Smaller centres and scattered mines are located at Mount Perseverance, Khartoum (molybdenite), Tinaroo, Kirrama, and the tin mining areas of Koorboora, Sunnymount, the Greater Herberton district, the Tate-Lynd River region between the former settlements of Fischerton and Fossilbrook, and a few other places (Fig. 34). The total recorded production from all sources in the map area is as follows: wolfram, 11,810 tons of concentrate; molybdenite, 2935 tons; and bismuth, 110 tons.

Wolfram Camp

Wolfram Camp, situated 15 miles by road northwest of Dimbulah, has been Queensland's most prolific wolfram and molybdenite field. The workings are located in the greisenized roof zone of a granite body intruded into the Hodgkinson Formation and late Palaeozoic volcanics. The granite dips to the north at 50° or more. The mineralization is confined to greisens, especially along and near the northern margin of the granite, in a zone 2 miles long and up to 2500 feet from the contact. The most important lode deposits consist of quartz pipes or chimneys, but disseminated orebodies, irregular segregations, and mineralized flat joints (near the roof of the intrusion) are also known. Of the 250 pipes only a small number have been worked below 50 to 100 feet, and very few have exceeded 500 feet. In section the pipes are roughly circular or elliptical, with diameters ranging from 1 to over 30 feet. The pipes are irregular and tortuous, of varying size and shape, and show repeated inconsistent changes of pitch. Branching is common. The pipes commonly change direction when abutting joints, faults, or barren quartz reefs, and are usually enriched at the contacts with these structures. There is no sharp boundary between the pipe and the surrounding greisen; the inner quartz core gradually passes into greisen and then into slightly altered granite.

Ore occurs in irregularly spaced shoots commonly containing from a hundredweight to several tons of ore with grades ranging from 1 to 50 percent. The shoots are apparently irregularly distributed, though bends in the pipes are reported to be favourable loci for ore concentration.

Wolfram predominates over molybdenite in most pipes and is distributed at random, whereas the molybdenite is generally concentrated on the outer edges, especially on the footwall of the pipe. In places the two minerals are intergrown The native bismuth is commonly intergrown with the wolfram, or is present as small blebs in the wolfram crystals. Minor amounts of scheelite, bismuthinite, arsenopyrite, chalcopyrite, pyrite, pyrrhotite, sphalerite, galena, tetrahedrite, stibnite, calcite, tourmaline, cassiterite, and topaz have been recorded (Ball, 1919).

Bamford Hill

Bamford Hill is situated 2½ miles along a track north-northwest of Petford, 60 miles west-southwest of Cairns. The geological setting and pattern of mineralization are similar to those at Wolfram Camp: quartz pipes occur in greisenized granite along a zone, 1½ mile long and ¼ mile wide, close to the contact with the Featherbed Volcanics. Ball (1914c) has described the mineral content of the 70 pipes worked: the minerals recorded include wolfram, molybdenite, and native bismuth, and small amounts of pyrite, chalcopyrite, sphalerite, galena, fluorite, kaolin, magnetite, and various secondary tungsten, molybdenum, and bismuth minerals such as powellite and scheelite. Many of the sulphides are concentrated in vugs, and there seems to be an increase in the proportion of sulphides in the lower parts of the pipes.

Mount Carbine

Eluvial wolfram was known from the Mount Carbine area 50 miles northwest from Cairns before 1895, but the black shoads were at first thought to be manganese (hence the name Manganese Creek for the little creek at the village). The geological setting and the mineralization differ from that at Wolfram Camp and Bamford Hill: the lodes consist of numerous subparallel anastomosing quartz-feldspar veins, which are grouped into a number of overlapping and slightly diverging zones, cropping out on a hill composed of sediments of the Hodgkinson Formation. The veins are commonly less than 2 feet wide, with local swells up to 6 feet. In places the veins are cut and displaced several feet by faults. The ore zone is about 1½ mile long and ¼ mile wide, and trends northwest. Barren quartz veins occur in the granite exposed about half a mile northeast and east of the workings.

The veins consist mainly of milky quartz with varying amounts of potash feldspar which is coarsely pegmatitic in places. Muscovite occurs in a few veins, commonly as a micaceous selvage on the vein walls. Tourmaline is distributed as fine needles throughout the lodes. Beryl is a rare constituent.

The ore mineral is high-grade ferberitic wolfram containing 70 to 73 percent WO_3, about 18 percent FeO, and 6 percent MnO. In places, especially in the eastern workings, it is associated with some scheelite which may be secondary as it does not persist in depth. Scheelite has also been mined from isolated lodes east of Mount Carbine township. The veins also contain pyrite, traces of chalcopyrite and molybdenite, and cassiterite. A few of the lodes such as the Vera mine northeast of Carbine Hill have been worked for cassiterite.

Mount Perseverance

Mount Perseverance, 6 miles south-southwest of Mossman, is a small tungsten field on the eastern side of the Mount Carbine Tableland. As at Mount Carbine, the shoots consist of anastomosing quartz-feldspar veins less than 2 feet wide, with a selvage of yellow mica several inches thick along the walls. The veins are faulted and irregularly arranged, probably partly owing to soil creep on the steep slopes on which the workings occur.

The ore minerals include wolfram, some scheelite, and tungstite, associated with pyrite, arsenopyrite, and traces of chalcopyrite and copper carbonates. Cassiterite is found in places, but not necessarily in association with wolfram.

Neither Morton (1938b) nor Levingston (1953) was impressed with the potential of Mount Perseverance because of the patchy distribution of the ore and the smallness of the veins.

Small pockets and lenses of tungsten ore have been mined near the granite dykes in the Rumula/Julatten area between Molloy and Mount Perseverance; from a pegmatite and greisen vein at Pom Pom Creek and other gullies on the western margin of the Mount Frazer/Mount Spurgeon granite batholith; and from a quartz-muscovite vein at the Cumble-Cumble mine on Reedy Creek, 11 miles north of Mount Carbine. Scheelite was mined for short periods in the Southern Cross and Tyrconnel mines in the Hodgkinson Goldfield.

Koorboora area

Several of the tin mines in the Koorboora area contained wolfram in the upper part of the lodes, but it was worked in three mines only. The mines are situated in steeply dipping micaceous arenite and shaly siltstone which are strongly ironstained near the surface. The Neville mine was an important wolfram producer between 1904 and 1909, and was claimed at the time to be one of the 'greatest single wolfram mines in the world'. Nearly all the ore came from one small but very rich shoot in the form of a more or less helical pipe extending to a depth of 140 feet. In the lower workings cassiterite appeared, and sulphides became increasingly abundant below the 200-foot level.

In the adjoining Telegraph mine, the ore was a mixture of wolfram, cassiterite, galena, chalcopyrite, and bismuth.

The Mavis Bruce lode, discovered in 1943, is altered near the surface to a mixture of kaolin, quartz, chlorite, and limonite, but it probably originally contained a high proportion of sulphides.

Some wolfram has also been won from the Sunnymount area, 5 miles southeast of Koorboora, as a by-product of tin mining.

Tate-Lynd River Region

Little is known about the mineralization and output from the Tate-Lynd River region, the area between the abandoned settlements of Fischerton and Fossilbrook. The names of various workings appeared from time to time in the Warden's reports and the Annual Reports of the Department of Mines. The most important centre seems to have been Galala, some 12 miles by pack horse northwest of Bullock Creek (Ridgway, 1945a), where mining and prospecting was carried out, as far as is known, in 1912-20, 1934-35, and 1942-45. Wolfram, and subordinate scheelite, molybdenite, bismuthinite, arsenopyrite, pyrite, and oxides of iron and

manganese occur in quartz-filled fissures and joints in granite, which is greisenized along the contacts. A large proportion of the workings was centred on two gently dipping veins. The granite is traversed by basic dykes, which are cut by the mineralized quartz veins.

Wolfram associated with a little cassiterite, bismuth, and molybdenite was mined at Four-mile Mountain and Eight-mile Mountain northwest of Fossilbrook.

Wolfram, associated with cassiterite, occurred in quartz-fluorspar veins at Garden Creek, 4 miles north of Fischerton; and with scheelite at Desert Creek, a branch of the Lynd River, 9 miles south-southwest of Fischerton. Wolfram is also known in an area 12 miles southwest of Fossilbrook, and as a by-product of the tin lodes in the Fossilbrook/Fischerton area (Zimmerman & Ruker, 1962, unpubl., pl. 1).

Although the total output from these occurrences is unknown, the lodes are probably too small to be mined systematically (Ridgway, 1945a).

Greater Herberton District

Minor tungsten mineralization is also widespread in the Greater Herberton district, mainly as wolfram, though scheelite is known from several localities (Blake, 1968, unpubl.). Production records are incomplete, and the output before 1900 is unknown. The deposits are small and of low grade; they occur within the Elizabeth Creek Granite or close to its contact. A little wolfram is also present in some of the tin and copper mines of the district.

The following types of wolfram lodes have been recognized in the Herberton district:

1. Narrow topaz veins with quartz, wolfram, bismuthinite, arsenopyrite, fluorite, and chalcopyrite, occupying horizontal joints in granite and greisenized granite.
2. Zoned greisen lodes in granite. Wolfram, and in some lodes molybdenite, is distributed sporadically in the central quartz-fluorite zone. Minor amounts of tourmaline, monazite, hematite, beryl, sulphides, and uranium minerals are also present.
3. Quartz veins in greisenized granite.
4. Quartz-wolfram-molybdenite veins or pipes localized in small shear zones transecting sediments close to granite contacts.
5. Large low-grade quartz-fluorite-wolfram lodes in the sediments.

Wolfram workings occur around Coolgarra, Emuford, Glenlinedale, and in other scattered localities (Blake, 1968, unpubl.). Some of the workings in the Emuford area (the Mistake and the Mystery mines) have been described by de Keyser & Wolff (1964). A little wolfram has also been reported from Gurrumba, Spinifex Creek, and the Gilmore tin mines (Ball, 1911b).

Wolfram is fairly common in some of the tin lodes at Mount Amos, Mount Hartley, and the Romeo district in the Annan River tinfield (Dunstan, 1913b, mineral ref. 7928-7934), but has been mined for very short periods only at Mount

Hartley and Romeo from steeply dipping quartz veins in granite.

Wolfram and molybdenite occur in quartz veins associated with joints in the granite at Scardons Camp, 5 miles north of Almaden (de Keyser & Wolff, 1964). The boundaries between the quartz lodes and the granite are gradational.

Molybdenite was mined between 1914 and 1918 in the Khartoum district, 9 miles southwest of Almaden (de Keyser & Wolff, 1964). It occurs in quartz reefs along the margin of fine-grained, partly greisenized acid granite which intrudes medium-grained hornblende-biotite granite. No preferred strike direction is apparent, and the lodes are commonly sinuous and gently dipping. Saint-Smith (1917d,e) was optimistic about the potential of the district because of the large tonnage of payable ore proved and developed, but no further reserves were discovered and the district was abandoned when the known shoots were exhausted. Molybdenite was the only payable mineral present; bismuth, wolfram, cassiterite, and sulphides occurred in traces only.

Other places where small amounts of wolfram have been won include Tinaroo, 10 miles southeast of Mareeba, where it is generally associated with cassiterite and base-metal sulphides; near Lake Eacham (Ann. Rep., Dep. Min., 1909); at Dingo Mountain near Kirrama homestead, 26 miles west of Rockingham Bay, where it is associated with a little molybdenite and bismuthinite in a northwesterly quartz vein in granite which is greisenized and chloritized alongside the lode Levingston, 1957, unpubl.); and on Noble Island, 30 miles southeast of Cape Melville, where it occurs in a network of regular subconjugate quartz veinlets in sediments of the Hodgkinson Formation (Lucas, 1965a). Wolfram is also reported in a slate-granite contact in the Altanmoui Range (Ball, 1939, unpubl.) and, with molybdenite, in a small quartz pipe in granite in the Tully Falls area (Ann. Rep. Dep. Min., 1952), while P. J. Stephenson (University College of Townsville, pers. comm.), reports that wolfram is occasionally present in granite boulders and quartz veins on Hinchinbrook Island.

Specks of molybdenite were noted in the granite at the quarry 3 miles west-southwest of Koombooloomba Dam.

Some bismuth is found in the low-grade gold and silver deposits at Nolan Creek, 33 miles northwest of Chillagoe (Morton, 1939c), and a trace of bismuth has been noted in a quartz vein 2 miles from the Pandora tin mine, 25 miles north of Chillagoe.

Copper, Lead, Silver, and Zinc

(Table 9, Fig. 35)

The sulphides of copper, lead, and zinc generally occur together in varying proportions. Most of the silver has been derived from the galena in the base-metal lodes, but some is also associated with the gold.

TABLE 9: COPPER-LEAD-SILVER DEPOSITS

(See Fig. 35)

Name of Mining Centre (Date of Discovery)	*Location*	*Approximate Production* *Ore* (tons)	*Copper* (tons)	*Lead* (tons)	*Silver* (oz)	*Description*	*References*
Chillagoe Gold and Mineral Field							
Mungana area (1888)	At Mungana, 9 miles WNW of Chillagoe	333,600	7910	31,835	3,228,600	(a) Pipe-like chert-breccia deposits in sediments (limestone) of Chillagoe Formation. Main mines: Girofla, Lady Jane (b) Contact - metasomatic deposits grading into hypothermal vein deposits	Broadhurst (1952, 1953a), Broadhurst & Edwards 1953), Jack (1891b, 1898), Jensen (1941c, unpubl.), de Keyser & Wolff (1964)
Redcap area (1888)	9 miles NW of Chillagoe	13,000+	300+	525+	23,500+	Several lode systems in the Chillagoe Formation; most of them strike NW. Largest is Redcap lode, along fault zone. Brecciation very common (hydrothermal breccias?)	Broadhurst (1952, 1953a), Jensen (1941c, unpubl.), de Keyser & Wolff (1964), Morton (1926b)
Ruddygore	2 miles NE of Chillagoe	32,750	1450	—	60,000	Disseminated low-grade orebody of the 'porphyry copper' type. Ore associated with stockworks, breccias, and cracked rock in metasomatized adamellite which is intruded by leucocratic microgranodiorite	Branch (1960a, unpubl.), Broadhurst (1949), Jensen (1941c, unpubl.), de Keyser & Wolff (1964)
Zillmanton	3 miles W of Chillagoe	35,000	1500?	—	?	Siliceous garnet-hematite lode probably occupying faulted contact zone between granite and limestone	Branch (1960a, unpubl.), Jensen (1941c, unpubl.), de Keyser & Wolff (1964), Langron (1957, unpubl.)

TABLE 9 (continued)

Name of Mining Centre (Date of Discovery)	*Location*	*Approximate Production* *Ore* (tons)	*Copper* (tons)	*Lead* (tons)	*Silver* (oz)	*Description*	*References*
Calcifer area (1888)	5½ miles SE of Chillagoe	26,450	1555	44 (bullion)	20,400	Contact-metasomatic deposits in roof pendants intruded by granite. Boomerang, Hobson, Harper workings	Broadhurst (1953a), Jensen (1941c, unpubl.), Denmead (1934f), Skertchly (1897)
Chillagoe group (1888)	Around Chillagoe	74,000+	500+	7200+	495,000+	Contact-metasomatic deposits grading into fissure lodes or faulted contact-metasomatic deposits. Chillagoe Consols, Lyonite Hills, Christmas Gift, Ti-tree, Otho, and Hensey are some of the workings. More than 1760 oz of gold won from Ti-tree as by-product	Jensen (1920b, 1941c, unpubl.), de Keyser & Wolff (1964)
Muldiva mines	8 miles WSW of Almaden	19,010	270	1150	315,000	Contact - metasomatic deposits. Workings include Eclipse, Paisley. Fair amounts of sphalerite, and bismuth impurities	Ball (1914a), Jensen (1923, 1941c, unpubl.), de Keyser & Wolff (1964)
Dargalong group (1889)	8 miles SW of Chillagoe	670	2.5	130	20,700	Ferruginous quartz lodes in NW shear zone through Precambrian rocks of Dargalong Metamorphics. Low-grade siliceous ore	Ball (1917d), Jack (1891b), Jensen (1941c, unpubl.), Q.G.M.J. (1906b)
Cardross (Arbouin or Klondyke)	20 miles WNW of Mungana	18,000+	2000+	—	87,200+	Irregular composite fissure systems with networks of intersecting veins and shears in altered rocks of Dargalong Metamorphics. Copper sulphides associated with arsenopyrite, pyrite, magnetite, wolframite, cassiterite; some topaz. Gold content high: at least 2200 oz won as by-product	Ball (1917b), de Keyser & Wolff (1964)

TABLE 9 (continued)

Name of Mining Centre (Date of Discovery)	*Location*	*Approximate Production* *Ore* (tons)	*Copper* (tons)	*Lead* (tons)	*Silver* (oz)	*Description*	*References*
Bamford area (Lappa mines)	4 miles NW of Petford	?	?	?	?	Siliceous lodes in Featherbed Volcanics. Proportion of sphalerite increases with depth. Workings include Comstock, Silver Bead, Better Luck	Jensen (1919, unpubl.), de Keyser & Wolff (1964)
Torpeys Crooked Creek	3 miles ENE of Almaden	6000+	1.0	920+	84,000+	Irregular lode deposit in sediments of Mount Garnet Formation. Proportion of sphalerite increases with depth. Ore below 365 ft unpayable	Dunstan (1905a), de Keyser & Wolff (1964)
O.K. Mines (1901)	40 miles NNW of Chillagoe	80,260	7685	?	3265	Pipe-like orebodies in SW belt of low-grade kaolinitic zone transecting sediments of Mount Garnet Formation. Mines include O.K., North O.K., South O.K	Edwards (1943), Gibb (1904), Jack (1907), Morton (1938c, 1939b)
Tartana/ Montevideo/King Vol group	At Bowler Cr., 25 miles NW of Chillagoe	?	?	?	?	Low-grade fissure lodes and impregnations in calcareous sediments of Chillagoe Formation. Copper-silver-lead-gold mineralization. Gangue of quartz and carbonates. Few data known	Edwards (1957), Jensen (1923)
Nightflower mine (1923)	22 miles N of Chillagoe	1215+	—	300+	36,700+	Mineralized NNE silicified fault zone across Featherbed Volcanics. Galena and stibnite accompanied by pyrite, chalcopyrite, sphalerite	Saint-Smith (1923a)

TABLE 9 (continued)

Name of Mining Centre (Date of Discovery)	*Location*	*Approximate Production* *Ore* (tons)	*Copper* (tons)	*Lead* (tons)	*Silver* (oz)	*Description*	*References*
Other occurrences	—	—	—	—	—	Include: scattered workings near Almaden, and N of Koorboora; Mitchell South copper workings, 8 miles NNE of the O.K. mines; MacKinlay copper mine on Big Watson Cr., 2 miles NE of Nightflower mine; few lead and copper mines in Tate/Lynd R. drainage area, of which nothing is known (see map for positions)	—
Herberton Gold and Mineral Field							See Blake (1968, unpubl.) for bibliography. Also Jensen (1939b, unpubl.)
Silver Valley (Newellton) (1880)	9 miles SW of Herberton	6100+	580+	60+	40,000+	Widespread mineralization, commonly associated with tin ores. Main base-metal centres, but copper, lead, and silver also obtained as by-products from tin mines. NW fissure lodes in chloritized and granite-intruded arenites of Ringrose(?) Formation. Complex sulphide-cassiterite ore	
Montalbion (1885)	15 miles W of Herberton	42,190	?	?	1,680,000	Production included ore from other localities. Lodes in Palaeozoic sediments	
Orient Camp	13 miles N of W of Herberton	3000+	—	700+	79,800+	Orient Camp lodes emplaced in Featherbed Volcanics	Morton (1936b)

TABLE 9 (continued)

Name of Mining Centre (Date of Discovery)	*Location*	*Approximate Production* *Ore* (tons)	*Copper* (tons)	*Lead* (tons)	*Silver* (oz)	*Description*	*References*
Mount Garnet mine (1883)	At Mt Garnet	94,360	4540	?	949,000	Lenses and pipe-like orebodies in vertical N-S zone, in calc-silicate hornfels. Sphalerite content increases in bottom levels	Zimmerman, Yates, & Amos (1963, unpubl.)
Mount Garnet area	E and NE of Mt Garnet	?	?	?	?	Silver-lead lodes associated with small shear zones in Mount Garnet Formation	Zimmerman, Yates, & Amos (1963, unpubl.)
Herberton area	Herberton	7745	476	?	47,245	Fissure and replacement lodes in Ringrose(?) Formation parallel with granite contact	
Watsonville area	5 miles W of Herberton	?	?	?	?	Mineralized NW faults in Palaeozoic sediments. Complex ores with cassiterite	
Emuford area	25 miles WSW of Herberton	?	?	?	?	Includes: Siberia lode (a long E-W fault zone); Emerald Hill copper mine, Silver Spray silver-lead mine (SE of Petford)	Morton (1941), de Keyser & Wolff (1964)
Flaggy Creek	34 miles W of Cardwell, 1 mile from Herbert R. gorge	?		?	?	Small lenticular deposits along joints in silicified and chloritized granodiorite. Copper and silver-lead lodes	Cameron (1914), Knight (1949, unpubl.)

TABLE 9 (continued)

Name of Mining Centre (Date of Discovery)	*Location*	*Approximate Production* *Ore* (tons)	*Copper* (tons)	*Lead* (tons)	*Silver* (oz)	*Description*	*References*
Mareeba Gold and Mineral Field							
Mount Molloy (1883)	4 miles S of Molloy, 32 miles NW of Cairns	42,960	3810	?	?	Lode in NNW shear zone in black siltstone and greywacke. Copper minerals, pyrite, and some sphalerite, in gossanous siliceous or kaolinized gangue	Connah (1965), Edwards (1943), Weinberg (1905)
Other occurrences	—	?	?	?	?	Include: Sweet William (3 miles NW of Molloy), quartz lode on granite contact	
Other areas	—	—	—	—	—	Include: Hannahbelle, Mitchell Surprise, and Red Hill prospects between Mitchell R. and Palmer R. S of Maytown. No production. Copper prospects in basic volcanics in Little Kennedy R. area, 7 to 15 miles N of Palmerville	Morton (1943a), Ball (1910a)
						Native copper in clay below surface, Noble Is., 30 miles SW of Cape Melville	Cherry (1908)

The first base-metal ores were found in the 1880's during the search for tin in the Herberton/Mount Garnet district. They included the silver-lead lodes at Silver Valley, Montalbion, Orient Camp, and the copper deposit at Mount Garnet. By 1883 an estimated 32 silver-lead mines were in operation in this district.

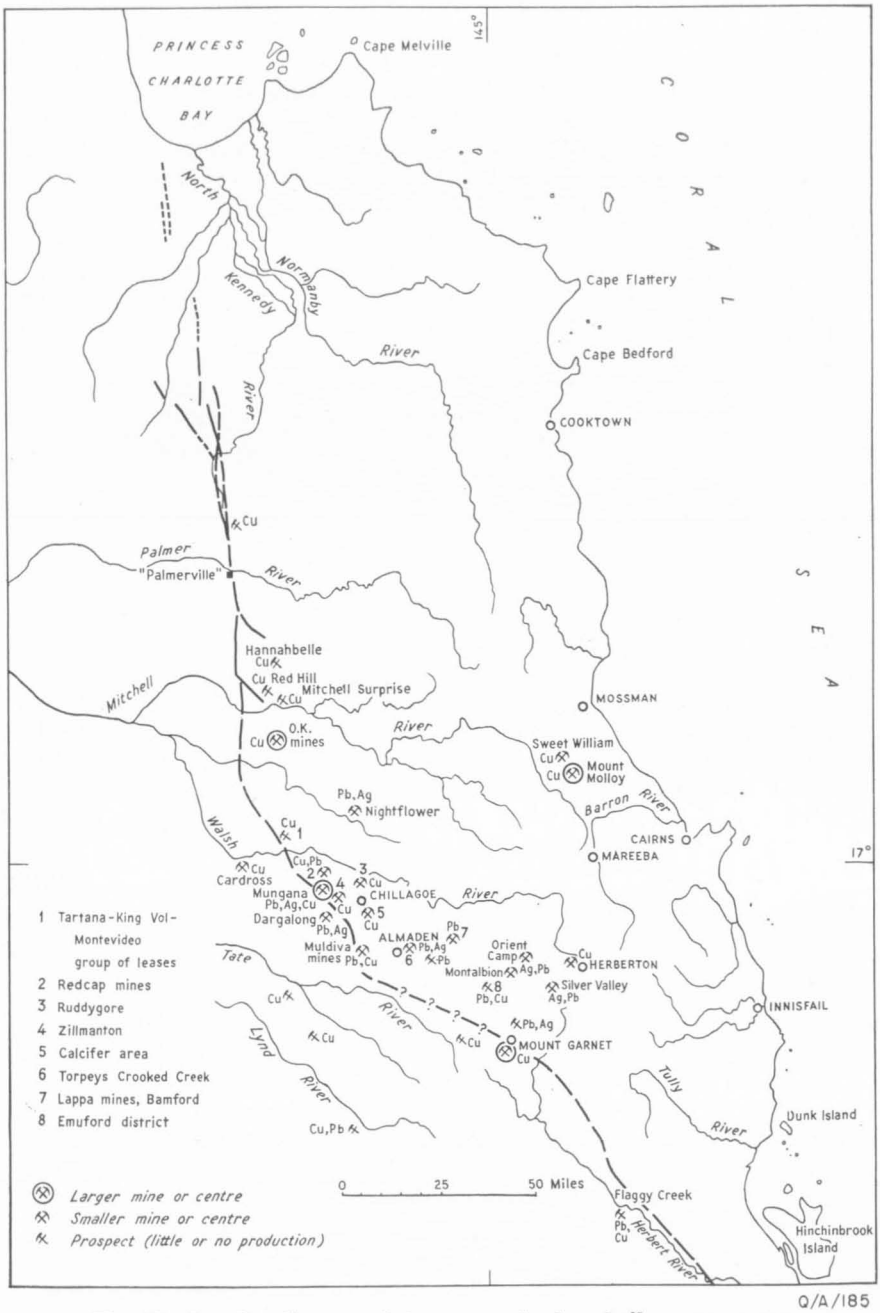


Fig. 35. Locality diagram of the copper, lead, and silver occurrences.

At the same time, copper was discovered at Mount Molloy, and by 1888 numerous copper and silver-lead lodes were developed around Chillagoe. With the revival of prices by the end of the 19th century, mining on a large scale began, but in many cases it was short-lived: the Mount Garnet mine was worked from 1898 to 1904, and production at Mount Molloy virtually ceased in 1905. The O.K. copper mines, a group of lodes 40 miles north-northwest of Chillagoe, were mainly worked from 1904 to 1911, when operations ceased because of industrial troubles. The Chillagoe district fared better because it included a large number of deposits of varied base-metal ores scattered around a central treatment plant, and was directly connected with Cairns by rail. The Chillagoe deposits have been described in numerous reports by many geologists (see de Keyser & Wolff, 1964, for summaries and bibliography).

The total recorded production from all sources is as follows: lead, 63,000 tons; zinc, 200 tons; silver, 8,150,800 oz.; and copper, 45,318 tons.

Chillagoe Gold and Mineral Field

The lodes in the Chillagoe Gold and Mineral Field generally contain a mixture of (silver)-lead, copper, and zinc minerals in varying proportions, from practically lead-free copper ore (as at Ruddygore) to copper-free silver-lead ore (as at Torpeys Crooked Creek mine, 3 miles east-northeast of Almaden). In most of the lead lodes the proportion of sphalerite increases in depth, and the copper ores generally contain a little bismuth. As the smelters were not equipped to separate the zinc, large tonnages of this metal were wasted.

In the Chillagoe district (sensu stricto: the area covered by the Chillagoe, Mungana, and Almaden one-mile Sheets), the workings are concentrated mainly in the region between Almaden and Mungana/Redcap, and around Cardross. Other mines exist near Bamford, Koorboora, and northwest of Emuford. Most of the workings are small and of limited vertical extent. The greatest production came from the Mungana lodes, which yielded roughly one-third of the total copper output and two-thirds of the total lead and silver. The Redcap area is larger than the Mungana belt and contained more workings, but production was less. Other centres included Zillmanton, Ruddygore, Calcifer, Chillagoe township, Muldiva, Dargalong, and Cardross. A brief description of the various mines and prospects and a bibliography is given by de Keyser & Wolff (1964).

Several other base-metal deposits occur outside the Chillagoe district (sensu stricto), but still within the limits of the Chillagoe Gold and Mineral Field; the most important were the O.K. mines, about 7 miles southeast of Bellview homestead, or some 40 miles north-northwest of Chillagoe. The group includes the O.K., the North O.K., and the South O.K. mines, in descending order of importance. They were discovered in 1901 and abandoned in 1912, although a little mining and prospecting took place in 1930-31 and intermittently between 1937 and 1942. Production to 1942 was 80,260 tons of ore, yielding 7685 tons of copper, 3265 oz of silver, and 390 oz of gold. During its heyday, the O.K. was the chief copper-producing mine in the Chillagoe field despite its isolation, and was the first copper mine in Queensland to pay dividends. In 1909, the company became involved in a costly lawsuit, and this together with a decrease in the grade of ore led to premature closure of the mine.

The O.K. lode consisted of a number of pipe-like orebodies enclosed in a northwest belt of low-grade kaolinitic material transecting folded chert, greywacke, and basic volcanics of the Mount Garnet Formation. The grade initially ranged from 8 to 18 percent copper, with less than 8 percent in the kaolin mantle. The copper carbonates, cuprite, and some chalcopyrite in the oxidized zone gave way to siliceous chalcopyrite-pyrite ore at a depth of 15 to 80 feet. Between the 45 and 115-foot levels the ore was enriched, but below the 115-foot level the grade decreased with an increasing proportion of pyrite in the primary sulphide ore.

Similar conditions existed at the smaller North O.K. lode, where a gossanous oxidation cap passed down into a zone of enrichment, 10 to 20 feet thick, with a copper content of 10 to 20 percent. Lower down, the grade gradually decreased, and at the 140-foot level the ore consisted mainly of pyrite, and assayed 5 to 6 percent copper.

Some 8 miles north-northeast of the O.K. mines are the small Mitchell South workings on gossanous carbonate ore in slate of the Hodgkinson Formation (Morton, 1945b).

Other copper shows in the Chillagoe Gold and Mineral Field include the Tartana/Montevideo/King Vol group at Bowler Creek, a tributary of the Walsh River, 25 miles northwest of Chillagoe. Very little is known about these low-grade deposits, apart from a brief description by Jensen (1923). The prospects consist of fissure lodes and impregnations in the calcareous sediments of the Chillagoe Formation. According to Jensen, the Tartana mines were worked for copper, silver, and gold; the copper mineralization is so widespread that the 'entire hill has been transformed into a low-grade copper ore' in which there are 'millions of tons of low-grade copper ore which . . . may some day be economically treated by leaching . . .'. The Annual Report of the Department of Mines for the year 1902 mentions development work being carried out at Tartana Hill, but no later work has been reported. Below a depth of 45 to 55 feet, the oxidized minerals gave way to primary sulphides.

The large gossan outcrop at the Montevideo mine was reported to contain silver, lead, copper, and gold minerals in a north-northwesterly crush breccia (Jensen, 1923).

Edwards (1957) has described a drill core from the King Vol mine submitted by Clutha Development Pty Ltd; it contained chalcopyrite, pyrite, arsenopyrite, marcasite, sphalerite, pyrrhotite, tetrahedrite, and traces of bismuth in a gangue of quartz and carbonates. The Annual Reports of the Department of Mines for the years 1922 to 1925 state that the soft carbonate ore averaged 23 percent lead, and that 2200 tons of ore yielded 364 tons of lead and 8261 oz of silver, and a little copper. Primary sulphides were met at a depth of 140 to 160 feet.

The copper lode on Big Watson Creek, 20 miles east-northeast of the King Vol mine, is probably the old MacKinley copper mine mentioned in the Annual Reports of the Department of Mines. The lode follows a ferruginous and kaolinitic shear zone trending southeast in sediments of the Hodgkinson Formation; it apparently contained only a small amount of copper.

About 2 miles southwest of the old MacKinley mine is the Nightflower mine, one of the few silver-lead workings in the Chillagoe Gold and Mineral Field outside the Chillagoe district, and the only one known in the Mossman Sheet area. The lode, discovered in 1923, is a mineralized north-northeasterly silicified fault zone within massive grey Permo-Carboniferous Featherbed(?) Volcanics. It contains argentiferous galena and fine-grained stibnite accompanied by some pyrite, chalcopyrite, and sphalerite. Secondary cerussite, pyromorphite, and cervantite were also present. The lead ore commonly contained between 40 and 50 oz of silver per ton, and 30 to 40 percent of lead (Saint-Smith, 1923a). Production figures are incomplete, but the output was at least 300 tons of lead and 36,700 oz of silver from 1215 tons of ore. After 1930, work ceased, probably because the richest ore had been extracted and values became inconsistent. The average grade of ore mined in the first few years was 25 to 30 percent lead, and 35 to 40 oz of silver per ton.

Nothing is known about the few lead and copper mines in the southern part of the Chillagoe Gold and Mineral Field, in the Tate-Lynd River drainage area, but the locations of some of the mines are shown on Plate 23 and Figure 35.

Herberton Gold and Mineral Field (Blake, 1968, unpubl.)

Base-metal mineralization is widespread in the Herberton and Mount Garnet districts, but it is generally of little economic importance. Sulphides of copper, lead, and zinc are common in the tin lodes and some of the complex ores were treated for both their tin and base-metal content. Deposits of base-metal ore free of cassiterite also occur: the Mount Garnet copper lode is the main deposit of this type.

The main silver-lead mining centres are Silver Valley, Montalbion, and Orient Camp. Production figures are incomplete. The Silver Valley deposits are northwesterly fissure lodes in chloritized and granite-intruded arenites of the Ringrose(?) Formation, and are composed of complex base-metal tin ores. They were characterized by high silver values in the oxidized zone and values ranging from 10 to 800 oz per ton have been reported. The recorded output from 6100 tons of ore is 580 tons of copper, 60 tons of lead, and 40,000 oz of silver.

The Montalbion workings produced 42,190 tons of ore for an approximate yield of 1,680,000 oz of silver. Again, silver values were high in the oxidized zone, and some of the earliest ore contained up to 4000 oz per ton. Below the water table the silver content decreased, and the proportion of iron, copper, and zinc sulphides increased. Some of the ores were complex base-metal tin ores.

Little is known of the history and production at Orient Camp. The lodes occur in the Featherbed Volcanics and not in the sedimentary formations as at Silver Valley and Montalbion. Recorded output is at least 700 tons of lead and 79,800 oz of silver from 3000 tons of ore, but the figures are incomplete (Morton, 1936b).

Silver-lead mineralization has also been recorded to the northeast and east of Mount Garnet, but the occurrences are of no economic importance. Production figures are incomplete. The lodes are associated with small shear zones in the Mount Garnet Formation, near the margin of Permo-Carboniferous volcanics. Most of

the ore mined came from the oxidized zone. The minerals present include cerussite, anglesite, pyromorphite, malachite, azurite, and beudantite or corkite, as well as some primary sulphides.

The biggest copper deposit was the Mount Garnet deposit, which was worked mainly from 1898 to 1904 for a return of 93,396 tons of ore yielding about 4540 tons of copper and 948,650 oz of silver. The Mount Garnet smelter closed in 1904 when the zinc content increased in the bottom levels. In 1926, an additional 966 tons of silver-lead ore containing some copper were produced.

The orebodies at Mount Garnet consist of copper, lead, and zinc minerals concentrated in a vertical fault zone striking N5°E. The ore occurs in lenses and pipe-like bodies within calc-silicate hornfels of the Mount Garnet (or Chillagoe?) Formation.

Other copper deposits in the Herberton/Mount Garnet area are much smaller. West and northwest of Herberton are the workings of the 'Copper Firing Line' which occur in sediments of the Ringrose(?) Formation along fissures roughly parallel to the granite contact. They are reported to have produced 476 tons of copper and 47,245 oz of silver from 7743 tons of ore, from 1930 to 1937.

The copper mineralization in the Watsonville area is controlled by northwest faults in arenite and siltstone, and forms complex ores in association with cassiterite.

The Siberia lode near Emuford (Morton, 1941) is an east-west fault-controlled deposit which extends for over 2 miles. The enriched secondary ore contains 20 to 50 percent copper, but in the primary zone the grade is less than 5 percent. Primary sulphides include chalcopyrite, galena, sphalerite, pyrite, bornite, and much arsenopyrite; cassiterite, and some wolfram and bismuth are also present.

At Flaggy Creek, about a mile south of its entrance into the Herbert River gorge, 34 miles west of Cardwell, a number of small lenticular deposits along joints in silicified and chloritized granodiorite have been worked from time to time, but Cameron (1914) considered them too small and discontinuous to be mined systematically. Similar lodes containing galena and cerussite (Cameron, 1914; Knight, 1949, unpubl.) occur in the same locality.

Mareeba Gold and Mineral Field

The only important copper mine in the Mareeba field was Mount Molloy. The lode was discovered in 1883, and is situated 4 miles south of Molloy township. It occurs along a north-northwesterly shear zone which dips at 50° to 70° to the west; it averages 6 to 8 feet wide, but is up to 20 feet wide in places. The footwall and hangingwall are well-defined slickensided surfaces. The oxidized zone extends to a depth of 90 feet with an average grade of 10 percent copper; it contains azurite, malachite, and other secondary copper minerals in a gossanous siliceous or kaolinitic gangue.

The primary ore below the 142-foot (bottom) level is composed of pyrite, chalcopyrite, and some sphalerite, contained in sheared black phyllitic siltstone and fine-grained quartz greywacke; the average grade is probably less than 3 percent copper (Knight, 1950, unpubl.).

The lode was worked over a length of about 800 feet for an output of 42,957 tons of ore returning 3808 tons of copper (Connah, 1965). Much of the early production, however, was not officially recorded. The reserves in 1905, when regular production stopped, were estimated (perhaps too optimistically) at 42,000 tons of 12 percent ore. Since then there has been sporadic activity, but production figures are not available.

Copper mineralization is also recorded in a few other scattered localities in the Ma[illegible] Gold and Mineral Field. Small amounts of copper were won from [illegible]artz vein at the Sweet William mine, 3 miles northwest of Molloy, on the contact of the Mount Frazer granite. A small prospect was found near Curraghmore homestead in 1958, but it was proved to be uneconomic.

In the Tinaroo tin and tungsten prospects, 8 to 10 miles north-northeast of Atherton, chalcopyrite is a minor constituent. A sprinkling of chalcopyrite also occurs in the gold lodes of the Bartle Frere and Mount Peter gold workings.

Other Areas

A few small copper prospects occur between the Mitchell and Little (Kennedy) Rivers.

There are three deposits within a dozen miles of the northern bank of the Mitchell River: the Hannahbelle, Mitchell Surprise, and Red Hill (Morton, 1943a). The Hannahbelle deposit, discovered before 1910 when a landslide uncovered a green copperstained rock face on the crest of a high hill 21 road miles north-northwest of the bridge over the Mitchell River, is 'made up of veins too far apart to be mined collectively' (Morton, 1943a). The country rock consists of sheared siltstone, steeply dipping to the west, with silicified and quartz-veined layers. Malachite, commonly with a core of cuprite, and hydrous copper silicates appear to be the chief ore minerals. A parcel sent to Mount Isa in 1953 assayed 11.7 percent copper.

The Mitchell Surprise is about 2 miles west of the Mitchell River bridge, on the north bank of the river. The orebody is located along a shear zone in siltstone and phyllonite, and is oxidized to a depth of 50 to 70 feet.

Red Hill was discovered only in 1940, and two parcels of ore sent to Chillagoe in 1941 assayed 23 and 25.5 percent copper.

A little copper mineralization was reported from a silicified fault zone 10 miles east-southeast of Maytown (Jack, 1884), and a small prospect was located 6 miles to the east in 1960.

From 7 to 15 miles north of Palmerville, small oxidized copper shoots are irregularly disseminated in the altered amygdaloidal basic volcanics of the Chillagoe Formation, but Ball (1910a) thought it unlikely that they are of economic value. Cuprite and malachite have also been reported from a lode 3 miles north of Palmerville (Dunstan, 1913b, Min. Ref. 2427).

Small quantities of galena and native copper have been reported in the tin lodes at Mount Amos, in the northern part of the Annan River tinfield (Saint-Smith, 1916e).

In the north, copper and silver have been recorded on Noble Island (Cherry, 1908), where small threads and beads of native copper and silver are found in clay down to a depth of 8 feet below the surface of the coral and sand, below high-water mark. The metals have apparently been deposited where hot spring water enters the zone of saline water.

Farther north still, galena is present in some of the gold lodes on the Hamilton Goldfield.

Antimony

The chief antimony deposits are found in parts of the Hodgkinson Goldfield and along the Mitchell River. Antimony has also been recorded, though generally not in payable quantities, in the Starcke Goldfields, the Cooktown area, and the Herberton/Mount Garnet district. The ore mineral is generally stibnite, but secondary cervantite is fairly common near the surface of some lodes.

Hodgkinson Goldfield

Stibnite is common in many of the auriferous quartz lodes, and a number of mines have produced both gold and stibnite. The grades ranged from 10 to 30 percent antimony. The main production centres were the (New) Northcote and Woodville areas (Pl. 19), where the first discoveries were made in 1877 immediately after gold was found.

According to the AGGSNA Report (1940b), three lines of quartz lodes trending northwest were developed in the Northcote area — the Emily, Ethel, and Black Bess. In the ore shoots, the gold/antimony ratio ranges from 1 : 4 to 1 : 1425 which suggests that there were two separate phases of mineralization — an older gold phase, followed by an antimony phase. The New Minnie Moxham gold mine was another major antimony mine in the Northcote area (Saint-Smith, 1917c); the ore assayed up to 41 percent antimony.

In the Woodville area, about 6 groups of quartz reefs contain gold-antimony ore shoots. The largest mine was the Jackson. Stibnite has also been found near the Tyrconnel gold lodes and in the Sam-the-Roman Creek area.

The total output of antimony from the Hodgkinson Goldfield is estimated to be 3104 tons valued at about £40,990 (Jensen, 1941a, unpubl.), of which about 1500 tons were obtained from the Northcote area.

Mitchell River Area

Along the Mitchell River antimony lodes are scattered from a point north of the Hodgkinson Goldfield downstream to the environs of Belleview homestead. The largest is the Mitchell River antimony mine, also known as the Peter Pan, 30 miles northwest of the deserted township of Mount Mulligan. The mine, which was opened in 1890 by Mulligan, is situated on a northwesterly quartz lode almost half a mile long, and had its own treatment plant. Early assays of bulk ore parcels ranged from 23 to 45 percent antimony, but later samples from greater depths were lower and less consistent in grade (Jensen, 1923; Fleischman, 1951b). The associated gold values were generally less than 1 oz per ton.

The Jestah lode, 7 to 8 miles west of the Peter Pan, was opened in 1949, and is located in a crush zone of quartz with inclusions of country rock. The grade is low. Similar small lodes occur elsewhere along the Mitchell River, but little information is available. In the King Pin deposit (precise location unknown) the stibnite appears to have crystallized after pyrite, arsenopyrite, sphalerite, chalcopyrite, and gold (Edwards, 1955c). Several antimony leases were situated on the north bank of the Mitchell River, about 6 miles southwest of its junction with the McLeod River.

Starcke Goldfields

Stibnite was mined for five years from the gold-quartz lodes on Cocoa Creek, at the southern end of the Starcke No. 1 Goldfield. The lode at the First Call claim, the principal working, trends west-northwest. Most of the ore was obtained from bulges in the quartz vein (Rands, 1893). Stibnite was probably also commonly associated with the gold lodes in the Starcke No. 2 Goldfield, but was not often reported. Some ore from a mine 2½ miles east-southeast of Munburra assayed 9 percent antimony (Ball, 1909e,f).

Other Areas

Small antimony lodes are associated with the gold workings 5 and 6 miles west of Cooktown (Saint-Smith, 1922; Shore, 1946; Denmead, 1948), but no reliable records are available. A few tons of ore were taken from Quins Hill in 1942 and 1945.

A little antimony has been obtained from the Herberton/Mount Garnet district (Blake, 1968, unpubl.); traces have been reported from the Mareeba and the Maytown gold reefs, the Mistake fluorspar mine near Emuford, and Dargalong and Scardons Camp in the Chillagoe district.

Iron

Iron deposits have been worked (mainly for use as a flux) in the belt occupied by the Chillagoe and Mount Garnet Formations. They consist of contact-metasomatic deposits around the granite intrusions, and most of them occur in the calcareous members of the formations. They are usually described as ironstone. Most of the deposits are small and discontinuous, and commonly highly siliceous. Magnetite and hematite are generally the chief iron minerals, and are commonly associated with garnet, which in places is predominant. Some of the deposits have been mined for copper and lead also (de Keyser & Wolff, 1964).

The most important iron deposit was Mount Lucy, a low hill about 3 miles west of Almaden, which was a regular producer of flux for the Chillagoe smelters. The orebody consists of magnetite, hematite, and garnet. The recorded production is 45,345 tons, which represents about 58 percent of the total output in the Chillagoe district.

Dunstan (1905c, 1906) and Denmead (1934f) concluded that the magnetite in the ironstones was probably formed by weathering and alteration of garnet, because the iron oxides invariably gave way to garnet rock wherever the depth of the shafts exceeded a few feet.

Similar small contact deposits of hematite are found in the Mount Garnet area (Blake, 1968, unpubl.).

The banded quartz-hematite deposit at Mourilyan Harbour, 8 miles southeast of Innisfail, is of a different type (Morton, 1937b). The deposit forms the backbone of a low hill on the western side of the harbour. It is 15 to 20 feet wide, and strikes northwest parallel with the surrounding steeply dipping schist. Iron-rich and quartzose layers alternate, and Morton considered the deposit to have been formed by replacement of the schist by silica and iron. The iron-rich portions assay from 45 to 58 percent iron, but the iron content of the quartzose layers is much lower.

Loose blocks of low-grade iron ore, composed of hematite, quartz, and some manganese oxide, have been reported from the granitic country on the eastern side of Hinchinbrook Island (Reid, 1919, unpubl.), but the lodes have not been found.

Manganese

Low-grade deposits of manganese ore are distributed in a broad belt along the coast between Cooktown and Gordonvale in the Cairns region. Manganese oxides also occur in small amounts in many of the mining areas in the Chillagoe and Herberton districts, generally in association with ferruginous base-metal deposits, e.g. at Redcap (de Keyser & Wolff, 1964).

The deposits in the coastal belt include, from north to south: Botts manganese lode, 14 miles southwest of Cooktown (Denmead, 1949b); outcrops between Bailey Point and the Daintree River; outcrops in the Cassowary Range between Mossman and Port Douglas, and 3 miles west of Mossman; exposures near Mona Mona Mission station, 20 miles northwest of Cairns; the Molloy area; and several localities between Cairns and Gordonvale.

With few exceptions the deposits are low grade, small, and commonly highly siliceous or, in places, somewhat ferruginous. The best ores were obtained at Mount Martin, 7 miles southwest of Cairns. The deposit is reported to be an irregular replacement body without sharply defined walls, dipping at right angles to the dip of the surrounding schist. Mount Martin is the only prospect from which ore has been marketed; total production was about 1120 tons of handpicked ore containing over 40 percent manganese. Assays of the ore ranged from 25 to 40 percent manganese oxide.

About 30 tons of ore were mined in the Cassowary Range near Mossman, where assays ranged from 17 to 51 percent manganese dioxide. The ore reserves are too small to be of economic value.

Many of the lodes are siliceous replacement deposits along shear zones, but in places the pockets of manganese oxides appear to have been formed by weathering processes, e.g. between Bailey Point and the Daintree River. One handpicked sample collected in 1960 assayed 46.3 percent manganese dioxide, but the average grade is probably lower.

The manganese minerals recorded include psilomelane, pyrolusite, wad, and some rhodonite and braunite; cryptomelane and gamma-MnO_2 have also been reported (Casey, 1956).

Other Metals

Arsenic. Arsenopyrite is common and widely distributed in most of the metalliferous deposits in the Hodgkinson Basin. Realgar has been reported from several mines in the Herberton district (Berge et al., 1900).

Chromium. Fragments of chromite, apparently derived from talcose schist nearby, have been reported from a site 7½ miles south-by-east of Mareeba (Connah, 1953b). They assayed between 40 and 50 percent chromium.

Cobalt. No payable deposits of cobalt are known in the area. Traces of cobalite occur in association with the chalcopyrite and chalcocite in the Cambourne lode southwest of Mount Redcap, in the Chillagoe district (Jensen, 1941c, unpubl.; de Keyser & Wolff, 1964). The lode was drilled by Metals Exploration Ltd in 1956, and was proved to be uneconomic.

Cobalt has been reported in a low-grade pipe-like orebody, containing gold, bismuth, and arsenic, in shale and greywacke near granodiorite, 32 miles northwest of Chillagoe (Morton, 1939c). Cobalt has also been recorded from one of the claims at Mount Hartley in the Annan River tinfield (Dunstan, 1913b, Min. Ref. 1834a) in association with pyrite and arsenopyrite in quartz.

Mercury. Cinnabar has been recorded from a few localities only. The best known occurrences are in the Little Kennedy River area, 7 to 15 miles north of Palmerville, where it is commonly associated with low-grade copper mineralization in amygdaloidal andesite or basalt of the Chillagoe Formation. Dunstan (1917) described the deposits as small and irregular, and thought that they were solfataric in origin. One grab sample contained 3 percent mercury, but other assays were less than 1 percent. The host rocks are kaolinized and sericitized.

Ball (1914d) and Jensen (1923) reported traces of cinnabar from the environs of the O.K. mines, and from a locality midway between the O.K. mines and the Mitchell River antimony mine, but no further details were given.

Mention was also made of cinnabar at Dargalong, 8 miles southwest of Chillagoe, and in various places in the Herberton district (Berge et al., 1900), but Ball (1914d) has cast some doubt on the reliability of these reports.

Minor Elements. Some *columbite-tantalite* has been found in the tin wash in Platypus Creek, a branch of the Mossman River, and may also be present in the Dargalong Metamorphics northwest of Mulgrave homestead, according to local sources. *Monazite* is recorded in some of the tin concentrates in the Herberton district and around Fossilbrook, and is associated with the wolfram deposits at Bamford Hill and Wolfram Camp, where it was often mistaken for scheelite (Dunstan, 1905d).

Platinum. Minute flakes of platinum are reported from the Russell River alluvial tin deposits (Jack, 1888c).

Titanium. The beach sands along the coast have been tested at various points for heavy minerals during the late 'fifties, e.g. on Hinchinbrook Island (Connah, 1961), but no significant concentrations of rutile have been found.

Rutile was reported in 1945 from the Muldiva Creek area west of Chillagoe, where it occurs in narrow aplitic bands in the Dargalong Metamorphics (de Keyser & Wolff, 1964). The deposit was tested in 1953-55 by Dowsett Engineering (Aust.) Pty Ltd, who found that the tonnage available was too small to be of economic interest.

Ilmenite is found in some of the beach sands; Dunstan (1905d) reported a concentrate with 84 percent ilmenite from near Innisfail, at the mouth of the Johnstone River.

Uranium. For some time uranium prospecting permits were held over sections of the Featherbed Volcanics northeast of Almaden, but no uranium mineralization was found. Torbernite has been reported from a 'wolfram mine at Lappa' in association with wolfram, molybdenite, and bismuth in a topaz-hematite-quartz lode in granite, and an unidentified uranium mineral was reported to be associated with wolfram in the Tommy Burns tin mine, west of Sunnymount (de Keyser & Wolff, 1964). Berge et al. (1900) recorded, without being able to verify, a report that uranium and torbernite were noted in two locations at Watsonville in the Herberton district.

Non-Metallic Minerals

Fluorspar, coal, limestone, and clay have been mined in the area, and small deposits of talc, mica, silica, diatomite, magnesite, pozzolan, sand, and gemstones are also known. Abundant supplies of stone suitable for aggregate, road metal, and building stone are available, but local demand is generally limited. Water of course is of prime importance.

Fluorspar

(Ridgway, 1945b; de Keyser & Wolff, 1964)

The Chillagoe Gold and Mineral Field, which contains all payable fluorspar deposits of the Hodgkinson Basin, has been Queensland's largest producer. The total recorded output has been about 31,730 tons, valued at £13,140 (Best, 1962). Production started in 1917, when 20 tons of fluorspar from the Mistake mine were shipped to New Caledonia. The mine, 8 miles southeast of Petford, has been the largest individual producer in the area, and was worked for both fluorspar and wolfram.

Most of the deposits, however, are concentrated in the region west and south of Chillagoe and Almaden (de Keyser & Wolff, 1964). Similar lodes occur in the Tate River and Bullock Creek area.

Although several of the lodes are reported to contain reserves of available fluorspar the workings have been closed because of low prices and the high cost of transport. In 1959, the last year of recorded production, only some of the Tate-Lynd River leases were still being worked. The following year, a number of lodes were tested and 'large' orebodies were reported in the True Blue and Hard-To-Find leases. In 1963, the Queensland Department of Mines drilled 12 holes with a total footage of 2142 feet on some of the leases west of Mungana and near Dargalong, but no workable deposits were found.

The fluorspar centres in the Chillagoe/Almaden area have been described by de Keyser & Wolff (1964). They include the extensive group of mines west of Mungana; workings near Dargalong; the lodes at Fluorspar, 7 miles west by north of Almaden; small workings about 9 miles southwest of Almaden; and the Mistake mine, 8 miles southeast of Petford.

The Mungana lodes form a system of subparallel, overlapping, and branching quartz-filled fissures, which crop out over a distance of about 4 miles, in mica schist and granitic gneiss of the Dargalong Metamorphics. The veins range from a few inches to 10 feet wide, and the average grade is reported to be about 85 to 88 percent CaF_2.

In the Dargalong area the most important works (Jackson group) occur in muscovite granite; others are found in schist and gneiss of the Dargalong Metamorphics.

The Perseverance is the only important fluorspar lode associated with the gold workings at Fluorspar north of Almaden. The lode is a fissure vein in hornblende granodiorite; it is up to 7 feet wide, and has been worked over a length of 1850 feet. Samples of the fluorspar were assayed in 1923 and found to contain 95 to 97 percent CaF_2 and 1 to 2 percent $CaCO_3$.

The small workings southwest of Almaden are on fluorite-quartz veins, 1 to 4 feet wide, in hornblende-biotite adamellite.

The McCords deposit occurs in biotite granite 20 miles southwest of Chillagoe. The grade of the fluorspar ranges from 92 to 96 percent CaF_2. The lode contains a little molybdenite, generally on the hangingwall.

The Rocky Tate mines, about 10 miles north-northwest from Bullock Creek siding, includes several leases. All except one are situated in granite.

The True Blue and Hard-To-Find group of leases, 18 miles west-northwest of Bullock Creek siding, were the last mines to be worked in 1959. The veins were tested in 1961 and were reported to contain large orebodies (Ann. Rep. Dep. Min., 1961), but no further development has taken place because of lack of demand and low prices.

The Sunset or Hales is a lode in granite, 8 miles east-southeast of Bullock Creek siding.

The Mistake mine, in the Emuford area southeast of Petford, was the first fluorspar producer in the Chillagoe district. The lode consists of a vertical fissure vein in granite and greisen, and is probably associated with a north-south fault. The lode is up to 9 feet wide; both fluorspar and wolfram were mined.

According to local residents, fluorspar lodes exist to the southwest of Mount Mulligan, probably in the Featherbed Volcanics, but access is difficult.

Coal

The only coal deposit of importance was found at Mount Mulligan, in 1907, and was mined continuously from 1914 to 1957 (Ball, 1912b, 1917a; Morton, 1945c; Shepherd, 1945; Connah, 1953a; Powell Duffryn, 1949). The mine closed

down when the Tulley Falls hydro-electric scheme was completed and the railway was dismantled. The mine provided fuel for power plants in the surrounding mining districts, and a total of almost 1 million tons of coal was produced from the State mine, and from the King Cole colliery (from 1941) operated by Tableland Tin Dredging N.L.

At the State mine, four composite coal horizons are interbedded with sand-shale sequences of late Permian age, the Mount Mulligan Coal Measures. The total thickness of the measures increases from zero (about 9 chains south of the King Cole colliery, see Pl. 19) to 120 feet at the State mine, to more than 300 feet a few miles farther north, and finally reaches a maximum of possibly over 800 feet in the conglomerate at the northeastern end of the outcrop area. The number of coal seams increases from one at the King Coal mine to four at the State mine, but farther north the quality of the coal deteriorates rapidly.

The interleaved shale bands within the coal horizons thin out uniformly towards the west, while the coal layers maintain a fairly constant thickness.

In 1913, Dunstan estimated that the coal reserves possibly amounted to 60 million tons, of which 15 million tons were 'actual'. Ball (1917) gave a figure of 19½ million tons, and still later estimates were reduced considerably when the facies changes to the west and north became better known. The last figure available is 1,175,000 tons for the two main seams of the three seams mined (Powell Duffryn, 1949).

The coals are classed by de Jersey (1949) as subhydrous high-volatile bituminous, with a calorific value between 14,000 and 14,600 BTU. The dominant type consists of subhydrous durain with some clarain bands. The coal has an ash content of 15 to 18 percent, and is unsuitable for coking.

Coal of Permian age has also been found at the Little (Kennedy) River area 15 miles north of Palmerville; the Oaky Creek coalfield 20 miles west-southwest of Cooktown; the Mitchell River area southeast of Mount Mulgrave homestead; and a small occurrence 3 miles northeast of Koorboora. None of the occurrences is of economic importance. The deposits in the Little (Kennedy) River area (the Little River Coal Measures) excited early interest because of their position on the projected railway to the Palmer Goldfield, and because of the thickness of some of the seams. However, the seams are strongly deformed and faulted, and the coal is heavily slickensided (Jack, 1882; Rands, 1893), and has a high ash content (14-46% according to Rands, and Powell Duffryn, 1949) — higher than originally reported.

The Oaky Creek coalfield (the Normanby Formation), received little attention after Jack's initial investigation (Jack, 1879). At least 100 feet of shaly coal crop out in Coal Creek, about a mile northeast of the Brothers, and smaller outcrops are found in neighbouring gullies. The Coal Creek seams are less intensely folded than elsewhere in the formation, but the coal is nevertheless faulted and crushed. No analyses are available.

In the Mitchell River area, about 4 feet of impure coal is exposed in a gully about 7 miles southeast of Mount Mulgrave homestead, in a sequence of shale and arkose intercalated in the Nychum Volcanics.

In 1910, a small deposit of impure coal was found 3 miles northeast of Koorboora. The discovery aroused great interest because of the need for fuel for the Chillagoe smelters. The Chillagoe Railway and Mining Co. Ltd arranged for several shafts to be sunk, but the coal and carbonaceous shale were found to be of no commercial value. The coal, which is associated with flaggy sandstone and grey waterlaid tuff at the base of the Featherbed Volcanics, is soft and crumbly, and probably has a high ash content.

Thin seams of coal and carbonaceous shale are common in parts of the Jurassic Dalrymple Sandstone (Ball, 1910a; Jack, 1895). The seams occur mostly in the eastern part of the sandstone outcrop area, in the lower 100 feet of the formation; some seams in the Battle Camp Range and Welcome Creek area are higher up in the succession. A 10-inch seam of coal was also penetrated in a bore about 28 miles northeast of Laura, at a depth of 120 feet. Most of the seams are less than 1 foot thick, and generally have a high ash content (8-47%) (Dunstan, 1913a).

Coal seams in the Cretaceous Battle Camp Formation have been reported from Stanley Island and Clack Island in the Flinders Group (Lee-Bryce, 1905); they are thin, but are possibly of fair quality.

Some thin coaly seams have been found in the sub-basaltic Tertiary clay and grit in a branch of Butcher Creek, 7 miles east-northeast of Malanda, but the deposit is too thin to be of value (Denmead, 1947a, unpubl.).

Limestone

Limestone for chemical and agricultural purposes is in increasing demand by the sugar cane industry around Cairns and Innisfail. In 1963, production for the first time since World War II exceeded 6000 tons. In the past, limestone was used extensively as a flux in the smelters.

There is abundant limestone in the Chillagoe Formation, which extends from north of the Palmer River, near Palmerville, southward to Chillagoe and Almaden. The limestone is light grey and dense, but is recrystallized around granite intrusions to a coarse white soft marble. The only deposit being mined at present is at Ootann, 7 miles south of Almaden (de Keyser & Wolff, 1964) on the Cairns/Forsayth railway. Massive limestone is worked for burnt lime, and coarsely crystalline calcite for pulverized lime. The calcium carbonate content is generally about 97 percent, with up to 1.7 percent iron oxide, and little silica. Production at the rate of a few thousand tons per year has been steady and reserves are large. The plant was being extended in 1963.

Other limestone deposits in the Chillagoe Formation are too remote to be worked profitably. Additional supplies for the sugar industry are obtained from a few smaller lenses of limestone in the Hodgkinson Formation and Barron River Metamorphics, which are closer at hand. The isolated lenses of limestone or marble which have been worked or prospected include: a bluff 16 miles north of Mareeba; an outcrop at Mowbray, 5 miles south of Port Douglas; Mount Peter, 3 miles west of Gordonvale; and Christmas Creek, a headwater branch of the West Mulgrave River, 12 miles east of Malanda. Other lenses are known west of Cooktown, but most of them are too remote.

The bluff north of Mareeba, 5 miles northeast of Southedge siding, consists of very fine limestone, but the reserves available are possibly not more than 100,000 tons (Levingston, 1958a). After a period of idleness since 1958, quarrying was resumed in 1963 and amounted to 2430 tons.

The Mowbray deposit (Denmead, 1949) is a lens of coarsely recrystallized white limestone with bands of dark impure limestone, intercalated in phyllite and greywacke of the Barron River Metamorphics. Annual production for the last few years to the end of 1963 ranged from 80 to 200 tons. Estimated reserves in 1949 were 17,500 tons above the quarry floor, plus 35,000 tons to a depth of 100 feet.

Several leases have been taken out recently at Mount Peter and on Christmas Creek, and several parcels of limestone have been sold. At Mount Peter and Christmas Creek the limestone occurs as lenses in the phyllite and schist of the Barron River Metamorphics (Connah, 1958).

Deposits near Mungana and Chillagoe, and northwest of the O.K. mines, have been worked for flux for the smelters.

'Earthy lime' or travertine, derived from the Palaeozoic limestone, has been deposited in gullies and depressions, and is used in agriculture. This type of deposit has been worked occasionally at Rookwood homestead (5 miles north of Mungana), and 4 miles northwest of Almaden (de Keyser & Wolff, 1964).

An unusual deposit of porous travertine occurs in the valley of the Little Mulgrave River, within a mile of the Gillies Highway (Reid, 1926). It consists of a superficial cover of Recent limestone up to 30 feet thick, and contains abundant plant remains and some gastropods. Whitehouse (1926) suggested that the deposit may be marine or brackish, whereas Reid was inclined to favour a freshwater origin. De Keyser (1964) concluded that the limestone was probably deposited in a freshwater lake formed by damming of the Little Mulgrave River by basalt flows in the main valley of the Mulgrave River.

'Iceland spar' was reported from a creek near Rookwood homestead (Morton, 1944d), but the quality is not good enough for use in the optical industry.

Clay

Clay deposits are being worked on the Clohesy River, 11 miles northeast of Mareeba, and in the Innisfail area. Large reserves are available in the vast stretches of Cainozoic alluvium covering the northern part of the Laura Basin, but the area is remote. In the old mining days, bricks for buildings and smelters were made from small local clay deposits, as at Chillagoe.

The Clohesy River Brickworks (formerly the Mareeba Brickworks) have produced 106,825 tons of clay up to the end of 1966, since they were opened in 1951. The deposits are in Pleistocene or Recent alluvium along the Clohesy River.

At Silkwood, 16 miles south of Innisfail, Quaternary clay has been used for the manufacture of bricks since about 1955. The total output to the end of 1966 has been 15,367 tons.

White kaolin, suitable for ceramics, has been reported from the southern coast of Hinchinbrook Island (Connah, 1952, unpubl.).

Other Non-Metallic Minerals

Quartz. Some 1430 tons of a fine-grained, sugary, pure quartzite were quarried at Chillagoe to the end of 1943 (de Keyser & Wolff, 1964), for use as metallurgical flux at the smelters. The quartzite is in contact with granite, and may have been formed by silicification of limestone or recrystallization of chert.

Several tons of quartz crystals were obtained from a vug in the wolfram pipes at Wolfram Camp, but only 25 lbs were suitable for piezo-electric uses.

Large deposits of quartz sand are available in the dunes and beaches north of Cooktown. Samples of white sand collected by J. W. Smith of the Bureau of Mineral Resources in the McIvor River area were found to be composed of 99 percent or more of angular and subangular quartz grains (Pontifex, 1965, unpubl.). The heavy minerals include 1 percent or less of magnetite, ilmenite, tourmaline, amphibole, epidote, zircon, rutile, beryl, and limonite pellets. The iron content ranges from 0.06 to 0.25 percent, which is above the acceptable limits for the manufacture of clear glass (Pontifex, 1965, unpubl.).

Diatomite. Deposits of diatomite have been found near the edges of the Atherton, Wallaroo, and McBride Basalt Provinces. Within the area mapped, deposits are known at Innot Hot Springs on Nettle Creek, 8 miles southeast of Mount Garnet, and at Flaggy Creek on the Lucy Tableland, 32 miles west of Cardwell (White & Crespin, 1959, unpubl.). They appear to have been deposited in lakes formed by the damming of streams by basalt flows. Best (1959, unpubl.) believes that the silica was derived from the acid igneous rocks in the hinterland of the drainage system.

At Flaggy Creek, the diatomite beds lie at, or close to, the top of a sequence of late Tertiary conglomerate, sandstone, and clay, 150 feet thick, and are possibly of Pliocene age. The diatomite is white, porous, and light, but is impure and of low grade.

The deposit at Innot Hot Springs is of Recent to sub-Recent age, and is of 'fairly good quality for filtration purposes' (Crespin, 1947). It is overlain by Recent basalt.

Pozzolan is a siliceous, or siliceous and aluminous, material which in itself possesses little or no cementitous value, but will, in finely divided form, and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

During the construction of the Koombooloomba Dam, on the upper Tully River 23 miles west-northwest of Tully, pozzolanic material was found along the road 8 miles northwest of the dam. The deposit consists of grey, massive, clayey material rapidly turning red-brown on exposure to the atmosphere, and samples were tested by CSIRO and later by the Department of Civil Engineering at the University of Queensland (Gipps & Britton, 1960). Bush (1960) and Best (1959, unpubl.) consider that the main mass of the deposit consists of volcanic ash. De Keyser, on the other hand, suggests that the deposit is a decomposed flow on the following grounds:

1. The bomb-like fragments in the deposit in no way resemble the scoriaceous or crusted true bombs found elsewhere in the Atherton Tableland, but consist of dense massive basalt showing flow lines in places.
2. Rudiments of spheroidal exfoliation can be recognized in the pozzolan, and in one place contained a core remnant of fresh basalt. A 'cylindrical' weathering structure found in the pozzolan is also imprinted on the surface of some of the 'bombs'.
3. The pozzolan is identical in texture, colour, and consistency with the decomposed basalt flow exposed in quarries and road cuttings.

The available evidence shows that the transition from fresh basalt into decomposed rock can be quite sharp, and that this feature cannot be used as an argument against considering the bomb-like fragments to be normal core-boulders.

Talc. Boulders of talc schist are found on the south side of the entrance to Mourilyan Harbour, and there is a zone of talc schist 350 feet wide trending northwest across the bottom of the harbour. Some specimens were found to contain 85 to 90 percent talc of moderate to fairly good grade. In thin section the rock is seen to consist of talc, up to 5 percent antigorite or biotite, and a little magnetite.

Another talcose rock is exposed in a road cutting on the Bruce Highway, about 12 miles south of Innisfail. It consists of tremolite-talc schist and tremolite-chlorite schist. The grade is lower than that of the material at Mourilyan Harbour.

A lens of basic and ultrabasic rock, 8 miles south-southeast of Mossman, is altered around the edges to serpentine and carbonate-talc rock, but no high-grade talc schist was noted. An occurrence of talcose schist containing chromite has been reported from the Mareeba area (Connah, 1953b).

Mica. Muscovite is very common in the Precambrian pegmatites and granulites of the Dargalong Metamorphics, but large crystals are known in two localities only. In the Mount Kitchin area, 30 miles west of Chillagoe (Owen, 1942, unpubl.; Morton & Ridgway, 1944a), the mica is concentrated in pockets and segregations in quartz-feldspar-mica pegmatite dykes and lenses. The books of mica range up to 1 foot square, but most of the material is soft, warped, fractured, and stained. In 1941, the deposit was closely examined, and it was found that the pegmatites, which had been thought to be shaped as pipes, consist of pockets and segregations which cut out at shallow depth.

The second deposit is located on the main divide at the head of the Morehead River, about 26 miles south-southwest of the Musgrave telegraph station (Ball, 1943). Large books of muscovite are concentrated in lenticular bodies in quartz-feldspar-mica pegmatites. The books contain microcrystalline inclusions of black tourmaline and rare magnetite, but are reported to have very good splitting qualities, and were classified as 'commercial clear' mica (Warden's reports). The deposit was tested and developed during the war, and about 7 tons of mica were raised, but no market was found for the product and the workings were closed.

In 1891 leases to work mica were taken up in the Wandoo area, about 10 miles west of Mungana, and in 1898 Jack noted mica at the head of Wandoo Creek, but no further details are available.

Aggregate, Road Metal, Building and Monumental Stone. Local demands for crushed aggregate, road metal, construction stone, and similar materials, are easily met by quarrying various rocks. Road metal in the Innisfail and Cairns areas is obtained from quarries in basalt flows and pyroclastic deposits, and lateritic buckshot gravel and other rocks are used elsewhere. Aggregate for the dams at Tinaroo and Koombooloomba was quarried from local granites. Mesozoic sandstone was used to construct the culverts on the Cooktown/Laura railway (now dismantled). The granite at Cooktown, and some of the crystalline marbles around Chillagoe, have been used locally for monumental and ornamental stone.

Gemstones and Semi-precious Stones. Varieties of semi-precious quartz in some of the mining areas include: rock crystal in the Annan River tinfield and in various places in the Herberton district; rose quartz at Rossville (Annan River tinfield) and at Mount Barunda near the old site of Fischerton on the Tate River; amethyst at Mount Barunda and near Coolgarra; and sagenite and smoky quartz in the Annan River tinfield (Dunstan, 1915b).

Good-quality agate is found along the Mitchell River near Mulgrave homestead, where it is derived from the amygdaloidal basalt and andesite of the Nychum Volcanics. In recent years this locality has become a source of supply for agate dealers. Carnelian or sard has been reported from the Upper Tate River and the Wild River, prase from the Dargalong mining area, and cairngorm from Wolfram Camp and Herberton.

Beryl, including aquamarine, is common in the tin wash of the Herberton and Chillagoe Gold and Mineral Fields. Corundum of various colours occurs in the alluvial tin deposits of the Annan River tinfield, the Jordan Creek and Russel Goldfields, Herberton, and the Tully River south of Herberton. Blue sapphire has been reported in the Butchers Hill area southwest of Cooktown, the Annan River tin wash, and the Starcke River. Ruby has been recorded from the Jordan Creek Goldfield, the Rocky Tate River west-southwest of Almaden, and Campbell Creek south of Laura.

Colourless, pale green, or blue topaz is common in the alluvial tin deposits of the Tate River, Dry River, at Coolgarra, Herberton, Lappa Junction, and in the Jordan Creek Goldfield. Large fractured crystals up to $2\frac{1}{2}$ feet long have been found in the Mount Garnet district (Zimmerman et al., 1963, unpubl.).

Diamond has been reported from Herberton by Dunstan (1913b, Min. Ref. 2579).

Garnet is very common in the skarn rocks of the Chillagoe and Mount Garnet districts, but it is generally not of gemstone quality.

Bauxite. The decomposed basalts in the humid tropical zone of the coastal area are rich enough in alumina to be considered as a possible source of aluminium (Denmead, 1956). They were included in a prospecting programme for bauxite carried out between Cairns and Townsville by Carpentaria Exploration Co. Pty Ltd in 1960 (Znebejanek, 1961, unpubl.). Numerous samples were found to contain an average of 35 percent acid-soluble alumina, but none of the decomposed basalts contained enough alumina to be classified as bauxite.

Magnesite. Magnesite is found as an encrustation on the bedrock and as a cement in the rubble along the creeks draining the McLean Basalt; it also occurs as nodules in the black soil derived from the basalt (Lucas, 1962, unpubl.).

Phosphate. In 1967, phosphatic beds belonging to the Hodgkinson Formation were discovered in the coastal area north of Cooktown, by a subsidiary exploration group of Mid-Eastern Oil N.L. The phosphate was reported to occur as veins of wavellite. The low grade (6% P_2O_5) of the sampled rock, and the steep bedding dips, reduce the chance of delineating economic orebodies, notwithstanding the favourable location close to the sea.

Salt. A reported occurrence of salt at Lake Emma, 4 miles southwest of Battle Camp homestead (Dunstan, 1920), could not be located, and local residents do not know of any salt deposits. The lake contains fresh water only.

Water

The rainfall is high in the coastal zone between Ingham and Cooktown, but farther inland it decreases sharply, and the streams stop flowing during the dry season; only the larger rivers are perennial. The limited supplies of surface water are supplemented where possible by bores in thick alluvial sands, and in the Mesozoic strata of the Laura Basin and Red Plateau, where the best aquifers are found in the basal parts of the Cretaceous and Jurassic formations. Spring water is available in some areas in the limestone belt of the Chillagoe Formation, and at the base of the mesas and plateaux of Mesozoic sandstone.

Although the rainfall in the coastal belt is high it is largely seasonal, and in the Annan River tinfield many long and costly flumes were built to carry water from the larger streams to the workings, and to provide sufficient pressure for hydraulic sluicing. The building of dams in the mountainous tinfields is generally beyond the resources of the small syndicates that usually work the deposits.

The seasonal rainfall disrupts mining operations farther inland, where there is a serious shortage of water during the dry season, and flooded streams disrupt communications and transport during the wet season.

Ample supplies of water can be obtained by building dams in the mountainous coastal belt. Two dams have been built since World War II: the Tinaroo Falls Dam 9 miles northeast of Atherton, and the Koombooloomba Dam 23 miles west-northwest of Tully. The Tinaroo Falls Dam, completed in 1958, provides water for the Mareeba-Dimbulah Irrigation Scheme which mainly serves the tobacco industry, and supplements the hydroelectric scheme at Barron Falls. The Koombooloomba Dam was nearly completed in 1964, and is to be used for the generation of power and possibly for irrigation. Other major schemes being investigated include the Herbert River (Carter, 1959, unpubl.; Wolff, 1962, unpubl.), North Johnstone River, and South Johnstone River. Hydroelectric power is generated at the Barron Falls (Kuranda) and Tully Falls, 13 miles south-southwest of Ravenshoe, without storage reservoirs.

Vast supplies of potable water are probably available in the extensive sand dune area north of Cooktown, where the rainfall is high enough to prevent depletion of this natural reservoir.

Oil

The Hodgkinson Basin is not a potential source of oil because the Palaeozoic formations are too severely folded, sheared, and faulted, and are intruded by granite batholiths.

The Laura Basin offers better prospects: the Mesozoic formations are only gently dipping and comprise clayey and sandy rock units which may form potential cap rocks and reservoir rocks. In 1962, Cabot Blueberry Marina No. 1 well was drilled about 75 miles north-northwest of Laura by Mines Administration Pty Ltd (1962, unpubl.) for Marathon Petroleum Australia Ltd; it was completed as a dry hole at a depth of 3829 feet.

Micro Magnetic Associates (1963, unpubl.), in a report to Gulf Interstate Overseas Ltd, recommended drilling at the southwest corner of Corbett Reef in Princess Charlotte Bay.

In 1963, the General Geophysical Co. (Bahamas) Ltd carried out a seismic survey over 80 square miles of the Laura Basin; this showed the basin to be a gently north-plunging, structurally depressed area.

The region of the Great Barrier Reef is little known stratigraphically, but might contain economic quantities of oil if the Cainozoic (and Mesozoic?) formations are thick enough.

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APPENDIX

PALAEOZOIC FOSSILS FROM THE HODGKINSON BASIN

Chillagoe Formation (Bryan & Jones, 1945; Ball, 1918; Etheridge, 1904, 1911; Dorothy Hill, 1943a and pers. comm.; Jensen, 1923, 1941).

Corals — *Campophyllum, Cladopora* sp., *Cyathophyllum* spp. (e.g. *C. dunstani, C. chillagoensis*), *Cystiphyllum* sp., *Favosites* spp. (e.g. *F. gothlandica* Lamarck forma *forbesi*), *?Fasciphyllum, Grypophyllum* sp., *Halysites* spp. (e.g. *H. chillagoensis, H. peristephesicus*), *Heliolites* spp. (e.g. *H. porosa*), *Kyphophyllum* sp., *Propora* sp., *Pseudamplexus* sp., *Spongophyllum* spp. (e.g. *S. cyathophylloides*), *Tryplasma* sp., *Xystriphyllum* sp.

Brachiopods — *Rhynchonella* sp., *Pentamerus* sp.

Gastropods.

Crinoids.

Demospongea (probably of the suborder Eutaxicladina).

Radiolaria.

Mount Garnet Formation (Bryan & Jones, 1946; Dorothy Hill, pers. comm.; Levingston, 1960).

Corals — *Alveolites* sp.?, Cyathophyllid corals, *Cyastiphyllum* sp., *Favosites* sp., *Heliolites* sp., rugose corals.

Crinoids.

Brachiopods.

Trilobites — *Calymene* impressions in sandstone.

Hodgkinson Formation (Dorothy Hill, pers. comm.; Jack, 1884; O'Mara, 1957; Mary White 1961b).

Corals — *Calceola sandalina, Cladopora* sp.?, *Coenites* sp., *Cyathophyllum helianthoides, Fasciphyllum conglomeratum, Favosites* sp. (e.g. *F. nitidus, F. ?goldfussii*), *Heliolites* sp., *?Hexagonaria* sp., *Pachypora* sp., *Pseudamplexus* sp., *Spongophyllum* aff. *halysitoides, Thamnopora* sp. cf. *reticulata, Xystriphyllum* sp. (e.g. *X. dunstani*).

Crinoids.

Brachiopods — *Atrypa* sp., *Spirifer* sp.

Stromatoporoids.

Polyzoa.

Plants — *Leptophloeum australe, Lepidodendron australe, Protolepidodendropsis* sp., *Retzia* sp.

Radiolaria.

Nychum Volcanics (Mary White, 1961a).

Abundant: *Glossopteris angustifolia* Brong., *G. indica* Sch. Equisetalian stem impressions. Seeds, e.g. of *Samaropsis barcellosa* White, *Carpolithes.*

Rare: *Taeniopteris* cf. *T. elongata* Walk., *T.* cf. *T. wainamattae* (Feist sp.)

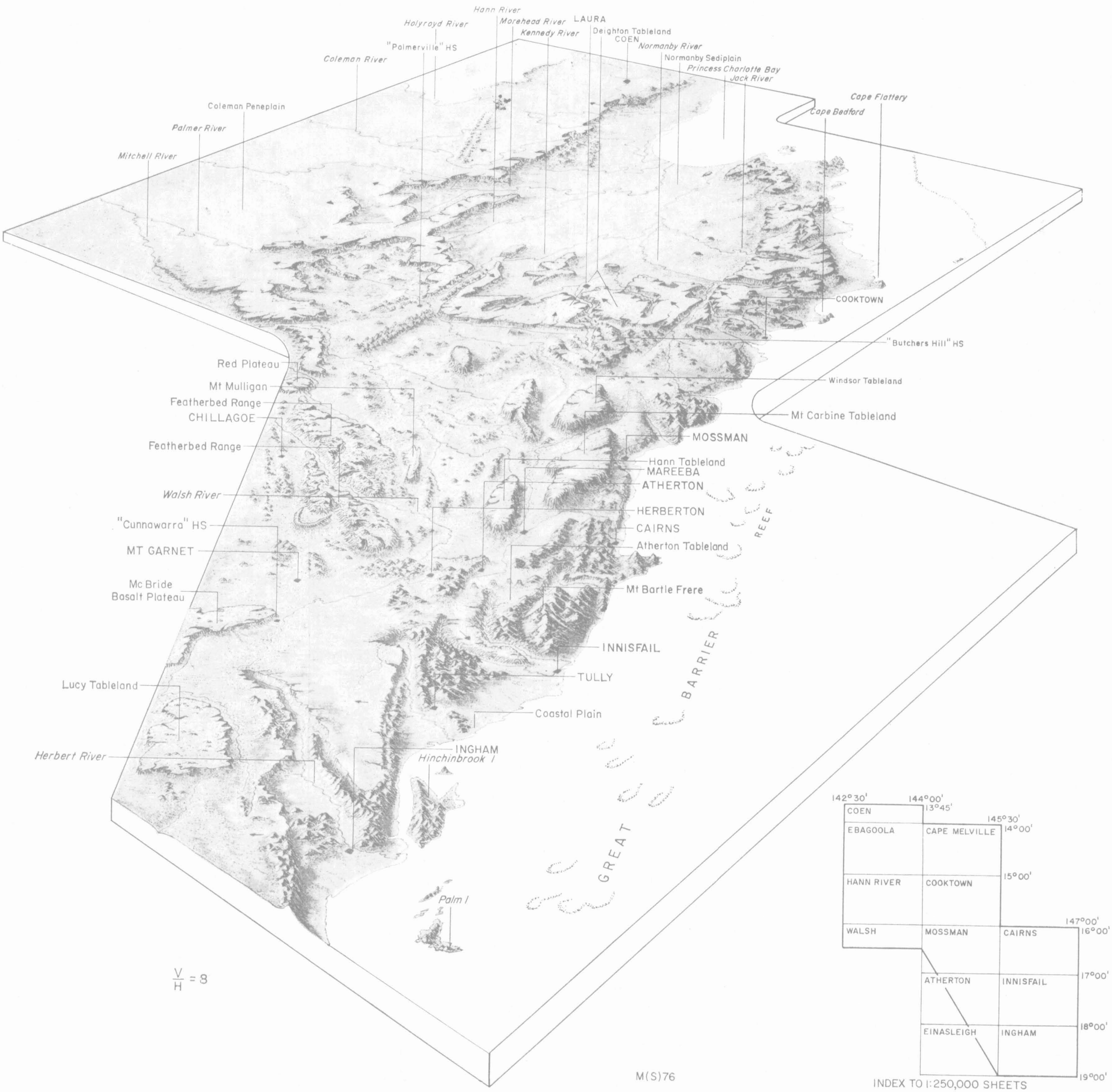
Pollen (B. E. Balme, pers. comm.)—Bisaccate genera including *Lunatisporites, Striatopodocarpidites, Pityosporites.* One abundant species is *Marsupipollenites triradiatus* Balme & Hennelly.

Mount Mulligan Coal Measures (Ball, 1910, 1912; Mary White, 1961; Whitehouse, 1933; AGGSNA, 1929).

Gangamopteris sp., *Glossopteris ampla, G. angustifolia* Brong., *G. browniana, G. indica* Sch., *Schizoneura gondwanensis* Feist., *Sphenophyllum* sp. (e.g. *S. speciosum*), *?Sphenopteris* sp., *Vertebraria indica* Royle.

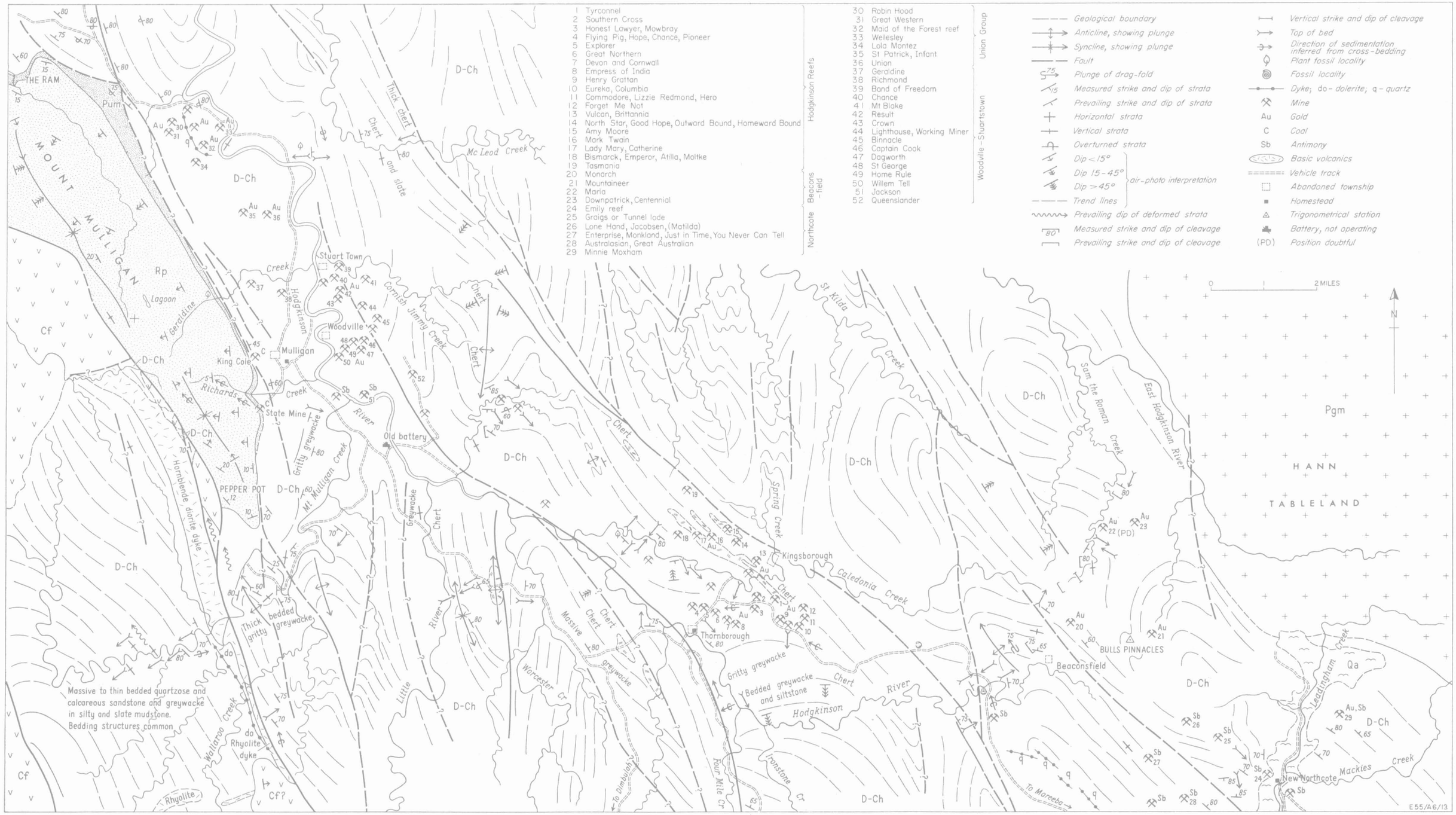
Spores and pollen.

CAINOZOIC
9
DEIGHTON TABLELAND
COASTAL PLAIN
SHELF
ATHERTON TABLELAND
FEATHERBED RANGE
LAURA BASIN
JURASSIC TO
LOWER CRETACEOUS
8
7
TRIASSIC (?)
UPPER PERMIAN
6
FEATHERBED
VOLCANICS
Cr Cm
MIDDLE CARBONIFEROUS
TO MIDDLE PERMIAN
5
LOWER
CARBONIFEROUS (?)
4
S-Dh, S-Dm, D-Ch
HODGKINSON
BASIN
S-Dh, S-Dm
MIDDLE TO UPPER
DEVONIAN
3
FEATHERBED BLOCK (?)
UPPER SILURIAN
TO
LOWER DEVONIAN
2
SHELF
CHILLAGOE
pC
REEFS
PALMERVILLE
FAULT
PRECAMBRIAN
1
M(S)75



M(S)76

INDEX TO 1:250,000 SHEETS


THE RAM
Purn
MOUNT MULLIGAN
Rp
Lagoon
Geraldine
Cf
D-Ch
King Cole
Mulligan
Richards
Creek
State Mine
Gritty greywacke
River
Old battery
Hornblende dolerite dyke
PEPPER POT
Mt Mulligan Creek
Greywacke
Chert
Thick chert
and slate
Mc Leod Creek
Stuart Town
Hodgkinson
Cornish Jimmy Creek
Woodville
Thick gritty bedded greywacke
Massive to thin bedded quartzose and calcareous sandstone and greywacke in silty and slate mudstone. Bedding structures common
Wallaroo Creek
Rhyolite dyke
Rhyolite
CF?
Little
Worcester Cr
Massive greywacke
To Dimbulah
Four Mile Cr
Thornborough
Gritty greywacke
Bedded greywacke and siltstone
Ironstone Cr
Spring Creek
Kingsborough
Caledonia Creek
St Kilda
Creek
Sam the Roman Creek
East Hodgkinson River
HANN TABLELAND
Pgm
BULLS PINNACLES
Beaconsfield
Qa
Leadingham Creek
Mackies Creek
New Northcote
To Mareeba
1 Tyrconnel
2 Southern Cross
3 Honest Lawyer, Mowbray
4 Flying Pig, Hope, Chance, Pioneer
5 Explorer
6 Great Northern
7 Devon and Cornwall
8 Empress of India
9 Henry Grattan
10 Eureka, Columbia
11 Commodore, Lizzie Redmond, Hero
12 Forget Me Not
13 Vulcan, Brittannia
14 North Star, Good Hope, Outward Bound, Homeward Bound
15 Amy Moore
16 Mark Twain
17 Lady Mary, Catherine
18 Bismarck, Emperor, Atilla, Moltke
19 Tasmania
20 Monarch
21 Mountaineer
22 Maria
23 Downpatrick, Centennial
24 Emily reef
25 Graigs or Tunnel lode
26 Lone Hand, Jacobsen, (Matilda)
27 Enterprise, Monkland, Just in Time, You Never Can Tell
28 Australasian, Great Australian
29 Minnie Moxham
Hodgkinson Reefs
Beacons - field
Northcote
30 Robin Hood
31 Great Western
32 Maid of the Forest reef
33 Wellesley
34 Lola Montez
35 St Patrick, Infant
36 Union
37 Geraldine
38 Richmond
39 Band of Freedom
40 Chance
41 Mt Blake
42 Result
43 Crown
44 Lighthouse, Working Miner
45 Binnacle
46 Captain Cook
47 Dagworth
48 St George
49 Home Rule
50 Willem Tell
51 Jackson
52 Queenslander
Union Group
Woodville - Stuartstown
Geological boundary
Anticline, showing plunge
Syncline, showing plunge
Fault
Plunge of drag-fold
Measured strike and dip of strata
Prevailing strike and dip of strata
Horizontal strata
Vertical strata
Overturned strata
Dip < 15°
Dip 15 - 45°
Dip > 45°
Trend lines
air-photo interpretation
Prevailing dip of deformed strata
Measured strike and dip of cleavage
Prevailing strike and dip of cleavage
Vertical strike and dip of cleavage
Top of bed
Direction of sedimentation inferred from cross-bedding
Plant fossil locality
Fossil locality
Dyke; do - dolerite, q - quartz
Mine
Au Gold
C Coal
Sb Antimony
Basic volcanics
Vehicle track
Abandoned township
Homestead
Trigonometrical station
Battery, not operating
(PD) Position doubtful
0 1 2 MILES
N
E55/A6/13

GEOLOGICAL MAP OF THE ANNAN RIVER TINFIELD

PLATE 22

SCALE

0 1 2 3 4 MILES

QUATERNARY	Qa	Alluvium
	Qd	Dune sand
TERTIARY TO QUATERNARY	Czt	Fossil talus
	Czx	Mottled alder alluvials
	Cze	Maclean Basalt
PERMIAN	Pgm	Mareeba Granite
	Pgv	Trevethan Granite
	Pgf	Finlayson Granite
MIDDLE DEVONIAN TO LOWER CARBONIFEROUS(?)	D-Ch	Hodgkinson Formation

Geological boundary

Fault
Where location of boundaries and faults is approximate, line is broken; where inferred, queried; where concealed, faults are shown by short dashes

Strike and dip of strata

Overturned strata

Strike and dip of cleavage

Trend lines

Joint pattern

Dyke do - dolerite gr - granite gn - granophyre p - porphyre

Mine

Alluvial working } mostly abandoned
Sn - Tin, W - Wolfram

Vehicle track

Foot track

Telephone line

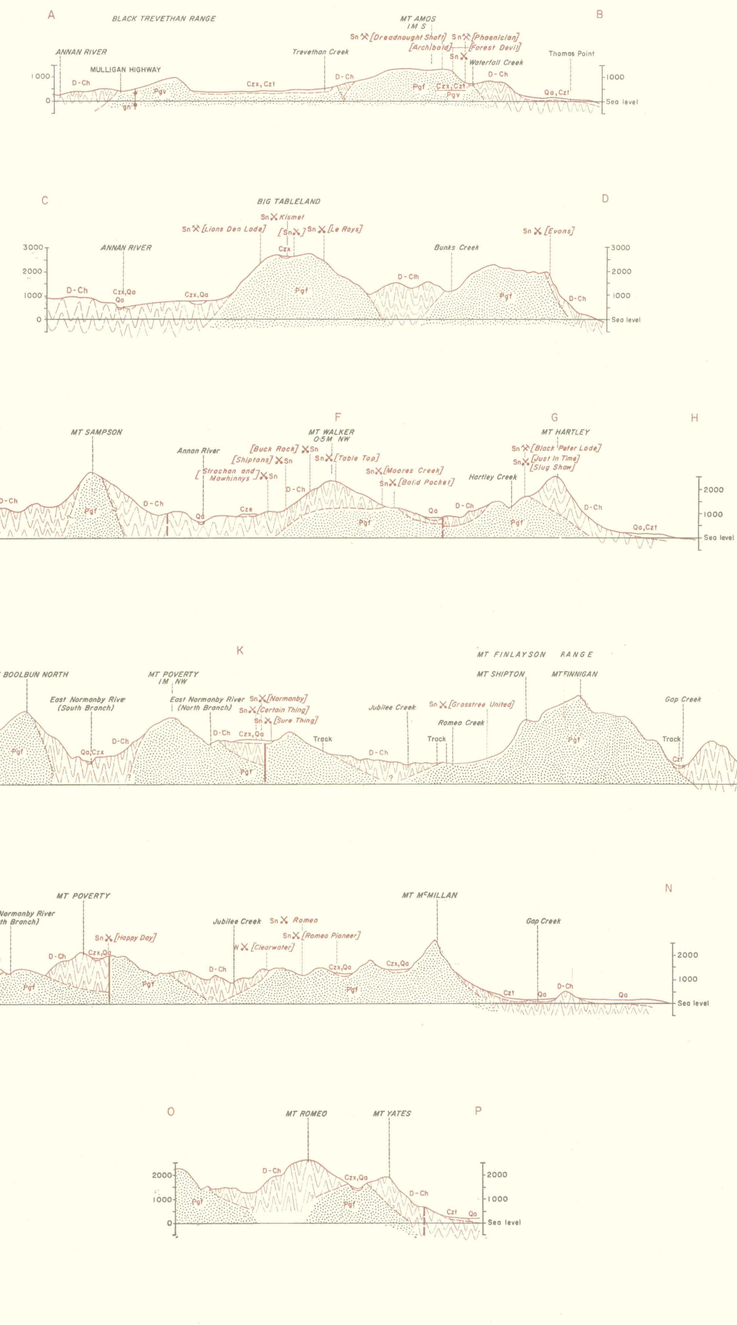
Trigonometrical station

2770 Height in feet

Settlement

SECTIONS V/H = 2·7

Vertical scale shown in thousands of feet
Mines and alluvial workings shown in brackets [ ] are projected



Drawn by: R. Swoboda

Q/A/198

MESOZOIC SECTIONS, LAURA BASIN

Horizontal scale 1:250,000 / Vertical scale 1 cm = 200 ft.

Compiled by K.G. Lucas

500' Thickness of section in feet
400' Probably marine sediments
Correlation lines, mostly stratigraphic
Klo Wolena Claystone (Albian)
Klc Battle Camp Formations (Neocomian-Aptian)
Jl Dalrymple Sandstone (Jurassic)
Basement-Palaeozoic sediment and granite
P Permian
S-Dh Chillagoe Formation
Conglomerate, pebbly beds
Grit
Sandstone-coarse, medium, fine
Shale partings and beds
Coal (impure)

"Pipe-rock"-sorted fine siliceous sst with vertical burrows
Cross-beddings and lamination))))))-oversteepened
Ripple marks, small scale asymetrical
Discoidal clay pellets
Common muscovite flakes
U Burrows, variously inclined
Tracks and trails
Marine macrofossils
Plant macrofossil & Plant microfossil
Wood-replaced fragments or impressions
Gl Glauconite-bearing sediment
Fe Ferruginisation, esp. along joints and shale beds
Ø3 Oil well core number
27 Fossil locality - See Part 2
R.N.11224 Water bore registered number, Irrigation & Water Supply Commission, Queensland
"Lakefield" Homestead
LAURA Township
Boundary of Laura Basin

COMPOSITE SECTION

1270' Fe Grit; ss; sh Wh mica ss
Flaggy pbly qtz ss
800' Thk qtz ss; thn cgl; pbly grit Red-brn silty sh Shy mica f ss
Thk qtz ss to arg f ss
Shy mica sltst; carb sh; coal; f ss
Mas cgl Buff shy mica sltst Gn m arg ss
500' Mass & thk polymict cgl; len grit ss
0

FLINDERS GROUP

Battle Camp Dalrymple Sandstone Formation

BATHURST RANGE

BATHURST RANGE 1070' Glis m qtz ss/ patchy kao mtx
Fe Wthrd mas glauc ss
Gy mica slty sh
Gn arg f lithic ss
Grit & c-m ss
Shy pel qtz grit
360' Thk gritty pbly qtz ss
Fe mica sh
Gritty & pbly c ss; thn cgl
0

JANE TABLE HILL

500' M-c gritty qtz ss; thn cgl
165' Flaggy gn calc m ss/carb deb
0

Wolena Clyst ?

Battle Camp Formation

CABOT-BLUEBERRY MARINA No1 Ø1,2

0 Mot cly sd & grit
140' Fld sd
240' F cgl
36 Fos dk olv calc clyst
Gy f glau ss
28 Dk gy shy slty mdst
Ø3
Dk gy slty mdst/siltst intbd
Ø4
C5 Gy-wh glau cly f-m ss
Qtz & pbly ss; dk sh
Wh c-m qtz ss; gy-brn slty mica sh/carb dtrl; thn dk gn f ss
Ø6
Gy f cly ss
Wh mica ss & sh
Ø7 2000' Brn lam kao f cgl-ic ss; gy-brn silty mica sh/ sh/coal lam
Brn cly m ss; wh ss & sh
Wh ss; dk sh; brn ss; gy-brn sh
Off-wh kao qtz ss/brn shy lam & mica sity carb sh
C8
Gritty ss; brn & gy sh
Ø10,11 Gy mica carb sh/f ss/bdg struc; coal; thn grd m-f kao ss-brec
As Ø9/off-wh m ss/carb & brn sh flks
3000'
Brn & gy sh
KOOLBURRA
Shy f ss / Rhizocorallium
200' Cgl
Wh m-f kao ss
Cgl-ic mica qtz ss
Ø12 Wh mica ss
Brn lam kao m qtz ss/carb & mica lam gy-brn slty sh
Gy shy f & wh ss
J Ø13 3566'
P Ø14
S-Dh? 3786' 3829'
11 Gy f & wh m ss; sh; coal
Off-wh m-c pbly mica carb qtz ss; brn sh
Gn sil ss or tuff
Glossopteris sh
550' Fe Mot sltst
Thk wh m-c qtz ss
300' Thk cgl & pbly ss
Thk m-c pale qtz ss; grit & cgl
0

Battle Camp Formation Dalrymple Sandstone

Wolena Clyst

Lateritized sh
200' Fe 16 Grit & sh
F-m arg ss
Qtz cgl/gn mica sh lenses
0
P

Battle Camp Formation Dalrymple Sandstone

210' Lateritized sltst
Gl Wh unsorted glau sltst/rr grit
0

BLACK HILL
80' Fe Lchd sh
0

"Lakefield"
Pbly glau ss 17
Shy mdst 26

Battle Camp Dalrymple Formation Sandstone

150' Gl M ss & thn cgl
Gl Olv arg feld m ss
0

ALTANMOUI RANGE

600' Glis m-c gritty ss
400' Gl
Wthrd sft glau & thn qtz ss
14(B15)
150' Wthrd glau ss; sh pel cgl; ang basal cgl
Grit; ss
0

Battle Camp Formation Dalrymple Sandstone

750' Fe Thk qtz ss
Gl? Sft glau ss & pbly grit?
350' Mas gritty m-c ss.?
Mas cgl; thn ss & sh?
0
(Partly air-photo interpretation)

1000' Fang cgl; grit & glis qtz ss
500' M qtz ss
Fe Basal brec, cgl grit
Coal; carb sh & ss
0
CAPE FLATTERY

MT JACK
Puddingstone Lchd arg f ss 120'
F-m glau ss; sltst
Gl U 0

Thk glis m-c qtz ss 400'
Fe grit thn cgl; sh
Thk gritty & pbly sl koo m ss 190'
0

520' Fe Vgt sltst
400' M qtz ss
Gl U Taylor's locality
Gn sdy cgl
Pbly qtz ss
Shy carb f lithic ss
Pbly arg calc c-f lithic ss/coal
0 Fe
Pbly m-c qtz ss
150'
BATTLE CAMP RANGE

750' Fe Lchd sh
Pbly grit
550' Fe Thk sdy cgl & pbly c ss
Mas sdy cgl; cbl base Carb sh lenses
Mas sdy Dk arg ss pbl cgl
0
HENDERSON RANGE

Mas pbl cgl & m-c qtz ss 310'
Thn m-f qtz ss & dk gy sh 150'
Ø6 0
INNER HILL

COOKTOWN

350' Fe Thn c-m qtz ss & sdy sltst
250' Mas cbl & pbl cgl; thk c qtz ss; dk gy sh
Ø1
0
THE BROTHERS

FAIRVIEW No2 R.N. 11224
0 Dk gy cly
Blk sh
Lt-col sh sa wtr
Sticky
blk sh
Pale sh
Wh sh & grit
Gy sh & wh ss frs wtr
1005'

140' Gl F qtz ss; kao ss; grit
Fe
Gl Wh mica kao m ss
0

Battle Camp Formation Dalrymple Sandstone

LAURA
Lateritized sltst
Mas cln & kao m qtz ss
Lithic ss & cgl Gl
Gn sdy cgl Fe
Pbly lithic ss
Mas cgl; ss & sh lenses
470' 430' 210' 0
Ss & Sh
About 1200'

Battle Camp Dalrymple Formation Sandstone

DEIGHTON BORE R.N. 10913
0
Ss & Sh

Battle Camp Formation Dalrymple Sandstone

430' Sh; fri ss; mudcracks
Fri f qtz ss
Arg m-f ss
220' Pbly c ss; sh; grit
130' Fri arg ss
Arg ss; grit, pbly, lensing/sltst
0 Polymict cgl & lithic ss
Wedge of P sh & ss
PALMERVILLE FAULT

INDEX TO 1:250,000 SHEETS

144°
CORAL SEA
SD/54-12 EBAGOOLA
SD/55-9 CAPE MELVILLE
15°
SD/54-16 HANN RIVER
SD/55-13 COOKTOWN
Cooktown

ABBREVIATIONS

ang	Angular	dk	Dark	mtx	Matrix
arg	Argillaceous	dtrl	Detrital(us)	olv	Olive
bdg	Bedding	f	Fine(ly)	pbl	Pebble
blk	Black	fe	Iron-Ferruginous	pbly	Pebbly
brec	Breccia(ed)	fld	Feldspar(thic)	pel	Pellet
brn	Brown	flk	Flake	qtz	Quartz
c	Coarse(ly)	flt	Fault(ed)	rr	Rare
ø	Core	fos	Fossil(iferous)	sa	Salt
calc	Calcite(areous)	frag	Fragment(al)	sd	Sand
carb	Carbonaceous	fri	Friable	sft	Soft
cbl	Cobble	frs	Fresh	sh	Shale
cgl	Conglomerate	glau	Glauconite(ic)	shy	Shaly
cln	Clean	glis	Glistening	sil	Silica(eous)
cly	Clay(ey)	gn	Green	sl	Slight(ly)
clyst	Claystone	grd	Grade(ed)	sltst	Siltstone
col	Colour(ed)	gy	Gray	slty	Silty
deb	Debris	intbd	Interbedded	ss	Sandstone
		kao	Kaolin	struc	Structure
		lam	Laminated	thk	Thick
		lchd	Leached	thn	Thin
		len	Lenticular	vgt	Varigated
		lt	Light	/	With
		m	Medium	wh	White
		mas	Massive	wthrd	Weathered
		mdst	Mudstone	wtr	Water
		mica	Mica(ceous)	Yel	Yellow

M(S)74

143°30' 144° 145°30' 14° 15° 16°

GEOLOGICAL MAP

HODGKINSON AND LAURA BASINS

QUEENSLAND

1:500.000

Reference

CAINOZOIC

QUATERNARY

- Qm — Coastal marine deposits: saltpans, mangrove swamps, lagoonal deposits
- Qr — Beach sand
- Qa — Alluvium and soil
- Qs — Interfluvial residual sand
- Qd — Younger dune sand and some minor older dune sand, with dune ridges

TERTIARY TO QUATERNARY

- Czd — Older dune sand
- Czt — Talus, piedmont fans (slightly ferruginous)
- Czx — Mottled gritty or pebbly, clayey sand, clay
- Piebald Basalt — Czp — Olivine basalt, pyroclastics
- McLean Basalt — Cze — Olivine basalt, pyroclastics; intercalated gravel beds
- Culgar Basalt — Czg — Olivine basalt
- Atherton Basalt — Cza — Olivine basalt, pyroclastics, some gravel and shale
- McBride Basalt — Czm — Olivine basalt
- Czb — Olivine basalt

TERTIARY

- Tl — Laterite or lateritic soil
- Tf — Gravel, sandstone, 'billy'
- Tl Cz — Conglomerate, sandstone, shale, diatomite (lateritized)

MESOZOIC

LOWER CRETACEOUS

- Albian — Wolena Claystone — Klo — Olive-grey silty and sandy claystone with calcareous concretions
- Aptian — Blackdown Formation — Klb — Grey shale and siltstone, with calcareous concretions; some sandstone lenses
- Neocomian - Aptian — Battle Camp Formation — Klc — Conglomerate, glauconitic and quartzose sandstone, shaly sandstone, siltstone, shale
- Neocomian — Wrotham Park Sandstone — Klw — Conglomerate, feldspathic sandstone, pebbly beds; thin shale beds

JURASSIC

- Dalrymple Sandstone — Jl — Quartz sandstone, conglomerate, grit, shale with coaly layers

TRIASSIC ?

- Pepper Pot Sandstone — Rp — Cross-bedded massive conglomerate and pebbly sandstone; flaggy kaolinitic and silty sandstone towards the top

PALAEOZOIC

UPPER PERMIAN

- Normanby Formation — Pn — Impure sandstone, siltstone, conglomerate, impure limestone, coal; rhyolite
- Little River Coal Measures — Pur — Sandstone, shale, impure coal, limestone
- Mt Mulligan Coal Measures — Pum — Massive conglomerate, bedded arkose, sandstone, shale, coal
- Nychum Volcanics — Pun — Bedded rhyolite, ignimbrite, andesite, basalt, tuff, arkose, shale, coaly shale

PERMIAN

- Altanmoui Granite — Pgi — Grey biotite adamellite, and other granitic rocks
- Puckley Granite — Pgk — Coarse-grained muscovite-biotite adamellite
- Trevethan Granite — Pgd — Hornblende-biotite granodiorite
- Finlayson Granite — Pgl — Muscovite-biotite adamellite
- Cannibal Creek Granite — Pgc — Cream muscovite-biotite-microcline granite
- Mareeba Granite — Pgm — Muscovite-biotite-microcline granite and adamellite; some quartz diorite
- Tully Granite Complex — Pgb — Biotite-hornblende adamellite, granodiorite, quartz gabbro, leucogranite
- Pgp — Fine-grained pink leucogranite
- Pgh — Undifferentiated granites; pink alaskite, pink biotite granite, arfvedsonite granite, grey hornblende-biotite adamellite
- Elizabeth Creek Granite — Pgz — Pink leucocratic biotite granite
- Herbert River Granite — Pgh — Grey to pink hornblende-biotite adamellite
- Almaden Granite — Pgg — Grey biotite-hornblende adamellite to quartz diorite, some pyroxene-biotite-hornblende quartz gabbro
- Ixe Microgranodiorite — Pmf — Grey porphyritic biotite microgranodiorite

CARBONIFEROUS TO PERMIAN

- Featherbed Volcanics — Cf — Mainly acid welded tuff with some flows and pyroclastics
- Doolan Creek Rhyodacite — Cd — Rhyodacite
- Boxwood Volcanics — Ce
- Claret Creek Volcanics — Cc
- Warby Volcanics — Cw
- Scardons Volcanics — Ca — Mainly acid welded tuff with some flows and pyroclastics
- Kallon Volcanics — Ck
- Walsh Bluff Volcanics — Ch
- Glen Gordon Volcanics — Cl
- Sunday Creek Volcanics — Cs — Acid welded tuff, andesite
- Nanyeta Volcanics — Cn — Acid welded tuff, green siltstone, andesite
- Pzu — Rhyolite, quartz porphyry, some dolerite and diorite

CARBONIFEROUS

- Silver Valley Conglomerate — Cms — Conglomerate, sandstone, siltstone, tuff

CARBONIFEROUS ?

- Montalbion Sandstone — Cm — Coarse sandstone, conglomerate
- Ringrose Formation — Cr — Siltstone, sandstone, conglomerate

MIDDLE DEVONIAN-LOWER CARBONIFEROUS?

- Hodgkinson Formation — D-Ch — Greywacke, siltstone, slate, subordinate chert, andesite, spilite, limestone and conglomerate; Ultrabasic lens: serpentinite, talc schist

UPPER SILURIAN-LOWER DEVONIAN

- Mt Garnet Formation — S-Dm — Greywacke, sandstone, siltstone, conglomerate, chert, limestone, basalt
- Chillagoe Formation — S-Dh — Limestone, chert, quartz greywacke, siltstone, sandstone, conglomerate, basalt

LOWER SILURIAN

- Wairuna Formation — Slw — Shale, claystone, sandstone

LOWER TO MIDDLE PALAEOZOIC

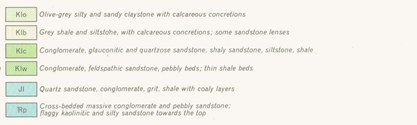
- Babalangee Amphibolite — Pzp — Plagioclase amphibolite
- Barron River Metamorphics — Pzb — Phyllite, slate, sericite schist, greywacke-quartzite; subordinate greenschist, rare limestone
- Barnard Metamorphics — Pza — Schist, gneiss, gneissic granite, migmatite

PRECAMBRIAN

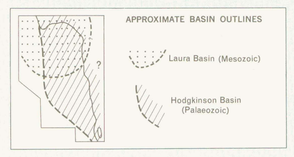
PROTEROZOIC ?

- pC — Schist, gneiss, granite, amphibolite, quartzite
- Forsayth Granite — Pgf — Grey biotite granite; anatectic muscovite granite?
- Cobbold Dolerite — Pdc — Dolerite, gabbro, amphibolite
- Sandalwood Serpentinite — Pss — Serpentinite, gabbro
- McDevitt Metamorphics — Pm — Schist, quartzite
- Dargalong Metamorphics — Pd — Schist, gneiss, pegmatite, quartzite, amphibolite, granite

DIAGRAMMATIC RELATIONSHIP OF MAIN ROCK UNITS



APPROXIMATE BASIN OUTLINES



Compiled, 1964, by: F. de Keyser, K. G. Lucas
Geology by: F. de Keyser, K. G. Lucas, J. G. Best, R. S. H. Fardon, C. D. Branch, B. J. Amos, W. R. Morgan, K. R. Yates, D. A. White, D. O. Zimmerman, J. W. Smith, M. B. Bayly, R. Z. de Ferranti, K. K. Hughes, D. H. Blake (Bureau of Mineral Resources); L. G. Cuttler, R. M. Tucker, K. W. Wolff, D. H. Wyatt, J. T. Woods (Geological Survey of Queensland)
Cartography by: Geological Branch, Bureau of Mineral Resources
Drawn, 1965, by: Mapping Systems, Brisbane

Reference

- Geological boundary
- Anticline, showing plunge
- Syncline, showing plunge
- Fault, showing 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 short dashes
- Strike and dip of strata
- Vertical strata
- Horizontal strata
- Overturned strata
- Dip < 15°
- Dip 15°-45°
- Dip > 45°
- Trend lines, with dip (air-photo interpretation)
- Joint pattern
- Shear zone
- Direction of movement of sediment-bearing currents
- Dyke or dyke swarm (do = dolerite, basalt, andesite; gr = granite; p = porphyry with large phenocrysts of quartz and feldspar; q = quartz; r = rhyolite, trachyte)
- Extinct acid volcanic vent
- Extinct basic volcanic vent
- Fossil locality, general
- Plant fossil locality
- Fossil wood locality
- Major mine
- Mine, group of prospects
- Prospect: little or no production
- Quarry, open cut
- Alluvial workings
- Minor mineral occurrence
- CBM No.1 — Dry hole (abandoned)
- Water bore with windpump
- Swamp
- Dam
- Escarpment
- Road
- Vehicle track
- Town, population over 1000
- Town or settlement, population under 1000
- Homestead
- Abandoned settlement
- Railway with siding (where abandoned, line is broken)
- Airport
- Landing ground
- Height in feet; datum: sea level
- Coral reef
- (PD) — Position doubtful

Ag	Silver	Mi	Mica
Au	Gold	Mn	Manganese
Bi	Bismuth	Mo	Molybdenum
C	Coal	Pb	Lead
Cl	Brick-clay	Pz	Pozzolan
Cu	Copper	Rc	Crushed rock aggregate, road metal
Di	Diatomite		
F	Fluorspar	Sb	Antimony
Fe	Iron	Sn	Tin
Hg	Mercury	W	Tungsten
La	Limestone	Zn	Zinc

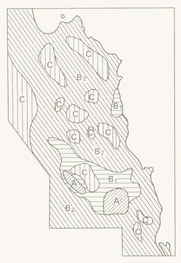
GEOLOGICAL RELIABILITY DIAGRAM

- A — Detailed mapping
- B1 — Detailed reconnaissance—numerous traverses and air-photo interpretation
- B2 — Reconnaissance—traverses and air-photo interpretation
- C — Air-photo interpretation

INDEX TO 1 : 250,000 SHEETS

Showing Magnetic Declination

AUBURN SE 54-7	COEN SD 54-3		
MOLESWORTH SD 54-11	EBAGOOLA SE 54-12	CAPE MELVILLE SD 55-1	
BELLENDEN KER SD 54-15	KIRKWOOD SE 55-16	COOKTOWN SD 55-13	
GALBRAITH SE 54-3	MALLANOY SE 54-4	MOSSMAN SE 55-1	CAIRNS SE 55-2
NORMANTON SE 54-7	RED RIVER SE 54-8	ATHERTON SE 55-5	INNISFAIL SE 55-6
CROYDON SD 54-11	GLORIETOWN SE 54-12	TOWNSVILLE SD 55-9	ROSS SE 55-10
WILLIAMINA SE 54-15	GILBERTON SE 54-16	CLARKE RIVER SE 55-13	TOWNSVILLE SE 55-14





Scale 1 : 500,000

10 0 10 20 30 MILES

10 0 10 20 30 40 KILOMETRES

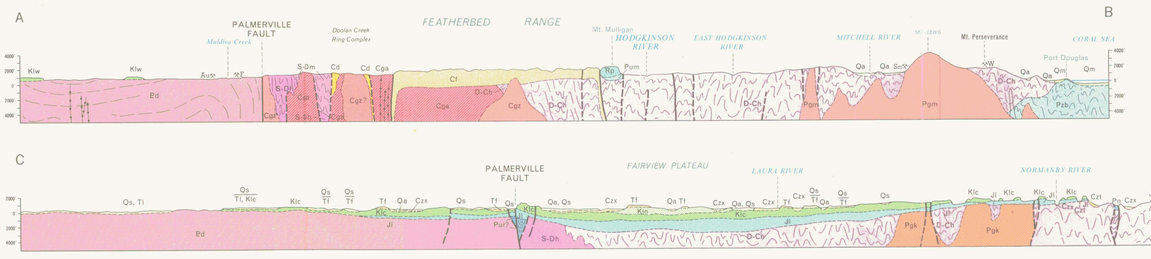
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1967



Sections

Folding diagrammatic

Scale: V/H = 4



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